Productivity Growth in the Nordic Countries

An Appraisal of Analysis, Data and Methodological Information

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Nordic co-operation

Nordic co-operation, one of the oldest and most wide-ranging regional partnerships in the world, involves Denmark, Finland, Iceland, Norway, Sweden, the Faroe Islands, Greenland and Åland. Co-operation reinforces the sense of Nordic community while respecting national differences and similarities, makes it possible to uphold Nordic interests in the world at large and promotes positive relations between neighbouring peoples.

Co-operation was formalised in 1952 when *the Nordic Council* was set up as a forum for parliamentarians and governments. The Helsinki Treaty of 1962 has formed the framework for Nordic partnership ever since. The *Nordic Council of Ministers* was set up in 1971 as the formal forum for co-operation between the governments of the Nordic countries and the political leadership of the autonomous areas, i.e. the Faroe Islands, Greenland and Åland.

Abstract

While focusing on the Nordic countries from the early 1980s, this study shows that real wages per employee are positively related to the level of labor productivity. This finding hence suggests that changes in relative standards of living in the Nordic countries are, at least in part, driven by parallel changes in relative productivity. The analysis also reveals that initial differences between the Nordic countries in terms of output per hours worked, output per employee, and wage per employee seem to fade away over time. Yet another finding is that the decline in the goods sector's share in total hours is, in general, larger than that of total output – i.e., the ongoing shifting out of goods production into services implies higher labor productivity in the goods sector.

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Preface

In October 2003 the Nordic Council of Ministers and the Nordic Council (in the following referred to as just the Council) agreed to support this work on Nordic productivity. The ambition with all projects tied to the Council is to pool experience, expertise, and knowledge from each of the Nordic countries in order to facilitate knowledge spillovers in the Nordic region as a whole and to improve the companionship between working professionals in these countries. In the end, faster accumulation of “Nordic knowledge” and a larger set of inter-country collaborations will undoubtedly boost the level of skills at the disaggregate (personal) level as well as improve the analysis, data production, and methodological scholarship at the aggregate (Nordic) level.

This Report finds that real wages per employee are positively related to the level of labor productivity – a finding that suggests that changes in relative standards of living in the Nordic countries are driven by parallel changes in relative productivity. The analysis also shows that initial differences between the Nordic countries in terms of output per hours worked, output per employee, and wage per employee appear to fade away over time. Moreover, it finds that the decline in the goods sector’s share in total hours is larger than that of total output – that is, the ongoing shifting out of goods production into services implies higher labor productivity in the goods sector. All these findings are of great importance for macroeconomic policymakers.

Yet another conclusion is that more work is clearly needed. In addition to the more technical issues listed below, it would (we think) be useful to establish a new standard for data production. For example, a permanent inter-country forum or working group could be established to handle both current and future data issues – a good example of this is this joint Nordic work (although it was only temporary).

The principal objective with the following (more technical) suggestions – which, by the way, originate from the experience, shortcomings and virtues of the present work – is that they will help us focus on the right issues in the future.

The first suggestion is that capital input should optimally be measured in terms of (the flow of) *capital services* rather than capital stocks.¹ The reason is that the true (effective) capital input is more likely to track capital services than the capital stock.

The second suggestion is that more work is needed on the productivity-growth effect from so-called labor quality. The underlying logic is

¹ These suggestions are presented in a random order (hence, nothing is said here about priorities).

that the rising scholarly proficiency in the labor force has, in general, positive productivity effects. In order to estimate this effect, it is essential to use rather detailed data on educational levels for employees in different industries and sectors. These kind of (employee-level) data are readily available in Denmark, Norway and Sweden (although they are pretty difficult to process due to their size).

A third suggestion is that it can be worthwhile to study the productivity growth effects of Research and Development (R&D) activities. So far, however, R&D spending is not included in the National Accounts (they are not included in the international classification systems SNA93/ESA95). Yet, it is, of course, possible to construct non-official and – at least to begin with – experimental accounts, including R&D outlays. For the moment, Statistics Denmark is planning to collect/construct this kind of R&D data – and this initiative can certainly serve as inspiration for the other Nordic countries. Statistics Canada also plans to construct similar experimental R&D data.

A fourth suggestion has to do with the measurement of prices. The Group has, for example, found that there is a lack of price data for, in particular, ICT-capital equipment – and this, of course, not only complicates the measurement of effective ICT capital, but also leads to large uncertainties as regards the role played by ICT for productivity growth in general. When ICT price data are missing for a particular country, corresponding price data from another country are sometimes used instead. This shortcut is, however, hardly satisfying. As a consequence, the Group now wants to put particular emphasis on this issue: it is essential that accurate price measures are used for all types of capital equipment.

A fifth suggestion is that it is important that the statistical authorities try to construct long enough time series. If not, statistical analysis (econometrics) cannot be used, and, as a consequence, the data analysis will suffer from data limitations. There are differences between the Nordic countries in this respect; for example, while Sweden only has detailed National Accounts time series data from 1993, Denmark has data from 1966, and Norway from 1970.

A sixth suggestion is that we should try to do more work on the definition of ICT production and use. For example, the role of ICT production for aggregate productivity growth is certainly, at least to some extent, reliant on how ICT production is defined. Moreover, in order to estimate the importance of ICT use for productivity growth, one must have high-quality measures on how much ICT capital equipment is actually used on a regular basis at the level of plants, firms, industries, and sectors. In the Group, we have experimented with different ways of identifying these categories (we were inspired by Eurostat) – and we think it is worthwhile to try to see to what extent these measures can spice up traditional studies on growth in the Nordic countries.

The last suggestion, finally, has already been mentioned above – it has to do with the benefits of international collaborations in general. The Group suggests that a permanent forum will be established in the Nordic countries which will focus in particular on issues relating to productivity. The objective is to pursue this Report's suggestions for future work within the Nordic countries, while at the same time reaching out for other international players (some of whom the Group has already met during the work with this Report). There are four organizations which may be of particular interest for us to work with: they are the OECD (the Economic Analysis and Statistics Division as well as the Division of Prices and Structural Economic Statistics), the so-called EU-KLEMS project (which is sponsored by the European Commission), and Statistics Canada (the Microeconomic Analysis Division).

The members of the Group have reached a set of common conclusions. The analysis is presented in this Report, which also includes the above-referenced proposals for future work – as regards analysis, data, and methodological issues – within the Nordic region. While all members of the Group share the basic connotation of these proposals, members may, of course, still retain their own particular perspective on specific aspects of these proposals.

While closing these leading words, I want to emphasize here that this Report is a joint product of an exceptional team, which includes not only the ordinary members of the Group, but also some distinguished people from outside who, in one way or another, have contributed to our work. In particular, I wish to thank Bart Van Ark at the University of Groningen and EU-KLEMS, John Baldwin at Statistics Canada, Gunnar Forsling at Infobey Research, and Paul Schreyer at the OECD for comments, helpful suggestions, and inspiration.

Yet, my greatest thanks belong to Tomas Lindström, the Head (and only) Secretary of this Group, not only for cleverly putting the pieces together and writing the whole Report, but also for his encouragement and untiring enthusiasm.

Lena Hagman, Chief Economist, Statistics Sweden
Chairman of the Group

Stockholm, April 2005

*Composition of the Group**Chairman*

Lena Hagman has worked as Chief Economist at Statistics Sweden for two years. Before that, she served as the Head Secretary of the Commission on the Review of Economic Statistics. She has also specialized in macroeconomic forecasting while working as the Chief Forecaster at the Federation of Swedish Industries.

Members

Jukka Jalava is a senior researcher at Statistics Finland and Helsinki School of Economics (HSE). His areas of responsibility at the statistical office's National Accounts Division include capital and productivity. At HSE he participates in the EU-KLEMS productivity project. He has published on capital, economic growth, ICT, and productivity.

Hans-Olof Hagén has senior executive experience in the public sector. Dr. Hagén has served as researcher as well as Head of Analysis at Departments at a range of government agencies in Sweden, such as the National Board of Industry, the National Board of Industrial and Technical Development, and the Ministry of Industry. He has also served at the Swedish Institute of Growth Policy Studies, where he brought important skills in data analysis and research support. His current work at Statistics Sweden focuses on productivity growth.

Tomas Lindström is a long-time senior economist with extensive experience in both applied macroeconomics research and policy-relevant work in national agencies. His areas of expertise include empirical macroeconomics in general, such as economic growth, household and local government consumption theory, old and recent theories of investments, and (on a more regular basis) monitoring and predicting business cycle movements and turning points. Dr. Lindström, who is now a Senior Economist at the Riksbank (the Central Bank of Sweden), has served as the Head Secretary of this Report.

Steinar Todsén is a Statistical Adviser in the Division for National Accounts in Statistics Norway. His areas of expertise include estimates of capital stocks and the compilation of so-called Input-Output and Supply-Use tables.

Dag Rønningen is a statistician at Statistics Norway, where he specializes in micro-data in general. He brings important skills in micro data construction as well as microeconomic and microeconomic analysis.

Benedikt Valsson is an economist at the Ministry of Finance in Iceland. He brings important skills in data analysis, macroeconomics (empirics as well as theory), and economic forecasting.

The other members are *Mickey Petersen* (Økonomi- og Erhvervsministeriet in Denmark), *Henrik Sejerbo Sørensen* (Statistics Denmark), and *Tomas Skyttesvall* (Statistics Sweden).

The Group met five times between March 2004 and February 2005. The first meeting was held in Stockholm, Sweden, in March 3, 2004. In this meeting, the Group discussed the general purpose of the upcoming work. As a starting point, they exploited a previous project supported by the Council.² After doing this, the Group agreed on some issues that – according to the Group – deserves much more attention, and, as such, could be of particular interest for the working agenda. The second meeting was held in Copenhagen, Denmark, in April 28, 2004. This time, the Group focused in particular on the unit of analysis, and to what extent various aggregates and disaggregates of data (i.e., plants, firms, industries, sectors) are comparable between the Nordic countries. While doing this, the Group realized that there are quite a few differences as regards the way data are collected and presented in the Nordic countries, and that these differences are at times sufficiently large so as to impede any cross-country empirical analysis.³ The Group also considered data construction in general, and to what extent there appears to be a consensus view (in the literature and in practice) on how to define ICT capital producers and ICT capital users. The third meeting was held in Reykjavik, Iceland, in September 3, 2004. Now, the Group focused in particular on how output should best be measured (value added vis-à-vis gross output) when trying to calculate true technological change. In addition, the Group talked about (quality-adjusted) price deflators and capital's (economic and physical) depreciation rate. Then, in September 14, 2004, some Group members traveled to the OECD in Paris, France, in order to see how this organization has arranged its work on productivity. Dr. P. Schreyer from the OECD's Economics Department then supplied some details about recent progress as regards the measurement of capital services. The fourth meeting was held in Oslo, Norway, in November 26, 2004. This time, the Group talked about what the Nordic countries can learn from other international work in general, for example the so-called EU-KLEMS productivity project. Dr. Van Ark from the University of Groninge had therefore joined the Group this time – he informed the members about some recent progress and future objectives of the EU-KLEMS project as well as provided constructive and helpful suggestions on a very preliminary draft

² See "The Nordic countries and the new economy" (2002).

³ In order to facilitate comparisons, the Group later on agreed to try to collect some of its own data.

form of this Report. A trip was then made to Statistics Canada in Ottawa in the end of 2004 to meet representatives from their Microeconomics Analysis Division (headed by Dr. John Baldwin). Here parts of the Group learned what has been accomplished in one of the world's best statistical offices as regards, for example, data production as well as economic analysis in general and productivity analysis in particular. The fifth meeting, finally, was held in Helsinki, Finland, on February 21, 2005. In this meeting the Group plowed through much of this Report while in draft form and suggested further improvements.

All members of the Group participated in a personal capacity – and this means that all opinions expressed in the Report are the views of the Group as a whole, and they should not be attributed to any one of the organizations with which the Group members are affiliated.

Throughout the work with this Report, a number of complex and rather technical data issues have attracted considerable attention. For example, the Group has devoted a substantial fraction of its efforts to issues like how we should best (at least in theory) measure the quality and use of factor inputs, capital's depreciation rates, and the true price development of goods and services whose qualities change (dramatically) over time. Other topics include, for example, the choice of value-added vis-à-vis gross output data in studies of economic (productivity) growth, and the definition of Information and Communication Technology (ICT) capital production and use. One ambition with this Report has been to discuss these issues in an intuitively appealing research framework – and, as a consequence, the Report attempts to present useful methodologies for analyzing these data while at the same time asking (and hopefully answering) some questions of relevance for the applied economist as well as macroeconomic policymakers. A number of issues have, however, been addressed only at the Group's meetings, and they are – for ease of presentation – not included in the Report.

The Report was first submitted to the Nordic Council of Ministers and the Nordic Council in March 2005.

Summary

The analysis finds that the real wage per employee in the Nordic countries is positively related to the level of labor productivity. This positive relationship suggests that changes in the relative standard of living in the Nordic countries have been driven by parallel changes in relative productivity.

The analysis also suggests that wages per employees have, in general, been higher in Denmark, Iceland, and mainland Norway than in Sweden, and that these higher wages do not, in fact, appear to be correlated with higher productivity.

The analysis also provides strong support for so-called absolute β -convergence among the Nordic countries. Thus, initial differences between the countries, in terms of real output per employee, real output per hour, and real wage per employee, slowly fade away over time. This finding tells us that the Nordic countries are not that different when it comes to saving rates, levels of the technology, and government policies.

This study also shows that the decline in the goods sector's share in total hours is typically larger than that of total output. This finding – which, however, is not true for Iceland – suggests that the relative output per hours worked (and per employee) has increased in the goods sector since at least the early 1980s. The implication is that the ongoing shifting out of goods production into services has resulted in a relatively higher labor productivity level in the goods sector.

1. Introduction

Productivity isn't everything, but in the long run it is almost everything.
[P. Krugman (1998)]⁴

In recent years, the implications of Information and Communication Technology (ICT) capital formation for the development of economies have attracted large interest and controversy. The reason for this is that the productivity resurgence in the second half of the 1990s – above all in the United States, but also in many other developed countries – was parallel to an investment boom in ICT capital equipment. In the United States, for example, this period has now been identified as the longest-ever-recorded time period of sustained growth and a low and stable inflation rate. These facets, in fact, are key insights in the so-called new doctrine (new economy or new era) literature which, as usually stated, rejects the deep-rooted idea that the risk for inflation limits the possibilities for rapid and long-lasting economic growth.⁵

The Nordic region as a whole has also experienced a productivity lift, although not as marked (and wide-ranging) as in the United States.⁶ For example, after growing only about 2.0 percent per year during the 1980s, labor productivity growth in the Swedish business sector jumped to 2.9 percent per year during the 1990s – thus, almost a 50 percent higher growth rate in the 1990s than in the 1980s (c.f. Table 1).⁷ The Swedish productivity lift has been fairly broad in the sense of including lots of industries and sectors. In Norway, likewise, productivity growth in the total (i.e., mainland as well as offshore) business sector increased from an annual average of 3.4 percent in the 1980s to 3.9 percent in the 1990s – hence, an almost 15 percent higher growth rate in the 1990s than in the 1980s.⁸ In mainland-Norway's business sector, similarly, the growth rate increased from 2.2 percent in the 1980s to 3.5 percent in the 1990s (not shown in Table 1).⁹ The growth rate in the Finnish business sector, in

⁴ Quoted from the book *The Age of Diminished Expectations*.

⁵ Studies relating to this new doctrine literature include, for example, Jorgenson and Stiroh (1999), who found that a combination of large technological improvements in ICT sectors and the follow-on investment boom in ICT equipment are the principal driving forces behind the recent U.S. productivity shift. The same result was found in Oliner and Sichel (2000). Jorgenson (2001) took the analysis further while arguing that the productivity revival to a large extent is due to the sharp decline in ICT capital equipment prices – deep-rooted in the development in the semiconductor technology.

⁶ Note that in contrast to the U.S., the role of ICT for growth in Europe as a whole is still not perfectly understood (see, e.g., Timmer and Van Ark (2004)).

⁷ The growth rate in the Swedish business sector then increased further to 4.4 percent in 2002 and 3.5 percent in 2003.

⁸ According to Statistics Norway's terminology, the offshore sector is often referred to as petroleum activities and ocean transport.

⁹ Mainland Norway is defined as the total economy exclusive of the shipping and oil industry.

turn, was pretty high already in the 1980s, and productivity growth in terms of output per hour did not rise in the 1990s. Still, due to a positive development in hours worked per employee, the growth rate of output per employee (worker) nevertheless rose from 3.3 percent in the 1980s to 3.6 percent in the 1990s. Similarly, a favorable development in hours worked per employee also added to faster output growth in the Danish business sector throughout the 1990s (although growth in output per hour fell from 2.2 percent in the 1980s to 1.7 percent in the 1990s). The growth rate (output per worker) also increased in Iceland; from an annual average of 1.5 percent in the 1980s to 2.0 percent in the 1990s, and to 3.2 percent 2001-2003.¹⁰

Table 1. Business sector growth since the early 1980s
Average annual growth rate in percent

	Y/NH			Y/N		
	1981-1990	1991-2000	2001-2003	1981-1990	1991-2000	2001-2003
DK	2.25	1.72	1.57	1.21	1.81	1.40
FI	3.71	3.69	2.08	3.32	3.61	1.36
IS	-	-	-	1.49	1.98	3.19
NO	3.43	3.90	4.72	2.94	3.69	3.48
SE	1.99	2.90	2.63	2.30	3.23	1.11

Note. Productivity growth is measured as real value-added output per hour (Y/NH) and real value-added output per employee (Y/N). Note that for Iceland, there are no available data for the number of hours worked in the business sector. Note also that during the course of this study it was discovered that parts of the data for Iceland are not fully consistent with other data sources. Given these findings, the Icelandic authorities have now started to review the data, which most likely will result in slight future modifications. This Report builds on the second version of the data, but will nevertheless probably be adjusted somewhat further down the road. Thus, the results should be interpreted liberally. In Norway, the business sector refers to the total business sector (and not only the part of the business sector tied to mainland Norway). In addition, for Norway the 2001-2003 figures refer only to the year 2001. Note also that if the third column in each section (Y/NH respectively Y/N) would refer to only 2002-2003 rather than to 2001-2003, then the growth rate would be larger because the year 2001 was a characterized by a fairly large growth slump in all the Nordic countries (the beginning of the collapse of the ICT epoch).

Yet, much scope remains to study the factual role of ICT capital equipment in recent years (in the Nordic countries as well as in other developed countries). For example, it is certainly possible (even likely?) that the short-term and long-term macroeconomic effects from the ICT revolution differ, and that the end result of a fast-growing ICT sector – with lots of new ICT-goods, -producers, and –users – do not always have to be positive. The reason, of course, is that a number of offsetting productivity effects, such as an increase in futile on-the-job ICT-related activities, may sometimes take over (e.g., when employees use their computers at work for various on-line activities and video games). It may also be the case that the ICT expansion merely results in a reorganization of market shares, such as when a traditional store loses its business to an on-line

¹⁰ The available data for Iceland do not include information on hours worked per employee in the business sector. Note also that during the course of this study, it was discovered that parts of the data for Iceland are not fully consistent with other data sources. Given these findings, the Icelandic authorities have now started to review the data, which most likely will result in slight future modifications. This Report builds on the second version of the data, but will nevertheless probably be adjusted somewhat further down the road. Thus, the results should be interpreted liberally.

equal. Another counteracting force is the (often pretty large) training costs related to the new ICT capital equipment.

Hence, not surprisingly, a number of researchers now claim that too much attention has, in fact, been paid to ICT while trying to explain the recent productivity revival, and that too little attention has, as a consequence, been paid to other factors, such as, e.g., the role of human (non-tangible) capital formation.¹¹ In addition, there are economists who lay emphasis on the growth effects of increased competition in the course of (a variety of) deregulations of product and labor markets in many developed countries. The ongoing global integration may, of course, also boost productivity. Yet others call attention to the usual pro-cyclical response of productivity when output grows faster than its trend. Other (more technical) explanations for the recent productivity lift include improved methods for measuring capital depreciation rates and the development of quality-adjusted prices.¹²

As already implicitly suggested above, productivity growth is vital for a number of (direct and indirect) reasons. To see why, it is helpful to realize that a country's ability to raise its standards of living over time (hence, a country's ability to offer growing real incomes for future generations) depends crucially on its ability to raise its output per worker (see, e.g., Krugman (1998)). This key insight – which, unfortunately, often seems to be forgotten, or even unfamiliar, by macroeconomic policymakers – is, in fact, an important reason why this joint Nordic work (and thus this Nordic Group and the writing of this Report) started off in the first place. Another reason is the above-referenced set of (not necessarily mutually exclusive) interpretations of the underlying causes of the recent productivity revival. As some of these interpretations put emphasis on various data problems, it would (we think) be a good thing to try to shed some light also on these issues.

The Report's first objective is to take a closer look at labor productivity (growth rates and levels) in the Nordic countries since the early 1980s while bringing up to date and expanding on prior country-level data analysis and research. The focal point here is to portray each Nordic country in terms of labor productivity during this period, and, at least in part, to try to see to what extent the results seem to originate from country-specific characteristics. Indeed, if large country-specific characteristics are present in the data – and, as we will argue below, we have every reason to believe this is the case – these will probably affect the data analysis as well as the results (c.f. Table A.1 in Appendix A). For exam-

¹¹ Bresnahan et al. (1999), for example, argued that the balance between tangible (physical) and non-tangible assets is vital. Their results suggest that producers typified by large ICT capital outlays and very skilled labor are often the most productive. They also found that producers characterized by low ICT capital outlays and unskilled labor are often more productive than producers that are characterized by either large ICT capital outlays and unskilled labor or small ICT capital outlays and skilled labor.

¹² This Report tries to relate to all these issues (in one way or another) while focusing in particular on relative productivity growth in the Nordic countries from the early 1980s.

ple, Iceland's economy is very reliant on the fishing industry, which provides about 70 percent of commodity export earnings and employs about 10 percent of the labor force. Consequently, Iceland's economy has been relatively exposed to fluctuations in world prices for fish and fish products (and also, in fact, to fluctuations in the prices of aluminum and ferro-silicon). Norway too, of course, stands out in this sample of countries, because it is so richly endowed with natural resources, such as fish, forests, minerals, and (in particular) gas and oil. Norway is, as a consequence, highly reliant on its oil production and global oil prices (with oil and gas accounting for about 30 percent of total exports).¹³ Finland is also, of course, special because it has so rapidly transformed itself from an agrarian country reliant on natural resources to a top-modern country distinguished by a one of the worlds' greatest telecommunications corporations (Nokia).¹⁴ Sweden, too, has world-class telecommunication production (Ericsson) – but its history goes far longer back in time than in Finland.

The second objective of this Report is to examine to what extent the empirical pattern of productivity growth in the Nordic countries is in line with the predictions of traditional theories of economic growth. For example, the initial level of real output should, according to the neoclassical (Solow-Swan) growth model, be inversely related to the following output growth (i.e., convergence). The Report takes a closer look at this – although without trying to identify the rate of convergence (which according to empirical findings and theory is approximately 2 percent per year). The analysis also tries to put together a rational frame (i.e., presentation) that embodies the role of capital accumulation for growth in general, and how it relates to what is often casually referred to as the new economy.

The third objective is to signal attention to a range of measurement difficulties and problems that typically show up in traditional productivity studies, and, while doing this, suggest how data production may be improved. For example, all the typical data problems as regards the true quality and use of capital and labor inputs may indeed be amplified by technical hitches related to the operation time of hardware and the true cost of hardware power. In theory, of course, measures of factor inputs should account for all quality differences and utilization rates. Hence, unlike many studies, this Report tries to go beyond simple analysis, descriptions of data, and discussions of data difficulties while also considering some suggestions for future data production. It does so because data production can (as everything else) be improved, and one good way to proceed is to pool experience, expertise and knowledge – for example, in the form of this joint Nordic effort.

¹³ This is, of course, the reason why the Norwegian economy is often split up into two parts, namely mainland Norway and the part of Norway that is tied to petroleum activities and ocean transport (this is Statistics Norway's terminology).

¹⁴ See, for example, Jalava and Pohjola (2005).

The analysis begins with the simple eye-ball observation that the real wage per employee in the Nordic countries is positively related to the level of labor productivity. This finding is obtained through scatter-plot diagrams – one plot per country and year from the early 1980s onwards – showing the relative wage per employee against relative labor productivity. Hence, taken at face value, this positive relationship suggests that changes in the relative standard of living in the Nordic countries have been driven by parallel changes in relative productivity. This finding is, of course, hardly sensational because it accords well with both the conventional wisdom and standard textbooks of economics. This analysis is, nonetheless, the first study (at least to our knowledge) to document this relationship formally (i.e., statistically) for the Nordic countries.

The analysis also suggests that wages per employees have, in general, been higher in Denmark, Iceland, and mainland Norway than in Sweden, and that these higher wages do not, in fact, appear to be correlated with higher productivity.¹⁵ The scatter-plots also show that relative wages per employees have (not surprisingly) been largest in the total business sector in Norway, and that these wages have been correlated with higher productivity. The reason for the higher productivity is, of course, that the total business sector in Norway includes not only mainland Norway's industries but also the very lucrative (and profitable) offshore industries.

The analysis also provides strong support for so-called absolute β -convergence among the Nordic countries – hence, in other words, the initial differences between the countries (i.e., the differences in 1980), in terms of real output per employee, real output per hour, and real wage per employee, slowly fade away over time.¹⁶ This holds for the business sector as a whole, as well as for the goods, services and manufacturing sector.¹⁷ This finding, hence, tells us that the Nordic countries are not that different when it comes to the steady-state values in the neoclassical growth model. More precisely, because absolute convergence implies that the regions have approximately the same steady state, it also implies that they are characterized by roughly the same saving rate, level of technology, and government policies (which can shift the production function down and up). This doesn't seem too implausible, after all, even though there certainly are large differences between the Nordic countries as regards, for example, the division of the economy into different sectors (c.f. Appendix A), the historical track record of exchange rates and price fluctuations, and the reliance on foreign trade.

¹⁵ There are a number of possible reasons for this lack of correlation, such as, for example, differences between the countries in terms of sector shares and capital-labor ratios.

¹⁶ In the growth literature, absolute convergence implies that poor countries tend to grow faster per capita than rich (i.e., there is no control for country-specific characteristics). Conditional convergence, in turn, means that poor countries tend to grow faster per capita than rich only if country-specific characteristics are controlled for. Hence, in other words, the neoclassical growth model predicts that a country converges to its own steady state, and that the speed of convergence relates inversely to the distance from steady state.

¹⁷ For Norway, convergence applies (not surprisingly) most clearly to the mainland economy.

This study also shows that the decline in the goods sector's share in total hours is typically larger than that of total output. This, finding – which, however, is not true for Iceland – suggests that the relative output per hours worked has increased in the goods sector since at least the early 1980s.¹⁸ The implication thus is that the ongoing shifting out of goods production into services in Denmark, Finland, Norway, and Sweden since at least the beginning of the 1980s has resulted in a relatively higher labor productivity level in the goods sector. The flip side, of course, is a relatively lower productivity level in the services sector. For Iceland, in contrast, the shifting out of goods production appears to (at least so far) have resulted in lower productivity in the goods sector.¹⁹ The reason is that for Iceland, the decline in the goods sector's share in total employment is lower than that of total output. The analysis hence supports the idea that a rising share of the service sector (services industries) in the Nordic countries (not Iceland) have contributed to a slower productivity growth for the business sector as a whole. However, the analysis also shows that this slower growth has, at least to some extent, been counteracted by a relatively high productivity level in the services sector.²⁰ Hence, the net effect of a growing services sector on (the growth and level of) productivity in the business sector is, as a consequence, likely to be smaller than what the shifting in (out) of services (goods) seems to suggest. Yet another possible (and more tentative) counteracting factor is that the services sector is, in general, a fairly large user of (presumably highly productive) ICT capital equipment.

All these empirical observations are, however, suggestive, and a more formal statistical assessment is needed to validate and refine our identification of the true underlying causes of why relative productivity has changed over the years. This, however, lies outside the scope of the present analysis.

The organization of the Report is the following.²¹ Section 2 presents the data at hand while showing how productivity and wage have developed in the Nordic countries since the early 1980s. This section also takes a closer look at the convergence hypothesis and – albeit very shortly – the interesting topic as to whether cycle or trend drives productivity. Section 3 focuses on capital accumulation, and the role of ICT capital equipment for productivity growth. It also briefly discusses another very interesting

¹⁸ Note, however, that the data for Iceland are preliminary, and that they will probably be adjusted somewhat further down the road. Hence, this calls for careful interpretations.

¹⁹ Note again that we lack information on hours worked in the business sector for Iceland (see footnote 10). As a consequence, Iceland's labor productivity is computed as output per employee, and not as output per hours worked.

²⁰ This appears to be a rather common finding (c.f., Van Ark (2003)).

²¹ In each of the following chapters, an attempt is made to limit the amount of technical information provided. Moreover, while each chapter follows the preceding chapter, deliberate efforts are made to make each of the chapters "self-contained". A reader may thus read the chapters in order of preference.

determinant of long-term growth, namely human (non-tangible) capital. Chapter 4 concludes.²²

²² There is also an appendix, which shows much working material (diagrams, tables, and models).

2. Productivity in the Nordic Countries

The work reported in this section focuses on relative labor productivity in the Nordic countries from the early 1980s. Hence at the most direct level, this section illustrates how the Nordic countries have performed relative to one another throughout this period, in particular in terms of real value-added output per hours worked.²³ In addition, this section tries to see to what extent changes in relative productivity have been passed on into changes in relative real wages. The principal focus is on productivity in the business sector. However, exactly the same information as shown in this section is also available for the goods, services, and manufacturing sector (see Appendix B).

This line of focus, however, raises a few empirical issues. The first concerns the value-added output methodology. If possible, value-added output measures for all the Nordic countries should, of course, be obtained from so-called Purchasing Power Parity (PPP) calculations, rather than from simple conversions at official currency exchange rates.²⁴ Data derived from the PPP method are, in general, regarded as the best starting point for country comparisons. However, while PPP estimates are, as a rule, quite reliable for developed countries, they may be rough approximations for developing and Newly Industrialized (NI) countries. PPP estimates may be rough approximations also for developed countries.²⁵ In this study, we have, for ease of calculations (and due to data limitations), used conversions at official currency rates rather than PPP. Indeed, one problem with this approach is that exchange rates may (randomly) go down or up as a result of a variety market forces and official interventions. In 1993, for example, the Swedish Krona (SEK) fell by a bit more than 30 percent against the U.S. dollar (USD) – and this change, of course, did not cut the real output by 30 percent (c.f. Diagram 1). In 1986 and 1987, in contrast, the SEK moved in the opposite direction (it gained almost 20 percent against the USD in 1986 and then 10 percent more in 1987). There are, of course, other examples of this kind of short-term fluctuations in the Nordic currencies. For example, the Danish Krone (DK) gained about 25 percent against the USD in 1986, and the Finnish Mark (FIM), which in 2002 was replaced by the Euro, gained almost 20

²³ Henceforth, the term output will often be used as a shorthand to refer to real value-added output.

²⁴ The PPP method typically involves international dollar price weights which, in turn, are applied to the quantities of goods and services that are produced in each country.

²⁵ Hence, this implies that country comparisons should always be interpreted liberally.

percent. The Norwegian Kroner (NOK), likewise, appreciated by 14 percent this year, while Iceland's Krona (ISK) appreciated by only 1 percent. Short- and long-term movements in exchange rates are, indeed, interesting in their own right – and they are also, at least in part, related to the development of relative productivity. In this Report (this chapter), however, we just illustrate to what extent the Nordic currencies have changed since the early 1980, and we highlight the implications of these movements for the calculations of relative productivity and real incomes. Questions about why the exchange rates have moved in the way they have are, in general, rather complex, and they are therefore postponed to future work.

Diagram 1. Exchange rates against the USD
Annual change in percent

Note. Denmark is marked by circles, Finland by triangles, Iceland by crosses, Norway by quadrates, and Sweden by diamonds. The correlation coefficient in the diagram is 0.42.

A second issue has to do with prices. To see why prices are important for (relative) productivity measures, it is helpful to realize that prices and productivity are often closely related. For example, better goods and services (that is, a productivity lift in the production of goods and services) can often be sold at higher prices. Hence, in order for a country to get a better price for its exports (so that it can afford to import more without borrowing), foreigners must (obviously) be willing to pay more – and, as Krugman (1998) puts it: “The only reliable way to do that is to make goods [and services] better – which is really just a productivity increase under another name”. Now, does this mean that a price increase in output (goods and services) is always a sign of productivity growth? Certainly not, and the simplest way to see this is to look at hardware (computer)

prices, which, according to quality-adjusted (hedonic) prices, have fallen rapidly since the beginning of the computer era in the early 1990s.²⁶ Hence, these prices have fallen as productivity has accelerated.²⁷ In addition, if capital (broadly defined) is not properly deflated by a hedonic price, its contribution to labor productivity growth may, in fact, be underestimated (and TFP growth may, as a consequence, be overestimated). Although this section illustrates to what extent relative price movements in the Nordic countries may affect the calculations of relative productivity, nothing is said here about how prices are settled on the market and why they have changed in the way they have. This interesting topic is (just as the exchange-rate topic) complicated, and it lies outside the scope of the present Report.

A third issue is more theoretical and has to do with causality: it is, already at this stage, essential to bear in mind that although the simple empirical exercises in this section (as well as standard textbook theories) suggest that productivity growth is the principal driving force of real income growth, this hypothesis is not formally (i.e., statistically) tested. Rather, this section relies only on eye-ball econometrics and simple correlations of data. An alternative would obviously be to present a simple model of growth in which this interpretation is warranted, and then use it to discuss the justification for, as well as the limitations of, this interpretation. This, too, lies outside the scope of this analysis.

Relative productivity and wage

Now, turning to relative productivity, one issue of interest (at least to begin with) is to be explicit about how (nominal) exchange rates and prices affect the data at hand. In order to accomplish this, we begin by showing three different chatter-plot diagrams of relative labor productivity (on the horizontal axis) and wage per employee (on the vertical axis). In the first diagram (Diagram 2), current prices are used for labor productivity and wage, and time-varying USD exchange rates are used for the conversion from Nordic currencies to USD.²⁸ In the second diagram (Diagram 3), labor productivity and wage are deflated (constant 2000-prices), but time-varying USD exchange rates are still used for the conversion from the Nordic currencies to USD. In the third diagram (Diagram 4), finally, labor productivity and wage are (still) deflated, but now constant USD conversion rates (the reference year is 2000) have been

²⁶ For details about hedonic prices, see for example Pakes (2002).

²⁷ A closely related example of this is the recent fall in the Swedish terms of trade (i.e., export prices in relation to import prices), which to a large extent has to do with the development of the highly productive Swedish telecommunications industry.

²⁸ Diagrams 2-4 show data for the business sector, but exactly the same calculations have also been made on the goods, services, and manufacturing sector (see Appendix B).

used for the translation of productivity and wage expressed in the Nordic currencies to USD.

Diagrams 2-4 provide detailed information on the role played by exchange rates and relative price levels in the Nordic countries since the early 1980s – each point in the diagrams refers to a productivity-wage combination for a single year. Note, however, that for Iceland, we restrict the sample to 1990-2000 when we use current (time-varying) USD conversion rates (Diagram 2 and 3). The reason is that the high inflation rate during the 1980s will otherwise (in combination with the current ISK/USD exchange rate) lead to quite implausible (and very hard-to-interpret) levels of both labor productivity and wage per employee.²⁹ Note also that in the diagrams, Sweden is always at the (100;100) point in the center – hence all numbers shown in the diagrams are relative to the levels of productivity and wage per employee in Sweden. This means, for example, that a specific point, say, the (103;149) point referring to Denmark-relative-to-Sweden in 1995 (the upper-right circle in Diagram 2), tells us that in this year the level of labor productivity in Denmark was 103 percent of the level of labor productivity in Sweden (measured in current prices and exchange rates), and that the wage level per employee was 149 percent of the wage level per employee in Sweden (still in current prices and exchange rates). The actual year is, however, not shown in the diagrams (due to space limits). For details about the development over time of relative productivity and wage per employee, see Appendix B.

²⁹ Note again that the data for Iceland are preliminary.

Diagram 2. Current prices and exchange rates

The Business sector

Relative wage per employee on the vertical axis, and relative labor productivity on the horizontal axis

Note. Denmark is marked by circles, Finland by triangles, Iceland by crosses, total Norway by quadrates, and mainland Norway by diamonds. The correlation coefficient in the diagram is 0.42.

Diagram 3. Constant prices and current exchange rates

The Business sector

Relative wage per employee on the vertical axis, and relative labor productivity on the horizontal axis

Note. Denmark is marked by circles, Finland by triangles, Iceland by crosses, total Norway by quadrates, and mainland Norway by diamonds. The correlation coefficient in the diagram is 0.66.

Diagram 4. Constant prices and exchange rates

The Business sector

Relative wage per employee on the vertical axis, and relative labor productivity on the horizontal axis

Note. Denmark is marked by circles, Finland by triangles, Iceland by crosses, total Norway by quadrates, and mainland Norway by diamonds. The correlation coefficient in the diagram is 0.55.

The principal messages of these diagrams are the following. First, Diagram 2 shows that there is, in general, a positive relationship between relative labor productivity and relative wage per employee. This accords – as has already been mentioned – both with the conventional wisdom and standard theories of economic growth.

Second, the diagrams show (not surprisingly) that the data are grouped in a way that suggests fairly large country-specific characteristics. For example, it appears as if wages per employee are relatively high in Denmark, Iceland, and mainland Norway.³⁰ Yet, in the total business sector in Norway (this sector includes the fishing and oil industry) relatively high wages per employee go hand in hand with high labor productivity. In addition, it appears as if the business sector in Finland is typified by a relatively low wage per employee as well as a relatively low productivity, a finding that, at first glance, may seem surprising – after all, this sector includes one of the world’s most successful telecommunications corporations (Nokia). It is important to bear in mind, however, that the scatter plots in the diagrams begin already in the early 1980s, and that the “Nokia-effect” is rather likely to be most pronounced in the late 1990s. Besides, this effect is more likely to be seen in the manufacturing sector

³⁰ It also appears as if these wages are not correlated with relatively high labor productivity. However, as mentioned above, there may be many reasons for this.

(rather than in the total business sector). This is also the case (see Table 7 below).

A third finding is that the scatter-plots are more clustered together in Diagram 2 than in Diagram 3. Obviously, this has to do with the development of prices, because Diagram 2 is in current prices whereas Diagram 3 is in constant (2000) prices. A closer look at single plots, in fact, shows that the clustering in Diagram 2 has, in half, to do with the Swedish price level being higher than in the other Nordic countries in the 1990s, and, in half, with the Swedish price level being lower than in the other Nordic countries (but Iceland) in the 1980s (c.f. Table 2).³¹ Hence, current-price productivity and wage per employee will, as a consequence, tend to be higher in Sweden in the 1990s, and, similarly, lower in the 1980s. It follows that the scatter-plots referring to single years in the 1990s, which typically are positioned a bit north-east in Diagram 2, will tend to go further to the north-east corner in Diagram 3. This hence implies that the Swedish economy was not as strong in the 1990s as suggested by Diagram 2. Likewise, the plots referring to the 1980s, which typically are positioned a bit south-west in Diagram 2, will tend to go further to the south-west corner in Diagram 3. This hence implies a better Swedish position in the 1980s than suggested by Diagram 2.

It is essential, however, to realize that this reallocation of the plots needs not, of course, necessarily result in a more stretched-out look in Diagram 3 than in Diagram 2. If, for example, the plots referring to the 1990s were instead placed south-west in Diagram 2 (rather than north-east), a move of these plots in a north-east direction would, in fact, instead result in a more clustered (compact) look in Diagram 3. Similarly, if the plots referring to the 1980s were placed north-east in Diagram 2 (rather than south-west), a move of these plots in a south-west direction would also result in a more clustered look in Diagram 3. Hence, it appears as if a relative decline for Sweden over the years in terms of current-prices productivity and wage per employee (hence, plots tied to the 1980s lay south-west in Diagram 2, and plots tied to the 1990s lay north-east) is enough to get this result.

³¹ The price level refers to the implicit (value-added output) price deflator, which is obtained directly from the available (nominal and real) data. Note also that in order to facilitate presentation, the same deflator is used for productivity and wage.

Table 2. Nominal exchange rates and implicit prices
Levels

	1980-1984	1985-1989	1990-1994	1995-2000	2000-2003
Exchange rates					
SEK/USD	6.31	6.93	6.66	7.54	9.75
DK/USD	8.12	7.92	6.29	6.34	8.10
FIM/USD	4.88	4.83	4.66	5.02	4.72
ISK/USD	16.26	44.34	62.56	69.20	89.36
NOK/USD	6.52	7.23	6.62	7.05	8.60
Implicit prices					
Sweden	0.50	0.71	0.92	1.00	1.02
Denmark	0.54	0.72	0.86	0.94	1.02
Finland	0.56	0.73	0.88	0.96	1.02
Iceland	0.11	0.42	0.82	0.93	1.12
Mainland Norway	0.53	0.65	0.74	0.77	1.00
Norway	0.51	0.74	0.86	0.92	1.02

Note. The implicit price indices (in the last five rows) are computed as the ratio of value-added output in current prices to value-added output in 2000-prices (hence, they are normalized to 1.00 in 2000). Note also that since these indices are computed from value-added output data, they may, of course, differ from official price data such as, for example, the Consumer Prices Index (CPI).

Fourth, the diagrams show that the exchange rates also play a role in this exercise. For example, a comparison of Diagram 3 and 4 shows that the scatter-plots become more clustered into country-specific sets when the effects from time-varying exchange rates are removed.³² The reason for this is the following. The Danish Krone (DK), for example, was worth less than its 2000 SEK exchange rate from the early 1980s to 1992 (c.f. Table 2). Hence, this implies that the Danish scatter-plots for these years will tend to move to the north-east corner when going from Diagram 3 to Diagram 4. This is the case, for example, for the three circles closest to the south-west corner in Diagram 3 (these plots refer to 1980, 1981, and 1983). For the years after 1992, however, the DK has often been stronger against the SEK (than its 2000 exchange rate), implying that these plots will go in the other (i.e., in a south-west) direction when moving from Diagram 3 to 4. The same story can, on the whole, be told for the Finnish Mark (FIM), which was weaker (than its 2000 SEK exchange rate) in the period 1980-1994 and stronger thereafter, and for the Norwegian Kroner (NOK), which was weaker (than its 2000 SEK exchange rate) 1980-1992 and then stronger in the remainder of the 1990s.³³ Iceland's Krona (ISK), in turn, has depreciated dramatically over the years, and has, as a consequence (and in contrast to the DK, FIM, and NOK), been stronger than its 2000 SEK exchange rate for all years except 2001, 2002, and 2003. The ISK, in fact, depreciated by roughly 56, 8, 2, and 4 percent per year in the

³² Remember that Diagram 3 uses current (time-varying) exchange rates while Diagram 4 uses the exchange rates from 2000 (which, of course, is constant).

³³ Note again that in 2002 the FIM was replaced by the Euro.

periods 1981-1985, 1986-1990, 1991-1995, and 1996-2001, respectively (c.f. Diagram 1).³⁴

A final point that stands out is – as has already been mentioned – Finland's position in the scatter-plot diagrams – above all its location in Diagram 4, which is derived from Diagram 3 by replacing the current (time-varying) FIM/SEK conversion rate by a fixed (2000) rate. Evidently, this location suggests a relatively slow productivity level and wage per employee in Finland from the early 1980s (this position, however, gradually improves over time). Although this result may certainly be accurate, it nevertheless warrants some further investigation.³⁵ For example, it may be a spurious finding due to the choice of fixed FIM/SEK conversion rate, which, as a matter of simple data construction, affects Finland's position in the diagram. The curvature of the scatter plots, however, does not depend on the choice of conversion rate.³⁶ In order to see to what extent the choice of conversion rate has affected the plots in Diagram 4, it is helpful to realize that a stronger FIM will always take Finland's plots further to the north-east corner when going from Diagram 3 to 4. For that reason, we have also tried the strongest FIM against SEK that has been recorded since the early 1980 (which was 1.63 SEK per FIM in 1995). This, of course, changes the placement of Finland's plots in the diagram (see Diagram 5), although 50 percent of the plots still lay in the south-west quadrant (1980-1985 and 1997-2001), while the rest lay in the north-west quadrant (1986-1996).

³⁴ This hence implies that the scatter-plots for Iceland in the 1980s would (if shown in Diagram 2 and 3) be placed far up in the north-east corner, and they should move in the south-west direction while going from Diagram 3 to 4.

³⁵ Other ways of transforming the data into a single currency may, for example, yield other results.

³⁶ By the curvature of the plots is meant the shape of the line between the plots if drawn in chronological order.

Diagram 5. Constant prices and exchange rates (again)

The Business sector

Relative wage per employee on the vertical axis, and relative labor productivity on the horizontal axis

Note. Denmark is marked by circles, Finland by triangles, Iceland by crosses, total Norway by quadrates, and mainland Norway by diamonds. Nominal exchange rates from 1995 have been used in this diagram (rather than rates from 2000). Thus, in this diagram, the FIM (as well as DK and NOK) is stronger against the SEK than in Diagrams 2-4. The correlation coefficient in the diagram is 0.52.

PPP

The analysis above shows that there is a positive correlation between productivity and real wages. It also tells us that the Nordic countries differ somewhat from one another; in particular, it appears as if real wages per employee are relatively high in Denmark, Iceland, and mainland Norway. However, as was discussed in some detail in the beginning of Section 2, data derived from the PPP method are in general regarded as the best starting point for country comparisons, in particular if there are large differences between the countries. However, for a homogenous set of countries – such as (presumably) the Nordic countries – there are, in general, no reason to believe that PPP calculations would lead to very (qualitatively) different results. In addition, PPP measures may just as well suffer from a variety of problems. In this study, we have for ease of calculations – and without downplaying the benefits of PPP measures – relied on conversions at official currency rates rather than PPP measures. This is, of course, a limitation in this work, but it nevertheless meets our requirements for the purpose of the present study. Yet, it is essential to realize that in other work, such as, for example, in the analysis and data in O'Mahony and van Ark's (2003) CD-ROM, Denmark and Finland seem to exhibit a stronger labor productivity than is the case in the present data.

In fact, according to O'Mahony and van Ark, productivity as well as real wage per employee in Denmark and Finland are higher than in Sweden in 2001 – these numbers may, however, change rather rapidly over time, and this (too) suggests that all rankings of productivity and wage performances should always be interpreted with care.

What about Convergence?

To this point, our discussion has focused on the relative development of productivity and wage per employee since the early 1980s. However, so far not much has been said about the factual (chronological) development over time – for example, we don't know yet if countries with initially lower capital per person tend to grow faster in per capita (per hour) terms than the other countries, or, equivalently, if there tend to be convergence across the Nordic countries. This is, of course, an important question because it is exactly what the neoclassical growth model predicts (if the countries are sufficiently similar).

More precisely, the neoclassical model asserts that structurally similar (homogenous) countries – in the sense that they have the same saving rate (i.e., the same fraction of output that is saved), population growth rate, capital depreciation rate, and the same production function – have the same steady-state values on capital per employee and output per employee. From this it follows that if the only difference between countries is the initial quantity of capital per person (employee or hour), the model predicts that the less-advanced countries will have higher growth rates of capital (and in general also output).³⁷ Hence, if countries are similar with respect to preferences and technology, then poor countries tend to grow faster than rich countries (because of diminishing returns to reproducible capital).

The prediction that poor countries tend to grow faster per capita (hour) than rich countries is – if not controlling for the position of the steady state – in general referred to as absolute β -convergence. Conditional β -convergence, in turn, means that a lower initial value cause a higher per capita (hour) growth rate only after conditioning on the country-specific characteristics that establish the steady state. It is, in fact, essential to distinguish between two concepts of convergence; while β -convergence implies that poor countries grow faster than rich ones, σ (or stochastic) convergence involves a decline over time in the cross-sectional dispersion. Convergence of the first kind (i.e., β -convergence in the sense that poor countries tend to grow faster than rich countries) tends to generate convergence of the second kind (reduced dispersion), although this proc-

³⁷ These differences in starting values are rather likely to reflect past disturbances, in the form of, for example, various demand and supply shocks.

ess is, in general, counterbalanced by a variety of disturbances that tend to increase dispersion.

In order to see to what extent the Nordic countries converge over time, we now take a closer look at the growth experience since the early 1980s. Diagram 6 shows the average growth rate of real output per hours worked 1981-2003 against the (natural logarithm of) real output per hour in 1980 in the business, goods, services, and manufacturing sector. Hence, each plot refers to a country-specific combination of the annual average growth rate of real output per hour (on the vertical axis) against the natural logarithm of real output per hour in 1980 (the horizontal axis) in a particular sector.³⁸ The diagram shows that the growth rates are, by and large, negatively related to the initial position: the correlation coefficient in the diagram is -0.65. Yet, all plots do not, of course, lie on a straight line. If, for example, the two plots highest up in the north-east corner of the diagram are removed (these plots refer to the business and goods sector in Norway), the correlation coefficient drops to -0.91. The diagram hence indicates that the initially poorer countries did in fact experience a higher growth rate in output per hours worked, and, accordingly, absolute β -convergence appears to apply for the Nordic countries.

³⁸ The reason why the natural logarithm is used here for the 1980-values is that output is, as a rule, log-normal (i.e., the natural logarithm of output is, as a rule, normally distributed). Hence, since the average growth rate is typically normally distributed, this log-transformation facilitates an eyeball judgment of various combinations of average growth rates and initial values.

Diagram 6. Absolute convergence across the Nordic countries
Real output per hours worked

Note. Each plot refers to a particular combination of annual average growth rate of real output per hours worked in the business, goods, services, and manufacturing sectors from 1981 to 2003 (on the vertical axis) against the natural logarithm of real output per hours worked in 1980 (on the horizontal axis). The sectors are hence not always non-overlapping. For Iceland, the average growth rate refers to the period 1981-2002, and for Norway it refers to 1981-2001. The correlation coefficient is -0.65.

Diagrams 7-8 illustrate the concept of absolute convergence for real output per employee and real wage per employee. Diagram 7 shows different combinations of average growth rates of real output per employee 1981-2003 (on the vertical axis) against the natural logarithm of the real output per employee in 1980 (horizontal axis). The correlation coefficient in this diagram is -0.70. However, if the two plots highest up in the north-east corner of the diagram (these plots also refer to the business and goods sector in Norway) are removed from the diagram, the correlation coefficient drops to -0.97. Moreover, Diagram 8 confirms a negative relationship between the annual average growth rate of the real wage per employee 1981-2003 and the natural logarithm of the real wage per employee in 1980. The correlation coefficient is -0.88.

Diagram 7. Absolute convergence across the Nordic countries

Real output per employee

Note. Each plot refers to a particular combination of annual average growth rate of real output per employee in the business, goods, services, and manufacturing sectors from 1981 to 2003 (on the vertical axis) against the natural logarithm of real output per employee in 1980 (on the horizontal axis). The sectors are hence not always non-overlapping. For Iceland, the average growth rate refers to the period 1981-2002, and for Norway it refers to 1981-2001. The correlation coefficient is -0.70.

Diagram 8. Absolute convergence across the Nordic countries

Real wage per employee

Note. Each plot refers to a particular combination of annual average growth rate of real wage per employee in the business, goods, services, and manufacturing sectors from 1981 to 2003 (on the vertical axis) against the natural logarithm of real wage per employee in 1980 (on the horizontal axis). The sectors are hence not always non-overlapping. For Iceland, the average growth rate refers to the period 1981-2002, and for Norway it refers to 1981-2001. The correlation coefficient is -0.88.

Now, while we find this simple exercise to have been worthwhile, we also believe that further work is needed, especially to validate and refine our identification of relative productivity shifts over the years, and also as regards more (empirical as well as theoretical) work on the factual causes of why relative productivity changes over time. All these very interesting subjects, however, are beyond the scope of the present study – some insights may however be obtained from the following chapters. For example, as Section 2.3 suggests, short-term cyclical fluctuations in the economy as a whole (as well as in individual industries and sectors) may certainly, to a fairly large extent, shape measured productivity, and, as suggested by the introduction, (ICT and human) capital accumulation may also be part of the story (see Chapter 3).

Cyclical v/s Structural Productivity Growth

In recent years there has been a massive amount of research on the procyclicality of measured productivity.³⁹ This strand of research is of considerable importance since it has large implications for macroeconomic modeling in general and the relative merits of different models of the business cycle. Fernald and Basu (1999), for example, tried to determine the empirical relevance of a number of competitive explanations for why productivity normally rises in business cycle upturns and falls in downturns.⁴⁰ Using a standard production-function framework and U.S. manufacturing data, they found that variable production factor use and resource reallocations are of crucial importance for pro-cyclical productivity. A similar result was found by Basu and Kimball (1997), who showed that variable capital and labor utilization may explain as much as 40-60 percent of the cyclicity of TFP growth (i.e., the so-called Solow residual) in U.S. manufacturing industries.

Distinguishing between cyclical and structural growth is, of course, important when it comes to getting the macroeconomic picture right – and given that all Nordic countries were, to a larger or lesser extent, hit by a recession in the early 1990s, this distinction may, in fact, seem crucial (especially for macroeconomic policymakers). However, in the remainder of this Report, the issue of cycle vis-à-vis trend is not high priority. Rather, the analysis focuses more on a selected set of determinants of (long-term) growth.⁴¹

³⁹ For a study on cyclical productivity, see for example Basu (1996).

⁴⁰ In particular, they analyzed the importance of procyclical shifts in the level of technology, imperfect competition and increasing returns, variable factor utilization, and variations in the allocation of resources.

⁴¹ To analyze all potential determinants of long-term growth is, of course, a big task, and as such it lies outside the scope of this Report. Instead, in Chapter 3, we choose to focus on the role of capital accumulation for productivity growth in the Nordic countries. For a study of the determinants of growth, see, for example, Sala-i-Martin (1997).

A closely related issue is the role of measurement problems in general. For example, the data available to the researcher may suffer from various errors, both at higher levels of data aggregation in terms of cyclical (composition-bias) effects, and at lower levels in terms of unsystematic errors originating from the data-collecting process. Hansen and Lindström (2004), for example, found that random errors in capital and labor can explain why estimates of internal returns-to-scale parameters rise at higher levels of data aggregation.

3. Determinants of Growth

When trying to analyze the underlying (long-term) determinants of the relative growth performance of countries, one problem is, in general, that growth theories are rarely explicit enough about exactly what explanatory (right-hand-side) variables belong in the true model. This is, of course, a problem for empirical economists (i.e., a practical problem) as well as for macroeconomic policymakers (who will then be short of clear political guidelines). It is, however, widely accepted by now that factors such as e.g. the attitude towards work, preservation of property rights, and taxes should, if possible, be included in most empirical growth-model regressions. For example, taxes (and public consumption) are in most cases negatively related to economic growth.

Having said that, this chapter now returns to the convergence results of the previous chapter, indicating that the average growth rate of real output per hours worked and per employee as well as real wage per employee in the Nordic countries from the early 1980s to 2000 is negatively related to the 1980 levels. This interesting (and important) finding is, as mentioned above, referred to as absolute β -convergence – it suggests that the Nordic countries are not, after all, very different in terms of the placement of the steady states. Hence, in other words, this kind of convergence suggests that the Nordic countries are characterized by roughly the same saving rate, population growth rate, capital depreciation rate, and production function.

In general, convergence implies that less-advanced countries – with lower starting values of real output per hours worked (and per employee) – have higher growth rates of real output per hours worked (and per employee) than more advanced countries.⁴² It also implies that the less-advanced countries have higher growth rates in real capital per employee.⁴³ This chapter, therefore, focuses on capital accumulation in general in the Nordic countries. It also describes a methodology for estimating the growth contribution of ICT capital.

⁴² More precisely, this holds when the production function is Cobb-Douglas, or when the real stock of capital per employee is below its steady-state value (or when the stock is just a small amount above its steady-state value).

⁴³ This model prediction does not require a particular production function (such as Cobb Douglas).

Capital accumulation

Turning now to capital accumulation, the issue of primary interest (at least to begin with) is to see if real capital per employee also converges over time. Diagram 9 plots the average growth rate of real capital per employee against the (natural) logarithm of real capital per employee in the beginning of the period. However, in contrast to the data for real output and wage, capital data is typically much harder to calculate (and thus to interpret while trying to do empirical analysis). For example, Sweden has for a long time lacked useful time-series data on capital. As for now, the time-series only date back to the early 1990s – hence, this shortcoming precludes a thorough analysis (as the one in the previous chapter) of capital accumulation for Sweden.⁴⁴ In Denmark, moreover, capital data are available from 1988, while in Finland capital data are available from the mid-1970s.⁴⁵

⁴⁴ Difficulties as regards the measurement of capital sometimes cause spurious findings. Hence, as a consequence, all results in this chapter should be interpreted with care.

⁴⁵ For a recent study on the productivity growth effect from capital accumulation in Denmark, see e.g. Bonde and Sejerbo Sorensen (2005).

Diagram 9. Absolute convergence across the Nordic countries
Real capital per employee

Note. Each plot refers to a particular combination of annual average growth rate of real capital per employee in the business, goods, services, and manufacturing sectors from 1994 to 2003 (on the vertical axis) against the natural logarithm of real capital per employee in 1993 (on the horizontal axis). The sectors are hence not always non-overlapping. In the diagram, capital is split into three different types: buildings, machinery exclusive of ICT capital equipment, and ICT capital equipment. The correlation coefficient is -0.83.

Diagram 9 shows that the growth rates of capital are, in general, negatively related to the initial position – a finding that also, at least at first glance, seems to support the view that the Nordic countries converge over time in terms of real capital per employee. The correlation coefficient in the diagram is -0.83. However, the diagram shows the development of three different types of capital (i.e., buildings, capital exclusive of ICT, and ICT capital) – and this implies that the negative relationship in the diagram may perhaps only represent a substitution effect when traditional capital (exclusive of ICT) is replaced by ICT capital (rather than convergence in each of these types of capital).

In order to investigate this more carefully, we next separate the different types of capital from each other. Diagrams 10-12 show the analogues to Diagram 9 for buildings (Diagram 10), machinery exclusive of ICT (Diagram 11), and ICT capital (Diagram 12). The correlation coefficients in the diagrams are -0.39 (for real buildings), -0.05 (real machinery exclusive of ICT), and -0.45 (ICT capital). Hence, according to the diagrams, there seems to be less support for absolute β -convergence in real capital per employee when we control for this replacement of traditional capital. Yet, however, an eye-ball appraisal of the scatter plots in the diagrams does not (we think) reject convergence hypothesis. Besides, a statistically meaningful comparison can, of course, not be carried out here in

order to test this hypothesis more formally (there are simply too few scatter plots).

Diagram 10. Absolute convergence across the Nordic countries

Real Buildings per employee

Note. Each plot refers to a particular combination of annual average growth rate of real buildings per employee in the business, goods, services, and manufacturing sectors from 1994 to 2003 (on the vertical axis) against the natural logarithm of real buildings per employee in 1993 (on the horizontal axis). The sectors are hence not always non-overlapping. The correlation coefficient is -0.39.

Diagram 11. Absolute convergence across the Nordic countries

Real Machinery exclusive of ICT per employee

Note. Each plot refers to a particular combination of annual average growth rate of real machinery exclusive of ICT capital per employee in the business, goods, services, and manufacturing sectors from 1994 to 2003 (on the vertical axis) against the natural logarithm of real machinery exclusive of ICT capital per employee in 1993 (on the horizontal axis). The sectors are hence not always non-overlapping. The correlation coefficient is -0.05.

Diagram 12. Absolute convergence across the Nordic countries

Real ICT capital equipment per employee

Note. Each plot refers to a particular combination of annual average growth rate of real ICT capital per employee in the business, goods, services, and manufacturing sectors from 1994 to 2003 (on the vertical axis) against the natural logarithm of real ICT capital per employee in 1993 (on the horizontal axis). The sectors are hence not always non-overlapping. The correlation coefficient is -0.45.

Hence, to sum up, there appears – at least at first consideration – to be absolute β -convergence in real capital per employee in the Nordic countries. The correlation coefficient in a diagram showing the average growth rate of real capital per employee 1981-2003 on the vertical axis against the natural logarithm of the real capital per employee in 1980 is -0.83. Yet, a closer look at the data reveals that a large part of this convergence reflect an ongoing substitution toward ICT capital equipment in the Nordic countries. This substitution away from traditional capital does not mean, however, that there is no absolute β -convergence in each of the three different types of capital. Rather, the scatter plots in Diagrams 9-12 suggest that the evidence for absolute convergence for each single capital type is weaker than the evidence for convergence when considering all three capital types at the same time – hence, in other words, the support for absolute convergence in real capital per employee is weaker when controlling for the ongoing switch toward ICT capital equipment. To see this more formally, it is sufficient to recognize that the correlation coefficients are -0.39, -0.05, and -0.45, respectively, for buildings, machinery exclusive of ICT capital, and ICT capital (while it is -0.83 for total capital). No formal convergence test can, however, be done at this point because there are simply too few data points – a more careful analysis of this interesting topic must therefore be postponed to future work.

In any case, in the next chapter we take a closer look at ICT capital accumulation in the Nordic countries, and its effect on labor productivity.

The Role of ICT

In the 1990s a number of business economists launched what came to be known as the new paradigm (new era) economics. As regularly stated, this new doctrine abandoned the old thought that the threat of inflation would limit the possibilities for persistent economic growth. According to this view, rapid productivity growth jointly with greater than before competition and integration would imply that even considerable growth rates would not cause inflation. This opinion is often casually referred to as something that has to do with the new economy.⁴⁶

ICT Capital Deepening

Diagrams 9 to 12 suggest that traditional capital seems to be replaced, at least in part, by ICT capital. This shift can be described by traditional economic theory: the replacement of traditional capital reflects a sharp decline in the prices of ICT goods – deep-rooted in the progress in semiconductor technology – and massive investments of ICT capital equip-

⁴⁶ The present work clearly relates to the new economy since it focuses on productivity growth in the Nordic countries from 1980 throughout the 1990s. This work does not, however, go into any details as regards the multiplicity of new era definitions that circulate, nor does it speculate about the future prospects of the new era and its likely effects in general on society as a whole.

ment (i.e., ICT capital deepening) elsewhere. Hence, in other words, ICT-producing firms have experienced considerable productivity gains, and other firms have responded to lower prices on ICT by investing a great deal in ICT capital equipment.

In order to estimate the productivity growth effect from ICT capital deepening it is useful to begin with a neoclassical production function and so-called growth accounting (c.f., Appendix C). The work reported in this section focuses on the benchmark growth-accounting relationship as described by equations C.6 and C.7 in Appendix C. These expressions split labor productivity growth into capital deepening, in the sense of capital per hours worked, and TFP growth. This exercise, however, first raises a few questions that, in one way or another, have been considered earlier. One concerns the nature of the data and the construction of the relevant variables. In particular, the short time series data imply that it is difficult to distinguish between cycle and trend productivity growth. Another shortcoming is that input quality and utilization rates are not completely accounted for. Furthermore, the benchmark equations implicitly assume constant returns to scale, which may not hold (although it certainly is a reasonable approximation, especially over longer time periods). The equations also allow for parameters varying over time and across sectors. In the analysis presented below, all cost shares are computed according to equations (C.10) and (C.12) – hence, these shares vary over time and between sectors.

Table 3 Accounting for productivity growth – Sweden
The business sector (ISIC 01-95)

	94-00	94	95	96	97	98	99	00
1 Growth in output	4.84	5.93	6.33	1.74	4.04	3.74	6.03	6.05
2 Growth in hours worked	1.67	2.75	2.82	-0.15	-1.01	1.75	3.50	2.02
3 Growth ALP	3.17	3.18	3.52	1.89	5.05	2.00	2.54	4.03
4 Capital deepening	0.67	-2.03	-1.02	1.83	2.27	1.19	0.87	1.61
5 Buildings	-0.14	-0.59	-0.72	0.08	0.39	0.09	-0.39	0.19
6 Machinery	-0.02	-1.55	-0.81	0.55	0.90	0.31	0.14	0.32
7 ICT	0.83	0.12	0.52	1.19	0.99	0.79	1.12	1.09
8 Labor quality	0.20	0.24	0.14	0.23	0.22	0.15	0.20	0.20
9 Growth in TFP	2.30	4.96	4.40	-0.17	2.55	0.66	1.47	2.22

Note: Machinery does not include ICT capital equipment. The data in this table are preliminary. It is, for example, unclear to what extent nominal ICT capital outlays have been deflated by quality-adjusted (hedonic) prices. As a result, ICT capital may be underestimated. In order to compensate for this, we have enlarged the user cost of capital (rather than speculated about the extent of this potential bias) so that it now equals the economic rate of depreciation. This is, of course, not a perfect solution, but it meets our requirements for the purpose of the present study. At this stage, these data are available only throughout 2000.

Source: Statistics Sweden.

Table 3 presents the growth-accounting results for Sweden during the period 1994–2000. The first two lines show the growth in output and the growth in hours worked. The third line is the growth rate of output per hour worked (i.e., the labor productivity growth), which can be calculated in the table by subtracting the growth rate of labor hours in the second line from the growth rate of output in the first line. Labor productivity growth, in turn, can be expressed as the sum of capital deepening (line 4),

which is the growth in capital per hour multiplied by capital's share in total factor costs, labor quality (line 8), which captures a switch towards workers with a relatively high marginal product, and total factor productivity growth (line 9). Hence, the growth rate of output per hour minus a fraction of the growth rate of capital per hour and the productivity effect of a shift in the labor force equals total factor productivity growth. Capital deepening is in turn split into buildings-related deepening (line 5), machinery-related deepening exclusive of ICT (line 6), and ICT-related deepening (line 7). Thus, the sum of lines (5), (6), and (7) equals line (4). The last line (line 9) is total factor productivity, which is productivity growth based on a weighted average of several inputs – in this case labor and capital with weights based on the share of each input in total factor costs.

The main conclusions from Table 3 are as follows. First, annual TFP growth was especially strong in 1994 and 1995 (4.96 and 4.40 percent, respectively), which probably has to do in part with cyclical forces – remember that Sweden escaped from a large recession in the middle of the 1990s. Second, the contribution from aggregate capital deepening to labor productivity growth is negative in 1994 and 1995. A negative contribution to productivity growth from aggregate capital deepening is a rather uncommon empirical finding, especially over longer periods of time. One possible reason for why capital per hours worked declined in 1994–1995 is that it represents a surge in working hours in the aftermath of the 1991–93 recession years (that is, this is a cyclical effect). Other potential explanations include various difficulties concerning, in particular, the measurement of capital inputs. For example, capital per hours worked may fall as a result of the implicit assumptions that are made in the construction of the data as regards the capital depreciation rate and the price of capital. Both a higher assumed computer hardware and software depreciation rate and an underestimation of the true quality-adjusted price decline of computer hardware and software will lead to an underestimation of the growth rate of computer capital, which, in turn, will drive down the capital-labor ratio. Third, the productivity contribution from ICT capital equipment has increased during the period – from 0.12 percentage points in 1994 to 1.09 percentage points in 2000 (see line 7).⁴⁷ These numbers imply that the contribution from ICT capital deepening to labor productivity growth has increased from almost 8 percent in 1994 to 27 percent in 2000 – hence the importance of ICT equipment for aggregate productivity growth has increased over the period. A fourth finding is that the productivity growth contribution from labor quality is 0.2 percentage points per year on average – a result that seems to be in line with what is found in other countries. Hence, in short, labor productivity growth in the

⁴⁷ Note that this table is preliminary, and that it will (without doubt) be revised somewhat later on in the future. In particular, more work is needed on the hedonic prices in general and on the user-cost-of-capital calculations. In addition, true capital input can be more accurately measured by capital-services measures rather than with (as is the case here) capital stock measures.

Swedish business sector is to a pretty large extent driven by rising ICT-related capital deepening, a more productive labor force, and rising TFP growth. The growth-accounting model does not, however, say anything about why ICT-related capital deepening, labor quality, and TFP growth have progressed in this way – in order to answer this we need other models.⁴⁸

Tables 4–7 repeat this exercise for Denmark, Finland, and Norway.

Table 4 Accounting for productivity growth – Denmark
The business sector (ISIC 01-95)

	94-00	94	95	96	97	98	99	00
1 Growth in output	3.8	5.7	4.1	2.4	3.4	2.5	3.8	4.8
2 Growth in hours worked	1.0	-1.3	1.7	0.0	1.2	2.0	1.2	2.3
3 Growth ALP	2.8	7.0	2.4	2.3	2.1	0.5	2.6	2.4
4 Capital deepening	0.7	1.2	0.3	1.0	0.6	0.5	0.8	0.4
5 Buildings								
6 Machinery								
7 ICT	0.7	0.7	0.6	0.8	0.6	0.7	0.8	0.5
8 Labor quality	0.2	0.2	0.2	0.2	0.3	0.3	0.2	0.2
9 Growth in TFP	1.8	5.6	1.9	1.0	1.2	-0.3	1.5	1.9

Note: Data for the productivity growth contribution from buildings and machinery are missing.
Source: Statistics Denmark.

Table 5 Accounting for productivity growth – Finland
The whole economy

	96-02	96	97	98	99	00	01	02
1 Growth in output	4.1	2.4	7.1	6.0	2.7	6.2	1.6	2.6
2 Growth in hours worked	1.6	1.3	3.1	1.4	2.7	1.4	0.6	0.6
3 Growth ALP	2.5	1.1	4.0	4.5	0.0	4.9	1.1	2.0
4 Capital deepening	0.5	0.0	-0.3	0.6	0.3	0.7	1.2	1.0
5 Dwellings	0.1	0.0	-0.1	0.1	0.0	0.1	0.2	0.2
6 Other capital	-0.1	-0.3	-0.4	0.0	-0.4	-0.1	0.1	0.1
7 ICT	0.6	0.3	0.3	0.5	0.6	0.8	0.9	0.7
8 Labor quality	0.2	0.0	0.1	0.2	0.0	0.4	0.1	0.4
9 Growth in TFP	1.8	1.1	4.2	3.7	-0.3	3.7	-0.3	0.5

Note: ICT-deflators are quality-adjusted.
Source: Jalava and Pohjola (2005).

⁴⁸ So-called endogenous growth models are, in general, better equipped for these kinds of questions.

Table 6 Accounting for productivity growth – Norway
The business sector (ISIC 01-95)

	94-00	94	95	96	97	98	99	00
1 Growth in output	4.9	7.0	5.8	6.2	6.9	2.0	2.4	3.7
2 Growth in hours worked	1.4	1.5	1.4	1.5	3.3	2.8	0.3	-0.8
3 Growth ALP	3.4	5.5	4.3	4.7	3.4	-0.8	2.1	4.6
4 Capital deepening	0.7	-0.2	0.3	0.7	0.5	0.7	1.3	1.3
5 Buildings	0.2	0.1	0.1	0.2	-0.2	0.2	0.5	0.6
6 Machinery	0.0	-0.4	0.0	0.0	0.1	-0.1	0.3	0.4
7 ICT	0.4	0.1	0.3	0.5	0.6	0.6	0.5	0.3
8 Labor quality								
9 Growth in TFP	2.8	5.7	4.0	4.0	3.0	-1.5	0.8	3.3

Note: This is the total business sector (i.e., mainland plus offshore). Data for labor quality are missing.
Source: Statistics Norway.

According to the tables, TFP growth in Denmark and Norway was especially strong in 1994 and 1995 (as was the case for Sweden). For Finland, TFP growth appears to have been particularly strong in 1997 and 1998 (the table does not show the growth rates for 1994 and 1995). In addition, the TFP growth rate in Finland reaches negative values both in 1999 and 2001 – a finding that, at first glance, may seem surprising because it suggests that the level of technology moves backwards. However, measures of TFP growth rates are, as a matter of simple calculation (TFP growth is a residual), rough approximations of the true level of technology, and, as such, it can sometimes be negative (and it should always be interpreted liberally). TFP growth is, for example, always model dependent, which implies that different models usually yield different estimates of TFP growth. The best way to look at TFP growth is probably as just a residual, showing the part of actual growth that is not (yet) explained by the right-hand-side variables – the simple logic is that the more detailed the production function is, the smaller will TFP growth probably be. Yet, it seems reasonable to believe that the high TFP growth rates around 1994-1995 have something to do with cyclical forces (the escape from the recession in the early 1990s).

Tables 4-6 also show that the capital-deepening effect is at times negative also for the other Nordic countries (as was the case for Sweden): -0.3 in 1997 for Finland, and -0.2 in 1994 for Norway. As mentioned above, negative capital deepening may represent a surge in working hours – for example, in the aftermath of the recession in the early 1990s (e.g., Norway in 1994). The tables also reveals that the productivity contribution from ICT capital deepening has, in general, increased over time, both in terms of percentage points (most noticeable for Finland and Sweden) and expressed as a share of labor productivity growth. Some observations (years) stand out, however, namely 1998 for Denmark, when the contribution from ICT constituted 140 percent of labor productivity growth, 2001 for Finland, when the growth contribution from ICT was 81 percent,

and 1996 for Sweden, when the growth contribution from ICT was 62 percent. These numbers may, of course, seem surprisingly large.⁴⁹

Finally, the tables show that the growth contribution from a rising educational attainment (i.e., the labor-quality effect) is also roughly the same for the Nordic countries – about 0.2 percentage points per year appears to be a good benchmark. However, the labor-quality effect sometimes fluctuates more than expected, which may be a sign of measurement difficulties. For example, the labor quality effect in Finland is 0.0 percentage points in 1996 and 1999, and 0.4 percentage points in 2000 and 2002. It would, of course, be interesting too see why the labor quality effect has evolved in this way. A more careful analysis of this, however, requires all information that is used in the construction of these labor-quality indices – and, hence, such an analysis is rather complex (and hence lies outside the scope of this study).

Much scope remains, however, to distinguish between cyclical and structural productivity gains. Bearing in mind that the Nordic countries escaped from a large recession in the middle of the 1990s, this distinction between fluctuation and trend seems crucial. Due to data limitations, however, this is postponed to future work. Another issue is causality. Even though the exercise above suggests that ICT capital investments improve productivity growth, it could also be the other way around – strong productivity growth would then lead to investments in ICT capital. Data limitations preclude a closer analysis of this as well.

Another issue is, as mentioned above, the negative effect from capital deepening. For example, in Sweden this is the case in 1994 and 1995, for Finland in 1997, and for Norway in 1994. The tables also show that buildings as well as machinery exclusive of ICT sometimes exhibit negative capital deepening, but that this is never the case for ICT capital equipment. This is, of course, an interesting finding. A negative capital deepening effect may, as mentioned above, be a sign of a surge in working hours in the aftermath of the recession in the early 1990s. Another possible explanation is that it represents various difficulties as regards the measurement of true capital inputs. For example (as also mentioned above) measured capital per hours worked depends on the assumptions made about capital's depreciation rate as well as price. It is also possible that measured capital underestimates true capital input in the sense of the effective (or flow of services from) capital.

The use of ICT

Another issue is the question of whether or not there is a link between ICT use (rather than production) and gains in TFP. The answer to this question determines if ICT-related capital deepening can be characterized as *productive* or *unproductive*. Indeed, during the 1990s, firms invested

⁴⁹ Note that all difficulties as regards the computation of real ICT capital equipment (e.g., depreciation rates and price deflators) make this kind of comparisons very uncertain.

heavily in ICT in the hope of improving profits and productivity. Potential gains from ICT could be realized through a number of channels, such as productive spillovers and network effects due to faster information flows within (and between) firms and plants. If investments in ICT capital equipment really result in TFP gains, one would expect to see a link between ICT-investment and gains in TFP across industries. Such a link would allow industries, and the economy as a whole, to produce more output for any given amount of inputs – and thus it would imply a true economic benefit from the ICT revolution. The present analysis cannot, however, shed much light on this issue due to data limitations (too short time series data).⁵⁰

The production of ICT

The production of ICT capital equipment is another issue. It lays beyond the scope of the present work to analyze this in any detail. However, some insights can certainly be obtained from simple tables showing how output per employee and hours worked as well as hours per employee evolve over time in different sectors. Tables 7-11 show this for the Nordic countries (in alphabetical order) for a set of sectors – for the usual business, goods, services, and manufacturing sectors as well as for a set of other sectors (the same for all countries), and then, finally, for some additional sectors for Iceland (fishing) and Norway (oil/shipping) that reflect country-specific characteristics.

Table 7. Denmark: Production per person and hour & Hours per person
Relative to the business sector (all figures in percent), Within-country analysis

	Production per person			Production per hour			Hours per person		
	1980	1990	2000	1980	1990	2000	1980	1990	2000
Business	100	100	100	100	100	100	100	100	100
Goods	86	95	108	78	85	95	111	112	113
Services	108	102	97	115	108	102	94	95	95
Manufacturing	95	93	104	96	91	99	99	102	105
Construction	93	94	84*	83	83	71*	112	113	117*
Electricity etc.	340	341	436	345	339	412	99	101	106
Financial interm.	187	213	188	208	232	223	90	92	84
Renting/Business	94	105	96	92	99	91	103	106	105
Railway transp.	125	111	91	114	101	78	110	110	117
Air transp.	223	204	125	219	198	118	102	103	105
Wholes./Retail tr.	93	89	93	90	88	97	103	102	96
Post/Courier	77	99	138	85	110	142	90	90	97
Taxi	-	-	-	-	-	-	-	-	-
Telecom.	-	-	-	-	-	-	-	-	-
ICT	-	-	-	-	-	-	-	-	-

Note. All figures are expressed as a share of the complete business sector. A * superscript implies that the actual date is 1994 rather than 2000 (due to lack of data).

⁵⁰ In order to investigate the importance of ICT use for productivity growth, some attempts have now been made to construct indices of ICT-intensity. For example, these calculations have now been made in Norway and Sweden. The next step, obviously, is to see how these measures relate to labor productivity growth and TFP growth.

Table 8. Finland: Production per person and hour & Hours per person
Relative to the business sector (all figures in percent), Within-country analysis

	Production per person			Production per hour			Hours per person		
	1980	1990	2000	1980	1990	2000	1980	1990	2000
Business	100	100	100	100	100	100	100	100	100
Goods	83	86	98	80	83	95	104	104	104
Services	125	115	102	132	121	105	95	95	97
Manufacturing	82	94	115	92	106	129	90	89	89
Construction	132	102	74	114	88	61	116	116	120
Electricity etc.	166	169	181	189	191	208	88	88	87
Financial interm.	152	169	189	183	193	220	83	87	86
Renting/Business	173	103	74	175	112	78	99	92	94
Railway transp.	61	54	73	71	63	84	85	87	87
Air transp.	166	193	196	204	220	222	81	88	88
Wholes./Retail tr.	88	85	70	88	88	72	100	97	97
Post/Courier	55	57	66	77	75	80	71	76	82
Taxi	142	100	68	132	89	58	108	112	117
Telecom.	69	110	237	80	121	264	87	91	90
ICT	78	98	169	86	108	182	91	91	93

Note. All figures are expressed as a share of the complete business sector.

Table 9. Iceland: Production per person and hour & Hours per person
Relative to the business sector (all figures in percent), Within-country analysis

	Production per person			Production per hour			Hours per person		
	1980	1990	2000	1980	1990	2000	1980	1990	2000
Business	100	100	100	100	100	100	100	100	100
Goods	109	102	105	-	-	-	-	-	-
Services	89	98	96	-	-	-	-	-	-
Manufacturing	121	86	88	-	-	-	-	-	-
Construction	87	95	94	-	-	-	-	-	-
Electricity etc.	314	364	393	-	-	-	-	-	-
Financial interm.	115	127	142	-	-	-	-	-	-
Renting/Business	-45	42	-1	-	-	-	-	-	-
Railway transp.	-	-	-	-	-	-	-	-	-
Air transp.	-	-	-	-	-	-	-	-	-
Wholes./Retail tr.	101	112	111	-	-	-	-	-	-
Post/Courier	40	91	214	-	-	-	-	-	-
Taxi	-	-	-	-	-	-	-	-	-
Telecom.	-	-	-	-	-	-	-	-	-
ICT	-	-	-	-	-	-	-	-	-
Fishing industry	107	124	109	-	-	-	-	-	-

Note. All figures are expressed as a share of the complete business sector.

Table 10. Norway: Production per person and hour & Hours per person
Relative to the business sector (all figures in percent), Within-country analysis

	Production per person			Production per hour			Hours per person		
	1980	1990	2000	1980	1990	2000	1980	1990	2000
Business	100	100	100	100	100	100	100	100	100
Goods	115	141	147	108	131	135	106	108	109
Services	86	72	73	92	77	77	94	94	95
Manufacturing	104	96	73	107	96	71	98	100	103
Construction	83	76	64	80	72	58	104	105	109
Electricity etc.	309	258	228	313	267	234	99	96	97
Financial interm.	151	107	137	162	111	136	93	96	100
Renting/Business	134	95	64	159	103	69	84	92	93
Railway transp.	103	62	48	103	59	45	100	106	106
Air transp.	218	175	93	211	168	90	103	104	104
Wholes./Retail tr.	56	51	64	60	55	70	93	92	92
Post/Courier	90	62	53	103	79	65	87	79	82
Taxi	93	86	54	88	80	52	107	107	104
Telecom.	20	37	132	21	39	130	97	96	102
ICT	48	65	91	48	65	87	98	100	104
Oil/shipping	497	689	754	422	577	625	118	119	121

Note. All figures are expressed as a share of the complete business sector (hence, not as a share of the mainland business sector).

Table 11. Sweden: Production per person and hour & Hours per person
Relative to the business sector (all figures in percent), Within-country analysis

	Production per person			Production per hour			Hours per person		
	1980	1990	2000	1980	1990	2000	1980	1990	2000
Business	100	100	100	100	100	100	100	100	100
Goods	73	81	100	73	79	95	100	101	105
Services	130	117	100	129	118	103	100	99	97
Manufacturing	68	73	108	72	77	107	94	95	101
Construction	86	83	66	80	74	60	108	111	110
Electricity etc.	264	322	278	274	322	264	96	100	105
Financial interm.	198	185	150	203	202	161	98	92	93
Renting/Business	145	120	89	135	124	90	107	97	98
Railway transp.	30	30	62	29	29	60	104	104	103
Air transp.	216	243	134	196	248	135	110	98	99
Wholes./Retail tr.	68	68	71	64	66	71	107	103	100
Post/Courier	66	67	55	72	72	66	92	93	83
Taxi	135	82	66	115	69	57	117	119	116
Telecom.	88	116	165	79	117	181	111	99	91
ICT	-	-	-	-	-	-	-	-	-

Note. All figures are expressed as a share of the complete business sector.

The tables show that the decline in the goods sector's share in total hours is typically larger than that of total output. This, finding (which, however, is not true for Iceland) suggests that the relative output per hours worked has increased in the goods sector since at least the early 1980s. This means that the ongoing shifting out of goods production into services in Denmark, Finland, Norway, and Sweden since at least the beginning of the 1980s has resulted in a (relatively) higher labor productivity level in the goods sector. The flip side is a relatively lower productivity level in the services sector. For Iceland, in contrast, the shifting out of goods production appears to (at least so far) have resulted in lower productivity in

the goods sector.⁵¹ The reason is that for Iceland, the decline in the goods sector's share in total employment is lower than that of total output. The analysis thus supports the idea that a rising share of the service sector (services industries) in the Nordic countries (not Iceland) have contributed to a slower productivity growth for the business sector as a whole. However, the analysis also shows that this slower growth has, at least to some extent, been counteracted by a relatively high productivity level in the services sector. Hence, the net effect of a growing services sector on (the growth and level of) productivity in the business sector is, as a consequence, likely to be smaller than what the shifting in (out) of services (goods) seems to suggest. Yet another possible counteracting factor is that the services sector is, in general, a fairly large user of (presumably highly productive) ICT capital equipment.

Labor's Scholarly Proficiency

Yet another potential reason why relative productivity changes over time is (as was also described in Tables 3-6) that it reflects parallel changes in the relative quality of the labor force. The underlying logic is that a gradual improvement in the quality of the labor force implies that measured labor productivity improves. In general, this quality effect represents a shift in the labor force towards more productive workers – labor input of some educational levels or types grows (falls) which has higher (lower) productivity than the average. Forsling and Lindström (2004), for example, found that a gradual change in the composition of the labor force in Swedish manufacturing has raised labor productivity growth by about 0.2 percentage points per year during the 1990s. They also found that the labor productivity effect has been larger in the services sector than in the goods sector, and that it reflects a growing share of employees with an economics or engineering bachelor's degree. This effect is, however, by no means a new phenomenon – on the contrary, it simply mirrors the increasing educational attainment of each new generation of employees. The flip side, of course, is a falling share of employees with only compulsory education. Similar results are also found for Denmark (see, e.g., Stenbaek and Sejerbo Sorensen (2004)) and for Finland (see Javalala and Pohjola (2005)). Studying the productivity effects of a rising educational attainment is, of course, interesting in its own right – but given the large similarities between the Nordic countries, there is no reason (we think) to believe that the development of relative labor quality can explain why relative productivity has change over time. This conclusion is also consistent with Tables 3-6.

⁵¹ Note again that we lack information on hours worked for Iceland. As a consequence, Iceland's labor productivity is (in this Report) computed as output per employee, and not as output per hours worked.

The growth literature regularly stresses the importance of human capital formation for economic development. Important contributions include, for example, Lucas (1988), who developed a theoretical model of growth where economic agents choose how much to invest in physical capital and how much to invest in non-physical (intangible) capital.⁵² Another contribution is Ho and Jorgenson (2001), who argued that a rising quality in the labor force has contributed about 0.6 percentage points to annual labor input growth, and that most of this effect originates from rising levels of formal schooling.⁵³

However, measuring the level of human capital is, of course, not easy in practice. For example, Mulligan and Sala-i-Martin (2000) argued that the level of education (i.e., the years of schooling) is not necessarily a good measure of knowledge. One important reason for this is that this measure implicitly assumes that productivity differences among employees with different levels of education are proportional to differences in the number of years of schooling. This is, of course, hardly the case. Another reason is that an extra year of education is assumed to give the same increase in human capital irrespectively of the field of study or the quality of the teachers.⁵⁴

The present study does not pursue this human-capital route any further. The reason is that all the above-mentioned difficulties (and others) are simply too large to be solved here. This does not mean, however, that changes in the labor force, in terms of the level of human capital, is necessarily superfluous while trying to explain short- and long-term movements in relative productivity. On the contrary, focusing on the productivity growth effects of educational skills is important, and it certainly deserves more attention.

⁵² Another example of the growing interest in human capital formation is the recently published manual of productivity measurement by the OECD (2001), which both provides an important step toward improving the official statistics in the OECD and highlights the value of accounting properly for the change in the quality of the labor force (see, e.g. Jalava (2002)).

⁵³ This study looked at U.S. data from 1948 through 1995.

⁵⁴ Judson (2002) exemplified these difficulties while using government expenditures on education as an approximating variable for human capital. This measure is, of course, a rougher estimate of human capital than is the years of schooling because it is based on money outlays rather than the characteristics of the labor force.

4. Concluding Remarks

This Report is the product of a joint Nordic effort to bring together the analytical and data work from each of the Nordic countries in order to boost progress in terms of analysis and data production for the region as a whole. The Report also presents new analysis (at least to our knowledge).

The analysis begins with the simple observation that the real wage per employee in the Nordic countries is positively related to the level of labor productivity. This finding is obtained through scatter-plot diagrams – one plot per country and year from the early 1980s onwards – showing the relative wage per employee against relative labor productivity. This positive relationship suggests that changes in the relative standard of living in the Nordic countries have been driven by parallel changes in relative productivity.

The analysis also suggests that wages per employees have, in general, been higher in Denmark, Iceland, and mainland Norway than in Sweden, and that these higher wages do not appear to be correlated with higher productivity. The scatter-plots also show that relative wages per employees have been largest in the total business sector in Norway, and that these wages have been correlated by higher productivity.

The analysis also provides strong support for so-called absolute β -convergence among the Nordic countries. Hence, the initial differences between the countries (i.e., the differences in 1980), in terms of real output per employee, real output per hour, and real wage per employee, slowly fade away over time. This holds for the business sector as a whole, as well as for the goods, services and manufacturing sector. This finding tells us that the Nordic countries are not in fact that different when it comes to the steady-state values in the neoclassical model of economic growth – hence, it suggests that the Nordic countries are characterized by roughly the same saving rate, level of the production function, and government policies (which can shift the production function down and up).

This study also shows that the decline in the goods sector's share in total hours is typically larger than that of total output. This, finding – which, however, is not true for Iceland – suggests that the relative output per hours worked has increased in the goods sector since at least the early 1980s. The implication thus is that the ongoing shifting out of goods production into services since at least the beginning of the 1980s has resulted in a relatively higher labor productivity level in the goods sector.

The study also brings together some earlier growth-accounting results from the Nordic countries (not for Iceland). A quick comparison reveals that Denmark, Finland, Norway, and Sweden are pretty similar – for example, it appears as if the productivity growth contribution from ICT-

capital deepening has been approximately the same across the countries (although there are some differences), and shifts in the labor force also yield similar productivity effect.

The questions addressed in this article have important implications for the economy as a whole and for macroeconomic policymakers. Consider for example the question whether productivity gains have occurred in the universe of industries or just in a few. If productivity increases are general, the productivity revival is probably more robust than would otherwise have been the case. Moreover, if the productivity increase is general, the resulting income and economic gains are very likely to be distributed more evenly over all industries, implying that it is also distributed more evenly over all employees – and because the distribution of income directly affects the well-being of employees this is, of course, of large importance for macroeconomic policymakers.

Sammanfattning

Analysen finner att det finns ett positivt samband mellan reallö-
neutvecklingen per anställd och arbetsproduktiviteten. Med andra ord
beror reallönen per anställd i hög grad på nivån på arbetsproduktiviteten.
Detta positiva samband indikerar att förändringar i relativ levnadsstan-
dard i de nordiska länderna har drivits av parallella förändringar i relativ
produktivitet.

Analysen visar också att lönen per anställd generellt har varit högre i
Danmark, Island och Norges fastlandsekonomi än i Sverige, och att dessa
högre löner inte verkar vara korrelerade med högre produktivitet i dessa
länder jämfört med Sverige.

Därtill ger analysen stöd åt så kallad absolut -konvergens bland de
nordiska länderna. Detta betyder att initiala skillnader mellan dessa län-
der, i termer av förädlingsvärdet per anställd, förädlingsvärdet per timme
och reallön per anställd, långsamt försvinner över tiden. Detta resultat
indikerar att de nordiska länderna inte är så olika vad gäller sparbeteende,
produktionsteknologi och politik.

Ett annat resultat är att andelen arbetade timmar i den varuproduce-
rande sektorn har minskat mer än denna sektors andel av produktionen.
Detta resultat – som dock inte stämmer för Island – indikerar att den rela-
tiva produktionen per timme har ökat i varusektorn sedan åtminstone
början av 1980-talet. Implikationen är att den gradvisa övergången från
varusektorn till fler arbetade timmar i näringslivets tjänstesektor har re-
sulterat i en relativt högre arbetsproduktivitet i varusektorn.

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Appendix A – Country-Specifics

Although the Nordic countries are similar in many respects, such as, for example, the flat income distribution and the wide-ranging welfare system, there are also differences. While presenting the development of some sector shares over time, Table A.1 below illustrates some of this diversity. In particular, Iceland's economy stands out in this sample of countries because it depends so heavily on the fishing industry. Norway is also a lot different because it is so highly dependent on its oil production (only Russia and Saudi Arabia export more oil than Norway).

Before looking at the table, however, it is important to recognize that output are (in the table) measured in terms of current prices, and that the computed output shares may, as a consequence, differ from the real output shares. This is, in particular, the case for Iceland, where the real output shares of the goods sector are 63, 50, and 45 (1990-prices) percent for 1980, 1990, and 2000 (rather than 56, 50, and 43 as in Table A.1). While considering real shares (which thus are computed from the same data that are used for the relative productivity figures in Table 9) it is clear that for Iceland the decline in the goods sector's share in the total number of employees (in the business sector) is less than the decline in the goods sector's share in total real output (-14 percentage points as compared with -18 percentage points). This shifting out of goods production has, as a consequence, resulted in a comparatively weaker labor productivity level (measured as the ratio of real output to the number of employees) in the goods sector – and this finding, in fact, differ from what is found for the other Nordic countries, where the decline in the goods sector's share in total hours is always larger than that of total output (c.f. Table A.1 and Tables 7-11).

Table A.1. Sector shares

Relative to the business sector (all figures in percent), Current Prices

	1980			1990			2000		
	N	NH	Y	N	NH	Y	N	NH	Y
Denmark									
Business*									
Goods	36	40	34	31	35	31	27	31	30
Services	64	60	66	69	65	69	73	69	70
Manufacturing	19	19	19	18	18	17	15	16	16
ICT	4.24	-	3.76	4.75	-	5.14	5.22	-	5.70
Finland									
Business*									
Goods	59	62	56	52	54	50	47	49	46
Services	41	38	44	48	46	50	53	51	54
Manufacturing	32	28	33	28	25	28	28	25	32
ICT	3.47	3.14	3.97	4.29	3.88	5.38	7.77	7.24	13
Iceland									
Business*	84	-	70	82	-	76	81	-	82
Goods	57	-	56	49	-	50	43	-	43
Services	42	-	44	51	-	50	57	-	57
Manufacturing	29	-	23	23	-	19	21	-	17
Fishing/Fish proc.	17	-	19	14	-	18	11	-	12
ICT	0.00	-	0.00	-	-	0.88	-	-	1.63
Norway									
Business*,		77	70		72	68		71	70
Business*, Mainland		73	52		69	52		67	45
Goods	49	52	55	42	45	50	37	40	55
Services	51	48	45	58	55	50	63	60	45
Manufacturing	26	26	21	21	21	17	20	20	14
Oil/shipping	3.44	4.06	25	4.16	4.96	23	4.40	5.31	36
ICT	2.93	2.88	2.91	3.07	3.08	3.99	4.40	4.59	4.03
Sweden									
Business*									
Goods	53	53	49	46	47	44	39	41	39
Services	47	47	51	54	53	56	61	59	61
Manufacturing	34	32	29	30	28	27	26	26	28
ICT	-	-	-	-	-	-	-	-	-

Note. A * superscript means that the figures relates to the total economy. Note that shares exceeding 10 percent are shown without decimals. For Norway, the Goods, Services, Manufacturing, and Oil/Shipping figures relate to the total Norwegian business sector (i.e., not only the mainland business sector).

Appendix B – Relative productivity and wage

This appendix shows the same diagrams for the goods, services, and manufacturing sector as was shown in the main text for the business sector.

Diagram B.1.1. Current prices and exchange rates

The Goods sector

Relative wage per employee on the y-axis, Relative labor productivity on the x-axis

Note. Denmark is marked by circles, Finland by triangles, Iceland by crosses, and Norway by quadrates. The correlation coefficient in the diagram is 0.35.

Diagram B.1.2. Constant prices and current exchange rates

The Goods sector

Relative wage per employee on the y-axis, Relative labor productivity on the x-axis

Note. Denmark is marked by circles, Finland by triangles, Iceland by crosses, and Norway by quadrates. The correlation coefficient in the diagram is 0.78.

Diagram B.1.3. Constant prices and exchange rates

The Goods sector

Relative wage per employee on the y-axis, Relative labor productivity on the x-axis

Note. Denmark is marked by circles, Finland by triangles, Iceland by crosses, and Norway by quadrates. The correlation coefficient in the diagram is 0.66.

Diagram B.2.1. Current prices and exchange rates

The Services sector

Relative wage per employee on the y-axis, Relative labor productivity on the x-axis

Note. Denmark is marked by circles, Finland by triangles, Iceland by crosses, and Norway by quadrates. The correlation coefficient in the diagram is 0.46.

Diagram B.2.2. Constant prices and current exchange rates

The Services sector

Relative wage per employee on the y-axis, Relative labor productivity on the x-axis

Note. Denmark is marked by circles, Finland by triangles, Iceland by crosses, and Norway by quadrates. The correlation coefficient in the diagram is 0.60.

Diagram B.2.3. Constant prices and exchange rates

The Services sector

Relative wage per employee on the y-axis, Relative labor productivity on the x-axis

Note. Denmark is marked by circles, Finland by triangles, Iceland by crosses, and Norway by quadrates. The correlation coefficient in the diagram is 0.56.

Diagram B.3.1. Current prices and exchange rates

The Manufacturing sector

Relative wage per employee on the y-axis, Relative labor productivity on the x-axis

Note. Denmark is marked by circles, Finland by triangles, Iceland by crosses, and Norway by quadrates. The correlation coefficient in the diagram is 0.15.

Diagram B.3.2. Constant prices and current exchange rates

The Manufacturing sector

Relative wage per employee on the y-axis, Relative labor productivity on the x-axis

Note. Denmark is marked by circles, Finland by triangles, Iceland by crosses, and Norway by quadrates. The correlation coefficient in the diagram is 0.77.

Diagram B.3.3. Constant prices and exchange rates

The Manufacturing sector

Relative wage per employee on the y-axis, Relative labor productivity on the x-axis

Note. Denmark is marked by circles, Finland by triangles, Iceland by crosses, and Norway by quadrates. The correlation coefficient in the diagram is 0.78.

Diagram B.4.1. The development of relative labor productivity from 1980 onwards

The Business sector, Constant prices and exchange rates

Note. Denmark is marked by circles, Finland by triangles, Iceland by crosses, and Norway by quadrates.

Diagram B.4.2. The development of relative labor productivity from 1980 onwards
The Goods sector, Constant prices and exchange rates

Note. Denmark is marked by circles, Finland by triangles, Iceland by crosses, and Norway by quadrates.

Diagram B.4.3. The development of relative labor productivity from 1980 onwards
The Services sector, Constant prices and exchange rates

Note. Denmark is marked by circles, Finland by triangles, Iceland by crosses, and Norway by quadrates.

Diagram B.4.4. The development of relative labor productivity from 1980 onwards
The Manufacturing sector, Constant prices and exchange rates

Note. Denmark is marked by circles, Finland by triangles, Iceland by crosses, and Norway by quadrates.

Diagram B.5.1. The development of relative wage per employee from 1980 onwards
The Business sector, Constant prices and exchange rates

Note. Denmark is marked by circles, Finland by triangles, Iceland by crosses, and Norway by quadrates.

Diagram B.5.2. The development of relative wage per employee from 1980 onwards
The Goods sector, Constant prices and exchange rates

Note. Denmark is marked by circles, Finland by triangles, Iceland by crosses, and Norway by quadrates.

Diagram B.5.3. The development of relative wage per employee from 1980 onwards
The Services sector, Constant prices and exchange rates

Note. Denmark is marked by circles, Finland by triangles, Iceland by crosses, and Norway by quadrates.

Diagram B.5.4. The development of relative wage per employee from 1980 onwards
 The Manufacturing sector, Constant prices and exchange rates

Note. Denmark is marked by circles, Finland by triangles, Iceland by crosses, and Norway by quadrates.

Appendix C – Growth Accounting

C.1 Relating Input and Output Growth

Consider a general production function $Y = F(K, L, V)$ for a single firm, where Y is value-added output (i.e., gross output net of intermediate inputs). Capital and labor inputs are denoted by K and L . V is an index of the level of technology.⁵⁵ Let the production function F be homogenous of degree γ in capital and labor, and of degree one in V . Logarithmic differentiating of F yields:

$$d \ln Y = \gamma d \ln K + \left(\frac{F_L L}{Y} \right) (d \ln L - d \ln K) + d \ln V, \quad (\text{C.1})$$

where $d \ln Y$, $d \ln K$, $d \ln L$, and $d \ln V$ are the growth rates of Y , K , L , and V . F_L is the marginal product of labor. The homogeneity conditions $(F_K K + F_L L)/Y = \gamma$ and $F_V V/Y = 1$ have been used in the derivation of (C.1). This model thus compares movements in output with movements in factor inputs and, accordingly, relates to the growth accounting literature originating from Solow (1957). The growth rate of technology is the so-called Solow residual.

Equation (C.1) can be simplified by making the assumptions that firms have some monopoly power in output markets, but not necessarily in the market for factor inputs, and that the behavior of firms can be approximated by a sequence of static problems. A simple expression for the ratio $F_L L/Y$ can then be found by assuming that a representative firm (to facilitate the presentation, the firm is now indexed by i) faces the demand function $Y_i = (P_i / P)^{-\eta} (M / P)$. The price level of firm i 's output is denoted by P_i , P is the general price level, M is the monetary base, and η is the elasticity of demand.

The firms are assumed to maximize the profit function $\pi_i = P_i Y_i - w L_i - r K_i$ with respect to labor and capital inputs in every time period. The wage rate w and capital cost r are taken as given by the firms. The two first-order conditions are:

⁵⁵ This level is often referred to as the level of the Total or Multi Factor Productivity (TFP or MFP).

$$\begin{aligned} P_i \mu^{-1} F_L &= w, \\ P_i \mu^{-1} F_K &= r, \end{aligned} \quad (C.2)$$

where $\mu = \eta/(\eta - 1)$ is the markup factor. Now, let α_v denote labor's share in total value-added output, that is $\alpha_v = wL_i / P_i Y_i$, and use the first relation in (C.2) to obtain $\mu \alpha_v = F_L L_i / Y_i$.⁵⁶ By combining the two first-order conditions with the homogeneity condition $(F_K K + F_L L)/Y = \gamma$, the product $\mu \alpha_v$ can be rewritten in terms of the (internal) returns-to-scale parameter γ and labor's share in total factor costs α_c :

$$\frac{P_i Y_i}{wL_i + rK_i} = \frac{\mu}{\gamma} \Leftrightarrow \mu \alpha_v = \gamma \alpha_c, \quad (C.3)$$

where $\alpha_c \equiv wL_i / (wL_i + rK_i)$. Substitution of $\gamma \alpha_c$ for $F_L L / Y$ in (C.1) yields the basic equation that is used in this study:

$$d \ln Y_{it} = \gamma_{it} d \ln X_{it} + d \ln V_{it}, \quad (C.4)$$

where dX_{it} is a weighted index of input growth:

$$d \ln X_{it} \equiv \alpha_{cit} d \ln L_{it} + (1 - \alpha_{cit}) d \ln K_{it}. \quad (C.5)$$

The variables and parameters are now written with firm as well as time subscripts to emphasize that they can change across firms as well as over time.

Equations (C.4) and (C.5) can be re-formulated in terms of labor productivity growth (instead of output growth) by assuming constant returns to scale and subtracting the growth rate of hours worked from both sides. Equation (C.6) splits labor productivity growth into capital deepening in the sense of capital per hour worked (the more capital there is per hour worked, the higher is labor productivity) and total factor productivity growth (higher TFP means higher ALP):

$$d \ln y_{it} = d \ln Y_{it} - d \ln L_{it} = d \ln x_{it} + d \ln V_{it}. \quad (C.6)$$

The growth of weighted inputs per worked hour is defined as:

⁵⁶ When input and output markets are competitive, the required conditions for producer equilibrium are that the share of every input in the value of output equals the output elasticity with respect to that input. It follows that under constant returns to scale (CRS) the value of output is equal to the total cost of the production factors, and hence the share of labor in output then equals the share of labor in total factor costs.

$$d \ln x_{it} = d \ln X_{it} - d \ln L_{it} \equiv (1 - \alpha_{cit}) d \ln k_{it}, \quad (C.7)$$

and

$$d \ln k_{it} = d \ln K_{it} - d \ln L_{it}. \quad (C.8)$$

C.2 Capital and labor

The real stock of capital is often split into (at least) three different types of capital: the first is *buildings*, the second is *machinery & equipment* exclusive of ICT equipment, and the third is *ICT equipment*. ICT equipment includes computer hardware and software as well as telecommunications equipment. By dividing real capital into these three parts yields a detailed analogue of equation (C.7):

$$d \ln x_{it} \equiv \beta_{Bit} d \ln k_{Bit} + \beta_{Mit} d \ln k_{Mit} + \beta_{ICTit} d \ln k_{ICTit}, \quad (C.9)$$

where subscripts B , M , and ICT refer to buildings, machinery & equipment, and ICT, respectively, and where the beta coefficient represents each capital's share in total costs:

$$\beta_{jit} = (1 - \alpha_{cit}) \frac{r_{jit} K_{jit}}{\sum_j r_{jit} K_{jit}}, \quad j = B, M, ICT. \quad (C.10)$$

Labor can (of course) also be split into different subgroups. For example, while experimenting with a number of settings, Forsling and Lindstrom (2004) divided labor into as much as 20 subgroups. They split labor along two dimensions. The first was the *level* of education, as measured by the number of schooling years (the level was categorized into four separate groups). The second was the *type* of education, which captured the particular focus of the education (the type was split into 5 groups).

Now, to facilitate exposition, let A be the set of separate labor types, and L_a the quantity of labor of type $a \in A$. The average wage for labor of type a is w_a . Dividing labor into these types expands equation (C.9) to:

$$d \ln x_{it} \equiv \beta_{Bit} d \ln k_{Bit} + \beta_{Mit} d \ln k_{Mit} + \beta_{ICTit} d \ln k_{ICTit} + \sum_{a \in A} \gamma_{ait} d \ln l_{ait}, \quad (C.11)$$

where $l_{ait} = \frac{L_{ait}}{\sum_a L_{ait}}$ is the share of type a labor in total labor (i.e., share in total cost), and the gamma coefficients represents each factor's

$$\gamma_{ait} = \alpha_{cit} \frac{w_{ait} L_{ait}}{\sum_a w_{ait} L_{ait}}. \quad (\text{C.12})$$

Equation (C.6) and (C.12) capture the essence of the growth-accounting approach. Take notice that if either of the basic assumptions in this model fail to hold, the Solow residual will include other factors than just true technological change.

C.3 Caveats

This section shortly describes some difficulties with the above-referenced growth-accounting approach.

Gross Output v/s Value-added

One limitation is that the data do not include information on intermediate inputs, such as energy, materials, and business services. This lack of information precludes a gross-output formulation of the growth-accounting setup, which, according to most economists, is the first choice.

For example, Basu and Fernald (1995) argued that the use of value-added data in the growth-accounting setup above may cause spurious findings of external-economies effects (i.e., a missing-variable bias) because value-added data may fail to account properly for the productivity contribution of so-called intermediate factor inputs (i.e., energy, materials, and business services). The underlying logic is that real value added should optimally be constructed by subtracting the productivity contribution of energy, material, and business services from real gross output. However, a problem may arise when this contribution of intermediate inputs is measured by the factor payments: When output markets are imperfectly competitive, the marginal products of intermediate inputs exceed their prices, and hence the computed value-added output may, as a consequence, depend directly on parts of the intermediate factors. This may lead to a missing-variable bias (which, in the context of Basu and Fernald's (1995) study was called a false externality effect).

This misspecification, however, can be largely corrected for by including the intermediate factor inputs on the right-hand side in the growth-accounting formulation. This is the reason why a gross-output formulation is typically preferred before a value-added analogue. Due to data limitations, however, this Report solely relies on value-added output.

The Quality of Inputs

Apart from potential measurement errors originating from, for example, the physical data collecting process (and mistakes made by the people collecting the data), one potential limitation of the data used above is that differences in input quality is not completely accounted for. This is most likely the case, even though capital is measured in three different ways. The problem is that there may certainly be more than three types of different types of capital and that the workforce, similarly, is also non-homogenous.⁵⁷

The Quantity of Inputs

Yet another limitation is the lack of information on the utilization rates of the factor inputs. The labor-hoarding hypothesis, for example, emphasizes transaction costs of adjustments in the labor force. According to this hypothesis, firms may find it profitable to substitute labor utilization rates for measured labor inputs when the labor force cannot be modified without hiring and firing costs, implying that effort levels may change over the business cycle instead of measured inputs.

Hence, the theoretical ideal should obviously be input measures adjusted for quality differences as well as utilization rates.⁵⁸

⁵⁷ However, in Basu and Fernald (1995), quality-adjusted workforce and capital data provided roughly the same results as non-adjusted data, suggesting that the induced error of not taking into account input qualities might not always be that crucial.

⁵⁸ Many studies have, in fact, noted the problems associated with the measurement of factor inputs. Griliches (1994), for example, argues that measurement difficulties may be a major cause of the slow progress in our understanding of productivity growth. In addition, due to difficulties in measuring input utilization rates, Benhabib and Jovanovic (1991) treated capital as well as labor as unobservable in some regressions.