Pellervon taloudellisen tutkimuslaitoksen työpapereita

Pellervo Economic Research Institute Working Papers

N:o 94 (April 2007)

THE ROLES OF ELECTRICITY AND ICT IN GROWTH AND PRODUCTIVITY: CASE FINLAND

Jukka Jalava

Matti Pohjola

Pellervon taloudellinen tutkimuslaitos PTT
Pellervo Ekonomiska Forskningsinstitut
Pellervo Economic Research Institute
Eerikinkatu 28 A, 00180 Helsinki
Puh. (09) 348 8844, fax (09) 3488 8500
E-mail: econ.res@ptt.fi
www.ptt.fi

Pellervon taloudellisen tutkimuslaitoksen työpapereita

Pellervo Economic Research Institute Working Papers

N:o 94 (April 2007)

THE ROLES OF ELECTRICITY AND ICT IN GROWTH AND PRODUCTIVITY: CASE FINLAND[*]

Jukka Jalava[†]

Matti Pohjola[‡]

[*] We are most grateful to Timo Myllyntaus and Pekka Tiainen for sharing some unpublished data with us and to Antti Kauhanen for help with statistical estimations. Without implicating them for any remaining errors, we also wish to thank Paul David, James Foreman-Peck, Mika Maliranta, Hans-Joachim Voth and seminar participants in Florence, Helsinki, Istanbul, Jyväskylä and Stanford for helpful comments. Jukka Jalava's research is partly supported by the EU KLEMS project "Productivity in the European Union: A Comparative Industry Approach", funded by the European Commission, Research Directorate General as part of the 6th Framework Programme, Priority 8, "Policy Support and Anticipating Scientific and Technological Needs". Matti Pohjola gratefully acknowledges financial support from the Yrjö Jahnsson Foundation.

[†] Pellervo Economic Research Institute, Eerikinkatu 28 A, FIN-00180 Helsinki, Finland. E-mail: jukka.jalava@ptt.fi

[‡] Helsinki School of Economics and HECER, P.O. Box 1210, FIN-00101 Helsinki, Finland. E-mail: matti.pohjola@hse.fi

ISBN 978-952-5594-52-2 (NID)
ISBN 978-952-5594-53-9 (PDF)
ISSN 1455-4623 (NID)
ISSN 1796-4784 (PDF)

Pellervon taloudellinen tutkimuslaitos PTT
Pellervo Economic Research Institute PTT
Eerikinkatu 28 A
00180 Helsinki

Helsinki 2007

JUKKA JALAVA - MATTI POHJOLA. 2007. THE ROLES OF ELECTRICITY AND ICT IN GROWTH AND PRODUCTIVITY: CASE FINLAND. Pellervon taloudellisen tutkimuslaitoksen työpapereita nro 94. Pellervo Economic Research Institute Working Papers No. 94. 25 s. p 25. ISBN 978-952-5594-52-2 (NID), ISBN 978-952-5594-53-9 (PDF), ISSN 1455-4623 (NID), ISSN 1796-4784 (PDF)

Tiivistelmä: Tässä työpaperissa tarkastelemme sähköä ja ICT:tä kasvun moottoreina prosessissa jossa Suomi muuntui alkutuotantovaltaisuudesta korkean teknologian maaksi. Suomi oli 1900-luvun alussa johtavia maita teollisuuden käyttövoiman sähköistämisessä. Nykyään Suomea pidetään eräänä johtavista tietoyhteiskunnista. Näytämme että ICT:n kontribuutio BKT:n kasvulle vuosina 1980–2004 oli lähes kaksi kertaa niin suuri kuin sähkön kontribuutio vuosina 1920–1938. Kokonaistuottavuuden kasvu vastasi 90 prosentista ICT:n kontribuutiosta mutta ainoastaan kolmasosasta sähkön kontribuutiosta. Suomi on ollut menestyksekkäämpi ICT:n tuotannossa kuin aikoinaan sähkön tuottamisessa. Sekä sähkön että ICT:n kasvuvaikutukset olivat Suomessa pienemmät kuin Yhdysvalloissa. Sähkön osalta ero tulee lähinnä pienemmistä kokonaistuottavuuden läikkymisvaikutuksista; Yhdysvalloissa läikkymisvaikutukset olivat huomattavasti suuremmat kuin Suomessa. ICT:n osalta pääomavaltaistuminen on ollut tärkeämpi Yhdysvalloissa ja ICT-tuotannon tuottavuuden parantaminen Suomessa. ICT:n käytöstä ei ilmennyt läikkymisvaikutuksia.
Avainsanat: *sähkö, ICT, yleisteknologia, kasvutilinpito, tuottavuus.*

Abstract: This paper takes a quantitative look at electricity and ICT as engines of growth in the process of Finland's transformation from a backward agricultural nation into a modern high-tech country. Finland was one of the leading countries in the electrification of mechanical drive in industry in the early 20th century. Today the country is generally regarded as one of the leading information societies. It is shown that ICT's contribution to GDP growth in 1980-2004 was almost twice as large as electricity's contribution in 1920-1938. The improvement of multi-factor productivity in production accounted for 90 per cent of ICT's contribution but only one third of electricity's. Finland has thus been far more successful as an ICT producer than a producer of electricity. The contributions of both electricity and ICT have been somewhat smaller in Finland than in the United States. For electricity, the main source of the difference is the multi-factor productivity spillovers associated with the use of electricity. They were much larger in the United States than in Finland. Regarding ICT, capital deepening has been important for the United States, improvement of productivity in ICT manufacturing for Finland. No evidence is found for spillovers arising from ICT use.
Keywords: *electricity, ICT, general purpose technology, growth accounting, productivity.*

CONTENTS

YHTEENVETO

Taloustiede selittää miten talouskasvun takana on teknologia, eli tieto ja ideat siitä miten tuotannontekijöistä saadaan lopputuotteita. Taloushistoriasta tiedämme, että kasvu ei ole tasaista vaan sille on ominaista nopean kasvun ja taantuman kaudet. Nämä liittyvät ns. yleisteknologioiden kuten höyryvoiman, sähkön ja tieto- ja viestintäteknologian syntymiseen, leviämiseen ja lopulta niiden tuottavuusvaikutusten hiipumiseen. Tässä työpaperissa tarkastelemme sähköä ja ICT:tä kasvun moottoreina prosessissa jossa Suomi muuntui alkutuotantovaltaisuudesta korkean teknologian maaksi. Suomi oli 1900-luvun alussa johtavia maita teollisuuden käyttövoiman sähköistämisessä. Nykyään Suomea pidetään eräänä johtavista tietoyhteiskunnista.

Kasvutilinpitoa (kasvutilinpito on menetelmä, jonka avulla talouskasvu voidaan osittaa tuotantopanosten ja teknologisen kehityksen osatekijöihin) käyttävissä tutkimuksissa nähdään uuden teknologian tuottavuusvaikutukset kolmivaiheisina. Ensiksi, johtuen nopeasta teknisestä kehityksestä kokonaistuottavuus paranee merkittävästi niillä toimialoilla jotka tuottavat ko. uutta teknologiaa. Toiseksi, uutta teknologiaa käyttävät toimialat kokevat myönteisiä työn tuottavuusvaikutuksia kun investoivat uusiin pääomatavaroihin. Kolmanneksi, toimialat jotka käyttävät uutta teknologiaa kokevat positiivisia kokonaistuottavuusvaikutuksia kun ottavat käyttöön uusia toimintatapoja (mahdollisesti uuden yleisteknologian mahdollistamia, eli ns. läikkymisvaikutuksia) ja parantavat jatkuvasti teknologiaa erilaisilla tuote- ja prosessi-innovaatioilla.

Näytämme että ICT:n kontribuutio BKT:n kasvulle vuosina 1980–2004 oli lähes kaksi kertaa niin suuri kuin sähkön kontribuutio vuosina 1920–1938. Kokonaistuottavuuden kasvu vastasi 90 prosentista ICT:n kontribuutiosta mutta ainoastaan kolmasosasta sähkön kontribuutiosta. Suomi on ollut menestyksekkäämpi ICT:n tuotannossa kuin aikoinaan sähkön tuottamisessa. Sekä sähkön että ICT:n kontribuutiot olivat Suomessa pienemmät kuin Yhdysvalloissa. Sähkön osalta ero tulee lähinnä pienemmistä kokonaistuottavuuden läikkymisvaikutuksista. Yhdysvalloissa ne olivat huomattavasti suuremmat kuin Suomessa. Pääomavaltaistuminen on ICT:n osalta ollut tärkeämpi Yhdysvalloissa ja ICT:n tuotannon tuottavuuden parantaminen Suomessa. ICT:n käytöstä ei ilmene läikkymisvaikutuksia.

1. INTRODUCTION

Economic theory explains how economic growth is driven by advances in technology, that is, in ideas about how to combine inputs to produce outputs. Economic history teaches that growth is not a smooth process but is subject to episodes of sharp acceleration and deceleration which are associated with the arrival, diffusion and exhaustion of new general purpose technologies (GPTs). These are technologies that affect the whole economy by transforming both household life and the ways in which firms conduct business (for a survey, see Jovanovic and Rousseau, 2006). Steam, electricity and information and communications technology (ICT) are the most important examples.

The empirical literature applying the growth accounting approach usually sees the productivity effects of a new technology as coming in three stages. Firstly, there are significant improvements in multi-factor productivity (MFP) in the industries producing the new technology due to rapid advances in technological knowledge. Secondly, the industries using the new technology experience positive labour productivity impacts as they increase their capital intensity by investing in new capital goods. Thirdly, the industries using the new technology experience a boost in multi-factor productivity growth as they introduce new modes of operation and continually improve the technology by incremental product and process innovations. Such spillovers may result from the re-organization of production that the new GPT makes possible.

Crafts (2002, 2004) has recently applied growth accounting in assessing and comparing the overall impacts of the three GPTs. In his 2004 study on the contribution of steam to British economic growth in the 19th century, he found that the output and productivity impacts were modest and long-delayed. Steam contributed very little (0.01–0.02 percentage points per year) to the growth of labour productivity before 1830. The peak impact occurred in the period 1850–70 and amounted to 0.4 percentage points per year. These numbers are much smaller than what we have come to expect from a GPT on the basis of many recent studies measuring the effects of ICT.

In his 2002 paper, Crafts also studied the impacts of electricity and ICT in the United States over comparable periods of time. The total contribution of electricity to GDP per person growth was about 0.6 percentage points per year in 1899–1929 and one percentage point in 1919–29. MFP spillovers resulting from the reorganization of factory work accounted for most of the impact (0.7 %-points) in the latter period. This estimate is based on David's (1990, 1991) and David and Wright's (1999) analyses of the impact of the adoption of the electric unit drive on multi-factor productivity growth in U.S. manufacturing. The shift from steam to electric power reduced the energy required to drive machinery but also, as DuBoff (1964: 143-8) and Devine (1983) show, it more importantly permitted substantial improvements in factory design. This increased flow of production, made working environment better, improved machine control and made plant expansion easier. Consequently, the electricity using industries were able to obtain greater output per unit of capital and labour input.

David and Wright (1999, 2003) show that capital productivity increased in U.S. manufacturing in the 1920s and that this increase was directly associated with the diffusions of the electric unit drive which they measured by the capacity of secondary electric motors. Contrary to what one would expect using a simple factor substitution model, the growth of capital productivity was associated with rising labour productivity.

The interesting difference between steam and electricity lies in the growth contribution of MFP spillovers. These seem to have been small for steam but very substantial for electricity. One explanation may be that such spillovers are more difficult to measure for steam than for electricity. Crafts (2004) does not even try to identify them but concludes that it is unlikely that they have been significant. This is confirmed by Devine's (1983) study which argues that the shift from steam power to electricity was fundamentally different from the previous transition from water power to steam. Electrification was accompanied with new methods of power transmission and distribution as well as improvements in factory design and machine organization whereas steam power was adopted by manufacturers primarily for reasons of locational and seasonal availability and of direct cost benefits.

The overall impacts of steam are not, however, easily measurable in a growth accounting framework and may be underestimated. As Rosenberg and Trajtenberg (2004) have shown, the Corliss steam engine served as a catalyst for the massive relocation of industrial activity into larger urban centers in the United States, thus fueling agglomeration economies, attracting further population and fostering economic growth. These relationships may have been different in Britain, but the link between technology and population growth is not accounted for in growth accounting.

Comparing the growth contributions of electricity with Oliner and Sichel's (2000) findings on the impacts of ICT in 1974–2000, Crafts concluded that ICT has had at least as large an impact on economic growth as electricity. ICT's overall contribution to GDP per person growth rose from 0.7 percentage points in 1974–1990 to 1.9 in 1996–2000. The notable difference between electricity and ICT is that the latter has not yet generated any measurable MFP spillovers in the ICT using industries. The growth impact has been achieved through the capital-deepening effect. In principle at least, ICT could generate re-organization effects in offices in the service sector in ways parallel to the experience of the factory.

Edquist and Henrekson (2006) rightly point out, however, that the output and productivity contributions from steam and electricity may be underestimated in comparison to ICT because hedonic prices have been used in measuring the quality of ICT products but not in measuring the quality of either steam engines or electric motors.

With this reservation, the existing cliometric evidence can be said to indicate that the contribution to economic growth of information and communications technology outweighs the contributions of the other two general purpose technologies. Crafts analyzed the impacts in those countries where the GPTs were discovered: steam in Great Britain and electricity and ICT in the United States. It might be interesting to see if the conclusion holds for countries which are not technology leaders but are followers, i.e. countries which have adopted technologies developed by others.

David and Wright (2003) show that the experience of delayed and then accelerated MFP growth associated with electrification was not a uniquely American phenomenon. They found similar patterns for the United Kingdom and Japan in the opening third of the 20th century. This they take to confirm the fact that factory electrification was indeed a GPT. In Britain, the diffusion of electric power lagged behind the U.S. in the beginning of the century but matched it already by the end of the 1930s. In Japan, the age of steam power was historically compressed by the rapid process of factory electrification. The transition to the new power regime was already underway before the mechanization of manufacturing plants had been completed. David and Wright conclude that the follower countries can in fact adopt a well-developed technology from abroad relatively quickly without having to go through the learning processes that had occurred in the pioneering country.

Edquist and Henrekson (2006) demonstrate that also Sweden adopted electricity swiftly and that labour productivity in manufacturing accelerated in the 1920s. However, they were not able to establish a clear correlation across industries between labour productivity growth and the increased use of electric motors.

It will be shown in Section 3 of this paper that the diffusion of electricity was as rapid in Finland as in the United States in the 1920s and 1930s. The contribution to economic growth of this GPT was however somewhat smaller in Finland (0.59 percentage points per year) than in the United States (0.98 percentage points) over comparable periods of time. The main source of the difference is the multi-factor productivity spillovers associated with the use of electricity. They were much larger in the United States than in Finland.

Section 4 demonstrates that the diffusion of ICT was slower in Finland than in the U.S. in 1975-2005. To assess its contribution to productivity growth, estimates based on non-hedonic and hedonic ICT prices are provided. The first ones make it possible to compare the impacts of ICT with the effects of electricity which are not derived using hedonic prices for electric motors. The second set of estimates allows comparisons between Finland and the United States for which only estimates based on quality-adjusted ICT prices are available.

It is shown that ICT's contribution to GDP growth in 1990-2004 (1.07 percentage points per year) was almost twice as large as electricity's contribution in 1920-1938 (0.59 percentage points). These GPTs also differ with respect to the relative importance of the sources of the growth contributions. The improvement of multi-factor productivity in production accounted for 90 per cent of ICT's contribution but only one third of electricity's. No evidence for spillovers from ICT use is found.

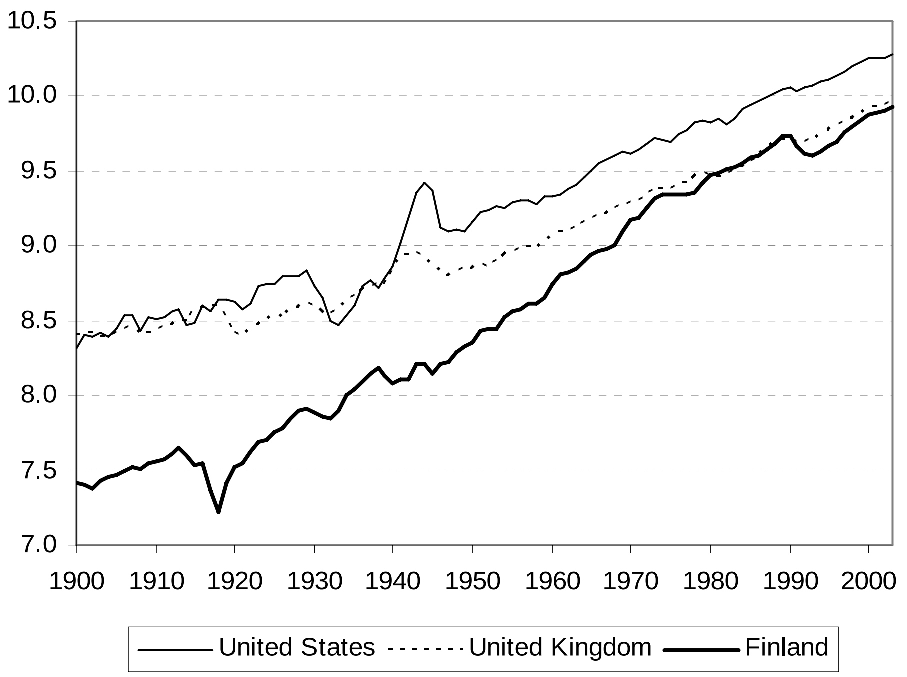
ICT's contribution to GDP growth has been somewhat higher in the United States than in Finland. The main sources of the contribution are different. ICT capital deepening has been important for the United States, MFP in ICT manufacturing for Finland.

Before going into the details of the growth accounting results, a brief history of Finnish economic growth is presented in Section 2. Section 5 concludes the paper.

2. OUTPUT GROWTH AND ITS PROXIMATE SOURCES

The growth rate of GDP per capita was in Finland among the highest in Western Europe in the 20th century. According to Maddison's (2003) data, the compound annual growth rate was 2.5 per cent in the period from 1900 to 2003. Given that the growth rate in the United States was 1.9 per cent per year, the Finnish GDP per capita increased from 41 per cent of the U.S. level in 1900 to 71 per cent in 2003. It reached the British level in the 1980s. This rapid convergence is displayed in Figure 1.

Figure 1. *GDP per capita, 1900-2003 (logarithmic scale, 1990 international Geary-Khamis dollars)*



Source: Maddison (2003), revised and updated data available on http://www.ggdc.net/maddison/

Finland developed from a relatively backward agricultural society to a modern Nordic welfare state during the 20th century. The advancement in prosperity was initially based on the successful utilization of natural resources by the forest and basic metal industries in the wake of the second industrial revolution. The information and communication technology sector has recently become the leading industry in terms of the contribution to labour productivity and GDP growth. In 2001, labour productivity as measured by value added per hour worked was in Finland higher than in any other EU-15 member country or in the United States in the following four manufacturing industries: pulp and paper, wood and wood products, basic metals, and telecommunications equipment.[1]

[1] Source: Groningen Growth and Development Centre, ICOP Database 1997 Benchmark,

To account for the sources of output growth, the aggregate production function

(1) $$Y_t = A_t F(K_t, L_t)$$

is used as a starting point. Here, at any given time *t*, the aggregate gross value added *Y* is produced from aggregate inputs consisting of capital *K* and labour *L*. The level of technology or multi-factor productivity is represented in the Hicks neutral or output-augmenting form by parameter *A*. The basic growth accounting equation gives the growth of output as the sum of the share weighted inputs and the growth in multi-factor productivity

(2) $$\Delta \ln Y = v_K \Delta \ln K + v_L \Delta \ln L + \Delta \ln A,$$

where the Δ-symbol refers to a first difference, i.e. $\Delta x \equiv x(t) - x(t-1)$, and where the time index *t* has been suppressed for the economy of exposition. The weights v_K and v_L sum to one and represent the nominal income shares of capital and labour, respectively. All shares are averaged over periods *t* and *t–1*.

The first two rows of Table 1 decompose output growth into the contributions from labour input and labour productivity for the period from 1900 to 2005. Output is measured by the real gross valued added. Instead of looking at the total economy, the analysis is confined to the non-residential market sector where the volume of output was 26 times higher at the end of our observation period than at its beginning.[2] Over the whole period, 90 per cent of output growth stemmed from increases in labour productivity and 10 per cent from increases in the number of hours worked. Labour input's contribution was at its highest (about 30 %) in the first two sub-periods. It was negative in the last two sub-periods. The beginning and endpoints of the periods have been chosen in such a way that the economy is at similar stages of the business cycle at them. This is done to eliminate the impact of cyclical factors on productivity measures.

Using equation (2), output growth is decomposed in the last three rows of Table 1 into the share weighted contributions of the capital stock, hours worked and the growth in multi-factor productivity, obtained as the residual.[3] Over the whole observation period the combined inputs contributed one third and MFP two thirds to the growth of output. In the pre-WWI era two thirds of the growth at the rate of 2.9 per cent came from capital and labour and one third from the residual. The years from 1900 to 1913 formed the only period during which capital's contribution was the largest. In the interwar epoch the MFP growth rate more than doubled to 2.3 per cent which meant that over

http://www.ggdc.net

[2] The share of the non-residential market sector in GDP at basic prices stayed rather constant at about 90 per cent in the period from 1900 to 1950. It has subsequently gradually declined to 73 per cent in 2005.

[3] The Appendix describes how the series are compiled.

half of aggregate growth stemmed from the residual. The contributions of capital and labour were 1.3 and 0.9 percentage points, respectively.

Table 1. *Growth accounting results for the Finnish non-residential market sector, 1900-2005*

	1900 - 2005	**1900 - 1913**	**1920 - 1938**	**1952 - 1973**	**1973 - 1990**	**1990 - 2005**
Labour input, ln%	0.3	1.0	1.4	0.0	-0.6	-0.8
Labour productivity, ln%	2.8	1.9	3.1	4.5	3.6	3.4
Output, ln%	3.1	2.9	4.5	4.5	3.0	2.6
Contributions, ln%-points:						
Capital	0.9	1.2	1.3	0.9	0.7	0.4
Labour	0.2	0.6	0.9	0.0	-0.5	-0.7
MFP	2.1	1.0	2.3	3.7	2.8	2.9

Source: Own calculations, data from Hjerppe (1988), Tiainen (1994), Statistics Finland. Numbers may not sum to totals due to rounding.

In the 1950s and 1960s, capital accounted for one fifth and MFP four fifths of the growth, labour's contribution being zero. In 1973-90, labour's contribution turned negative (-0.5 percentage points annually), capital was the source of 0.7 percentage points, and MFP contributed 2.8 percentage points to output growth at the rate of 3.0 per cent. The last sub-period covers the severe depression of the early 1990s and the rapid recovery from it. The average growth rate over the whole period was 2.6 per cent with MFP contributing 2.9, capital 0.4 and labour -0.7 percentage points.

In the next two sections of the paper, the basic growth accounting equation (2) will be used in measuring the output growth contributions of a general purpose technology—electricity in section 3 and ICT in section 4. To do this, three modifications are made to this equation. First, a distinction is made between two types of capital—GPT capital, K_{GPT}, and other capital, K_O. Second, two channels are introduced for multi-factor productivity growth—one arising in the manufacturing of the GPT, A_{GPT}, and the other in the rest of the economy, A_O. Finally, following Crafts (2002), a term is included to capture the possible spillovers from the use of the GPT capital. The modified equation can be written as

(3)

$$\Delta \ln Y = v_{KGPT}\Delta \ln K_{GPT} + v_{KO}\Delta \ln K_O + v_L \Delta \ln L + u_{GPT}\Delta \ln A_{GPT} + u_O \Delta \ln A_O + \gamma \Delta \ln K_{GPT}$$

.

Here, v_{KGPT} and v_O are the income shares of GPT and other capital, respectively. Variables u_{GPT} and u_O denote the ratios of output in the GPT manufacturing and other industries, respectively, to aggregate value added. If a non-zero γ can be identified, then the last term captures the spillovers associated with the use of the GPT.

3. ELECTRICITY AS A SOURCE OF OUTPUT GROWTH IN 1900–1938

3.1 Electrifying Finnish Production

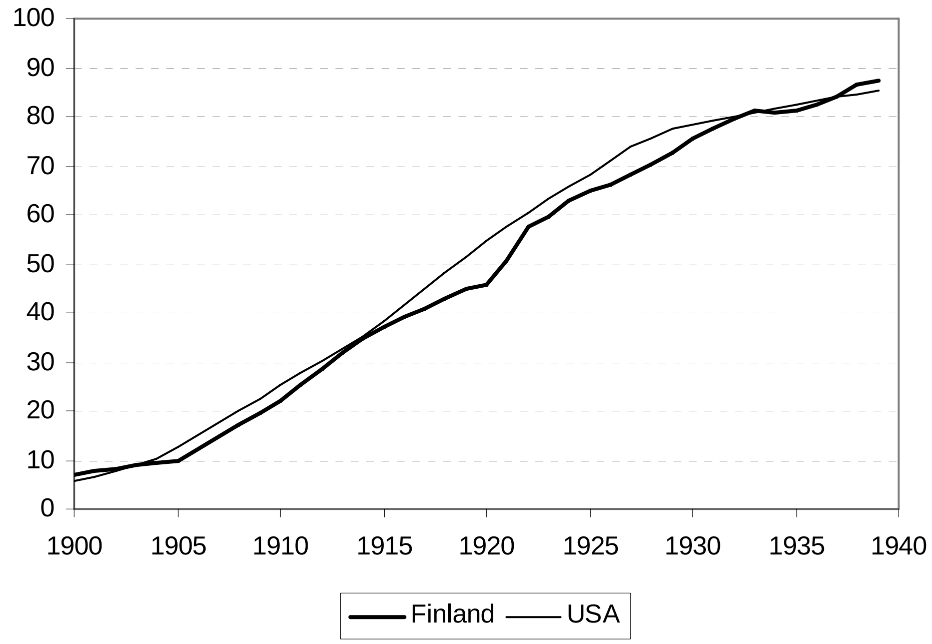
Electric lighting was first demonstrated in Finland in 1877. Five years later the Finlayson cotton mill in Tampere installed incandescent lights. This was the fifth permanent installation in Europe. In 1888, the city of Tampere installed its own street lighting plants, and by the autumn of 1914 all 38 Finnish towns had one or more electric utilities (Myllyntaus, 1991).

At the turn of the century, mining and manufacturing formed a small sector of the economy but consumed most of the electricity generated in the country. The growth of the energy intensive forest and metal industries enhanced the demand for electricity by Finnish manufacturing. In the saw-milling industry, four mills installed electric lighting in 1882/3; by 1900 the number increased to more than 40 (approx. 7 per cent of the saw-milling firms). The electrification of motive power was slower as electrical engines accounted for only 0.3 per cent of the motive power in the saw-milling industry in 1900. The share slowly increased to 9 per cent in 1910 and to 36 per cent by 1920. In metal-working, the first machine shops used electric lighting by 1884, and at the turn of the century one third of the enterprises had electric lighting. The electrification of motive power proceeded rapidly from 4 per cent of total motive power in 1898 to 47 per cent in 1913, reaching 75 per cent by 1920. In the pulp and paper industry, electric lighting was first used in the late 1880s. The electrification of motive power increased from 6 per cent of total motive power in 1900 to 20 per cent in 1910 and to 38 per cent by 1920 (Myllyntaus *et al.*, 1986).

The volume index of motive power grew at a compound average annual rate of 7.5 per cent in the Finnish manufacturing industry in the period from 1900 to 1938 (Hjerppe *et al.*, 1976). Before the Second World War, the industry was very energy intensive: in 1890–1938, an increase in industrial volume growth by one per cent required a growth in electricity use by 3.5 per cent. In the interwar period, the industry actually used 70-85 per cent of all electricity output in Finland. The rise in the electricity-intensity slowed down in the 1949-67 period when increases of industrial output by one per cent were accompanied by a growth of electricity use by 1.3 per cent. (Myllyntaus, 1991).

In an international comparison, Finland was not a latecomer but was in fact one of the leading countries in the electrification of mechanical drive in industry. To see this in greater detail, Figure 2 compares the diffusions of electricity in manufacturing between Finland and the United States. It displays the shares of electricity in total motive power capacity. It is seen that the electrification of manufacturing was very rapid in the United States from 1900 to 1939. The share of electric power increased from 5.6 to 85.5 per cent. But electrification was equally rapid in Finland. Electricity's power share went up from 7.0 in 1900 to 87.3 per cent in 1939.

Figure 2. *Shares of electricity in total motive power in the U.S. and Finnish manufacturing, 1900-1939 (per cent)*



Source: US data from DuBoff (1964) table 15 (intermediate years interpolated), Finnish data from Myllyntaus (1991) for years 1900-1920 and from Teollisuustilastoa SVT XVIIIA (i.e. the annual industry statistics publications) for years 1920-1939.

Industrialization started late in Finland. Agriculture accounted for 70 per cent of employment in 1913. Industry's share was 10 and services' 20 per cent. In Britain, the respective employment shares were 12, 44 and 44 per cent (Broadberry, *et al*, 2005). Much like in Japan, the age of steam power was in Finland historically compressed by the rapid process of the electrification of manufacturing. The transition to the new power regime happened at the same time as productive resources shifted from agriculture to manufacturing. One of the factors which contributed to the rapid adoption of electricity in a technologically backward country must have been the fact that there was not much existing manufacturing capacity based on old technology. The coexistence of older and newer forms of capital is known to have restricted the scope for exploiting electricity's potential in the United States (David and Wright, 2003).

3.2 Electricity's Growth Effect

The growth accounting framework (3) is here applied to assess the contribution of electricity to the growth of the Finnish GDP in the periods 1900-1913 and 1920-1938. The war years have been left out from the analysis. As shown in Table 1, the average output growth rate was 2.9 per cent in the first period and 4.5 per cent in the second.

Table 2 summarizes the findings.[4] Electricity's total contribution was rather low, 0.18 percentage points, in the first period. It picked up to 0.59 percentage points in the second period. The total contribution is obtained as the sum of the impacts arising from increases in electrical capital, from multi-factor productivity improvements in the production of electricity and electric machinery as well as from the multi-factor productivity spillovers resulting from electrical capital.

Table 2. *Electricity's contribution to the output growth of the Finnish non-residential market sector, 1900-1913 and 1920-1938*

		1900-13	1920-38
Growth of real gross value added at basic prices (less dwellings)1		2.91	4.53
Total contribution2 from electricity		0.18	0.59
Contributions from capital	Electric utilities' capital	0.07	0.29
	Electrical capital goods	0.04	0.03
Contributions from MFP	Electric utilities	0.05	0.19
	Electrical machinery	0.01	0.01
	Spillovers from the use of electrical capital goods	…	0.07
Memoranda			
Income shares1	Electric utilities capital	0.76	3.64
	Electric capital goods	0.47	0.48
Volume growth1	Electric utilities' capital	9.30	8.00
	Electrical capital goods	9.21	7.22
Output shares3	Electric utilities	0.51	2.24
	Manufacture of electrical machinery	0.24	0.31
Volume growth1	MFP of electric utilities	8.20	9.00
	MFP in the manufacture of electrical machinery	3.19	2.64

[1] In per cent. [2] In percentage points. [3] per cent.
Sources: Own calculations; electric utilities income share and volume growth data from Tiainen (1994), electric capital goods volume growth data from Hjerppe *et al.* (1976) and income share from BEA applied on own capital stocks, electric utilities' and electrical machinery's output shares and MFP growth data from Tiainen (1994).

[4] The results are expressed in two decimal digits to minimize the impact of the rounding error, not to emphasize their accuracy.

The capital contribution is estimated as in Crafts (2002) by breaking electrical capital into two components: electric utilities' capital stock and the stock of electrical capital goods. The data sources are documented in a footnote to Table 2. As information on the income shares of the two components of electricity capital is not available, it is assumed that the income shares correspond to the capital stock shares. This means that the profits from owning these news forms of capital are assumed to be competitive rather than supernormal.

The problem that information about electrical machinery's capital stock share is not available for Finland was solved by resorting to the U.S. data provided by the Bureau of Economic Analysis. It is assumed that the share of electrical machinery in equipment was the same in Finland as in the United States in the period considered.[5] This can be justified by referring to Figure 2 which shows that the diffusion of electricity was as rapid in the Finnish as in the U.S. manufacturing. Data on equipment's capital share was obtained from Hjerppe *et. al* (1976) and from the Finnish National Accounts. As shown in Table 2, the use of these two types of electrical capital goods contributed altogether 0.11 percentage points to output growth in 1900-13 and 0.32 percentage points in 1920-38.

As explained in Section 2, a general purpose technology contributes to multi-factor productivity through its manufacturing and through the possible spillovers arising from its use. To estimate the first contribution, the multifactor-productivity growth rates of electric utilities and of the manufacturing of electrical machinery where multiplied by their shares in total output. For reasons of data availability, the valued-added shares were used instead of the gross output shares. The combined contribution was 0.06 percentage points in the first period and 0.20 percentage points in the second. The contribution from the production of electrical machinery was very small (0.01 percentage points) in both periods reflecting its small share in output (about 0.3 per cent.)

David and Wright (1999) have shown that large spillovers resulted from the widespread adoption of the electric unit drive in the U.S. manufacturing in the 1920s. Electrification was accompanied by new methods of power transmission and distribution as well as improvements in factory design and machine organization. David and Wright estimated the spillovers for a cross-section of manufacturing industries by regressing the observed acceleration of MFP growth on the increase in the share of aggregate direct factory drive represented by the capacity of secondary electric motors. Their regression results imply that the spillovers contributed 2.4 percentage points per year to total manufacturing MPF growth. Crafts (2002) multiplied this number by the manufacturing

[5] BEA's Fixed Assets Tables are available on www.bea.gov. As the first year in this data is 1925, this year's share was used for the earlier years as well. This creates an upward bias to the estimate.

sector's GDP share (0.3) to obtain an estimate that electricity's MFP spillover contribution was 0.7 percentage points per year in the United States in the 1920s. As his estimate for electricity's total contribution to GDP growth is one percentage points per year, this means that spillovers accounted for 70 per cent on the total contribution.

To estimate the spillovers for Finland, the multi-factor productivity growth rate was regressed on the increase in the capacity of electric motors and on year dummy variables using panel data from 15 manufacturing industries in 1921-38. The relationship is positive, although statistically rather weak, and imply that the spillovers contributed 0.33 percentage points to the annual MFP growth in manufacturing.[6] Multiplying this by manufacturing's average GDP share in 1921-38 (21.7 per cent) gives the 0.07 percentage point MFP contribution displayed in Table 2.

This contribution is quite small compared to the U.S. estimate. The weak relationship may indicate that the spillovers were indeed weaker in Finland than in the United States or it may just reflect the problems with the data. The spillovers may have been small because Finland was a latecomer to industrialization. There was not much existing industrial work that could be reorganized using electricity as the source of motive power.[7]

The first data problem is the fact that only MFP growth rates based on value-added output measures are available. This may result in an underestimation of the spillover effects simply because the MFP growth rates are not adjusted to take account of purchased energy inputs. The second problem is that the data do not allow a distinction between power generated by the primary and secondary electric motors. Consequently, it is not possible in the analysis to capture the cross-section variation in the pace of diffusion of the group drive and unit drive systems. As David and Wright (1999) argue, the spillovers arose from changes in the internal power transmission arrangements within plants which the unit drive made possible.

To sum up, electricity's overall contribution to GDP growth was 0.59 percentage points per year in 1920-38. Its capital contribution was 0.32, MFP contribution in production 0.20 and MFP spillover contribution 0.07 percentage points. These can be compared with Crafts' (2002) estimates for the United States in 1919-29. The total contribution was 0.98 percentage points of which 0.70 resulted from spillovers. Capital contribution was 0.23 and MFP contributed 0.05 percentage points. The largest difference is in the spillovers.

---

[6] The relationship was estimated in the form $\Delta\ln MFP_{i,t} = \beta \Delta\ln X_{i,t} + \lambda_t + u_{i,t}$ where X denotes the capacity of electric motors measured in horsepower, λ is a dummy variable, u the residual, i refers to industry and t denotes time. The point estimate of β is 0.039 with p-value 0.144. Multiplying the value of β by the average value of X (0.08445) gives the estimate of 0.33 ln-percentage points for the contribution of the spillovers.

[7] Edquist and Henrekson (2006) were not either able to find a clear correlation between labour productivity growth and the use of electric motors for different manufacturing industries in Sweden.

4. ICT AS A SOURCE OF OUTPUT GROWTH IN 1980–2004

4.1 Digitalizing Finnish Production

As was pointed out above, Finland was one of the leading countries in adopting electricity. This holds for telecommunications as well. The first telephone line was built in Helsinki in December 1877, only 18 months after the telephone was patented in the United States (Turpeinen, 1981). The Helsinki Telephone Corporation was established in 1882. There were already 3.3 telephone lines per 100 inhabitants in Helsinki in 1900, making it one of the major telephone cities in the world.

According to historians (e.g., Turpeinen, 1981), politics was one of the factors explaining the rapid adoption of the new communication technology.[8] When the telephone was invented, Finland was an autonomous Grand Duchy of the Russian Empire. The Finnish Telegraph Office was operated by the Russian authorities, but it was not clear who should grant permissions for operating the telephone. Upon application, the Senate of Finland decided that it has the right to do so. This decision was endorsed by Czar Alexander III, and it resulted in the establishment of private, regional telephone corporations all over the country. The statute the Senate issued made a sharp distinction between telephone and telegraph regulation and created a competitive telecommunications market. Just before World War II there were 815 telephone companies in Finland. In most other countries, the telephone was considered to be a successor to the telegraph and thereby a state monopoly.

In 1961, the Helsinki Telephone Corporation started experimenting with data transmission systems. The first commercial connection was installed in a retail group in 1964 (Häikiö, 1995). The Finnish era of information technology had started a few years earlier when the first computer was purchased by the government-owned Post and Savings Bank in 1958 to oversee entries in savings accounts (Pukonen, 1993). The first Finnish computer was built in 1960 under the auspices of the Finnish Committee for Mathematical Machines (Andersin and Carlson, 1993).

In the early 1960s, a cable factory, Finnish Cable Works, with its 30 plus years of experience in manufacturing telecommunications cables, launched itself into the production of telecom equipment. Its long-term plan was to eventually start constructing computers. It also set up a computing centre, which was the foundation of Nokia’s electronics department, when in 1966 the company was merged with Nokia, a wood-pulp/papermill founded in 1865. In the early 1970s Nokia began producing computers,

[8] Castells and Himanen (2002: 56-57) provide a summary in English.

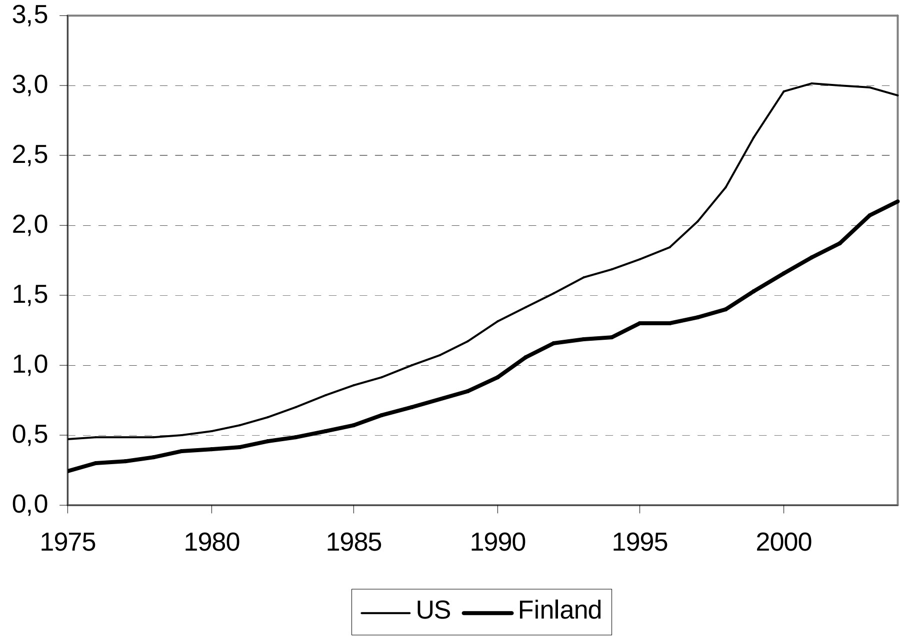
which was a major part of Nokia until the computer division was sold to ICL-Fujitsu in 1991, and digital telephone exchanges. The electronics division did not become profitable until 1971 and it did not contribute significantly to Nokia's net sales until the late 1980s. The company's main emphasis shifted to electronics only in the 1990s (Häikiö, 2002; Jalava, 2004).

Finland is generally regarded as one of the leading information societies. For example, it ranks seventh in IDC's (2006) Information Society Index which measures the ability of 53 countries to participate in the information revolution. The country's telecommunications manufacturing industry is also competitive in the world market, Nokia's share of the global mobile phone market being about 35 per cent. This industry's share of non-residential market production was 5.9 per cent and share of exports 19.9 per cent in 2004.[9]

However, as displayed in Figure 3, the diffusion of ICT has been slower in Finland than in the United States when measured by the share of computer software in private, non-residential fixed assets. This measure is more relevant for output and productivity growth comparisons than mere headcounts of computer or Internet users. It is also one for which official data for both countries exist. Comparing this diagram with Figure 2, one is inclined to conclude that Finland has not adopted ICT as rapidly as it adopted electricity. Consequently, the contribution of ICT use to output growth should be smaller in Finland than in the leading ICT-using countries.

[9] For comparison, the respective shares for the paper and pulp industry were 4.4 per cent of production and 14.6 per cent of exports.

Figure 3. *Share of computer software in private, non-residential fixed assets, 1975-2004 (per cent)*



Source: US data from the Bureau of Economic Analysis, NIPA Table 2.1; Finnish data from Statistics Finland.

4.2 ICT's Growth Impact

Table 3 displays the results obtained by applying growth accounting to assess the contributions of information and communication technology to GDP growth in the non-residential market sector. The year 1990 divides the overall period to two sub-periods in such a way that the latter period covers both the depression and the recovery from it.

Two sets of estimates are presented. The first set in column (a) contains the results obtained using the official national accounts data for Finland which are not based on any hedonic prices indexes for ICT investment. These results are here used to compare the growth impacts of ICT and electricity. As mentioned earlier, hedonic price indexes are not available for electricity. Using such prices for one GPT and not for the other would create a measurement bias. The second set in column (b) is derived from the EU KLEMS database which has been created for analyses of growth and productivity in the European Union. The Finnish ICT investment data contained in this database were created by using the hedonic price indexes derived by Jalava and Pohjola (2006). These estimates are here used first to assess the impact of the quality adjustment on ICT's growth impact and, second, to compare the Finnish numbers with those obtained for the United States whose estimates are based on hedonic prices. The GDP growth rates differ somewhat between columns (a) and (b) because of the slightly different definitions of the market sector in the two datasets.

According to the estimates based on the official national accounts (column (a)), ICT's overall contribution to GDP growth was 0.29 percentage points in 1980-1990 and 1.07 percentage points in 1990-2004. The largest contribution resulted from the improvement of multi-factor productivity in ICT production which here includes both the manufacturing of ICT equipment (industries 30 and 32) and the provision of telecommunication services (industry 642) and information technology services (industry 72). The MFP contribution increased from 0.21 percentage points in the first sub-period to 0.97 points in the second. The contributions of ICT capital were about 0.1 percentage points in both sub-periods.

To estimate the spillovers from ICT use, the total non-residential market economy was divided into 15 industries. Industry-level multi-factor productivity growth rates were then regressed on the changes in the ICT capital stocks and, alternatively, on the changes in the software capital stocks as well as on year dummy variables. The results were disappointing in the sense that no statistically significant impacts were found for the whole period 1980-2004 or any of the two sub-periods. The finding is not, however, surprising as any strong evidence for ICT spillovers does not exist for the United States either (Stiroh, 2002).

Comparing Table 3 with Table 2, it is seen that ICT's contribution to GDP growth in 1990-2004 was almost twice as large as electricity's contribution in 1920-1938. The GPTs also differ with respect to the relative importance of the sources of the growth contributions. The improvement of MFP in production accounted for 90 per cent of ICT's contribution but only one third of electricity's.

Table 3. *ICT's contribution to the output growth of the Finnish non-residential market sector, 1975-1990 and 1990-2005 ((a) estimates based on non-hedonic ICT prices, (b) estimates based on hedonic ICT prices)*

	1980-1990		1990-2004	
	(a)	(b)	(a)	(b)
Growth of real gross value added at basic prices (less dwellings)1	3.08	3.15	2.73	2.53
Total contribution2 from ICT	0.29	0.63	1.07	1.07
Contribution from ICT capital	0.08	0.44	0.10	0.43
Contributions from MFP in ICT production	0.21	0.19	0.97	0.64
Memoranda				
Income share of ICT capital3	0.92	2.62	1.63	4.62
Volume growth of ICT capital1	8.68	17.00	4.99	7.83
Output share of ICT production3	3.67	4.16	8.55	7.17
MFP growth in ICT production1	5.78	4.61	11.14	8.84

[1]In per cent. [2] In percentage points. [3] per cent.
Sources: Column (a): own calculations based on the Finnish National Accounts (see Appendix), column (b): EU KLEMS Database, March 2007, http://www.euklems.net.

The estimates in column (b) of Table 3 are derived using ICT investment series based on hedonic prices. The contribution from ICT use is four times higher than in column (a) in both periods. This does not, however, increase the total ICT contribution in the latter period as the MFP component is smaller in (b) than in (a) reflecting the fact that ICT output series are not adjusted for quality in the EU KLEMS database.

ICT's contribution to GDP growth has been somewhat higher in the United States than in Finland. According to the EU KLEMS database, the total contribution was 0.90 percentage points in 1980-1990 and 1.24 percentage points in 1990-2004. The sources of the contribution are different from those in Finland in the sense that the share of ICT capital is large (60 %). For Finland, MFP in ICT production dominates reflecting its specialization in the production of telecommunications equipment and services.

5. CONCLUSIONS

This paper took a quantitative look at electricity and ICT as engines of growth in the process of Finland's transformation from a backward agricultural nation in 1900 into a modern high-tech country with GDP per capita nowadays comparable to Western Europe. Although being relatively poor, Finland was not a latecomer but was in fact one of the leading countries in the electrification of mechanical drive in industry in the early 20th century. Today, the country is generally regarded as one of the leading information societies. Its telecommunications manufacturing industry is competitive in the world market and one of the key drivers of economic growth. Interestingly, however, the diffusion of ICT has been slower in Finland than in the United States when measured by the share of computer software in private, non-residential fixed assets.

It was shown that ICT's contribution to GDP growth was almost twice as large as electricity's contribution over comparable periods of time. The improvement of multi-factor productivity in production accounted for 90 per cent of ICT's contribution but only one third of electricity's. Finland has thus been far more successful as an ICT producer than a producer of electricity.

The contributions of both electricity and ICT have been somewhat smaller in Finland than in the United States. Regarding electricity, the main source of the difference is the multi-factor productivity spillovers associated with the use of electricity. They were much larger in the United States than in Finland. Regarding ICT, capital deepening has been important for the United States, improvement of productivity in ICT manufacturing for Finland. No evidence was found for spillovers from ICT use.

During the period considered in this paper, Finland switched from resource-based to ICT-based growth. However, given the large dependency on the ICT-producing sector, the ongoing outsourcing of ICT production to low wage countries provides a threat to productivity performance in the future. Finland may have to restructure its economy once again in the digital era.

REFERENCES

Andersin, H. and Carlson, T. (1993), "ESKO – ensimmäinen suomalainen tietokone", in: Tienari, M. (ed.), Tietotekniikan alkuvuodet Suomessa, Gummerus Kirjapaino Oy, Jyväskylä.

Broadberry, S., Federico, G. and Klein, A. (2005), "An Economic History of Modern Europe: Sectoral Developments, 1870-1914", to be published in: Broadberry, S. and O'Rourke, K. (eds), Unifying the European Experience: An Economic History of Modern Europe, Volume 2, 1870-2000.

Castells, M. and Himanen, P. (2002), The Information Society and the Welfare State: The Finnish Model, Oxford University Press, Oxford.

Crafts, N. (2002), "The Solow Productivity Paradox in Historical Perspective", Centre for Economic Policy Research, Discussion Paper No. 3142, January.

Crafts, N. (2004), "Steam as a General Purpose Technology: A Growth Accounting Perspective", Economic Journal 114, 338-351.

David, P.A. (1990), "The Dynamo and the Computer: An Historical Perspective on the Modern Productivity Paradox", American Economic Review 80, 355-361.

David, P.A. (1991), "Computer and Dynamo: The Modern Productivity Paradox in a Not-too-distant Mirror", in Technology and Productivity, OECD, Paris, 315-347.

David, P.A. and Wright, G. (1999), "Early Twentieth Century Production Growth Dynamics: An Inquiry into the Economic History of "Our Ignorance"", Discussion Papers in Economic and Social History, University of Oxford.

David, P. A. and Wright, G. (2003), "General Purpose Technologies and Surges in Productivity: Historical Reflections on the Future of the ICT Revolution", in: David, P.A. and Taylor, M. (eds.), The Economic Future in Historical Perspective, Oxford University Press, Oxford, 135- 166.

Devine, W.D. (1983), "From Shafts to Wires: Historical Perspective on Electrification", Journal of Economic History 43, 347-372.

DuBoff, R. B. (1964), Electric Power in American Manufacturing, 1889-1958, Ph.D. dissertation, University of Pennsylvania; printed in 1979 by Arno Press Inc.

Edquist, H. and Henrekson. M. (2006), "Technological Breakthroughs and Productivity Growth", Research in Economic History 24.

Hjerppe, R. (1988), Suomen talous 1860–1985, kasvu ja rakennemuutos (The Finnish Economy 1860-1985. Growth and Structural Change), Studies on Finland's Economic Growth XIII, Bank of Finland Publications, Helsinki.

Hjerppe, R., Hjerppe, R., Mannermaa, K., Niitamo, O. E. and Siltari, K. (1976), Suomen teollisuus ja teollinen käsityö 1900–1965 (Industry and Industrial Handicraft in Finland, 1900-65), Studies on Finland's Economic Growth VII, Bank of Finland Publications, Helsinki.

Häikiö, M. (1995), Reikäkorttimodeemista tiedon valtatielle: Suomen datasiirron historia (From the Punch Card Modem to the Information Superhighway: The History of Data Transmission in Finland), Oy Datatie Ab, Helsinki.

Häikiö, M. (2002), Nokia: The Inside Story, Edita, Helsinki.

IDC (2006), The Information Society Index, http://www.idc.com/groups/isi/main.html, accessed 10 November 2006.

Jalava, J. (2004), "Electrifying and Digitalising the Finnish Manufacturing Industry: Historical Notes on Diffusion and Productivity", in: Heikkinen, S. and van Zanden, J.L. (eds.), Explorations in Economic Growth, Aksant Academic Publishers, Amsterdam.

Jalava, J. and Pohjola, M. (2006), "ICT as a Source of Output and Productivity Growth in Finland", unpublished paper.

Jovanovic, B. and Rousseau, P.L. (2006), "General Purpose Technologies", in: Aghion, P. and Durlauf, S. (eds), Handbook of Economic Growth, North Holland, Amsterdam.

Maddison, A. (2003), The World Economy: Historical Statistics, Development Centre Studies, OECD, Paris.

Myllyntaus, T. (1991), Electrifying Finland: The Transfer of a New Technology into a Late Industrialising Country, Macmillan & ETLA, London.

Myllyntaus, T., Michelsen, K.-E. and Herranen, T. (1986), Teknologinen muutos Suomen teollisuudessa 1885–1920: Metalli-, saha- ja paperiteollisuuden vertailu energiatalouden näkökulmasta, Bidrag till kännedom av Finlands natur och folk, H. 134, The Finnish Society of Sciences and Letters, Helsinki.

Pukonen, R. (1993), "Automaattisen tietojenkäsittelyn ENSI-askeleet Suomessa (Postipankin ENSI-tietokone)", in: Tienari, M. (ed.), Tietotekniikan alkuvuodet Suomessa, Gummerus Kirjapaino Oy, Jyväskylä.

Rosenberg, N. and Trajtenberg, M. (2004), "A General-Purpose Technology at Work: The Corliss Steam Engine in the Late-Nineteenth-Century United States", Journal of Economic History 64, 1-39.

Stiroh, K. (2002), "Are ICT Spillovers Driving the New Economy?", Review of Income and Wealth 48, 33-57.

Tiainen, P. (1994), Taloudellisen kasvun tekijät Suomessa. Työvoiman, pääoman ja kokonaistuottavuuden osuus vuosina 1900–90 (Sources of Growth in Finland. Contribution of Labour Force, Capital and Total Productivity in the Years 1900–90, in Finnish with English Summary and Tables), Helsinki.

Turpeinen, O. (1981), Helsingin Seudun Puhelinlaitos 1882–1982 (Helsinki Region Telephone Association 1882–1982), Helsinki.

APPENDIX

Description of data sources used:

GDP. Aggregate gross value added at basic prices less the public sector and the letting and operation of dwellings. The current price series of GDP and dwellings for the years 1900-59 from Hjerppe (1988), for the years 1960-74 from Finnish National Accounts base year 1980 (FNA80) series and for the years 1975-2005 from Finnish National Accounts chain-linked Laspeyres type series with reference year 2000 (FNA2005)[10]. The constant price series was constructed so that the level of the latest series was extrapolated with the changes in the other two series. I.e., the 1975 figure in chain-linked reference year 2000 prices was continued backwards with the volume changes in the FNA80 and Hjerppe (1988) series.

Labor. Total hours worked less hours worked in public sector and owning and letting of dwellings. The series for the years 1900-59 from Hjerppe (1988) lacks hours worked information hence work-years data was used, for the years 1960-74 hours worked from FNA80 series and for the years 1975-2005 hours worked from FNA2005. The series were constructed so that the level of the most current series was extrapolated with the changes in the other two series. I.e., the 1975 FNA2005 hours worked figure was continued backwards with the changes in the FNA80 and Hjerppe (1988) series.

Investment and Capital Data. Data on current price gross fixed capital formation for the years 1860-1959 from Hjerppe (1988), for the years 1960-2005 in current and constant prices from FNA2005 for the nonresidential market sector (the breakdown of current price investments in computers, communications equipment and other machinery and equipment in 1970-2004 from Jalava and Pohjola (2006); for 2005 same structure as in 2004 assumed).[11] The volume series was obtained by extrapolating the year 1960 figures in year 2000 prices backwards by the volume changes obtained when deflating the current price investments in non-residential buildings and civil engineering and other structures with the building cost index and the current price investments in machinery and equipment with the wholesale price index.

The capital stocks were calculated using the perpetual inventory method with the assumption of geometric age-efficiency profiles:

---

[10] Version: January 2007. Chain-linked volume figures (1975-2005) made additive by switching to additive previous years prices and deducting general government's and letting & operation of dwellings' gross value added from aggregate value added and thereafter switching back to chain-linked volumes. Finnish NA is using a Laspeyres type volume index at previous years prices in accordance with Eurostat's recommendation from March 2006 onwards.

[11] NB. In contrast with Jalava and Pohjola (2006) the official deflator for machinery and equipment used on hardware and communications equipment – and not a hedonic index.

$$K_t = K_{t-1}(1-d) + I_t = \sum_{\tau=0}^{\infty}(1-d)^{\tau} I_{t-\tau} ,$$

where K denotes year-end real capital stock, I is investment, d is the rate of depreciation and t is time. The rates of depreciation used were: 0.025 for non-residential structures, 0.025 for civil engineering and other structures, 0.25 for transportation equipment, 0.315 for computers, 0.11 for communications equipment, 0.13 for other machinery and equipment, 0.012 for transfer of ownership of land, 0.33 for mineral exploration, 0.315 for computer software and 0.33 for originals.

Electric utilities' capital's contribution was calculated by multiplying its capital stock growth (from Tiainen, 1994: Industry Electricity, gas and water, Net Capital Stock at 1980 prices) by its income share (Tiainen, 1994: Industry Electricity, gas and water, share of capital stock multiplied with capital's income share). Electrical capital good's capital contribution was calculated by multiplying its capital stock growth (Hjerppe *et al.*, 1976: index of installed power in large and medium scale manufacturing industry) by its income share (the share of electric machinery (the share of electrical machinery in equipment in the United States) in the share of machinery and equipment (less transportation equipment) in total non-residential market sector's capital stock from our capital stock calculations times the income share of capital).

Income shares. Labor's income share contains wages, salaries and employers' social contributions plus imputed wages of self-employed. Wages imputed for self-employed by multiplying average employees' hourly wage by number of hours worked by the self-employed. Data for the 1900-1959 period from Tiainen (1994), for the years 1960-74 from FNA80 and for the years 1975-2005 from FNA2005. Capital's income share is obtained by subtracting labor's share from unity, with the share of labour constrained to a maximum of unity.

Output shares. The share of electric utilities and the share of the manufacture of electrical machinery of total non-residential gross valued added from unpublished figures of Tiainen (1974). The output share of ICT comprises industries' 30, 32, 642 and 72 gross value added of total nonresidential GVA.

MFP. The MFP growth of electric utilities and manufacture of electrical machinery from unpublished figures of Tiainen (1994). The MFP change of ICT production calculated by computing the geometric average of ICT production's (industries 30, 32, 642 and 72) labour productivity growth and capital productivity growth using FNA2005 data. The weights used were the income shares of ICT production's labour input (labor's income share contains wages, salaries and employers' social contributions plus imputed wages of self-employed) and capital input (capital's income share is obtained by subtracting labor's share from unity, with the share of labour constrained to a maximum of unity).

PELLERVON TALOUDELLINEN TUTKIMUSLAITOS PTT
Pellervo Ekonomiska Forskningsinstitut
Eerikinkatu 28 A, 00180 Helsinki, Finland
puh. (09) 348 8844, telefax (09) 3488 8500
sähköposti: econ.res@ptt.fi, www.ptt.fi

Pellervon taloudellisen tutkimuslaitoksen julkaisuja, publikationer, Publications

19. Perttu Pyykkönen. 2006. Factors affecting farmland prices in Finland
18. Vesa Silaskivi. 2004. Tutkimus kilpailuoikeuden ja maatalouden sääntelyn yhteensovittamisesta
17. Aki Kangasharju. 1998. Regional Economic Differences in Finland: Variations in Income Growth and Firm Formation.
16. Pertti Kukkonen. 1997. Rahapolitiikka ja Suomen kriisi

Pellervon taloudellisen tutkimuslaitoksen raportteja, forskningsrapporter, Reports

201. Meri Virolainen – Panu Kallio – Philip Abbott. 2006. Implications of export subsidy removal for the Finnish and EU dairy sectors
200. Pasi Holm - Jaakko Kiander - Timo Rauhanen - Matti Virén. 2007. Elintarvikkeiden arvonlisäverokannan alentamisen vaikutukset
199. Erno Järvinen – Anna-Kaisa Rämö – Harri Silvennoinen. 2006. Energiapuun tuotanto ja markkinat: Metsänomistajakysely
198. Janne Huovari – Jaakko Kiander - Raija Volk. 2006. Väestörakenteen muutos, tuottavuus ja kasvu
197. Anssi Rantala. 2006. Growth of new firms: Evidence from Finland 1996-2003
196. Timo Rauhanen – Ari Peltoniemi. 2006. Elintarvikkeiden ja ruokapalveluiden arvonlisäverotus EU:ssa ja Suomessa. VATT-tutkimuksia 122.
195. Pasi Holm – Jukka Jalava – Pekka Ylöstalo. 2006. Työttömien työkyky vuonna 2005. Työpoliittinen tutkimus 308., työministeriö
194. Marko Mäki-Hakola – Mikko Toropainen. 2005. Metsien suojelun vaikutukset tuotantoon ja työllisyyteen – Alueellinen ja valtakunnallinen panos-tuotosanalyysi

Pellervon taloudellisen tutkimuslaitoksen työpapereita, diskussionsunderlag, Working Papers

93. Arto Kokkinen - Jukka Jalava – Riitta Hjerppe - Matti Hannikainen. 2007. Catching-up in Europe: Finland’s convergence to Sweden and EU15
92. Petri Soppi - Raija Volk. 2007. Julkisen palvelutuotannon kilpailuttaminen taloudellisesta näkökulmasta – Katsaus kansainvälisiin kokemuksiin
91. Pasi Holm. 2007. Matalan tuottavuuden työn tukimallin laajentaminen alle 26-vuotiaisiin
90. Kalle Laaksonen – Petri Mäki-Fränti – Meri Virolainen. 2006. Mauritius and Jamaica as Case Studies of the Lomé Sugar Protocol
89. Kalle Laaksonen – Petri Mäki-Fränti – Meri Virolainen. 2006. Lomé Convention, Agriculture and Trade Relations between the EU and the ACP Countries in 1975-2000
88. Terhi Latvala – Erno Järvinen – Harri Silvennoinen. 2007. Bioenergiaa pellolta – Maa- ja metsätilan omistajien halukkuus viljellä peltobio-massaa
87. Toppinen, A, Toivonen, R., Järvinen, E., Goltsev, V., Tatti, N. & Mutanen, A. 2007 Business environment and strategies of wood industry companies in Leningrad and Vologda regions – results from a pilot study
86. Janne Huovari – Petri Mäki-Fränti – Raija Volk.. 2006. Alueellisten asuntomarkkinoiden kehitys vuoteen 2009
85. Meri Virolainen. 2006. Implications of changes in the Russian agro-food sector and effects of Russia’s likely membership of the WTO on Finland