Tilastokeskus
Statistikcentralen
Statistics Finland

Tutkimuksia
Forskningsrapporter
Research Reports
248

Essays on Finnish Economic Growth and Productivity, 1860–2005

Jukka Jalava

Tilastokeskus
Statistikcentralen
Statistics Finland

Tutkimuksia
Forskningsrapporter
Research Reports
248

Essays on Finnish Economic Growth and Productivity, 1860–2005

Jukka Jalava

Päätoimittaja – Chefredaktör – Principal editor
Timo Alanko

Toimittaja – Redaktör – Editor
Jukka Jalava

Taitto – Ombrytning – Layout
Hilkka Lehtonen

ISSN 0355-2071
= Tutkimuksia
ISBN 978-952-467-746-2

Multiprint Oy

Helsinki – Helsingfors 2007

Preface

"..med tiden mognar en bra ekonom till en ekonomisk historiker".
(..given time a good economist matures into an economic historian)
Öller (2006) citing Dahmén.

My interest in research first awoke when I started working with national accounts at Statistics Finland. After a brief stint with regional accounts I was put in charge of capital stock statistics and somewhat later on also productivity statistics. Taking part in the work of the balancing and summing-up team the marvelous system of national accounts slowly unraveled itself to me. Early on my employer showed faith in me as a very junior employee was sent to participate as the Finnish representative in the OECD Canberra Group on Capital Stock Statistics. Sitting at the same table as giants of the field was really an eye-opening experience. My interest in the theory of capital and productivity was further deepened when I was fortunate enough to get docent Pirkko Aulin-Ahmavaara as a colleague and mentor. Co-operating with Pirkko was my first real exposure to the world of science.

As I realized that I wanted to pursue post-graduate studies I was fortuitous enough to get in contact with professor Riitta Hjerppe and docent Sakari Heikkinen; both eminent economic historians at the University of Helsinki's Department of Social Science History. Riitta personifies Finnish historical national accounts and it was hard to find a topic that she had not done already. Sakari's skills in advising how to finish an article are extraordinary. I am honored by their friendship and inspired by their example. My greatest stroke of good fortune came when I met professor Matti Pohjola of the Helsinki School of Economics. Over the years he has been my co-author and supervisor. His professionalism and perceptive insights into what is relevant and what not holds me in awe to this day.

Professor Hannu Tervo and docent Magnus Lindmark were the pre-examiners of my manuscript appointed by the Faculty of Social Sciences of the University of Helsinki. They provided discerning observations and constructive criticism. Docent Timo Alanko was kind enough to accept this thesis to be published in Statistics Finland's Research Reports Series. Other persons that have influenced my work include: professor Bart van Ark, Jaakko Autio, asst. professor Jari Eloranta, docent Susanna Fellman, doctor Matti Hannikainen, Janne Huovari, Heli Jeskanen-Sundström, Ilja Kristian Kavonius, Arto Kokkinen, doctor Mika Maliranta, professor Jari Ojala, Lea Parjo, doctor Petri Rouvinen, Olli Savela, doctor Pekka Tiainen, Steinar Todsen, and many others far too numerous to list.

This doctoral thesis was written while being employed by Statistics Finland, Helsinki School of Economics, Pellervo Economic Research Institute and Eurostat. One year was funded by the Yrjö Jahnsson Foundation. The latter part of my research was done while partly employed 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".

My deepest gratitude and love goes to my beautiful wife Merja and our children Vilma and Axel. I cannot forget my mother Marianne's and my mother-in-law Marjatta's extensive babysitting and dog sitting efforts over the years either. Thank you.

Luxembourg, November 2007

Jukka Jalava

Abstract

This study examines Finnish economic growth. The key driver of economic growth was productivity. And the major engine of productivity growth was technology, especially the general purpose technologies (GPTs) electricity and ICT. A new GPT builds on previous knowledge, yet often in an uncertain, punctuated, fashion.

Economic history, as well as the Finnish data analyzed in this study, 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. These are technologies that affect the whole economy by transforming both household life and the ways in which firms conduct business.

The findings of previous research, that Finnish economic growth exhibited late industrialisation and significant structural changes were corroborated by this study. Yet, it was not solely a story of manufacturing and structural change was more the effect of than the cause for economic growth. We offered an empirical resolution to the Artto-Pohjola paradox as we showed that a high rate of return on capital was combined with low capital productivity growth. This result is important in understanding Finnish economic growth 1975–90.

The main contribution of this thesis was the growth accounting results on the impact of ICT on growth and productivity, as well as the comparison of electricity and ICT. It was shown that ICT's contribution to GDP growth was almost twice as large as electricity's contribution over comparable periods of time. Finland has thus been far more successful as an ICT producer than a producer of electricity. Unfortunately in the use of ICT the results were still more modest than for electricity. During the end of the period considered in this thesis, 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. For a developed country only change is constant and history teaches us that it is likely that Finland is obliged to reorganize its economy once again in the digital era.

Keywords: growth, productivity, ICT, growth accounting, electricity, general purpose technology, capital, structural change

Tiivistelmä

Tässä tutkimuksessa tarkastellaan Suomen talouskasvua. Tärkeimmäksi tekijäksi Suomen talouskasvun selittäjänä tutkimuksessa havaitaan tuottavuuden kasvu. Tuottavuuden kasvun moottori on teknologinen kehitys, erityisen tärkeitä ovat ns. yleisteknologiat kuten sähkö sekä tieto- ja viestintäteknologia (ICT). Taloushistoriasta – ja myös tässä tutkimuksessa analysoidusta Suomea koskevasta aineistosta – tiedämme että talouskasvuun kuuluu sekä nopean että hidastuvan kasvun kausia. Tällaiset suhdannevaihteluita pidemmät taloudellisen kasvun vaihtelut liittyvät uusien yleisteknologioiden ilmestymiseen, leviämiseen ja häviämiseen.

Tutkimus vahvistaa aiemmat havainnot siitä, että Suomi teollistui myöhään ja että Suomen kasvuun liittyi huomattava talouden rakennemuutos. Kuitenkaan yksinomaan tehdasteollisuuden kehitys ei riitä kasvun selittäjäksi, ja rakennemuutos oli pikemmin talouskasvun seuraus kuin syy. Tutkimuksessa esitetään miten korkea pääoman tuottoaste yhdistyi matalaan pääoman tuottavuuskasvuun vuosina 1975–1990; tämä ratkaisee ristiriidan ns. tehottoman pääoman koulukunnan sekä niiden välillä jotka havaitsivat tietyillä toimialoilla kohtuullisia pääoman tuottoasteita.

Tutkimuksen päätulos on ICT:n kasvu- ja tuottavuushajotelma (käyttäen kasvutilinpitoa, jonka avulla talouskasvu voidaan osittaa tuotantopanosten ja teknologisen kehityksen osatekijöihin) sekä vertailu kahden yleisteknologian – sähkön ja ICT:n – käyttöönoton ja leviämisen vaikutusten välillä. ICT:n kontribuutio BKT:n kasvulle oli vertailukelpoisina ajankohtina kaksi kertaa suurempi kuin sähkön. Suomi onkin ollut huomattavasti menestyksekkäämpi ICT:n tuottajana kuin sähkön tuottajana. Valitettavasti ICT:n käytön suhteen tulokset olivat vaatimattomammat kuin sähkön osalta. Tarkastelujakson aikana Suomi muuntui alkutuotantovaltaisesta, luonnonvaroistaan riippuvaisesta maasta, vauraaksi maaksi, jonka ICT-tuotanto on maailman huippuluokkaa. ICT-toimialojen suuresta merkityksestä johtuen ICT-tuotannon ulkoistaminen matalan palkkatason maihin muodostaa uhan tulevalle tuottavuuskasvulle. Kehittyneen maan taloudessa vain muutos on pysyvää. Historian oppien perusteella Suomi joutuu todennäköisesti jälleen kerran organisoimaan tuotantorakenteensa digitaaliaikakaudella uudelleen.

Avainsanoja: kasvu, tuottavuus, ICT, kasvutilinpito, sähkö, yleisteknologia, pääoma, rakennemuutos

Contents

List of figures

List of tables

List of original publications

Chapter 2: Jalava, J. (2006): "Production, Primary, Secondary, and Tertiary: Finnish Growth and Structural Change, 1860–2004", Pellervo Economic Research Institute, *Working Papers No. 80*, January.

Chapter 3: Aulin-Ahmavaara, P. and Jalava, J. (2003): "Capital and its Productivity in Finland, 1975-2001", *Scandinavian Economic History Review*, Vol. 50 (3), pp. 62–79.

Chapter 4: Jalava, J. (2004): "Electrifying and Digitalising the Finnish Manufacturing Industry: Historical Notes on Diffusion and Productivity", in S. Heikkinen and J.L. van Zanden (eds.), *Explorations in Economic Growth*, Amsterdam: Aksant Academic Publishers.

Chapter 5: Jalava, J. and Pohjola, M. (2002): "Economic Growth in the New Economy: Evidence from Advanced Economies", *Information Economics and Policy*, Vol. 14 (2), pp. 189–210.

Chapter 6: Jalava, J. and Pohjola, M. (2007a): "ICT as a Source of Output and Productivity Growth in Finland", *Telecommunications Policy*, Vol. 31 (8–9), pp. 463–472.

Chapter 7: Jalava, J. and Pohjola, M. (2007b): "The Roles of Electricity and ICT in Growth and Productivity: Case Finland", Pellervo Economic Research Institute, *Working Papers No. 94*, April.

1 Introduction

Jukka Jalava

1.1 The enigma of economic growth

"Indeed, it can be said without exaggeration that in the long run probably nothing is as important for economic welfare as the rate of productivity growth."[1]

Economic historians and economists have long struggled with finding an explanation for economic growth. Why is it so that Western Europe was in 1000 Anno Domini lagging behind both Asia and Africa in Gross Domestic Product (GDP)[2] per capita terms, took the lead by 1500 Anno Domini and kept pushing farther away from the rest of the world? Only West Europe's own offshoots – Australia, New Zealand, Canada and the US – caught up with her and surpassed her in the late 19th and early 20th centuries.[3] According to table 1.1 the world's total Gross Domestic Product per capita was only 1.4 times larger in 1820 than it was in Anno Domini 1. Yet GDP per capita in 2003 was almost 14 times that of year 1 while the population simultaneously increased nearly 28-fold. This is astonishing. What happened? Why did the great transformation take place during the two latest centuries?

What lies behind modern economic growth is truly the most important enigma of contemporary society.[4] This topic has been intensively studied by both economic historians and economists. The usual suspects as drivers of economic growth include the accumulation of physical and human capital[5], productivity and the impact of research and development on productivity, international trade and the role of institutions. The early studies of Colin Clark[6], Robert Solow[7] and Moses Abramovitz[8] laid the foundation for a multitude of quantitative studies into economic growth, productivity and structural change. A central property in Solow's model was a negative correlation between output per capita growth and capital per labour growth. Due to capital's decreasing returns to scale output per capita grows slower and slower as the

1 Baumol, Blackman and Wolff (1989).

2 The concept of Gross Domestic Product, i.e. the value of goods and services produced during a year, is in itself an important tool necessary for comparisons of economic growth and development. Landefeld (2000) coined GDP as one of the great inventions of the 20th century.

3 Maddison (2003).

4 Mokyr (1990b) argues convincingly that the answer to this question lies in Western Europe's superior technology. The constant struggle for economic and political dominance was a natural incentive for technological progress.

5 E.g., Easterlin (1996).

6 Clark (1940).

7 Solow (1956, 1957).

8 Abramovitz (1956).

Table 1.1 World GDP, population and GDP per capita, 1–2003

	1	1000	1820	1950	2003
GDP, billion 1990 USD (PPP)	105.4	120.3	694.5	5,336.7	40,913.4
Population, million	225.8	267.3	1,041.7	2,525.5	6,278.6
GDP per person	467	450	667	2,113	6,516
Compound average growth, %		1–1000	1000–1820	1820–1950	1950–2003
GDP		0.01	0.21	1.58	3.92
Population		0.02	0.17	0.68	1.73
GDP per person		0.00	0.05	0.89	2.15

Source: Angus Maddison, http://www.ggdc.net/Maddison/, downloaded on April 2, 2007.

amount of capital per labour input increases. So on the one hand the growth rate of a country's economy slows down as its capital intensity increases, while on the other hand countries with lower capital-labour ratios grow faster than those with higher capital-labour ratios.

Production takes place by combining labour with capital at some technology. In addition to the accumulation of inputs also substitution between the inputs and substitution within inputs, that is, the change in their quality must be taken into account. In growth accounting the inputs', i.e. labour's and capital's, quantity and quality is deducted from economic growth by assuming constant returns to scale and weighting them with their income shares. The remaining unexplained factor or residual is often called multi-factor productivity (MFP). The residual captures technical change, logistical improvements, changes in corporate governance, economies of scale, the impacts of tax policy and economic policy, calculations errors, etc.[9] Multi-factor productivity explains the lion's share of level and growth rate differences in economic welfare between countries.

But what explains MFP? The most important factor behind multi-factor productivity change is technical change. Especially significant technological leaps are general purpose technologies such as steam power, electricity and information and communications technology (ICT) all of which have over time contributed significantly to economic growth. A new technology's impact is, however, not necessarily immediately seen in the productivity and growth figures.[10] Already Joseph Schumpeter stressed that an invention's and its economic application's (which in Schumpeter's terminology is an innovation) impact is discerned only when its diffusion has spread widely enough.[11]

What about the nature of inventive activity? Are inventions incremental by nature, so that like a building where brick upon brick is laid finally the whole becomes

9 Gould (1972).

10 "We see the computer age everywhere except in the productivity statistics" was a famous quip made by Robert Solow in the 1980s (Solow, 1987). A decade later it was clear that the impact of computers and other information and communications technologies on US productivity growth was major. See also Crafts (2004a).

11 Schumpeter (1928).

larger than the sum of the parts? Charles Jones propagates the view that the accumulation of knowledge leads to a virtuous circle where population increase leads to an increase in the stock of knowledge (which almost inevitably leads to industrial revolutions).[12] Joel Mokyr on the other hand argues that: "...macroinventions are inventions that start the emergence of a new 'technological species' or 'paradigm'". The macroinventions are followed by a string of microinventions as the macroinventions often at first are crude but are successively improved.[13] Paul David is along the lines of Mokyr as he states that: "... the evolution of techno-economic regimes [is] formed around general purpose engines".[14] Also Timothy Bresnahan and Manuel Trajtenberg offer general purpose technologies (GPT's) such as the steam engine, the electric motor and semiconductors as engines of economic growth.[15] Matti Pohjola defines technology, which is the knowledge of how to produce goods and services more efficiently, as the engine of economic growth.[16] He mentions information and communications technology as the present manifestation of technological revolutions.

In the traditional neoclassical model technical change was assumed to be completely exogenous, i.e. the model did not explain technical change which almost miraculously came as though it was the proverbial manna from heaven. Growth could be attained by capital accumulation through refraining from consumption. There was also in Finland a strong belief in capital fundamentalism after the Second World War as becomes obvious when observing the Finnish investment ratio in figure 1.1.[17] Unfortunately investments into fixed capital are not enough to ensure economic growth.[18]

Paul Romer[19] found the neoclassical growth model to be unrealistic and he strived to endogenize technical change. His insight was that ideas, which are nonrivalrous, are fundamentally different from other goods. Hence the name endogenous growth implying that growth comes from within the economic system and not from the outside. According to him growth depended on – in addition to the traditional input factors – spillovers from private research endeavours that led to im-

---

12 Jones (2001) also points out the importance of the evolution of property rights as incentives for would-be inventors/innovators that thus are ensured more rents from their inventions and innovations. North and Thomas (1973) do not see the first industrial revolution as the genesis of modern economic growth. They point out the importance of raising the private rate of return on developing new techniques and implementing these new techniques in the production process.

13 Mokyr (1997).

14 David (1990).

15 Bresnahan and Trajtenberg (1995).

16 Pohjola (2002).

17 See also Pohjola (1996).

18 Yet it is no surprise that studies looking into the relation between e.g. machinery investment and growth find strong associations in success stories, i.e., in countries that are presently industrialized and advanced (DeLong, 1992).

19 Romer (1986). In his production function the income shares of capital and labour did not sum to unity, since the social return to capital ($\alpha+\beta$) used in the growth accounting was bigger than the private return to capital (α) familiar from the neoclassical growth accounting equations (see equation 1.2). Not all endogenous models have increasing returns, e.g. Rebelo (1991) is an example of an endogenous growth model with constant returns to scale technologies.

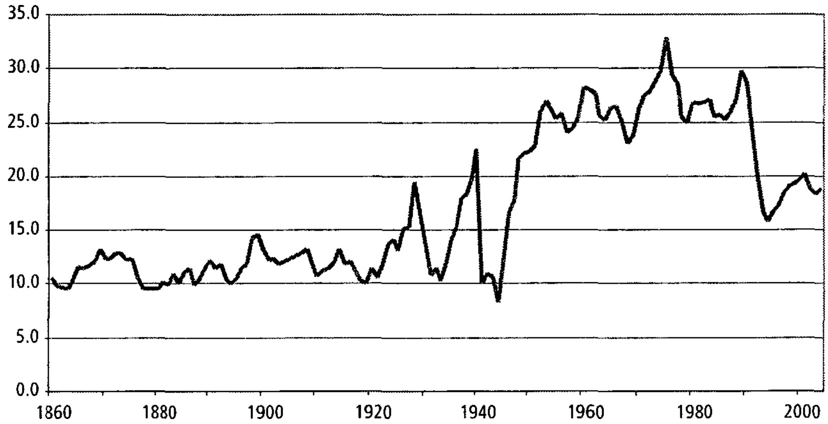


Figure 1.1 The share of gross fixed capital formation in GDP in Finland, 1860–2004 (per cent)
Source: Statistics Finland (2005a).

provements in the public stock of knowledge with increasing returns to scale.[20] Also Robert Lucas had positive externalities in his model, but he connected them with investments in human capital.[21] Romer modified his model to one in which companies invest in research and development (R&D) in order to be able to produce new products.[22] This research and development activity increases the amount of available information and therefore makes life easier also for competitors. In short: the more research and development done yesterday the larger is the stock of knowledge and the easier it is to do research and development today.

Small nations can avoid the plight of diminishing returns by specialising in products suited to their present stage of development.[23] Along with goods and services information spreads (some studies have shown that a country's trade partner's stocks of research and development impact significantly the said country's MFP[24]) and if large markets can be entered it is worth a small country's while to engage in R&D investments. Presumably protectionism is bad for growth.[25] The role of institutions is important.[26] Especially ownership rights are crucial.[27] It is hard to imagine investments or R&D expenditure taking place without guaranteed ownership rights. Robert Barro showed that the standard neoclassical Solow residual can be modified to allow for increasing returns,

---

20 Romer (1994).

21 Lucas (1988).

22 Romer (1990).

23 See also Romer (1987).

24 Helpman (2004).

25 Although it would seem that for a newly industrialized country it is wise to protect industries in their infancy. The difficulty is of course to lift protectionist measures when they are no longer needed. Otherwise maximum productivity growth will not be attained.

26 North and Thomas (1973).

27 Helpman (2004).

spillovers or R&D.[28] Thus the theories of exogenous growth and endogenous growth are complimentary and not rivals.

Walt Rostow's[29] model was an at-the-time prominent attempt at generalizing modern economic growth. He defined five stages-of-growth that all societies linearly pass through. The first category is the *traditional society.* A traditional society is, according to Rostow, one which has limited production functions as well as pre-Newtonian science, technology and outlook. These societies can develop only up to a point. The second stage is the *precondition for take-off.*[30] This is a society that is transforming itself from the traditional kind using the fruits of modern science. Necessary preconditions include building up the infrastructure: roads, railways and ports, and in laying the stage for a shift from primary production and commerce to manufacturing. The third stage is the *take-off.* The take-off, or the industrial revolution, takes place when the threshold to steady economic growth is passed and growth becomes the norm.[31] Rostow furthermore emphasizes the emergence of one or several manufacturing industries as spearheading this stage in combination with the necessary political and social changes. The fourth stage is the *drive to maturity* when the investment ratio ranges between 10–20 per cent and the structure of the economy changes continuously. The final stage is the *age of high mass consumption.* By now the economy's leading sectors have switched to consumer durables and services. As tempting as the thought of the economy once and for all taking-off is, Rostow's linear view on economic development based on British historical evolution is unrealistic.[32]

Alexander Gerschenkron also subscribed to the view that countries are in different phases of economic development.[33] Gerschenkron differed from Rostow in the sense that he did not list a number of set preconditions that had to be fulfilled before growth could be achieved. His key insight was that: "... the development of a backward country may, by the very virtue of its backwardness, tend to differ fundamentally from that of an advanced country". An underdeveloped country has an advantage of backwardness as it can implement a multitude of technological innovations at once when industrialising. And the more backward a country is the more take-off like will its industrialisation be with rapid industrial output growth. Similarly, more emphasis is on capital intensive investment goods than

---

28 Barro (1999).

29 Rostow (1960, 1971). The first edition appeared in 1960 and the second edition in 1971. A translation in Finnish was available as early as 1962 (Taloudellisen kasvun vaiheet, Porvoo: WSOY). Incredibly the Swedish translation was published already in 1959 (Industrisamhällets utvecklingsstadier: ett icke-kommunistiskt manifest, Samhällsdebatten 15, Stockholm): before the original! Rostow's book was in its time very influential and was the cause for heated debate (e.g. Supple, 1963; Gerschenkron, 1963).

30 Rostow wrote that the investment ratio would in this stage be between 5–10 per cent. From figure 1.1 can be seen that Finland had higher investment ratios than predicted by Rostow's stages-of-growth theory already from the 1860s on-wards. This was also pointed out by Hjerppe (1999).

31 According to Krantz (2001) the interwar period was the time of the Finnish take-off.

32 It must be said in Rostow's defence that in Appendix B of the second edition of his book he added that growth is not mechanically assured after the initial take-off but that a country must repeatedly go through the process of take-off to ensure continued growth.

33 Gerschenkron (1952, 1962).

consumption goods in the more backward cases. Undeveloped countries need help from financial institutions and the most underdeveloped nations need state intervention as well as their agricultural sectors are unlikely to provide a growing market for industry by creating a surplus. Gerschenkron's concept of relative backwardness is influential to this day although it is difficult to quantify and put to statistical test as he did not give a formal analytical definition of the concept.[34]

Abramovitz further developed Gerschenkron's idea of the advantage of backwardness.[35] According to the definition of Abramovitz countries with a low level of productivity have a *potential* for rapid growth and catching-up with more prosperous countries. This potential is conditional on the country's *social capability*. That is, a country must be socially advanced to be able to reap the gains from the backlog of technology they can implement. When technological progress is achieved, it is accompanied with structural changes of the economy, meaning both changes in the shares of different industries and structural changes inside the same industry when unprofitable old technology firms are replaced with more profitable new technology firms. In his empirical work Abramovitz often identified a country's social capability with its technical competence – which he proxied with years of education – and qualitative indicators relating to political, commercial, industrial and financial institutions. In addition to this Abramovitz is of course known for his meticulous work on long-term economic growth. His seminal 1956 article, from which the characterisation of multi-factor productivity as "the measure of our ignorance" springs, was one of the first studies that empirically showed (using US data) that when subtracting the contributions of the inputs from the output a significant residual remains.[36]

Simon Kuznets defined economic growth of nations as a sustained increase in product per capita or worker associated with population increase and structural change.[37] Kuznets' life work was the conscientious gathering of national income data for the US and other countries where he distinguished between data breakdowns by industry and by final use. Kuznets realized that the modern economic epoch is distinguished from earlier ones by the extensive application of science to economic production and social organisation and the thereby following high rate of growth. An epochal innovation was defined by him as one that gave a major enlargement to the stock of knowledge and functioned as an engine of sustained economic growth. This is evidenced by the fact that increases in per capita output largely can be explained by agricultural and industrial revolutions and therefore only to a limited extent by increases in inputs per capita. An outcome of the process of modern economic growth is that the structure of the economy changes with a significant drop in the total economy share of primary production, an increase in secondary production's share and a marked boost in the share of services, as well as technological change affecting all sectors individually. In addition to the aggregate and industry level effects of modern growth there is also an international dimension with cross-border flows of people, goods and capital.

---

34 Prados de la Escosura (2005) is a recent empirical application.

35 Abramovitz (1986).

36 Abramovitz (1956).

37 Kuznets (1966).

Joel Mokyr distinguishes between several types of economic growth.[38] *Smithian growth* is growth that is achieved through successful commercial efforts. *Northian growth* is growth gained through more efficient allocation of resources thanks to institutional changes. *Solovian growth* is acquired by increasing the stock of fixed capital. It was only in the latter part of the 18th century, due to the advent of the first industrial revolution, that technological progress started its ascent to become the prime mover of sustained economic growth it is to this day. Technology equals knowledge and according to Mokyr[39] the kind of growth driven by increases in the stock of human knowledge is *Schumpeterian growth*. Mokyr distinguishes between *prescriptive* and *propositional* knowledge. The former one relates to different techniques how to produce (and also include GPTs). An example is the knowledge how to construct a mobile phone. The latter type of knowledge concerns the epistemic base on which the techniques are founded. Propositional knowledge concerns human knowledge of nature.[40] An example is discovering human DNA. DNA has existed as long as life but it was only in the mid-20th century that we became aware of it. Needless to say such a widening of our knowledge base makes it easier to create novel techniques. Occasionally it can be vice versa when a revolutionary new technique widens our knowledge base.

Mokyr[41] finds that *macroinventions*[42] are especially important. He defines them as: "... technological breakthroughs that constitute discontinuous leaps in the information set and create new techniques". Richard Lipsey, Kenneth Carlaw and Clifford Bekar find that most GPTs are what they call "use-radical" ("...an innovation that could not have emerged out of the technologies that preceded it in that specific use"; the example they give is the copying by hand of religious texts in monasteries' scriptoriums, no matter how the use of quill and ink would have been perfected the printing press would not have developed step-by-step), which comes into existence when combining existing technology used for other purposes. The other alternative is "technology-radical"; i.e., a technology is produced which has no apparent "parents".[43] Mokyr gives mechanical clocks, hot-air ballooning and smallpox-vaccination as examples.[44] Lipsey, Carlaw and Bekar define a GPT as a generic historical product, process or organizational model which is distinguished as such right through.[45] An example is the computer. No matter which generation it belongs to (see chapter 4.3) it can be distinguished as a device which can perform arithmetic or logical operations.

The concept of macroinvention also resembles Thomas Kuhn's definition of a scientific revolution as a "...non-cumulative developmental episode[s] in which

38 Mokyr (2005).

39 Mokyr (1990b).

40 Mokyr (2006) suggests that his term propositional knowledge is what Lipsey, Carlaw and Bekar (2005) call general purpose principles: "...a scientific or technological principle that shares many of the characteristics of a GPT, with the important exception that it is not embodied in a distinct generic technology that is recognisable as such over its life-time".

41 Mokyr (1990a).

42 The terms macroinvention and general purpose technology are used interchangeably in this thesis.

43 Lipsey, Carlaw and Bekar (2005).

44 Mokyr (2006).

45 Lipsey, Carlaw and Bekar (2005).

an older paradigm is replaced in whole or in part by an incompatible new one".[46] Importantly these macroinventions make it possible to escape from the claws of diminishing returns.[47] Macroinventions are followed by a string of *micro-inventions* that actually account for most of the concrete productivity increases as the macroinventions are often at first crude but are successively improved. These terms are derived by Mokyr from a comparison with biology where a macromutation stands for the genesis of a new species and a micromutation for a smaller change in an existing species.[48]

1.2 The Finnish growth performance[49]

The cliometric[50] research approach has never been firmly entrenched in Finnish economic history; with the exception of certain scholars and studies.[51] The most notable exception is of course the Finnish historical national accounts research project.[52] The research on Finnish historical national accounts produced series on Finland's GDP growth from 1860 on. The lengthy research was done by scholars of Statistics Finland, the Bank of Finland and the Department of Economic and Social History at the University of Helsinki and ended in the late 1980s when Riitta Hjerppe unified the twelve sectoral studies into consistent historical national accounts for Finland in monograph number thirteen.[53] We thus have fairly detailed annual series for the balance of total supply and demand in current and constant prices since 1860, production and employment for the different industries, the structure of foreign trade according to commodities and countries, and so forth. The framework used is that of historical national accounting where growth at both national and industry levels is accounted for in the tradition of the seminal work of Kuznets.

The total population of Finland in the late 16th century was a mere 300,000, and grew to 450,000 by the end of the following century. The Finnish population roughly doubled every fifty years from 1750 to 1950. Troughs in population growth were due to: the annexation of Finland into the Russian Empire in the early 19th century; a famine in the late 1860s; the Civil War in 1918; the Second World War in the 1940s; and finally at the turn of the 1970s as a result of emigration. Finland is one of the larger countries in Europe in area with a total sur-

46 Kuhn (1996).

47 Smits (2003).

48 Mokyr (1990b).

49 This section draws on Hjerppe and Jalava (2006) and Eloranta, García-Iglesias, Ojala and Jalava (2006).

50 The concept of cliometrics (a combination of history (clio) and measurement (metric)) was born in the early 1960s in the United States as an academic joke. It soon became a leading strand of US economic history research (Jalava, Eloranta and Ojala, 2007a).

51 E.g. Jutikkala, Kaukiainen and Åström (1980); Ahvenainen, Pihkala and Rasila (1982); Vattula (1983). Jalava, Eloranta and Ojala (2007b) is a recent effort to use economic theory and econometric methods on Finnish economic history research.

52 See Hjerppe (1999) for a retrospect of the Finnish historical national accounts project.

53 Hjerppe (1988). The series are updated in Hjerppe (1996).

face area of 338,145 km^2, but it is sparsely populated with 15 persons per square km and a total population of 5.2 million people.[54]

Finland was part of Sweden until 1809 and a Grand Duchy of Russia from 1809 to 1917, with a relatively wide autonomy in economic affairs. Finland gained the status of an independent republic in 1917. Finland in the pre-industrial period was an agrarian country, with a few small towns mostly in the coastal area. Money came to the countryside from tar burning and a few water-powered sawmills, while the towns flourished by exporting the products of these activities; Finland was among the most important tar-producing areas in the world in the 18th century. Sailing ships built in the coastal area exported these items to the Baltic Sea area and western and southern European ports. The ships brought back necessities like salt and iron as well as a few luxuries like cloth, wines and spices. The era of merchant capitalism lasted in Finland from the early 17th century until the 1870s. A transfer to industrial capitalism was evident from the middle of the 19th century onwards and continued for the next 100 years.[55]

Finland in the early 2000s is an industrialised country with a standard of living ranked the 13th highest in the world in the year 2005.[56] One hundred years ago it was a poor agrarian country; with a GDP per capita less than half of that of the world leaders; the United Kingdom and the United States. Albeit the era of financial capitalism began in the early 20th century (and lasted until the mid-1990s[57]) Finland remained an agrarian country up to the period after the Second World War, and the forest industry was the dominant industry in manufacturing. This is to be expected as Finland has large forest areas of coniferous trees, and forests have been and still are an important factor in its economic development. Two thirds of Finland's total area consists of forests and other wooded land. Other natural resources are scarce. Finland embarked on the road to prosperity utilizing its forest sector, its hydropower potential and the rural labour reserve.[58] By the turn of the millennium rapid economic growth combined with a diversification of the economy and the building of a welfare state made the country one of the wealthiest Western economies in the world and a clear case of absolute convergence (figure 1.2[59]). Most of the convergence seems to have taken place after World War II. In Finland the industrialisation phase started late compared with Sweden and the EU15 average.[60] The world's most affluent nations became richer themselves, Finland just grew even faster. Finnish GDP per capita reached parity with the UK, was above OECD and EU averages and was three quarters of that of the US in

54 Statistics Finland (2005a).

55 Ojala and Karonen (2007). In the system of merchant capitalism business was restricted by the Swedish mercantile legislation. Furthermore, it was concentrated in trading houses and ironworks. In industrial capitalism, the Grand Duchy of Finland gained several regulatory privileges, more liberal economic regulations, an own currency and a parliament that renewed its activities. This was a period of rapid industrialisation with the forest industry as spearhead.

56 IMF (2006).

57 Ojala and Karonen (2007). Financial institutions played a significant, commanding and co-ordinating, role vis-à-vis businesses during the era of financial capitalism.

58 Heikkinen and Hjerppe (1986).

59 See also Lindmark and Vikström (2003).

60 Kokkinen, Jalava, Hjerppe and Hannikainen (2007).

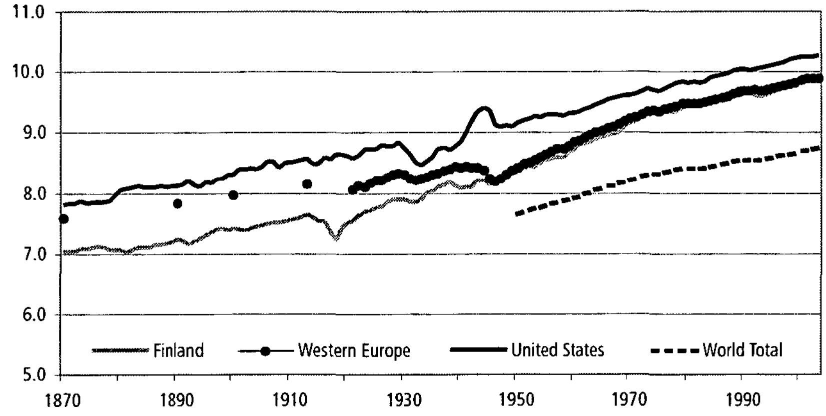


Figure 1.2 **GDP per capita, 1870–2003 (logarithmic scale, 1990 International Geary-Khamis dollars)**
Source: *Maddison (2003). 2006 update downloaded from www.ggdc.net/maddison/ on 17.8.2006.*

2001.[61] During recent decades, the Finnish economy has been characterised by adaptation to globalization and an enormous growth of high tech industries. Unfortunately all nations in the world have not been as fortunate as Finland. World total GDP per capita has continued growing but there has in the latest decades been a regrettable flattening of the curve.[62]

So how does the 20th century productivity growth look in retrospect for Finland? The short answer is that growth can be said to have been labour-saving. We see two major developments: the productivity growth of capital, (Y/K), was almost zero in the long run, while the productivity of labour, (Y/L), grew. Figure 1.3 shows that in the Finnish non-residential market sector, the curve for capital productivity, (Y/K), is virtually horizontal. This means that the change in capital productivity was zero over the long run. Thus the property of the neo-classical growth theory that postulates that the capital stock and real economic growth of the economy expand at the same rate and thus keeps the capital-output ratio constant is satisfied. The curve for labour productivity, (Y/L), on the other hand, has not been horizontal; indeed, quite the opposite. The ratio of capital to labour, (K/L), closely followed labour productivity since capital input per unit of labour increased steadily. The ratio of capital to labour, often called capital deepening, no doubt was influenced by the relative prices of the production factors since labour and capital cannot be used free of charge in production.

The rental prices, the costs of using one unit of labour or capital, are denoted by (w) and (r), respectively.[63] The real wage, (w/p), series increased steadily following the change in labour productivity and the capital-labour, (K/L), ratio

61 Maddison (2003).

62 See also DeLong (1988); Pritchett (1997).

63 The rental price of capital, in the computations underlying figure 1.3, was calculated as the ratio of nominal capital income to the real capital stock (see Antràs, 2004).

closely. It is understandable that, given the steadily increasing real wage, growth was labour-saving. Conversely, given the fact that growth was labour-saving, it was possible to continuously increase the real wage. The labour productivity gain seems mostly to have been used to finance the increased real wage. The rental price of capital was cheaper than the price of using labour, as is shown by the rising, (w/r), curve. The ratio of the price of using one unit of labour to the price of using one unit of capital, (w/r), increased until the 1990s. The real rental price of capital (the rental price deflated with the GDP deflator, (r/p)) more or less declined until the 1990s. Thus substituting labour with capital has been relatively cheap especially after the Second World War. After the early 1990s depression, the share of capital in GDP increased, and there was a clear change in some of these relationships as the mid-1990s with Finnish EU membership saw a shift to maximisation of shareholder value. The real rental price of capital, (r/p), rose, capital intensity, (K/L), stopped growing and capital productivity, (Y/K), improved. This could be related to the rise in the real interest rate, when after decades of zero and sometimes even negative real interest rates there started to be a positive interest on capital in the 1990s.

While the view on Finnish economic performance that figure 1.3 presents us with is in broad terms in accordance with the neoclassical theory of a stable production function[64], two time periods in particular stand out. The interwar period and particularly the post-1990s recession era exhibit simultaneous labour and capital productivity growth. So in these two periods the general pattern is punctuated by phases of both inputs' productivities increasing.[65]

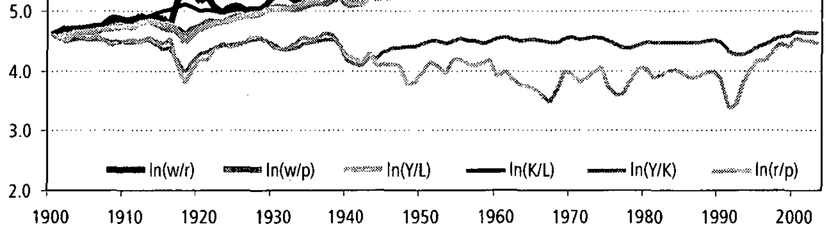


Figure 1.3 Productivity and related indicators in the Finnish non-residential market sector, 1901–2003, 1900=LN (100)
Source: Jalava, Pohjola, Ripatti and Vilmunen (2006).

64 Also according to one of Kaldor's (1957) stylized facts the growth rate of the capital-output ratio should be without a trend as capital and output grow at approximately the same rate.

65 See also Marquetti (2003).

1.3 Objective of study and methods and sources used

To date the literature on growth and productivity has grown to enormous proportions. This body of evidence virtually unanimously singles out the importance of technology – i.e. the knowledge and ideas of how to turn raw materials into goods and services – for productivity growth and in turn the importance of productivity for economic growth. This much we know, although there remains much that we do not know for sure; causalities that we suspect but the mechanisms of which we are not totally familiar with as yet. Neoclassical growth accounting embedded in the national accounting framework while carefully and properly treating the data is the quintessential methodology for discerning the impact of a general purpose technology like ICT (and electricity) on the proximate sources of economic growth.[66]

The traditional Finnish historical national accounts approach did a laudable job in quantifying past historical economic developments, comparable to the efforts in Sweden and the Netherlands.[67] The fundamental role of technical change was implicitly acknowledged, but the main story told was one of growth and structural change. Pekka Tiainen did an independent effort, inspired by the work of Edward Denison[68], which went a step further by also compiling the series on MFP by industry and total economy from 1900 onwards.[69] Unfortunately Tiainen stopped at the MFP figures; he did not decipher the causes behind the MFP growth.

Previous research on Finnish economic growth and structural change inspired by Kuznets neglected to outline the explicit and fundamental importance of productivity.[70] This is why the first research question of this thesis is to ascertain whether the classical view of structural change[71] is sufficient in explaining the Finnish growth record? I look in particular at the role of manufacturing as the proverbial engine of growth. Unfortunately the previous Finnish economic historical research, both the traditional one as well as the one influenced by Denison, ignored the impacts of macroinventions or general purpose technologies on economic growth. The main objective of this study is to remedy this lacuna and shed new light on the Finnish growth miracle by presenting new evidence on the impacts of the general purpose technologies ICT and electricity on Finnish productivity and growth. Therefore the second research objective of this thesis is to find out what new insights on Finnish growth can be gained, by using state-of-the-art neoclassical growth accounting on Finnish historical national ac-

66 Jorgenson, Ho and Stiroh (2005) named quantifying the impact of information technology on economic growth as the "killer application" of their productivity framework.

67 Bohlin (2003); Smits, Horlings and van Zanden (2000).

68 Denison (1962a).

69 The data compiled by Hjerppe (1988) was, of course, the starting point for Tiainen (1994).

70 Jorgenson (2005) wonders at the lack of connection between Kuznets' empirical work and Solow's theoretical work even though they worked at the same physical location – Cambridge, Massachusetts – at virtually the same time.

71 Clark (1940), Kuznets (1966) and Hartwell (1973).

counting data[72], on the impacts of electricity and ICT on Finnish economic growth and productivity. Especially the production, use and productivity of these technologies is analyzed. As the third research question I want to shed light on the Artto-Pohjola paradox, that is, how capital has influenced recent Finnish economic history.

The overall research focus in this thesis is binary. Attention is given both to detailed empirical work on data issues, where every effort is made to respect the data, and above all to analytical topics, where the aim is to see the wood for the trees. The general approach used in this thesis is economic historical at the macro level. The System of National Accounts (SNA93) is the guiding principle.[73] I do not step outside of the SNA's production or asset boundaries. What I do is to reclassify industries or assets to serve my purposes. Mostly the data used is from the most recent version of official national accounts and from the historical national accounts project. Often the splicing together of the most up-to-date series and the historical series is done by me. Use of official data has also for several years included direct access to data underlying the accounts in various Statistics Finland's databases while I have worked at the Economic Statistics Division of Statistics Finland. At times our breakdowns are novel as e.g. in the case of investment data for electrical capital goods in 1900–13 and 1920–38, or for more recent decades in the case of investments in hardware and communications equipment.[74] In this way insights that were not readily discernible directly from the data were gained.[75]

Following the official data has at times been like trying to hit a moving target. The most fundamental revisions in the almost six decades long history of compiling Finnish national accounts have been made during the time of our research. Supply and use tables at the level of almost 1,000 goods and services, in both current and constant prices, now form the core of the accounts beginning with the publication in spring 2006.[76] This relates to current price supply and use tables from the statistical year 1995 onwards and for the constant price series from 2001 onwards. Consistent double deflation[77] has also been introduced at approx-

---

72 Lindmark (2004) points out that certain disrespect for orthodox source criticism is inherent in historical national accounting work. That can also be said for the work at hand, since similarly as is the case with Vikström (2002), no new primary data has been uncovered from the depths of archives.

73 Pohjola (2007) highlights the system of national accounts as the foremost achievement of economics. We do not feel that it is too heroic a statement to assert that the same is true also for economic history. Easterlin (1996) states that: "lacking such quantitative data, the historical record is liable to obscure interpretation." See also O'Brien (1994) on the importance of historical national accounts.

74 Investments for hardware and communications equipment are still not compiled by Statistics Finland although it will be required by Eurostat in the near future. The classification compiled by us for ICT goods and services was first published in Jalava and Pohjola (2003).

75 Kuhn (1996) spoke of how scientists during revolutions see novel and different things when looking at phenomena they have observed before using familiar tools.

76 Statistics Finland (2006).

77 This means that output and intermediate consumption are deflated with their own, separate, indexes. In single deflation output is deflated with some index and the volume change of output is used for intermediate consumption as well. Single deflation was used in Finnish national accounts e.g. for manufacturing industries until the implementation of double deflation.

imately the level of 120 industries and 950 goods and services.[78] When beginning our research total supply and demand were still balanced at the aggregate total economy level by manipulating the usual suspects on the demand side (the production approach has traditionally been the main method in compiling Finnish national accounts), while this balancing is now done individually for all 1,000 products. Also the volume series have changed. When making our first calculations the underlying national accounts series were compiled with a fixed base year with 1995=100. This was changed to a fixed base year with 2000=100. The most recent change is that Finnish national accounts use a chain-linked Laspeyres type volume index with the reference year being 2000 starting with the publication in spring 2006.[79]

The system of national accounts, the current version of which is SNA93, is not simply a statistical device.[80] It is a rich system that connects the macroeconomic transactions taking place during a year to their impacts on the balance sheets. Such activities as production, generation of income and the distribution or use of income are all accounted for. These flows are linked to the balance sheets (stocks) of assets and liabilities. The flow accounts are also linked to each other so that the balancing item of each account, which is defined as the difference between total uses and resources, is carried forward to the following account. In that way, the transactions of each institutional sector are enumerated beginning with production and going all the way to the financial status of the sector. This shows whether the sector is a net lender or net borrower with regard to other sectors. Transactions across sectors, i.e. households, non-financial corporations, housing corporations, financial and insurance corporations, general government, non-profit institutions serving households, and rest of the world, are also consistently recorded. GDP, the value of goods and services produced during a year, is the best known and most widely used statistical product of these flow accounts. GDP includes goods and services that have markets (or which could have markets) and products which are produced by general government and non-profit institutions.

Figure 1.4 shows graphically the process of economic growth. It should be noted that no explicit attempt has been made here to quantify the stock of human capital or to explicitly estimate its impact on economic growth as human capital is outside the present asset boundary of national accounts.[81]

Philippe Aghion and Peter Howitt have shown that the distance to the technology frontier, that is, to the most advanced producers, plays an important

78 Aulin-Ahmavaara (2006).

79 See Statistics Finland (2006) that also lists a number of other of the most recent revisions.

80 See Aulin-Ahmavaara (2007) for the narrative of how the first crude national income measures of the 17th century evolved into the modern, complicated, national accounting framework. Grönlund and Niitamo (1968) recount the story of how national accounts became a part of the production of official statistics in Finland.

81 The two best known approaches of measuring human capital are Kendrick (1976) and Jorgenson and Fraumeni (1989). The first approach is cost based and the latter approach estimates human capital by discounting future labour income. See Aulin-Ahmavaara (2004) for a discussion of the pros and cons of including human capital in the SNA framework.

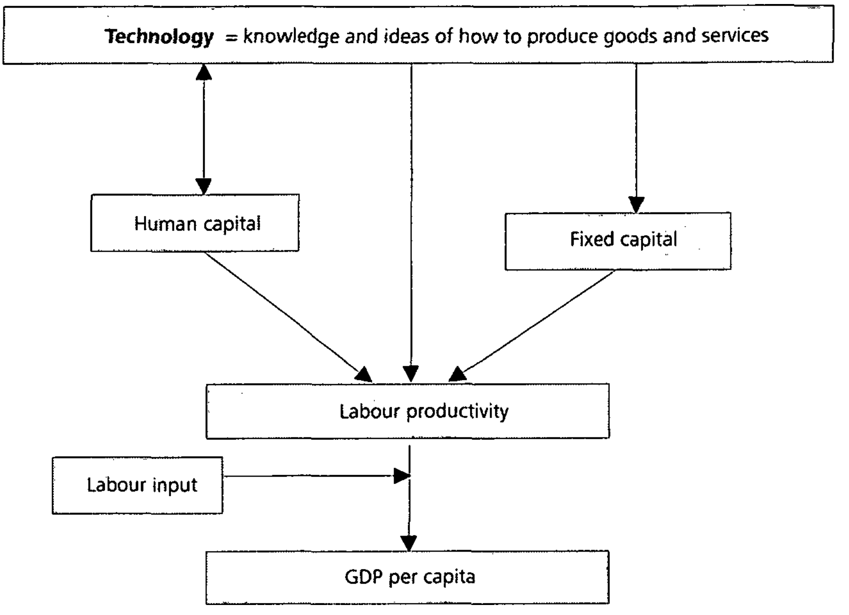


Figure 1.4 The process of economic growth
Source: Adapted from Jalava and Pohjola (2004).

role.[82] It is not possible to adapt technology developed elsewhere if one is on or close to the frontier in a specific industry. It was as late as the 1990s when the Finnish level of labour productivity in manufacturing surpassed EU and reached US levels.[83] Before that Finland could in many industries use its advantage of backwardness. By the 21st century Finland had to abandon the previously successful strategy of growth through investment and adopt a new strategy of growth through innovation.[84] From the 1990s onwards human capital[85] and other intangible capital is crucial for the Finnish story. For the task at hand, i.e. to account for 20th century growth and productivity, the tools we are using are more than sufficient.

In order to be able to produce correct productivity calculations, the quality of the underlying national accounts data is of paramount importance. Eurostat has done extensive work on the harmonisation of national accounts within the EU member states. At first the focus was on current price data, because national accounts data is used widely for administrative purposes, e.g. to determine countries' contributions to the EU budget, for regional funds, etc. Since the signing of the *Stability and Growth Pact* in July 1997, the focus has also turned to price and

82 Aghion and Howitt (2005).

83 O'Mahony and van Ark (2003); Maliranta (2003); Jalava (2006a).

84 Asplund and Maliranta (2006).

85 While human capital naturally is important for absorbing frontier technology quality adjusting the labour input for shifts to labour with higher marginal products approximates the impact of human capital on production when viewing human capital as being generated outside the production process as is done in this thesis (in accordance with SNA93's recommendations).

volume measures. Consequently, Eurostat together with the national statistical institutes started the work to improve price and volume calculations. The results of this work was summarised by Eurostat.[86] Three topics stand out as being of the highest priority: i) the choice of index formula, ii) the work on hedonic indexes for high-tech goods, and iii) the work on volume measures for services. All these topics have clear links to the quantification of the so-called New Economy[87] and especially to the measurement of growth and productivity.

The national account deflators in many countries have traditionally been based on the matched pairs method. The idea is simply to match pairs of goods, i.e. the same product basket is priced at time *t* and then again at time *t+1* to observe how the price of the basket has changed. The thus compiled price indices were then customarily used by national accountants to deflate their current price figures into prices of the base year to obtain Laspeyres volume indexes. However, using an index formula with a fixed base year has the well known drawback of substitution bias, which occurs when the relative prices of certain industries fall very rapidly, causing these industries volume growths to be overstated.[88] This is why the use of chain-linked indexes, where the weights of the previous year are used, is preferred. Eurostat recommends that member states use Laspeyres type chain-linked volume indexes.

When calculating price indexes for high-tech goods that appear and vanish in a rapid succession, it is difficult to pinpoint the quality changes taking place.[89] In such cases, the usage of the matched pairs-method results in a serious loss of information, since only perfect matches from one period to the next are used.[90] To remedy this, different techniques have been tried. The so-called hedonic method has been seen as a good method in dealing with high-tech goods and their inherent quality adjustment problem. It is based on the idea that a good is decomposed into certain qualities and characteristics that can be quantified. For instance Timo Koskimäki and Yrjö Vartia have shown that a large part of the price variations of personal computers can be explained by two factors, processor speed and size of memory.[91] Regression analysis is then utilised to quantify the reason for the price differential between two computers. Notwithstanding the promising results of hedonic methods, there are also some drawbacks. The compilation of the hedonic price index is much more knowledge intensive and time consuming than compiling price indices in the traditional way, and it is also more expensive to collect not only data on prices of goods, but also on their technical characteristics.

---

86 Eurostat (2001).

87 Lipsey (2002) defines the phenomenon of the New Economy as the: "... the full effects on the economic, political and social systems of the ICT revolution that is driven by the computer, lasers, satellites, the internet and a few other re-lated communication technologies with the computer at the centre."

88 See Whelan (2002).

89 In the national accounts only price changes are to be reflected in the price index. All other changes are to be captured by the volume component (Eurostat, 2001).

90 Unless of course the matched model indexes are constructed at a high degree of disaggregation and use high frequency data (Aizcorbe, Corrado and Doms, 2003).

91 Koskimäki and Vartia (2001).

Finnish national accounts do not use hedonic techniques for ICT products. This is why we turned to data from the US Bureau of Economic Analysis. The methodology utilized here is broadly that of Paul Schreyer.[92] The idea is that the annual changes in the Bureau of Economic Analysis' price index for non-ICT fixed investments are contrasted with the annual changes in the Bureau of Economic Analysis' ICT price indexes. We smoothed the series thus obtained, after which they were multiplied with the Finnish investment deflator to obtain the Finnish quality adjusted ICT deflators.

The third important price and volume topic is the ongoing work to obtain better volume measures for services, since they presently are very unsatisfactory indeed, with for instance average earnings indices being used as proxies for price changes of output. The development work on service statistics is ongoing both on international fora and in national statistical institutes. The focus of the development work is on the methods used compiling producer price indexes for the services sector, on the classification of service products and on statistics on service production by products. Statistics Finland has started to produce producer price indexes for a limited amount of service industries and will gradually extend the coverage.[93]

A core part of the neoclassical model of economic growth[94] was the formulation of an aggregate production function.[95] There economic output is explained as a function of capital and labour inputs and time. Usually the aggregate production function is expressed in the form:

$$Y_t = A_t f(K_t, L_t), \qquad (1.1)$$

where, at any given time t, aggregate value added Y is produced from aggregate inputs consisting of capital services K and labour services L. The level of technology or multi-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 markets are competitive, growth accounting gives the share weighted growth of outputs as the sum of share weighted inputs and growth in multi-factor productivity:

$$\Delta Y = \alpha \Delta K + (1-\alpha)\Delta L + \Delta A, \qquad (1.2)$$

where the Δ-symbol refers to a first difference, i.e. $\Delta x \equiv x(t) - x(t-1)$, $(1-\alpha)$ is the income share of labour and α is the income share of capital. Due to constant returns to scale the income shares (which are averaged over the periods t and

92 Schreyer (2000).

93 Statistics Finland (2005b).

94 Solow (1956, 1957).

95 What Solow had in mind when working with growth theory was to find a systematic way to analyze equilibrium growth paths for the economy (Solow, 2000).

t–1) sum to unity. ΔA is the residual that remains after the share weighted changes in inputs have been deducted from the change in output.[96]

Neoclassical growth accounting basically divides output growth into the contributions of input growth, i.e. labour and capital, with multi-factor productivity growth being the residual. The classic production function of Robert Solow[97], where he theoretically linked the production function with the non-parametric index approach, was further developed by Dale Jorgenson and Zvi Griliches who broadened the concept of substitution in Solow's growth accounting framework and showed that it is also important to account for substitution between different kinds of capital and labour.[98] The inputs are corrected for changes in quality and weighted with their marginal products – their market prices. MFP catches all unmeasured factors such as technical change (a shift of the production function), organisational improvements, economies of scale and measurement errors. The neoclassical theory is based on many assumptions, which are important to keep in mind when analysing the results. Most importantly, capital – though considered the engine of growth in the short run – is seen to suffer from diminishing returns, so that productivity growth in the long run is completely exogenous.[99]

In the production possibility frontier[100] approach on the other hand aggregate outputs consist of outputs of investment goods and consumption goods which in their turn are produced by aggregate inputs (capital and labour services at some technology)[101]:

$$Y(Y_{ICT}(t), Y_O(t)) = A(t)F(K_{ICT}(t), K_O(t), L(t)), \qquad (1.3)$$

where, at any given time t, aggregate value added Y is assumed to consist of the production of ICT goods and services Y_{ICT} as well as of other production Y_O. These outputs are produced from aggregate inputs consisting of ICT capital services K_{ICT}, other capital services K_O and labour services L. The level of technology or multi-factor productivity is represented in the Hicks neutral or output-augmenting form by parameter A.

Assuming constant returns to scale in production and competitive product and factor markets, growth accounting gives the share weighted growth of outputs as the sum of the share weighted inputs and growth in multi-factor productivity:

$$\begin{aligned} \Delta \ln Y &= \overline{w}_{ICT}\Delta \ln Y_{ICT} + \overline{w}_O \Delta \ln Y_O \\ &= \overline{v}_{ICT}\Delta \ln K_{ICT} + \overline{v}_O \Delta \ln K_O + \overline{v}_L \Delta \ln L + \Delta \ln A, \end{aligned} \qquad (1.4)$$

---

96 Griliches (1996) finds the first mention of an output-over-input index in Copeland (1937). Griliches (1996) credits Tinbergen (1942) for the first explicit calculations of "technical developments", followed by Stigler (1947), Schmookler (1952), Fabricant (1954), Kendrick (1955), Abramovitz (1956) and Solow (1957). See also Fabricant (1974) and Hulten (2000).

97 Solow (1957).

98 Jorgenson and Griliches (1967).

99 The aggregate production function gives a single output as a combination of capital and labour at some technology. Therefore there is no role for separate prices for investment and consumption goods Jorgenson (2005).

100 E.g. Jorgenson (2005).

101 This is my favoured approach. As it is very data intensive it is only used in chapter 6.

where Δ 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 $\overline{w}_{ICT}$ and $\overline{w}_{O}$ depict the average nominal value-added shares of ICT and other production, respectively, and they sum to one. The weights $\overline{v}_{ICT}$, $\overline{v}_{O}$ and $\overline{v}_{L}$ also sum to one and respectively represent the average nominal income shares of ICT capital, other capital and labour. All shares are averaged over the periods t and $t\text{–}1$.

Concerning fixed capital SNA93 is not adequate for growth accounting. In the national accounts there are two measures of capital stocks: the gross capital stock and the net capital stock. The traditional capital stock measures have been developed since the 1950s and due to their easy availability they have been widely used in productivity calculations. However, neither national accounts capital stock measure is appropriate for use in productivity or growth accounting computations. The gross capital stock does not take into account the possible decline in the capital good's productive capacity as it ages. The net capital stock depicts the market value of capital and not its productive capacity. In growth accounting based on neoclassical theory, the measure of capital input to be used (instead of gross or net stocks) is widely accepted to be the Jorgenson and Griliches measure of capital services based on the concept of productive capital. The price indexes of the homogeneous asset types are assumed to convert nominal investments in different years into identical units of efficiency. Thereafter the productive capital stocks of homogeneous capital goods are aggregated using their Hall-Jorgenson[102] rental prices. Concerning capital I could be said to belong to the Jorgensonian school.[103] In this thesis I also favour the (non-parametric) index approach to productivity measurement rather than the regression approach (although regression techniques are used in studying structural change); since the index approach is recommended by the OECD as well as Jorgenson and Steven Landefeld.[104] However, I prefer to use the Törnqvist index.[105] The reason for this is that Erwin Diewert showed that the Törnqvist index is superlative which the Laspeyres index is not.[106] The index approach is the system used by the official producer's of national accounts and productivity statistics.[107] It enables national statistical institutes to produce reliable productivity statistics on a continuous basis. The alternative would be for them to re-parameterize their regressions whenever a new year's observations become available. Not to mention that regression results are more difficult to explain to those users of statistics that are not technically oriented.

102 Hall and Jorgenson (1967).

103 I do not treat consumer durables as investment as e.g. Jalava and Kavonius (2007) does nor do I compute stocks of inventories or land as does Jalava (2002).

104 OECD (2001b); Jorgenson and Landefeld (2006). Diewert (1980) finds that the main disadvantage of the econometric approach is that it becomes unworkable when the number of outputs and inputs is large. This property is not shared by the index approach.

105 Törnqvist (1936).

106 Diewert (1976, 1978). It was shown that the Laspeyres index (unlike a superlative index) signifies a production function where the inputs can be combined only in set proportions.

107 Statistics Finland's productivity publications used the index approach (e.g. Statistics Finland, 1996, 1997, 1998, 1999a, 2000a, 2002a, 2003; Jalava, 2004b; Jalava 2005).

1.4 Structure of thesis and main results

This thesis consists of an introductory chapter, six research chapters and a chapter with concluding remarks. In chapter 2 Finnish economic growth and the evolvement of the structure of the economy is observed. Finland was a late industrialized country that managed to transform itself from a predominantly primary production based economy to a modern welfare state with a large service sector. In raising the level of Finnish GDP per capita to three quarters of the US level the role of labour productivity was cardinal. Secondary production was the leading sector in labour productivity change due to rapid technical progress. In the late 1800s and early 1900s labour shifting out of primary production contributed at best half of overall labour productivity growth. Recently productivity growth has been more concentrated than before as the rural surplus labour has long since shifted to secondary production and services.[108] Our analysis confirms the idea of economic growth taking place in stages. Yet, the role of secondary production as the single engine of growth remains uncorroborated by my regressions.[109] Chapter 2 furthermore demonstrates the considerable impact of labour productivity on GDP per capita. Finland's industrialization changed her economic structure irrevocably. Structural change in itself was more an effect of rather than the cause for Finnish economic growth. Finland's share of secondary production in GDP still exceeded its US equivalent by approximately ten percentage points at the turn of the millennium.

The fundamental role of capital in economic growth has been long known. How capital should be defined and measured has been the subject of much discussion. The starting point in chapter 3, which was co-authored with Pirkko Aulin-Ahmavaara, is methodological as we define starting from a neoclassical production function the indicators for capital input and compare these with the traditional capital stocks of national accounts. The origin of Finnish capital measurement is also traced. The different capital measures are applied to Finnish data in 1975–2001. This period is interesting as the early 1990s was a turbulent period for Finland with GDP declining by more than 10 per cent. We find that there was a spectacular increase in capital productivity growth after the 1990s recession. Finally, we observe how our new estimates accord with the previous view on how capital has influenced recent Finnish historical economic development. Our main result is a resolution of the Artto-Pohjola paradox, as we show that a high rate of return was combined with a low capital productivity growth in 1975–1990. The effect (of which alternative capital measure is used) on multi-factor productivity is minor at the level of the whole economy. Although the composition of capital has shifted into a more short-lived and intangible direction, the good old K in the production function is by no means obsolete. It has just transformed, which poses a great challenge for an historical analysis of the

---

108 The result of this is often large scale urbanization. The rural labour force can also take recourse to self-employment; this is an alternative to migration (Tervo, 2004).

109 See also Broadberry (1993) who found that US, UK and German convergence can not be explained solely by manufacturing. Kokkinen, Jalava, Hjerppe and Hannikainen (2007) found that Finland's convergence to Sweden in GDP per capita terms relied to a significant extent on the service industries (especially after 1965).

proximate sources of Finland's economic growth. To put it another way, the greater part of Finnish economic growth is left unexplained when using traditional growth accounting.

Advanced economies are becoming more and more "weightless", as the share of the production of tangible goods in their GDPs diminishes.[110] Has something profoundly new taken place? That is, could it be that we actually are in the midst of an information and communication technology revolution, as ICT follows in the footsteps of steam and electricity in becoming a general purpose technology? The diffusion of two general purpose technologies, electricity and information and communication technology, throughout the Finnish manufacturing industry is described in chapter 4. The historical genesis of electricity and ICT is also briefly outlined. The full diffusion of electricity as motive power in the 1920s and 1930s led to an increase of nearly 4 percentage points in manufacturing labour productivity growth. Furthermore, all industries gained across the board in productivity. In contrast, by the time ICT was fully diffused, towards the end of the twentieth century, yeast-like productivity gains were nowhere to be found. In fact, labour productivity growth had slowed down in many industries, the notable exception being the manufacture of electrical and optical equipment industries, in which labour productivity growth mushroomed. From a breakdown of growth in labour productivity into the contributions of internal productivity growth, employment share effect and a cross term, I found that labour shifting to industries with differing levels or growth rates of labour productivity explains less of aggregate labour productivity change in the period 1920–1938 (and even less in the period 1974–2000) than it does for the period 1901–1920.

Although investment in ICT has exploded since the mid-1970s, aggregate productivity growth remained sluggish until the mid-1990s in the United States which is the world's leader in both the production and use of ICT. Therefore, many researchers have taken the strong performance of the US economy in the late 1990s as most welcome evidence for the view that the large investments in ICT have finally started to pay off. It is generally believed that the United States has become a "New Economy" in which business firms have learnt to take advantage of both the ICT revolution and the globalization of business activities in ways which improve productivity. Indeed, the US growth rate of labour productivity has doubled in the late 1990s. By surveying recent research, chapter 5 which was co-authored with Matti Pohjola, confirms that both the production and use of ICT have been the factors behind the improved economic performance of the United States in the 1990s. The evidence for the New Economy is much weaker outside the United States. Growth accounting is applied to estimate the impacts in Finland using provisional, unofficial, data. It is shown that the contribution to output growth from ICT use has increased from the early 1990s to the late 1990s. In addition, the fast growth of multi-factor productivity in the ICT producing industries has had an even larger impact. But, unlike in the US, there has been no acceleration in the trend rate of labour productivity.

Chapter 6, which was co-authored with Matti Pohjola, analyzes the impacts of information and communications technology on output and labour productivity

---

110 Quah (2001).

growth in Finland in 1995–2005. Using the production possibility frontier approach the chapter analyzes the impacts of information and communications technology on output and labour productivity growth in Finland in 1995–2005. ICT is a general purpose technology that spreads to all sectors of the economy, improving and becoming cheaper over time and facilitating the creation of new goods, services and modes of operation. It affects economic growth both as a component of aggregate output in the form of ICT production and as a component of aggregate input in the form of ICT capital services. Furthermore, it has an impact on growth via the effect of multi-factor productivity gains induced by rapid technological advances in the ICT producing industries. ICT accounted for nearly two thirds (ICT capital deepening one sixth plus ICT related contribution to MFP one half) of the observed labour productivity growth. The rest is attributed to multi-factor productivity growth in non-ICT production. It is shown how properly quality adjusting capital and labour inputs and, above all, using hedonic indexes for ICT products gives a clearer picture of the true sources of growth.

The roles of two macroinventions, electricity and ICT, as engines of growth in Finland's economic transformation from a backward agricultural nation to a prominent high-tech producer are explored in chapter 7, which was co-authored with Matti Pohjola. 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 foremost information societies. 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.

Economic theory explains how economic growth is driven by advances in technology, that is, in ideas about how to combine inputs to produce outputs. 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 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.

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. 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.

Chapter 8 offers concluding remarks on how successful this thesis was in answering the research questions and what this works' contribution to our understanding of the Finnish economic historical development is.

2

Production, primary, secondary, and tertiary: Finnish growth and structural change, 1860–2004[111] [112]

Jukka Jalava

Abstract: In this chapter Finnish economic growth and the evolvement of the structure of the economy is observed. In 1860 primary production still dominated, while by year 2004 the share of services was the greatest. Characteristic to the Finnish long run economic transformation was that industrialization started late and that services increased directly at the expense of primary production. Industries' internal productivity growth was more important than structural change although growth and productivity in secondary production was consistently highest. Our analysis confirms the idea of economic growth taking place in stages. Yet, the role of secondary production as the single engine of growth remains uncorroborated.

2.1 Introduction

In the 1800s Finland was a backward agrarian country where as late as 1867–8 a significant part of the population suffered death by starvation when the crops failed. Finland embarked on the road of industrialization utilizing her forest sector, her hydropower potential and the rural labour reserve. The role of electrification as an enabler of productivity boosting technical innovations was critical. Characteristic to the Finnish long run economic transformation was that industrialization started late and that services increased directly at the expense of primary production. The share of secondary production in Gross Domestic Product (GDP) did not decrease until the 1970s. The classical view of structural change is that the main contributor to economic growth first shifts from primary production to secondary production during the process of industrialization, and subsequently from secondary production to tertiary production as the post-industrial stage is entered. What happens to growth

111 This chapter first appeared as: Jukka Jalava (2006b): "Production, Primary, Secondary, and Tertiary: Finnish Growth and Structural Change, 1860–2004", *Pellervo Economic Research Institute, Working Papers No. 80*, January.

112 I wish to thank Janne Huovari, Arto Kokkinen and Petri Rouvinen for helpful comments and discussions without implicating them for any remaining errors. My 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" (www.euklems.net).

when the gains from industrialization are depleted or the labour-saving nature of secondary production's productivity growth shifts the focus of the economy to services? Is it so as Baumol's (1967) hypothesis of unbalanced growth predicts that productivity growth in the whole economy will slow down when resources shift to service industries? Fortunately Oulton (2001) showed that that is only the case for those service industries which produce final goods, and not for the industries producing intermediate goods. What about Griliches' (1992) concern that when the difficult to measure industries' share of the economy grow, an inevitable slowdown in aggregate productivity is the result? The resolution of the quantification puzzle lies in better measurement, something which both the academic community and statistical institutes have focused on recently.

The Finnish share of services in GDP was only two thirds and the respective US ratio close to three quarters in 2001 (OECD, 2003). Therefore, in an historical perspective, the challenges facing Finland in the 21st century are similar to those facing her when embracing the fruits of the second industrial revolution. It is inevitable that structural change will continue, and the role of service industries, particularly those using the fruits of the third industrial revolution, is paramount as our economy becomes increasingly weightless (Quah, 2001).

In this paper the evolvement of the present industrial structure will be observed and the impact of structural change on growth and productivity quantified. Special attention will be given to the hypothesis that manufacturing is the engine of total economy growth and that it exhibits increasing returns to scale; the Kaldor-Verdoorn growth laws. In the next section the growth of GDP per capita and its components are delineated from 1860 to 2004. Section three looks at the three main sectors and their development. The penultimate section tests whether Kaldor-Verdoorn laws stand the test of Finnish data and the final section concludes.

2.2 GDP per capita

A nation's economic standard of living is usually measured with Gross Domestic Product per capita. GDP is a flow measure that denotes the value of the goods and services produced during one year. GDP includes in its production boundary goods and services that have markets (or which could have markets) and products which are produced by general government and non-profit institutions. GDP is the best known and most widely used final product of national accounts. The system of national accounts, the current incarnation of which is SNA93, comprehensively connects flow accounts that capture various economic transactions taking place during the accounting period. Such activities as production, generation of income, and the distribution or use of income are all accounted for. These flows are linked with the balance sheets (stocks) of assets and liabilities. The flow accounts are also linked with each other so that the balancing item of each account, which is defined as the difference between total uses and resources, is carried forward to the following account. In that way each institutional sector's transactions are enumerated beginning with production and going all the way to the sector's financial status. That is, whether the sector is a net lender or net borrower with regards to other sectors.

Unfortunately national accounts do not measure the positive factors of the quality of life such as expected life length, health and clean environment. National accounts do not either measure the drawbacks on nature and human well-being due to negative externalities from production such as the pollution of the environment caused by spills or leaks from production plants. Furthermore, the production of "bads" like tobacco and pesticides is recorded as increases in output. An additional drawback with national accounts is that it is not designed to quantify income and wealth inequalities between social and economic classes.

Notwithstanding the aforementioned caveats GDP per person is the most valuable tool for measuring the economic well-being of a nation.[113] For an inter-temporal comparison of how a nation's living standards have evolved over time the impact of inflation needs to be subtracted. I.e., the GDP's per person in consecutive years must be expressed in the prices of some base year. The standard of living can be expressed as a product of its two components: labour productivity and labour input per capita. Labour productivity (GDP per labour input) is the more important one as it can grow without bounds. For the amount of work that can be done per person there is an upper limit. Therefore economic growth can in a long run perspective only be sustained by labour productivity change. Equation 2.1 shows GDP per person and its components:

$$\frac{GDP}{population} = \frac{GDP}{labour\ input} \times \frac{labour\ input}{population}. \tag{2.1}$$

Labour input can be quantified either by using number of persons employed or by hours actually worked. The latter one is preferable as changes in the hours worked by employees due to longer vacations or shifts to atypical employment patterns otherwise distort the results. Hence the basic unit for labour productivity (LP) is GDP per hour worked. GDP per person is the higher the higher LP is, the larger the employment share of population is and the more each employee works. Economies can settle for a lower living standard by choosing to work less. This choice depends on how much society values leisure versus material well-being. A point in case can be discerned from the numbers compiled by the Groningen Growth and Development Centre.[114] Their purchasing power corrected GDP per capita figures for 2004 reveal that the United States had one of the highest living standards in the world. A result that is hardly surprising. Yet, countries such as Belgium, France, Ireland, the Netherlands, and Norway all simultaneously exhibited a higher level of LP and a lower level of GDP per capita than the US. Looking at equation 2.1 it is easy to figure out that these countries worked less per average person than what was done in the US.

Figure 2.1 shows the levels of Finnish GDP per capita and its components for the years 1860–2004. GDP at market prices is expressed in the constant prices of year 2000. The variables are in natural logarithms so that the logarithm of the

113 Development economists, such as Easterly (2001), have found strong positive correlations between the positive factors of the quality of life and GDP per capita.

114 See www.ggdc.net, Total Economy Database, January 2005.

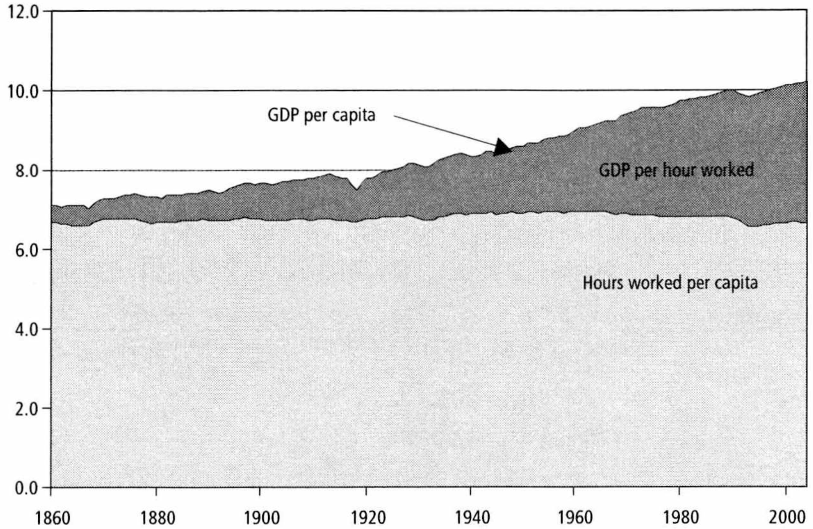


Figure 2.1 GDP per capita and its components in Finland, 1860–2004 (LN, GDP at year 2000 prices)
Source: Own calculations; data from Hjerppe (1996) and Statistics Finland.

material living standard is the sum of the logarithms of labour productivity and labour input per person:

$$\ln(GDP / population) = \ln(GDP / \; labour\ input) + \ln(labour\ input / population). \quad (2.2)$$

Two lessons can be learned from figure 2.1. First, it is obvious that the main contribution to the standard of living came from labour input. In 2004 each Finn worked on average 778 hours per year and GDP per hour worked was 35.3 euro. This means that GDP per capita was 27,400 euro. Second, the graph shows that the increase in material well-being stemmed from LP growth. In 1860 each Finn worked approximately 794 hours while LP was only 1.5 euro per hour. This amounted to 1,225 euro in the prices of year 2000. The standard of living grew 22-fold in less than a century and a half, even though fewer hours were worked in 2004 per capita compared to 1860. The explanation to this is that labour productivity increased 23-fold.

The labour input increased to approximately 1,000 hours per person in the 1940s. This level was kept until the late 1960s when the hours worked started to decline. The recession of the early 1990s brought the hours down to 700 per person from which level they rebounded to somewhat less than 800 hours. Interestingly, Finns are presently working less than ever before during their independence.

Figure 2.2 shows the growth rates of figure 2.1's three level variables in the years 1861–2004. The annual observations often fluctuate quite much from year

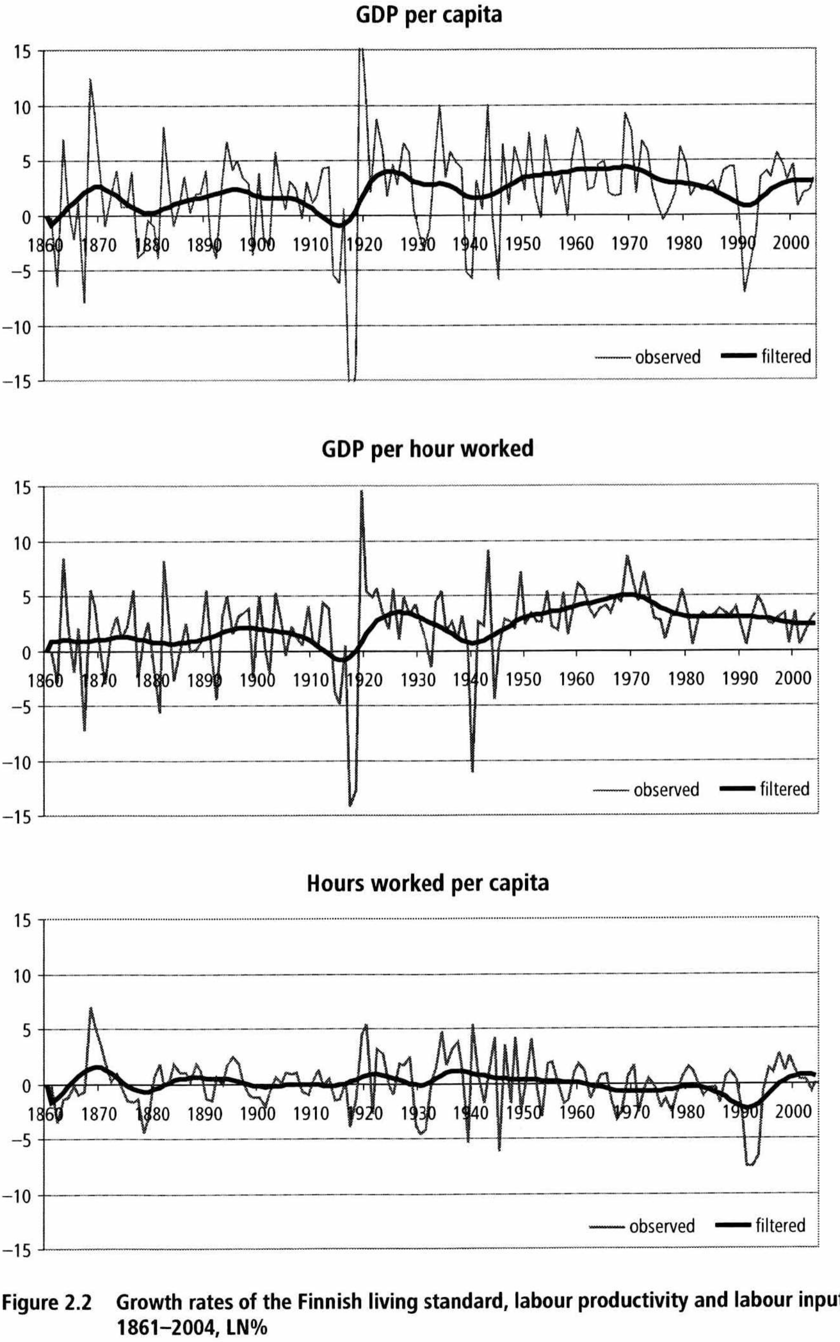


Figure 2.2 Growth rates of the Finnish living standard, labour productivity and labour input, 1861–2004, LN%

Source: Own calculations; data from Hjerppe (1996) and Statistics Finland.

to year. Hence, a line from which short-term variations have been smoothed[115] out was added to the graphs. This simplifies the visual interpretation of the average growth rates. The top part of figure 2.2 depicts GDP per capita growth. The standard of living gradually increased its growth rate from the 1920s – with the exception of wartimes – until peaking in the 1960s at 4 per cent. This growth stemmed in the early years from both LP and hours worked. During the latest decades growth relied solely on LP. This changed once again after the recession of the early 1990s, when also labour input contributed to GDP per capita growth. The most recent average observations of GDP per capita change have shifted into slower gear – around 3 per cent per annum – due to a decline in LP growth. The decline in hours worked that began in the late 1960s stands out as negative growth in the lowest part of the graph. It did not turn positive until the 1990s. Also LP growth halved from the 1960s peak 4–5 per cent growth to somewhat more than 2 per cent per annum recently.

It is easy to show that the slowdown in LP growth – and not a decrease in labour input – poses a threat to the future growth of the Finnish standard of living. From equation 2.1 and figure 2.1 it can be seen that an increase in labour input has a level effect on GDP per capita. Productivity growth on the other hand acts through the interest on interest principle. Even a slight change in growth rates has significant long term implications.

2.3 Structural change

Economic activity takes place in three major sectors. What is the difference between primary, secondary and tertiary production? Fisher (1939) called primary production something which is "...concerned with satisfying the basic primary needs, in the absence of which any kind of activity would be impossible". Clark (1957)[116] defined primary production as depending on first-hand and instant use of natural resources. A distinguishing feature of primary production is that it can be carried out only where the natural resources are situated, and it can also be dependent on climatic and seasonal constraints. On that note one could also include mining and quarrying, as Kaldor (1967) did, because it is an extractive activity. In this paper, however, mining and quarrying is incorporated in secondary production since it requires considerable investments into fixed capital and is as an economic activity more similar to manufacturing than to agriculture or forestry, a point which Kuznets (1966) agreed with. Table 2.1 contains the used taxonomy.

Secondary production is not straightforwardly the refinement of primary products. Clark (1957) included into secondary production such large scale, capital intensive and continuous production that produces transportable goods. Fisher (1939) thought that secondary production contained such manufacturing activities that catered for the standardized demand for less than essential things. So by default tertiary production was according to him the production and distribution of new things which come about as a result of improving technology, i.e.,

---

115 The Hodrick-Prescott (1997) filter was used with the smoothing parameter $\lambda=100$.

116 The first edition appeared in 1940. The 1957 version was a third largely rewritten edition.

Table 2.1 Taxonomy of primary, secondary and tertiary production by branch of economic activity

Primary production	A	Agriculture, hunting and forestry
	B	Fishing
Secondary production	C	Mining and quarrying
	D	Manufacturing
	E	Electricity, gas and water supply
	F	Construction
Tertiary production	G	Wholesale and retail trade; repair of motor vehicles etc.
	H	Hotels and restaurants
	I	Transport, storage and communications
	J	Financial intermediation
	K	Real estate, renting and business activities
	L	Public administration and defence; compulsory social security
	M	Education
	N	Health and social work
	O	Other community, social and personal service activities
	P	Activities of private households as employers etc.

Source: *Adaptation of the UN International Standard Industrial Classification of All Economic Activities, Revision 3.1 (ISIC Rev. 3.1).*

items which could be called luxury goods and services. Kuznets (1966) wanted to include transport and communications into secondary production. Kaldor (1967) thought that secondary production encompassed industry, construction and public utilities. Hartwell (1973) defined the tertiary sector as the residual after subtracting agriculture, industry and construction. In this paper it was decided to classify transport and communications and public utilities in tertiary production or services as the SNA93 calls it. The justification for this decision is in SNA93's paragraph 6.8:

"Services are not separate entities over which ownership rights can be established. They cannot be traded separately from their production. Services are heterogeneous outputs produced to order and typically consist of changes in the conditions of the consuming units realized by the activities of producers at the demand of the consumers. By the time their production is completed they must have been provided to the consumers."

As early as in the 17th century Sir William Petty (1676) wrote:

> "There is much more to be gained by Manufacture than Husbandry, and by Merchandize than Manufacture...Now here we may take notice, that as Trades and curious Arts increase; so the Trade of Husbandry will decrease, or else the Wages of Husband men must rise, and consequently the Rents of Lands must fall."

Petty realized that shifting resources away from less productive sectors into more productive ones is not only beneficial but actually a prerequisite for increased growth. Clark (1957) was along the same lines as he described how primary production, which is dependent on local natural resources and climate, usually faces diminishing returns and that as economies become more advanced the share of the labour force employed in primary production shifts relative to secondary production, which in turn declines relative to tertiary production. How then is a nation able to avoid the Malthusian Trap[117] in the first place? Many authors agree that the first industrial revolution was THE watershed in human economic history after which we were freed from the Malthusian Trap (Hansen and Prescott, 2002; Komlos, 2003; Mokyr, 2005; and Clark, 2005). However, as Mokyr (2005) points out, societies with sound institutions and active trading enjoyed growth even prior to the industrial revolution. The point is that after the industrial revolution the importance of technology[118] to growth became paramount. Hansen and Prescott (2002) described this as a shift from a pre-industrial land-intensive Malthusian technology, with decreasing returns to labour, to a modern era Solowian constant returns to scale technology, with both capital and labour as inputs. This shift is of relatively recent origin as modern economic growth as we know it today has actually existed only for the last two centuries.

Kuznets (1966) stressed four arguments which cause a declining share of primary production in total output. Firstly, as incomes per capita grow there might be a proportionately larger demand for non-agricultural products. Secondly, as an increasing agricultural output volume goes hand in hand with increased population and incomes (as it must in a non-Malthusian economy) the widening domestic markets provide more opportunities for non-agricultural import competing industries. Thirdly, Kuznets noted declining primary production shares in developed countries especially after they began trading with less developed countries and fourthly, he observed that technological change was an important factor; he actually stated that the rapider the technical change the faster the change in sectoral shares. In secondary production the fruits of technological change are most readily harnessed for productive use, so although its relative share first increases at the expense of primary production the rapid productivity increases potentially makes its labour share decrease in favour of the tertiary sector. This classic view is not unchallenged as e.g. Broadberry (1998) argued that Germany and the United States surpassed Britain's level of aggregate labour productivity by shifting resources out of agriculture and improving the productivity of services rather than manufacturing.

What about Finland? Characteristic to the Finnish long run economic transformation was that industrialization started late and that services increased directly at the expense of primary production, since the share of secondary production in GDP did not decrease until the 1970s (figure 2.3). Finland embarked on the road of industrialization utilizing her forest sector, her hydropower potential and the rural labour reserve. The role of electrification as an enabler of productivity boosting technical innovations was critical. In the 1860s only a fraction of the Finnish populace was employed in industry or industrial handicrafts. Fifty years later a tenth of the workforce was employed in industry, with a share in total output of one fifth by 1913. At the eve of WWII industry's share in GDP amounted to nearly one in four.

117 If the size of the population grows, i.e. births outnumber deaths, the material living standard declines in a pre-industrial society due to diminishing returns to land (Clark, 2005).

118 Technology is here widely interpreted to include all knowledge and ideas of how to produce goods and services.

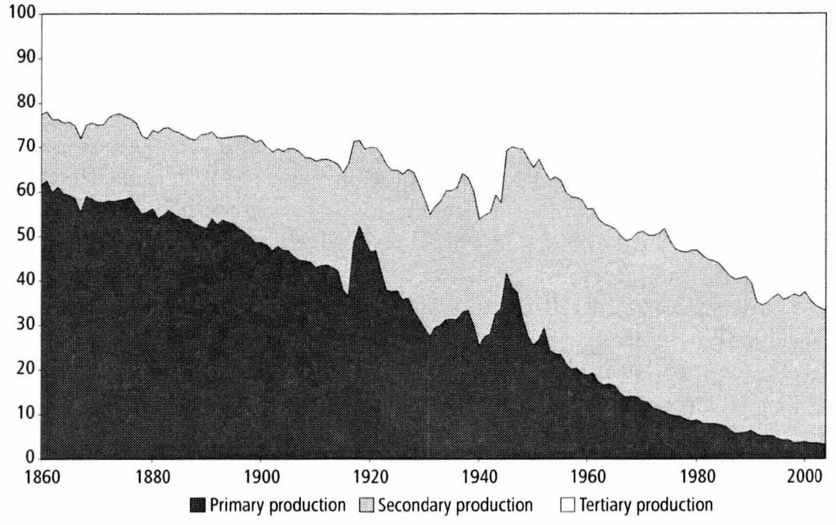


Figure 2.3 Shares of primary production, secondary production and tertiary production in Finnish GDP, 1860–2004, %

Source: Own calculations; data from Hjerppe (1996) and Statistics Finland.

In 1860 four out of five persons were employed in primary production. As productivity was low they managed to generate only 60 per cent of value added. Less than 15 per cent were working in secondary production and their value added shares and employment ratios were approximately on par. The labour share of services was low: just 7 per cent. Yet their share of GDP was one in five. This high productivity was to a significant extent explained by the large share of ownership of dwellings in services: two fifths of services' value added with no labour input in 1860 (Hjerppe, 1996).[119]

Tertiary production's labour share caught up with that of secondary production during and after the civil war of 1918, during the turbulent early 1930s and during the Second World War. Employment in industry and construction rebounded each time (Hjerppe, 1996). From 1955 onwards services permanently employed more persons than secondary production and three years later even more than primary production. The share of secondary production in GDP peaked both in 1951 and 1974 at more than 40 per cent. By the beginning of the 21st century industry and construction's share of GDP was 30 per cent and primary production's only three per cent. The rest originated from services. The Finnish economy had in Quah's (2001) terminology become increasingly weightless. Since the US share of services in GDP was close to three quarters in 2001 (OECD, 2003) it does not take a crystal ball to predict that the Finnish economy will become even more weightless in the future. Increased globalization has already shifted secondary production to countries with lower unit labour costs and close proximity to developing markets.

119 These extraordinary figures do raise a question of the correctness of the deflators of services; a topic which goes beyond the scope of this paper.

During the whole 1860–2004 period GDP grew on average by almost 3 per cent, the value added of primary production by one per cent, secondary production by 4 per cent and services by three (table 2.2). Growth was especially rapid in the 1920s and 1930s and in the post-WWII pre-oil crisis era. As a result of this consistent growth Finland's GDP per capita converged to 77 per cent of its US equivalent in 2004.[120]

Value added growth can be decomposed into the contributions of a change in labour input and a change in labour productivity. More formally:

$$\Delta \ln(GDP) = \Delta \ln(\mathit{labour\ input}) + \Delta \ln(GDP / \mathit{labour\ input}), \qquad (2.3)$$

where Δ refers to a first difference. Tables 2.3 and 2.4 contain average yearly growth rates of labour input and LP. Tables 2.2–4 can be interpreted in the following way: of the average yearly 2.9 per cent GDP growth in services in 1861–1949 2.7 percentage points stemmed from increases in labour input and 0.2 percentage points from LP change. Of the overall average GDP growth of

Table 2.2 Growth rates of value added at 2000 prices, LN%

	1861–1949	1950–2004	1861–2004
Primary production	1.1	0.6	0.9
Secondary production	4.0	4.0	4.0
Tertiary production	2.9	3.9	3.3
Total	**2.6**	**3.5**	**2.9**

Source: *Own calculations, data from Hjerppe (1996) and Statistics Finland.*

Table 2.3 Growth rates of labour input, LN%

	1861–1949	1950–2004	1861–2004
Primary production	0.4	−3.2	−1.0
Secondary production	2.1	−0.1	1.3
Tertiary production	2.7	1.7	2.3
Total	**1.2**	**0.1**	**0.7**

Source: *Own calculations, data from Hjerppe (1996) and Statistics Finland.*

Table 2.4 Growth rates of labour productivity, LN%

	1861–1949	1950–2004	1861–2004
Primary production	0.6	3.8	1.9
Secondary production	1.9	4.0	2.7
Tertiary production	0.2	2.2	1.0
Total	**1.4**	**3.4**	**2.2**

Source: *Own calculations, data from Hjerppe (1996) and Statistics Finland.*

120 See Groningen Growth and Development Centre and The Conference Board, Total Economy Database, August 2005, http://www.ggdc.net.

2.9 per cent in 1861–2004 only 0.7 percentage points were the result of increased labour input and 2.2 percentage points came from LP improvement.

The growth of labour input in primary production was consistently slower than in the other sectors in 1861–1949. Growth turned negative after WWII. The decline accelerated from period to period until it was more than 5 per cent in 1995–2004. Labour input in secondary production grew faster than the national average in the first observation period. In the latter period it was close to zero. The labour input in services increased at a pace above average in every period. LP growth was faster than average every period in industry and construction. LP change in agriculture and forestry was more than average in 1950–2004 thanks to extensive labour shedding – and not due to rapid growth of value added.

A shift-share analysis was performed in order to find out what the impact of structural change, that is of labour shifting to industries with either a higher level of or higher growth rate of LP was on labour productivity growth (see Syrquin, 1984). The relative change in labour productivity can be expressed as:

$$\frac{LP_t - LP_{t-1}}{LP_{t-1}}$$

$$= \frac{\sum_{i=1}^{n}(LP_{i,t} - LP_{i,t-1})S_{i,t-1} + \sum_{i=1}^{n}(S_{i,t} - S_{i,t-1})LP_{i,t-1} + \sum_{i=1}^{n}(S_{i,t} - S_{i,t-1})(LP_{i,t} - LP_{i,t-1})}{LP_{t-1}} \quad (2.4)$$

where *LP* is the level of labour productivity, S_i is sector *i*'s share of all hours worked (the sectors used are primary production, secondary production and tertiary production) and *t* is time. The first term on the right side of the equation is the industries' internal (within) productivity effect, i.e., sub-industries impact on aggregate productivity change. The second term on the right is the static shift effect of labour, that is, the contribution of a shift of labour to industries with a higher level of LP. The third term on the right captures the dynamic shift effect of labour, i.e., the contribution of labour shifting to industries with a higher than average LP growth rate.

It can be seen from table 2.5 that one half to eight tenths of LP growth emanated from internal productivity increase. The rest was due to structural change. The effect of structural change was largest in the 1800s when labour shifted from primary production to industry and construction. In the years between the two world wars Finnish manufacturing was fully electrified (Jalava, 2004a). The impact of static shift diminished when there was a step-up in LP growth across all sectors in the post-WWII period (table 2.4). The dynamic shift has slowed productivity

Table 2.5 The impact of structural change on labour productivity growth, %

	1861–1949	1950–2004	1861–2004
Within	48.3%	81.6%	69.2%
Static	55.1%	18.2%	31.9%
Dynamic	−3.4%	0.1%	−1.2%
Total	**100.0%**	**100.0%**	**100.0%**

Source: Own calculations, data from Hjerppe (1996) and Statistics Finland.

growth in the first observation period whereas it was negligible in the latter period. All in all the dynamic effect's impact has been minor. Table 2.5 shows us that internal productivity growth is more important than structural change and that productivity change was more concentrated than ever before in the latest period.

2.4 Phases of growth

Hartwell (1973) defined successive stages of economic development according to the share employed in services. First, agricultural countries with a small industrial sector exhibit slow growth rates of services. Second, industrialising nations display declining agricultural employment and industry and services that grow at similar rates. The third stage is industrial nations with minimum agricultural and maximum industrial employment. The final stage is a service economy where services grow at the expense of secondary production. Hartwell (1973) found phase one to have ended in Western Europe between 1800 and 1850. Stage two took place between 1840 and 1910, and stage three between 1920 and 1970. Writing in the early 1970s he concluded that stage four was just beginning. Hjerppe (1990) defined stage one to have lasted in Finland until the mid-1880s. She found stage two to have continued until the 1950s. A similar development as portrayed by Hartwell's stage three was not found by Hjerppe (1990) for Finland at all. She concluded that the employment share of primary production was still high in the 1950s and that it subsequently diminished directly in favour of services. At the time of writing Hjerppe (1990) found the employment share in secondary production to have decreased only mildly. It is easy to concur with Hjerppe that Hartwell's stage three as such did not take place in Finland. Industry's employment did not peak simultaneously with a trough in primary production employment. The employment of secondary production is presently in a post-peak declining phase whereas employment in agriculture and forestry has failed to reach a bottom as yet.

What is the role of the three sectors in overall growth? Kaldor (1967) stressed that a precondition for the growths of the secondary and tertiary sectors is that primary production produce a surplus over the bare subsistence minimum. As a nation passes from economic immaturity to maturity, by which Kaldor (1978) meant a state where real incomes per head in each sector are comparatively similar, the role of secondary production is crucial due to increasing returns to scale. Kaldor (1967, 1978) suggested that aggregate economic growth is related to growth in manufacturing, that manufacturing productivity growth is related to manufacturing output growth and that manufacturing productivity increases the productivity of the other sectors. These observations are often called Kaldor's growth laws[121] (e.g. Stoneman, 1979; Bairam, 1990; Mamgain, 1999; Wells and Thirlwall, 2003).

Ordinary Least Squares (OLS) regressions were carried out to cast some light on the applicability of Kaldor's laws' on Finnish historical economic development. As a proxy for the first proposition GDP growth was explained with sec-

121 Not to be confused with Kaldor's stylized facts.

ondary production's real value added growth (and as checks also with value added of primary production and services).[122]

$$\Delta Y_{GDP} = \alpha_1 + \beta_1 \Delta Y_{SEC} + \varepsilon_1 \ , \qquad (2.5)$$

$$\Delta Y_{GDP} = \alpha_2 + \beta_2 \Delta Y_{PRIM} + \varepsilon_2 \ , \qquad (2.6)$$

$$\Delta Y_{GDP} = \alpha_3 + \beta_3 \Delta Y_{TERT} + \varepsilon_3 \ , \qquad (2.7)$$

$$\Delta Y_{GDP} = \alpha_4 + \beta_4 \Delta Y_{SEC} + \beta_5 \Delta Y_{PRIM} + \beta_6 \Delta Y_{TERT} + \varepsilon_4 \ , \qquad (2.8)$$

where ΔY_{GDP} is volume growth of GDP and ΔY_{SEC} , ΔY_{PRIM}, and ΔY_{TERT} are respectively secondary production, primary production and tertiary production real value added change. The error term is ε. The error term is often called the residual as it captures all that is left unexplained. The index for time *t* has been suppressed for the economy of notation. The results are shown in table 2.6 and table 2.7 (the numbers in brackets are the t-statistics).[123]

Looking at table 2.6 it does seem that our basic regressions, where GDP growth is explained with secondary production value added (equation 2.5), are highly significant. All of the explanatory variables are significant at the 0.1 per cent level. This means that the likelihood that the beta coefficients equal zero is

Table 2.6 Regression results for equations 2.5 and 2.6

	1861–1949	1950–2004	1861–2004	1861–1949	1950–2004	1861–2004
N	89	55	144	89	55	144
equation	2.5	2.5	2.5	2.6	2.6	2.6
constant	0.012** (2.84)	0.010** (3.31)	0.015*** (6.71)	0.021*** (4.55)	0.035*** (7.33)	0.026*** (7.36)
β_1 (ΔY_{SEC})	0.306*** (5.27)	0.671*** (14.26)	0.345*** (6.71)			
β_2 (ΔY_{PRIM})				0.296* (2.15)	0.223*** (3.77)	0.272** (2.67)
Adj. R^2	0.391	0.863	0.434	0.198	0.165	0.184
D.W.	2.35	1.76	2.12	1.99	1.00	1.72
F	27.79***	203.48***	45.00***	4.62*	14.24***	7.12**

*** = significant at the 0.1% level.
** = significant at the 1% level.
* = significant at the 5% level.
+ = significant at the 10% level.

Source: Own calculations, data from Hjerppe (1996) and Statistics Finland.

---

122 See Appendix for graphs of all variables and their unit root tests.

123 The t-statistics and F-statistics have been obtained using the Newey-West (1987) regression procedure in the software Intercooled Stata 8.2 for Windows. The idea is that the error structure is expected to be heteroskedastic and autocorrelated up to some predetermined lag. We chose the lag length to be $N^{1/3}$, this means 4 for each of the both sub-periods and 5 for the whole period.

very low. The highest adjusted[124] R^2, our measure for goodness-of-fit, is for the post-WWII period at 0.86 and the beta coefficient more than doubles to 0.67. The implication is that 86% of GDP growth is accounted for by equation 2.5 in 1950–2004 and that it according to the model takes on average 1.5 units (=1/0.671) of industry and construction growth per unit of GDP increase. The significance of agriculture is also very high in the latter period although the explanatory power of equation 2.6 is rather low. The R^2:s fail to rise above 0.2 and the beta coefficients vary between 0.2–0.3. Agriculture does explain GDP slightly better in the first period, 1861–1949, than in the latter which corresponds with intuition. Interestingly equation 2.7 is very significant with good linear fits (table 2.7). Especially in 1950–2004 the R^2:s are close to 0.9 and the beta coefficient is very near unity. Kaldor (1978) also found similar results for twelve industrial countries in 1953–1964 and interpreted them the other way round; i.e. as the rate of GDP growth determining growth in services. We would not go as far as to claim anything definitive about causation based on these regressions. It is, however, interesting to observe that GDP and services have over the past half-century grown hand-in-hand. As all of the explanatory variables in equations 2.5–7 are significant they are combined in equation 2.8 to explain GDP growth with primary, secondary and tertiary production value added. The results reinforce those of equations 2.5–7 except for agriculture in 1950–2004; the drop in the beta coefficient to 0.07 from 0.34 is quite dramatic. Furthermore, the F-tests reject for all periods for equations 2.5–8 the likelihood that the linear relationship is nonexistent. The weakest rejection is for agriculture in the earlier

Table 2.7 Regression results for equations 2.7 and 2.8

	1861–1949	1950–2004	1861–2004	1861–1949	1950–2004	1861–2004
N	89	55	144	89	55	144
equation	2.7	2.7	2.7	2.8	2.8	2.8
constant	0.008+ (1.76)	−0.001 (−0.46)	0.009+ (1.97)	−0.002+ (−1.87)	0.001 (0.99)	0.000 (0.39)
β_4 (ΔY_{SEC})				0.116*** (5.87)	0.305*** (14.56)	0.155*** (7.94)
β_5 (ΔY_{PRIM})				0.341*** (8.21)	0.071*** (5.03)	0.253*** (6.67)
β_3 or β_6 (ΔY_{TERT})	0.555*** (4.91)	0.963*** (16.19)	0.615*** (5.17)	0.621*** (35.78)	0.595*** (20.93)	0.607*** (34.23)
Adj. R^2	0.509	0.875	0.563	0.963	0.992	0.931
D.W.	1.77	1.84	1.75	1.62	1.87	1.74
F	24.13***	262.12***	26.72***	555.93***	6061.23***	569.16***

*** = significant at the 0.1% level.
** = significant at the 1% level.
* = significant at the 5% level.
+ = significant at the 10% level.

Source: Own calculations, data from Hjerppe (1996) and Statistics Finland.

124 Adjusted means that it is corrected for the degrees of freedom lost when estimating the regression parameters.

period. Kaldor's first law holds in the Finnish case for industry and construction. Especially the latter period shows strong correlations. The regressions for primary production and services also pass the statistical tests.

Kaldor's second law is about increasing returns to scale in manufacturing. In testing Kaldor's second proposition (which is also known as Verdoorn's law), we used industry and construction LP growth which was explained by its value added growth (and as checks similar regressions were performed also for primary production and services). It is clear from figure 2.1 that most of long-run economic growth comes from LP growth. So there would be little point in applying regressions 2.9-11 at the level of the total economy.

$$\Delta LP_{SEC} = \alpha_5 + \beta_7 \Delta Y_{SEC} + \varepsilon_5 \, , \tag{2.9}$$

$$\Delta LP_{PRIM} = \alpha_6 + \beta_8 \Delta Y_{PRIM} + \varepsilon_6 \, , \tag{2.10}$$

$$\Delta LP_{TERT} = \alpha_7 + \beta_9 \Delta Y_{TERT} + \varepsilon_7 \, , \tag{2.11}$$

where ΔLP_{SEC}, ΔLP_{PRIM} and ΔLP_{TERT} are respectively secondary, primary and tertiary production labour productivity growth. The results for equations 2.9 and 2.10 are in table 2.8 and the results for equation 2.11 are in table 2.9.

Observing tables 2.8 and 2.9 it would seem that there is statistical support for secondary production, for tertiary production in 1950–2004 and surprisingly for agriculture and forestry the whole period; both for the equations as a whole according to the F-tests and for the explanatory variables individually according to the t-tests.

Table 2.8 Regression results for equations 2.9 and 2.10

	1861–1949	1950–2004	1861–2004	1861–1949	1950–2004	1861–2004
N	89	55	144	89	55	144
equation	2.9	2.9	2.9	2.10	2.10	2.10
constant	0.003 (0.47)	0.029*** (4.94)	0.011* (2.16)	–0.002 (–0.86)	0.033*** (6.64)	0.011** (2.60)
β_7 (ΔY_{SEC})	0.416*** (6.24)	0.283*** (3.38)	0.401*** (5.73)			
β_8 (ΔY_{PRIM})				0.821*** (24.80)	0.876*** (11.07)	0.829*** (21.68)
Adj. R^2	0.490	0.302	0.448	0.875	0.726	0.753
D.W.	2.00	1.43	1.74	1.55	1.50	1.05
F	38.92***	11.43**	32.79***	615.17***	122.52***	470.05***

*** = significant at the 0.1% level.
** = significant at the 1% level.
* = significant at the 5% level.
+ = significant at the 10% level.

Source: Own calculations, data from Hjerppe (1996) and Statistics Finland.

As a specification for Kaldor's third proposition aggregate LP growth was explained by secondary production's value added growth and the non-secondary sectors' labour input growth.

$$\Delta LP_{GDP} = \alpha_8 + \beta_{10}\Delta Y_{SEC} + \beta_{11}\Delta E_{PRIM\&TERT} + \varepsilon_8 \,, \qquad (2.12)$$

where ΔLP_{GDP} is total economy LP change and $\Delta E_{PRIM\&TERT}$ is change in non-secondary production labour input. The results are in table 2.9. In the latter period the R^2:s climb to 0.71. Aggregate LP growth is explained by industry and services' value added growth; beta coefficient 0.43 and by the decrease in non-secondary production value added, beta coefficient –0.43 (both are significant at the 0.1% level). This means that our results suggest that a one unit increase in secondary production's value added increased aggregate LP by 0.43 units and a one unit increase in non-secondary production's labour input decreased aggregate productivity by 0.43 units. We must keep in mind that 29 per cent of productivity growth was left unexplained and that the scope of general government increased in the same period.[125] This latter relation was in 1861–1949 only –0.14 (although statistically insignificant). Kaldor's third law does seem to hold for Finland in 1950–2004. The unfortunate implicit implication of equation 2.12 is that it supports Baumol's unbalanced growth hypothesis given the facts that the beta coefficient is much larger in the second period and the only sector that has increased its labour input after the oil crisis is services. Taking a second look at fig-

Table 2.9 Regression results for equations 2.11 and 2.12

	1861–1949	1950–2004	1861–2004	1861–1949	1950–2004	1861–2004
N	89	55	144	89	55	144
equation	2.11	2.11	2.11	2.12	2.12	2.12
constant	0.000 (–0.01)	0.007+ (1.67)	0.005 (0.65)	0.006 (1.25)	0.019*** (9.10)	0.014*** (4.02)
β_{10} (ΔY_{SEC})				0.199*** (3.58)	0.428*** (11.20)	0.226*** (4.21)
β_9 (ΔY_{TERT})	0.072 (0.36)	0.377*** (4.53)	0.131 (0.66)			
β_{11} ($\Delta E_{PRIM\&TERT}$)				–0.138 (–0.49)	–0.429*** (–4.07)	–0.261 (–1.14)
Adj. R^2	0.002	0.461	0.036	0.236	0.708	0.260
D.W.	1.60	1.28	1.48	2.10	1.75	1.78
F	0.13	20.48***	0.44	6.86**	76.83***	10.08***

*** = significant at the 0.1% level.
** = significant at the 1% level.
* = significant at the 5% level.
+ = significant at the 10% level.

Source: Own calculations, data from Hjerppe (1996) and Statistics Finland.

125 As modern national accounts computes the output of general government using the sum of costs principle the implication is that the calculated productivity increase is virtually zero (with the exception of an increase in labour quality).

ure 2.2's middle panel we see that LP growth has nearly halved from what it was in the 1960s and 1970s.

2.5 Conclusions

In this chapter we set out to describe Finnish long run economic growth and the role structural change played in this transformation. Finland was a late industrialized country that managed to transform itself from a predominantly primary production based economy to a modern welfare state with a large service sector. In raising the level of Finnish GDP per capita to three quarters of the US level the role of labour productivity was cardinal. Secondary production was the leading sector in LP change due to rapid technical progress. Until the first oil crisis the labour input in secondary production grew faster than the national average, whereas the labour input in services increased at a pace above average in every period. In the late 1800s and early 1900s labour shifting out of primary production contributed at best half of overall LP growth. Recently productivity growth has been more concentrated than before as the rural surplus labour has long since shifted to secondary production and services.

What did our number crunching efforts reveal of the Kaldor-Verdoorn laws in the Finnish case? Was it so that secondary production and its productivity was the engine of economic growth in Finland? Yes and no. Our regressions support the role of industry and services as explaining GDP growth to a large part. However, the first law holds also for primary production and services; for primary production only barely in the early years. Services actually explained GDP growth better than secondary production. Did economic growth cause growth of services or vice versa? Unfortunately our regressions cannot give a definitive answer to the direction of causation. Kaldor's second law, which he used to test for increasing returns to scale, holds for secondary production (although more so in the first period than in the latter), for services in 1950–2004 and surprisingly for agriculture and forestry for the whole observation period. The equation we used as a proxy for Kaldor's third law – explaining aggregate labour productivity change with secondary production value added and non-secondary production labour input – did corroborate the theory for 1950–2004. Inopportunely this meant, given the fact that only services increased their labour input after the first oil crises, rending implicit support for Baumol's theory of aggregate LP growth slowing down as the share of services in the economy grew.

In conclusion we can say that our numbers confirmed Hartwell's basic idea of economic growth taking place in different phases. Finland's industrialization changed her economic structure irrevocably. Structural change in itself was more an effect of rather than the cause for Finnish economic growth. It does not take a crystal ball to realize that the Finnish economic structure will continue evolving, since Finland's share of secondary production in GDP still exceeded its US equivalent by approximately ten percentage points at the turn of the millennium. For a developed nation change is the only thing that is constant.

Appendix

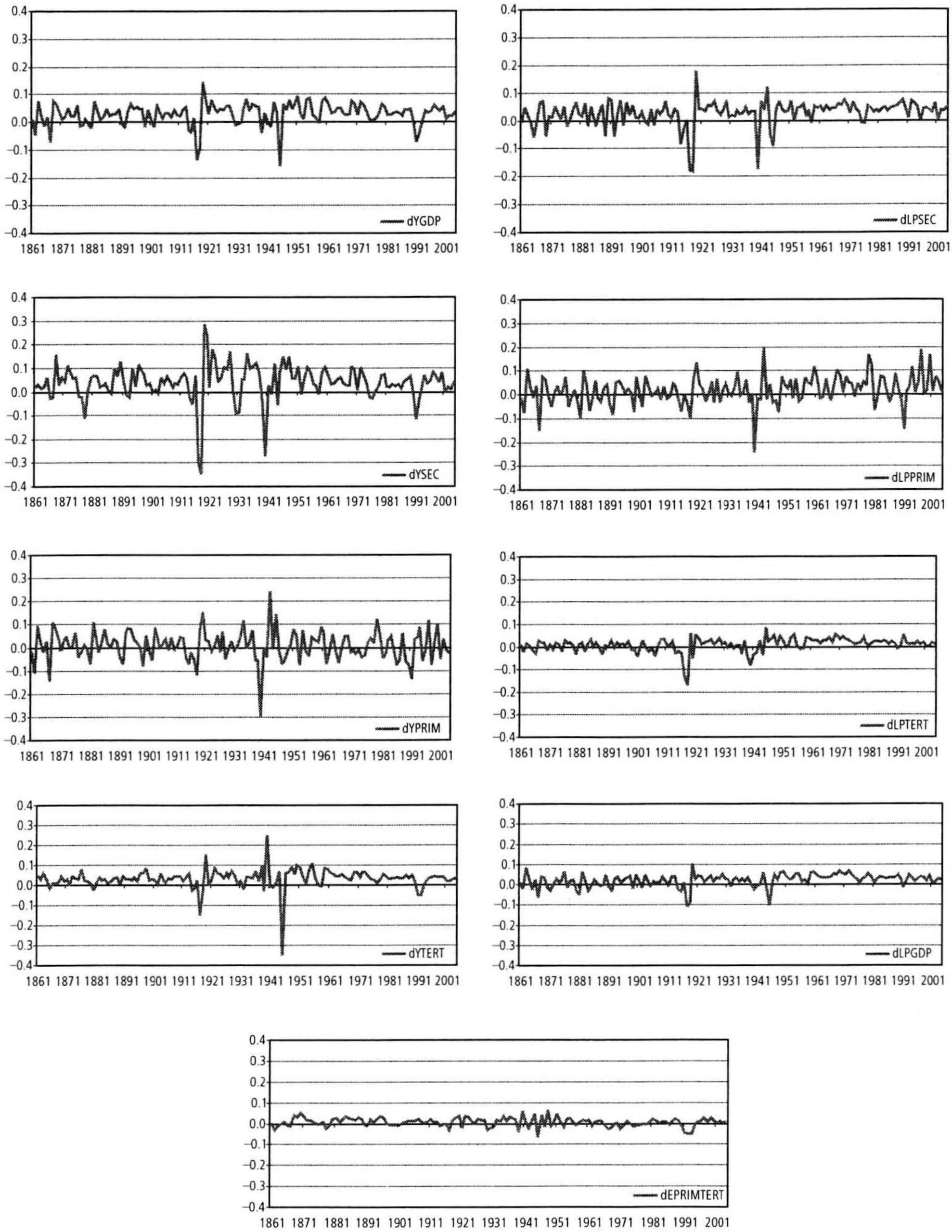


Figure 2.4 **Series of ΔY_{GDP}, ΔY_{SEC}, ΔY_{PRIM}, ΔY_{TERT}, ΔLP_{SEC}, ΔLP_{PRIM}, ΔLP_{TERT}, ΔLP_{GDP}, and $\Delta E_{PRIM\&TERT}$, 1861–2004, LN%**

Source: *Own calculations; data from Hjerppe (1996) and Statistics Finland.*

The augmented Dickey-Fuller (ADF) test was used to test for a unit root in the time series. As the graphs contain no visible trend we felt comfortable in omitting a trend-term from the tests. The null hypothesis of the ADF test is that of a unit root and the results are in table 2.10. To our convenience it would seem that the existence of a unit root is rejected for most series and most time periods. The null hypothesis is not rejected for services' labour productivity in 1950–2004 and is significant only at the 10 per cent level for total economy LP in the same period. Overall the rejections in 1950–2004 are weaker than in 1861–1949 or the whole period.

Table 2.10 Results for the Augmented Dickey-Fuller tests with no trend and four lags in the sub-periods and no trend and five lags in the whole period

	1861–1949	1950–2004	1861–2004
ΔY_{GDP}	–5.01***	–3.29*	–5.23***
ΔY_{SEC}	–5.52***	–3.13*	–6.28***
ΔY_{PRIM}	–6.27***	–3.42*	–6.90***
ΔY_{TERT}	–6.82***	–3.47**	–5.81***
ΔLP_{SEC}	–4.06**	–2.95*	–4.17***
ΔLP_{PRIM}	–6.37***	–3.18*	–4.66***
ΔLP_{TERT}	–4.31***	–2.06	–4.15***
ΔLP_{GDP}	–4.14***	–2.76+	–3.60**
$\Delta E_{PRIM\&TERT}$	–5.51***	–-3.42*	–5.55***

*** = significant at the 0.1% level.
** = significant at the 1% level.
* = significant at the 5% level.
+ = significant at the 10% level.

Source: Own calculations, data from Hjerppe (1996) and Statistics Finland.

3
Capital and its productivity in Finland, 1975–2001[126] [127]

Pirkko Aulin-Ahmavaara and Jukka Jalava

Abstract: The fundamental role of capital in economic growth has been long known. How capital should be defined and measured has been the subject of much discussion. The starting point of this study is methodological as we define starting from a neoclassical production function the indicators for capital input and compare these with the traditional capital stocks of national accounts. The origin of Finnish capital measurement is also traced. In the empirical part of the paper we apply the different capital measures to Finnish data in 1975–2001. This period is interesting as the early 1990s was a turbulent period for Finland with GDP declining by 11 per cent. We find as a result of our number-crunching effort that there was a spectacular increase in capital productivity growth after the recession. Finally, we observe how our new estimates accord with the previous view on how capital has influenced recent Finnish historical economic development. Our main result is a resolution of the Artto-Pohjola paradox, as we show that a high rate of return was combined with a low capital productivity growth in 1975–1990.

3.1 Introduction

The fundamental role of capital in economic growth has been known at least since the writings of the physiocrat Anne-Robert-Jacques Turgot and Adam Smith in the 18th century. Since Karl Marx and the Cambridge controversies there has been constant dissension on how to define capital and what for instance is meant by the quantity of capital. Separate views even exist on the question whether heterogeneous capital can be aggregated into a single measure of capital at all. The practical measurement of capital is also subject to opposing views. Therefore the economic historian doing research on matters pertaining to capital should be prepared to meet criticism. However, as Hicks has it:

---

126 This chapter was first published as: Pirkko Aulin-Ahmavaara and Jukka Jalava (2003): "Capital and its productivity in Finland, 1975–2001", *Scandinavian Economic History Review* (50) 3, pp. 62–79.

127 We thank Sakari Heikkinen, Reino Hjerppe, Pekka Sauramo, two anonymous referees and seminar participants in Reykjavik for helpful comments. The views expressed are those of the authors and do not necessarily reflect the views of Statistics Finland. Jukka Jalava gratefully acknowledges financial support from the Yrjö Jahnsson Foundation.

"*Capital (I am not the first to discover) is a very large subject, with many aspects; wherever one starts it is hard to bring more than a few of them into view. It is just as if one were making pictures of a building; though it is the same building it looks quite different from different angles.*"[128]

While the recent discussion in the historical economics literature has focused on alternative models explaining economic growth[129], i.e. exogenous or endogenous growth[130], institutions[131] and catching-up[132], the problems relating to capital measurement are many times ignored altogether, and often K is casually written to denote both the value of capital and the input into production it provides, both of which are then assumed to decline uniformly by the same rate δ, which is called the depreciation rate.

In the national accounts (SNA93 and ESA95) on the other hand, there are two measures of capital stocks: the gross capital stock and the net capital stock. The traditional capital stock measures have been developed since the 1950s and due to their easy availability they have been widely used in productivity calculations. However, neither national accounts capital stock measure is appropriate for use in productivity or growth accounting computations. The gross capital stock does not take into account the possible decline in the capital good's productive capacity as it ages. The net capital stock depicts the market value of capital and not its productive capacity.

In growth accounting based on neoclassical theory (and the productivity research associated with it), the measure of capital input to be used (instead of gross or net stocks) is widely accepted to be the Jorgenson and Griliches[133] measure of capital services based on the concept of productive capital. The productive capital stocks of homogeneous capital goods are aggregated using their rental prices. Complete consensus has not been reached on the empirical side either, though there has been a vivid recent discussion, especially under the auspices of the OECD.[134] The differences in opinion mainly focus on the definition and quantification of depreciation.[135] There is no consensus on what the measure of capital should encompass either. In productivity research produced fixed assets, land and inventories are often included in capital input. In addition to these, human capital and natural resources are needed in production. Research and development expenditure can also be seen as capital formation. In some cases even the inclusion of financial capital into the measure of capital input has been suggested.[136]

The purpose of this paper is twofold. Firstly, we introduce state-of-the-art tools of economic analysis to Finnish data and extensively discuss what kind of

128 Hicks (1973).

129 For an overview of the models, see: Crafts (1992).

130 Crafts (1995), Greasley and Oxley (1997).

131 Booth, Melling and Dartmann (1997).

132 Abramovitz (1986).

133 Jorgenson and Griliches (1967).

134 OECD (1993); OECD (2001a); OECD (2001b); Aulin-Ahmavaara (2003).

135 Hill and Hill (1999).

136 Keuning (1999).

theoretical and empirical choices have to be made in quantifying capital and its contribution to growth and productivity in the period 1975 to 2001.[137] The origin of Finnish capital measurement is also traced. We observe how the different capital measures perform in a turbulent period in Finnish economic history. This period is interesting because the Finnish economic recession in the early 1990s was very severe; with GDP declining by 11 per cent from 1990 to 1993 (the 1930s recession was much less severe in comparison as GDP declined by only 3.5 per cent 1929–1931). We define capital as produced tangible fixed assets such as machinery, equipment, and produced intangible fixed assets such as computer software, and construct in the neoclassical tradition the indicators for capital input and compare these with the traditional capital stocks of national accounts in Finland. We show how the rental prices are used in the aggregation of heterogeneous productive capital stocks into a volume index of capital services for the whole economy, and discuss the alternative rates of return on capital. A sensitivity analysis on the impacts of the different capital measures on growth, capital productivity and multi-factor productivity (MFP) is also performed, which to our knowledge has not been done for Finland before. The most significant result of our number-crunching effort is an observation of a spectacular increase in capital productivity growth in the latter part of the 1990s. Secondly, we observe how our new estimates accord with the previous view on how capital has influenced recent Finnish historical economic development. Olli Haltia and Mikko Leppämäki coined the term Artto-Pohjola paradox, to describe the seemingly conflicting observations of Matti Pohjola and Eero Artto.[138] Pohjola observed that in 1960–90 a high investment ratio resulted in low capital productivity growth and concluded that capital was inefficiently used in Finland. Pohjola acknowledged that capital fundamentalism, the view that economic growth would be attained by massive fixed investments, did result in growth. His point was that the high social cost paid by Finland due to high investment ratios could have been lower with a more efficient use of capital. Artto countered with his findings of reasonable returns on capital especially in the paper industry. We offer an empirical resolution (as Haltia and Leppämäki already presented a theoretical one) to the Artto-Pohjola paradox by observing how capital productivity and the return on capital have evolved. In our results we show that a high rate of return was combined with a low capital productivity growth in 1975–1990.

This paper is organized in the following way. First the stage is set by going through the genealogy of capital measurement in Finland until their incorporation in the national accounts. We continue by showing how capital is defined in the national accounts and how these definitions are related to the productive

137 The reason we start our periodization from the year 1975 is that the share of secondary production in GDP only peaked as late as 1974. Thus the pattern of development thus far had differed in Finland from other developed countries, where usually the main contribution to economic growth first shifted from primary production to secondary production during the process of industrialization, and subsequently from secondary production to tertiary production as countries entered the post-industrial stage. Although the absolute contribution of services to GDP in Finland surpassed that of secondary production already in 1956, both continued by and large to increase their relative shares at the expense of primary production until 1974 (Hjerppe 1988).

138 Haltia and Leppämäki (2000); Pohjola (1996); Artto (1997).

capital stocks and their rental prices. The penultimate section contains our empirical results and the ultimate section concludes.

3.2 Previous research

Both in productivity analysis and growth accounting capital input is often measured by using either gross[139] or net[140] capital stocks (or both[141]). The stocks are constructed using the perpetual inventory method (PIM) pioneered by Raymond Goldsmith in 1951.[142] Neither of these stock measures, however, depicts the productive capacity of capital. In the GCS the capital good is assumed to retain its full productive capacity until retirement. The NCS is a measure of wealth; it describes the market value of the capital stock. The market value is of course dependent on the expected evolution of the productive capacity, but does not reflect the productive capacity at a certain point in time. The value of the asset declines as its service life draws to an end (with smaller future revenues accruing) even though no physical deterioration in the capital good's productive capacity necessarily takes place. In growth accounting based on neoclassical theory, the measure of capital input to be used is widely accepted to be the Jorgenson and Griliches[143] measure of capital services based on the concept of productive capital. The productive capital stocks for homogeneous capital goods are aggregated using their rental prices. Intuitively, when adding up e.g. the stocks of non-residential buildings and computer software, we must in the production function take notice of the fact that their respective service lives and price changes are very different (computer software must generate revenue in a much shorter period than buildings, since capital theory[144] tells us that the capital assets value equals the discounted flow of future rental payments that the good is expected to accrue).

Olavi Niitamo[145] distinguished the difference between the capital in place (stock) and the capital in use (services) in an early MFP calculation for the Finnish manufacturing industry. As capital input he quite elegantly used the volume index of the electricity used in manufacturing. An early attempt to construct actual capital stocks for Finland was done by Kalevi Koljonen.[146] He was well versed in state-of-the-art capital measurement, but decided not to use the PIM method when constructing residential and non-residential capital stocks due to data availability and reliability issues. Instead Koljonen used data on building stocks in the 1950 and 1960 censuses as bench-marks. He estimated the flows in

139 Denison (1962b); Maddison (1987); Kendrick (1993); Maddison (1996); O'Mahony (1996).

140 Kendrick (1961); Nordhaus (1972).

141 Denison (1983).

142 Goldsmith (1951).

143 Jorgenson and Griliches (1967).

144 Diewert (2001).

145 In his earlier work Niitamo alternatively used consumption of electricity in industry and power directly installed for driving machines, and in his later work only electricity as proxies for capital services. Niitamo (1958, 1969).

146 Koljonen (1968).

the interim years using construction statistics as proxies for investments and the volume changes by type of building as basis for estimates of retirements. In an other study done the same year Eino Laurila did not even attempt to measure capital stocks, he simply defined ΔK (the change in capital) as investments and calculated capital-output ratios at constant 1954 prices.[147] These ratios he compared with those of other advanced European economies, respectively at different stages in the business cycle and by industry. In the mid-1970s Reino Hjerppe and Pertti Kohi calculated gross capital stocks for the years 1960, 1965 and 1967 at fixed 1963 prices.[148] In addition to buildings they also incorporated measures for civil engineering construction and machinery and equipment. The methodology used was a combination of the PIM, bench-marks plus investments less retirements and physical quantities times their unit prices. Seppo Suokko and Pirkko Valppu used the perpetual inventory method consistently to estimate gross capital stocks at constant 1975 prices for the years 1960–1975.[149] Their work laid the foundations for a joint venture three years later, when Statistics Finland also started to compile capital stock statistics as a part of implementing SNA68.[150] Both gross and net stocks, as well as retirements and consumption of fixed capital, in current and constant 1975 prices were included in the measures of the stocks and flows of fixed capital. As the investment series were (and are) the main inputs into the Finnish national account's capital stock calculations, the stock series were rebased to a new base year whenever the capital formation (and production) series were rebased. The base years have been 1975, 1980, 1985, 1990, and 1995. The switch to 1995 also entailed an enlargement of the asset classification as the intangible fixed assets as defined by SNA93/ESA95 were introduced.

3.3 Capital in the national accounts

In SNA93, the most recent international recommendations for national accounting, the passages on capital stocks are rather dispersed. Paragraph 15.101 states that the perpetual inventory method is usually used to obtain measures for gross and net capital stocks. According to SNA93 stock measures are needed for analyzing production and productivity and for balance sheets. Based on SNA93, the European system of national accounts has been revised. ESA95 also deals with capital stocks briefly and fragmentarily. In paragraph 6.04, the PIM is recommended whenever direct information on capital stocks is missing. The net capital stock is the stock measure in both SNA93 and ESA95. It is used in balance sheets, input-output analysis and use tables.[151]

Gross capital stock (GCS) is the value of the capital used in production, valued at "as new" prices, i.e. regardless of age or actual condition, at a certain point

147 Laurila (1968).

148 Hjerppe and Kohi (1975).

149 Suokko and Valppu (1977).

150 Vihavainen, Valppu, Suokko and Björk (1980).

151 The use table describes the use of goods and services by product and type of use, i.e. intermediate consumption, final consumption, capital formation or export. ESA95, paragraph 9.04.

of time. GCS consists of the value of the cumulated past investments less the cumulated retirements of fixed assets. A capital good is retired from the capital stock when its service life expires. Gross capital stock K_t^G at the end of year t is estimated using the perpetual inventory method:

$$K_t^G = \sum_{s=0}^{S-1} d_s^G I_{t-s} , \qquad (3.1)$$

where d_s^G is the surviving share of the cohort of capital goods that are s years old in year t and S is the maximum service life of the asset type.[152] The relative share of survivors is declining and eventually goes to zero. The GCS of the whole economy is calculated as the sum of the gross capital stocks by asset type, industry and type of producer.

The gross capital stock as such is not needed in the SNA93/ESA95 accounting framework. Previously the GCS was thought of as a kind of production potential. However, since the gross capital stock does not take into account the physical deterioration of assets, it is only used as an intermediate step in calculating productive and net capital stocks, and not always even for that. For instance the US Bureau of Economic Analysis now directly calculates net capital stocks for all capital assets.[153]

Net capital stock (NCS) is the market value of the capital in use. The net value of the capital good is defined as the current purchaser's price of a new asset of the same type less the cumulated consumption of fixed capital.[154] The national accounts term consumption of fixed capital broadly equals the term depreciation, which is more widely used in economics and economic history.[155] According to the SNA93 consumption of fixed capital is calculated for all capital goods in the GCS using either the linear or geometric depreciation formula. Consumption of fixed capital is the decline in the value of capital during the accounting period due to physical deterioration, normal obsolescence, normal accidental damage and aging.[156]

3.4 Productive capital stocks and rental prices

Capital performs capital services, being a factor of production along with labour and intermediate goods. The quantity of services a capital asset produces is usually dependent on its age. Assuming that the capital service a new homogeneous asset performs is one, and that the flow of relative services is declining:

---

152 SNA93 and ESA95 do not present formulas. The equation shown here is the authors' interpretation of the SNA93 and ESA95 verbal definitions.

153 Katz and Herman (1997); Fraumeni (1997).

154 SNA93, para. 6.199.

155 By depreciation is in the productivity literature usually meant the difference in price at the same time point in time between two otherwise identical capital goods of successive vintages. This is the loss in value due to aging, which is often called cross-section depreciation (Diewert, 2001; Hill, 1999).

156 SNA93, para. 6.179; ESA95, para. 6.02; Katz and Herman (1997).

$$d_0^P = 1 \text{ and } d_s^P - d_{s-1}^P \leq 0 \qquad (s = 0,1,...). \tag{3.2}$$

Assuming that all capital assets eventually are discarded or retired, so that the capital service diminishes to zero:

$$\lim_{s \to \infty} d_s^P = 0. \tag{3.3}$$

The capital service of a new, year t acquired, capital good is I_t. The capital service of the capital good acquired the previous year, $t-1$, is then $d_1^P I_{t-1}$ and $d_s^P I_{t-s}$ for the assets invested in year $t-s$. When the flow of capital services of a new asset is thought to be proportional to the capital asset, d_s^P can also be said to represent the relative efficiency of the capital goods acquired in year $t-s$.

The flow of capital services can be perceived as representing the services of fixed capital analogously to labour representing the services of human capital in the production function. Furthermore, assuming that the different vintages of capital services are completely substitutable and that there is only one kind of capital (and no intermediate goods), the production function can be written as:

$$Q = A_t F(L_t, K_t) = AF(L_t, [d_0^P I_t + d_1^P I_{t-1} + ... + d_{S-1}^P I_{t-S+1}]). \tag{3.4}$$

The sum within brackets can also be expressed as:

$$K_t^P = \sum_{s=0}^{S-1} d_s^P I_{t-s}, \tag{3.5}$$

which is often called the productive capital stock (PCS).[157] Equation (3.5) is meant to be used directly on the investment vintages.

A first step in calculating productive capital stocks is to choose the profile of efficiency decline. Commonly used assumptions are the hyperbolic and the geometric age-efficiency profile.[158] In this paper we will only deal with geometric decline in efficiency[159], thus

$$d_s^P = (1-\delta)^s. \tag{3.6}$$

The point of departure in a growth accounting exercise is often a standard neoclassical production function, where the change in MFP is calculated using the Törnqvist-index. The Törnqvist-index is also used in aggregating heterogeneous capital input. Different types of capital are aggregated using their respective rental prices, which takes into account the contributions of different types of capital to production. A substitution towards capital assets with higher marginal

---

157 OECD (2001a and b).

158 For an extensive coverage of the subject, see: Jorgenson, Gollop and Fraumeni (1987) and OECD (2001a).

159 Empirical research performed in the US has supported the use of geometric depreciation applied directly on the investment vintages: Hulten and Wykoff (1981), Hulten and Wykoff (1996), Jorgenson (1996) and Fraumeni (1997).

products implies a change in capital quality. As rental price the Hall-Jorgenson[160] rental price is used:

$$P^K_{t,0} = rP^I_{t,0} + \delta_{t,0}P^I_{t,0} - \rho_{t,0}P^I_{t,0} \,. \tag{3.7}$$

In equation (3.7) the depreciation rate δ can be estimated from the expected age-efficiency profile. Holding gain/loss ρ can be obtained from the price index of new capital assets. The remaining unknown term is the net rate of return on capital r. In the *ex-ante* approach some interest rate can be used as return on capital, e.g. the base rate of the central bank. In the *ex-post* approach the internal return on capital is estimated. That is, it is assumed that the industry's capital income Ψ is equivalent to the imputed rents it receives each period t:

$$\Psi_t = \sum_j P^K_{j,t,0} K^P_{j,t} \,. \tag{3.8}$$

The rate of return can be solved by placing equation (3.7) into equation (3.8):

$$r_t = \frac{\Psi_t - \sum_j (\delta_{j,t,0} - \rho_{j,t,0}) P^I_{j,t,0} K^P_{j,t}}{\sum_j P^I_{j,t,0} K^P_{j,t}} \,. \tag{3.9}$$

In empirical work nominal value added less labour income[161] is mostly used as capital income.

The rental prices are used to aggregate productive capital stocks by asset type into a measure of capital services by industry. If the capital input is a translogarithmic function of its components, then the capital service of industry i, that is, the volume index of its capital input can be expressed as[162]

$$c_{it} = \frac{K^P_{i,t}}{K^P_{i,t-1}} = \prod_j \left(\frac{K^P_{ij,t}}{K^P_{ij,t,-1}} \right)^{v_{ijt}} , \tag{3.10}$$

where the weights v are defined as:

$$v_{i,t} = \left(\frac{P^K_{ij,t} K^P_{ij,t}}{\sum_i P^K_{ij,t} K^P_{ij,t}} + \frac{P^K_{ij,t-1} K^P_{ij,t-1}}{\sum_i P^K_{ij,t-1} K^P_{ij,t-1}} \right) / 2 \,. \tag{3.11}$$

160 Hall and Jorgenson (1967).

161 This equals the national accounts compensation of employees plus the imputed labour income of the self-employed. The imputed labour income is usually estimated by multiplying the self-employed's hours worked by wage earners average hourly earnings.

162 Jorgenson, Gollop and Fraumeni (1987).

3.5 Capital in Finland: Resolution of a debate

Our focus shifts from theory to application as we turn our attention to how different capital measures perform in quantifying a turbulent period in recent Finnish economic history. This period is interesting because the Finnish economic recession in the early 1990s was very severe; with GDP declining by 11 per cent from 1990 to 1993 (the 1930s recession was much less severe in comparison as GDP declined by only 3.5 per cent 1929–1931). Our results also enable us to compare capital productivity growth and the rate of return on capital prior to the 1990s recession, the indicators which are the main ingredients of the Artto-Pohjola paradox.

We used a geometric age-efficiency profile in calculating productive capital stocks for Finland. The productive capital stock in year t for a homogeneous capital asset type is defined as[163]:

$$K_t = K_{t-1}(1-d) + I_t = \sum_{\tau=0}^{\infty}(1-d)^{\tau} I_{t-\tau}\ , \tag{3.12}$$

where I is gross fixed capital formation and d is rate of depreciation. The symbols for industry and asset type (i and j) have been suppressed for notational simplicity. In the ex-ante method we used the central bank's base rate as rate of return and used equation (3.7) to calculate the rental prices. In the ex-post method we used equation (3.9) to calculate the internal rate of return and equation (3.7) to calculate the rental prices. These rental prices were used to aggregate the eight different capital asset types into a volume index of capital services (see table 3.1 for the asset type classification and the average service lives).[164] The capital goods are also classified by type of producer and industry, which accounts for the variation in service lives. Consumer durable goods, inventories and land are not included in the capital stocks.

Table 3.1 Asset types and average service lives of fixed assets

Asset type	Average service life in years
Non-residential buildings	20–50
Civil engineering and other structures	20–70
Transport equipment	7–25
Other machinery and equipment	5–32
Mineral exploration	10
Computer software	5
Entertainment, literary or artistic originals	10
Improvement of land	30–50

163 For recent applications see: Jorgenson and Stiroh (2000), Timmer, Ypma and van Ark (2003).

164 When the fixed price productive capital stocks are aggregated using the prices of new investment goods as weights the result is capital quantity, and when they are aggregated using rental prices as weights the result is capital services.

Since residential buildings are a significant part of the capital stock (39% of the nominal productive stock in 2001), but are not actually a production factor we decided to omit residential investments from our definition of capital and, symmetrically, we omitted also the value added of industry operating and letting of dwellings from GDP at basic prices.

Table 3.2 displays the shares of the PCS by asset type. The share of non-residential buildings has grown nearly 10 percentage points and constitutes close to half of the capital stock, while the share of civil engineering has declined to 22 per cent. Together, non-residential buildings and civil engineering structures form more than two thirds of the capital stock in 2001. The share of transport and other machinery and equipment was one third of the stock in 1975, but their share has declined to slightly more than a quarter in 2001. The share of intangible produced assets (mineral exploration, software and originals) was less than 3 per cent of the PCS and improvement of land 2 per cent in the year 2001. The investment ratio less residential gross fixed capital formation (i.e., nominal investments divided by nominal value added) changed from 23.2 per cent in 1975–1990, via the early 1990s 18.5 per cent to 17.7 per cent in the years 1995–2001. As far as capital was concerned, after the recession of the early 1990s there was a shift to more intensive growth – that is, economic growth was achieved with less investments and greater capital productivity than previously.[165]

The lower investment ratio in the 1990s resulted in a deceleration of the growth rates of the different kinds of capital[166] as can be seen in table 3.3 and in figure 3.1[167] where the volume indexes are shown graphically with year 1975 normalized as 100. The GCS has consistently grown faster than the other kinds of capital throughout the observation period. The other capital measures grew in 1975–1990 on average by 2.6–2.9 per cent per year, but the picture changes during the recession. By 1995, the NCS is nearly at the pre-recession level, as the average growth rate in 1990–1995 is close to zero. At the same time the growth rates of the capital services were the weakest: –0.5 per cent. In the years 1995–2001, the

Table 3.2 Shares of nominal productive capital stock by asset type, 1975–2001, %

	1975	1980	1985	1990	1995	2001
Non-resid. buildings	36.8	39.6	42.9	46.3	42.1	46.2
Civil engineering etc.	26.3	24.7	23.0	20.0	23.4	22.4
Transport equipment	6.4	6.0	5.5	5.1	5.5	5.3
Other machinery and eq.	26.5	25.3	24.2	24.5	24.4	21.5
Mineral exploration	0.0	0.0	0.0	0.1	0.1	0.1
Computer software	0.3	0.5	0.7	1.1	1.4	2.1
Originals	0.3	0.4	0.5	0.4	0.5	0.5
Improvement of land	3.4	3.4	3.1	2.6	2.7	2.0
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Source: Own calculations; data from Statistics Finland.

165 Jalava (2002).

166 On the definition of GCS and NCS in Finnish national accounts, see Statistics Finland (2000b).

167 See the appendix for the series. The early 1990s economic recession is clearly visible in the graph and is the reason behind the periodization of time in the subsequent tables.

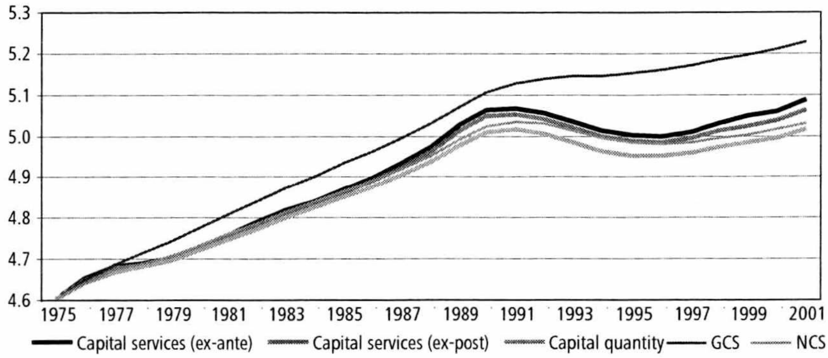


Figure 3.1 Capital services, capital quantity, GCS and NCS, volume-indexes 1975–2001, 1975=log (100)

Source: Own calculations; data from Statistics Finland.

Table 3.3 Growth rates of capital, 1975–2001, %

	1975–1990	1990–1995	1995–2001
Capital services (ex-ante)	2.9	−0.5	1.1
Capital services (ex-post)	2.8	−0.5	0.9
Capital quantity	2.6	−0.4	0.7
GCS	3.2	1.4	1.2
NCS	2.7	−0.1	0.5

Source: Own calculations; data from Statistics Finland.

ex-ante capital services grew 1.1 per cent per year, the ex-post capital services by 0.9 per cent per year, the net stock by half a per cent and capital quantity by 0.7 per cent. The main differences between NCS, capital quantity and capital services are due to different assumptions regarding retirements/depreciation. In the case of capital services a compositional shift towards intangible capital has also taken place (table 3.4). After the recession the growth rate of the gross stock is closer to that of the capital services than the NCS. The growth rates of the stocks are also influenced by

Table 3.4 Growth rates of the productive capital stock by asset type, 1975–2001, %

	1975–1990	1990–1995	1995–2001
Non-resid. buildings	3.2	0.4	0.8
Civil engineering etc.	1.2	0.8	0.6
Transport equipment	1.3	−3.0	0.0
Other machinery and eq.	3.3	−2.2	0.8
Mineral exploration	15.2	2.4	2.8
Computer software	10.2	1.8	6.4
Originals	2.1	−0.2	2.2
Improvement of land	−0.4	−2.2	−3.2

Source: Own calculations; data from Statistics Finland.

the depreciation rates, which have increased since there has been a shift to capital goods with shorter service lives (table 3.5).

Table 3.6 shows the average annual growths of the prices of new investment goods. The most moderate price increases are to be seen in machinery and equipment. By 2001 the price development has been most rapid in software, non-residential buildings and mineral exploration.

The small share of profits in national income keeps the ex-post rate of return smaller than the ex-ante rate of return during the recession of the early 1990s (table 3.7). Correspondingly, the boom years of the late 1990s are reflected as ex-post rates of return being higher than their ex-ante equivalents. In a study of the manufacturing industry in the United States, where they treat capital as a quasi-fixed production factor, Ernst Berndt and Melvyn Fuss[168] observe that the use of the ex-ante rate of return during cyclical swings leads to the marginal product of capital differing from capital's income share. When using the ex-post rate of return there is no such problem. According to Paul Schreyer, Pierre-Emmanuel Bignon and Julien Dupont this is only so when the quantity of capital

Table 3.5 Depreciation rates of the productive capital stock by asset type, 1975–2001, %

	1975	1980	1985	1990	1995	2001
Non-resid. buildings	5.1	5.1	5.0	5.1	5.0	5.2
Civil engineering etc.	5.0	5.1	5.2	5.4	5.2	5.3
Transport equipment	16.2	15.0	14.4	15.4	14.7	15.4
Other machinery and eq.	14.0	13.7	14.7	15.2	15.4	16.8
Mineral exploration	30.0	24.5	25.5	25.0	25.5	24.9
Computer software	57.4	54.5	52.9	52.3	53.9	53.6
Originals	25.1	25.3	25.0	25.9	25.2	25.4
Improvement of land	5.7	6.0	6.2	6.4	6.9	7.9
Total	**8.4**	**8.3**	**8.6**	**9.3**	**8.9**	**9.7**

Source: *Own calculations; data from Statistics Finland.*

Table 3.6 Average annual growths in prices of new investment goods, 1975–2001, %

	1975–1990	1990–1995	1995–2001
Non-resid. buildings	9.0	–2.7	4.3
Civil engineering etc.	7.6	1.6	2.5
Transport equipment	7.9	5.1	2.4
Other machinery and eq.	6.7	2.3	0.5
Mineral exploration	9.9	2.8	3.4
Computer software	10.0	2.5	4.4
Originals	9.6	4.4	1.6
Improvement of land	9.4	1.9	2.0

Source: *Own calculations; data from Statistics Finland.*

168 Berndt and Fuss (1986).

Table 3.7 Rates of return, 1975–2001 (arithmetic averages), %

	1975–1990	1990–1995	1995–2001
Ex-ante	8.5	7.2	4.4
Ex-post	11.5	5.7	14.4

Source: Own calculations; data from Statistics Finland.

cannot be adjusted during the period of production.[169] Furthermore, the ex-post measure is prone to measurement errors and it requires knowledge of levels of capital stocks. Estimates of capital stock levels are usually less reliable than measures of changes in capital.

The capital productivities (table 3.8) reinforce the picture given in table 3.3. The gross capital stock has grown most rapidly during the observation period; hence, capital productivity measured with the GCS is always the lowest. The net capital stock usually overestimates the relative change in capital productivity (except during the recession). The most eye-catching feature of table 3.8 is the significant increase in capital productivity during the latter part of the 1990s. However, as we have not included inventories and land in our measure of capital stocks, our ex-post rates of return are likely to be somewhat overstated. Still capital's growth contributions calculated with both ex-ante and ex-post measures are nearly identical (table 3.9). The growth contributions of gross and net capital stocks do not differ that much from that of the capital services, except during the recession when the GCS overestimates capital's contribution. After the recession, the contribution of the NCS is slightly smaller than that of the other kinds of capital. Gauged by all measures of capital both the absolute and relative impact of capital on Finnish economic growth has diminished.

The results in tables 3.7 and 3.8 can be used to offer a resolution to the Artto-Pohjola paradox. Our figures show that capital productivity growth was very low in the period 1975–1990. In this sense, we corroborate Matti Pohjola's view that capital was inefficient during this period.[170] However, a recent study by Marcel Timmer, Gerard Ypma and Bart van Ark reports that the ratio of labour productivity growth to MFP growth in 1980–95 is very similar in Finland, the United States and the European Union. Finnish labour productivity (LP)

Table 3.8 Capital productivity, 1975–2001, %

	1975–1990	1990–1995	1995–2001
Capital services (ex-ante)	0.0	–0.1	3.5
Capital services (ex-post)	0.1	–0.1	3.7
GCS	–0.3	–1.9	3.5
NCS	0.3	–0.4	4.1

Source: Own calculations; data from Statistics Finland.

169 Schreyer, Bignon and Dupont (2003).

170 Pohjola (1996).

Table 3.9 Alternative growth contributions of capital, 1975–2001

		1975–1990	1990–1995	1995–2001
GDP at basic prices (excl. dwellings), average annual volume growth[1]		2.9	–0.5	4.7
Contribution[2]				
	Capital services (ex-ante)	0.6	–0.1	0.3
	Capital quantity	0.5	–0.1	0.2
	Capital quality	0.1	0.0	0.1
	Capital services (ex-post)	0.5	–0.1	0.3
	Capital quantity	0.5	–0.1	0.2
	Capital quality	0.1	0.0	0.0
	GCS	0.6	0.3	0.3
	NCS	0.5	0.0	0.2
Capital's income share[1]		19.3	19.9	27.1

1 Per cent.
2 Percentage points.
Numbers may not add to totals due to rounding.
Source: *Own calculations; data from Statistics Finland.*

grew 1.9 times faster than MFP and the ratios were 2.0 and 2.1 respectively in the US and the EU.[171] These findings imply that the contribution of Finnish capital productivity growth to MFP was not that different from the EU and US averages. That Eero Artto would find high returns on capital in the paper industry in the same period that Pohjola coined as inefficient we also find plausible as we report a double-digit ex-post rate of return for the whole economy in 1975–90.[172] Our results were preceded by Olli Haltia and Mikko Leppämäki who demonstrated mathematically that it is possible for shareholders' financial return to grow faster than capital productivity.[173] They showed that this could happen if the growth in the value of shareholders' equity is positive, but that the financial return would be higher if the shareholders invested elsewhere. Thus, the owners do not interfere with the managers' unsuccessful investments that are depleting the value of the firm. In addition, Jukka Jalava implicitly showed that there was a major increase in capital productivity growth after 1995. He reported a simultaneous increase in MFP growth and decrease in labour productivity growth (MFP is the geometric average of labour and capital productivity, so if MFP growth goes up and LP growth down then CP growth must also go up).[174] However, here we demonstrated explicitly that growth in capital productivity was low although the rate of return on capital was quite reasonable. This is intuitively understandable as when the return on capital is high (the rate of return on capital equals capital's marginal product), there is not necessarily a need to improve capital's average productivity (table 3.8 shows the average productivities) until

171 Timmer, Ypma and van Ark (2003).

172 Artto (1997).

173 Haltia and Leppämäki (2000).

174 Jalava (2002). The exceptional increase in Finnish capital productivity is also corroborated by the results of Timmer, Ypma and van Ark (2003) as the Finnish LP/MFP growth ratio declined to 1.1 in 1995–2001, whereas it was 2.3 in the US and 2.8 in the EU.

the rate of return goes down. Only when faced with declining returns would the firms act to utilize capital more efficiently.[175] Therefore, we concur with Haltia and Leppämäki's conclusion that the paradox is actually no paradox at all. It would seem that Artto failed to discern the difference in capital's good performance in gaining a reasonable return on capital (its marginal product) with its less than good performance in average productivity growth.

Table 3.10 shows the MFP estimates by alternative types of capital. Labour input is here hours worked unadjusted for quality changes. The tendency of the NCS to overestimate capital productivity is not reflected that much in MFP due to capital's small income share. In the late 1990s the relative change in MFP is ever so slightly larger when using the NCS than when using the other measures of capital, due both to an increase in capital's share of income and the faster growth rate of the net stock. Again, the picture given by the GCS during the recession differs most from that of the capital services. On the whole, when comparing the MFP growth rates in table 3.10 with the growth of GDP it is clear that the residual is and has been the most important contributor to economic growth in Finland during the whole observation period.

Table 3.10 Alternative multi-factor productivity measures, %

	1975–1990	1990–1995	1995–2001
Capital services (ex-ante)	2.4	2.6	2.9
Capital services (ex-post)	2.5	2.6	2.9
GCS	2.4	2.2	2.9
NCS	2.5	2.5	3.0

Source: Own calculations; data from Statistics Finland.

3.6 Conclusion

The starting point of this chapter was methodological as we introduced state-of-the-art tools of economic analysis to the Finnish case and discussed extensively what kind of theoretical and empirical choices have to be made in quantifying capital and its contribution to growth and productivity. The use of capital services, instead of gross or net capital stocks, does not alter the previously held view of the development of capital input during the 1975–90 period. During the economic recession of the early 1990s, the volume index of capital services shows a much greater decline in capital input than does the net stock. Correspondingly, in the late 1990s capital services grow faster than the net stock. The gross stock grows during the whole observation period at the most rapid rate. The calculations based on the net capital stock somewhat exaggerate the decline in capital productivity in the early 1990s and overstate the growth in capital productivity after 1995. The most significant feature observed is common to all measures of capital, i.e. a marked increase in capital productivity in the latter part of the 1990s.

175 Our intuition is reinforced by Figure 13 in a recent paper by Pekka Sauramo (2003).

The differences in growth contributions are also not that striking. The contribution of capital to Finnish economic growth looks rather similar both when using the theoretically correct capital services measure and when using gross or net capital stocks. However, during the recession, the gross stock clearly overstates the case. After the recession, the contribution of the net stock is slightly smaller than that of the other capital types and both the growth rate and the contribution of the gross stock are closer to the correct one. The effect (of which alternative capital measure is used) on multi-factor productivity is minor at the level of the whole economy. Although the composition of capital has shifted into a more short-lived and intangible direction, the good old *K* in the production function is by no means obsolete. It has just transformed, which poses a great challenge for an historical analysis of the proximate sources of our economic growth.

We also observed how our new estimates accorded with the previous view on how capital has influenced recent Finnish economic history. Our empirical findings show that reasonably high rates of return on capital and low productivity growth of capital did coexist in Finland in 1975–1995. This confirms the theoretical result to this effect obtained by Olli Haltia and Mikko Leppämäki. Therefore, we concur with their conclusion that the Artto-Pohjola paradox is no paradox at all. The era of low capital productivity growth ended with a step-up after 1995. The increase in capital productivity notwithstanding, the contribution of capital to Finnish economic growth has declined significantly. This is because the Finnish economy relies more on MFP after the 1990s recession than previously as growth has become more intensive than before. The diminishing importance of capital stems from the fact – as Paul David[176] points out – that the focus in developed countries' production has shifted from the mere efficient management of routines to the ability to solve problems and innovate. Hence, work on better understanding the measure of our ignorance, i.e. MFP, is called for, especially as the residual is the most important contributor to Finnish economic growth. To put it another way, the greater part of our growth is presently left unexplained.

176 David (2002).

Appendix

Table 3.11 Volume indexes of the capital series, 1975=100

	Capital services (ex-ante)	Capital services (ex-post)	Capital quantity	GCS	NCS
1975	100.0	100.0	100.0	100.0	100.0
1976	105.0	104.6	103.9	104.5	104.0
1977	108.1	107.6	106.7	108.5	107.2
1978	108.9	108.5	107.9	111.7	108.9
1979	110.3	110.0	109.6	114.9	110.9
1980	113.1	112.8	112.3	118.7	113.7
1981	116.6	116.0	115.2	122.6	116.7
1982	120.2	119.5	118.4	126.6	120.0
1983	123.7	122.9	121.8	130.8	123.5
1984	126.7	125.9	124.6	134.6	126.4
1985	130.1	129.3	127.8	138.8	129.7
1986	134.1	133.2	131.1	143.1	133.1
1987	138.7	137.6	134.8	147.7	137.0
1988	144.5	143.1	139.2	153.0	141.5
1989	152.7	150.6	145.1	159.2	147.4
1990	158.1	155.8	149.6	164.9	152.1
1991	158.6	156.3	150.7	168.5	153.5
1992	157.2	154.9	149.4	170.7	152.8
1993	153.9	151.6	146.2	171.4	150.2
1994	150.1	148.0	143.0	171.8	147.5
1995	148.5	146.5	141.6	172.7	146.1
1996	148.2	146.2	141.4	174.1	145.6
1997	149.7	147.5	142.3	175.9	146.1
1998	152.9	150.1	144.3	178.3	147.5
1999	155.6	152.2	145.9	180.6	148.9
2000	157.8	154.3	147.8	183.0	150.6
2001	162.2	157.8	150.7	186.1	153.2

Source: *Own calculations; data from Statistics Finland.*

4
Electrifying and digitalising the Finnish manufacturing industry: Historical notes on diffusion and productivity[177] [178]

Jukka Jalava

Abstract: The diffusion of two general purpose technologies, electricity and information and communication technology (ICT), throughout the Finnish manufacturing industry is described. The full diffusion of electricity as motive power in the 1920s and 1930s led to an increase of nearly 4 percentage points in manufacturing labour productivity (LP). Furthermore, all industries gained across the board in productivity. In contrast, by the time ICT was fully diffused, towards the end of the twentieth century, yeast-like productivity gains were nowhere to be found. In fact, LP had slowed down in many industries, the notable exception being the electric and electronic appliance industries, in which LP growth had mushroomed. From a breakdown of growth in labour productivity into the contributions of internal productivity growth, employment share effect and a cross term, we found that labour shifting to industries with differing levels or growth rates of LP explains less of aggregate LP change in the period 1920–1938 (and even less in the period 1974–2000) than it does for the period 1901–1920.

4.1 Introduction

Advanced economies are becoming more and more "weightless" (Quah, 2001), as the share of the production of tangible goods in their GDPs diminishes. Has something profoundly new taken place? That is, could it be that we actually are in the midst of an information and communication technology (ICT) revolution, as ICT follows in the footsteps of steam and electricity in becoming a general purpose technology (GPT)? Indeed, the quantification of ICT capital's deepening contribution to labour productivity (LP) and that of ICT capital services to growth has revived interest in neoclassical growth accounting in both the fields

---

177 This chapter was first published as: Jukka Jalava (2004a): "Electrifying and digitalising the Finnish manufacturing industry: Historical notes on diffusion and productivity" in Sakari Heikkinen and Jan Luiten van Zanden (eds.), *Explorations in Economic Growth*, Aksant Academic Publishers, Amsterdam.

178 I thank Mika Maliranta, Matti Pohjola and Petri Rouvinen for their helpful comments. This research is part of the wireless communication research program (brie-etla.org) of BRIE, the Berkeley Roundtable on the International Economy at the University of California at Berkeley, and ETLA, the Research Institute of the Finnish Economy. Financial support from the Yrjö Jahnsson Foundation, Nokia and TEKES is gratefully acknowledged. The usual caveat applies to any errors in this paper.

of economics and economic history. Many a study has found that ICT use and/or ICT production contribute significantly to growth and productivity (e.g. Oliner and Sichel, 2000; Jorgenson and Stiroh, 2000; Daveri, 2002; van Ark, Melka, Mulder, Timmer and Ypma, 2002; Jalava and Pohjola, 2002).

Lipsey, Bekar and Carlaw (1998) define a GPT as a technology that is widely used, has many uses, has scope for improvement, and has many complementarities with other existing or potential technologies. Mokyr (1990a) too stresses the historical importance of macro-inventions, which he defines as "technological breakthroughs that constitute discontinuous leaps in the information set and create new techniques". These macro-inventions are then followed and perfected by a string of micro-inventions. Stoneman and David (1986) emphasise the importance of the third part of the Schumpeterian trilogy. For them it is not the first two parts, invention (a new discovery) and innovation ("the successful solution ... of putting an untried method into practice", Schumpeter, 1928), that matter but the third and last part, the diffusion of a new technology: "What determines improvements in productivity and product quality, thereby enhancing economic welfare and the competitiveness of firms and industries, is not the rate of development of new technologies but the speed and extent of their application in commercial operations".

In an empirical study of three GPTs: steam, electricity and ICT, Crafts (2002) found, when analysing UK and US data, that ICT had contributed more to growth than steam, and at least as much as electricity in similar, early stages of diffusion. However, even after a new technology is fully diffused there might be a considerable lag of 5–15 years before productivity effects emerge. Productivity literature usually sees the productivity effects of the adoption of a new technology as being threefold. First, productivity growth picks up in those industries that actually produce the new technology, due to rapid technological advances. Second, productivity increases take place in industries using the new technology through capital deepening – as the old capital is gradually substituted by new capital, and third, industries using the technology experience multi-factor productivity increases as new organisational models emerge and as the new technology is followed by incremental product and process innovations.

Needless to say, technology is not the whole story. Human capital and R&D expenditure should be seen as vital parts of the modern economy's toolbox. Pinpointing contributions to productivity of, for example, innovations, improvements in corporate governance or refinements in logistics is also an important task for the economic historian. The availability/unavailability of venture capital for new start-ups and, more generally, the impact of competition for necessary micro-level structural changes should not be forgotten, either. Indeed, for Finnish manufacturing there is by now ample evidence gathered by Maliranta (2003) that during the recession of the early 1990s, productivity-improving creative destruction took place.

The aim of this chapter is to review and compare historical evidence of the effects of electrifying and digitalising Finnish manufacturing industry. What were the impacts on the productivity of Finnish manufacturing of the diffusion of these two GPTs? Section 4.2 starts by tracing the introduction and diffusion of electricity in the Finnish manufacturing industry. Section 4.3 does the same for ICT. A breakdown of growth is shown in Section 4.4 and in Section 4.5 some conclusions are drawn.

4.2 Electrifying the production process

William Gilbert (1544–1603), a physician to Elizabeth I, was the first person to distinguish between magnetic and electrical attractive forces. The word electricity is derived from the Greek word *ilektro*, which means amber (amber acts like a magnet, attracting small objects when rubbed). His major work, *De magnete*, was published in 1600. Six decades later the German scientist Otto von Guericke started experimenting with *static electricity*, and finally discovered *electroluminescence* in 1672. Von Guericke was followed by Stephen Gray, who in the 1720s conducted electricity down a string of silk, concluding that electricity could be transmitted from one object to another object. He furthermore showed that the material of the string influenced the conductance (Hager, 1997; Windelspecht, 2002).

In the 1790s, Luigi Galvani experimented with frogs, and found that an electric current is produced when two different metals touch a frog's muscle. Later that same decade Alessandro Volta showed that the same phenomenon occurs when two metals are put into a conducting fluid, i.e. he invented the first battery. Using batteries the Dane Hans Christian Oersted discovered *electromagnetism* in 1819 and, improving on Oersted's discovery, the following year Michael Faraday found in experiments on *electromagnetic rotation* that magnetism can also create electricity. These experiments led him, in 1831, to discover the *dynamo*. In 1879 Thomas Alva Edison patented the *incandescent light bulb* (Rozakis, 2001).

In Finland the first demonstration of electric lighting took place in 1877. Five years later the Finlayson cotton mill in Tampere installed Edison's incandescent lights. This was the fifth permanent installation in Europe: London, Paris, Milan and Strasbourg had been earlier. In 1888, the city of Tampere and, in 1890, the city of Oulu installed its own street lighting plants, and by the autumn of 1914 all 38 Finnish towns had at least one electric utility (Myllyntaus, 1991).

In the saw-milling industry, four mills had already installed electric lighting from 1882 to 1883; by 1900 the number had increased to more than 40 mills (about 7 per cent of saw-milling firms). The electrification of motive power in saw-mills was slower than for electric lighting. Electrical engines accounted for only 0.3 per cent of the motive power in the saw-milling industry in 1900[179], which slowly increased to 9 per cent in 1910; by 1920 it had reached 36 per cent. In the metal-working sector, the first machine shops to use electric lighting were doing so by 1884. By the turn of the century approximately one-third of the metal-working industry's enterprises had electric lighting. The electrification of motive power in the metal-working sector increased rapidly from 4 per cent of total motive power in 1898 to 47 per cent in 1913, and reached 75 per cent by 1920. In the pulp and paper industry the first steps towards electric lighting were taken in the late 1880s. The electrification of motive power in the pulp and paper industry increased from 6 per cent of total motive power in 1900 to 20 per cent in 1910, and 38 per cent by 1920 (Myllyntaus, Michelsen and Herranen, 1986). The volume index of motive power grew in the Finnish manufacturing industry from 1900 to 1938 at a compound average annual

179 From 1860 to 1900, saw-mills shifted from using water power to thermal power as an energy source. This freed the mills of the geographical constraint of having to be located next to rivers (Hoffman 1980).

rate of 7.5 per cent. The growth was particularly rapid in the chemicals sector (10.0 per cent), in the manufacture of leather, leather products and rubber products (10.0 per cent), in the food, beverage and tobacco industries (9.7 per cent), in the manufacture of non-metallic mineral products (9.1 per cent), in the manufacture of pulp and paper (8.9 per cent), and in printing and publishing (8.4 per cent) (Hjerppe, Hjerppe, Mannermaa, Niitamo and Siltari, 1976). Before the Second World War, Finnish industry was very energy intensive: in the period 1890 and 1938 an increase in volume growth of one per cent required a growth of 3.5 per cent in electricity use (Myllyntaus, 1991).

The full diffusion of electric motors as the motive power of Finnish industry took place during the 1920s and 1930s. In the year 1913 the share was 32 per cent; in 1925 it was already 63 per cent; and by 1938 it was as much as 87 per cent. In comparison, the diffusion of electric motors as the source of mechanical power in US manufacturing industry was 25 per cent in 1909, 53 per cent in 1919, 78 per cent in 1929 and 86 per cent in 1939 (Devine, 1983). The pace of diffusion of electricity in the Finnish manufacturing process bears close resemblance to that of the United States.

As parliament decided in the early 1920s to build more hydropower electricity generating plants, more transmission lines had to be built as a consequence, laying the foundation for the national grid of transmission lines. The decision brought a switch from half to three-quarters of the electricity output coming from hydropower (of the country's total electricity supply, manufacturing actually used 70–85 per cent). In the interwar period, Finland's power distribution system was also significantly extended: for example, the length of transmission lines increased from 7,406 kilometres in 1923 to 18,016 kilometres in 1938 (Myllyntaus, 1991; Herranen, 1996).

Warren Devine has traced the evolution of power distribution in US manufacturing plants. In *direct drive* systems, production machines were directly linked to their power source. In most cases, one machine supplied the power for an entire factory via pulleys and leather belts. This severely constrained the physical design of the factories as well as imposing restrictions on the organisation of work. When power failures occurred or the power source had to be serviced, the entire plant came to a stand still. In the subsequent stage, the machine that drove the line-shaft was simply replaced by an electric motor, in the *electric line-shaft drive* system. The next step was the electric group drive system, where factories single giant line-shafts were replaced by many shorter line-shafts with electric motors connected to groups of production machines. Finally, in the *electric unit drive* system, individual production machines were connected to electric motors (Devine, 1983).

David and Wright (1999) attribute the slow diffusion of electricity[180] in the US to the long lag in profits accruing from implementing this new technology in production, which was due to the unprofitability of scrapping existing factories and the capital and production systems they embodied (similarly, there was not enough incentive in the Finnish saw-milling industry to rapidly adopt electricity and new labour-saving technology in production because the costs of raw materials and labour

---

180 "Slow", as the first time electricity was used in US to drive machinery for manufacturing was in 1883 (Devine, 1983).

were low up until the First World War (Myllyntaus, Michelsen and Herranen, 1986)). However, once the increased use of electric motors was well underway, a step-up in the labour productivity of the US manufacturing sector of 4.5 percentage points from 1909–1919 to 1919–29 (to an annual average of 5.6 per cent) took place (David and Wright, 1999). Devine (1983) sees the productivity increases that ensued as the result of an increased flow of production, an improved working environment, improvement in machine control and increased ease of plant expansion. After WWI, power capital was substituted for other capital, which markedly increased capital productivity (Du Boff, 1966). Not to be forgotten is the protectionist stance the United States took in the interwar era, thus avoiding the problems many export-oriented countries had. The US domestic market grew sufficiently enough to ensure rapid productivity growth (Nelson and Wright, 1992).

In 1860 only 4 per cent of the Finnish population worked in the industrial and handicrafts sectors, which managed to generate 7–8 per cent of GDP at basic prices. Half a century later, 10 per cent of the economically active population was employed in industry, and as industrial output grew faster than GDP, the share of industry and handicrafts in total output was one-fifth in 1913 (Heikkinen and Hjerppe, 1986). By 1938 the industrial sector's share in GDP had increased to almost one-quarter. Industry's contribution to GDP growth was even higher, i.e. an average of 39 per cent in the period 1920–1938. Primary production lost its position as the Finnish economy's growth engine after the 1890s, but in the period 1890–1913 primary production, secondary production and tertiary production still did not differ significantly in their relative contributions to growth. The rapid decline of the contribution of primary production to growth and the pre-eminence of secondary production began in the 1920s. Tertiary production did not take the lead in contributions to growth until the mid-1950s (Hjerppe, 1988). Heikkinen and Hjerppe (1986) sum up the Finnish model of industrialisation as follows: the country's main assets were its vast forests, its hydropower potential and a labour reserve in the rural areas. Export demand was crucial from the 1860s to the 1880s. During the unfavourable export conditions of the mid-1880s to the mid-1890s, an increase in domestic demand and a growing domestic market share in industry was favourable for growth. From the 1890s until WWI, both exports (the forest sector) and domestic markets contributed to growth. Wood processing was crucial for the economy as it was an export industry with multiplier effects in primary production and transportation, and the international price development was favourable for Finland as the terms-of-trade increased approximately 100 per cent from the end of the 1860s to the early twentieth century. Myllyntaus (1991) also points out the crucial role of electrification as a catalyst for modernisation and the introduction of productivity enhancing technical innovations. As the twentieth century's first two decades, in which the compound annual average increase in manufacturing LP was only 0.3 per cent, continued into the 1920s and 1930s and the diffusion of electricity was nearing completion, the step-up in LP growth was 3.9 percentage points (to 4.2 per cent per year). The best performer in terms of LP growth for the period 1920–1938 was the pulp and paper industry with 7.9 per cent (see table 4.1). However, all observed manufacturing sub-industries increased their LP growth, with the largest absolute improvements taking place in the printing

Table 4.1 Output per employment in manufacturing, compound average annual growth

	1901–1920 %	1920–1938 %	1920–1938 less 1901–1920 %-points
Manufacturing	0.3	4.2	3.9
Food, beverages & tobacco	0.3	3.3	3.0
Textiles	0.3	1.1	0.8
Wood-working	0.2	2.7	2.5
Pulp and paper industry	3.0	7.9	4.9
Printing and publishing	−1.2	4.0	5.2
Leather industries	−0.9	3.7	4.6
Chemicals	3.2	5.0	1.8
Non-metal mineral products	1.0	4.2	3.2
Metal-working	−0.7	4.2	4.9
Miscellaneous	0.6	4.9	4.3

Source: Own calculations, data from Hjerppe, Hjerppe, Mannermaa, Niitamo and Siltari (1976).

and publishing industries, the pulp and paper industry, the metal industry, in leather manufacturing and other, miscellaneous manufacturing.

The investments in electrification were mainly financed by the industrial firms independently or through bank loans. Private power utilities and/or distribution companies issued shares to acquire financing, and municipalities used tax revenues or other income (Myllyntaus, 1991). Although financial capital was not obtained from abroad to a significant degree (the role of foreign direct investment was small due to strong Finnish economic nationalism (Myllyntaus, 1992)), foreign experts were often encouraged to join companies that adopted new technology (Hjerppe, 1988). Finns also studied abroad in the period prior to domestic technical education gaining momentum. The educational aspect was always at the forefront. Imported turn-key technology construction was not sought after. Usually the more cumbersome road of Finnish firms participating in installing as much of the new technology as feasible was chosen (Myllyntaus, 1991).

Due to shortcomings in data availability, we cannot perform an LP comparison for the main electricity producing industry (the electricity, gas and water supply industry) for the same period as we did for the manufacturing industry. However, we extracted data from Statistics Finland's Historical National Accounts Database from 1914 to 1938 that enabled us to compute the annual LP growth in the period 1915–1938. We found that the compound average annual LP growth for 1915–1920 was 8.2 per cent; for 1920–1938 it was 10.7 per cent. This agrees with views in the productivity literature that productivity gains first emerge in those industries that produce a new technology.

4.3 The digital revolution

Gottfried Wilhelm von Leibniz (1646–1716), a German mathematician and philosopher invented the binary system of notation in 1679. The binary system was fundamental to the invention of electronic calculating machines, the first completely electronic computer, the ENIAC, in 1946 and ultimately all computers (Windelspecht, 2002). The ENIAC used 18,000 *vacuum tubes*, which had the awkward tendency of frequently burning out. In addition, the warmth and glow of the tubes attracted moths, causing short circuits.[181] The problem of overheating was solved by the invention of the *transistor* (made of the semi-conducting material germanium; later silicon was also used) in 1947 by William Shockley, Walter Brattain, and John Bardeen at Bell Labs. In the year 1959, Jack Kilby at Texas Instruments invented the microchip, the first *integrated circuit* to defeat the "tyranny of numbers" that had hitherto constrained technical progress (Reid, 2001). In 1971, Intel created the *microprocessor*, and the fourth generation of computers was born. Other important milestones in the development of ICT were the use of fibre optics to transmit data in 1966; the invention of ARPANET (the first computer network) in 1969 by the US Department of Defense; the creation in 1975 of what was to become the world's leading software company, Microsoft; the first testing of cell phones in 1978; the market launch of personal computers for the general public by IBM in 1981; the market launch of cell phones for the general public by Motorola in 1984; and the invention of the World Wide Web in 1989 (Rozakis, 2001).

In introducing the computer in Finland, the role of the Finnish Committee for Mathematical Machines was crucial. The committee started its work in 1954 with the objective of establishing the need for mathematical machines and to make recommendations on their purchase or construction. The decision was made to copy a computer designed in Göttingen, the G1a. What the committee was unaware of was that the G1a was still only a blueprint, and therefore what had been intended to be a quick one-and-a-half year long task of duplication actually became the construction and design of a computer. Completion was therefore delayed until 1960, when a by then outdated computer was presented to the University of Helsinki. The acronym ESKO, derived from Elektroninen Sarja KOmputaattori, was chosen for this Finnish venture, which as it turned out produced the only G1a ever completed (Andersin and Carlson, 1993). Although the ESKO was a failure in a technical sense, it played an important educational role as the first effort by Finnish engineers to study computer technology (Paju, 2003). While the ESKO project was still in progress the government-owned Postisäästöpankki (Post and Savings Bank) purchased from IBM an IBM 650 computer, which was delivered in the autumn of 1958. Finland's first computer was quite fittingly christened ENSI (first, earliest). The primary objective of the ENSI was to oversee entries in savings accounts. Although the ENSI did not altogether replace punched cards, it simplified and rationalised many stages of work (Pukonen, 1993). Both ESKO and the ENSI were first generation computers (Seppänen, 1993).

---

181 Hence the term debugging when attending to computer related problems.

International Business Machine Corporation (IBM) had a strong position in Finland. Its predecessor (the Computing-Tabulating-Recording Company changed its name to International Business Machine Corporation in 1924 (Pusateri, 1988)) had already in 1922 supplied the first punch card machines in Finland, to Statistics Finland. The subsidiary IBM Finland was founded in 1936, and it consolidated its position as a supplier of punch card machines, precision instruments and electrical typewriters. IBM Finland founded a computing centre, what they called a service bureau, in 1939. However, in the beginning there were no machines in the centre. In the 1960s the service bureau entered a new era when it used IBM 1401s to cater for the needs of customers. The success of IBM Finland was mirrored by the increase in its employees. In 1951 the company employed 48 persons in Finland, by 1961 approximately 200 and by 1964 about 500 (Dickman, 1993). IBM also dominated the market in the US. In 1965 it had a market share of 65 per cent, while the second largest company, Sperry Rand (that manufactured the ENIAC's successors, UNIVACs), had a mere 12 per cent market share. By 1987 IBM became the third largest industrial corporation in the US (Pusateri, 1988).

One of the two original engineers that had started to build the ESKO, Tage Carlsson, was hired in 1960 by Suomen Kaapelitehdas Oy (Finnish Cable Works) (Aaltonen, 1993). The other original engineer, Hans Andersin, had already gone to work for IBM Finland. Kaapelitehdas was one of the three companies that in 1966 merged to form Oy Nokia Ab (Häikiö, 2002). Kaapelitehdas had in 1958 decided to explore the possibility of starting to sell electronics (with the long-term plan of eventually constructing computers), and therefore in the following year it acquired a majority of shares in an electronics importer, Chester Oy, that represented in Finland companies such as Texas Instruments and Isotope Developments. In 1960 Kaapelitehdas decided to set up a computing centre, which laid the foundation for Nokia's electronics department. The first computers the centre purchased were the Elliot 803 and the Siemens 2002, which were operational in 1960 and 1961, respectively (Aaltonen, 1993). The idea was to sell services to clients, and later on computers, as the clients' needs grew. The Elliot 803 was a fully transistorised, second generation computer and it had been purchased to meet the needs of scientifically- and technically-oriented customers; the Siemens 2002 was meant to service administrative and commercial clients (Seppänen, 1993). In the early 1960s the Cable Works, which had more than 30 years of experience in manufacturing telecommunications cables, launched itself into the production of telecom equipment. The development work was divided into three categories: microwave technology; UHF- and radiophones; and carrier-wave technology. An important customer was the Finnish Defence Forces. In the mid-1960s the Cable Works started to supply alarm systems to power utilities and registering systems to saw-mills. The company also designed dataloggers for manufacturing, and power production and distribution systems in co-operation with power plants (Aaltonen, 1993). In the early 1970s Nokia started manufacturing computers (computer production was a major part of Nokia until it was sold to ICL-Fujitsu in 1991), and digital telephone exchanges. The beginning of the electronics division was humble as it did not contribute significantly to Nokia's net sales until the late 1980s (actually electronics did not become profitable until 1971), and it was not until the 1990s that Nokia started focusing on electronics (Häikiö, 2002).

The diffusion of ICT in Finnish manufacturing was three-phased. First, in the 1960s and 1970s firms started using ICT for administrative purposes. Second, in the 1970s and 1980s ICT found its way into manufacturing processes. By the beginning of the 1990s close to half the Finnish manufacturing firms used ICT in their production processes, with higher than average use in the pulp and paper industry, the printing and publishing industries, and the chemical industry. Finally, third, in the 1980s and 1990s ICT was embedded into manufactured products. The main driver in adopting the new technology was the desire to decrease production costs, to improve process and product quality, and to ensure reliable operations and delivery (Jaakkola, 1992). By the year 2001, ICT had diffused widely throughout the *manufacturing* industry: of all firms, 96 per cent used computers; 91 per cent used the internet; 59 per cent had homepages; 42 per cent used broadband connections; 27 per cent used intranet; 10 per cent used extranet; and 12 per cent used EDI. For *all* enterprises the corresponding statistics were: 95 per cent used computers; 90 per cent used the internet; 51 per cent had homepages; 39 per cent used broadband connections; 24 per cent used intranet 10 per cent had extranet; and 10 per cent used EDI. Of all firms in Finland, the share of those for which at least one-quarter of employee working time was spent using computers was 69 per cent in 2001 (Statistics Finland, 2002b). That statistic had been only 17 per cent in 1984, 44 per cent in 1990 and 66 per cent in 1997. Thus by the turn of the millennium, the Finnish workplace had become quite extensively computerised (Statistics Finland, 1999b). Micro-level evidence from the end of the 1990s indicates that the diffusion of the use of ICT in firms was a within firm story (and not so much one of restructuring), with stronger productivity impacts in especially young, ICT-intensive firms (Maliranta and Rouvinen, 2003).

Table 4.2 Output per hours worked in manufacturing, compound average annual growth

	1974–1990 %	1990–2000 %	1990–2000 less 1974–1990 %-points
Manufacturing	4.4	6.2	1.8
Food, beverages & tobacco	3.4	4.9	1.5
Textiles	4.2	3.4	−0.8
Wood-working	4.3	4.8	0.5
Pulp and paper industry	4.8	6.0	1.2
Printing and publishing	3.7	3.4	−0.3
Leather industries	5.3	2.0	−3.3
Chemicals	3.6	4.7	1.1
Non-metal mineral products	3.5	3.0	−0.5
Metal-working (excl. electrical)	4.6	3.4	−1.2
Electrical and electronic appliances	5.2	14.2	9.0
Miscellaneous	3.6	2.5	−1.1

Source: Statistics Finland.

A step-up in the manufacturing industry's LP was to be seen in the 1990s (see table 4.2). However, the increase did not take place across the board, for all industries, as was the case when electricity was adopted. LP growth actually slowed in the leather industry, the metal-working industry (excluding electronics), in miscellaneous manufacturing, the textile industry and in printing and publishing. The increase was moderate in the pulp and paper industry, the chemical industry, the food, beverage and tobacco industry and in saw-milling and other timber-related activities. The performance of the electric and electronic appliance industry was astonishing. At first sight growth in productivity seemed to mushroom in contrast to the steady yeast-like rise in productivity growth that resulted from the widespread use of electricity.[182] This impression is reinforced when ones looks at the whole non-residential business sector. In the latter part of the 1990s, the LP growth of ICT producers experienced a major boost, but it remained at the same level in industries using ICT and even fell in other branches of industry (Jalava, 2003).

The 1990s was a decade in which there was a shift in corporate governance of major Finnish firms from the Continental system – with a strong position of banks as sources of credit and significant shareholders, concentrated ownership and a limited amount of listed companies – to the Anglo-Saxon model, which is distinguished by a large number of listed firms, a broad base of ownership, and, above all, the maximisation of shareholder value. This shift was the result of a rapid increase in the share of foreign ownership in Finnish stock-exchange listed firms. Whereas foreigners owned approximately 10 per cent of the market capitalisation in 1992, in 2000 that share had risen to 70 per cent (from whence it declined to 60 per cent in 2002). Empirical evidence shows that the foreign owned companies performed better than those that were Finnish owned (Ali-Yrkkö and Ylä-Anttila, 2003). As the Finnish financial system became more diversified and stock-oriented, the prospect of innovative and possibly high-risk SMEs attaining financing improved in comparison with earlier, bank-dominated times. Thus the focus of Finnish industrial development shifted from investment-driven growth to innovation-driven growth, which was characterised by a rapid multi-factor productivity growth (Jalava, 2002; Hyytinen, Rouvinen, Toivanen and Ylä-Anttila, 2003).

4.4 Electricity vs. ICT: Decomposing growth

To compare the productivity dynamics that the diffusion of electricity and ICT led to, we broke down labour productivity growth into the impacts of a component reflecting industries' internal productivity growth (the within-component), an employment share effect, i.e. the positive (negative) impact of the labour share increasing (decreasing) in a sub-industry with a level of LP higher than the aggregate level of LP (the static shift effect), and a cross term, i.e. the combined

182 Harberger (1998) was the first person to coin the terms "mushroom" and "yeast" when talking of growth.

impact of a shift in the sub-industries' labour share and LP growth rate (the dynamic shift effect). Formally:

$$
\begin{aligned}
(LP_t - LP_{t-1}) / LP_{t-1} &= (\sum_{i=1}^{n} (LP_{i,t} - LP_{i,t-1}) S_{i,t-1}) / LP_{t-1} \\
&+ (\sum_{i=1}^{n} (S_{i,t} - S_{i,t-1}) LP_{i,t-1}) / LP_{t-1} \\
&+ (\sum_{i=1}^{n} (S_{i,t} - S_{i,t-1})(LP_{i,t} - LP_{i,t-1})) / LP_{t-1} \ ,
\end{aligned} \qquad (4.1)
$$

where *LP* is level of labour productivity, S_i is sub-industry *i*'s share of hours worked and *t* denotes time. The first term on the right is the within-component, the second term is the static shift effect and the third term is the dynamic shift effect.[183]

From 1901 to 1920 the cross-term was very negative, indicating that industries with above average LP growth rates had diminishing labour shares (table 4.3). On the other hand, a positive employment share effect signified an increasing labour share in industries with an above average level of LP. All in all, structural change was much less marked in the other periods than in the 1900s and 1910s; the shift factors are furthermore positive in the latter two periods. For LP growth in the 1990s, 5 percentage points of that can be attributed to structural change, i.e. that labour shifted to industries with either a higher level of LP or a higher growth rate of LP (Jalava, Heikkinen and Hjerppe, 2002; see also Maliranta, 2003).

In the first two decades of the twentieth century, the pulp and paper industry alone accounted for almost half the growth of the manufacturing industry's aggregate within-component (table 4.4). Another strong performer was the wood manufacturing industry. The food, beverage and tobacco industry, the textile industry and the non-metallic mineral product industry were also strong performers. The largest drag on the aggregate within-component came from the metal-working industry and from printing and publishing. In the 1920s and 1930s this picture changed. The metal-working industry became the second largest contributor. The pulp and paper industry was still the biggest contributor, but its rela-

Table 4.3 The impact of structural change on labour productivity growth in the manufacturing industry in 1901–1920, 1920–1938, 1974–1990 and 1990–2000

	1901–1920 %	1920–1938 %	1974–1990 %	1990–2000 %
Within	113.6	104.6	97.7	94.9
Static	12.2	−1.7	2.2	3.8
Dynamic	−25.8	−2.8	0.2	1.2
Total	**100.0**	**100.0**	**100.0**	**100.0**

Sources: *own calculations; data for 1901–1938 from Hjerppe, Hjerppe, Mannermaa, Niitamo and Siltari (1976); the breakdowns for 1974–2000 from Jalava, Heikkinen and Hjerppe (2002)*

183 For a nice overview of different productivity decomposition methods, see Maliranta (2003).

Table 4.4 Breakdown of manufacturing sub-industries' within-components' contributions to labour productivity growth in 1901–1938

	1901–1920 %	1920–1938 %	1920–1938 less 1901–1920 %-points
Manufacturing	100.0	100.0	0.0
Food, beverages & tobacco	16.6	13.8	–2.8
Textiles	16.5	3.1	–13.4
Wood-working	23.2	14.4	–8.8
Pulp and paper industry	48.2	39.6	–8.6
Printing and publishing	–5.4	6.0	11.4
Leather industries	–0.8	1.9	2.7
Chemicals	2.1	1.5	–0.6
Non-metal mineral products	10.5	4.3	–6.2
Metal-working	–11.0	14.9	25.9
Miscellaneous	0.3	0.5	0.2

Source: *own calculations; data from Hjerppe, Hjerppe, Mannermaa, Niitamo and Siltari (1976)*

tive share declined. That was also the case for the former number two: the wood manufacturing industry. The biggest decline in contribution was experienced by the textile industry. In the 1920s and 1930s no industries' within-component contributed negatively to aggregate LP growth, as had been the case two decades earlier. During the period 1974–1990 the non-electric metal industry was the growth engine of the within-component for the aggregate manufacturing industry (table 4.5). The pulp and paper industry was a distinct second, with the remaining industries contributing evenly. In the 1990s, the contributions of almost

Table 4.5 Decomposition of manufacturing sub-industries' within components' contributions to labour productivity growth in 1974–2000

	1974–1990 %	1990–2000 %	1990–2000 less 1974–1990 %-points
Manufacturing	100.0	100.0	0.0
Food, beverages & tobacco	8.8	8.3	–0.5
Textiles	6.6	1.7	–4.9
Wood-working.	6.1	4.2	–1.9
Pulp and paper	19.8	19.6	–0.2
Printing and publishing	6.4	4.0	–2.4
Leather industries	4.8	1.2	–3.6
Chemicals	6.0	6.2	0.2
Non-metal mineral products	3.4	1.6	–1.8
Metal-working	27.9	15.0	–12.9
Electrical and electronic appliances	7.3	36.9	29.6
Miscellaneous	2.9	1.1	–1.8

Source: *Jalava, Heikkinen and Hjerppe (2002)* all industries decreased, as the electric and electronic appliance industry resumed the responsibility as the engine of aggregate growth.

4.5 Conclusion

In this chapter we have surveyed the diffusion of two general purpose technologies (GPTs) – electricity and ICT – in the Finnish manufacturing industry. The full diffusion of electricity as motive power in the 1920s and 1930s led to an increase of nearly 4 percentage points in manufacturing labour productivity. Indeed, all industries across the board gained in productivity. In contrast, when ICT was fully diffused – by the end of the twentieth century – a steady yeast-like growth of productivity could not be observed. In fact, LP slowed down in many industries, the notable exception being the electrical and electronic appliance industries (Finland's main ICT producer), in which LP growth mushroomed. The electronic industry is the natural place to expect the first sign of productivity gains, as it is the main producer of ICT in Finland. Similarly, LP growth surged in the electricity producing industry before gains were visible in the main manufacturing industries using electricity. Therefore there is, as historical precedent has shown, likely to be a lag of several years before the productivity gains of widespread adoption of ICT become visible.

From a breakdown of LP growth during both GPTs' periods of diffusion, it was found that labour shifting to industries with differing levels or growth rates of LP explains less of aggregate LP change in period 1920–1938 (and even less in period 1974–2000) than it did in the period 1901–1920. Sub-industry contributions to the aggregate manufacturing industry's within-component remain rather concentrated. In the first two decades of the twentieth century, the pulp and paper industry and wood manufacturing contributed more than 70 percentage points. Two decades later, the pulp and paper industry, the wood manufacturing industry and the metal-working industry contributed close to 70 percentage points of the within-component. In the period 1974–1990, the non-electric metal industry and the pulp and paper industry contributed approximately 50 percentage points and, finally, in the period 1990–2000 the electronic industry, the metal-working industry and the pulp and paper industry contributed more than 70 percentage points. As the within-component's share of aggregate LP growth is even larger in the latter two periods than it was in the first two, we conclude that productivity growth is more concentrated in current times of diffused ICT than that experienced by our grandfathers and grandmothers in the 1920s and 1930s. What started as a transfer of technology to a late industrialising country through the import of foreign machinery and equipment, the recruitment of skilled foreign workers and study trips abroad has through post-World War II investment-driven growth successfully evolved into a growth driven by innovation.

5
Economic growth in the new economy: Evidence from advanced economies[184] [185]

Jukka Jalava and Matti Pohjola

Abstract: Firstly, by surveying recent research, this chapter confirms that both the production and use of ICT have been the factors behind the improved economic performance of the United States in the 1990s. However, the evidence for the New Economy is much weaker outside the United States. Secondly, the chapter applies growth accounting to estimate the impacts in Finland. It is shown that the contribution to output growth from ICT use has increased from 0.3 percentage points in the early 1990s to 0.7 points in the late 1990s. In addition, the fast growth of multi-factor productivity in the ICT producing industries has had an even larger impact. But, unlike in the US, there has been no acceleration in the trend rate of labour productivity.

5.1 Introduction

The popular view is that information and communication technology (ICT) will change the world by boosting productivity and economic growth. But while ICT has many visible effects on the modern economy – the growth in electronic commerce and in Internet use for example – its impact on productivity and economic growth has been surprisingly difficult to detect. Although investment in ICT has exploded since the mid-1970s, aggregate productivity growth remained sluggish until the mid-1990s in the United States which is the world's leader in both the production and use of ICT. Therefore, many policy-makers and economists have taken the strong performance of the US economy in the late 1990s as most welcome evidence for the view that the large investments in ICT have finally started to pay off. It is generally believed that the United States has become a "New Economy" in which business firms have learnt to take advantage of both the ICT revolution and the globalization of business activities in ways which improve productivity. Indeed, the growth rate of labour productivity has doubled in the late 1990s.

The defining characteristics of the ICT revolution are the fast improvement in the quality of ICT equipment and software, and the concomitant sharp decline in their quality adjusted prices. For example, in the United States the price of com-

---

184 This chapter was first published as: Jukka Jalava and Matti Pohjola (2002): "Economic growth in the new economy: Evidence from advanced economies", *Information Economics and Policy* (14) 2, pp. 189–210.

185 The authors wish to thank Pirkko Aulin-Ahmavaara and Pekka Ylä-Anttila for helpful comments and Paul Schreyer for providing his data.

puter investment declined 18 per cent per year in 1960–95 and 28 per cent per year in 1995–98 (Jorgenson and Stiroh, 2000). Profit maximizing firms respond to the change in relative prices by substituting ICT equipment and software for other capital equipment and structures. A larger portion of investment will be in assets with relatively high marginal products, and the aggregate capital service flow increases. This increase in capital intensity raises labour productivity in the ICT using industries. The standard argument for the fact that it has taken so long for the productivity impact to show up in the productivity statistics is that firms have not yet invested enough in ICT (see, e.g., Oliner and Sichel, 2000). Even if information and communication technology investments earn hefty returns, the share of nominal income accruing to computers has been rather small until recently.

Besides improving productivity in the ICT using industries, the rapid technological advance should also raise productivity in the ICT producing industries and, consequently, should contribute to productivity at the aggregate level as well. Consequently, the mechanisms underlying the structural transformation of the industrial economy into a "new", ICT-based economy are easy to understand by applying the basic principles of economic theory. The problems lie on the empirical side.

Growth accounting is the standard technique for assessing the impacts of both the use and production of different types of assets including ICT. The method is briefly reviewed in the next section. Sections 5.3 and 5.4 take stock of the productivity debate by reviewing recent research on the impacts of both the use and production of ICT in the United States and other advanced countries. Section 5.5 contains the findings of our own application to explaining economic growth in Finland. This country is of special interest because it is one of the leading producers of ICT in Europe and is sometimes regarded as a model country in ICT consumption as well. It is well known that Finland ranks among the top countries in the world in terms of the number of Internet hosts and mobile phones per capita.

5.2 Accounting for ICT's contribution to output and productivity growth

Information and communication technology is both an output from the ICT producing industries and an input into the ICT using industries. Therefore, to assess ICT's contribution to economic growth, it is helpful to express the aggregate production function in the form

$$Y(Y_{ICT}(t), Y_O(t)) = A(t)F(K_{ICT}(t), K_O(t), L(t)) \tag{5.1}$$

where, at any given time t, aggregate value added Y is assumed to consist of ICT goods and services Y_{ICT} as well as of other production Y_O. These outputs are produced from aggregate inputs consisting of ICT capital services K_{ICT}, other capital services K_O and labour services L. The level of technology or multi-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 product and factor markets are competitive, growth accounting gives the share weighted growth of outputs as the sum of share weighted inputs and growth in multi-factor productivity (see, e.g., Jorgenson and Stiroh, 2000):

$$\hat{Y} = w_{ICT}\hat{Y}_{ICT} + w_{O}\hat{Y}_{O} = v_{ICT}\hat{K}_{ICT} + v_{O}\hat{K}_{O} + v_{L}\hat{L} + \hat{A} \qquad (5.2)$$

where the ^-symbol indicates the rate of change and where, for the economy of notation, the time index t has been suppressed. The weights w_{ICT} and w_{O} denote the nominal output shares of ICT and other production, respectively, and they sum to one. The weights v_{ICT}, v_{O} and v_{L} also sum to one and represent the nominal income shares of ICT capital, other capital and labour, respectively.

It can now be seen from eq. (5.2) that information and communication technology can enhance economic growth in the following three basic ways. Firstly, the *production of ICT* goods and services contributes directly to the total value added generated in an economy. This contribution – $w_{ICT}\hat{Y}_{ICT}$ in eq. (5.2) – is calculated by multiplying ICT's nominal output share by the growth rate of the volume of ICT production. OECD (2000) estimates that ICT goods and services typically constitute between 3 and 5 per cent of total GDP at current prices. But their contribution to output growth can be larger than what these shares imply when ICT industries grow faster than the rest of the economy.

Secondly, the *use of ICT* capital as an input in the production of other goods and services can also make a significant contribution to economic growth. The benefits from ICT use are even likely to outweigh the benefits from ICT production, which are limited to just one sector of the economy. As is shown in the next section, Oliner and Sichel (2000) estimate that almost one-half of the recent labour productivity pick-up in the United States is due to the increased use of ICT capital in the production of output in the overall economy whereas close to 25 per cent of the labour productivity step-up is due to multi-factor productivity improvements in the ICT industry. The standard way of estimating the growth contribution of ICT use is to treat ICT as a specific type of capital good in which firms invest and which they combine with all other types of capital as well as with labour to produce output. As shown in eq. (5.2), the growth contribution of each input is then obtained by weighting its rate of change with a coefficient that represents its share in nominal income. ICT's contribution is thus $v_{ICT}\hat{K}_{ICT}$.

The third way in which information and communication technology can enhance economic growth is via the *impact of ICT industries on multi-factor productivity*. If the rapid growth of ICT production is based on efficiency and productivity gains in these industries, this contributes to productivity growth at the macro level as well. For example, Gordon (2000) argues that improvements in the production of computer hardware account for the entire acceleration in labour productivity which has occurred in the United States since the mid-1990s. The productivity impact of ICT production cannot, however, be directly deduced from eq. (5.2) but the analysis has to be accompanied by an evaluation of the part of $\hat{A}$ attributed to productivity growth in the ICT industry. The problem with interpreting an increase in multi-factor productivity as being caused by technological change is, however, that other non-technology factors will also be picked up by the residual. Such factors include changes in efficiency, scale and cyclical factors and measurement errors.

To assess the contribution from ICT use and from multi-factor productivity improvement to the growth of labour productivity, let us denote the number of hours worked by $H(t)$ and labour productivity by $Y(t)/H(t)$. The basic growth accounting equation (5.2) can be rearranged to

$$\hat{Y} - \hat{H} = v_{ICT}(\hat{K}_{ICT} - \hat{H}) + v_O(\hat{K}_O - \hat{H}) + v_L(\hat{L} - \hat{H}) + \hat{A}. \qquad (5.3)$$

It shows that there are four sources of labour productivity growth. The first one is ICT capital deepening, i.e. an increase in ICT capital services per hour worked, and the second source is other capital deepening. The third component is the improvement in labour quality which is defined as the difference between the growth rates of labour services and hours worked. The fourth source is a general advance in multi-factor productivity.

Eqs. (5.2) and (5.3) are based on the assumption that the private and social rates of return from the use of ICT capital are equal to each other. But they can also be applied in the case where ICT generates positive externalities. The benefits above those reflected in the measured income share cannot, however, be directly observed but will be captured by the multi-factor productivity residual $\hat{A}$. Consequently, there is no reason to expect such externalities to exist if increases in multi-factor productivity cannot be observed. And even if they can, the problem is that they may have been caused by other factors than those associated with externalities emanating from the use of ICT.

The growth accounting technique described above can be applied to incorporate the fact that the capital input is not homogenous but consists of heterogeneous assets. A dollar spent on new ICT equipment can provide more productive services per period than, say, a dollar spent on a new building. For any given type of asset, there is a flow of productive services from the cumulative stock of past investments. These flows are not usually directly observable but have to be approximated. The standard assumption in growth accounting is that service flows are in proportion to the stock of assets after each vintage has been converted into standard "efficiency" units. The so computed capital stock is called the productive stock of a given type of asset (see, e.g. OECD, 2001b). It is the appropriate measure for growth accounting, as it measures the income-generating capacity of the existing stock over a given time period. This concept differs from the wealth stock which measures the current market value of the assets in use.

Aggregate capital service flows can be estimated by using asset-specific user costs or rental prices to weight each heterogeneous asset and to account for substitution between them. Under competitive markets and equilibrium conditions, user costs reflect the marginal productivity of the different assets. They thus provide a means to incorporate differences in the productive contribution of heterogeneous investments as the composition of investments and capital changes (OECD, 2001b). For example, as firms respond to fast declining ICT prices by substituting away from other capital equipment or structures and toward ICT equipment, a larger portion of investment will be in assets with relatively high marginal products, and the aggregate capital service flow increases. This can also be interpreted as an increase in the quality of capital (Jorgenson and Stiroh, 2000).

The user cost of ICT capital services will also be needed in estimating the share of nominal income accruing to ICT capital. Unlike the wage share, it is not directly observable in income statistics. The user cost is obtained as

$$r_{ICT} = p_{ICT}(i + d_{ICT} - \hat{p}_{ICT}) \tag{5.4}$$

where p_{ICT} is the acquisition price of new ICT capital goods and $\hat{p}_{ICT}$ its rate of change, i is the internal rate of return and d_{ICT} captures economic depreciation. ICT capital's income share is then obtained as $r_{ICT}S_{ICT} / p_Y Y$ where S_{ICT} is the real wealth stock of ICT capital and p_Y is the output price.

5.3 Lessons from the United States

The performance of the US economy was remarkable in the 1990s. The trend rate of GDP growth rose from 2.5 per cent at the start of the decade to 4.5 per cent at the end. This rapid advance was accompanied by a substantial increase in the growth of labour productivity. The growth of output per hour worked in the non-farm business sector accelerated from around 1.6 per cent per annum before 1995 to almost 2.7 in the period 1996–99. By applying the standard growth accounting framework (5.3), Oliner and Sichel (2000) estimate that the growing use of ICT equipment and the efficiency improvements in computer production account for about two-thirds of this one percentage point step-up in labour productivity growth.

Table 5.1 summarizes Oliner and Sichel's (2000) findings on the contributions of the input factors to real non-farm business output for three time periods. Output rose at an average pace of about 3 per cent in the first two periods covering 1974–90 and 1991–95 and all ICT capital services accounted for about 0.5 percentage points of this growth. The contribution from computer hardware was the highest of the ICT components: about 0.3 percentage points a year. The third period, 1996–99, displays a significant change in the growth process. Output grew at the average rate of 4.8 per cent and the ICT contribution increased to 1.1 percentage points per year. Computer hardware contributed 0.6, software 0.3 and communications equipment 0.2 percentage points, respectively. It is also interesting to see that since the start of the 1990s, ICT contribution to output growth has exceeded the contribution from the rest of the capital stock.[186] An increasing share of growth can also be attributed to multi-factor productivity whose contribution seems to have more than doubled in the late 1990s.

Jorgenson and Stiroh (2000) come up with estimates which are quite similar to Oliner and Sichel's. They show that in the late 1990s the growth contribution of computer hardware was 0.5, software 0.2 and communications equipment 0.1 percentage points per year. The discrepancies in the findings primarily reflect the slight differences in the time periods and output concepts. Jorgenson and

186 The measure of the rest of the capital stock encompasses producers' durable equipment, non-residential structures, residential rental structures, inventories, and land.

Table 5.1 Contributions to real non-farm business output in the US, 1974–99

		1974–90	1991–95	1996–99
Output growth[1]		3.1	2.8	4.8
Contributions[2] from:	ICT capital	0.5	0.6	1.1
	Hardware	0.3	0.3	0.6
	Software	0.1	0.3	0.3
	Communications eq.	0.1	0.1	0.2
	Other capital	0.9	0.4	0.8
	Labour hours	1.2	0.8	1.5
	Labour quality	0.2	0.4	0.3
	Multi-factor productivity	0.3	0.5	1.2

1 Average annual log difference multiplied by 100,
2 Percentage points per year.
Numbers may not add to totals due to rounding.

Source: Oliner and Sichel (2000).

Stiroh's output concept is somewhat broader than the one used by Oliner and Sichel, making ICT output shares lower.

But what explains the observed increase in the growth contribution from information and communications technology? In their previous analysis, Oliner and Sichel (1994) concluded that this contribution had been relatively small through the early 1990s, especially if one focused on computer hardware alone. The reason was that, in spite of the large investments, computers were still only a small fraction (3–4 per cent) of the existing capital stock, and, consequently, the share of nominal gross income accruing to computers was rather small, about 1 per cent. Now they find that this share increased to 1.8 per cent in the late 1990s. Similar increases are also observed for software (from 0.9 to 2.4 per cent) and for communications equipment (from 1.6 to 2.1 per cent). In conclusion, 6.3 per cent of income accrues to ICT capital, making it an important component of the capital stock in the US. This technology has diffused sufficiently widely to have a visible impact on aggregate economic growth.

Both Oliner and Sichel (2000) and Jorgenson and Stiroh (2000) also apply growth accounting to break down the observed one percentage point step-up in the growth rate of labour productivity between the first and second halves of the decade. The results are displayed in table 5.2 which shows that the growing use of ICT capital accounted for almost half a point of the rise in productivity.

In addition, Oliner and Sichel (2000) observe that the rapidly improving technology for producing computers and embedded semiconductors has contributed another 0.3 percentage points to the acceleration. This second channel works through the multi-factor productivity (A) residual in the standard growth accounting model (5.3), and Oliner and Sichel estimate the impact of the efficiency improvement of computer and semiconductor production in a three-sector model. Taken together, these two factors – the use and the production of ICT – account for about two-thirds to four-fifths of the pick-up in labour productivity growth since 1995. Multi-factor productivity in the rest of the economy provided the remainder, with labour quality actually falling somewhat

Table 5.2 Alternative estimates of the source of the acceleration in labour productivity in the US in the second half of the 1990s

	Oliner and Sichel (2000)	Jorgenson and Stiroh (2000)
Change in the average growth rate of labour productivity	1.0	1.0
Contributions from:		
Capital deepening	0.5	0.5
ICT	0.5	0.3
Other	0.0	0.2
Labour quality	–0.1	–0.1
Multi-factor productivity	0.7	0.6
Production of ICT	0.3	0.2
Other production	0.4	0.4

Numbers may not add to totals due to rounding.

Source: *Sichel (2000).*

which is consistent with the marked expansion in employment in this period. Jorgenson and Stiroh (2000) analyse a broader set of 37 industries, but their findings about the productivity impacts of the use and production of ICT are again quite similar to Oliner and Sichel's.

Regarding the acceleration of the multi-factor productivity from about 0.3–0.5 per cent per year in 1974–95 to over one per cent per year in the late 1990s, Jorgenson and Stiroh (2000) conclude that its source can be traced in large part, but not entirely, to the industries which produce computers, semi-conductors and other high-technology equipment. There is, however, little evidence of spillovers from production of ICT to the industries using this technology intensively such as finance, insurance and real estate and other services. The reasons for the sluggish productivity growth in services are not self-evident. Productivity is, of course, difficult to measure in many service activities and ICT is still a rather new technology, but it may also be the case that computers and telecommunications equipment are not very productive in some industries.

Gordon's (2000) view about the impacts of ICT on labour productivity is somewhat more pessimistic than either Oliner and Sichel's or Jorgenson and Stiroh's. He first attributes a sizeable part of labour productivity growth in the late 1990s to cyclical factors. Labour, being a quasi-fixed production factor, tends to adjust only partially during cyclical swings of output. Consequently, if output is growing faster than trend, then labour productivity is also growing faster than trend. Secondly, after making adjustment for ICT capital deepening and other factors, Gordon finds that there has been virtually no change in the rate of productivity growth outside of the durable goods manufacturing sector which accounts for 12 per cent of the US GDP. He concludes that, in the remaining 88 per cent of the economy, the New Economy's impacts on productivity growth are surprisingly absent and that ICT capital deepening has been remarkably unproductive. Consequently, the productivity impacts of ICT investments have been limited to the computer and other durable goods manufacturing sector. However, a recent study by Nordhaus (2001), based on a new dataset and on new methods of measuring productivity growth, confirms that there indeed has been a rebound in labour productivity growth in the US but that it is not narrowly focused in the ICT sectors only. Baily and Lawrence (2001) arrive at similar conclusions.

But if information and communication technology has been the key factor of the improved productivity performance of the US economy in recent years, when can we expect the ICT revolution to occur in the rest of the advanced industrial countries?

5.4 Lessons from the G7 countries

The principal problem in analysing the impacts of ICT is that, except in the US, national income and product accounts do not provide detailed enough information about ICT investment, quality-adjusted price indices and measures of the ICT capital stocks. As described above, there now exists a view of the role that ICT plays in the US economy, while even most other OECD economies still leave ICT out of the picture. The lack of data on other countries makes it difficult to make international comparisons that have to rely on alternative sources and use simplifying assumptions for purposes of comparison between countries. It also explains the bias towards the United States which is reflected in many studies in this field.

There are, however, some private providers of ICT data. For example, International Data Corporation (IDC) publishes an annual report on the status of the world-wide information technology market in about 50 countries. The report contains data, based on the revenues of primary vendors, on spending on computer hardware equipment, data communications equipment, computer software and computer services including both professional and support services. The data produced by private consulting and other agencies may not be as accurate and reliable as the national accounting data, but they have the advantage of a symmetric treatment of all countries.

Schreyer (2000) has tapped this data source for current price expenditure on ICT goods, software excluded, in the G7 countries. Indicators of ICT investment volumes can be obtained from such data by dividing current price expenditures with appropriate price indices, but the problem here is that methodologies to measure price change in ICT goods vary greatly across OECD countries. Schreyer has solved this problem by developing a common deflator for all the countries under investigation. It is based on the assumption that the differences between price changes for ICT capital goods and non-ICT capital goods are the same across countries. Under this assumption, information about the quality-adjusted ICT prices for the United States can be used in estimating similar prices for the other countries.

Given information about the age-efficiency patterns of ICT goods, the investment volume data can be used to estimate productive capital stocks for ICT goods. Schreyer (2000) applies an age-efficiency pattern that declines slowly in the early years of an ICT capital good's service life and rapidly at the end, similar to the ones used by the US Bureau of Labor Statistics (1997) and the Australian Bureau of Statistics.

Figure 5.1 displays Schreyer's estimates for the shares of ICT in the productive, non-residential capital stocks of the G7 countries.[187] In 1996, the share was the highest, 7.4 per cent, in the United Sates and the lowest, 2.1 per cent, in Italy. All the G7 countries have been adding to their IT capital stock at two-digit rates over the period 1979–96. However, only in the United States, Canada and the United Kingdom has this process of building up IT capital accelerated in the mid-1990s. With the exception of Japan, the G7 countries have accumulated communication technology capital at a much lower pace than IT capital, the average annual growth rate being 8 per cent in 1979–96.

Table 5.3 summarizes Schreyer's (2000) estimates of the contributions from ICT capital to output growth in the G7 countries in 1990–96. They are obtained by multiplying the annual growth rates of the IT and CT productive capital stocks by their respective income shares, by adding the IT and CT contributions together and by averaging over the period. In 1990–96, the ICT contribution to GDP growth was roughly 0.2 percentage points a year in France, Western Germany, Italy and Japan, 0.3 percentage points in Canada and the UK, and 0.4 percentage points in the US where it amounted to almost half of the contribution of the entire fixed capital stock. The growth contribution was larger in the US than elsewhere because both the ICT investment rate was higher and the ICT income share was larger there than in the rest of the G7 countries. The higher income share, in turn, reflects the larger share of ICT assets in the total capital stock, as shown in figure 5.1.

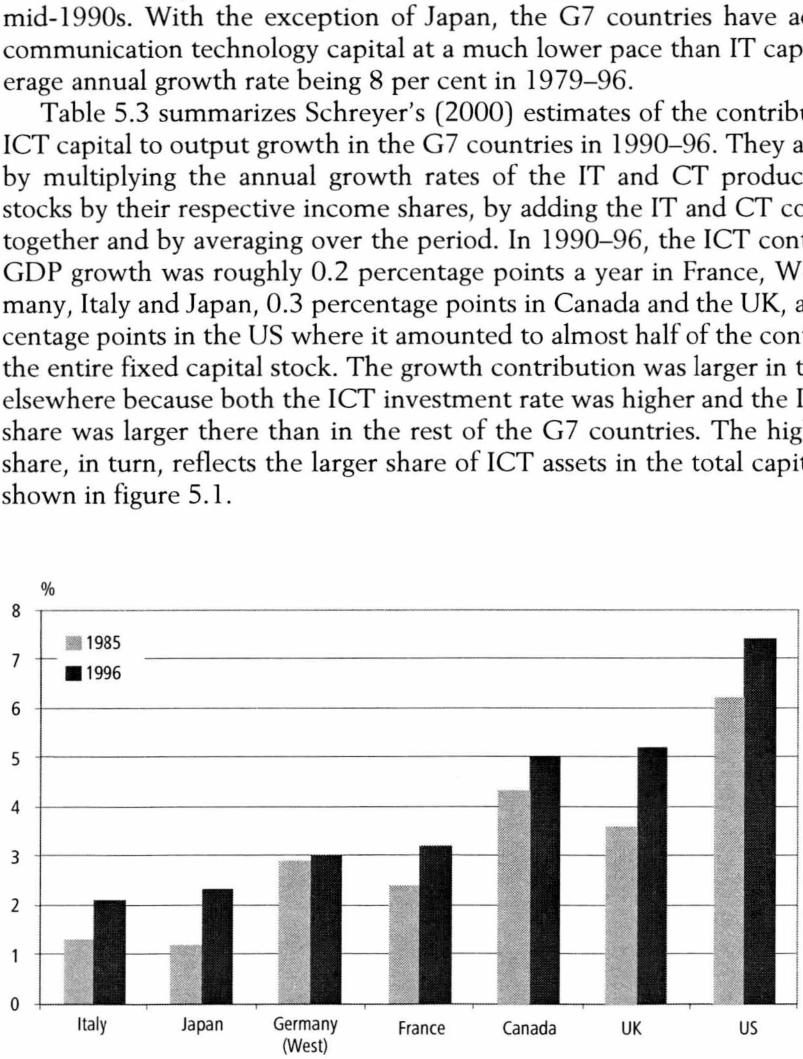


Figure 5.1 ICT capital as a percentage of the productive capital stock
Source: Schreyer (2000).

187 Schreyer's measure of the capital stock encompasses non-residential structures, other non-residential construction, transport equipment, IT hardware, communications equipment, and other non-transport equipment. Software is not included.

Table 5.3 ICT contribution to output growth in the G7 countries, 1990–96

	Average annual growth rate of *			Income shares in 1996:**		Contributions to output growth from:*	
	Total output	IT capital	CT capital	IT capital	CT capital	ICT capital	Total capital
Canada	1.7	17.6	4.3	1.5	1.3	0.28	0.7
France	0.9	11.0	2.1	0.9	0.9	0.17	1.0
West Germany	1.8	18.6	3.4	0.8	1.1	0.19	1.0
Italy	1.2	12.9	9.2	0.9	0.9	0.21	0.7
Japan	1.8	14.5	15.0	0.8	0.4	0.19	1.0
UK	2.1	17.6	2.2	1.5	1.6	0.28	0.8
US	2.7	23.8	5.1	1.7	1.9	0.42	0.9
US 1996–98	4.6	..	..	..	..	0.72	1.8

* = percentage points,
** = per cent,
.. = information not available.

Source: Schreyer (2000).

Schreyer also shows that the ICT contribution has been relatively stable in all countries over the longer period 1980–96. But when considered in terms of a share in total output growth, its relative importance to economic growth has risen in all countries in the 1990s. Interestingly, however, as shown in the last row of table 5.3, even the absolute contribution measured in terms of percentage points per year seems to have increased significantly in the US in the late 1990s, confirming Oliner and Sichel's (2000) findings.

Moreover, the new version of the System of National Accounts (SNA93) recommends treating computer software as gross fixed capital formation, and not as intermediate consumption as previously. Also the US has implemented this recommendation in its national accounts, making it possible to assess its contribution to output growth. Schreyer (2000) estimates that in 1996–98 software added 0.2 percentage points of growth to the 0.72 percentage points of ICT hardware displayed in the last row of table 5.3. Consequently, ICT hardware and software accounted for a larger share of growth than the rest of the capital stock did.

Schreyer's (2000) cross-country comparison raises at least two important questions. First, has the growth contribution of ICT been larger in those countries which are more advanced in the deployment of ICT than in the other G7 countries except the US? Second, has the growth contribution picked up in such countries in the late 1990s?

5.5 Evidence from Finland

Finland is one of the leading ICT producers in Europe (see Koski, Rouvinen and Ylä-Anttila, 2002), and is also often regarded as being one of the leading New Economies defined more generally. For example, UNDP's (2001) new technology achievement index ranks Finland as the top country followed by the United

States, Sweden, Japan and the Republic of Korea in the ability to participate in the network age. Consequently, comparing the economic impacts of ICT in the two top countries is of special interest.

However, not much systematic evidence is available about the impacts of the production and use of ICT in this country. The only macroeconomic analysis we are aware of is Niininen's (2001) growth accounting study in which he demonstrates, among other things, that IT hardware contributed 0.4 percentage points of GDP growth at the average annual rate of 2.4 in the period from 1983 to 1996.

Our aim here is to update and extend Niininen's (2001) findings in such a way that the results become comparable with the findings for the G7 countries reviewed above. Besides IT hardware, we also include software and communications equipment in our measure of the ICT capital stock. And, instead of using the net capital stock as the capital input measure like Niininen does, we estimate the productive capital stocks and apply them in the growth accounting analysis. In fact, this is the first time that productive capital stocks are estimated for Finland. As explained earlier, the productive capital stock is the appropriate measure for growth accounting as it measures the income-generating capacity of the existing stock over a given time period. This concept differs from the wealth stock which measures the current market value of the assets in use. The difference between these measures can be quite substantial for assets like computers which tend to lose their market value at a much faster rate than their income-generating capacity.

5.5.1 Growth contribution from the production of ICT

Figure 5.2 displays the annual changes of the volume of GDP, hours worked and labour productivity in Finland in 1976–99. The recession of the early 1990s was one of the most severe ever experienced in an industrial country in peacetime. The volume of GDP declined by 10.4 per cent between 1990 and 1993. Since 1994, GDP has grown at the average annual rate of 4.6 per cent which is sub-

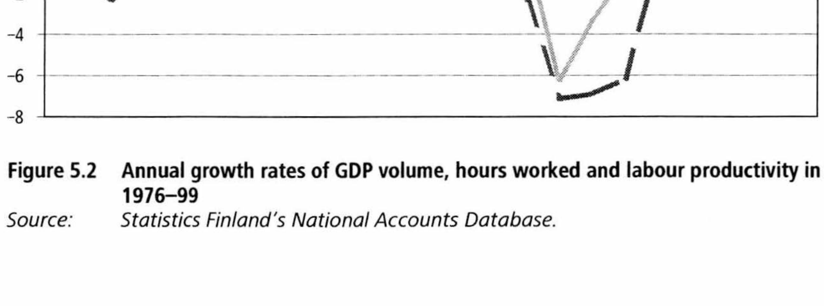


Figure 5.2 Annual growth rates of GDP volume, hours worked and labour productivity in Finland, 1976–99

Source: Statistics Finland's National Accounts Database.

stantially higher than the pre-recession rate of 3.0 per cent. However, similar acceleration cannot be observed in labour productivity which is here defined as real GDP divided by the number of hours worked. In fact, its annual growth rate has been smaller (2.5 per cent) after the recession than before it (3.1 per cent) although a substantial adjustment in the level of labour productivity took place during the recession years. At a first glance, it is difficult to detect any signs of the new economy in these time series, and it may be the case that the economy is returning to its trend growth path.

It is well known that the production of ICT goods and services has played an important role in the recovery from the recession. As shown in eq. (5.2), the direct growth contribution of the ICT industry can be calculated by multiplying the rate of change of its value added by its share in nominal income. To make the results comparable to those reviewed above, our analysis is confined to the market sector which encompasses non-financial corporations, financial and insurance corporations and unincorporated enterprises. Table 5.4 shows that the direct contribution to output growth from the production of ICT goods and services increased fourfold in the late 1990s amounting to two percentage points per year.

Table 5.5 presents our definition of ICT industries and shows that their output share has increased steadily.[188] In 1999, the Finnish nominal GDP was 6.8 times as large as in 1975, but the nominal gross value added of ICT industries

Table 5.4 Output contribution of ICT production in the market sector, 1975–99

	1975–90	1990–95	1995–99*
Output growth, %	3.2	-0.7	6.0
Contribution from ICT industries, percentage points	0.3	0.5	2.0

* preliminary estimate.

Source: Statistics Finland's National Accounts Database.

Table 5.5 Shares of ICT industries in the value added of the market sector, %

	1975	1980	1985	1990	1995	1999*
Manufacture of electrical and optical equipment:	2.1	2.0	2.6	2.9	4.8	7.9
Office machinery and computers (ISIC 30)	0.1	0.1	0.3	0.4	0.2	0.1
Electrical machinery (ISIC 31)	1.2	1.2	1.1	1.0	1.2	1.1
Radio, television and communication equipment (ISIC 32)	0.5	0.4	0.8	1.0	2.7	5.9
Medical and precision products (ISIC 33)	0.3	0.3	0.4	0.5	0.7	0.8
Telecommunications services (ISIC 642)	1.2	1.6	1.8	1.7	1.9	3.0
Computer software and services (ISIC 72)	0.4	0.6	0.9	1.2	1.3	2.1
Total ICT	**3.7**	**4.2**	**5.3**	**5.8**	**8.0**	**13.0**

* preliminary estimate.

Source: Statistics Finland's National Accounts Database.

188 Because of problems with data availability, the ICT industries include neither wholesale trade in nor renting of office machinery and computers.

was 21 times as large as it was in 1975. Manufacture of radio, television and communications equipment and apparatus (i.e. ISIC industry 32) has been the real success story. Its nominal gross value added was more than 72 times as large in 1999 as it was back in 1975.

5.5.2 Growth contribution from the use of ICT

The growth accounting framework of eq. (5.2) is applied next to assess the contribution to output growth from the use of ICT capital as an input in the production of other goods and services in the market sector. Our definition of ICT capital encompasses IT hardware, software and telecommunications equipment. Since Finnish national accounts data are not available on hardware and telecommunications gross fixed capital formation, the analysis is based on the ICT expenditure data published by the World Information Technology and Services Alliance (WITSA 2001) for the years 1992–99 and provided by International Data Corporation Finland for the period 1983–91. For the earlier years ITC expenditure was estimated using the ITC output shares for the first year for which data exist. As telecommunications expenditure in the WITSA dataset includes both investment and services, we follow Schreyer (2000) in assuming that a 30 per cent share constitutes a lower bound on the investment expenditure component in the total telecommunications spending. Information about software[189] investment was received from Statistics Finland.

To deflate the current price ICT investment series, we use the same US indexes as Schreyer (2000) for computer IT hardware and telecommunication equipment and correct them for the exchange rate changes.[190] The deflator for software investment is a weighted (50/50) average earnings index for industry computer and related activities and the pre-packaged software producer price index, corrected for the exchange rate, provided by the US Bureau of Labor Statistics.

Productive capital stocks are calculated by industry and asset type, and they are aggregated using their user costs – the rate of return *plus* depreciation *minus* holding gain – to get the appropriate measure of capital services (see the Appendix in Jalava and Pohjola (2001) for a more detailed explanation). Ten types of assets are distinguished, including the three ICT assets, transport equipment, other machinery and equipment, non-residential buildings and other structures. Residential buildings, consumer durables, inventories and land are not included. Hyperbolic age-efficiency profiles are applied to account for the loss in efficiency of the assets as they age. The rate of return needed for the evaluation of the user costs (see eq. (5.4)) is estimated with the help of the accounting identity by which capital income equals the difference between value added and labour compensation. Given this estimate for the value of capital services, and given a measure of the capital stock, of depreciation and of capital gains, the rate of return is obtained as a residual.

---

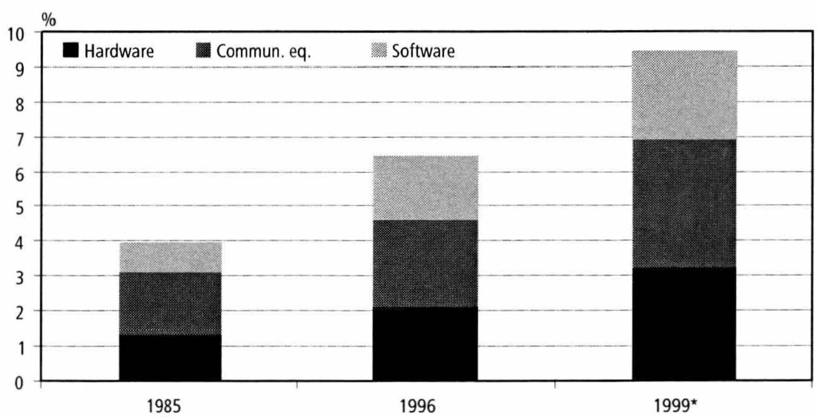
189 Purchased and own-account software compiled using the commodity-flow method.

190 As the last year in Schreyer's analysis is 1996, we extrapolated the deflator series until 1999 by using the relative changes of the appropriate indexes obtained from the US Bureau of Labor Statistics.

Figure 5.3 displays our estimate of the shares of the ICT assets in the total productive capital stock. In 1999, about 9 per cent of this stock was in the form of ICT assets. Comparing Finland with the G7 countries shown in figure 5.1, we have to exclude software and consider the latest year for which comparable data exist. In 1996, IT hardware and telecommunications equipment accounted for about 4.5 per cent of the Finnish productive non-residential capital stock. This share is close to the ones displayed in figure 5.1 for Canada (5.0 per cent) and the United Kingdom (5.2 per cent) but well below the one for the United States (7.4 per cent).

As a measure of labour input we use hours worked adjusted for labour quality measured by the level of education. The hours worked are cross-classified by educational level, and the marginal product of each educational group is measured by the average salary of the group. Increases in labour quality reflect the substitution of workers with high marginal products for workers with low marginal products.

Table 5.6 presents the results of the growth accounting analysis. The entire period is divided into three subperiods. In the first phase, covering the years 1975–90, the value added of the market sector grew at the average annual rate of 3.2 per cent. ICT capital accounted for 0.2 percentage points of this growth. The second phase covers the first half of the 1990s and includes the deep recession in the Finnish economy. Market output declined, but the growth contribution of ICT capital remained positive averaging 0.3 percentage points per year. The third phase, consisting of the years 1995–99, depicts the rapid recovery from the recession. Output increased at the average annual pace of 6.0 per cent, and ICT capital's contribution doubled to 0.7 percentage points per year. Interestingly, however, the growth contribution from the rest of the capital services was still negative. This reflects the fact that capital was used rather inefficiently in the Finnish business sector in the past decades (Pohjola, 1996) and that considerable improvement in its productivity has occurred after the recession.



* preliminary estimate.

Figure 5.3 ICT capital as a percentage of the nominal productive non-residential capital stock in Finland

Sources: Statistics Finland's National Accounts Database and WITSA (2001).

A recent study by Colecchia and Schreyer (2001) finds as well that the growth contribution from the use of ICT capital has doubled in Finland in the late 1990s. The output contribution was 0.62 percentage points in 1995–99. This is quite similar to our estimate of 0.7 percentage points. A closer comparison of these findings is, however, difficult because the OECD study does not describe the source of the ICT investment data. Also Daveri (2001) in his comparison of the EU countries obtains results for Finland which are quite close to our estimates. He uses the same datasource for ICT investment.

When Finland is compared with the other countries analysed above, the following observations are immediate. First, in the period up to the mid-1990s, the contribution to output growth from ICT hardware was in Finland in the same range – from 0.2 to 0.3 percentage points per year – as in Canada and the United Kingdom. This contribution was, however, only about half of the level achieved in the United States. Second, just like in the US, the output growth attributed to the use of ICT, including software, doubled to 0.7 percentage points in the second half of the 1990s, but still remained at a level well below the US record of 1.1 percentage points per year. The panel in the middle of table 5.6 shows the

Table 5.6 Contributions to real output growth in the market sector, 1975–99

		1975–90	1990–95	1995–99*
Output growth[1]		3.2	-0.7	6.0
Contributions[2] from	ICT capital	0.2	0.3	0.7
	Hardware	0.1	0.2	0.4
	Software	0.1	0.1	0.1
	Communications eq.	0.0	0.1	0.1
	Other capital	0.8	−0.7	−0.4
	Labour hours	−0.4	−2.9	1.3
	Labour quality	0.2	0.2	0.3
	Multi-factor productivity	2.2	2.3	4.2
Income shares[1]	ICT capital	1.7	5.0	5.6
	Hardware	0.5	1.5	1.7
	Software	0.6	2.4	2.4
	Communications eq.	0.5	1.1	1.5
	Other capital	33.9	33.8	38.8
	Labour	64.4	61.3	55.6
Growth rates[1]	ICT capital	16.5	7.2	12.4
	Hardware	29.7	15.1	28.1
	Software	12.9	2.7	5.6
	Communications eq.	9.9	9.1	10.2
	Other capital	2.8	−2.1	−1.1
	Labour hours	−0.7	−4.5	2.3

* = preliminary estimate,
1 = per cent,
2 =percentage points.
Numbers may not add to totals due to rounding.

increasing importance of the ICT capital which is reflected in the rising income share attributed to this factor of production.

The third observation is rather surprising. In spite of the rapid accumulation of ICT capital, the growth rate of labour productivity declined in the Finnish market sector in the second half of the 1990s. This is seen from table 5.7 which, by applying eq. (5.3), displays the contributions of the production factors to the growth in labour productivity. It can be argued that its growth rate was unusually high in the early 1990s because of the structural adjustments which took place during the recession. But in the late 1990s labour productivity grew also at a lower rate than it did in 1975-90.

Table 5.8 looks for an explanation for the deceleration in labour productivity growth by contrasting the labour productivity trends in Finland and the United States. As noted above, the contribution from ICT capital deepening has been lower in Finland than in the US, but this cannot explain the observed fall in the growth rate of labour productivity. Also, the contributions from multi-factor productivity have had similar impacts in both countries, increasing rather than

Table 5.7 Contributions to labour productivity in the market sector, 1975–99

	1975–90	1990–95	1995–99*
Growth rate of labour productivity[1]	3.7	3.9	3.5
Contributions from[2]			
ICT capital	0.3	0.6	0.5
Hardware	0.1	0.3	0.4
Software	0.1	0.2	0.1
Communications eq.	0.0	0.1	0.1
Other capital	1.0	0.7	−1.3
Labour quality	0.2	0.2	0.3
Multifactor productivity	2.2	2.3	4.2

* = preliminary estimate,
1 = per cent,
2 = percentage points.
Numbers may not sum to totals due to rounding.

Table 5.8 Sources of the changes in labour productivity growth rates in the second half of the 1990s

	Finland	United States
Change in the average growth rate of labour productivity in 1995–99 over 1990–95	−0.4	1.0
Contributions from:		
Capital deepening	−2.1	0.5
ICT capital	0.0	0.5
Other capital	−2.1	0.0
Labour quality	0.0	−0.1
Multi-factor productivity	1.8	0.7

Notes: Percentage points. Numbers may not sum to totals due to rounding.

Source: Oliner and Sichel (2000) for the United States.

decreasing the pace of improvement in labour productivity. Consequently, the explanation lies in the decline of the amount of non-ICT capital per worker. As mentioned above, this reflects the fact that capital was used rather inefficiently in the pre-recession era. It is worth pointing out, however, that even in the late 1990s the growth rate of labour productivity was higher in Finland than in the US. It is not the level of this growth which is the problem but its declining trend.

5.5.3 Growth contribution from productivity improvement in ICT industries

Regarding the comparison between Finland and the other countries, the final observation concerns the contribution to output growth from multi-factor productivity. As shown in table 5.6, this has been quite large in Finland. Moreover, it has increased over time from 2.2 percentage points in 1975–90 to 4.2 percentage points in 1995–99. Although rising over time as well, the growth rates have been more modest in the United States: 0.3 and 1.2 percentage points, respectively (see table 5.1). Schreyer (2000) finds growth contributions of equal size for the rest of the G7 countries in the first half of the 1990s, ranging from 0.4 percentage points in France to 1.3 in Germany.

International comparisons of multi-factor productivity should, however, be interpreted with caution. For one, the quality of the growth accounting data differs between countries and these differences will be picked up by the residual term $\hat{A}$ which is used as an estimate of multi-factor productivity growth. If, for example, the quality of capital and labour cannot be measured accurately, the measurement errors will be reflected in the residual. For another, this residual also picks up the impacts of other non-technology factors such as business cycles and changes in the scale and efficiency of economic activity. As already noted above, efficiency improvement may be one of the explanations for the fast productivity growth in Finland after the recession.

Leaving these problems aside, we could still try to trace aggregate multi-factor productivity growth to its sources in the productivity growth of individual industries following Oliner and Sichel (2000) and Jorgenson and Stiroh (2000). To do this properly, however, would require the estimation of the productive capital stock for each industry. Also, because industries differ from each other with respect to their use of intermediate inputs, the application of the so-called *KLEMS* growth accounting framework would be preferable instead of the one applied here which is based on measuring output in terms of value added. In the *KLEMS* approach, industry output is measured using a gross output concept and the inputs include capital services (K), labour services (L) as well as intermediate inputs, energy (E), materials (M) and services (S) (see, e.g., Jorgenson and Stiroh 2000). Unfortunately, adequate data are not available in Finland for measuring either the industry-level productive capital stocks or the intermediate inputs, and we have to be content with less satisfactory methods.

A recent study by Pilat and Lee (2001) evaluates the contributions of ICT using and ICT producing industries to labour and multi-factor productivity growth in 11 member countries using OECD's STAN database and measuring output in value-added terms. For Finland, the study finds that about 20 per cent of the multi-factor productivity growth in the total economy can be attributed to the ICT industries in the 1990s. Using our estimate of productivity growth, this means that the contribution from ICT industries was 0.8 percentage points on average in the late 1990s. Adding this up with our estimate of the contribution from the use of ICT implies that the overall ICT contribution to output growth was 1.5 percentage points in 1995–99.

5.6 Conclusions

The research findings surveyed in the first part of this chapter confirm that both the production and the use of ICT have been the factors behind the improved economic performance of the United States in the 1990s. The acceleration in the growth rates of labour and multi-factor productivity has not only been limited to the computer and semi-conductor producing industries but much – if not even most – of it has taken place outside this sector, i.e., in the industries using ICT.

The evidence for the New Economy is much weaker outside the United States. In the other G7 countries, the contributions to output growth from the use of ICT were less than half of the contributions estimated for the US in the early 1990s. Moreover, a recent update of these calculations (OECD, 2001d) finds that the output contributions have increased only in the US, Australia and Finland in the late 1990s, being 0.9, 0.6 and 0.6 percentage points, respectively. The fact that Australia is not a significant producer of ICT can be taken as evidence that ICT production is not a necessary condition to experience the growth effects of ICT.

Our analysis of the Finnish growth experience confirms that indeed the contribution from the use of ICT to output growth in the market sector has increased from 0.3 percentage points in the early 1990s to 0.7 points in the late 1990s. In addition, the fast growth of multi-factor productivity in the ICT producing industries has had a substantial growth contribution which has been at least as large as that from the use of ICT.

However, in spite of the significant role played by ICT in the recovery from the deep recession, there has been no acceleration in the trend rate of labour productivity. Other factors, notably the decline in the use of non-ICT capital per worker, have offset the growth-enhancing impact of ICT. In fact, the growth performance of the Finnish economy has not been very outstanding when considered over the whole decade of the 1990s. The unemployment rate is now around 9 per cent, and the economy is still returning to its trend growth path. The New Economy is yet to demonstrate its strength.

What is it then that the US economy has and the others do not have to enable it to benefit so much better from the diffusion of ICT? Baily and Lawrence (2001) suggest that the answer lies in the fact that the US has globally competitive service industries seeking out new technologies to improve their productivity. ICT innovations have been driven by the demand for improved technologies in the using industries. But the productivity gains not only reflect increased investment in ICT, but also complementary innovations in business organization and strategy. This is what the New Economy is all about.

6
Ict as a source of output and productivity growth in Finland[191] [192]

Jukka Jalava and Matti Pohjola

Abstract: The chapter analyzes the impacts of information and communications technology on output and labour productivity growth in Finland in 1995–2005. Information and communications technology (ICT) accounted for 1.87 percentage points of the observed labour productivity growth at the average rate of 2.87 per cent. The contribution from increases in ICT capital intensity was 0.46 percentage points. The rest is attributed to multi-factor productivity growth in ICT production, especially in telecommunications production. The ongoing outsourcing of ICT production to low-wage countries provides a threat to productivity performance in the future. Policy makers should consider where the next wave of productivity growth will come from.

6.1 Introduction

Finland transformed itself in the 20th century from a backward agrarian country reliant on its natural resources into a modern industrial society whose telecommunications manufacturing is at the cutting edge of the world. The flagship of Finnish telecommunications is of course Nokia (see Häikiö, 2002). Back in 1950 the Finnish living standard, as measured by gross domestic product (GDP) per capita, was less than half of the US equivalent. In 2003, this ratio was three-quarters.[193] The road to prosperity, however, has not always been smooth (see Ojala, Eloranta and Jalava, 2006). The largest peace-time hurdle was the recession in the early 1990s when real GDP plummeted by 11 per cent during the years from 1990 to 1993.

The tale of Finnish economic growth is very much one of productivity. From the year 1900 to 2005, the standard of living has increased 13-fold although the

---

191 This chapter was first published as: Jalava, J. and Pohjola, M. (2007a): "ICT as a source of output and productivity growth in Finland", *Telecommunications Policy* (31) 8–9, pp. 463–472.

192 The helpful comments of the editor and two anonymous referees are gratefully acknowledged. All remaining errors are the responsibility of the authors. 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 and from the HSE Foundation.

193 Source: Groningen Growth and Development Centre and The Conference Board, Total Economy database, August 2004 http://www.ggdc.net.

number of hours worked per capita has declined. This was possible because labour productivity – GDP per hour worked – rose 14-fold.

In an historical perspective, Finland is now in a similar situation as it was a century ago when the basis for electricity and telecommunications – the new technologies of the day – was laid. Past economic success was achieved through the adoption of electricity in the extraction of rents from its natural endowments – forests and minerals. The process created the present industrial structure in which the forest and metal sectors dominate. At best, GDP per hour worked increased at the average rate of five per cent per year. Starting in the early 1970s, however, there has been a worrisome shift into slower gear, as the gains from industrialization have been depleting. After the turn of the millennium, labour productivity change averaged only half of its earlier peak figures (figure 6.1).[194]

The slowing down of productivity growth would not be a policy problem if it could not be remedied. But as the recent success of the US economy shows, decelerating productivity growth can be turned into an accelerating one. The observed step-up in the trend of US labour productivity in the post-1995 era was traced by Jorgenson, Ho and Stiroh (2003, 2006) to the impact of information and communications technology (ICT) on GDP growth. This growth resurgence prompts the question: How can the same outcome be accomplished elsewhere? This is especially topical in a country like Finland which has reaped the benefits of the Nokia-phenomenon – the case in point of a successful production of a new technology – but has not as yet fully learnt to use this new technology in the production processes of other industries.

Like electricity, ICT is a general purpose technology (Bresnahan and Trajtenberg, 1995) that spreads to all sectors of the economy, improving and becoming cheaper over time and facilitating the creation of new goods, services and modes of operation. It affects economic growth both as a component of aggregate output in the form of ICT production and as a component of aggregate input in the form of ICT capital services. Furthermore, it has an impact on growth

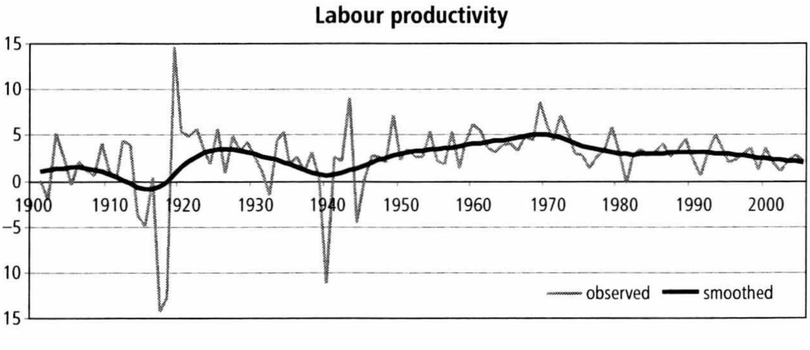


Figure 6.1 Growth of labour productivity, 1901–2005, %
Source: Statistics Finland's National Accounts Database.

194 The labour productivity series was smoothed using the Hodrick-Prescott (1997) filter.

via the effect of multi-factor productivity (MFP) gains induced by rapid technological advances in the ICT-producing industries.

To provide a background for policy conclusions, a brief history of ICT in Finland is presented in Section 6.2. Neoclassical growth accounting is then applied to delineate ICT's influence on output and labour productivity growth. Due to the extraordinary severity of the recession in the early 1990s, the focus is on the 1995–2005 period. In Section 6.3 the growth accounting methodology is outlined. Section 6.4 describes the data, and Section 6.5 presents the results. The last section presents a projection of labour productivity growth in the future and draws conclusions for policy.

6.2 A brief history of ICT in Finland

Finland was one of the leading countries in adopting the telephone. The first 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. 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. The first Finnish computer was built in 1960 under the auspices of the Finnish Committee for Mathematical Machines. (Jalava, 2004a)

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 and digital telephone exchanges. The production of computers was a major part of Nokia until the computer division was sold to ICL-Fujitsu in 1991. 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)

Finland was not as fast in utilizing information technology as it was in adopting telecommunications technology, but today it 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.

6.3 Growth accounting methodology

Information and communications technology[195] affects economic growth both as a component of aggregate output in the form of ICT production and as a component of aggregate input in the form of ICT capital services. Therefore, the aggregate production function is expressed in the form of the production possibility frontier as formulated by Jorgenson, Ho and Stiroh (2003):

$$Y(Y_{ICT}(t), Y_O(t)) = A(t)F(K_{ICT}(t), K_O(t), L(t)), \quad (6.1)$$

where at any given time t, aggregate value added Y is assumed to consist of the production of ICT goods and services Y_{ICT} as well as of other production Y_O.[196] These outputs are produced from aggregate inputs consisting of ICT capital services K_{ICT}, other capital services K_O and labour services L. The level of technology or multi-factor productivity is represented in the Hicks neutral or output-augmenting form by parameter A.

Assuming constant returns to scale in production and competitive product and factor markets, growth accounting gives the share weighted growth of outputs as the sum of the share weighted inputs and growth in MFP:

$$\Delta \ln Y = \overline{w}_{ICT}\Delta \ln Y_{ICT} + \overline{w}_O \Delta \ln Y_O = \overline{v}_{ICT}\Delta \ln K_{ICT} + \overline{v}_O \Delta \ln K_O + \overline{v}_L \Delta \ln L + \Delta \ln A, \quad (6.2)$$

where Δ refers to a first difference, i.e. $\Delta x = x(t) - x(t-1)$, and where the time index t has been suppressed for the economy of exposition. The weights $\overline{w}_{ICT}$ and $\overline{w}_O$ depict the average nominal value-added shares of ICT and other production, respectively, and they sum to one. The weights $\overline{v}_{ICT}$, $\overline{v}_O$ and $\overline{v}_L$ also sum to one and respectively represent the average nominal income shares of ICT capital, other capital and labour. All shares are averaged over the periods t and $t-1$.

---

195 Our definition of ICT goods and services is based on OECD (2004). ICT capital contains the ICT goods and software.

196 The approach in this chapter is different from Jorgenson, Ho and Stiroh (2003) in that they include only ICT investment goods in the production of ICT.

Equation (6.2) is used to show that information and communications technology can have an impact on economic growth via three channels. First, the most obvious effect on the total value-added generated in an economy is the direct contribution of the production of ICT goods and services. This contribution – $\bar{w}_{ICT}\Delta\ln Y_{ICT}$ in eq. (6.2) – is computed by multiplying ICT's nominal value-added share by the growth rate of the volume of its production.

Secondly, ICT capital services contribute to economic growth as an input into production. In the United States, the benefits from ICT use even surpass the gains from its production in the post-1995 era (Jorgenson, Ho and Stiroh, 2003). The way to estimate the growth contribution of ICT capital services is to weight its rate of change with a coefficient that represents its share in nominal income: $\bar{v}_{ICT}\Delta\ln K_{ICT}$.

The third channel for information and communications technology to enhance economic growth is via the impact of ICT production on MFP:

$$\Delta\ln A = \bar{u}_{ICT}\Delta\ln A_{ICT} + \bar{u}_O\Delta\ln A_O \,, \qquad (6.3)$$

where $\Delta\ln A_{ICT}$ is MFP growth in ICT production and $\Delta\ln A_O$ is MFP growth in other production. The weights $\bar{u}_{ICT}$ and $\bar{u}_O$ applied in decomposing the aggregate MFP growth are the ICT products' output shares of GDP.

To estimate sectoral multi-factor productivity growth, the price dual method is employed. It uses data on the prices of inputs and outputs, rather than their quantities, to calculate MFP growth. The underlying idea is that decline in the relative prices of ICT goods reflects productivity growth in their production $\Delta\ln A_{ICT}$. Assuming that the aggregate share weighted price change of labour and capital is representative also at the disaggregated level, MFP growth in ICT production can be calculated as the negative of the ICT output price change relative to the share weighted price change of labour and capital (Jorgenson, Ho and Stiroh, 2003). Multiplying this by the output share $\bar{u}_{ICT}$ gives ICT's contribution to the aggregate MFP growth. The contribution of non-ICT productivity growth $\bar{u}_O\Delta\ln A_O$ is obtained from equation (6.3) as a residual.

To assess the contribution of ICT on the growth of labour productivity, the number of hours worked are denoted by $H(t)$ and labour productivity by $Y(t)/H(t)$. The basic growth accounting equation (6.2) can be rewritten as

$$\begin{aligned}&\Delta\ln Y - \Delta\ln H = \\ &v_{ICT}(\Delta\ln K_{ICT} - \Delta\ln H) + v_O(\Delta\ln K_O - \Delta\ln H) + v_L(\Delta\ln L - \Delta\ln H) + \Delta\ln A\end{aligned} \qquad (6.4)$$

There are four sources of labour productivity growth. The first one is ICT capital deepening[197], i.e. the income share weighted increase of ICT capital services per hour worked. The second source is the income share weighted increase of other capital services per hour worked. The third component is the improvement in labour quality which is defined as the difference between the growth rates of la-

197 Capital deepening signifies an increase in the capital-labour ratio. That is, there are more capital services available per hour worked.

bour services and hours worked multiplied by labour's income share. The fourth source is a general advance in multi-factor productivity which increases labour productivity point for point.

Jorgenson and Griliches (1967) showed that it is important to account for substitution between capital and labour of different quality. Similarly as the services provided by a truck built in 1968 differs from a truck of vintage 1998, also the hours worked by a high school dropout and by a holder of a Master's degree are not equal. The aggregate capital service flow, which is assumed to be proportional to the capital stock, is estimated by using asset-specific user costs to weight each heterogeneous asset and to account for substitution between them. Under competitive markets and equilibrium conditions, user costs reflect the marginal productivity of the different assets. They thus provide a means of incorporating differences in the productive contribution of heterogeneous investments as the composition of investments and capital changes. For example, as firms respond to fast declining ICT prices by substituting away from other capital equipment or structures and toward ICT equipment, a larger portion of investment will be in assets with relatively high marginal products, and the aggregate capital service flow increases. This can also be interpreted as an increase in the quality of capital.

The user cost of ICT capital services is also needed in estimating the share of nominal income accruing to ICT capital. It is obtained as

$$r_{ICT} = p_{ICT}\,(i + d_{ICT} - \Delta \ln p_{ICT}\,), \tag{6.5}$$

where p_{ICT} is the asset price of new ICT capital goods and $\Delta \ln p_{ICT}$ its rate of change, i is the internal rate of return and d_{ICT} denotes depreciation. ICT capital's income share is then obtained as $r_{ICT}\bar{S}_{ICT} \,/\, p_Y Y$ where $\bar{S}_{ICT}$ is the mid-year real stock of ICT capital and p_Y is the output price. The productive capital stock at year-end t for a homogeneous capital asset type is defined as the following perpetual inventory equation:

$$S(t) = S(t-1)(1-d) + I_t = \sum_{\tau=0}^{\infty}(1-d)^{\tau} I(t-\tau)\,, \tag{6.6}$$

where I is investment. The symbol for asset type has been left out for notational simplicity.

For labour the difference between labour quantity and labour services (hours worked adjusted for labour quality) is distinguished. The hours worked are cross-classified by educational level and by age. The average wages and salaries of each group are assumed to represent their marginal productivity. Labour quality is defined as the ratio of labour services to hours worked. The variable $\Delta \ln L - \Delta \ln H$ measures its rate of change in equation (6.4). Labour quality increases as firms hire relatively more skilled and highly compensated workers.

6.4 The data

The basic computational framework is the balance of aggregate supply and demand. GDP at market prices plus imports equals private and government consumption expenditure plus investment plus changes in inventories plus exports:

$$GDP + Imports = Consumption + Investment + \Delta Inventories + Exports. \quad (6.7)$$

When imports are moved to the right-hand side of the identity, GDP is calculated using the expenditure approach.

The official investment asset breakdown is further refined here by separating from machinery and equipment computers and communications equipment. ICT capital is defined as: computers, communications equipment and software.

To obtain data on nominal ICT investment, the detailed annual supply and use tables of Statistics Finland for the years 1995–2003 were used.[198] Of the grand total of almost 1,000 goods and services those pertaining to ICT were delineated. To compute investment in hardware and communications equipment in current prices for 1975–94 a series on investments into electrical machinery and optical equipment obtained from Statistics Finland was used to extrapolate the 1995–2005 series backwards.[199]

Traditionally price indexes are compiled by comparing the same product's prices in adjacent periods. In the case of ICT's rapid technological advances, the situation is more complex. Products appear and disappear at a rapid pace. That is why so called hedonic indexes should be used instead of the traditional matched-model indexes. Hedonic functions are relations between the prices of characteristics, such as computer speed, to the prices of the goods themselves.

Unfortunately hedonic indexes do not exist for Finnish ICT products, which is why the paper turned to data from the US Bureau of Economic Analysis (BEA). The methodology utilized is broadly that of Schreyer (2000). The annual changes in the BEA's price index for private non-ICT fixed investments were contrasted with the annual changes in the BEA's price indexes for computers, software and communication equipment, respectively. The three series thus obtained were first smoothed using the Hodrick-Prescott (1997) filter, after which they were multiplied with the implicit Finnish aggregate investment deflator to obtain the Finnish quality adjusted ICT deflators.

The drastic differences in the new computer deflator (and new communications equipment deflator) vis-à-vis the official machinery and equipment price index can be clearly seen in figure 6.2. The new software index is also compared with the official one. In addition to investments, the ICT deflators were also applied to imports and exports of information and communications products. The result is that the GDP measure used here differs from the official one. The quality adjusted average GDP growth for 1995–2005 is 4.06 per cent, as will be seen

198 As the detailed supply and use tables are only available at a significant lag we used the ratio of hardware and communications equipment, respectively, to machinery and equipment in 2003 also for the years 2004 and 2005.

199 For software an official time series existed.

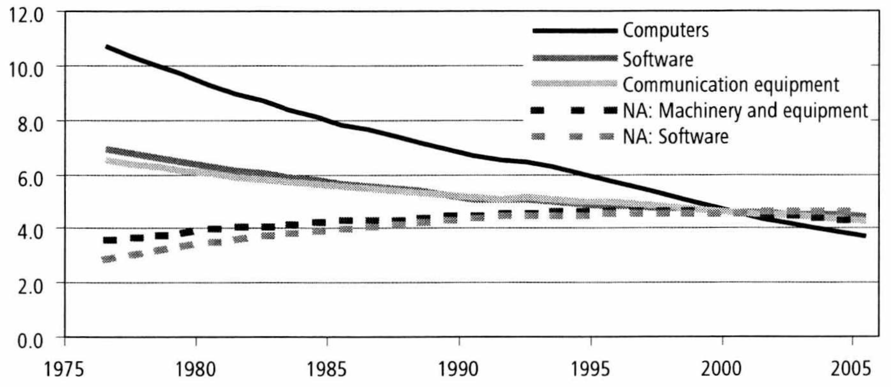


Figure 6.2 Price indexes for ICT and National Account's price index for machinery and equipment, 1976–2005, 2000=LN(100)

in the next section. Since the revised official estimate is 3.56 per cent, it can be concluded that the impact of quality adjustment is significant.

Productive capital stocks for each homogeneous asset type were calculated with the perpetual inventory method utilizing geometric depreciation rates. The depreciation rates used were: 0.012 for dwellings, 0.025 for non-residential buildings and civil engineering constructions, 0.25 for transportation equipment, 0.13 for non-ICT equipment, 0.33 for mineral exploration and originals, 0.012 for transfer of ownership of land, 0.315 for computers, 0.11 for all communication equipment, and 0.315 for software. No rate of depreciation was applied to cultivated assets.[200] The user costs were used as weights to aggregate the stocks into a measure of capital services. For the internal rate of return *i* contained in the user cost formula (6.5), the realized rate of return derived from national accounts was used.

The labour input and its remuneration were divided into 36 classes. Labour was cross-classified by three age groups (15–29 years, 30–49 years and 50 years and older), six educational classes (lower secondary education or less, upper secondary education, first stage of tertiary education (i–iii) and second stage of tertiary education) as well as by occupational status (employee or self-employed). The labour compensations were used as weights in aggregating the labour hours per class into a measure of labour services. Labour compensation for the self-employed was imputed by multiplying their hours worked with the employees' average hourly compensation.

200 Cultivated assets encompass only livestock for breeding and dairy in Finland. The European practice is to include a so called culling discount – the difference between the value of a production animal less its slaughter value – on this investment item as a proxy for depreciation. Hence using the PIM on cultivated assets is out of the question.

6.5 The results

The upper panel of Table 6.1 shows the impact of the production of ICT goods and services as well as other products on the Finnish economy in the years 1995–2005. The first column contains the nominal value-added shares and the second column the volume growth of production. In the third column are the contributions[201] to GDP growth. It can be seen that ICT production's GDP share is 5.10 per cent and its volume growth 17.74 per cent.[202] The growth contribution is 0.87 percentage points. The manufacture of television and radio transmitters and apparatus for line telephony and line telegraphy (a crude proxy for the Nokia-effect), had a ratio of value-added to GDP of 4.1 per cent and boasted a volume growth of 19.73 per cent per annum 1995–2005. Approximately one-fifth (21%) of the 4.06 per cent GDP growth stemmed from ICT production, which encompasses the production of computers, software, communications equipment and telecommunications services, and as much as 19 per cent of the growth could be traced to the Nokia phenomenon.[203]

Table 6.1 Average growth of GDP and its components, 1995–2005

	Share of GDP (%)	Volume growth (ln %)	Contribution (ln %)
GDP at market prices	100.00	4.06	4.06
Production of goods and services			
ICT products	5.10	17.74	0.87
Other products	94.90	3.36	3.19
Capital services	34.62	3.05	1.07
Dwellings	9.92	2.34	0.25
ICT capital	3.27	15.14	0.50
Other capital	21.42	1.51	0.32
Labour services	65.38	1.41	0.92
Multi-factor productivity			2.07
Capital quality	34.62	0.73	0.25
Capital quantity	34.62	2.32	0.82
Labour quality	65.38	0.22	0.14
Labour quantity	65.38	1.19	0.78

Numbers may not add to totals due to rounding.

201 The Törnqvist index is used throughout the chapter in aggregations and computations of growth contributions. The volume growth is thus weighted with the average *t* and *t–1* nominal shares. The implication of using the Törnqvist index for GDP calculations with the expenditure approach is that the term for changes in inventories (which occasionally is negative) had to be distributed to the other expenditure items. This was calculated in relation to each other expenditure item's relative size.

202 ICT production is also deflated with the quality-adjusted deflators.

203 Contribution 0.78 percentage points (of 4.06 per cent GDP growth). These are the direct effects; the indirect spillover effects are not caught by this methodology. An anonymous referee is thanked for suggesting that the Nokia-effect be explicitly reported.

The panel in the middle of Table 6.1 reports the results of growth accounting on the input side. On average, ICT-capital contributed 0.50 percentage points to GDP growth. This means that 12 per cent of growth was due to ICT investments. The contribution of total capital services was 1.07 percentage points. Information and communications technology alone thus stood for almost half the contribution although its share of the nominal mid-year capital stock in 2005 was still less than 3 per cent. The big contribution is explained by the rapid growth of ICT capital services at the average rate of 15.14 per cent.

The estimate presented here for the growth contribution of ICT capital is quite close to other estimates. Using unofficial ICT-data Jalava and Pohjola (2002) and Jalava (2003) estimated the contribution to be 0.6 percentage points in the years 1995–2001 in the non-residential market sector. In their comparison of EU countries, Timmer, Ypma and van Ark (2003) ended up at 0.7 percentage points for Finland in the same period. These earlier studies were not based on the best-available data, i.e., the official supply and use tables.

Capital quality rises when capital services grow faster than capital quantity. As reported in the lower panel of Table 6.1, capital quality grew on average by 0.73 per cent in 1995–2005. As capital's income share was one third, the contribution of quality was 0.25 percentage points. Consequently, capital quality contributed one-quarter and capital quantity three-quarters of the total contribution of capital services at the rate of 1.07 percentage points. As can be further seen from Table 6.1, 0.92 percentage points of GDP growth can be attributed to labour services. Labour quality contributed 0.14 and quantity 0.78 percentage points.

The combined growth effect of the inputs was 1.99 percentage points which is half (49 per cent) of the GDP growth. Of the inputs 0.39 percentage points were traced to quality improvements. The residual or MFP term, i.e., the estimate for technological change broadly defined, contributed the remaining 2.07 percentage points.

Table 6.2 shows the decomposition of labour productivity growth. As already seen in Table 6.1, GDP grew at the pace of 4.06 per cent and the hours worked at the rate of 1.19 per cent. Hence, labour productivity increased on average by

Table 6.2 Average growth of labour productivity and its components, 1995–2005

	Share of GDP (%)	Volume growth (ln %)	Contribution (ln %)
GDP at market prices	100.00	4.06	4.06
Hours worked		1.19	1.19
Labour productivity		2.87	2.87
Capital deepening	34.62	1.86	0.66
Dwellings	9.92	1.15	0.13
ICT capital	3.27	13.95	0.46
Other capital	21.42	0.01	0.07
Labour quality	65.38	0.22	0.14
Multi-factor productivity		2.07	2.07
ICT related contribution			1.41
Other contribution			0.66

Numbers may not sum to totals due to rounding.

2.87 per cent a year. The contribution of ICT capital deepening was 0.46 whereas dwellings and other capital contributed 0.13 and 0.07 percentage points, respectively.

The culprit behind the recent shift to a slower gear in labour productivity growth is the low contribution of other capital deepening. The volume of other capital per hour increased by only 0.01 per cent annually, whereas the volume of ICT capital deepening increased by 13.95 per cent each year. The contribution of labour quality was 0.14 percentage points and that of MFP 2.07 percentage points.

Although the contribution of ICT capital deepening is the strongest among the components of capital, it is smaller than in the US and in the UK. The contribution was 0.78 percentage points in the US in 1995–2004 (Jorgenson, Ho and Stiroh, 2006).

In the last two rows of Table 6.2, the aggregate multi-factor productivity growth is decomposed into ICT related and other contributions in the way specified in equation (6.3). Of the total increase at the rate of 2.07 per cent, 1.41 percentage points came from ICT production and 0.66 percentage points from other production. Hence, almost 70 per cent of the aggregate MFP growth can be attributed to this new technology. The respective contribution was 0.43 percentage points in the US in 1995–2004 (Jorgenson, Ho and Stiroh, 2006).

ICT's overall contribution to labour productivity growth is obtained by summing up the impacts of ICT capital deepening (0.46) and ICT-related multi-factor productivity growth (1.41). The result is 1.87 percentage points, i.e. 65 per cent of the observed growth of GDP per hour worked at the rate of 2.87 per cent.

6.6 *Projections for the future and conclusions for policy*

In this chapter, stock was taken of the impacts of information and communications technology on output and labour productivity growth in Finland between 1995 and 2005. The results showed that one-fifth of the quality adjusted GDP growth at the rate of 4.06 per cent stemmed from ICT production. This is remarkable as the share of ICT production of GDP was only 5 per cent. Nearly one-fifth of the growth was traced to the manufacture of electronics: Finland's Nokia-phenomenon.

On the input side, the authors' growth accounting results showed that ICT capital services contributed 0.50 percentage points to economic growth. The contribution of total capital services was 1.07 percentage points, so information and communications technology alone stood for almost one-half of the contribution. The inputs combined contributed 1.99 percentage points of growth and 0.39 percentage points of this was traced to quality improvements.

Labour productivity increased on average by 2.87 per cent a year. The contribution of ICT capital deepening was 0.46. Summing this up with the ICT-related multi-factor productivity growth, ICT accounted altogether for 1.87 percentage points of the improvement in GDP per hour worked. This amounts to 65 per cent of the observed labour productivity growth.

But what are the future prospects of the Finnish economy? A simple projection can be made on the basis of the growth accounting analysis of labour productivity. Assuming that the economy will be in a steady-state where output and capital services grow at the same rate, equation (6.4) turns into

$$\Delta \ln Y - \Delta \ln H = \Delta \ln L - \Delta \ln H + \Delta \ln A / v_L \, . \qquad (6.8)$$

Jalava and Pohjola (2004) estimated that the growth of labour quality $\Delta \ln Y - \Delta \ln H$ is likely to turn negative and may lie in the range between –0.10 and –0.15 per cent in the coming years. This follows from the adverse effects of an aging population on labour productivity. Assuming that labour's income share and multi-factor productivity growth will be the same in the future as in 1995–2005; equation (6.8) predicts that labour productivity will grow at a rate of approximately 3 per cent.

This projection may be on the optimistic side, although the historical evidence in figure 6.1 shows that it is not completely unrealistic, because MFP growth might have been exceptionally high in the 1995–2005 period as the economy was recovering from the deep recession of the early 1990s and reaping the fruits of the Nokia phenomenon. But even if MFP growth were to decline to more modest numbers, the growth prospects of the Finnish economy are not as gloomy as often claimed in public debate.

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. How should the policy-makers react to this threat?

It was shown in Section 6.2 that Finland was one of the leading countries in adopting the telephone. For political reasons, a competitive telecommunications market was created whereas in most other countries the telephone was a state monopoly. It took however a long time, about 100 years, until Finland's competitive advantage in the production of telecommunications equipment and services was revealed. Admittedly, the chapter has not been able to prove that a causal link exists between the decisions made by policy-makers more than one hundred years ago and the success of the present-day Finnish economy. But it is hard to think how such success would have been possible without being close to the frontier in the use of this technology.

The lesson learnt is that the output and productivity impacts of the new technologies can be long-delayed. Consequently, current policy-makers should consider whence will come the next wave of productivity growth.

As shown, ICT has already contributed to economic growth by improving productivity in the industries producing ICT equipment. It has also enhanced labour productivity in the rest of the economy through capital deepening, i.e. through the substitution of ICT capital for other forms of capital. However, the effects on MFP from the re-organization of production and work are yet to come (see, e.g., Pohjola, 2006).

ICT is expected to increase productivity by standardizing, automating and outsourcing white-collar work in basically the same way as the assembly line mechanized manufacturing. The on-going digitalization and outsourcing of business processes will result in the restructuring of white-collar work at the global level and, consequently, may bring about a new wave of productivity growth. Various business information systems, such as Enterprise Resource Planning software, play here much the same role as the assembly line did in the transformation of industrial work.

Digitally stored information (R&D, financing, insurance services, accounting, payroll, etc.) can already be generated away from the office. Intelligent use of information is a source of increased productivity, just as natural resources were in the 20th century. The difference is that natural resources are tied to a certain place, whereas information has no such restrictions. It can be produced just as well in India, China, Russia or Estonia as in Finland. Geography is no longer of essence, as everyone has equal access to global information networks. The new restructuring of the economy may be as great as the one witnessed over 100 years ago when electricity and the telephone were invented.

7

The roles of electricity and ict in growth and productivity: Case Finland[204] [205]

Jukka Jalava and Matti Pohjola

Abstract: This chapter 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.

7.1 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

204 This chapter first appeared as: Jukka Jalava and Matti Pohjola (2007b): "The Roles of Electricity and ICT in Growth and Productivity: Case Finland", *Pellervo Economic Research Institute, Working Papers No. 94*, April.

205 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.

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, 2004b) 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 (2004b) 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 7.3 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 7.4 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 7.2. Section 7.5 concludes.

7.2 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 7.1.

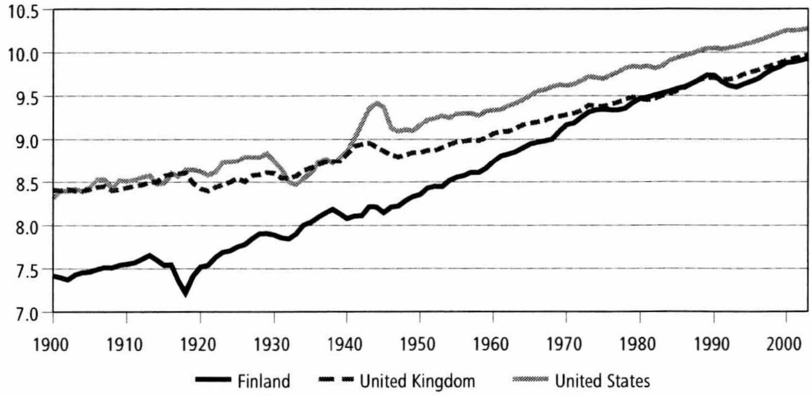


Figure 7.1 GDP per capita, 1900–2003 (logarithmic scale, 1990 international Geary-Khamis dollars)
Source: Maddison (2003), revised and updated data available on http://www.ggdc.net/maddison/.

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.[206]

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

$$Y_t = A_t F(K_t, L_t) \tag{7.1}$$

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

$$\Delta \ln Y = v_K \Delta \ln K + v_L \Delta \ln L + \Delta \ln A , \tag{7.2}$$

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 $t-1$.

206 Source: Groningen Growth and Development Centre, ICOP Database 1997 Benchmark, http://www.ggdc.net

The first two rows of Table 7.1 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.[207] 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 (7.2), output growth is decomposed in the last three rows of Table 7.1 into the share weighted contributions of the capital stock, hours worked and the growth in multi-factor productivity, obtained as the residual.[208] 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 half of aggregate growth stemmed from the residual. The contributions of capital and labour were 1.3 and 0.9 percentage points, respectively.

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

Table 7.1 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.*

207 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.

208 The Appendix describes how the series are compiled.

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 chapter, the basic growth accounting equation (7.2) will be used in measuring the output growth contributions of a general purpose technology – electricity in section 7.3 and ICT in section 7.4. 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

$$\begin{aligned} \Delta \ln Y &= v_{KGPT}\,\Delta \ln K_{GPT} + v_{KO}\,\Delta \ln K_O + v_L\,\Delta \ln L \\ &\quad + u_{GPT}\,\Delta \ln A_{GPT} + u_O\,\Delta \ln A_O + \gamma \Delta \ln K_{GPT}\,. \end{aligned} \qquad (7.3).$$

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.

7.3 Electricity as a source of output growth in 1900–1938

7.3.1 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, Michelsen and Herranen, 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, Hjerppe, Mannermaa, Niitamo and Siltari, 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 7.2 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.

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, Federico and Klein, 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

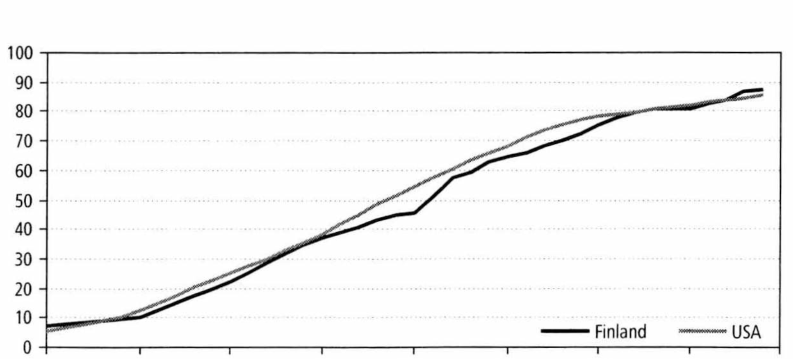


Figure 7.2 Shares of electricity in total motive power in the U.S. and Finnish manufacturing, 1900–1939 (per cent)

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.

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).

7.3.2 Electricity's growth effect

The growth accounting framework (7.3) 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 7.1, the average output growth rate was 2.9 per cent in the first period and 4.5 per cent in the second.

Table 7.2 summarizes the findings.[209] 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

Table 7.2 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 contribution[2] 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 shares[1]	Electric utilities capital	0.76	3.64
	Electric capital goods	0.47	0.48
Volume growth[1]	Electric utilities' capital	9.30	8.00
	Electrical capital goods	9.21	7.22
Output shares[3]	Electric utilities	0.51	2.24
	Manufacture of electrical machinery	0.24	0.31
Volume growth[1]	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, Hjerppe, Mannermaa, Niitamo and Siltari (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).*

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

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.

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 7.2. 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 new 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 US 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.[210] This can be justified by referring to Figure 7.2 which shows that the diffusion of electricity was as rapid in the Finnish as in the US manufacturing. Data on equipment's capital share was obtained from Hjerppe, Hjerppe, Mannermaa, Niitamo and Siltari (1976) and from the Finnish National Accounts. As shown in Table 7.2, 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 7.2, 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 multi-factor-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 US 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 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

210 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.

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.[211] 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 7.2.

This contribution is quite small compared to the US 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.[212]

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.

---

211 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.

212 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.

7.4 ICT as a source of output growth in 1980–2004

7.4.1 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.[213] 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, 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, 2004a).

---

213 Castells and Himanen (2002: 56–57) provide a summary in English.

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.[214]

However, as displayed in Figure 7.3, 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 7.2, 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.

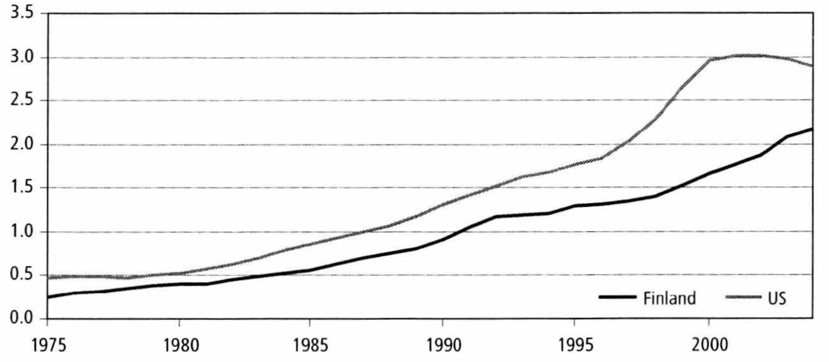


Figure 7.3 Share of computer software in private, non-residential fixed assets, 1975–2004 (per cent)
Source: US data from the Bureau of Economic Analysis, NIPA Table 2.1; Finnish data from Statistics Finland.

7.4.2 ICT's growth effect

Table 7.3 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

214 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.

Table 7.3 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 contribution[2] 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 capital[3]	0.92	2.62	1.63	4.62
Volume growth of ICT capital[1]	8.68	17.00	4.99	7.83
Output share of ICT production[3]	3.67	4.16	8.55	7.17
MFP growth in ICT production[1]	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.*

not based on any hedonic price 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 (2007a). 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 7.3 with Table 7.2, 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.

The estimates in column (b) of Table 7.3 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.

7.5 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.

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)[215]. 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 non-residential market sector (the breakdown of current price investments in computers, communications equipment and other machinery and equipment in 1970–2004 from Jalava and Pohjola (2007a); for 2005 same structure as in 2004 assumed).[216] 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:

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

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-resi-

---

215 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.

216 NB. In contrast with Jalava and Pohjola (2007a) the official deflator for machinery and equipment used on hardware and communications equipment – and not a hedonic index.

dential 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, Hjerppe, Mannermaa, Niitamo and Siltari, 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).

8
Concluding remarks

Jukka Jalava

In his magnum opus John Kendrick wrote: "The story of productivity, the ratio of output to input, is at heart the record of man's efforts to raise himself from poverty."[217] In this thesis we have strived to tell the story of how Finland raised itself from poverty. Key in this endeavour was productivity. And the major engines of productivity growth were the macroinventions electricity and ICT. This was of course linked to the unique historical Finnish situation with the sufficient institutional, political, social, etc. settings in place. Had the same macroinventions been introduced at another time (or in another country) the same positive outcomes might not have ensued. A new GPT builds on previous knowledge, yet often in an uncertain, punctuated, fashion.[218]

Economic history, as well as the Finnish data analyzed in this thesis, 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. These are technologies that affect the whole economy by transforming both household life and the ways in which firms conduct business. Steam, electricity and information and communications technology are the most important examples. Looking at figure 1.3 we saw that the interwar era, as well as the post-1995 period were the periods to scrutinize with particular attention; they were times where both labour productivity and capital productivity growth were positive in Finland. They were times when two GPTs made their mark on the Finnish economy.

So what were the research questions? Were they answered and what is the contribution of this thesis to our understanding of the Finnish historical economic development. The first research question of this thesis was to ascertain whether the classical view of structural change[219] is sufficient in explaining the Finnish growth record? The role of manufacturing as the proverbial engine of growth was in particular analyzed. The second research objective of this thesis was to find out what new insights on Finnish growth could be gained, by using state-of-the-art neoclassical growth accounting on Finnish historical national accounting data, on the impacts of electricity and ICT on Finnish economic growth and productivity. Especially the production, use and productivity of these technologies was analyzed. As the third research question the Artto-Pohjola paradox, that is, how capital has influenced recent Finnish economic history was tackled.

217 Kendrick (1961).

218 Lipsey, Carlaw and Bekar (2005).

219 Clark (1940), Kuznets (1966) and Hartwell (1973).

The answer to the first research question was a corroboration of the findings of previous research that Finnish economic growth exhibited late industrialisation and significant structural changes. Yet, it was not solely a story of manufacturing and structural change was more the effect of than the cause for economic growth. Hence, more research was necessary to better understand the dynamics of Finnish economic growth. Regarding research question number three we offered an empirical resolution to the Artto-Pohjola paradox as we showed that a high rate of return on capital was combined with low capital productivity growth. This result is important in understanding Finnish economic growth 1975–90.

The main contribution of this thesis was the growth accounting results on the impact of ICT on growth and productivity, as well as the comparison of electricity and ICT.[220] It was shown in this thesis that ICT's contribution to GDP growth was almost twice as large as electricity's contribution over comparable periods of time. Finland has thus been far more successful as an ICT producer than a producer of electricity. Unfortunately in the use of ICT the results were still more modest than for electricity. During the end of the period considered in this thesis, 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. For a developed country only change is constant and history teaches us that it is likely that Finland is obliged to reorganize its economy once again in the digital era.

220 One implicit outcome of our research was also that we initiated improvements to the content and usability of national accounts.

Sources and literature

Archives

Statistics Finland's National Accounts Database.

Published sources

Australian Bureau of Statistics (2000): *Australian National Accounts; Concepts, Sources and Methods*, 52160.0, Canberra.

Bureau of Labor Statistics (1997): *BLS Handbook of Methods*, Washington.

ESA95 (1996): *European System of Accounts*, Luxembourg: Eurostat.

Eurostat (2001): *Handbook on Price and Volume Measures in National Accounts*, Luxembourg: Office for Official Publications of the European Communities.

IDC (2006): The Information Society Index, Downloaded 10.11.2006. http://www.idc.com/groups/isi/main.html

IMF (2006): *World Economic Outlook Database, April 2006*. Downloaded 2.8.2006. http://www.imf.org/external/pubs/ft/weo/2006/01/data/index.htm

Jalava, J. (ed.) (2004b): *Tuottavuuskatsaus 2003* (Review of productivity 2003), Reviews 2004/3, Statistics Finland, Helsinki: Multiprint Oy.

Jalava, J. (ed.) (2005): *Tuottavuuskatsaus 2004* (Review of productivity 2004), Reviews 2005/1, Statistics Finland, Helsinki: Multiprint Oy.

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

OECD (1993): *Methods Used by OECD Countries to Measure Stocks of Fixed Capital*, National Accounts: Sources and Methods, No. 2, Paris: OECD.

OECD (2000): *Information Technology Outlook 2000*, Paris: OECD.

OECD (2001a): *OECD, Measuring Capital – OECD Manual: Measurement of Capital Stocks, Consumption of Fixed Capital and Capital Services*, Paris: OECD.

OECD (2001b): *OECD Productivity Manual: A Guide to the Measurement of Industry-level and Aggregate Productivity Growth*, Paris: OECD.

OECD (2003): *National Accounts of OECD Countries, Main Aggregates, Volume I, 1990–2001*, Paris: OECD.

OECD (2004): A proposed classification of ICT goods, paper presented at the meeting of of the UN Technical Subgroup of the Expert Group on International Economic and Social Classifications, 18–21/10, in New York.

SNA93 (1993): *System of National Accounts 1993*, UN, OECD, EU, IMF, World Bank, Series F, No. 2, Rev. 4,. New York: United Nations.

Statistics Finland (1996): *Tuottavuuskatsaus 1996* (Review of productivity 1996), Official Statistics of Finland: National Accounts 1996:7, Helsinki: Statistics Finland.

Statistics Finland (1997): *Tuottavuuskatsaus 1997* (Review of productivity 1997), Official Statistics of Finland: National Accounts 1997:10, Helsinki: Statistics Finland.

Statistics Finland (1998): *Tuottavuuskatsaus 1998* (Review of productivity 1998), Official Statistics of Finland: National Accounts 1998:21, Helsinki: Statistics Finland.

Statistics Finland (1999a): *Tuottavuuskatsaus 1999* (Review of productivity 1999), Official Statistics of Finland: National Accounts 1999:24, Helsinki: Statistics Finland.

Statistics Finland (1999b): *On the Road to the Finnish Information Society II*, Helsinki: University Press.

Statistics Finland (2000a): *Tuottavuuskatsaus 2000* (Review of productivity 2000), Official Statistics of Finland: National Accounts 2000:26, Helsinki: Statistics Finland.

Statistics Finland (2000b): *Capital Stock Data 1975–1998, Time series, ESA95 revision*, Official Statistics of Finland: National Accounts 2000:7, Helsinki: Statistics Finland.

Statistics Finland (2002a): *Tuottavuuskatsaus 2001* (Review of productivity 2001), Official Statistics of Finland: National Accounts 2001:12, Helsinki: Statistics Finland.

Statistics Finland (2002b): *Internet Use and E-commerce in Enterprises*, Official Statistics of Finland: Science, Technology and Research 2002:4, Helsinki: Statistics Finland.

Statistics Finland (2003): *Tuottavuuskatsaus 2002* (Review of productivity 2002), Official Statistics of Finland: National Accounts 2003:1, Helsinki: Statistics Finland.

Statistics Finland (2004): *Internet Use and E-commerce in Enterprises*, Official Statistics of Finland: Science, Technology and Research 2004:3, Helsinki: Statistics Finland.

Statistics Finland (2005a): *Statistical Yearbook of Finland 2005*, Helsinki: Statistics Finland.

Statistics Finland (2005b): *Producer Price Indices for Services 2004, 4th quarter*, Helsinki: Statistics Finland.

Statistics Finland (2006): *National Accounts 1995–2004 – Revised Time Series*, Official Statistics of Finland: National Accounts 2006, Helsinki: Statistics Finland.

Teollisuustilastoa SVT XVIII: 1900–12.

Teollisuustilastoa SVT XVIIIA: 1913, 1920–39.

UNDP (2001): *Human Development Report 2001*, Oxford University Press for UNDP, New York.

UNDP (2005): *Human Development Report 2005*. Downloaded 2.8.2006. http://hdr.undp.org/reports/global/2005/

WITSA (2001): *Digital Planet 2000: The Global Information Economy*, World Information Technology and Services Alliance.

World Economic Forum (2005): *The Global Competitiveness Report 2005–2006*, Houndmills: Palgrave Macmillan.

Literature

Aaltonen, A. (1993): "Nokian elektroniikkateollisuuden synty: nuorten kokeilijoiden ja keksijöiden pajasta huipputeollisuudeksi", in M. Tienari (ed.), *Tietotekniikan alkuvuodet Suomessa*, Jyväskylä: Gummerus Kirjapaino Oy.

Abramovitz, M. (1956): "Resource and output trends in the United States since 1870", *American Economic Review*, Vol. 46, pp. 5–23.

Abramovitz, M. (1986): "Catching up, forging ahead, and falling behind", *Journal of Economic History*, Vol. 46, pp. 385–406.

Aghion, P. and Howitt, P. (2005): "Appropriate Growth Policy: A Unifying Framework", unpublished manuscript.

Ahvenainen, J., Pihkala, E. and Rasila, V. (1982) (eds.): *Suomen taloushistoria 2: teollistuva Suomi*, Helsinki: Tammi.

Aizcorbe, A., Corrado, C. and Doms, M. (2003): "When do matched-model and hedonic techniques yield similar price measures?", FRBSF Working paper 2003–14, June.

Ali-Yrkkö, J. and Ylä-Anttila, P. (2003): "Globalization of business in a small country – does ownership matter?", in A. Hyytinen and M. Pajarinen (eds.), *Financial Systems and Firm Performance: Theoretical and Empirical Perspectives*, ETLA B: 200, Helsinki: Yliopistopaino.

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

Antràs, P. (2004): "Is the U.S. aggregate production function Cobb-Douglas? New estimates of the elasticity of substitution", *Contributions to Macroeconomics*, Vol. 4 (1), Article 4.

van Ark, B., Melka, J., Mulder, N., Timmer, M. and Ypma, G. (2002): *ICT investment and growth accounts for the European Union, 1980–2000*, GGDC Research Memorandum, No. 56.

Artto, E.W. (1997): "Performance and international competitiveness of listed paper industry Groups 1982–1996 – Finland vs Sweden, Canada and USA", Helsinki School of Economics, Working Papers W-182.

Asplund, R. and Maliranta, M. (2006): "Productivity Growth: The Role of Human Capital and Technology", in J. Ojala, J. Eloranta and J. Jalava (eds.): *The Road to Prosperity: An Economic History of Finland*, SKS, Jyväskylä: Gummerus Oy.

Aulin-Ahmavaara, P. (2003): "The SNA93 values as a consistent framework for productivity measurement: Unsolved issues", *Review of Income and Wealth*, Vol. 49, pp. 117–133.

Aulin-Ahmavaara, P. (2004): "Moving Human Capital inside the Production Boundary", *Review of Income and Wealth*, Vol. 50, pp. 213–228.

Aulin-Ahmavaara, P. (2006): "On accounting for growth within the national accounts framework" (in Finnish), *Finnish Economic Journal*, Vol. 102, pp. 157–178.

Aulin-Ahmavaara, P. (2007): "From national income to national accounts" (in Finnish), in J. Jalava, J. Eloranta and J. Ojala (eds.), *Muutoksen merkit. Kvantitatiivisia perspektiivejä Suomen taloushistoriaan*, Statistics Finland Research Reports 245, Helsinki: Yliopistopaino.

Aulin-Ahmavaara, P. and Jalava, J. (2003): "Capital and its Productivity in Finland, 1975–2001", *Scandinavian Economic History Review*, Vol. 50 (3), pp. 62–79.

Baily, M.N., Bartelsman, E.J., Haltiwanger, J. (1996): "Labour productivity: Structural change and cyclical dynamics", National Bureau of Economic Research (NBER), WP 5503.

Baily, M.N. and Lawrence, R. Z. (2001): "Do we have a new e-conomy?", *NBER Working Paper No. 8243*.

Bairam, E. (1990): "Verdoorn's Original Model and the Verdoorn Law Controversy: Some New Empirical Evidence Using the Australian Manufacturing Data", *Australian Economic Papers*, Vol. 29, pp. 107–112.

Barro, R.J. (1999): "Notes on Growth Accounting", *Journal of Economic Growth*, Vol. 4, pp. 119–137.

Baumol, W.J. (1967): "Macroeconomics of unbalanced growth: The anatomy of urban crises", *American Economic Review*, Vol. 57, pp. 415–26.

Baumol, W.J., Blackman, S.A.B. and Wolff, E.N. (1989): *Productivity and American Leadership: The Long View*, Cambridge, Massachusetts and London, England: The MIT Press.

Berndt, E.R. and Fuss, M.A. (1986): "Productivity measurement with adjustments for variations in capacity utilization and other forms of temporary equilibrium", *Journal of Econometrics*, Vol. 33, pp. 7–29.

Bohlin, J. (2003): "Swedish historical national accounts: The fifth generation", *European Review of Economic History*, Vol. 7, pp. 73–97.

Booth, A., Melling, J. and Dartmann, C. (1997): "Institutions and economic growth: The politics of productivity in West Germany, Sweden, and the United Kingdom, 1945–1955", *Journal of Economic History*, Vol. 57, pp. 416–444.

Bresnahan, T.F. and Trajtenberg, M. (1995): "General purpose technologies 'engines of growth?'", *Journal of Econometrics*, Vol. 65, pp. 83–108.

Broadberry, S.N. (1993): "Manufacturing and the Convergence Hypothesis: What the Long-Run Data Show", *Journal of Economic History*, Vol. 53, pp. 772–795.

Broadberry, S.N. (1998): "How did the United States and Germany Overtake Britain? A Sectoral Analysis of Comparative Productivity Levels, 1870–1990", *Journal of Economic History*, Vol. 58, pp. 375–407.

Broadberry, S.N., Federico, G. and Klein, A. (2005): "An Economic History of Modern Europe: Sectoral Developments, 1870–1914", forthcoming 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: Oxford University Press.

Clark, C. (1940): *The Conditions of Economic Progress*, London: Macmillan.

Clark, C. (1957): *The Conditions of Economic Progress*, 3rd edition, London: Macmillan.

Clark, G. (2005): *The Conquest of Nature: A Brief Economic History of the World*, unpublished manuscript.

Colecchia, A. and Schreyer, P. (2001): "ICT investment and economic growth in the 1990s: Is the United states a unique case? A comparative study of nine OECD countries", OECD STI Working Paper 2001/7.

Copeland, M.A. (1937): "Concepts of National Income", in *Studies in income and wealth, Vol. 1*, New York: National Bureau of Economic Research.

Crafts, N. (1992): "Productivity growth reconsidered", *Economic Policy*, Vol. 15, pp. 388–426.

Crafts, N. (1995): "Exogenous or endogenous growth? The industrial revolution reconsidered", *Journal of Economic History*, Vol. 55, pp. 745–772.

Crafts, N. (2002): "The Solow productivity paradox in historical perspective", *Centre for Economic Policy Research, Discussion Paper No. 3142*, January.

Crafts, N. (2004a): "Productivity Growth in the Industrial Revolution: A New Growth Accounting Perspective", *Journal of Economic History*, Vol. 64, pp. 521–535.

Crafts, N. (2004b): "Steam as a general purpose technology: A growth accounting perspective", *Economic Journal*, Vol. 114, pp. 338–351.

Daveri, F. (2001): "Information technology and growth in Europe", unpublished manuscript.

Daveri, F. (2002): "The new economy in Europe, 1992–2001", *Oxford Review of Economic Policy*, Vol. 18, pp. 345–62.

David, P.A. (1990): "The dynamo and the computer: An historical perspective on the modern productivity paradox", *American Economic Review*, Vol. 80, pp. 355–361.

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

David, P.A. (2002): "Does the new economy need all the old IPR institutions? Digital information goods and access to knowledge for economic development", paper presented at WIDER Conference on The New Economy in Development, May 2002, Helsinki.

David, P.A. and Wright, G. (1999): "Early twentieth century productivity growth dynamics: An inquiry into the economic history of "our ignorance"", University of Oxford Discussion Papers in Economic and Social History, No. 33.

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: Oxford University Press, 135–166.

DeLong, J.B. (1988): "Productivity Growth, Convergence, and Welfare: Comment", *American Economic Review*, Vol. 78, pp. 1138–1154.

DeLong, J.B. (1992): "Productivity Growth and Machinery Investment: A Long-Run Look, 1870–1980", *Journal of Economic History*, Vol. 52, pp. 307–324.

Denison, E.F. (1962a): *The Sources of Economic Growth in the United States and the Alternatives Before Us*, New York: Committee on Economic Development.

Denison, E.F. (1962b): "United States economic growth", *Journal of Business*, Vol. 35, pp. 109–121.

Denison, E.F. (1983): "The interruption of productivity growth in the United States", *Economic Journal*, Vol. 93, pp. 56–77.

Devine Jr, W.D. (1983): "From shafts to wires: Historical perspective on electrification", *Journal of Economic History*, Vol. 43, pp. 347–72.

Dickman, K. (1993): "Uudet tuotteet – tuttu ympäristö", in M. Tienari (ed.), *Tietotekniikan alkuvuodet Suomessa*, Jyväskylä: Gummerus Kirjapaino Oy.

Diewert, W.E. (1976): "Exact and Superlative Index Numbers", *Journal of Econometrics*, Vol. 4, pp. 115–135.

Diewert, W.E. (1978): "Superlative Index Numbers and Consistency in Aggregation", *Econometrica*, Vol. 46, pp. 883–900.

Diewert, W.E. (1980): "Capital and the Theory of Productivity Measurement", *American Economic Review*, Vol. 70, pp. 260–267.

Diewert, W.E. (2001): "Measuring the price and quantity as capital services under alternative assumptions", *Discussion Paper No. 01–24, Department of Economics, The University of British Columbia.*

DuBoff, R.B. (1964): *Electric power in American manufacturing, 1889–1958*, (Ph.D. dissertation, University of Pennsylvania; printed in 1979 by Arno Press Inc.).

DuBoff, R.B. (1966): "Electrification and capital productivity: A suggested approach", *Review of Economics and Statistics*, Vol. 48, pp. 426–31.

Easterlin, R.A. (1996): *Growth Triumphant. The Twenty-first Century in Historical Perspective*, Ann Arbor: University of Michigan Press.

Easterly, W. (2001): *The Elusive Quest for Growth. Economists' Adventures and Misadventures in the Tropics*, Cambridge MA: The MIT Press.

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

Eloranta, J., García-Iglesias, C., Ojala, J. and Jalava, J. (2006): "On the Road to Prosperity: An Introduction", in J. Ojala, J. Eloranta and J. Jalava (eds.): *The Road to Prosperity: An Economic History of Finland*, SKS, Gummerus Oy, Jyväskylä.

Fabricant, S. (1954): *Economic progress and economic change,* New York: NBER, 34th annual report.

Fabricant, S. (1974): "Perspective on Productivity Research", Review *of Income and Wealth,* Vol. 20, pp. 235–249.

Fisher, A.G.B. (1939): "Production, Primary, Secondary and Tertiary", *Economic Record,* Vol. 15, pp. 24–38.

Fraumeni, B.M. (1997): "The measurement of depreciation in the US national income and product accounts", *Survey of Current Business,* Vol. 77, July, pp. 7–23.

Gerschenkron, A. (1952): "Economic Backwardness in Historical Perspective", in B.F. Hoselitz (ed.), *The Progress of Underdeveloped Areas,* Chicago: University of Chicago Press.

Gerschenkron, A. (1962): *Economic Backwardness in Historical Perspective. A Book of Essays,* Boston: Harvard University Printing Office.

Gerschenkron, A. (1963): "The Early Phases of Industrialization in Russia and Their Relationship to the Historical Study of Economic Growth", in B.E. Supple (ed.), *The Experience of Economic Growth: Case Studies in Economic History,* New York and Toronto: Random House, Inc.

Goldsmith, R.W. (1951): *A Perpetual Inventory of National Wealth,* Studies in Income and Wealth, XIV, New York: NBER.

Gordon, R.J. (2000): "Does the "new economy" measure up to the great inventions of the past", *Journal of Economic Perspectives,* Vol. 14, pp. 49–74.

Gould, J.D. (1972): *Economic Growth in History,* London: Methuen & Co. Ltd.

Greasley, D. and Oxley, L. (1997): "Endogenous growth or "big bang": Two views of the first industrial revolution", *Journal of Economic History,* Vol. 57, pp. 935–949.

Griliches, Z. (1992): "Introduction", in Z. Griliches (ed.), *Output Measurement in the Service Sectors,* NBER Studies in Income and Wealth, Volume 56, Chicago/London: University of Chicago Press.

Griliches, Z. (1996): "The Discovery of the Residual: A Historical Note", *Journal of Economic Literature,* Vol. 34, pp. 1324–1330.

Grönlund, P. and Niitamo, O.E. (1968): *Suomen kansantalouden tilinpito vuosina 1948–1964: käsitteet ja menetelmät,* Tilastollinen päätoimisto, Monistettuja tutkimuksia N:o 5, maaliskuu.

Hager, A. (ed.) (1997): *Major Tudor Authors: A Bio-bibliographical Critical Sourcebook.* Westport, CT: Greenwood Publishing Group.

Hall, R.E. and Jorgenson, D.W. (1967): "Tax policy and investment behavior", *American Economic Review,* Vol. 57, pp. 391–414.

Haltia, O. and Leppämäki, M. (2000): "Do shareholders care about corporate investment returns?", *Finnish Economic Papers,* Vol. 13, pp. 19–27.

Hansen, G.D. and Prescott, E.C. (2002): "Malthus to Solow", *American Economic Review,* Vol. 92, pp. 1205–1217.

Harberger, A.C. (1998): "A vision of the growth process", *American Economic Review,* Vol. 88, pp. 1–32.

Hartwell, R.M. (1973): "The Service Revolution: The Growth of Services in Modern Economy", in C.M. Cipolla (ed.), *The Fontana Economic History of Europe: The Industrial Revolution,* Glasgow: Fontana/Collins.

Heikkinen, S. and Hjerppe, R. (1986): *Suomen teollisuus ja teollinen käsityö 1860–1913,* (Industry and industrial handicraft in Finland, 1860–1913), Studies on Finland's economic growth XII, Helsinki: Bank of Finland publications.

Helpman, E. (2004): *The mystery of economic growth*, Cambridge, Massachusetts, and London: The Belknap Press of Harvard University Press.

Herranen, T. (1996): *Valtakunnan sähköistyskysymys: Strategiat, siirtojärjestelmät sekä alueellinen sähköistys vuoteen 1940*, Bibliotheca Historica 14, Helsinki: Suomen Historiallinen Seura.

Hicks, J. (1965): *Capital and Growth*, Oxford: Clarendon Press.

Hicks, J. (1973): *Capital and Time*, Oxford: Clarendon Press.

Hill, T.P. (1999): "The productive capital stock and the quantity index for flows of capital services", paper presented at the meeting of the Canberra-group in Washington, D. C., November 1999.

Hill, R.J. and Hill, T.P. (1999): "A new conceptual approach to the measurement of capital gains, depletion and net national product", School of Economics, University of South Wales, Discussion Paper 99/9.

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, Helsinki: Bank of Finland publications.

Hjerppe, R. (1990): *Kasvun vuosisata*, Helsinki: VAPK-kustannus.

Hjerppe, R. (1996): *Finland's Historical National Accounts 1860–1994:* Calculation Methods and Statistical Tables, Jyväskylän yliopisto historian laitos, Suomen historian julkaisuja 24, Jyväskylä: Kopi-Jyvä Oy.

Hjerppe, R. (1999): "Understanding Economic Development through Historical National Accounts", in J. Alho (ed.), *Statistics, Registries, and Science – Experiences from Finland*, Statistics Finland, Keuruu: Otava Book Printing Co. Ltd.

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, Helsinki: Bank of Finland publications.

Hjerppe, R. and Jalava, J. (2006): "Economic Growth and Structural Change. A Century and a Half of Catching-up", in J. Ojala, J. Eloranta and J. Jalava (eds.): *The Road to Prosperity: An Economic History of Finland*, SKS, Jyväskylä: Gummerus Oy.

Hjerppe, R. and Kohi, P. (1975): "Pääomakantalaskelmien ongelmista" in *Kokonaistaloudellisia ongelmia II*, Tilastokeskus tutkimuksia nro. 34.

Hodrick, R.J. and Prescott, E.C. (1997): "Postwar US business cycles: An empirical investigation", *Journal of Money, Credit and Banking*, Vol. 29, pp. 1–16.

Hoffman, K. (1980): *Suomen sahateollisuuden kasvu, rakenne ja rahoitus 1800-luvun jälkipuoliskolla*, Bidrag till kännedom av Finlands natur och folk, H. 124, Helsinki: The Finnish Society of Sciences and Letters.

Hulten, C.R. (2000): "Total Factor Productivity: A Short Biography", University of Maryland and NBER, August.

Hulten, C.R. (2006): "The "Architecture" of Capital Accounting: Basic Design Principles", in D.W. Jorgenson, J.S. Landefeld, and W.D. Nordhaus (eds.), *A New Architecture for the U.S. National Accounts*, NBER Studies in Income and Wealth, Vol. 66, Chicago and London: University of Chicago Press.

Hulten, C.R. and Wykoff, F.C. (1981): "The measurement of economic depreciation" in Hulten, C.R. (ed.), *Depreciation, Inflation and Taxation of Income from Capital*, Washington, D. C.: The Urban Institute Press.

Hulten, C.R. and Wyckoff, F.C. (1996): "Issues in the measurement of economic depreciation: Introductory remarks", *Economic Inquiry*, Vol. 34, pp. 10–23.

Hyytinen, A., Rouvinen, P., Toivanen, O. and Ylä-Anttila, P. (2003): "Does financial development matter for innovation and economic growth? Implications for public policy", in A. Hyytinen and M. Pajarinen (eds.), *Financial Systems and Firm Performance: Theoretical and Empirical Perspectives*, ETLA B: 200, Helsinki: Yliopistopaino.

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

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

Jaakkola, H. (1992): "The diffusion of information technology in Finnish industry: State of the art and analysis", in S. Vuori and P. Ylä-Anttila (eds.), *Mastering Technology Diffusion – The Finnish Experience*, ETLA B: 82, Helsinki: Taloustieto Oy.

Jalava, J. (2002): "Accounting for growth and productivity: Finnish multi-factor productivity 1975–99", *Finnish Economic Papers*, Vol. 15, pp. 76–86.

Jalava, J. (2003): "Den nya ekonomin i Finland: produktion och användning av IKT", *Ekonomiska Samfundets Tidskrift*, Vol. 56, pp. 17–24.

Jalava, J. (2004a): "Electrifying and digitalising the Finnish manufacturing industry: Historical notes on diffusion and productivity", in S. Heikkinen and J.L. van Zanden (eds.), *Explorations in Economic Growth*, Aksant Academic Publishers, Amsterdam.

Jalava, J. (2006a): "Catching up with the Technology Frontier: Finnish Manufacturing Productivity, 1975–2003", *Scandinavian Economic History Review*, Vol. 54, pp. 47–63.

Jalava, J. (2006b): "Production, Primary, Secondary, and Tertiary: Finnish Growth and Structural Change, 1860–2004", Pellervo Economic Research Institute, Working Papers No. 80.

Jalava, J., Eloranta, J. and Ojala, J. (2007a): "Muutoksen merkkejä etsimässä: Suomen taloushistoria ja kliometria", in J. Jalava, J. Eloranta and J. Ojala (eds.), *Muutoksen merkit. Kvantitatiivisia perspektiivejä Suomen taloushistoriaan*, Statistics Finland Research Reports 245, Helsinki: Yliopistopaino.

Jalava, J., Eloranta, J. and Ojala, J. (eds.) (2007b): *Muutoksen merkit. Kvantitatiivisia perspektiivejä Suomen taloushistoriaan*, Statistics Finland Research Reports 245, Helsinki: Yliopistopaino.

Jalava, J., Heikkinen, S. and Hjerppe, R. (2002): "Technology and structural change: Productivity in the Finnish manufacturing industries, 1925–2000", Transformation, Integration and Globalization Economic Research (TIGER), WP No. 34.

Jalava, J. and Kavonius, I.K. (2007): "Durable Goods and Their Effect on Household Saving Ratios in the Euro Area", European Central Bank, Working Paper Series No. 755, May.

Jalava, J. and Pohjola, M. (2001): "Economic growth in the new economy: Evidence from advanced economies", World Institute for Development Economics Research, Discussion Paper 2001/5.

Jalava, J. and Pohjola, M. (2002): "Economic growth in the new economy: Evidence from advanced economies", *Information Economics and Policy*, Vol. 14, pp. 189–210.

Jalava, J. and Pohjola, M. (2003): "Quantifying ICT – Challenges for statistics and research" (in Finnish), *Finnish Economic Journal*, Vol. 99, pp. 255–265.

Jalava, J. and Pohjola, M. (2004): "Finnish labour productivity in 1900–2003 and growth projections for the years 2004–2030" (in Finnish), *Finnish Economic Journal*, Vol. 100, pp. 355–370.

Jalava, J. and Pohjola, M. (2007a): "ICT as a source of output and productivity growth in Finland", *Telecommunications Policy*, Vol. 31, pp. 463–472.

Jalava, J. and Pohjola, M. (2007b): "The Roles of Electricity and ICT in Growth and Productivity: Case Finland", Pellervo Economic Research Institute, Working Papers No. 94, April.

Jalava, J., Pohjola, M., Ripatti, A. and Vilmunen, J. (2006): "Biased Technical Change and Capital-Labour Substitution in Finland, 1902–2003", *Topics in Macroeconomics*, Vol. 6 (1), Article 8.

Jones, C.I. (2001): "Was an industrial revolution inevitable? Economic growth over the very long run", *Advances in Macroeconomics*, Vol. 1, pp. 1–43.

Jorgenson, D.W. (1996): "Empirical studies of depreciation", *Economic Inquiry*, Vol. 34, pp. 24–42.

Jorgenson, D.W. (2005): "Accounting for growth in the information age" in Aghion, P. and Durlauf, S. (eds.), *Handbook of Economic Growth*, Vol. 1A, Amsterdam: North-Holland.

Jorgenson, D.W. and Fraumeni, B. (1989): "The Accumulation of Human and Nonhuman Capital, 1948–1984", in R.E. Lipsey and H.S. Tice (eds.), *The Measurement of Saving, Investment and Wealth*, Studies in Income and Wealth, Vol. 52, Chicago: University of Chicago Press.

Jorgenson, D.W., Gollop, F. and Fraumeni, B. (1987): *Productivity and US economic growth*, Cambridge, MA: Harvard University Press.

Jorgenson, D.W. and Griliches, Z. (1967): "The explanation of productivity change", *Review of Economic Studies*, Vol. 34, pp. 249–283.

Jorgenson, D.W., Ho, M.S. and Stiroh, K.J. (2003): "Lessons from the US growth resurgence", *Journal of Policy Modeling*, Vol. 25, pp. 453–470.

Jorgenson, D.W., Ho, M.S. and Stiroh, K.J. (2005): *Productivity Volume 3: Information Technology and the American Growth Resurgence*, Cambridge, Massachusetts and London, England: The MIT Press.

Jorgenson, D.W., Ho, M.S. and Stiroh, K.J. (2006): "Potential growth of the U.S. economy: Will the productivity resurgence continue?", *Business Economics*, Vol. 41, pp. 67–76.

Jorgenson, D.W. and Landefeld, J.S. (2006): "Blueprint for Expanded and Integrated U.S. Accounts. Review, Assessment, and Next Steps", in D.W. Jorgenson, J.S. Landefeld, and W.D. Nordhaus (eds.), *A New Architecture for the U.S. National Accounts*, NBER Studies in Income and Wealth, Vol. 66, Chicago and London: University of Chicago Press.

Jorgenson, D.W. and Stiroh, K.J. (2000): "Raising the speed limit: US economic growth in the information age", *Brookings Papers on Economic Activity*, Vol. 1, pp. 125–211.

Jorgenson, D.W. and Stiroh, K.J. (2001): "Raising the speed limit: US economic growth in the information age", in D.W. Jorgenson and F.C. Lee (eds.), *Industry-level Productivity and International Competitiveness between Canada and the United States*, Industry Canada Research Monograph.

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

Jutikkala, E., Kaukiainen, Y. and Åström, S.E. (1980) (eds.): *Suomen taloushistoria 1: agraarinen Suomi*, Helsinki: Tammi.

Kaldor, N. (1957): "A Model of Economic Growth", *Economic Journal*, Vol. 67, pp. 591–624.

Kaldor, N. (1967): *Strategic Factors in Economic Development*, Ithaca, New York: New York State School of Industrial and Labor Relations, Cornell University.

Kaldor, N. (1978): *Further Essays on Economic Theory*, London: Gerald Duckworth & Co. Ltd.

Katz, A.J. and Herman, S.W. (1997): "Improved estimates of fixed reproducible tangible wealth, 1929–95", *Survey of Current Business*, May 1997, pp. 69–92.

Kendrick, J.W. (1955): "Productivity", in S. Fabricant (ed.), *Government in economic life*, New York: NBER, 35th annual report.

Kendrick, J.W. (1961): *Productivity Trends in the United States*, National Bureau of Economic Research, Number 71, General Series, Princeton: Princeton University Press.

Kendrick, J.W. (1976): *The Formation and Stocks of Total Capital*, New York: Columbia University Press for NBER.

Kendrick, J.W. (1993): "How much does capital explain?" in A. Szirmai, B. van Ark and D. Pilat (eds.), *Explaining Economic Growth, Essays in Honour of Angus Maddison*, Contributions to Economic Analysis, North Holland.

Keuning, S. (1999): "The role of financial capital in production", *Review of Income and Wealth*, Vol. 45, pp. 419–34.

Kokkinen, A., Jalava, J., Hjerppe, R. and Hannikainen, M. (2007): "Catching up in Europe: Finland's Convergence with Sweden and the EU15", *Scandinavian Economic History Review*, Vol. 55, pp. 153–171.

Koljonen, K. (1968): *Pääomakannan käsite ja mittaaminen sekä sovellutus Suomen rakennuskantaan vuosina 1950–60*, Monistettuja tutkimuksia n:o 8, Tilastollinen Päätoimisto.

Komlos, J. (1989): "Thinking About the Industrial Revolution", *Journal of European Economic History*, Vol. 18, pp. 191–206.

Komlos, J. (2003): "The Industrial Revolution as the Escape from the Malthusian Trap", Discussion Papers in Economics 57, Department of Economics, University of Munich.

Koski, H., Rouvinen, P. and Ylä-Anttila, P. (2002): "ICT clusters in Europe: The great central banana and small Nordic potato", *Information Economics and Policy*, Vol. 14, pp. 145–66.

Koskimäki, T. and Vartia, Y. (2001): "Beyond matched pairs and Griliches-type Hedonic Methods for Controlling Quality Changes in CPI Sub-indices: Mathematical Considerations and Empirical Examples on the Use of Linear and Non-linear Hedonic Models with Time-dependent Quality Parameters", paper presented at the 6th meeting of the Ottawa-group, 2–6/4 2001, in Canberra, Australia.

Krantz, O. (2001): "Industrialisation in Three Nordic Countries: A Long-Term Quantitative View", in H. Kryger Larsen, (ed.), *Convergence? Industrialisation of Denmark, Finland and Sweden, 1870–1940*, Helsinki: The Finnish Society of Sciences and Letters.

Kuhn, T.S. (1996): *The Structure of Scientific Revolutions*, 3rd edition, Chicago and London: University of Chicago Press.

Kuznets, S. (1966): *Modern Economic Growth: Rate, Structure, and Spread*, New Haven: Yale University Press.

Landefeld, J.S. (2000): "GDP: One of the great inventions of the 20th century", *Survey of Current Business*, Vol. 80, January, pp. 6–14.

Laurila, E.H. (1968): "Kapitalbildningen och kapitalets produktivitet i Finland åren 1948–1967", *Ekonomiska Samfundets Tidskrift*, 1968:3, pp. 160–167.

Lindmark, M. (2004): "Öringsvatten eller terawatt? Naturskydd i ett grönt strukturanalytiskt perspektiv", in L. Andersson-Skog and M. Lindmark (eds.), *Strukturernas dynamik. Kontinuitet och förändring i ekonomisk historia. Festskrift till Olle Krantz*, Occasional papers in Economic History, No. 8, Umeå: Umeå universitet.

Lindmark, M. and Vikström, P. (2003): "Growth and Structural Change in Sweden and Finland: A Story of Convergence", *Scandinavian Economic History Review*, Vol. 51 (1), pp. 46–74.

Lipsey, R.G. (2002): "The Productivity Paradox: A Case of the Emperor's New Clothes", ISUMA: *Canadian Journal of Policy Research*, Vol. 3 (1), pp 120–126.

Lipsey, R.G., Bekar, C. and Carlaw, K. (1998): "What requires explanation?", in E. Helpman (ed.), *General Purpose Technologies and Economic Growth*, Cambridge, MA: The MIT Press.

Lipsey, R.G., Carlaw, K.I. and Bekar, C.T. (2005): *Economic Transformations. General Purpose Technologies and Long Term Economic Growth*, Oxford, New York: Oxford University Press.

Lucas, R.E., Jr. (1988): "On the mechanics of economic development", *Journal of Monetary Economics*, Vol. 22, pp. 3–42.

Maddison, A. (1987): "Growth and slowdown in advanced capitalist economies", *Journal of Economic Literature*, Vol. 25, pp. 649–698.

Maddison, A. (1996): "Macroeconomic accounts for European countries", in B. van Ark and N. Crafts (eds.), *Quantitative Aspects of Post-war European Economic Growth*, CEPR, Cambridge University Press.

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

Maliranta, M. (2003): "Micro level dynamics of productivity growth, an empirical analysis of the great leap in the Finnish manufacturing productivity in 1975–2000", ETLA A:38, Helsinki: Taloustieto Oy.

Maliranta, M. and Rouvinen, P. (2003): "Productivity effects of ICT in Finnish business", The Research Institute of the Finnish Economy (ETLA), DP No. 852.

Mamgain, V. (1999): "Are the Kaldor-Verdoorn Laws Applicable in the Newly Industrializing Countries?", *Review of Development Economics*, Vol. 3, pp. 295–309

Marquetti, A. A. (2003): "Analyzing historical and regional patterns of technical change from a classical-Marxian perspective", *Journal of Economic Behavior & Organization*, Vol. 52, pp. 191–200.

Mokyr, J. (1990a): "Punctuated equilibria and technological progress", *American Economic Review*, Vol. 80, pp. 350–4.

Mokyr, J. (1990b): *The Lever of Riches: Technological Creativity and Economic Progress*, New York, Oxford: Oxford University Press.

Mokyr, J. (1997): "Invention and rebellion: Why do innovations occur at all? An evolutionary approach", unpublished manuscript.

Mokyr, J. (2005): "Long-term Economic Growth and the History of Technology", in P. Aghion and S.N. Durlauf (eds.), *Handbook of Economic Growth*, Volume 1B, Amsterdam: North-Holland.

Mokyr, J. (2006): "Economic Transformations", *Journal of Economic History*, Vol. 66, pp. 1072–1075.

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

Myllyntaus, T. (1992): "Technology transfer and the contextual filter in the Finnish setting: Transfer channels and mechanisms in a historical perspective", in S. Vuori and P. Ylä-Anttila (eds.), *Mastering Technology Diffusion – The Finnish Experience*, ETLA B: 82, Helsinki: Taloustieto Oy.

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, Helsinki: The Finnish Society of Sciences and Letters.

Nelson, R.R. and Wright, G. (1992): "The rise and fall of American technological leadership: The postwar era in historical perspective", *Journal of Economic Literature*, Vol. 30, pp. 1931–64.

Newey, W.K. and West, K.D. (1987): "A Simple, Positive Semi-definite, Heteroscedasticity and Autocorrelation Consistent Covariance Matrix", *Econometrica*, Vol. 55, pp. 703–708.

Niininen, P. (2001): "Computers and economic growth in Finland", in M. Pohjola (ed.), *Information Technology, Productivity, and Economic Growth: International Evidence and Implications for Economic Development*, Oxford: Oxford University Press.

Niitamo, O. (1958): *Tuottavuuden kehitys Suomen teollisuudessa vuosina 1925–1952* (The development of productivity in Finnish industry 1925–1952), Kansantaloudellisia tutkimuksia, XX.

Niitamo, O. (1969): *Tuotantofunktio, sen jäännöstermi ja teknillinen kehitys*, Monistettuja tutkimuksia n:o 9, Tilastollinen Päätoimisto.

Nordhaus, W.D. (1972): "The recent productivity slowdown", Brookings Papers on Economic Activity, Vol. 1972, pp. 493–545.

Nordhaus, W. (2001): "Productivity growth and the new economy", NBER Working Paper, No. 8096.

North, D.C. and Thomas, R.P. (1973): *The Rise of the Western World: A New Economic History*, Cambridge: Cambridge University Press.

O'Brien, P.K. (1994): "Introduction", in P.K. O'Brien (ed.), *The Industrial Revolution in Europe I*, The Economic History Society, Oxford, UK and Cambridge, USA: Blackwell Publishers.

Ojala, J., Eloranta, J. and Jalava, J. (2006): *The road to prosperity. An economic history of Finland*, Suomalaisen Kirjallisuuden Seura, Jyväskylä: Gummerus Oy.

Ojala, J. and Karonen, P. (2007): "Yritysten ja yhteiskunnan yhteisevoluutio", in J. Jalava, J. Eloranta and J. Ojala (eds.), *Muutoksen merkit. Kvantitatiivisia perspektiivejä Suomen taloushistoriaan*, Statistics Finland Research Reports 245, Helsinki: Yliopistopaino.

Oliner, S.D., and Sichel, D.E. (1994): "Computers and output growth revisited: How big is the puzzle?", *Brooking Papers on Economic Activity*, Vol. 2, pp. 273–334.

Oliner, S. E. and Sichel, D. E. (2000): "The resurgence of growth in the late 1990s: Is information technology the story?", *Journal of Economic Perspectives*, Vol. 14, pp. 3–22.

O'Mahony, M. (1996): "Measures of fixed capital stocks in the post-war period: A five country study", in B. van Ark and N. Crafts (eds.), *Quantitative Aspects of Post-war European Economic Growth*.

O'Mahony, M. and van Ark, B. (eds.) (2003): *EU Productivity and Competitiveness: An Industry Perspective. Can Europe Resume the Catching-up Process?*, Luxembourg: Office for Official Publications of the European Communities.

Oulton, N. (2001): "Must the Unbalanced Growth Rate Decline? Baumol's Unbalanced Growth Rate Revisited", *Oxford Economic Papers*, Vol. 53, pp. 605–627.

Paju, P. (2003): "A failure revisited: The first computer construction and the establishing of a national computer center in Finland", University of Turku, unpublished manuscript.

Petty, W. (1676): *Political Arithmetick*.

Pilat, D. and Lee, F.C. (2001): "Productivity growth in ICT-producing and ICT-using industries: A source of growth differentials in the OECD?", OECD *STI Working paper 2001/4.*

Pohjola, M. (1996): *Tehoton pääoma. Uusi näkökulma taloutemme ongelmiin* (Inefficient capital. A new view to our economic problems) (in Finnish), Porvoo: WSOY.

Pohjola, M. (2002): "The new economy in growth and development", *Oxford Review of Economic Policy,* Vol. 18, pp. 380–96.

Pohjola, M. (2003): "Olemmeko maailman parhaimmistoa? Kansallisen kilpailukykymme puntarointia", in K. Alho, J. Lassila and P. Ylä-Anttila (eds.): *Talouden tutkimus ja päätöksenteko – kirjoituksia rakennemuutoksesta, kasvusta ja talouspolitiikasta. Juhlakirja Pentti Vartian 60-vuotispäivän kunniaksi,* ETLA A 36, Helsinki.

Pohjola, M. (2006): "ICT, productivity and economic growth: What will be the next wave?", in P. Heikkinen and K. Korhonen (eds.): *Technology-driven efficiencies in financial markets,* Expository studies A:110, Helsinki: Bank of Finland.

Pohjola, M. (2007): "Is our national accounts up to speed?" (in Finnish), *Finnish Economic Journal,* Vol. 103, pp. 3–7.

Prados de la Escosura, L. (2005) : "Gerschenkron Revisited. European Patterns of Development in Historical Perspective", Universidad Carlos III, *Working Paper 05–79,* December.

Pritchett, L. (1997): "Divergence, Big Time", *Journal of Economic Perspectives,* Vol. 11, pp. 3–17.

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

Pusateri, C.J. (1988): *A History of American Business,* Arlington Heights, IL: Harlan Davidson

Quah, D. (2001): "The weightless economy in economic development", in M. Pohjola (ed.), *Information Technology, Productivity, and Economic Growth,* Oxford: Oxford University Press.

Rebelo, S. (1991): "Long-Run Policy Analysis and Long-Run Growth", *Journal of Political Economy,* Vol. 99, pp. 500–521.

Reid, T.R. (2001): *Chip: How Two Americans Invented the Microchip and Launched a Revolution,* Westminster, MD: Random House Adult Trade Group.

Romer, P.M. (1986): "Increasing Returns and Long-Run Growth," *Journal of Political Economy,* Vol. 94 (5), pp. 1002–37.

Romer, P.M. (1990): "Endogenous Technological Change", *Journal of Political Economy,* Vol. 98, pp. S71–102.

Romer, P.M. (1994): "The Origins of Endogenous Growth", *Journal of Economic Perspectives,* Vol. 8 (1), pp. 3–22.

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.

Rostow, W.W. (1960): *The Stages of Economic Growth. A Non-communist Manifesto,* Cambridge: Cambridge University Press.

Rostow, W.W. (1971): *The Stages of Economic Growth. A Non-communist Manifesto, 2nd edition,* Cambridge: Cambridge University Press.

Rozakis, L. (2001): *The Big Book of Dates,* New York: McGraw-Hill.

Sauramo, P. (2003): "Funktionaalinen tulonjako Suomessa: ollaanko tasapainossa?", Discussion Papers 192, Labour Institute for Economic Research, December 2003.

Schmookler, J. (1952): "The Changing Efficiency of the American Economy, 1869–1938", *Review of Economics and Statistics*, Vol. 34, pp. 214–231.

Schreyer, P. (2000): "The contribution of information and communication technology to output growth: A study of the G7 countries", OECD STI Working Paper 2000/2.

Schreyer, P., Bignon, P.-E. and Dupont, J. (2003): "OECD capital services estimates: Methodology and a first set of results", OECD Statistics Working Paper 2003/6.

Schumpeter, J. (1928): "The instability of capitalism", *Economic Journal*, Vol. 38, pp. 361–86.

Seppänen, J. (1993): "30 vuotta tietokoneaikaa Teknillisessä korkeakoulussa", in M. Tienari (ed.), *Tietotekniikan alkuvuodet Suomessa*, Jyväskylä: Gummerus Kirjapaino Oy.

Sichel, D.E. (2000): "Comments and discussion", *Brookings Papers on Economic Activity* 2000, Vol. 1, pp. 222–7.

Smits, J.-P. (2003): "Historical national accounts: Where do we go from here?", in G. Jonsson (ed.), *Nordic Historical National Accounts. Proceedings of Workshop VI. Reykjavik 19–20 September 2003*, Reykjavik: Institute of History, University of Iceland.

Smits, J.-P., Horlings, E. and van Zanden, J.L. (2000): *Dutch GNP and Its Components, 1800–1913*, Groningen Growth and Development Centre Monograph Series No. 5.

Solow, R.M. (1956): "A contribution to the theory of economic growth", *Quarterly Journal of Economics*, Vol. 70, pp. 65–94.

Solow, R.M. (1957): "Technical change and the aggregate production function", *Review of Economics and Statistics*, Vol. 39, pp. 312–320.

Solow, R.M. (1987): "We'd Better Watch Out", *New York Review of Books*, July 12.

Solow, R.M. (2000): *Growth Theory. An Exposition, 2nd edition*, New York and Oxford: Oxford University Press.

Stigler, G.J. (1947): *Trends in output and employment*, New York: NBER.

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

Stoneman, P. (1979): "Kaldor's law and British economic growth: 1800–1970", *Applied Economics*, Vol. 11, pp. 309–319.

Stoneman, P.L. and David, P.A. (1986): "Adoption subsidies vs. information provision as instruments of technology policy", *Economic Journal*, Vol. 96, pp. 142–50.

Suokko, S. and Valppu, P. (1977): *Pääomakanta vuosina 1960–1975*, Taloudellinen suunnittelukeskus.

Supple, B.E. (1963): "Introduction: Economic History, Economic Theory, and Economic Growth", in B.E. Supple (ed.), *The Experience of Economic Growth: Case Studies in Economic History*, New York and Toronto: Random House, Inc.

Syrquin, M. (1984): "Resource Reallocation and Productivity Growth", in M. Syrquin, L. Taylor and L.E. Westphal (eds.), *Economic Structure and Performance – Essays in Honour of Hollis B. Chenery*, Orlando: Academic Press Inc.

Tervo, H. (2004): "Self-employment dynamics in rural and urban labour markets", paper presented at the 44th European Congress of the European Regional Science Association, Porto, Portugal, 25–29 August 2004.

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.

Timmer, M., Ypma, G. and van Ark, B. (2003): "IT in the European Union: Driving productivity divergence?", Groningen Growth and Development Centre Research Memorandum GD–67.

Tinbergen, J. (1942): "Zur Theorie der Langfristigen Wirtschaftsentwicklung", *Weltwirtschaftliches Archiv*, Vol. 55, pp. 511–549.

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

Törnqvist, L. (1936): "The Bank of Finland's Consumption Price Index", *Bank of Finland Monthly Bulletin*, Vol. 10, pp. 1–8.

Vattula, K. (1983) (ed.): *Suomen taloushistoria 3: historiallinen tilasto*, Helsinki: Tammi.

Vihavainen, H., Valppu, P., Suokko, S. and Björk, B.-C. (1980): *Pääomakanta vuosina 1965–1977*, Tilastokeskus tutkimuksia nro. 58.

Vikström, P. (2002): *The Big Picture. A Historical National Accounts Approach to Growth, Structural Change and Income Distribution in Sweden 1870–1990*, Umeå Studies in Economic History, Nr. 26/2002, Umeå: Umeå universitet.

Wells, H. and Thirlwall, A.P. (2003): "Testing Kaldor's Growth Laws across the Countries of Africa", *African Development Review*, Vol. 15, pp. 89–105.

Whelan, K. (2002): "A Guide to U.S. Chain Aggregated NIPA Data", *Review of Income and Wealth*, Vol. 48, pp. 217–33.

Windelspecht, M. (2002): *Groundbreaking Scientific Experiments, Inventions and Discoveries of the 17th century*, Westport, CT: Greenwood Publishing Group.

Öller, L.-E. (2006): "Erik Dahmén", *Ekonomiska Samfundets Tidskrift*, Vol. 59, pp. 39–42.

TUTKIMUKSIA-SARJA
RESEARCH REPORTS SERIES

Tilastokeskus on julkaissut Tutkimuksia v. 1966 alkaen, v. 1990 lähtien ovat ilmestyneet seuraavat:

164. **Henry Takala,** Kunnat ja kuntainliitot kansantalouden tilinpidossa. Tammikuu 1990. 60 s.

165. **Jarmo Hyrkkö,** Palkansaajien ansiotasoindeksi 1985=100. Tammikuu 1990. 66 s.

166. **Pekka Rytkönen,** Siivouspalvelu, ympäristöhuolto ja pesulapalvelu 1980-luvulla. Tammikuu 1990. 70 s.

167. **Jukka Muukkonen,** Luonnonvaratilinpito kestävän kehityksen kuvaajana. 1990. 119 s.

168. **Juha-Pekka Ollila,** Tieliikenteen tavarankuljetus 1980-luvulla. Helmikuu 1990. 45 s.

169. **Tuovi Allén – Seppo Laaksonen – Päivi Keinänen – Seija Ilmakunnas,** Palkkaa työstä ja sukupuolesta. Huhtikuu 1990. 90 s.

170. **Ari Tyrkkö,** Asuinolotiedot väestölaskennassa ja kotitaloustiedustelussa. Huhtikuu 1990. 63 s.

171. **Hannu Isoaho – Osmo Kivinen – Risto Rinne,** Nuorten koulutus ja kotitausta. Toukokuu 1990. 115 s.

171b.**Hannu Isoaho – Osmo Kivinen – Risto Rinne,** Education and the family background of the young in Finland. 1990. 115 pp.

172. **Tapani Valkonen – Tuija Martelin – Arja Rimpelä,** Eriarvoisuus kuoleman edessä. Sosioekonomiset kuolleisuuserot Suomessa 1971–85. Kesäkuu 1990. 145 s.

173. **Jukka Muukkonen,** Sustainable development and natural resource accounting. August 1990. 96 pp.

174. **Iiris Niemi – Hannu Pääkkönen,** Time use changes in Finland in the 1980s. August 1990. 118 pp.

175. **Väinö Kannisto,** Mortality of the elderly in late 19th and early 20th century Finland. August 1990. 50 pp.

176. **Tapani Valkonen – Tuija Martelin – Arja Rimpelä,** Socioeconomic mortality differences in Finland 1971–85. December 1990. 108 pp.

177. **Jaana Lähteenmaa – Lasse Siurala,** Nuoret ja muutos. Tammikuu 1991. 211 s.

178. **Tuomo Martikainen – Risto Yrjönen,** Vaalit, puolueet ja yhteiskunnan muutos. Maaliskuu 1991. 120 s.

179. **Seppo Laaksonen,** Comparative Adjustments for Missingness in Short-term Panels. April 1991. 74 pp.

180. **Ágnes Babarczy – István Harcsa – Hannu Pääkkönen,** Time use trends in Finland and in Hungary. April 1991. 72 pp.

181. **Timo Matala,** Asumisen tuki 1988. Kesäkuu 1991. 64 s.

182. **Iiris Niemi – Parsla Eglite – Algimantas Mitrikas – V.D. Patrushev – Hannu Pääkkönen,** Time Use in Finland, Latvia, Lithuania and Russia. July 1991. 80 pp.

183. **Iiris Niemi – Hannu Pääkkönen,** Vuotuinen ajankäyttö. Joulukuu 1992. 83 s.

183b.**Iiris Niemi – Hannu Pääkkönen – Veli Rajaniemi – Seppo Laaksonen – Jarmo Lauri,** Vuotuinen ajankäyttö. Ajankäyttötutkimuksen 1987–88 taulukot. Elokuu 1991. 116 s.

184. **Ari Leppälahti – Mikael Åkerblom,** Industrial Innovation in Finland. August 1991. 82 pp.

185. **Maarit Säynevirta,** Indeksiteoria ja ansiotasoindeksi. Lokakuu 1991. 95 s.

186. **Ari Tyrkkö,** Ahtaasti asuvat. Syyskuu 1991. 134 s.

187. **Tuomo Martikainen – Risto Yrjönen,** Voting, parties and social change in Finland. October 1991. 108 pp.

188. **Timo Kolu,** Työelämän laatu 1977–1990. Työn ja hyvinvoinnin koettuja muutoksia. Tammikuu 1992. 194 s.

189. **Anna-Maija Lehto,** Työelämän laatu ja tasa-arvo. Tammikuu 1992. 196 s.

190. **Tuovi Allén – Päivi Keinänen – Seppo Laaksonen – Seija Ilmakunnas,** Wage from Work and Gender. A Study on Wage Differentials in Finland in 1985. 88 pp.

191. **Kirsti Ahlqvist,** Kodinomistajaksi velalla. Maaliskuu 1992. 98 s.

192. **Matti Simpanen – Irja Blomqvist,** Aikuiskoulutukseen osallistuminen. Aikuiskoulutustutkimus 1990. Toukokuu 1992. 135 s.

193. **Leena M. Kirjavainen – Bistra Anachkova – Seppo Laaksonen – Iiris Niemi – Hannu Pääkkönen** – Zahari Staikov, Housework Time in Bulgaria and Finland. June 1992. 131 pp.

194. **Pekka Haapala – Seppo Kouvonen,** Kuntasektorin työvoimakustannukset. Kesäkuu 1992. 70 s.

195. **Pirkko Aulin-Ahmavaara,** The Productivity of a Nation. November 1992. 72 pp.

196. **Tuula Melkas,** Valtion ja markkinoiden tuolla puolen. Kanssaihmisten apu Suomessa 1980-luvun lopulla. Joulukuu 1992. 150 s.

197. **Fjalar Finnäs,** Formation of unions and families in Finnish cohorts born 1938–67. April 1993. 58 pp.

198. **Antti Siikanen – Ari Tyrkkö,** Koti – Talous – Asuntomarkkinat. Kesäkuu 1993. 167 s.

199. **Timo Matala,** Asumisen tuki ja aravavuokralaiset. Kesäkuu 1993. 84 s.

200. **Arja Kinnunen,** Kuluttajahintaindeksi 1990=100. Menetelmät ja käytäntö. Elokuu 1993. 89 s.

201. **Matti Simpanen,** Aikuiskoulutus ja työelämä. Aikuiskoulutustutkimus 1990. Syyskuu 1993. 150 s.

202. **Martti Puohiniemi,** Suomalaisten arvot ja tulevaisuus. Lokakuu 1993. 100 s.

203. **Juha Kivinen – Ari Mäkinen,** Suomen elintarvike- ja metallituoteteollisuuden rakenteen, kannattavuuden ja suhdannevaihteluiden yhteys; ekonometrinen analyysi vuosilta 1974 – 1990. Marraskuu 1993. 92 s.

204. **Juha Nurmela,** Kotitalouksien energian kokonaiskulutus 1990. Marraskuu 1993. 108 s.

205a. **Georg Luther,** Suomen tilastotoimen historia vuoteen 1970. Joulukuu 1993. 382 s.

205b. **Georg Luther,** Statistikens historia i Finland till 1970. December 1993. 380 s.

206. **Riitta Harala – Eva Hänninen-Salmelin – Kaisa Kauppinen-Toropainen – Päivi Keinänen – Tuulikki Petäjäniemi – Sinikka Vanhala,** Naiset huipulla. Huhtikuu 1994. 64 s.

207. **Wangqiu Song,** Hedoninen regressioanalyysi kuluttajahintaindeksissä. Huhtikuu 1994. 100 s.

208. **Anne Koponen,** Työolot ja ammattillinen aikuiskoulutus 1990. Toukokuu 1994. 118 s.

209. **Fjalar Finnäs,** Language Shifts and Migration. May 1994. 37 pp.

210. **Erkki Pahkinen – Veijo Ritola,** Suhdannekäänne ja taloudelliset aikasarjat. Kesäkuu 1994. 200 s.

211. **Riitta Harala – Eva Hänninen-Salmelin – Kaisa Kauppinen-Toropainen – Päivi Keinänen – Tuulikki Petäjäniemi – Sinikka Vanhala,** Women at the Top. July 1994. 66 pp.

212. **Olavi Lehtoranta,** Teollisuuden tuottavuuskehityksen mittaaminen toimialatasolla. Tammikuu 1995. 73 s.

213. **Kristiina Manderbacka,** Terveydentilan mittarit. Syyskuu 1995. 121 s.

214. **Andres Vikat,** Perheellistyminen Virossa ja Suomessa. Joulukuu 1995. 52 s.

215. **Mika Maliranta,** Suomen tehdasteollisuuden tuottavuus. Helmikuu 1996. 189 s.

216. **Juha Nurmela,** Kotitaloudet ja energia vuonna 2015. Huhtikuu 1996. 285 s.

217. **Rauno Sairinen,** Suomalaiset ja ympäristöpolitiikka. Elokuu 1996. 179 s.

218. **Johanna Moisander,** Attitudes and Ecologically Responsible Consumption. August 1996. 159 pp.

219. **Seppo Laaksonen** (ed.), International Perspectives on Nonresponse. Proceedings of the Sixth International Workshop on Household Survey Nonresponse. December 1996. 240 pp.

220. **Jukka Hoffrén,** Metsien ekologisen laadun mittaaminen. Elokuu 1996. 79 s.

221. **Jarmo Rusanen – Arvo Naukkarinen** – Alfred Colpaert – Toivo Muilu, Differences in the Spatial Structure of the Population Between Finland and Sweden in 1995 – a GIS viewpoint. March 1997. 46 pp.

222. **Anna-Maija Lehto,** Työolot tutkimuskohteena. Marraskuu 1996. 289 s.

223. **Seppo Laaksonen** (ed.), The Evolution of Firms and Industries. June 1997. 505 pp.

224. **Jukka Hoffrén,** Finnish Forest Resource Accounting and Ecological Sustainability. June 1997. 132 pp.

225. **Eero Tanskanen,** Suomalaiset ja ympäristö kansainvälisestä näkökulmasta. Elokuu 1997. 153 s.

226. **Jukka Hoffrén,** Talous hyvinvoinnin ja ympäristöhaittojen tuottajana –Suomen ekotehokkuuden mittaaminen. Toukokuu 1999. 154 s.

227. **Sirpa Kolehmainen,** Naisten ja miesten työt. Työmarkkinoiden segregoituminen Suomessa 1970–1990. Lokakuu 1999. 321 s.

228. **Seppo Paananen,** Suomalaisuuden armoilla. Ulkomaalaisten työnhakijoiden luokittelu. Lokakuu 1999. 152 s.

229. **Jukka Hoffrén,** Measuring the Eco-efficiency of the Finnish Economy. October 1999. 80 pp.

230. **Anna-Maija Lehto – Noora Järnefelt** (toim.), Jaksaen ja joustaen. Artikkeleita työolotutkimuksesta. Joulukuu 2000. 264 s.

231. **Kari Djerf,** Properties of some estimators under unit nonresponse. January 2001. 76 pp.

232. **Ismo Teikari,** Poisson mixture sampling in controlling the distribution of response burden in longitudinal and cross section business surveys. March 2001. 120 pp.

233. **Jukka Hoffrén,** Measuring the Eco-efficiency of Welfare Generation in a National Economy. The Case of Finland. November 2001. 199 pp.

234. **Pia Pulkkinen,** "Vähän enemmän arvoinen" Tutkimus tasa-arvokokemuksista työpaikoilla. Tammikuu 2002. 154 s.

235. **Noora Järnefelt – Anna-Maija Lehto,** Työhulluja vai hulluja töitä? Tutkimus kiirekokemuksista työpaikoilla. Huhtikuu 2002. 130 s.

236. **Markku Heiskanen,** Väkivalta, pelko, turvattomuus. Surveytutkimusten näkökulmia suomalaisten turvallisuuteen. Huhtikuu 2002. 323 s.

237. **Tuula Melkas,** Sosiaalisesta muodosta toiseen. Suomalaisten yksityiselämän sosiaalisuuden tarkastelua vuosilta 1986 ja 1994. Huhtikuu 2003. 195 s.

238. **Rune Höglund – Markus Jäntti – Gunnar Rosenqvist (eds.),** Statistics, econometrics and society: Essays in honour of Leif Nordberg. April 2003. 260 pp.

239. **Johanna Laiho – Tarja Nieminen (toim.),** Terveys 2000 -tutkimus. Aikuisväestön haastatteluaineiston tilastollinen laatu. Otanta-asetelma, tiedonkeruu, vastauskato ja estimointi- ja analyysiasetelma. Maaliskuu 2004. 95 s.

240. **Pauli Ollila,** A Theoretical Overview for Variance Estimation in Sampling Theory with Some New Techniques for Complex Estimators. September 2004. 151 pp.

241. **Minna Piispa.** Väkivalta ja parisuhde. Nuorten naisten kokeman parisuhdeväkivallan määrittely surveytutkimuksessa. Syyskuu 2004. 216 s.

242. **Eugen Koev.** Combining Classification and Hedonic Quality Adjustment in Constructing a House Price Index. (Tulossa).

243. **Henna Isoniemi – Irmeli Penttilä (toim.),** Perheiden muuttuvat elinolot. Artikkeleita lapsiperheiden elämänmuutoksista. Syyskuu 2005. 168 s.

244. **Anna-Maija Lehto – Hanna Sutela – Arto Miettinen (toim.),** Kaikilla mausteilla. Artikkeleita työolotutkimuksesta. Toukokuu 2006. 385 s.

245. **Jukka Jalava – Jari Eloranta – Jari Ojala (toim.)** Muutoksen merkit – Kvantitatiivisia perspektiivejä Suomen taloushistoriaan. Tammikuu 2007. 373 s.

246. **Jari Kauppila.** The Structure and Short-Term Development of Finnish Industries in the 1920s and 1930s. An Input-output Approach. Elokuu 2007. 274 s.

247. **Mikko Myrskylä.** Generalised Regression Estimation for Domain Class Frequencies. Elokuu 2007. 137 s.

248. **Jukka Jalava.** Essays on Finnish Economic Growth and Productivity, 1860–2005. Joulukuu 2007. 154 s.

The Research Reports series describes Finnish society in the light of up-to-date research results. Scientific studies that are carried out at Statistics Finland or are based on the datasets of Statistics Finland are published in the series.

This study examines Finnish economic growth, 1860–2005. The key driver of economic growth was productivity. And the major engine of productivity growth was technology, especially the general purpose technologies (GPTs) electricity and ICT. A new GPT builds on previous knowledge, yet often in an uncertain, punctuated, fashion.

Economic history, as well as the Finnish data analyzed in this study, 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. These are technologies that affect the whole economy by transforming both household life and the ways in which firms conduct business.

9789524677462

Tilastokeskus, myyntipalvelu
PL 4C
00022 TILASTOKESKUS
puh. (09) 1734 2011
faksi (09) 1734 2500
myynti@tilastokeskus.fi
www.tilastokeskus.fi

Statistikcentralen, försäljning
PB 4C
00022 STATISTIKCENTRALEN
tfn (09) 1734 2011
fax (09) 1734 2500
myynti@stat.fi
www.stat.fi

Statistics Finland, Sales Services
P.O.Box 4C
FI-00022 STATISTICS FINLAND
Tel. +358 9 1734 2011
Fax +358 9 1734 2500
sales@stat.fi
www.stat.fi

ISSN 0355-2071
= Tutkimuksia
ISBN 978-952-467-746-2