Productivity growth dynamics in the EU
a sector level study

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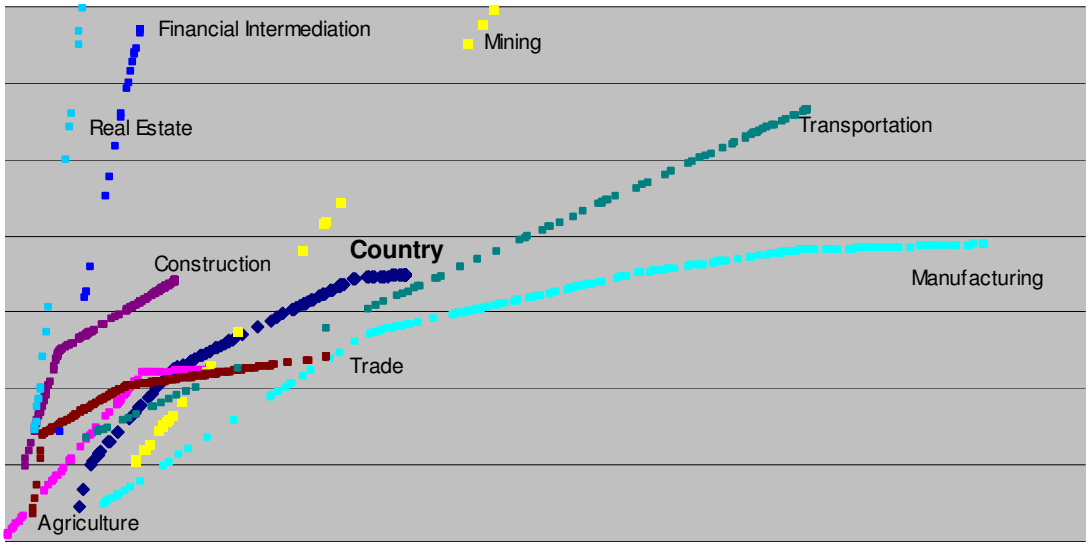

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Executive Summary

This study directly refers to the prime objectives of the EU, growth and becoming a knowledge based economy. It covers the structural change processes, studied from the inter sectoral shift of labor, and the process of technological change. Prime interest is with the growth dynamics. The central research question of this study is:

To what extent have 'structural change' and 'technological change' contributed to growth of labor productivity in the EU member countries in the period 1985-2005

The framework of analysis that is used in this study is a Solow-like framework because it relates labor productivity to the capital intensity. Capital intensity represents the technological advance of countries. Nevertheless countries operate at comparable capital intensities with varying levels of labor productivity.
Additional to this 'technological change' based framework the structural change is analyzed. An addition that, to my knowledge, has never been made before but is interesting because of the ongoing tertiarization, the recently admitted countries that opened up their local markets, and the notion that technological change changes the demand for labor.

Technological change is assessed by a decomposition of growth rates in relation to the productivity frontier. The growth decomposition explains growth by the country performance in the assimilation of knowledge, capital intensification and innovativeness.
Based on the notion that catching up to the frontier is not the simple result of imitation but requires the ability to absorb knowledge to operate the capital equipment, the level of schooling of the workforce is added.
Structural change is assessed with the standard shift-share analysis. This shift-share analysis studies the additional growth that is the result of labor reallocation between sectors.
A correlation analysis between 'technological change' and 'structural change' facilitates the synthesis of both lines of analysis.

It is concluded that the 'technological change', especially in the period 1995 to 2005, is primarily the result of capital intensification. But the lack of innovativeness and growth in this period indicates that countries did not make the necessary adjustments to benefit fully of the new technologies, yet. As a result the assimilation performance and innovative power in countries are too low.
The introduction of the NMS in 1995 adjusts the frontier to new, less capital intensive, but efficient technologies. Because labor productivity growth in the period 1995 to 2005 is clearly concentrated in the NMS, these develop to competitors for the former low performers in the EU, Spain and Portugal.
In the period 1985 to 1995 the country-level overall country frontier is slightly raised, indicating small innovative activity in the EU member countries.

At the sector level three levels of innovativeness are found. Sectors in which countries are innovative until the mid-1980s. These are characterized by frontiers above the country level and show fast capital intensification unrelated to growth. Sectors, in which countries have

been innovative until the mid-1990s, show low capital intensities and low labor productivity levels. And sectors in which countries are innovative throughout the period.
From these frontier developments at sector level is argued that, although in some sectors innovation is ongoing, the lack of innovation in most sectors results in the absence of a further raise of the overall country frontier in this 1995 to 2005 period.

The results of the shift-share analysis point out that within countries a shift towards the services sectors is present; especially towards real estate, renting of machinery and equipment, and business activities, which is an expected result in the EU. The unexpected outcome is that this shift positively contributes to labor productivity growth. Services sectors are usually associated with low levels of labor productivity, but the production frontiers of these sectors show labor productivity levels above country level.
The countries newly admitted to the EU, which operate at low productivity levels, show high labor productivity growth and the largest contribution from the shift of labor share between sectors. This is a shift out of agriculture, mining and manufacturing towards services, and especially real estate, renting of machinery and equipment, and business activities. In the first period these countries are Portugal, Greece and Spain, and in the second period the NMS, although some countries stay behind, Lithuania for instance.

The results of the correlation analysis between 'structural change' and 'technological change' point at related underlying processes but the assumptions on the relation are just partly confirmed. In the first period a significant correlation is found between growth by assimilation and intra-sector growth, indicating that the assimilation of knowledge is related to the increase of capital efficiency. And in the second period a significant correlation is found between growth by capital intensification and inter-sector growth, indicating that technological change reallocates labor to higher productive sectors. This positive contribution is unexpected but in line with the shift-share analysis findings.
Further research is necessary to explain why only one relation per period is found. And further whether a time-lag interferes with the analysis because using the possibilities of the new technology also requires organizational changes which are difficult and time consuming (Bresnahan, Brynjolfsson & Hitt, 2002).

The results of this study might be confirmed designing a more longitudinal study and using a more extensive dataset. This will give the results more significance. Attention then should be paid towards the labor productivity levels in the services sectors and investment in IT.
The two other points for further study are related to the efficiency differences between countries. The level of schooling incorporated in this analysis, as proxy for labor quality, has not been able to explain differences in efficiencies on country level. Other methods to incorporate schooling are known, but it might also be useful to look for measures which are more specifically related to production itself. The introduction of knowledge and skills via services and intermediate goods for example.
The second point is the assessment of the sector-country relation. Because this sector-country relation is affected by the share of labor within the individual countries it is mainly explored qualitative in this study. For further study and further development of the framework the (statistical) methods should be developed to indicate this relation quantitatively.

Preface

The development of the European Union has been, besides successful, also one of conflicts between sentiments and economic reality. On the one hand, for example, for most companies intra-European trade has been a common reality and a stronger integration and harmonization of the regulatory framework has lowered their administrative burden. On the other hand was the European constitution rejected in the referendum because people were anxious of loosing their countries' identity.
This conflict between economic reality and sentiment is the reality we live in and makes that European development studies are interesting to me. Because this conflict and the underlying powers and decision schemes are also at the heart of the master course Technology Policy, I have chosen a study on European productivity growth dynamics as the prime subject for my final thesis.

When I look back at the past years I feel that I have reached my primary objectives to deepen my knowledge in general sense, to acquire research skills and getting to know more about technological change and organizational response. Over the years spending free time at the course did became more demanding. Both because the subject matter took me more time to study and more importantly, the group of students which continued attending the course became smaller over time.
With my graduation an intense period of 6 years combining work with a part time master course is closed. This is also the moment to be grateful and say thanks to everyone who supported me and made combining work with this course possible.
First to dr. Önder Nomaler and dr. Alessandro Nuvolari who provided me with the supervision on this research and writing the thesis. I thank them for their time, effort and the long discussions we have had about the project and all subjects which have passed. They were great, helpful and useful in bringing me and the project further.
At this point I also thank my (former) colleagues and employers for providing me with study time, being flexible and extra coffee in the morning (sometimes). Without you I wouldn't have succeeded. Special attention is there for you, Rob. Your input, comments and motivation on times I needed them most have been of invaluable support to me.

But last and most importantly I thank you, Marit. Thanks for all you have done to make me successful in finishing this course and final project. Thank you.

Bart Schotsman

Rotterdam, August 2009

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Figures and tables

Abbreviations

Abbreviations

DEA	Data Envelopment Analysis; i.e. Frontier Analysis
ECSC	European Coal and Steel Community
EEC	European Economic Community
EMU	European Monetary Union
EU	European Union
EU KLEMS	EU dataset on Capital Labor Energy Materials and Services
FDI	Foreign direct investment
IT	Information technology
NMS	New Member States
OECD	Organization for Economic co-Operation and Development
PIM	Perpetual inventory method
PPP	Purchase power parities
PWT	Penn World Tables
SBTC	Skills Biased Technological Change
TFP	Total Factor Productivity
VA	Value Added

Country abbreviations

AUT	Austria	ITA	Italy
BEL	Belgium	LTU	Lithuania
CYP	Cyprus	LUX	Luxembourg
CZE	Czech Republic	LVA	Latvia
DNK	Denmark	MLT	Malta
ESP	Spain	NLD	Netherlands
EST	Estonia	POL	Poland
FIN	Finland	PRT	Portugal
FRA	France	SVK	Slovakia
GER	Germany	SVN	Slovenia
GRC	Greece	SWE	Sweden
HUN	Hungary	UK	United Kingdom
IRL	Ireland		

EU-15	EU-15 countries in analysis 1985-1995; member states: AUT, BEL, DNK, ESP, FIN, FRA, GER, GRC, IRL, ITA, LUX, NLD, PRT, SWE, UK
EU-25	EU-25 countries in analysis 1995-2005, the EU-25 is made up from the EU-15 and CYP, CZE, EST, HUN, LTU, LVA, MLT, POL, SVK, SVN.

Symbols

Symbol	*Denotation*
Φ	Efficiency
C	Capital
c	Capital intensity
ċ	Capital intensification
d	Depreciation rate
l	Labor growth
L	Labor
N	Population
n	Population growth rate
P	Panel
q	Country
Q	Group of countries
r	Sector
S	Share of labor
ŝ	Growth rate of the share of labor
T	Period
TC	Technological change (in Solow growth growth model)
t	Year
Y	Output
y	Labor productivity
ẏ	Labor productivity growth
y_a	Target labor productivity
y_b	Target labor productivity year 1
y_c	Productivity leader
y_d	Productivity leader year 1
lc	Leading productivity country
ls	Level of labor skills
I	Growth contribution from shift of labor
II	Interaction
III	Growth contribution from labor productivity growth

Introduction

The European Union (EU) has been established in 1957 and has grown to an important regional economic block in the world's economy today. But it was already after WWII that the first steps were taken. The Treaty of Paris, signed in 1952, founded the European Coal and Steel Community (ECSC) and is considered to be the formal start of European integration.

Since its establishment the EU, founded as the European Economic Community (EEC), has been geographically expanding and extending its field of activity.
Geographical expansion is the simple result of the admittance of new member states that searched the benefits of an economic community. After the original six, the Benelux countries, the former West Germany, France and Italy, which founded the EU, in 1973 Ireland, the UK and Denmark were admitted. In 1981 Greece, in 1986 Spain and Portugal and in 1995 Finland, Sweden and Austria, followed. The fall of the Iron Curtain changed the horizon for the EU and acceptance criteria, the 1993 Copenhagen criteria, were formulated. These criteria are the political, economic and legislative minimum requirements for new applicants. After an extensive support program to meet these requirements the biggest enlargement came in 2004, with 8 Central and East European countries together with Malta and Cyprus. In 2007 Romania and Bulgaria joined, and in the upcoming years Iceland and countries from the former Republic of Yugoslavia are expected to apply for membership.

The prime interest of the EU has been with growth and stability in Europe. The first objective was to create an internal EU customs union and install a common external trade policy. The ambition was to establish a common market soon after that, but it took until 1993, with the Treaty of Maastricht, that a common EU market legislation was established. Aside from the founding of the common EU-market, the treaty also replaced the numerous agreements which were settled to harmonize the regulatory framework. In 1999 the European Monetary Union (EMU) followed which led to the introduction of the common currency, the Euro, in 2002. Today's objectives of the EU are to become the most competitive, knowledge based economy in the world.

The admittance of new member states since the 1970s has introduced countries with different levels of productivity, industrialization and history to the Union. With the recent admittance of the Middle- and Central European countries as most pronounced example.
The economy in the EU is expected to further develop not only by the enlargement of the internal market but also by the ongoing integration and harmonizing of the regulatory framework. In this study that development of the EU is studied from the perspective of its prime objective, growth, using a recently developed framework of analysis and dataset.

In the next subsection first the framework of analysis will be introduced, § 1.1, *Research*. In § 1.2, *questions*, the research question is posed and in the last subsection, § 1.3, the outline of the thesis is given.

1.1 Research

The framework employed in this study has been derived from recent literature (Los & Timmer, 2005, Kumar & Russell, 2002, Basu & Weil, 1998), and the study is further based on a newly available EU-dataset and covers the period from 1985 to 2005.
In this subsection first the framework of analysis will be introduced. After this introduction the analysis itself and the three framework extensions made in this study, are explained.

The framework of analysis explains growth and growth differentials. With growth the growth in labor productivity (the measure for output produced per hour worked) is indicated. And with growth differentials the different speeds of labor productivity growth in countries within the EU. The framework explains these growth and growth differentials from three different country aspects, each pointing at a different source of growth. The first aspect is how efficient the country uses its technology. The second is the capital intensity representing the technology itself, and the third is innovation.
Each technology is associated with a best practice labor productivity level, i.e. the level at which it is fully efficient. The efficiency indicates the growth potential left, without switching to new more productive technologies. The more efficient a country operates its technology the less growth potential remains. Growth, the increase in efficiency, results from learning and from the assimilation of knowledge from countries using the same technology.
The second source of growth is the result of the new potential for growth which becomes available through investment in more capital intensive but yet existing technologies. By switching to new, more capital intensive, technology, higher best practice labor productivities become available, together with a new pool of knowledge.
The increase of the best practice labor productivity is the result of the production of new knowledge and is therefore considered an innovative activity. The new knowledge which becomes available results in additional potential and is the third source of growth.
The results of this decomposition in three sources in this 'technology change' based framework, the assimilation of knowledge, the creation of potential and innovation, together cover the total labor productivity growth in the country.

The scope of this study is limited to the EU and thus has a local context. The first step in this local analysis therefore is the estimation of the EU best practice labor productivity level for each of the technologies operated in the EU, the local production frontier. The three sources of growth, as are introduced, are analyzed in relation to this frontier. A local study also means that learning is restricted to this local frontier.
This basic analysis is then extended in three ways: the level of schooling to further explain the performance of countries; to sector level to study the sector-country differences; and with an additional shift-share analysis to study the 'structural change' of countries in relation to 'technological change'.
The growth by assimilation of knowledge is not the result of simple imitation, but is the result of learning. This learning results in the efficiency increase of the technology used and requires certain country abilities, generalized as 'absorptive capacity' (Verspagen & Fagerberg, 2003: 10). As a proxy for this capacity the level of schooling of the workforce is incorporated in the analysis.

The second extension on the analysis is the extension to sector level. The results add the insight in sector-country differences to the study to explain the country level findings in more detail.
The third extension incorporates the analysis of 'structural change'. This structural change analysis studies changes in the economic structure brought about by the reallocation of labor between sectors, the shift of labor share. The framework extension with this shift-share analysis provides the possibility to study the reallocation of labor in relation to 'technological change'. This is interesting because recent studies point at the market driven reallocation of labor associated with 'technological change' (Betts, a.o.).
Because, to my knowledge, the 'structural change' and 'technological change' analysis are never brought together in an integrated study, an additional goal of this thesis is to facilitate a synthesis of the literatures on 'technological change' and the reallocation of labor.

1.2 Questions

This study directly refers to the prime objectives of the EU, growth and becoming knowledge based. It covers the structural change processes, studied by the shift of labor, and the process of technological change. Prime interest are the growth dynamics which are explained from the three sources of growth; the increase of efficiency by the assimilation of knowledge, the capital intensification, and innovation. The central research question of this study is:

To what extent have 'structural change' and 'technological change' contributed to growth of labor productivity in the EU member countries in the period 1985 to 2005

This central research question is further specified to sub-questions on 'structural change', 'technological change' and their relation.
The first sub-question is to what extent the sources of growth, assimilation of knowledge, the capital intensification and innovation have respectively contributed to labor productivity growth in the EU. By using a newly available dataset on a different set of countries and a different era, the second question is whether the results of Los & Timmer (2005) are confirmed on the EU member countries. Los & Timmer employed the framework on OECD-countries for the period 1965 to 1990. The third sub-question is whether the level of schooling is able to explain growth differences, to what extent, and to which of the three sources it is most related.
The framework extension to sector level analysis primarily intends to study country-sector differences and relate these to country performance. The fourth question is how these are connected.
Further the 'structural change' is incorporated in the analysis. The fifth question is whether the, primarily market-driven reallocation of labor shares among sectors, especially in new member states which are opening up their markets, have resulted in additional labor productivity growth on country level.
The last sub-question is derived from the additional goal of this thesis is to facilitate a synthesis of the literatures on 'technological change' and the reallocation of labor. Is a relation present.

1.3 Outline of the thesis

In the next section, *modern economic growth*, the framework of analysis for this study will be build from literature and earlier research results. First the Solow model of growth will be introduced. Then the properties of the framework and its basic assumptions are further explained, § 2.2. The extensions made to the analysis are introduced thereafter in § 2.4. The last subsection summarizes the main properties of the framework of analysis used in this study, § 2.5.

In section three, *methodology and data*, first the method of analysis is introduced, thereafter the data and selection of variables.
The methodology subsection sets off by the estimation of the production frontier and the necessary panel construction, § 3.1.1. The production frontier will thereafter foster the labor productivity growth decomposition, § 3.1.2, and the EU generalization to explain the EU growth, § 3.1.3. The additional shift-share analysis and the analysis to study the relation with the growth decomposition are introduced in § 3.1.4.
In the data section, § 3.2, first the dataset is described. Further the sector lay-out, the countries used, the variables and the concepts used, are introduced.
The last subsection, § 3.3, summarizes the steps of analysis to a plan of analysis.

Section four, *productivity growth dynamics on country level*, is the first section to present the results of the analysis. Since its establishment in 1957 the EU has admitted 19 countries until 2005. Member states show various levels of productivity and capital intensity. In § 4.1 a brief general picture on the country differences will be sketched.
Then in § 4.2 the results of the growth decomposition are presented. First the estimated frontier and then the sources of growth in relation to that frontier including the additional level of schooling. Results of the shift-share analysis, to identify structural change through shift in labor inputs, are presented in § 4.3. The results of the relation between both analyses are explored in § 4.4. The last subsection, § 4.5, concludes.

Section 5, *productivity growth and structural change on sector level*, the sector level results of analysis are presented. In § 5.1, *frontier estimation*, the sector frontiers are described. In § 5.2 the labor productivity growth decomposition is presented. The country level shift-share analysis is studied in more detail on sector level in § 5.3. The last subsection, § 5.4, concludes.

In the last section, 6, *conclusions and discussion*, the final conclusions are presented, as are the suggestions for further research.

Modern Economic Growth

Modern economic growth is the term introduced by Simon Kuznets, economy Nobel Prize winner in 1971, to describe the economic development throughout the last centuries. Among the six characteristics he formulated are the pervasive application of science-based technology into production, and the structural transformation of societies, that are necessary to realize growth. Although labor productivity growth rates have slowed down since 1973 (Maddison, 1987: 649), it is expected that 'structural change' and 'technological change' are still important. Technological change improves labor productivity but also continuously changes the demand for labor, as has been argued in § 1.1.

The aim of this chapter is to build the framework of analysis, as has been briefly introduced already in the introduction. In § 2.2, *framework properties*, the framework properties and its basic assumptions are explained followed by the framework extensions in § 2.3.
Countries operating the same technologies do not necessarily show equal labor productivity levels. The analysis is therefore extended with the level of schooling of the workforce, § 2.3.1. Further the extension to sector level analysis is expected to unravel the specific economic structures and processes related to country level development, § 2.3.2.
To complete, in § 2.4, an addition will be made to the analysis by the introduction of the shift-share analysis. The last subsection, § 2.5, summarizes the main properties of the framework of analysis used in this study.
To start first the Solow growth model and the assumptions at which the framework of analysis is based, will be, briefly, introduced.

2.1 The Solow growth model

Solow introduced his model of growth the 1956. In the Solow growth model, presented by eq. 1, is the aggregated output, Y, the result of the combined inputs capital, C, and labor, L. The model therefore suggests that, given a level of technology, an economy can increase its per-capita consumption by increasing its capital intensity in production.
The introduction of new yet existing technologies into production, changes the input-output ratio. In the Solow-model this introduction of new more productive capital is covered by the total factor productivity, TC, often generalized as *'technological change'*, measuring the joint effects of quality changes in inputs, the capital efficiency, like new technology (quality of capital) and higher educated workers (quality of labor).
The α, the labor to capital ratio, was applied to historical data (on US).

$$Y(t) = [C(t)]^{\alpha} [L(t) \cdot TC(t)]^{1-\alpha} \qquad (1)$$

By differentiating eq. 1 to time the growth accounting notation is derived, presented by eq. 2. The total factor productivity is brought to the left-hand side of the equation and is, in this way, presented as the Solow residual, covering all growth that results of input quality changes. This Solow-residual indicates how much the changes in input quality, for the largest part explained

by the change of the technology used in production, has contributed to the increase of labor productivity over time.
Within the Solow-model no assumptions are incorporated on the selection or development of these changed input qualities, i.e. technological change.

$$tc(t) = y(t) - (1-\alpha)\cdot l(t) - \alpha \cdot c(t) \qquad (2)$$

The model outcome is additionally defined by three important basic assumptions; capital is subject to decreasing returns; (production) knowledge spillovers are public and diffuse instantaneously; and countries use their resources efficiently.
Decreasing returns to capital in the Solow growth model, means that, at a given technology, each new investment in capital will generate lower returns. The result of decreasing returns to capital is that at ever increasing capital-labor ratios simultaneously the return on investment steadily falls, and at the steady state growth even stops. In the steady state each additional investment only compensates for the increase in the labor force and for depreciation. Only the introduction of new production technology then makes additional labor productivity growth possible.
The second assumption is the public availability of knowledge. Public indicates that all countries have access to this knowledge and are able to learn and benefit of this knowledge; knowledge is non-rival and non-excludable. The assumption of public availability of knowledge further means that the assimilation of the knowledge spillovers is merely the result of imitation, unrelated to the countries' level of development.
The last assumption that countries use their resources efficiently, suggests that a given technology deterministically results in a predefined output level.
The long run model outcome and the assumptions therefore suggest that countries converge in terms of labor productivity, i.e. catch-up, and also converge in terms of the production technology used. As a result undercapitalized countries are expected to catch-up because their investment is rewarded with higher returns and they can further simply assimilate the available knowledge.

The framework used in this study is a Solow-like framework because it studies capital intensity in relation to labor productivity. It adds to the Solow decomposition into capital intensification and technological change a new assumption to explain growth differences between countries. Knowledge production is considered a local process, as are the spillovers of this knowledge to production in other countries.
In the Solow model countries are able to catch-up by investment in new capital equipment. This investment thus results in convergence. The locality assumption of knowledge spillovers causes tendencies towards divergence, because countries have to invest in new capital equipment to benefit from knowledge spillovers, otherwise they would fall behind. So spillovers are still immediate but the knowledge is not purely a public good, it is technology specific. The assumption of locality of knowledge is known as 'appropriateness' and has been introduced by Basu & Weil (Basu & Weil, 1998: 1026).
In this framework is further the Solow-assumption of efficient use of inputs loosened. Countries therefore operate at comparable capital intensities showing varying levels of labor productivity. Implementing new capital equipment in the existing production environment requires learning-by-doing necessary as just part of the knowledge is made tacit in the capital equipment. A large part stays in the minds of people and can therefore only be accessed from close personal interaction, a process which is costly in time and resources (Stiglitz, 1999: 6).

The third additional assumption directly refers to these varying levels of labor productivity. Knowledge applied by firms is not general purpose and easily transmitted or reproduced (Pavitt, 1984: 353). These varying levels are therefore the result of different performances in the assimilation of knowledge spillovers. And, as will be further explained in § 2.3, it is assumed that assimilation of knowledge is not simple imitation, given the 'appropriateness', but that it also requires certain abilities of countries, generalized as 'absorptive capacity'.

Newer models that explain growth that are introduced in the late 1980s and thereafter tend to focus on the technological progress as the intended result of activities undertaken by people (Romer, 1990: S72) and country specific developments to explain growth differentials. These models tend to endogenize technological change. The use of a Solow-like growth model in this study means that the focus is on growth itself. The production and diffusion of new knowledge and technology is outside the model and both are assumed to be simply available. In the remainder of this chapter the framework and its extensions are further introduced.

2.2 Framework properties

According to the Solow growth model, growth is the result of capital intensification and of technological change; i.e. capital efficiency. In figure 1, *the labor productivity frontier*, both processes are represented. Capital intensification is presented by the horizontal movement of the country from (0) to (1). And because more advanced technologies are associated with higher capital intensities, the capital intensities on this axis are interpreted as proxies for technologies (Basu & Weil, 1998: 1028).

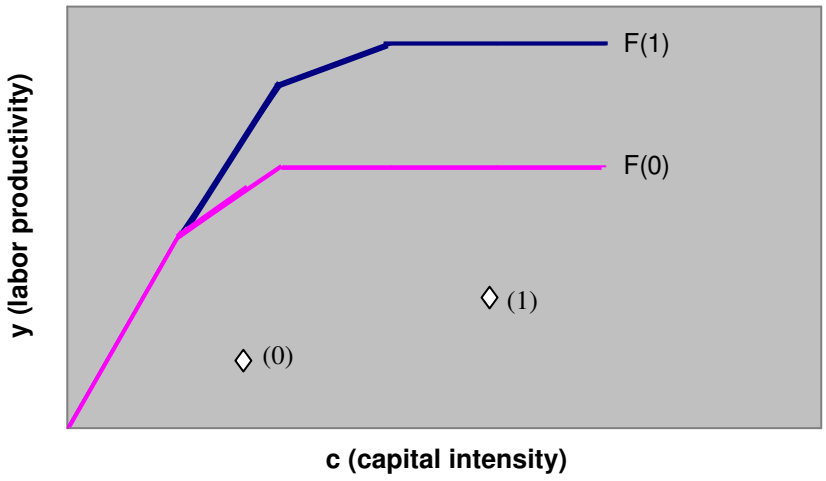

Figure 1: The labor productivity frontier

The efficient use of inputs is in figure 1 represented by the labor productivity frontier. Frontier F(0) for year 0, and frontier F(1) for year 1. The vertical distance between both is the result of increasing capital efficiency, in this study defined as innovation. A technology becomes more productive through learning-by-doing or sheer innovativeness; putting given technologies to new productive uses.

Due to diminishing returns on capital, that is each additional investment in capital will generate lower returns, the frontiers F(0) and F(1) are typically log-linear shaped.
In the context of this frontier the sources of labor productivity growth are studied. The model assumptions that are previously introduced are decomposition into the three sources of growth, assimilating knowledge, capital intensification, and innovation, as are explained in § 1.1.
Catching up to the frontier, resulting in higher labor productivity levels, is reached by assimilation of knowledge from the frontier. Because capital intensities are considered to be technology specific, the assimilation is restricted to spillovers from countries operating comparable technologies efficiently. These countries have built the necessary knowledge stock of codified and non-codified knowledge.
Growth from assimilation is realized as the efficiency, the relative distance to the frontier, becomes smaller over time. For the country in figure 1 this is not the case. Although the country shows labor productivity growth, its efficiency in year 1 to F(1) is not increased compared to the efficiency in year 0 to F(0).
The capital intensification, the horizontal movement of the country under the frontier, is associated with the introduction of more advanced technologies, which in turn are associated with higher potential labor productivity levels. In figure 1 the movement of the country is awarded with higher potential labor productivity and thus growth by creating potential for knowledge spillovers.

These two sources of growth, assimilation of knowledge spillovers and creating potential for knowledge spillovers cannot be considered totally independent as will be argued in § 2.3.1, *level of schooling*. Assimilation is not simple imitation but requires the ability to assimilate knowledge spillovers. The selected new capital equipment therefore has to fit in the countries' economic structure.

Recapitulating, within the analysis the frontier is the current efficient relation between the capital intensity as input and the labor productivity as output. This frontier offers the context for the labor productivity growth decomposition into assimilation of knowledge spillovers, creating potential for knowledge spillovers and local innovation.
The growth of assimilation of knowledge spillovers is measured by the increased efficiency of the country catching up to the frontier. The notion of 'technological appropriateness' means that assimilated knowledge, are spillovers from countries showing best practice performance at equal capital intensities, i.e. from the frontier.
The second source of growth is the creation of potential for knowledge spillovers by moving to higher capital intensities, usually associated with higher potential output.
The third source of growth is local innovation. Increased capital efficiency raises the frontier locally, i.e. at a specific capital intensity level. Growth is the result of the new knowledge which becomes available.
The country specific performance in each of the three decomposed sources of growth determines the productivity growth dynamics in the EU.

2.3 Framework extensions

2.3.1 Level of schooling

In the previous subsection the basic framework of analysis has been introduced. In this framework countries operate at different levels of efficiency. Besides the 'appropriateness' of knowledge spillovers, the additional assumption to further explain the different assimilation performances of countries and the various efficiencies which are the result of this, is the quality of labor quality. In this study represented by the level of schooling.

Growth is the result of assimilation of knowledge spillovers, and of capital intensification. In the introduction has been argued previously that the varying performance in assimilation is the result of varying capacities to absorb existing knowledge, summarized as 'absorptive capacity'. And therefore not the simple result of imitation.
One of the factors that determines absorptive capacity is the investment in education (Verspagen & Fagerberg, 2003: 10). The level of schooling, which should be the result of this investment, is added to the analysis as an indicator of this capacity, as also suggested by Los & Timmer (Los & Timmer, 2005: 529).

The frontier sets an upper limit to the growth through assimilation. This growth can only reach to the frontier. For enduring growth it is necessary to shift to new, more capital intensive, technologies offering additional potential. This necessary shift requires the ability to generate (or attract) sufficient investments. One is otherwise locked in low potential technologies.
To grow successfully the choice of these new technologies should be the adequate one from various suppliers on the market. With adequate is meant that it fits in existing structures, or that one is able to adjust it to local circumstances.
This shift to more capital intensive technologies, which are adequate to the country, is expected to be faster with better educated workforce (Ciccone & Papaiannou, 2005, Coe, Helpman & Hoffmaister, 1997). As is the growth from this shift.

As a result countries that invest to increase the level of schooling of the workforce are expected to show higher performance in the assimilation of knowledge spillovers and more growth from capital intensification.

2.3.2 Sector level analysis

The second extension is the extension to a sector level analysis. This extension of the analysis of labor productivity growth dynamics is expected to unravel the sources of growth in relation to the country's performance, the specific economic structure and its development. Processes which otherwise would stay covered.
Since the 1970s the EU has been gradually extending with countries showing different levels of industrialization and labor productivity. For these countries the framework extension to sector level provides the benefit of getting insights in processes of adaptation to the EU market conditions. A process expected to shift inputs towards more productive and efficient activities (Timmer & Szirmai, 2000: 374).
The sector level analysis is, in the Northern and Western-European countries, interesting because of the far reaching tertiarization, which influences labor productivity growth and the economic structure. With regard to this tertiarization Baumol (1967) even argued that rising

costs of, especially social, services is the result of the lack of productivity growth. This effect is known as Baumol's disease. Newer literature on the contrary show, on the American services sectors, accelerated labor productivity growth since 1995 (Triplett & Bosworth, 2003: 23). European data confirm these results for services sectors investing in IT-capital stock (Schettkat & Yocarini, 2005). Schettkat & Yocarini further argue that this initial American-European difference originates from earlier IT-investment in the US and the longer tradition to monitor performance in services.

Apart from the ongoing tertiarization and the adjustment to new market conditions the analysis extension to sector level also extents the framework and its basic assumptions. Comparable to the development of the framework to the local EU-analysis, this framework extension is made by the estimation of a sector frontier. This frontier presents the best practice labor productivities for the technologies operated in the sector.
Because knowledge spillovers are assimilated from the frontier, the extension restricts spillovers to the specific sector. Special attention is therefore paid to whether there are spillovers available or that these originate from, for instance, technology developing sectors from which spillovers are excluded on sector level. The consequences of this will be further explained in the *methodology and data* section.

2.4 Structural change

The third extension is the addition of the analysis of 'structural change'. This structural change analysis studies changes in the economic structure from the reallocation of labor between sectors, the shift of labor share. In the previous subsection this shift of inputs has been introduced as the consequence of adaptation to the EU market conditions.

Within the structural change analysis the reallocation of labor itself is fuelled by labor productivity differences between sectors, assuming that these differences are, partly, reflected in salaries. So it is market-driven.
Other drivers are technological upgrading and the skills-bias of technological change.
The first, technological upgrading, the process of specialization in activities further up the production chain, is in fact also a labor productivity argument as these activities are usually associated with higher labor productivity.
The second, the 'skills-bias of technological change', SBTC, points at the shift of labor demand associated with the increasing IT-intensity of production (Bresnahan, Brynjolfsson & Hitt, 2002: 340). This labor demand shifts towards more highly skilled workers relative to the less skilled, a process that is often accompanied with diminishing labor intensity. Betts therefore simply states that when more skills are required a shift out of the sector is expected (Betts, 1994: 489).

The SBTC-argument as driver of labor reallocation, brings 'technological change', studied with the growth decomposition, closer to 'structural change'.
The addition of the shift-share analysis to the 'technological change' based framework in this study, can be considered a first attempt to bring these different lines of analysis together.

2.5 Summary: framework of analysis

In this chapter the framework of analysis has been build to study the contribution of 'technological change' and 'structural change' in the EU.
The framework of analysis is a Solow like framework as it studies labor productivity in relation to the capital intensity representing the technological advance of countries. The addition made to the Solow growth model is threefold; knowledge has to be 'appropriate', countries operate comparable capital intensities with varying levels of labor productivity; and learning and the assimilation performance are explained by the labor quality.

The starting point of the analysis is the labor productivity frontier of the EU. This frontier shows the best practice labor productivities and whether or not these are increased over time. The increase of the best practice labor productivity results in a raise of the frontier and is in the context of this study considered innovation.
The frontier offers the context to study 'technological change' from the labor productivity growth decomposition point of view into local innovation, assimilation of knowledge spillovers and creation of knowledge spillover potential.
Growth from local innovation indicates the growth from new knowledge to assimilate which becomes available by raising the frontier.
Growth derived from the assimilation of knowledge spillovers points at growth by the absorption of technology specific knowledge, measured by the increased efficiency of the country catching up to the frontier. The creation of spillover potential points at the capital intensification, usually associated with higher potential output.
To further explain the performance in the sources of growth decomposition the level of schooling of the workforce is added. Catch-up to the frontier is not the simple result of imitation but requires the ability to absorb knowledge to operate the capital equipment. Also a higher educated labor force is expected to select equipment which is better fit for the economic structure.
The extension of the analysis to sector level is added to study the sector-country differences and explain the country development in more detail. Interesting because of the ongoing tertiarization and the recently admitted countries that opened up their local markets.

Additionally to the 'technological change' based framework the 'structural change', by which the reallocation of labor between sectors is indicated, is analyzed.
This analysis will first of all describe structural change in countries just admitted to the EU. And further it adds to the discussion of labor skills biased technological change.
A correlation analysis between 'technological change' and 'structural change' facilitates the synthesis of both lines of analysis.

Methodology and Data

In the previous chapter, *modern economic growth*, the outline of the research framework has been presented. This framework draws on the recent literature by Los & Timmer (2005), Basu & Weil (1998) and Kumar & Russell (2002). The framework is in this study extended with the level of schooling to explain the different assimilation performances, and to sector level. Additionally the analysis of 'structural change' is connected to 'technological change' because it is expected that technological change changes the demand for labor.

In this chapter *methodology and data* the methodology on the 'technological change' and 'structural change' analysis are defined. After that are the data and variables introduced.
In the subsection *methodology* first the frontier estimation is defined. This frontier fosters the growth decomposition which is introduced thereafter. The generalization of the results is found from the regression on the decomposition results in relation to the frontier.
The *'structural change'* addition is analyzed with the conventional shift-share analysis, which decomposes growth into a static-shift effect (growth from shift of labor), and intra-sector growth (the growth from increased capital efficiency).
In the *data* section of this chapter first the dataset is introduced. Disaggregating to sector level in relation to the availability is explained. In the last part the variables and the preparation are introduced.

3.1 Methodology

3.1.1 Frontier estimation

The frontier represents the best practice labor productivity for each capital intensity and 'envelopes' the production plans of the period under study. These production plans are made up of the output and input quantities of a country. The labor productivity frontier is time-specific as innovation raises the capital efficiency and therefore the frontier. Before going deeper into the methodology of frontier estimation first the panel construction is introduced.

Panel construction
The panel construction basically is the selection of production plans for analysis. In this study the intertemporal panel construction, as described by Tulkens & Vanden Eeckaut (1995) is used.
A production plan presents the quantity of outputs generated by a specific number of inputs and normally refers to a single company. In the context of this study a production plan is made up of the input capital intensity, and output labor productivity, of a country. Both the input and output are present on the axes of figure 2.
With intertemporal panel the selection of all production plans is indicated, from start to final year, for the panel. This contrary to the selection of the production plans of only the first and last year.
This intertemporal panel construction adds to the study that the confidence intervals on the estimated frontier are strongly reduced as a result of the increased number of production plans in analysis (Enflo & Hjerstrand, 2006: 8). Further, by taking all production plans into account, the frontier deflection is prevented when labor productivity diminishes. In terms of assimilation of knowledge from the frontier thus is assumed that spillovers are still available

to catch-up to the frontier. Even when countries are falling back or have moved to more capital intensive production.
Notated as an equation, eq. 3, the panel for the EU is made up from the combination of input, c, and output, y, for the countries, *q*. The total of countries is *q = 1…n*, Q, and the intertemporal years in the period, *t = 1…m*, T.

$$P_{QT} = \{(c_{qt}, y_{qt}), q = 1,2,...,n; t = 1,2,...,m\} \qquad (3)$$

In this local study a local EU frontier will be used and only production plans from the EU member states are taken into account. Q in eq. 3 therefore is made up of EU member countries only. This choice in the research-design makes that country structures are more comparable and spillovers are assumed to be from countries that are geographically close. A downside of this choice is that production plans on the boundary of the local set might belong to the interior of the world set. The strong local economic position of the productivity leader as a consequence might be a weak one in the world's economy. The assimilation of knowledge spillovers in that case are mistakenly labeled as acts of innovation.
The focus on the internal EU development in this study, the size of the internal EU market, and the position as a strong regional economic block, makes the local frontier nevertheless the obvious choice. Especially as the sector level analysis makes predictions on labor productivity leaders in the world nearly impossible.

Frontier estimation
The frontier results from the data envelopment analysis (DEA) which maximizes the efficiency in production, Φ. This maximum efficiency is calculated for each production plan separately by solving a linear programming problem, eq. 4. Countries which are estimated 100% efficient are on the frontier, all others are below it.

$$\max_{\Phi,\lambda} \Phi,$$

$$\text{subject to:} \quad -\Phi y_1 - y\lambda \geq 0,$$

$$c_i - c\lambda \geq 0,$$

$$N1'\lambda = 1$$

$$\lambda \geq 0 \qquad (4)$$

In eq. 4 this linear programming problem for this study is presented. This problem, a system with the output, labor productivity, and input, capital intensity, is solved by finding λ, $\lambda \geq 0$. The third subject of the equation is the convexity constraint. This convexity constraint results in the frontier facets on the frontier associated with variable returns to scale.
For the estimation of the frontier the Coelli DEAP 2.1 (Data Envelopment Analysis Program) program is used (Coelli, 1996).

As explained earlier the frontier estimation is the start of the analysis and fosters the labor productivity growth decomposition. Because the period 1985-2005 will be studied in two periods of ten years, 1985-1995 and 1995-2005, three frontiers are estimated, 1985, 1995, and

2005. All three from intertemporal panels containing production plans from 1985, 1985 to 1995, and 1985 to 2005.

3.1.2 Labor productivity growth decomposition

The growth decomposition, eq. 5, decomposes the labor productivity growth, on the left, in a growth contribution from each of the decomposed parts. From left to right the assimilation of knowledge spillovers, the creation of potential for knowledge spillovers and local innovation. The growth from assimilation of knowledge spillovers is calculated by using the increase in efficiency that results in higher labor productivity. For the country in figure 2 this growth contribution is calculated from the relative distance of the country in year 1, y_1, to the frontier F(1), y_d, and the inverted relative distance of the country in year 0, y_0, to frontier F(0), y_a. By using the inverted efficiency of year 0, the increase in efficiency is expressed relative to the initial value.

$$\frac{y_1}{y_0} = \left(\frac{y_1}{y_d} \cdot \frac{y_a}{y_0}\right) \cdot \left(\frac{y_c}{y_a} \cdot \frac{y_d}{y_b}\right)^{0.5} \cdot \left(\frac{y_b}{y_a} \cdot \frac{y_d}{y_c}\right)^{0.5} \qquad (5)$$

Values over 1 mean that the country has been able to (partly) close the gap from assimilation of knowledge. Values smaller than 1 indicate that countries fall back and a value of 1 indicates that the country is able to keep up with the raise of the frontier. This last situation is present for the country in figure 2.

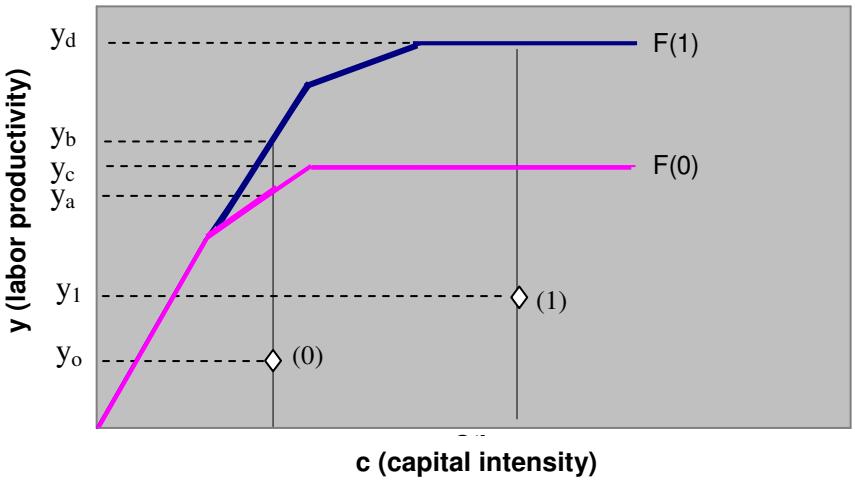

Figure 2: The labor productivity frontier and growth decomposition

More capital intensive technologies are expected to be more productive. The increase of capital intensity is therefore considered to create potential for knowledge spillovers.
To overcome the problem that results differ from calculating the additional potential from F(0) or F(1), the Fisher ideal decomposition is used (Kumar & Russell, 2002: 535).
For the country in figure 2 this means that its potential growth from y_a to y_c, under F(0), is multiplied with the growth from y_b to y_d under F(1), and then squared.

A value over 1 indicates that the country started to operate higher potential capital equipment. A value of 1 indicates that no additional potential is available at increased capital intensification.

The third term in eq. 5 calculates the growth through local innovation. Which is defined as the growth triggered by the raise of the frontier for a particular capital intensity. In figure 2 this growth for the country is calculated by the frontier raise at the capital intensity in year 0, y_a is raised to y_b, and multiplied with the local innovation in year 1, y_c is raised to y_d.
A value over 1 means that the country gained from improvements in the target for its technology. Regress of the frontier is excluded so values under 1 will not be found in the results. A value of 1 indicates that no innovative activity is present. Or that the country, as innovation is locally defined, has not been able to benefit.

3.1.3 Sources of growth

In the previous subsection the country specific growth decomposition is introduced. To estimate the relation for the EU between growth of each of the decomposed sources and the relative position under the frontier a simple β-convergence regression is used.

Sources of growth
In this β-convergence the labor productivity of the initial year is regressed on the growth rates, to study whether lagging countries tend to show higher labor productivity growth so they catch-up to the leaders.
In eq. 6, *total*, the initial ratio of labor productivity to the productivity leader, $y_{0,i}/ y_{0,l}$, is regressed on the relative growth rate. Negative loadings on β indicate that countries are catching up.

Total:
$$\dot{y}_i^T - \dot{y}_{lc}^T = \alpha_T + \beta_T \ln\left(\frac{y_{0,i}}{y_{0,lc}}\right) + \beta_2\left(\frac{ls_{0,i}}{ls_{0,lc}}\right) + \varepsilon_i^T \qquad (6)$$

In the β-convergence regression of the decomposed sources of growth in relation to the frontier, is first the initial ratio of efficiencies regressed on the relative average annual growth rates from assimilation of knowledge spillovers, eq. 7. Negative loadings on β indicate that countries grow faster from assimilation when they are initially operating at lower efficiencies. The relative output target is then regressed on the growth rates from creating spillover potential, eq. 8. Negative loadings indicate that countries with low targets grow faster from creating spillover potential. And last is the relative output target regressed on the growth rates from localized innovation, eq. 9. Negative loadings indicate that countries with low targets benefit more from innovativeness at the frontier.

Assimilation:
$$\dot{y}_i^A - \dot{y}_{lc}^A = \alpha_A + \beta_A \ln\left(\frac{y_{0,i}}{y_{a,i}} \Big/ \frac{y_{0,lc}}{y_{a,lc}}\right) + \beta_2\left(\frac{ls_{0,i}}{ls_{0,lc}}\right) + \varepsilon_i^A \qquad (7)$$

Creating spillover potential:
$$\dot{y}_i^C - \dot{y}_{lc}^C = \alpha_C + \beta_C \ln\left(\frac{y_{a,i}}{y_{a,lc}}\right) + \beta_2\left(\frac{ls_{0,i}}{ls_{0,lc}}\right) + \varepsilon_i^C \qquad (8)$$

Localized innovation: $$\dot{y}_i^I - \dot{y}_{lc}^I = \alpha_I + \beta_I \ln\left(\frac{y_{a,i}}{y_{a,lc}}\right) + \beta_2\left(\frac{ls_{0,i}}{ls_{0,lc}}\right) + \varepsilon_i^I \qquad (9)$$

The level of schooling
The level of schooling of the workforce is expected to be partly explaining assimilation performance of countries and the rate of capital intensification, as argued in § 2.3. The level of schooling is incorporated in the β-convergence regressions as the initial ratio of level of schooling of the workforce to the productivity leader. This additional relative level of schooling can theoretically range from zero to infinite but is expected to be close to one for the generally high educated workforce in the countries of the EU.

The advantage of incorporating the level of schooling into the analysis over, for example, an integrated level of schooling augmented analysis, is that the additional variance explained shows directly. In larger samples it might be worthwhile to develop the labor skills variable to discrete classes representing low, medium and high skilled.

3.1.4 Shift-share analysis of structural change

The structural change analysis is added to the framework which, contrary to the other analyses, is just labor productivity based. As has been argued in § 2.4, the addition is valuable from the skills bias argument in technological change and the structural change because countries open up to EU market conditions.
In this subsection first the shift-share analysis to study structural change will be explained, after that the connection of both analyses, 'structural change' and 'technological change', will be made.

Shift-share analysis
The shift-share analysis is based on the property that the labor productivity, output, Y divided by labor input, L, of a country can also be calculated from the individual contributions of sectors when the individual sector productivity, y_i, is weighed to the labor shares, S_i, in the economy, as is presented in eq. 10.

$$Y/L = \frac{Y}{L} = \sum_{i=1}^{n} \frac{Y_i L_i}{L_i L} = \sum_{i=1}^{n} y_i S_i \qquad (10)$$

The change in labor productivity can subsequently be formulated as the result of growth through each of the components labor productivity and the share of labor, on sector level, as is presented in eq. 11, the shift-share formula.

$$\frac{y^1 - y^0}{y^0} = \sum_{i=1}^{n} \frac{\left(S_i^1 - S_i^o\right) y_i^0}{y^0} + \sum_{i=1}^{n} \frac{\left(S_i^1 - S_i^o\right)\left(y_i^1 - y_i^o\right)}{y^0} + \sum_{i=1}^{n} \frac{S_i^0\left(y_i^1 - y_i^o\right)}{y^0} \qquad (11)$$

The first term on the right-hand side presents the contribution on country level of the inter sectoral shift of labor, the static-shift effect. It calculates the contribution to growth from the

change between first years' share and last years' share. A positive contribution on that country level is the result of shift of labor to more productive sectors.
The third term calculates the contribution of increasing labor productivity in sectors, the intra-sector growth.
In the middle term the interaction between productivity growth and growth in share of labor is caught, the interaction. Also referred to as dynamic shift (Timmer & Szirmai, 2000: 376). In economies which are not changing at a high rate, the Western-European countries for example, the interaction is expected to be small compared to, especially, intra-sector growth. In economic transition, for instance the NMS, the effect can be significant.
In figure 3 the contributions to growth by the static-shift, I, intra-sector growth, III, and the interaction, II, are presented for the EU-15, the countries available to the 1985 to 1995 analysis. The Total is the sum of the three.
The Southern European countries, Greece, Portugal and Spain, show the highest contribution from static-shift and the interaction. This indicates changes in economic structure in this period. This finding is expected as all three were admitted to the EU in the 1980s and operate at low labor productivity levels, initially. France and Austria show hardly any contribution from inter-sector growth at all.

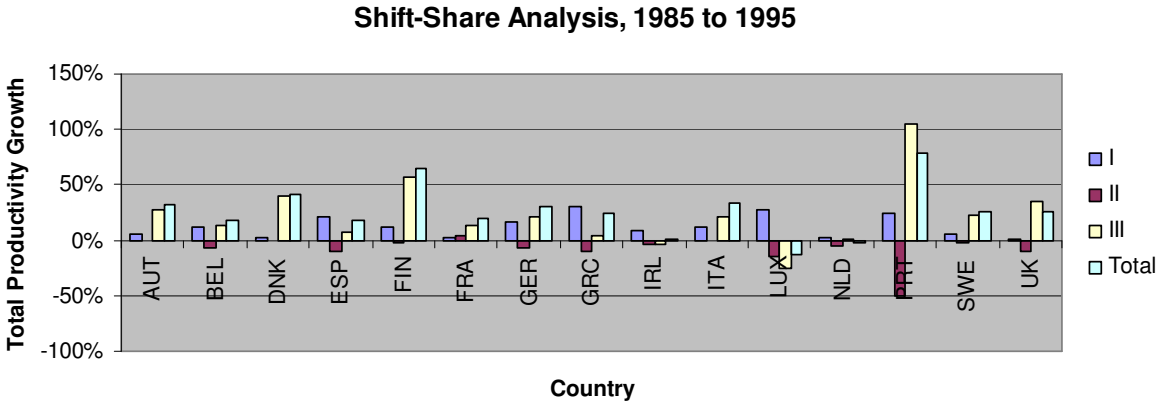

Figure 3: The results of the country level analysis on the EU-15, for the period 1985 to 1995. The I, II, and III correspond to the terms in eq. 13 and therefore represent the static shift, I, the interaction, II, and the intra-sector growth, III. The sum is presented by *total*.

Relation of both analyses
Both the sources of growth decomposition, eq. 5, and that of shift-share, eq. 11, cover total labor productivity growth and estimations on totals are mathematically comparable as is shown in eq.12.

$$\frac{y^1}{y^0} - 1 = \frac{y^1 - y^0}{y^0} \qquad (12)$$

The underlying relations of both decompositions are tested with a standard correlation analysis. Because technological change is expected to also changes the demand for labor significant correlations are expected between the creating of spillover potential and static-shift.

The assimilation of knowledge spillovers represents the actual catching up to the frontier and is expected to be correlated to the intra-sector growth, because both are closely related processes.
The interaction of growth of labor productivity growth and of shift of labor is affected by both processes and therefore it is expected to be correlated according to the dominance in the underlying processes.

3.2 Data

The analyses made operational in the previous subsection, are executed on a dataset which will be introduced in this subsection, *data*. Five different subjects are discussed. The dataset, the period, the country availability to the analysis, the sectors and the variables.

Dataset
The analyses require an extensive and detailed dataset on the EU. This has been found in the newly available EU KLEMS, Capital Labor Energy, Material, and Services, dataset which is specifically built to verify the EU-policy outcomes.
This EU KLEMS dataset is the result of the EU-project to build a harmonized dataset on the EU-25 countries. It contains variables on outputs and intermediary inputs to support the EU-policy evaluation of the Lisbon and Barcelona summit goals. Which are: *to become the most competitive and dynamic knowledge-based economy in the world, capable of achieving a sustainable economic growth with more and better jobs and a greater social cohesion* (Molle, 2006: 350).
The dataset, which was presented in March 2008, is divided into four tables. The standard output tables, the alternative output tables, the capital input tables and the labor input tables. Additional to this the purchase power parities (PPP), to convert all variables to 1995 German Euro, are available from 1970 onwards.
The gross value added (VA) and labor input in total hours worked by persons engaged (H_EMP) from the basic tables are used to calculate the labor productivity. The labor input table contains data on labor input, assigned to age groups, levels of schooling and gender. From this table, the level of schooling used in this study, is constructed. The capital input presents the capital stock divided into 9 asset types with special attention on ICT stock. These assets are calculated by the investment using sector specific geometric depreciation rates, the perpetual inventory method (PIM).
All aggregates, as the tables do not contain totals, are built from the industry level. This industry level availability of the data is presented in appendix B. The exact calculation of the variables is presented in appendix C.

Period
1985 has been chosen as the starting date of the analysis because of the development of the EU and the availability of the country data. In the EU-KLEMS dataset data are available until 2005, this also provides the possibility to divide the analysis into two 10-year periods. Furthermore these equal length periods, from 1985 until 1995, and 1995 until 2005, also start well after the 1980-81 recession.

The start year of the EU KLEMS dataset is 1970 but capital input and labor input data are available from the beginning of the 1980s. Data on all EU-25-member countries are available from 1995 until 2005. About 9 years of data before the admittance of the NMS to the EU. A

period in which most of the NMS already where influenced by the EU-policy and development aid.

Country availability
To the shift-share analysis, as it is based on the simple variables labor productivity and labor hours, the EU-15 countries are available for the period 1985-1995 and the EU-25 countries for the period 1995 to 2005.
For the growth decomposition 12 EU member states are available for the period of 1995 to 2005. Eight of them are available for the period 1985 to 1995.
This restriction to the growth decomposition analysis is the result of small economies can't provide, especially the capital stock, data, and further the result of confidentiality issues on the data. Issues that have apparently not been negotiable. This confidentiality concerns data on France, Hungary, Ireland and Luxembourg. In appendix A the country availability to analysis is present.
Although capital input data is only available on half of the EU member states, the results are meaningful as is believed that the countries represent geographically as well as economically all parts of the EU.

Sector aggregation
To extent the analysis to sector level the data set has to support this on simple economic indicators for the shift-share analysis, but also on capital input and labor input, for the growth decomposition.
The sector aggregation within the EU-KLEMS dataset is restricted to 8 sectors. These 8 sectors are constructed from the collective level of measurement of the labor input variables in the selected countries. These sectors are presented in appendix B.
The 8 sectors used in the sector level analysis are survey able number in describing the results of analysis. They also fit the sector classification scheme into an *extractive sector*, a *transformative sector*, *distributive services*, and *producer services* as proposed by Schettkat & Yocarini (2006). This classification is build along the expected knowledge content of different sectors and whether the sector produces final or intermediate goods. Similar directions of development are expected.
The *extractive* sector is made up from agriculture and mining. Then the *transformative* sector is made up from manufacturing, energy services, and construction. The *distributive services* are made up from transportation, storage, communication and trade. A deviation from the original classification scheme is that hotels and restaurants are incorporated. And the last sector the *producer services* is made up from financial intermediation, real estate, renting and business activities.

Variables
After selecting the dataset, the available countries and the sector level aggregation in the last part of this chapter the variables are selected. These variables are the labor productivity, capital intensity and the level of schooling.
The labor productivity is defined as value added per hour worked for persons engaged in economic activity. This definition makes labor productivity comparable within the EU as country and sector differences in annual hours worked per person are in both present. The value added is first adjusted to the 1995 price level in Germany.
The capital intensity is defined as the value of the capital per hour worked. Since producer durables are most interesting from a technology perspective the technologies are indexed from

these durables only (Los & Timmer, 2005: 522). From the available asset types, *Machinery & Equipment* and *IT* are selected.
The capital input data are available in 1995 local currency, the capital input is, for non-Euro countries, converted to the Euro by the fixed official conversion rate of EuroStat.
Germany has a special position as East- and West-Germany merged into Germany in 1990. For 1985-1995 the input data on Germany are presented harmonized within the EU-KLEMS tables. For the input data the figures on West-Germany are imputed on Germany for 1985 to 1990 after first harmonizing to the level of Germany in 1991.
The last variable is the level of schooling. The level of schooling is in the analysis represented by the summed share of medium and high educated labor hours in the industry.
In appendix C, *variables*, the variable selection and necessary calculations are presented.

3.3 Summary: plan of analysis

In this chapter *methodology and data* the methodology of the analyses is study are introduced.

The first step in the analysis is the construction of panels to estimate the 1985, 1995, and 2005 production frontiers. These panels are intertemporally constructed by production plans containing one input, the capital intensity from producer durables, expressed in 1995 Euros per hour, and one output, the labor productivity in 1995 German Euro per hour. All derived from the EU KLEMS data set, March 2008 edition.

The second step is to analyze the sources of growth in relation to the frontier. Growth through the assimilation of knowledge spillovers is calculated as the multiplication of the relative distances to the frontier year 1 and year 0 and expressed as part of the year 0-efficiency. The growth of knowledge spillover potential is calculated by the additional potential which becomes available from capital intensification. The last source is growth through local innovation. This is derived from the improvement of the target labor productivity for the particular capital intensity at which the country operates.
The results are generalized to the EU development using a simple β-convergence regression in relation to the relative position under the frontier. The extension with level of schooling, made operational as the share of medium and high skilled labor, is added as extra variable to these β-convergence regressions.
In the third step of analysis is the growth decomposition taken to a sector level analysis were the classification fits the sector classification scheme into an *extractive sector*, a *transformative sector*, *distributive services*, and *producer services*.
For this part of the analysis 12 EU member states are available for the period of 1995 to 2005, eight of these 12 are available for the period 1985 to1995.

With the additional 'structural change' analysis is growth contributed to shift of labor and increased capital efficiency. Contrary to the previous analysis it is just labor productivity based and data on the EU-15, 1985 to 1995, and the EU-25, 1995 to 2005, are available.
The last step in analysis is to test with a standard correlation analysis the similarity in both decompositions. As 'technological change' is expected to also change the demand for labor, significant correlations are expected between the creating of spillover potential and static-shift. And as assimilation of knowledge spillovers represents the actual catching up to the frontier, it is expected to be correlated to the intra-sector growth.

Productivity growth dynamics on country level

In this chapter the country level results of the analysis are presented. The prime objective of this analysis is to answer the research question as formulated in chapter 1, *introduction*. This question is:

to what extent have 'structural' and 'technological change' contributed to growth of labor productivity in the EU member countries, in the period 1985 to 2005.

'Structural change' in this question indicates the development of specific sectors measured by the reallocation of labor input of sectors and the additional growth which results from this shift. *'Technological change'* is assessed with the growth decomposition and points at the country performance in each of the decomposed sources of growth.

The chapter is organized along the sequential steps in analysis as are presented in § 3.3. In § 4.2, the results of the labor productivity growth decomposition and the framework extensions are presented. Then, in § 4.3, the structural change is studied using the results of the shift-share analysis. In the subsection is concluded whether shift of labor share has contributed to additional growth, and if the NMS benefit from opening up their local markets. In § 4.4 the relation between the growth decomposition and shift-share analysis is explored. The conclusions of the country level analysis are then presented in § 4.5. But first a general picture on labor productivity growth, convergence and capital intensification in the EU, between 1985 and 2005, will be sketched in § 4.1.

4.1 General

Table 1 presents the labor productivity and capital intensity figures for the years 1985, 1995 and 2005. The table shows the countries available to both the growth decomposition and the shift-share analysis where countries available to the first have a light grey background.

The data on 1985, only available for the EU-15 only, show that Luxembourg is the definite productivity leader, followed by Belgium and the Netherlands. On the lowest ranks of productivity are, except for Sweden, the countries which are admitted in the 1980s and 1990s. Portugal is ranked 15th, Greece, 14th, Finland, 13th, Austria, 12th, and Spain, 10th.
Although not for all countries the capital intensity is available, it shows lower dispersion compared to productivity, and it is highest for Denmark, followed by Austria and the Netherlands. The lowest capital intensity is found for Spain.
The growth rate of productivity between 1985 and 1995, is highest in Finland, Portugal and Denmark. These last two countries also increase capital intensity the fastest. Slowest growth is found in Ireland and growth is even negative for Luxembourg and the Netherlands.

Table 1: Labor productivity levels, y, on the EU-15, 1985, and EU-25, 1995 and 2005, and the average annual growth rates, ẏ, and positions, #. For the available countries also the capital intensity, c, and annual average growth rates, ċ, for the same years are added.

	Productivity				**Capital Intensity**				**Productivity**				**Capital Intensity**				**Productivity**			**Capital Intensity**	
Country	***y***	***#***	***ẏ***		***c***	***#***	***ċ***		***y***	***#***	***ẏ***		***c***	***#***	***ċ***		***y***	***#***		***c***	***#***
	1985	***1985***			***1985***	***1985***			***1995***	***1995***			***1995***	***1995***			***2005***	***2005***		***2005***	
AUT	18.12	12	2.76%		15.34	2	2.44%		23.89	11	-0.18%		19.58	2	2.69%		23.47	10		25.63	5
BEL	34.88	2	1.71%						41.38	2	-0.50%						39.34	1			
CYP									18.49	14	-0.27%						17.99	13			
CZE									10.5	20	3.60%		3.63	11	9.42%		15.05	16		9.31	10
DNK	23.25	8	3.49%		15.92	1	4.68%		32.97	3	-0.36%		25.42	1	5.31%		31.79	4		43.25	1
ESP	21.92	10	1.71%		7.17	8	2.68%		26.01	10	-2.30%		9.37	9	3.33%		20.66	12		13.08	9
EST									5.73	24	2.49%						7.35	22			
FIN	16.3	13	5.01%		11.36	6	4.23%		26.91	9	-0.93%		17.34	5	1.83%		24.52	9		20.82	8
FRA	23.94	5	1.75%						28.51	8	-0.05%						28.37	8			
GER	23.4	6	2.68%		12.44	5	4.13%		30.6	6	1.25%		18.81	3	4.42%		34.67	3		29.25	3
GRC	11.1	14	2.15%						13.77	15	0.02%						13.8	19			
HUN									11.11	19	0.49%						11.66	21			
IRL	23.31	7	0.02%						23.35	12	-3.10%						17.13	15			
ITA	22.13	9	2.89%		11.33	7	4.06%		29.56	7	-0.14%		17.01	6	2.85%		29.16	7		22.61	7
LTU									6.3	23	0.29%						6.49	23			
LUX	64.84	1	-1.31%						56.88	1	-3.86%						38.66	2			
LVA									6.62	22	-1.37%						5.77	24			
MLT									12.07	18	0.09%						12.19	20			
NLD	33.2	3	-0.24%		14.09	3	1.68%		32.42	4	-0.45%		16.67	7	4.00%		30.98	5		24.87	6
POL									9.64	21	5.90%						17.39	14			
PRT	7.48	15	5.82%						13.38	16	0.55%		5.61	10	4.94%		14.14	17		9.2	11
SVK									12.21	17	1.23%						13.81	18			
SVN									4.63	25	1.25%		3.09	12	8.31%		5.24	25		7.09	12
SWE	24.68	4	2.31%						31.11	5	-0.51%		17.89	4	7.19%		29.56	6		36.7	2
UK	18.34	11	2.27%		13.94	4	-0.91%		23.01	13	0.02%		12.73	8	7.26%		23.06	11		26.32	4

y: labor productivity (1995 Euro / hour), c: capital intensity (1995 Euro / hour), #: rank of labor productivity
ẏ: labor productivity growth (annual average growth), ċ: capital intensification (annual average growth)

In the second period, 1995 to 2005, the highest growth rates are present in the NMS, except for Latvia and Lithuania, who don't seem to be able to catch-up yet. As a result operate some of the NMS, by 2005, at productivity levels close to the Southern European countries. Contrary to these growth rates show most West-European countries decreasing labor productivities, except for the re-united Germany. The largest decrease is found in Luxembourg, Ireland and Spain.
Capital intensification accelerates in this period. This intensification is, for most countries and sectors, driven by the investment in IT-capital. The Czech Republic and Slovenia, show highest rate of capital intensification, followed by the UK and Sweden. Italy and Finland show the slowest increase.

In the remainder of this chapter is growth and capital intensification studied in more detail. First from the growth decomposition and then by the shift-share analysis.

4.2 Growth decomposition on country level

The analysis of the labor productivity growth decomposition sets of with the estimation of the local EU production frontier, § 4.2.1. This frontier provides the context for the remainder of the analysis, the growth decomposition. The results of this growth decomposition are presented in § 4.2.2.

4.2.1 Frontier estimation

In figure 4, the frontier is presented with the production plans of the countries in the three years marking the period under study, 1985, 1995, and 2005, projected underneath.
In this figure the frontier is not represented by a single line but by the scatter of the most efficient production plans using different colors and shapes for the three years.
The production plans that are on the frontier can be found in table 2.

The 1985 production frontier
The 1985 EU production frontier is defined by the production plans of Spain and the Netherlands. Both are estimated fully efficient in that year. From the eight available countries to estimate the frontier from, Spain operates at the lowest capital intensity showing the 10th labor productivity level, see table 1. The Netherlands shows the highest labor productivity of the country available to the growth decomposition. The countries operating more capital intensive, Austria and Denmark, are not able to translate this into a higher labor productivity. Their target labor productivity is therefore equal to the labor productivity of the Netherlands.

Table 2: Countries on the EU production frontier in 1985, 1995, and 2005.

1985				1995				2005			
Country	***Year***	***y***	***c***	***Country***	***Year***	***y***	***c***	***Country***	***Year***	***y***	***c***
NLD	1985	33.20	14.09	NLD	1994	34.85	16.65	NLD	1994	34.85	16.65
ESP	1985	21.92	7.17	NLD	1987	34.61	15.15	NLD	1987	34.61	15.15
				NLD	1986	34.43	14.55	NLD	1986	34.43	14.55
				ESP	1986	22.55	7.05	ESP	1986	22.55	7.05
				CZE	1995	10.50	3.63	CZE	1995	10.51	3.63
				SVN	1995	4.63	3.09	SVN	1995	4.63	3.09

y: Labor productivity (1995 Euro / hour)
c: Capital intensity (1995 Euro / hour)

In figure 4 it is shown that the other countries operate at capital intensities between Spain and the Netherlands, and have both the options to grow from assimilation of knowledge spillovers and increase the labor productivity or increase potential by investment in new capital equipment.
The figure further shows that the countries that are not on the frontier can be, in terms of input efficiency, divided into two groups. The first group operates at an efficiency level of 56% and is made out of Finland, the UK and Austria. The second group operates at efficiencies between 70% and 77%. These countries are Denmark, Germany and Italy.

The 1995 production frontier
Where the 1985 frontier is a single line, the 1995 the frontier is build out of five facets, each showing different productivity to capital intensity ratios, indicating different paths of development.
The upper bound of the frontier is defined by the Netherlands, that is on the frontier with production plans of the years 1986, 1987, and 1994. This last is clearly the result of the intertemporal panel use. But indicates also that capital intensification is faster than labor productivity growth, a development which results in a flattening of the frontier.
The extension of the frontier to the low capital intensity side is simply the result of the introduction of the NMS to the EU dataset. This shift of the frontier is independent from growth or innovative activities but indicates that the NMS bring new, capital extensive, and efficient, technologies to the EU.
In figure 4 are the frontier and country specific production plans yellow for 1995. The figure shows the capital intensification of production in all countries, except the UK. It further shows that the Netherlands falls back from the frontier after 1994. Slovenia and the Czech Republic operate efficiently at low capital intensities, i.e. simple technologies. The other countries show increasing efficiencies, although Austria stays somewhat behind.

The 2005 production frontier
The 2005 frontier is made out of all available production plans from 1985 to 2005 and is in figure 4 presented in green.
Due to the ceased growth in labor productivity in the period 1995 to 2005, as is already known from the previous subsection, this frontier falls together with the 1995 frontier.
In contrast to the labor productivity growth the rate of capital intensification is accelerating in this period as is shown by the large horizontal movement under the frontier.
Capital intensification results in Spain, Slovenia, the Czech Republic, Portugal and the UK in additional potential for knowledge spillovers, as they move towards higher potential areas under the frontier. But as the labor productivity growth rate cannot keep up with the additional potential, a decline in efficiency is visible. Capital intensification didn't result in additional potential for the other countries. This will be further explained in the next subsection.

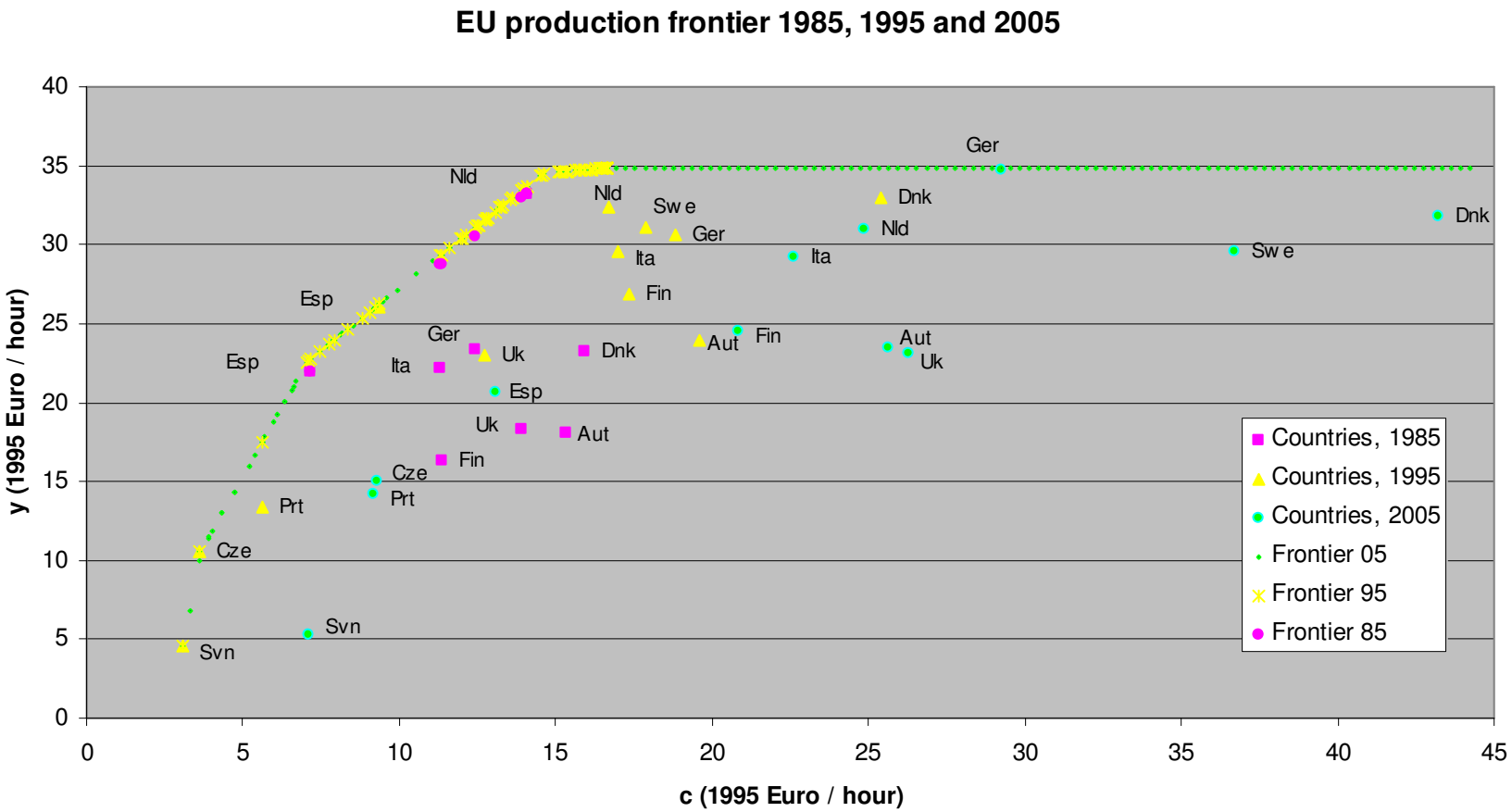

Figure 4: The 1985, 1995, and 2005 EU production frontier with the country specific production plans projected underneath.
The frontier itself is visualized by a scatter plot representing the labor productivity targets from which knowledge spillovers are available.
The horizontal movement of the countries represents their capital intensification, the vertical movement the increase in labor productivity. The efficiency of countries is represented by the vertical distance of countries to the frontier.

4.2.2 Sources of growth decomposition

The country movement underneath the frontier, as described in the previous subsection is captured in the sources of growth decomposition. This growth decomposition is calculated according to eq. 5, § 3.1.2. The results are presented in table 3.

Growth decomposition

The first source of growth is growth through the assimilation of knowledge spillovers. In figure 4 this growth is shown as the vertical movement towards the frontier. The growth contribution is calculated by the relative distance to this frontier at start and end of the period. In the first period growth from assimilation shows values over 1 for most countries indicating that countries catch-up to the frontier. The efficiency decrease of the Netherlands after 1994 is shown from the assimilation growth value under 1. In the period 1995 to 2005, all countries, except Germany, fall back from the frontier as is shown by values under 1 for the growth contribution through assimilation.

Table 3: Growth decomposition into assimilation of knowledge spillovers, *assimilation*, creating spillover potential, *potential*, and local innovation, *innovation,* for the periods 1985 to 1995 and 1995 to 2005. On country level. In the columns the growth contribution from each of the decomposed sources is presented.

	Assimilation		**Potential**		**Innovation**	
Country	***1985-1995***	***1995-2005***	***1985-1995***	***1995-2005***	***1985-1995***	***1995-2005***
AUT	1.25	0.98	1.00	1.00	1.05	1.00
CZE		0.58		2.49		1.00
DNK	1.35	0.96	1.02	1.00	1.03	1.00
ESP	0.99	0.65	1.16	1.22	1.03	1.00
FIN	1.36	0.91	1.17	1.00	1.04	1.00
GER	1.14	1.13	1.11	1.00	1.03	1.00
ITA	1.10	0.99	1.17	1.00	1.04	1.00
NLD	0.93	0.96	1.02	1.00	1.03	1.00
PRT		0.71		1.48		1.00
SVN		0.23		4.88		1.00
SWE		0.95		1.00		1.00
UK	1.31	0.91	0.94	1.10	1.02	1.00

The second source of growth, growth from creating potential, contributes to countries operating at capital intensity levels between the Netherlands and Spain, as is discussed earlier. In the figure this growth is represented by the horizontal movement towards higher potential output. Finland, Germany and Italy, have a relative position under the frontier that provides the option to grow through assimilation and potential. All three do both. The value smaller than 1 for the UK is the result of decreasing capital intensity.
The high rates of capital intensification in Slovenia, Portugal, and the Czech Republic in the second period, create a large potential for growth. But as they are not able to benefit fully from this potential their efficiency decreases as is shown by the values on assimilation.

The last source of growth is growth through local innovativeness.
In the period 1985 to 1995 the frontier is raised by the labor productivity growth in the Netherlands. This results in growth from local innovation as is shown in table 3. All countries are able to benefit. Because the frontier remains unchanged in the second period no growth contribution from local innovation is available.

Sources of growth β-regression analysis
The β-regression on the results of the growth decomposition analysis generalizes the sources of growth findings to the EU development. These regressions are performed according to eq. 6 to 9. The results are presented in table 4.

In the first column of the table the two periods for each of the equations are given. In the last column the coefficient of determination, adjusted for the number of explanatory variables. In the second column the Y-intercept, α, is presented with the probability between brackets. The slopes, β and β2 are presented in the third and fourth column, resulting from the relative labor productivity and relative level of schooling. Both are relative to the levels of Denmark, the country showing the highest labor productivity from the countries in this analysis in 1995.

Table 4: Sources of growth analysis from the β-convergence equations 6 to 9. Depended variable is the difference in growth contribution with the productivity leader in 1995, Denmark. Independent variables are the ratios of the productivity level, beta, and the ratio of the medium + high schooled share of labor, β2. On country level for the periods 1985 to 1995 and 1995 to 2005.

Period	*α*	*β*	*β2*	R^2 *(adj)*
Total (Eq. 6)				
1985-1995	-.189 (p=.295)	-.686 (p=.047)*	.021 (p=.863)	0.426
1995-2005	.131 (p=.308)	-.362 (p=.009)**	.198 (p=.053)	0.510
Assimilation (Eq. 7)				
1985-1995	-0.147 (p=.390)	-.822 (p=.129)	-.096 (p=.470)	0.161
1985-1995	-.255 (p=.012)*	-.711 (p=.138)		0.215
1995-2005	-.413 (p=.093)	-.921 (p=.117)	.175 (p=.356)	0.137
1995-2005	-.215 (p=.025)*	-.887 (p=.124)		0.124
Creating Spillover Potential (Eq. 8)				
1985-1995	-.111 (p=.367)	-.690 (p=.040)*	.093 (p=.256)	0.464
1995-2005	-.495 (p=.106)	-1.740 (p=.000)**	.349 (p=.160)	0.936
Local Innovation (Eq. 9)				
1985-1995	-.008 (p=.794)	.300 (p=.657)	-.005 (p=.801)	-0.340
1995-2005				

at the 0.05 level, ** at the 0.01 level

The results of eq. 6 show that convergence is present since countries operating at low productivity levels grow faster. The large values, indicating fast catch-up to the productivity leader, are partly the result of the use of labor productivity levels of first and last year, which is in line with the calculation of the growth decomposition.
The high significance in the second period is caused by the increased number of countries in the analysis and the large productivity growth in the NMS versus decrease in the other countries.

The results of eq. 7 indicate, although convergence is present, that the countries operating further from the frontier do not significantly grow faster through assimilation. Leaving out the level of schooling doesn't change this result.

The results of eq. 8 show that, in the period 1995 to 2005, the countries operating at low potential capital intensities, show the largest growth from creating potential. An expected result considering figure 4. In the first period, 1985 to 1995, this catch-up is half as large because no extreme potential performance is shown.
In absolute terms of labor productivity is the local innovation small in the first period and absent in the second, as is also seen in table 3. The regression on local innovation is therefore not available on the second period, and the results are not significant in the first.
These findings indicate that innovativeness is low in the EU and the contribution to growth is unrelated to the distance to the frontier.

The results show that, throughout the total period, countries which lag behind catch-up to the labor productivity leader. This process is almost twice as fast in the first period, 1985 to1995, compared to the second period, 1995 to 2005.
Further although almost all countries show growth through assimilation of knowledge spillovers in the first period, this doesn't show in the β-convergence analysis results. Not even when the labor skills are left out of the equation. In the second period the same results are found. This result means that it cannot be significantly concluded that, within the EU, countries showing lower input efficiency grow faster from assimilation.
Countries that operate at low potential capital intensities benefit, throughout the period, from creating knowledge spillovers by capital intensification. In the period 1985 to 1995, this process is half as fast because no extreme potential performance is shown.
The contribution of local innovation is absent in the second period and the regression can therefore not be made. In the first period the results are not significant. These findings mean that innovativeness is low in the EU and the contribution to growth is unrelated to the distance to the frontier.
Although, according to the argument of absorptive capacity, the level of schooling was expected to be significant, this assumption is not confirmed on country level.

4.3 Shift-share analysis

In chapter 2, *modern economic growth*, it has been argued that the analysis of 'structural change' is interesting from the rapid transition of countries newly admitted to the EU, especially the NMS. Another argument is the ongoing tertiarization in North- and West-Europe.
The results of the shift-share analysis, by which 'structural change' is studied, are presented in table 5.

Table 5 is built as follows. The first five columns contain the results over the first period, and the next five over the last period. *Total* indicates the total productivity growth in the period. In the columns *I*, *II*, *III*, the relative contributions from the static-shift, the interaction, and the intra-sector growth are presented. Relative as the results are normalized to add up to 1, in order to increase the interpretability. The last rows, av-15 and av-25, present the un-weighed

averages on the separate contributions. Within the table the country figures with the light grey background are the countries also available for the growth decomposition.

Table 5: Results of the shift share analysis. (I) is the contribution from shift in labor share, (III) from productivity growth and (II) the interaction between both effects. Total is the total productivity growth in the period. The separate contributions are normalized by the total productivity growth rates.
Countries available to the growth decomposition analysis are with the grey background.

EU-15	**1985-1995**				**EU-25**	**1995-2005**			
Country	***I***	***II***	***III***	***Total***	***Country***	***I***	***II***	***III***	***Total***
AUT	0.17	-0.01	0.84	31.81%	AUT	-0.35	2.58	-1.23	-1.74%
BEL	0.63	-0.34	0.71	18.66%	BEL	-0.50	0.66	0.84	-4.92%
CYP					CYP	-3.93	3.12	1.81	-2.67%
CZE					CZE	0.24	-0.99	1.74	43.27%
DNK	0.07	0.00	0.93	41.81%	DNK	-.72	1.56	0.16	-3.56%
ESP	1.15	-0.52	0.37	18.65%	ESP	-0.68	0.54	1.15	-20.59%
EST					EST	0.78	-0.53	0.75	28.26%
FIN	0.18	-0.04	0.86	65.07%	FIN	-0.17	0.32	0.84	-8.86%
FRA	0.09	0.17	0.73	19.09%	FRA	0.99	3.56	-3.55	-0.49%
GER	0.54	-0.23	0.69	30.75%	GER	0.48	-0.45	0.96	13.30%
GRC	1.27	-0.42	0.15	24.05%	GRC	77.79	-29.69	-47.10	0.24%
HUN					HUN	1.32	-2.30	1.98	4.99%
IRL	48.83	-23.21	-24.62	0.18%	IRL	-0.30	0.43	0.87	-26.65%
ITA	0.37	-0.01	0.65	33.56%	ITA	0.04	2.98	-2.02	-1.36%
LTU					LTU	0.37	-2.81	3.44	2.83%
LUX	-2.26	1.18	2.08	-12.28%	LUX	-0.28	0.23	1.04	-32.02%
LVA					LVA	-0.54	1.00	0.53	-12.82%
MLT					MLT	13.04	-12.05	0.01	0.95%
NLD	-0.90	2.04	-0.14	-2.25%	NLD	0.48	0.36	0.16	-4.44%
POL					POL	0.07	-0.67	1.60	80.35%
PRT	0.31	-0.64	1.33	78.97%	PRT	0.61	-0.41	0.81	5.67%
SVK					SVK	0.14	-0.49	1.34	13.13%
SVN					SVN	3.28	-2.05	-0.23	13.28%
SWE	0.21	-0.07	0.85	26.03%	SWE	0.15	0.09	0.76	-4.96%
UK	0.03	-0.39	1.36	25.44%	UK	3.18	-30.32	28.13	0.21%
Av, EU-15	12.21%	-7.89%	22.31%	26.63%	Av, EU-15	4.23%	-4.67%	-5.16%	-5.60%
Av, EU-25					Av, EU-25	7.39%	-10.69%	6.80%	3.50%

1985 to 1995

§ 4.1, *general*, already points out that Portugal, Finland and Denmark show the highest labor productivity growth rates in the period 1985 to 1995. This is also visible in table 5 as these countries show the highest *total*. Portugal, 79.0%, Finland, 65.1%, and Denmark, 41.8%. The average total productivity growth in this period is about 26.6%. Composed out of static-shift, 12.2%, labor reallocation that increases the labor productivity, the interaction, -7.9%, and the intra-sector growth, 22.3%. These results are derived from un-weighed averages, and indicate that in most countries both the static-shift and intra-sector growth contribute positively to total labor productivity growth.

The results on the separate countries show that the contribution of the static-shift is smallest in the UK, Denmark and France indicating that minor changes in the labor location are present.

And largest in Ireland, Luxembourg, Greece, Spain, the Netherlands and Portugal. In Ireland and the Netherlands these findings are of minor importance as the total growth is small, but in the other four countries the contribution is considerable.
The intra-sector growth is largest in Ireland, Luxembourg, the UK and Portugal. The lowest contribution is found in the Netherlands and Spain.
In figure 3 the absolute figures are presented, clearly showing the large *total* in Portugal, Finland and Denmark, and the relative contributions of static-shift and intra-sector growth.

1995 to 2005
Compared to the period 1985 to 1995, the period 1995 to 2005 shows a totally different picture. The highest *totals* are found in the Czech Republic, Poland, Estonia and Germany as is already known from § 4.1. The largest negative values in Luxembourg, Ireland and Spain.

In the EU-25 a positive contribution is found from the static-shift, 7.39%, and an increase from intra-sector growth, 6.80%. Leaving the NMS out of the results for the EU-15 a positive contribution of 4.23% is found by static-shift and a slow down from the intra-sector growth, -5.60%.

So on average in this period a positive contribution from both the static-shift and intra-sector growth found. The averages further show that the NMS gain considerable growth through shift of labor share. And further that they generally show a high level of labor productivity growth. The labor productivity decreases in the EU-15 are caused by accelerated capital intensification unrelated to growth, as is shown in the growth decomposition in the previous subsection.

Figure 5 presents the absolute figures on the period 1995 to 2005. When the separate countries are studied, starting with the static-shift, the highest contributions are found in Slovenia, Estonia and Greece. The smallest contributions are observed in France, Italy and Austria. Countries showing large intra-sector growth are Poland and the Czech Republic. Large negative contributions are found in Spain, Ireland and Luxembourg.

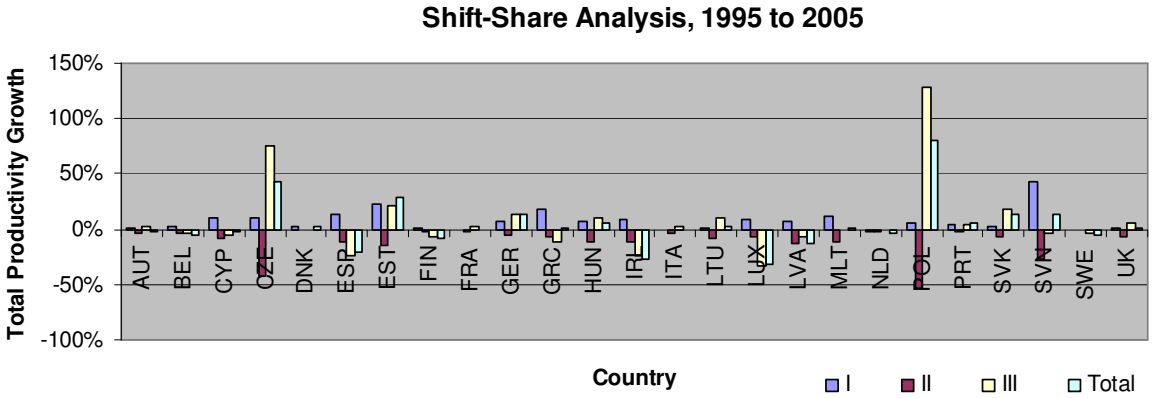

Figure 5: Results of the country level analysis on the EU-25, for the period 1995 to 2005. The I, II, III, correspond to the terms in eq. 11 and therefore represent static-shift, I, the interaction, II, and the intra-sector growth, III. The sum is presented as *total*.

The results of the shift-share analysis show that the reallocation of labor has a positive contribution to the total growth, throughout the period.
In the first decade the static-shift contributes most to countries which became member the latest, Portugal, Spain and Greece. Also Luxembourg shows a positive contribution on a further negative productivity growth.
In the second period the contribution of static-shift is largest in the NMS and then in the countries, Spain, Greece, Ireland and Luxembourg, which were also present as largest in the first period. Poland and the Czech Republic behave differently and show large intra-sector growth at relatively low levels of static-shift.
The positive contribution in the NMS and other countries newly admitted to the EU is expected because they open up their local markets. But the positive contribution from static-shift in the EU-15 is unexpected. Structural change in these countries is associated with a shift to the services sectors. Sectors usually associated with low labor productivity levels.

4.4 Connection of analyses

In the previous two subsections the labor productivity growth decomposition and the results of the shift-share analysis have been studied. In this subsection the relation between both is tested with a simple correlation analysis.
From the skills bias in technological change (SBTC)-argument, as has been explained in chapter 2, a negative correlation is expected between creating potential for knowledge spillovers and the static-shift. Further is a positive correlation expected between the assimilation of knowledge spillovers and the intra-sector growth.
The data used to test the relation on are the normalized results of the shift-share analysis, as are presented in table 5. The results of the growth decomposition as are presented in table 4. Only the countries available in the growth decomposition are incorporated in the analysis. The results are presented in table 6.
In table 6 does the upper panel present the results of the period 1985 to 1995, the middle panel the results of 1995 to 2005, but only for the same 8 countries, and the lower panel the results for 1995 to 2005. Only the bottom part of the correlation matrix is shown.

In the first period, 1985 to 1995, the expected correlation between the assimilation and intra-sector growth is strong and significant. This confirms that growth from assimilation and intra-sector growth are related processes in this period.
This correlation further indicates that assimilation as such is indeed an important source of growth. Earlier was in § 4.2 from the β-regression in relation to the frontier, no significant relation with the distance to the frontier found.
Also the correlation between assimilation and total growth is significant, indicating that assimilation and total growth are also closely related in this period. The relation between *total* and *assimilation*, suggested by these to findings, is not present.

Table 6: Correlations between the growth decomposition into assimilation, potential and innovation and the conventional shift-share analysis into static-shift, I, intra-sector growth, III, and the interaction, II. For the periods 1985-1995 and 1995-2005.

85-95	***I***	***II***	***III***	***Total***	***Assimilation***	***Potential***
N=8						
II	-.848 (.008)**					
III	.251 (.549)	-.725 (.042)*				
Total	.310 (.455)	-.558 (.151)	.616 (.104)			
Assimilation	.030 (.944)	-.497 (.210)	.871 (.005)**	.806 (.016)*		
Potential	.510(.196)	-.230 (.584)	-.244 (.561)	.454 (.259)	-.156 (.713)	
Innovation	.082 (.848)	.119 (.779)	-.323 (.435)	-.531 (.176)	-.442 (.273)	-.300 (.470)**
95-05 (n=8)						
II	-.939 (.001)**					
III	.923 (.001)**	-.999 (.000)**				
Total	.376 (.359)	-.159 (.707)	.130 (.758)			
Assimilation	.150 (.722)	.088 (.835)	-.118 (.781)	.938 (.001)**		
Potential	.117 (.783)	-.327 (.429)	.351 (.394)	-.639 (.088)	-.862 (.006)**	
Innovation						
95-05 (n=12)						
II	-.702 (.011)*					
III	.614 (.034)*	-.993 (.000)**				
Total	.277 (.384)	-.032 (.922)	-.010 (.975)			
Assimilation	-.459 (.133)	.004 (.991)	.071 (.826)	-.342 (.276)		
Potential	.610 (.035)*	.006 (.986)	-.106 (.743)	.495 (.101)	-.898 (.000)**	
Innovation	.					

* 0.05 level, ** 0.01 level.

The correlations between static-shift, I, and interaction, II, and interaction and intra-sector growth, III, are explained through the shift-share equation, eq. 11. This equation shows that the interaction, II, is affected by the growth in labor share and growth in labor productivity and therefore closely relates to both. The negative correlations are the result of structural change in underlying sectors on which the analysis is built. These indicate the opposite development in the static-shift and intra-sector growth.

In the second period, 1995 to 2005, is, on the total sample, n = 12, a significant correlation is found between creating potential and static-shift.
From this correlation can be concluded that, in this period, creating potential motivates shift of labor share. A conclusion which was expected because of the introduction of the NMS to the EU. The positive sign is unexpected, indicating that static-shift positively contributes to labor productivity growth, but in line with the shift-share findings.

The strong negative correlation between creating potential and assimilation confirms what has been found earlier. Countries create potential in this period from capital intensification, but are not able to absorb this new potential and are therefore confronted with diminishing efficiencies.
The strong correlations among the terms of the shift-share analysis point at developments in opposite directions.
In this panel no correlations on innovation are presented, as no growth from innovation is present in this period.

The significant correlations between the growth through assimilation and intra-sector growth in the first period, and between the static-shift and the growth through creating spillover potential in the second, indicate that both explain related processes.
The correlation analysis has also been executed on the raw shift-share results. But using the normalized results provides a better insight in the mutual relations. The results also make clear that further study is necessary as the expected relations are just partly found. In addition to this the results also appear to be sensitive to the introduction of new countries in the analysis and seem to be time depended.

4.5 Summary and conclusions from the country level analysis

In this chapter the sources of labor productivity growth have been studied on the country level for the EU member states. Further this analysis has been extended to an additional shift-share analysis to study the structural change in the EU.
The prime objective of this analysis is to answer the research question as is posed in the introduction. The first part of the question is *to what extent has 'technological change' contributed to growth*. This is answered by the growth decomposition analysis. The second part is *to what extend has 'structural change' added to labor productivity growth*. This is answered by the shift-share analysis. The complementary character of both analyses has been tested. Further the level of schooling as an addition to the growth differentials has been studied.

The results of the analysis in § 4.1, *general*, show that the EU-15 show higher labor productivity growth in the first half of the period, 1985 to1995, than in the second half, 1995 to 2005. In this second decade most of these EU-15 countries even show a decrease in labor productivity, with the largest decrease in countries which seem most depended on services, like Spain and Luxembourg. Contrary to these results most NMS show labor productivity growth. Although some grow fast, like Poland and the Czech Republic and others lag behind, like Estonia and Lithuania.
Contrary to the labor productivity the capital intensification is accelerating, especially in the second period. The highest rates of capital intensification are shown in the NMS.

The growth decomposition to estimate the 'technological change' and answer the first research question, starts with the estimation of the local EU production frontier.
In 1985 the frontier is defined by the production plans of Spain and The Netherlands. In 1995 the frontier is made up from five facets, each showing different labor productivity to capital

intensity ratios. The 2005 frontier coincides with the one in 1995 as no innovative activity is found.
In the context of this frontier the growth decomposition, attributing growth to assimilation of knowledge spillovers, creating potential and local innovation, is analyzed.

The results show that in the total period countries which lag behind catch-up to the productivity leader. This effect is almost twice as large in the first period as in the second period. The result indicates that within the EU a process of convergence is present. Convergence is in the EU a general process unrelated to the initial distance to the frontier, as is shown in the β-convergence analysis.
The most important source of growth is creating potential by capital intensification, the proxy for technological change. Capital intensification is also found to contribute more to growth in countries operating at low capital intensities, although these findings are only based on those countries that have additional potential left. The large capital intensification within the NMS indicates that they are not stuck in low potential technologies. An observation often made for developing countries (Los & Timmer, 2005, a.o.).
The results on the growth from local innovation show that, in the first half of the period, 1985 to 1995, all countries are able to benefit from the innovative activities in the Netherlands and the introduction of the NMS. But the regression doesn't show a significant result. In the second period local innovation is absent, as is the growth contribution related to this process.

In all analyses is the level of schooling not significant in explaining growth differentials. This can be the result of the fact that the level of schooling is no distinguishing factor in the EU, or the result of the small number of countries or an awkward development of the concept schooling. In the next chapter the concept will be tested on the sector level.

The contribution of *'structural change'* to aggregate labor productivity growth is assessed from the shift-share analysis. It is concluded that the shift of labor towards other sectors, the static-shift, has a positive contribution to total growth, throughout the period.
In absolute terms the contribution of the static-shift is largest in Portugal, Spain and Luxembourg and lowest in the UK and France.
From the differences in the results of the EU-25 and the EU-15 in the second period, can be derived that the NMS show larger static-shift and intra-sector growth compared to the EU-15. But also that in the EU-15 the inter-sector growth contributes positively to total growth.

The results on the correlation analysis between the assimilation of knowledge spillovers and the intra-sector growth, which are closely related processes, show a significant association. No correlation with creating potential is found, in this period, but in the second period, 1995 to 2005, it is present. The sign is, unexpectedly, positive, indicating that, on country level, static-shift contributes to shift of labor to higher labor productivity sectors. This finding is in line with the results of the shift-share analysis.
The assumptions in this study on the relation between the growth decomposition and the shift-share analysis are partly confirmed. One expected correlation is found in the first period and the other in the second period. This indicates that the relation might be not robust and time depended. Further study is necessary.

In the next chapter, *productivity growth dynamics on sector level*, the framework of analysis is brought to the sector level analysis. On sector level the individual sector level developments are studied to further explain the country level results as are found in this chapter.

Productivity growth dynamics on sector level

In this chapter the analysis is taken to the sector level. The goal of the sector level analysis is to study the 'technological change' on this level and explain the country level findings in more detail.
To analyze the 'technological change' this chapter starts with § 5.1, *frontier estimation*. In this subsection the sector level frontiers are presented. Then in § 5.2, *growth decomposition on sector level*, the results of the sources of growth analysis are discussed. In *shift-share analysis*, § 5.3, the country level results from the shift-share analysis are studied in more detail. And the last subsection, § 5.4, presents the summary of the chapter and the conclusions of this sector level analysis.

5.1 Frontier estimation

The objective of this subsection *frontier estimation* is to study the 8 sector frontiers separately and to estimate the country frontier development from the results. This estimation of the country frontier is merely qualitative because the country-sector relation is interfered with the sector distribution of the sectors within the individual countries.
The sector frontiers are, equal to the country frontier, estimated from intertemporal panels. But they differ on the point that technologies are restricted to the specific sectors within the individual countries. This is also the case for the labor productivity levels.
In table 7, which can be found at the end of this subsection, the sector frontiers are presented by the countries and the production plans on the frontier for the years 1985, 1995, and 2005. In the upper panel the countries on the country frontier are presented. The other panels present the frontiers of the separate sectors.
The table shows that in some sectors the frontier is raised throughout the period but that some sectors however show no raise at all. The frontier description is hereafter ordered along these differences in innovative activity.

Sector frontiers showing innovation until the mid-1980s
The first group of sectors is made up from sectors that show no innovation, almost throughout the period. That is, within countries no innovative activity is present in these sectors. The sectors are transportation, financial intermediation, real estate, renting of machinery and equipment and business activities, further indicated as real estate, and mining. In the figures 6 to 9 the 2005 frontiers on each of the sectors are presented with the country specific production plans for 1985, 1995 and 2005 underneath. In figure 14 the 2005 overall country frontier is presented together with the 2005 sector frontiers to compare the overall frontier with the sector frontier, and the sector frontiers mutually.
The frontier in the figures is visualized by a scatter plot from the output of the DEAP-program used to estimate the frontiers. The horizontal upper bound of the frontier is not present in the DEAP results because there is no additional labor productivity potential available beyond the peak of the frontier.

The results of the frontier estimation shows that, besides the fact that the countries show hardly any innovative activity, these four estimated frontiers have three other properties in common. The first is that the frontier peak lies above the country level frontier. The second is that throughout the period the capital intensification is unrelated to labor productivity growth. This indicates that the technology used changes but without becoming more productive. The last property is that, equal to the country level frontier, the 1995 introduction of the NMS introduces new, efficient technologies to the frontier and extents it to lower capital intensities. Hereafter are some specific points on each of the four sectors are highlighted.

Transportation is made up from the activities in transportation, storage and communication. Figure 6 shows that, compared to the country level, the capital intensity of these activities is higher and also the rate of capital intensification is above the country level rate.
This capital intensification is only rewarded with additional potential for growth in countries operating at moderate capital intensities. In figure 6 the countries that operate at capital intensities 'beyond' the frontier can be seen.
The last observation on transportation is that labor productivity levels are converging. Several countries show decreasing labor productivity levels, which, together with the capital intensification, results that none of the countries operates close to the frontier in 2005.

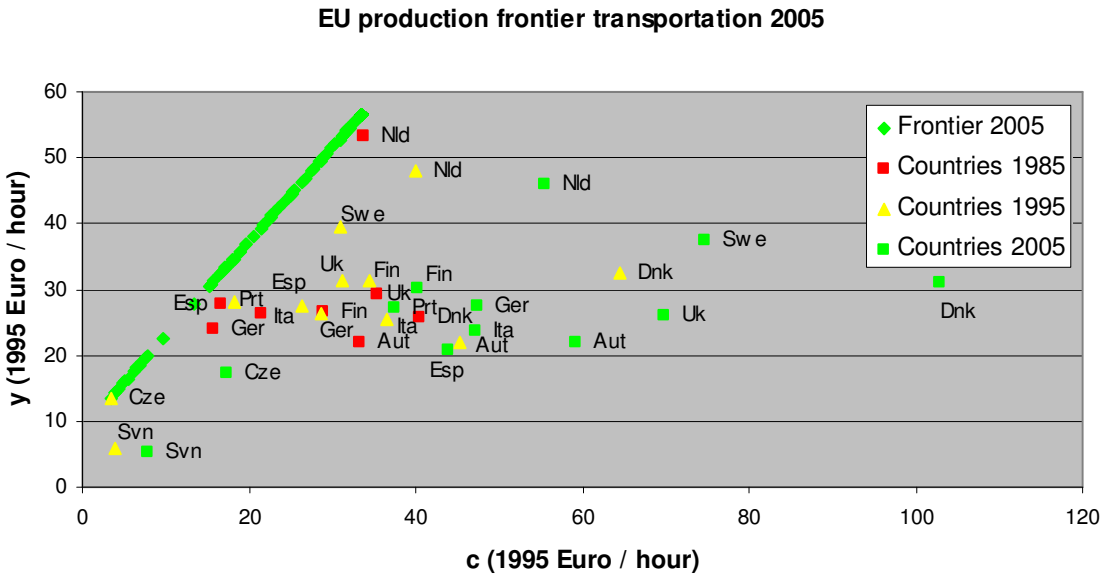

Figure 6: The 2005 production frontier of the transportation sector with horizontally the capital intensity and vertically the labor productivity. The country specific production plans are projected underneath.

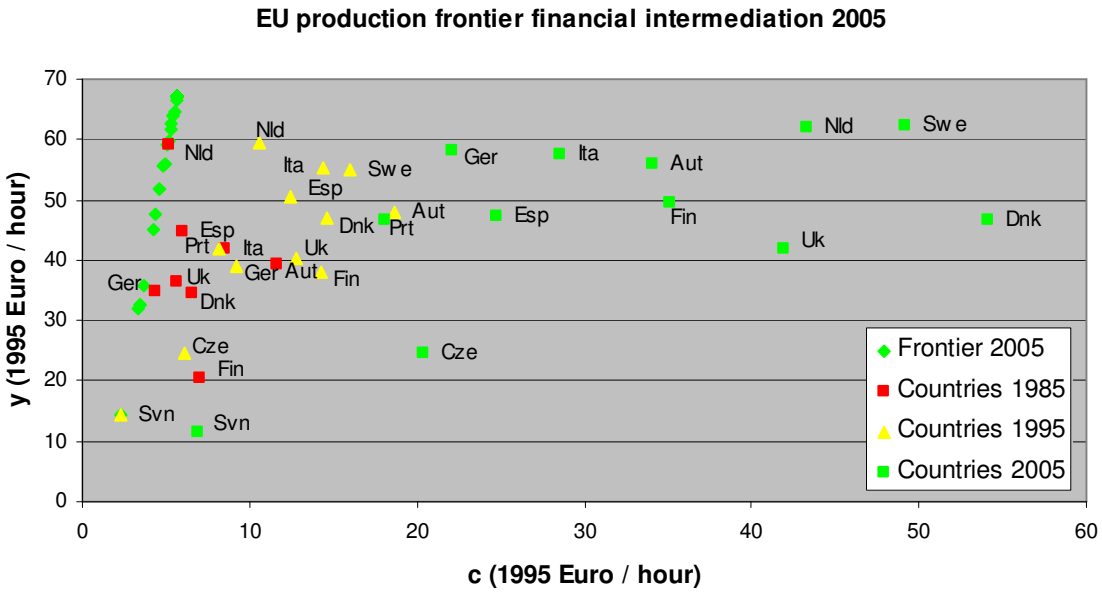

Figure 7: The 2005 production frontier of the financial intermediation sector with horizontally the capital intensity and vertically the labor productivity. The country specific production plans are projected underneath.

Contrary to the overall country frontier is the frontier for financial intermediation defined at very low capital intensities, as is shown in figures 7 and 14. Labor productivity growth is therefore for most countries only present at capital intensities far 'beyond' the frontier.
The labor productivity growth is the result of assimilation of knowledge. This growth from assimilation is shown by increasing efficiencies.
The highest efficiencies are found in Sweden, 93%, and the Netherlands, 92%, the countries that are operating at high capital intensities. Slovenia and the Czech Republic show the lowest efficiencies, 17% and 37%. These countries seem not able to assimilate the knowledge of financial intermediation.

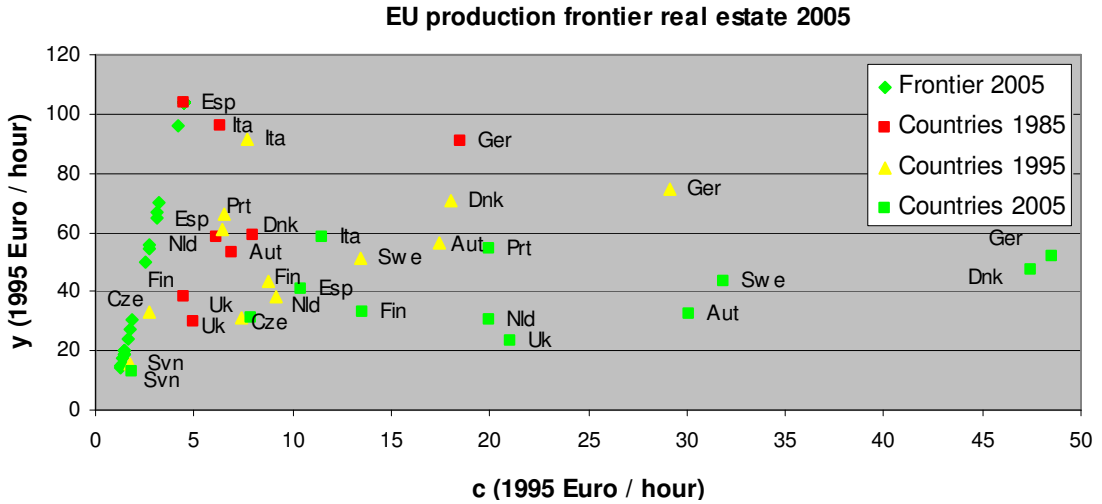

Figure 8: The 2005 production frontier of the real estate sector with horizontally the capital intensity and vertically the labor productivity. The country specific production plans are projected underneath.

The real estate sector shows at the frontier peak the highest labor productivity frontier after mining, at a capital intensity level comparable with the financial intermediation sector. This peak is outside the frame in figure 14.
This frontier is in 1985 only an efficient projected point by the production plan of Spain. Throughout the period is the only adjustment the introduction of Slovenia which extents the frontier to even lower capital intensities.
The decreasing labor productivity and increasing capital intensities that are shown in figure 8 are in this sector the result of the rapid growth of the activities renting of machinery and equipment and business activities.

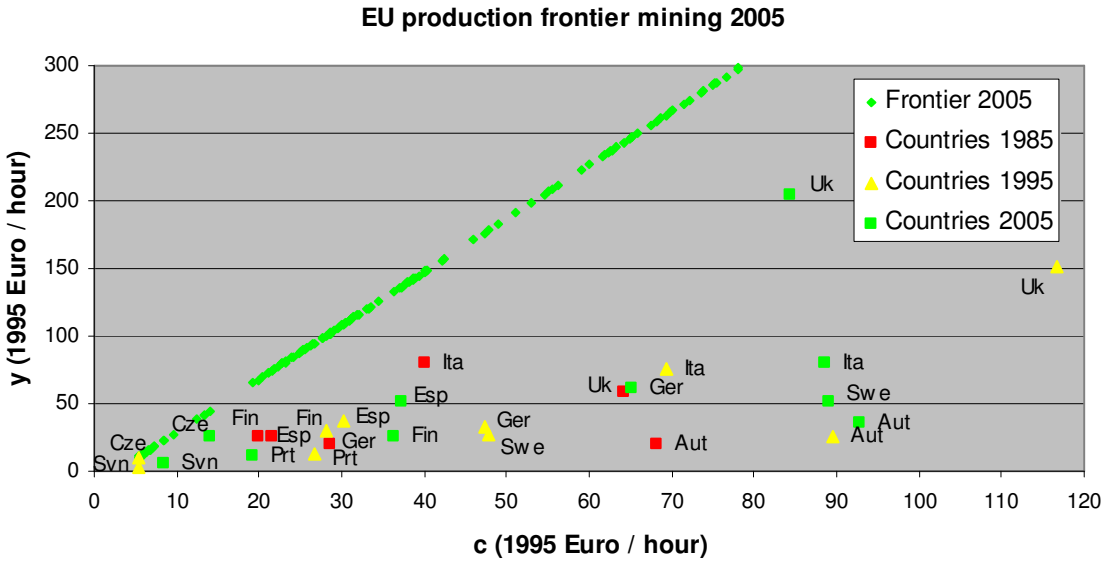

Figure 9: The 2005 production frontier of the mining sector with horizontally the capital intensity and vertically the labor productivity. The country specific production plans are projected underneath.

The mining sector is the last sector in this group. It is made up from a diverse group of activities restricted by the availability of natural resources. These activities show different labor productivity levels and capital intensities. Both are, on average, higher than the country level.
In figure 9 an excerpt of the sector frontier is shown. The Netherlands, that is on the frontier throughout the period, is positioned outside the frame, together with Denmark.
The high levels of labor productivity and capital intensity in the Netherlands are related to the activities in oil and natural gas. This also explains the lack of growth. In 1985 the world market price for oil was still high because of the second energy crisis and has been decreasing until around 2000.
The boundlessly available potential under this frontier results in high growth in potential, and a fall in efficiency, at capital intensification. This last is visible through the increasing distance to the frontier. The UK is the only country to assimilate knowledge and increase its efficiency fast.

Sector frontiers showing innovation until the mid-1990s

The second group is made up from sectors in which countries have been innovating until somewhere in the 1990s. These sectors are the agricultural sector and the trade sector.
The figure 14 shows that both frontiers are lower than the country level frontier and also that both frontier peaks are defined by Denmark.

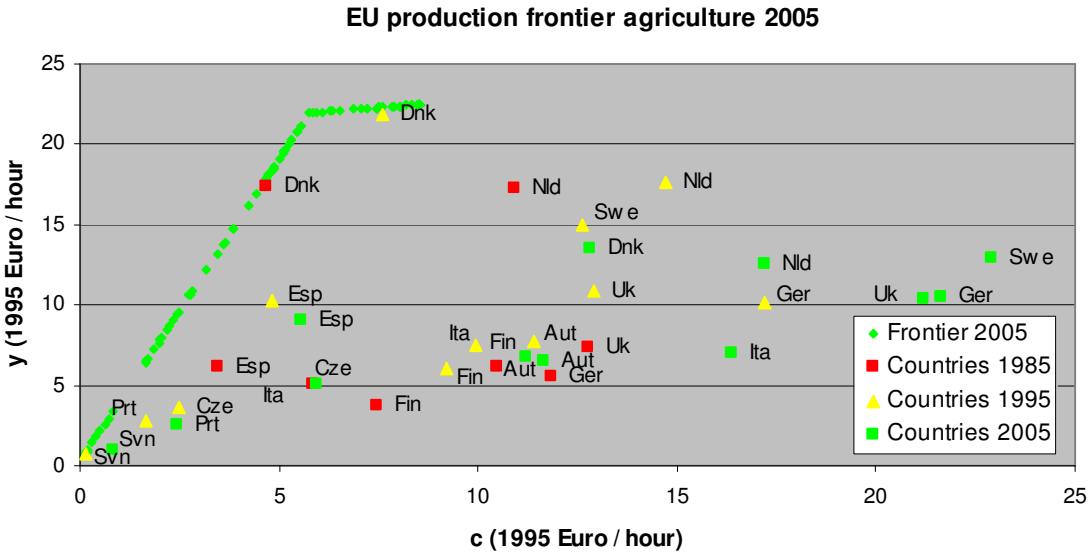

Figure 10: The 2005 production frontier of the agricultural sector with horizontally the capital intensity and vertically the labor productivity. The country specific production plans are projected underneath.

The agricultural sector frontier is characterized by the lowest productivity of all sectors. The frontier top is around 65% of the country frontier, at 50% of the capital intensity.
Due to capital intensification operate most countries by 2005 more capital intensive than this efficient level. In figure 10 this is shown by the country movement 'beyond' the frontier to locations where no additional potential is available. A process that is also present on the country level, and in several of the previously described sectors.
In the figure two more things attract the attention. The first is the decreasing productivity. The second is the group of countries operating at relatively low capital intensities.
This decreasing productivity is primarily situated in countries showing high levels of labor productivity. The Netherlands operates in 1985 relatively close to the frontier, but lags behind in the years after that, together with Denmark and Sweden. The result is that countries operate closer to each other at the end of the period.
The second group of countries operate at relatively low capital intensities and doesn't show catch-up to the frontier. These 'non-specialists', Austria, Italy and Finland, operate at efficiencies between 21% and 35%.
Because the capital intensity is an indicator for the technology used, the availability of two groups shows a different mode for agriculture. Modern and capital intensive versus more traditional.

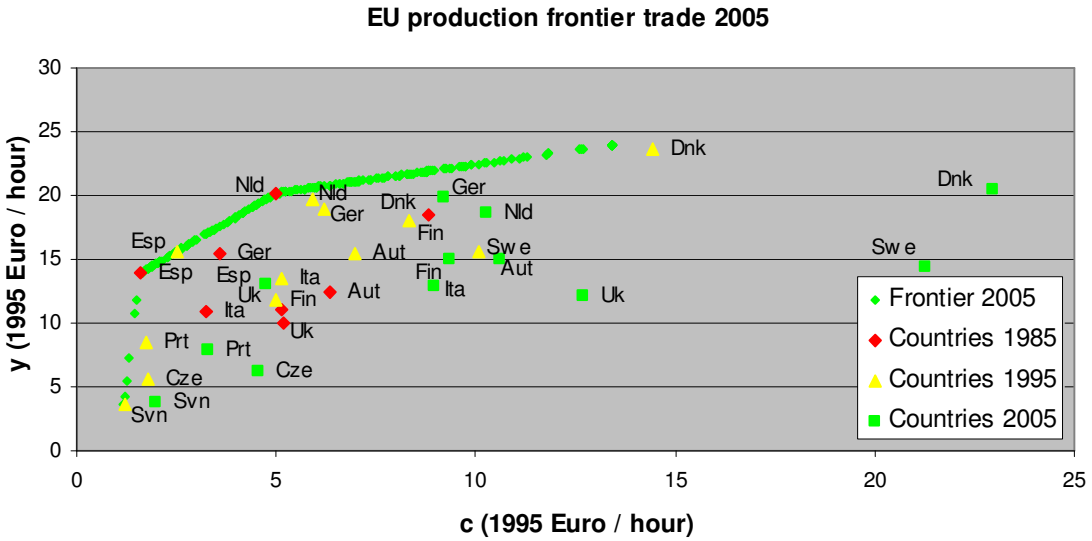

Figure 11: The 2005 production frontier of the trade sector with horizontally the capital intensity and vertically the labor productivity. The country specific production plans are projected underneath.

The trade sector frontier in figure 11 shows two properties that directly attract the eye. The first is that it is made up from six facets, each showing different labor productivity to capital intensity ratios. The second is that the frontier 'envelopes' almost all production plans.
This frontier is in 1985 defined by the Netherlands and Spain as is shown from the red dots in the frontier. The high labor productivity in the Netherlands in this first year is mainly the result of the importance of the wholesale trade, usually associated with higher labor productivities. In Spain, on the contrary, the retail trade and hotels dominate the total value added in this sector. Innovation in Spain, the Netherlands and Denmark raises, the 1995 frontier, with Denmark showing the highest labor productivity. The introduction of Slovenia further extents the frontier to lower capital intensities.
The facets in the frontier indicate that innovation and capital intensification are related processes in trade. New investment results in a raise of the frontier where older technologies stay on the frontier as well. The logical outcome of this joint development is that the trade sector frontier 'envelopes' most production plans present. Capital intensification in countries underneath this frontier is, as a result, always rewarded with additional potential.

Sector frontiers showing innovation after the year 2000
The third and last group is made up from only two sectors. In these sectors is, from ongoing innovation in countries, the production frontier raised throughout the period. These sectors are manufacturing and construction. The frontiers of both sectors are presented in figures 12 and 13.
In figure 14 is shown that the maximum labor productivity at the frontier is comparable to the country level frontier. But also that this labor productivity is realized with totally different technologies which is shown by the different levels of capital intensity.

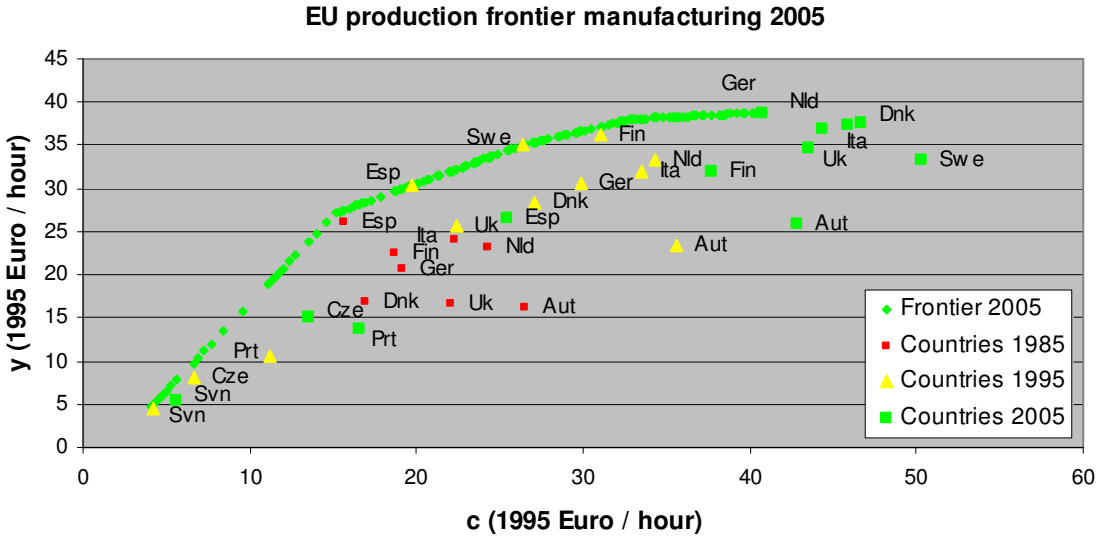

Figure 12: The 2005 production frontier of the manufacturing sector with horizontally the capital intensity and vertically the labor productivity. The country specific production plans are projected underneath.

Figure 12 presents the manufacturing frontier that is, comparable to the trade frontier, composed of several different facets. Each new facet contributes less to the labor productivity growth pointing at diminishing returns on the new investment. And it, also similar to the trade frontier, 'envelopes' most production plans. The last observation is that countries operate relatively close to the frontier.
The 1985 manufacturing frontier is defined by Spain only. This is earlier found for the real estate sector frontier. Other countries operate more capital intensive, but Spain is because of the high labor productivity in the *chemicals industry* and the *electricity supply* most productive. The frontier is raised until 2005 through ongoing innovative activities at increasing capital intensities. This ongoing innovation at high capital intensities results in the facets and a frontier that envelopes most of the production plans, as has been discussed on the trade sector.
Compared to the trade sector these production plans of the countries are closer to the frontier. This is shown by the West-European countries moving as a related block of countries along the frontier. These West European countries operate close together, only Spain is falling behind. Slovenia, the Czech Republic and Portugal, are newly introduced in 1995 at a large capital intensity distance which results in a large gap between the two groups.

The second sector in this group is the construction sector. The striking property of this sector is the country movement underneath the frontier indicating that growth from assimilation of knowledge is the dominant process.
The 1985 frontier of the construction sector is defined by Spain and Austria. Towards 1995 this frontier is raised by innovative activities in both countries, and extended to lower productivity levels because of the introduction of the Czech Republic to the frontier. After 1995, the frontier is further raised by innovation in Austria.
The innovative activity in Austria is first of all the result of sheer innovativeness. It is, different from development in all other sectors, unrelated to capital intensification.
Other countries show labor productivity increase by pure assimilation in the first period, the Netherlands, Spain and Italy. In the second period a decrease in productivity is shown accompanied by capital intensification.

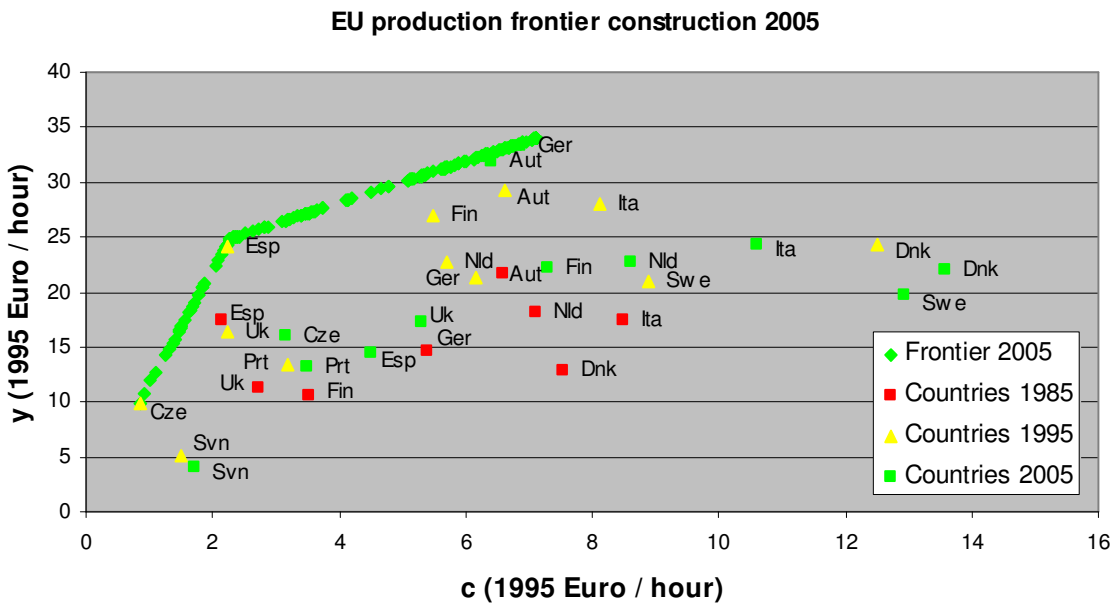

Figure 13: The 2005 production frontier of the construction sector with horizontally the capital intensity and vertically the labor productivity. The country specific production plans are projected underneath.

The country-sector relation

The objective of this subsection is to study the separate sector frontiers and make a qualitative approximation of the country level frontier based on these results.
The sectors have been studied in three groups, ordered by the innovativeness and are presented in figure 14, together with the overall country frontier. The first group shows no raise of the frontier after the mid-1980s. The second group not after the mid-1990s. And the last group shows a raise of the frontier throughout the period.

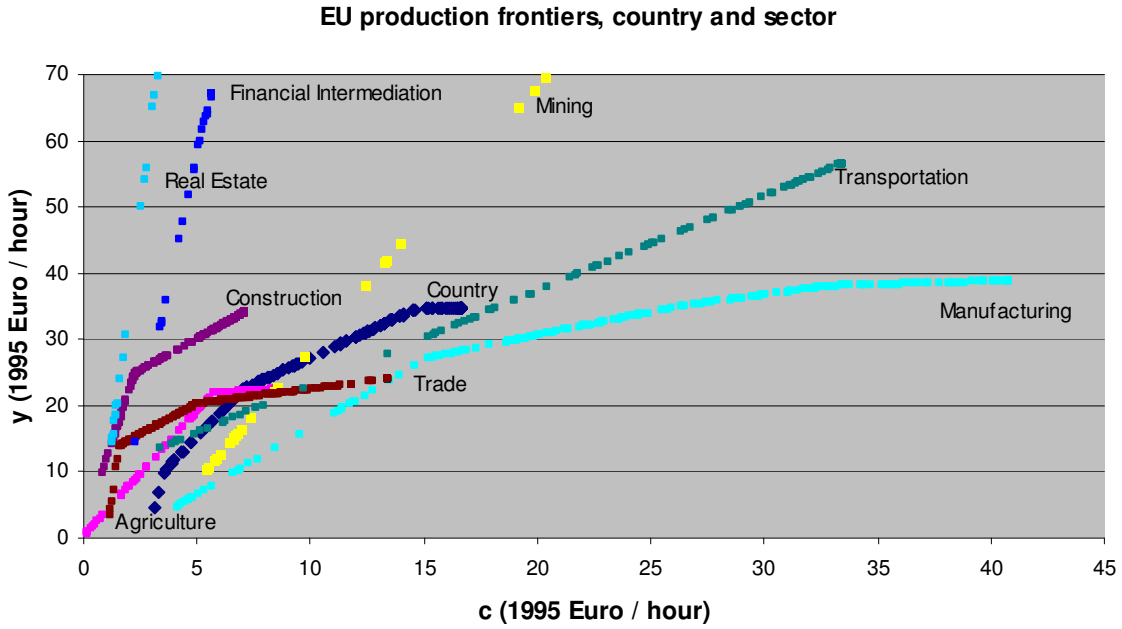

Figure 14: The 2005 EU country production frontier and the separate sector frontiers. The frame is an excerpt. Both the mining and the real estate sector frontiers are cut-off.

From these separate sector developments the development of the country level frontier is not simply estimated because the shares of labor and the sector distributions within the country affect the country-sector relation. But the frontier development can be explained by looking at the sector level developments, though. This explanation is sought for by the sector innovativeness, the dominant source of growth and the labor share of the sector in the economy.
The country level study and table 7 showed known that the country level frontier is raised until 1994 by the Netherlands and also that after 1994 capital intensification accelerates without growing from it. The frontier shows five facets because capital intensification is faster than labor productivity growth, as is also shown in the trade and manufacturing sectors.

In the period 1985 to 1995 is the production frontier of the sectors agriculture, trade, construction and manufacturing raised. This is the result of innovative activity in the countries defining the frontier. In mining, transportation and both producer sectors no innovation is present.
The four innovative sectors cover, in 1985, around 70% of the labor share, as can be found in appendix I. So developments in these sectors are dominant in the explanation of country level development. The innovative activities in these sectors, together with decreasing labor productivity levels in some of the other sectors, therefore explain the raise of the country frontier in this period. The capital intensification present in the non-innovative sectors, is also present at country level. This capital intensification is shown by the facets on the country frontier, as is discussed earlier.
In the second period is the only raise of the frontier shown in manufacturing and construction. These two sectors only make up for around 35% of the labor share. The other sectors make up for the other 65% and show no innovative activity. The dominant process is that of capital intensification.
The overall country frontier therefore shows no raise and at the country level is capital intensification dominant.

Table 7: Countries on the EU production frontier, and the specific sector frontiers, in 1985, 1995, and 2005.

	1985				1995				2005			
	Country	***Year***	***y***	***c***	***Country***	***Year***	***y***	***c***	***Country***	***Year***	***y***	***c***
Total EU	NLD	1985	33.20	14.09	NLD	1994	34.85	16.65	NLD	1994	34.85	16.65
	ESP	1985	21.92	7.17	NLD	1987	34.61	15.15	NLD	1987	34.61	15.15
					NLD	1986	34.43	14.55	NLD	1986	34.43	14.55
					ESP	1986	22.55	7.05	ESP	1986	22.55	7.05
					CZE	1995	10.50	3.63	CZE	1995	10.51	3.63
					SVN	1995	4.63	3.09	SVN	1995	4.63	3.09
Extraction												
Agriculture	DNK	1985	17.43	4.70	DNK	1989	21.97	5.77	DNK	1997	22.49	8.55
	ESP	1985	6.11	3.44	SVN	1995	0.72	0.14	DNK	1989	21.97	5.77
									SVN	1996	0.76	0.15
									SVN	1995	0.72	0.14
Mining	NLD	1985	1114.85	284.61	NLD	1985	1114.85	284.61	NLD	1985	1114.85	284.61
	ESP	1985	25.844	19.848	CZE	1995	10.53	5.39	CZE	1995	10.53	5.39
Transformative												
Manufacturing	ESP	1985	26.14	15.69	FIN	1993	38.00	32.91	GER	2005	38.81	40.77
					SWE	1995	35.01	26.39	FIN	1993	38.00	32.91
									SWE	1995	35.01	26.39
									ESP	1986	27.20	15.2
									SVN	1996	4.72	4.11
Construction	AUT	1985	21.60	6.58	AUT	1993	30.03	6.96	AUT	2002	34.03	7.12
	ESP	1985	17.53	2.15	ESP	1994	24.84	2.28	ESP	1994	24.84	2.28
					CZE	1995	9.79	0.85	CZE	1996	10.8	0.92
									CZE	1995	9.79	0.85
Distributive services												
Trade	NLD	1985	20.17	5.01	DNK	1994	23.99	13.44	DNK	1994	23.99	13.44
	ESP	1985	13.92	1.62	NLD	1986	20.31	5.24	NLD	1986	20.31	5.24
					NLD	1985	20.17	5.01	NLD	1985	20.17	5.01
					ESP	1995	15.65	2.51	ESP	1995	15.65	2.51
					ESP	1994	15.45	2.40	ESP	1994	15.45	2.40
					ESP	1985	13.92	1.62	ESP	1985	13.92	1.62
					SVN	1995	3.57	1.19	SVN	1996	3.60	1.16
Transportation	NLD	1985	53.28	33.70	NLD	1987	56.46	33.43	NLD	1987	56.46	33.43
	ESP	1985	27.91	16.58	CZE	1995	13.54	3.40	CZE	1995	13.54	3.40
	GER	1985	24.04	15.83								
Producer services												
Financial intermediation	NLD	1985	59.20	5.15	NLD	1988	67.08	5.69	NLD	1988	67.08	5.69
	GER	1985	34.88	4.38	NLD	1986	61.59	5.26	NLD	1986	61.59	5.26
					SVN	1995	14.37	2.29	SVN	1995	14.37	2.29
Real estate	ESP	1985	103.89	4.46	ESP	1985	103.89	4.46	ESP	1985	103.89	4.46
					SVN	1995	14.48	1.28	SVN	1995	14.48	1.28

y: labor productivity (1995 Euro / hour)
c: capital intensity (1995 Euro / hour)

5.2 Growth decomposition on sector level

In this subsection is the growth decomposition on sector level studied in relation to the sector frontiers as are presented in the previous subsection. The goal is to find the dominant sources of growth and relate these to the findings in § 5.1 and to the country level development.
The results are presented in tables 8 and 9.

Methodology
To study the sources of growth is, equal to the country level analysis, first the growth decomposition calculated. The three decomposed sources of growth are the growth from assimilation of knowledge spillovers, creating potential and local innovation. As far as the results are not discussed in the previous subsection, these are presented on the tables in appendices F, G, and H.
The three regressions to study the sources of growth from the growth decomposition are represented by eq. 7, eq. 8, and eq. 9. The A-, CSP-, and LI-regression. Negative signs on β in the results indicate that countries operating further from the frontier are growing faster from the source used to regress on. The analysis starts with the total regression, T-regression, that studies convergence unrelated to the frontier, as is represented by eq. 6.
The methodology is equal to the country level calculation as again Denmark is used as reference country. This choice to use Denmark is based on the following considerations. The first is that the methodology is equal to the country level which enhances the comparability with the sector level results. And second, considering the top labor productivity in Denmark in 1995, this country has found a successful mix over sectors and provides a reference to others.
In the remainder of this section are the findings presented and discussed. Equal to the previous subsection ordered by innovativeness.

Sector frontiers showing innovation until the mid-1980s
This group of four sectors has previously been characterized by the absence of the raise of the frontier, the result of the lack of innovativeness. And secondly by capital intensification unrelated to growth.

In table 8 the results of the analysis show the lack of innovativeness by the absence of most of the LI-results. This is also the expected result. The growth contribution from local innovation in financial intermediation is the result of the frontier raise in 1988 by the Netherlands. All countries are able to benefit from this. But the largest contribution is found in Germany, see appendix H. This large benefit is the result of operating close to the frontier in 1985.
The contribution from innovation in the mining sector is the result of the introduction of the Czech Republic on the frontier. The Czech Republic introduces a new, efficient, technology of which other countries benefit.

The second characteristic is the capital intensification. The regression results in all four sectors show that capital intensification results in faster growth in countries that operate at lower capital intensities. This growth in potential is in both producer services sectors restricted to countries that operate at low capital intensities. As is expected from the low capital intensive frontiers in the figures 7 and 8. In the transportation sector also the medium capital intensive countries benefit. It is also in the transportation sector that the contribution to growth of schooling is significant. Countries that benefit most from creating potential show high levels of schooling. In mining, with almost endless potential for growth, takes a special position due to the high capital intensity in the mining sector in the Netherlands.

The last point on these sectors is convergence between countries. This convergence is clearly visible in the frontier figures. In transportation, financial intermediation and real estate, this results in growth from assimilation.

Table 8: Sources of growth analysis for the periods 1985 to 1995, and 1995 to 2005.

Transportation	**α**	**ß**	**ß2**	**R^2 (adj)**
T: 85-95	-.108 (p=.384)	-.183 (p=.319)	-.050 (p=.529)	0.029
T: 95-05	-.196 (p=.221)	-.030 (p=.689)	.130 (p=.240)	0.013
A: 85-95	-.116 (p=.577)	-.528 (p=.039)*	-.030 (.800)	0.471
A: 95-05	.160 (p=.519)	-.179 (p=.370)	-.026 (p=.885)	-0.123
CSP: 85-95	-.121 (p=.027)	-.896 (p=.000)**	.093 (p=.014)*	0.986
CSP: 95-05	.048 (p=.896)	-.670 (p=.003)**	-.024 (p=.930)	0.639
LI: 85-95***				
LI: 95-05***				
Financial intermediation	**α**	**ß**	**ß2**	**R^2 (adj)**
T: 85-95	-.089 (p=.577)	-.787 (p=.010)*	.040 (p=.697)	0.674
T: 95-05	.040 (p=.862)	.167 (p=.299)	.053 (p=.741)	-0.083
A: 85-95	-.081 (p=.569)	-.835 (p=.003)*	.048 (.603)	0.800
A: 95-05	.786 (p=.463)	-.557 (p=.162)	-.736 (p=.475)	-0.079
CSP: 85-95	-.034 (p=.460)	-1.009 (p=.000)**	.040 (p=.352)	0.987
CSP: 95-05	.002 (p=.448)	-2.381 (p=.000)**	.000 (p=.704)	1.000
LI: 85-95	.036 (p=.458)	-.234 (p=.004)**	-.043 (p=.349)	0.764
LI: 95-05***				
Real estate	**α**	**ß**	**ß2**	**R^2 (adj)**
T: 85-95	-.293 (p=.236)	-.280 (p=.196)	.025 (p=.864)	0.067
T: 95-05	-.006 (p=.953)	-.131 (p=.062)	.018 (p=.817)	0.278
A: 85-95	-.293 (p=.235)	-.279 (p=.198)	.025 (p=.863)	0.065
A: 95-05	.162 (p=.497)	-.267 (p=.018)*	-.195 (p=.358)	0.438
CSP: 85-95***				
CSP: 95-05	-.618 (p=.500)	-.166 (p=.473)	.626 (p=.448)	-0.031
LI: 85-95***				
LI: 95-05***				
Mining	**α**	**ß**	**ß2**	**R^2 (adj)**
T: 85-95	.228 (p=.769)	-.215 (p=.282)	.006 (p=.988)	-0.057
T: 95-05	-.195 (p=0.727)	-.152 (p=0.217)	.015 (p=.968)	-0.021
A: 85-95	-.034 (p=.913)	-.208 (p=0.163)	.092 (p=.635)	0.152
A: 95-05	-.161 (p=.716)	-.210 (p=.257)	-.037 (p=.906)	-0.031
CSP: 85-95	.365 (p=.384)	-.466 (p=.003)**	-.272 (p=.223)	0.867
CSP: 95-05	-.796 (p=.333)	-.476 (p=.008)**	.283 (p=.595)	0.530
LI: 85-95	.038 (p=.671)	-.066 (p=.016)*	-.038 (p=.416)	0.719
LI: 95-05***				

***** at 0.05, ** at 0.01, *** not available

Sector frontiers showing innovation until the mid-1990s
The sectors trade and agriculture are the two sectors that have been innovative until the mid-1990s. In the trade sector the frontier is raised until 1994 by Denmark, and in agriculture also by Denmark, but until 1997. The second characteristic is that both frontiers are below the country level frontier. The results are presented in table 9.

The typical characteristic of agriculture is that a low capital intensity group and a high capital intensity group are present. In growth through innovation the low capital intensity countries benefit more from the introduction of Slovenia, whereas the high capital intensity countries benefit more from the innovativeness of Denmark. These two sources of innovation in one sector make that the results on the LI-correlation analysis are not significant as can be seen in table 9.
In the second period have most countries moved towards higher capital intensities, as is visible in figure 10, and benefit from the frontier raise in 1997. This regression result is then significant.
In the trade sector innovation is even more local, considering the six facets of the frontier. Also in trade the regression is not significant and in the second period not available.

The regression results of the CSP-regression show that growth from creating potential is in agriculture concentrated in specific, low capital intensity, countries. Indicated by the high R^2.
The results further show that countries with lower targets grow faster from capital accumulation. From the figure on the sector frontier this is an expected result. The Czech Republic and Spain are two low capital intensity examples of this.
In the trade sector the frontier envelopes almost all production plans. Capital intensification is therefore rewarded with additional potential. Due to the facets on the frontier is the reward larger for low capital intensities than for higher intensities, because the successive facets add less target labor productivity potential.
Equal to the transportation sector indicates the regression for the period 1985 to 1995, that the level of schooling is positively associated with growth.

The last two observations on these sectors are that within the high labor productivity countries decreasing growth rates are shown and countries as a result operate closer together, and the growth from assimilation.
In table 9 the T-regression results on agriculture show convergence from countries lagging behind growing faster. In the first period this is shown by countries like Spain, Finland, and Italy. In the second period the relation is stronger because the labor productivity is decreasing in countries showing high levels, like Denmark.
These processes result in corresponding growth from assimilation, although in the first period one can discuss whether or not 0.05 indicates a significant result. Growth from assimilation is also found in the trade sector. And although the model in the second period explains a large part of the variance no significant result is.

Table 9: Sources of growth analysis for the periods 1985 to 1995, and 1995 to 2005.

Agriculture	**α**	**ß**	**ß2**	**R^2 (adj)**
T: 85-95	-.027 (p=.890)	-.349 (p=.047)*	-.033 (p=.579)	0.425
T: 95-05	-.20 (p=.872)	-.228 (p=.001)**	.087 (p=.190)	0.715
A: 85-95	-.285 (p=.095)	-.306 (p=.050)	.051 (p=.396)	0.571
A: 95-05	-.084 (p=.576)	-.348 (p=.036)*	.026 (p=.782)	0.397
CSP: 85-95	-.031 (p=.468)	-1.752 (p=.000)**	-.028 (p=.106)	0.997
CSP: 95-05	-.141 (p=.483)	-.771 (p=.000)**	.112 (p=.315)	0.927
LI: 85-95	.350 (p=.468)	.131 (p=.074)	.031 (p=.106)	0.775
LI: 95-05	-.001 (p=.975)	-.090 (p=.000)**	-.004 (p=.811)	0.878
Trade	**A**	**ß**	**ß2**	**R^2 (adj)**
T: 85-95	-.083 (p=.685)	-.360 (p=.248)	-.043 (p=.730)	-0.037
T: 95-05	-.110 (p=.159)	-.083 (p=.054)	.110 (p=.068)	0.571
A: 85-95	.020 (p=.958)	-.939 (p=.014)*	.003 (p=.993)	0.448
A: 95-05	.141 (p=.419)	-.330 (p=.150)	-.230 (p=.121)	0.171
CSP: 85-95	-.160 (p=.028)	-.588 (p=.005)**	.106 (p=.030)*	0.760
CSP: 95-05	-.277 (p=.185)	-1.624 (p=.000)**	.080 (p=.621)	0.962
LI: 85-95	-.025 (p=.688)	.218 (p=.174)	-.049 (p=.283)	0.096
LI: 95-05***				
Manufacturing	**α**	**ß**	**ß2**	**R^2 (adj)**
T: 85-95	13.057 (p=.000)**	-.568 (p=.115)	.038 (p=.765)	0.210
T:95-05	-.585 (p=.102)	-.191 (p=.123)	.333 (p =.235)	0.252
A: 85-95	.016 (p=.892)	-.441 (p=.069)	-.078 (p=.357)	0.364
A: 95-05	-.242 (p=.339)	-.729 (p=.071)	.071 (.713)	0.235
CSP: 85-95	-.062 (p=.114)	-.276 (p=.662)	.047 (p=.109)	0.219
CSP: 95-05	.254 (p=.708)	1.070 (p=.721)	-.310 (p=.554)	-0.218
LI: 85-95	-.093 (p=.076)	-.555 (p=.496)	.084 (p=.042)*	0.453
LI: 95-05	-.392 (p=.096)	-2.013 (p=.056)	.331 (p=.073)	0.261
Construction	**α**	**ß**	**ß2**	**R^2 (adj)**
T: 85-95	-.095 (p=.799)	-1.195 (p=.084)	.006 (p=.979)	0.285
T: 95-05	-.328 (p=.401)	-.042 (p=.838)	.309 (p=.270)	-0.026
A: 85-95	.077 (p=.728)	-.858 (p=.047)*	-.059 (p=.650)	0.417
A: 95-05	.020 (p=.958)	-.939 (p=.014)*	.003 (.993)	0.442
CSP: 85-95	.108 (p=.287)	.012 (p=.956)	-.085 (p=.271)	0.022
CSP: 95-05	-.147 (p=.598)	-1.240 (p=.000)**	.095 (p=.706)	0.779
LI: 85-95	-.037 (p=.170)	-.005 (p=.921)	.024 (p=.223)	0.086
LI: 95-05	-.079 (p=.040)	.129 (p=.001)**	.054 (p=.101)	0.704

* at 0.05, ** at 0.01, *** not available

Sector frontiers showing innovation after the year 2000

This last group of sectors is made up of the sectors manufacturing and construction. In these sectors the frontier is raised throughout the period.

Within the manufacturing sector none of the regressions shows a significant relation between growth and position under the frontier. The only significant results are with the Y-intercept in the *total* regression, and the level of schooling in the innovativeness regression.

The R^2 of the regression results indicate that the models are only explaining a small part of the variance of the sector development. This indicates that growth is unrelated to the position under the frontier, the result of countries operating close to the frontier and the different facets that make benefits local.

The significance in the Y-intercept indicates that in 1985 the countries operate close together, as was observed in the sector figure.

The significant results on the level of schooling indicate that benefits from local innovativeness are associated with high levels of schooling.

The sources of growth regressions in the sector construction show a different image. The growth from assimilation, earlier noticed in figure 13, is strongly shown in the results. In the first period the results are explained by catching up to the frontier, and in the second by countries close to the frontier falling back from it again.
The observations in the figure are also confirmed by the creating spillover potential regressions. The low contribution of capital intensification in the first period and the presence in the second are shown in the results.
The frontier raise throughout the period only in the second period results in a significant correlation result on innovation. But contrary to findings in other sectors is the growth contribution largest close to the frontier. For the first period it is in appendices G and H shown that all countries benefit equally from the innovation at the frontier which results in a high p-level, as is found.

Conclusions
On sector level are the findings from the previous subsection, *frontier estimation*, largely confirmed.
The sector level results show that the 'non-innovative' sectors show growth by capital intensification. Although in the real estate sector the capital intensity is raised to a level that additional potential is not available. The growth from assimilation points at a catch-up to the frontier.
In agriculture and trade the image is mixed. Innovation does hardly contribute to growth. And also in these sectors is capital intensification the most important source.
In trade is assimilation an important source of growth were in agriculture this contributes less.
The last group of sectors contains sectors that are innovative throughout the period. Due to the innovation at high capital intensities in manufacturing is the frontier made up from several facets. Although in the second period innovation seems important, no significant results are found at all. In the construction sector assimilation is, together with creating spillover potential, the largest source of growth.

From these observations is clearly visible that, comparable to the country level, also on sector level the growth from creating spillover potential is the most important source of growth. But the clearly higher contribution in the second period that is found on country level, is less pronounced. Although in some of the sectors the sources are more local, is also shown that assimilation performance and innovative power are too low.

Although convergence as such is no source of growth but only an observation of changing country distributions, the process is studied. On country level convergence is a strong process. But on sector level it is only shown in agriculture and financial intermediation, two relatively small, in terms of shares of labor, sectors. Here the country-sector relation is affected by the sector distributions within the individual countries.

5.3 Understanding the country level shift-share results

The structural change in the EU member states has been studied on the results of the shift-share analysis as is implemented in eq. 11. To explore the country level findings in more detail, the shift-share processes are studied on sector level as well. But first the shares of labor per sector are studied to support this detail analysis and also the analysis of the country-sector relation.

5.3.1 Shares of labor

The shift-share analysis is based on the property that labor productivity can be calculated by the sector level labor productivity and the share of labor in the economy, as is earlier explained by eq. 12. Growth is the result of the increase in labor share, static shift, or increase in productivity, intra-sector growth.
The static-shift is associated with the change in labor share in the sector and insight in shares of labor will therefore support the detail study of the shift-share results as are presented in chapter 4.
The sector shares of labor are presented in appendix I, the shares of the 8 sectors count up to 100%.

Sectors showing decreasing shares
In the shift-share analysis results the decrease of the share of labor on sector level in negative growth rates on the static-shift, as has been explained in § 3.1. The labor shifts out of the sector and becomes available to other sectors. In three sectors decreasing labor shares are present; agriculture, mining and manufacturing.
Shares range in 2005 for agriculture from 2.6% in Belgium to 27.9% in Poland, the only country showing an increase. The NMS show average shares, except for Poland and Lithuania. In mining the volume of labor ranges from 0.12% in Belgium to 1.60% in Poland. In 1995 the highest volumes were found in the NMS, indicating a mode difference for their energy supply, accompanied by a rapid decrease.
Like agriculture and mining also manufacturing shows decreasing labor shares, except for the Czech Republic, but at a lower rate. In the EU-15 the shares in 2005 range from 20.0% in Greece to 29.2% in Sweden. Within the NMS this is higher on average and ranges from 25.1% in Poland to 33.5 % in Slovakia.

Sectors showing increasing shares
Sectors that attract labor from other sectors show an increasing share in the economy. Within the shift-share this results in a positive contribution on sector level of the static-shift.
Two sectors are characterized by increasing shares; the trade sector and the real estate sector.

In the trade sector the share of labor is about as large as the manufacturing sector, showing increasing shares in the whole period. These shares range in 2005 from 23.4% in Finland to 30.8% in Spain, and are somewhat lower in the NMS.
The real estates sector shows a large increase in the labor shares from the development in machinery and equipment and the business activities. The shares range from 7.1% in Portugal, the lowest in EU, to 24.0% in the Netherlands, the highest in the EU.

Miscellaneous
The remaining last three sectors show various directions of development at a, mostly, slow rate.
The labor shares in construction range from 8.6% in Belgium to 18.4% in Ireland. The NMS show average shares compared to the EU-15. Only Poland is an exception, with a share of just 5.8%.
The transportation sector has a share of labor of ca. 9% in the EU. And in the financial intermediation the labor shares in Luxembourg are by far the highest, 13.8% in 2005. But the average is around 4% in the EU-15 and somewhat lower in the NMS.

5.3.2 Detailed study of the shift-share analysis results

To study the shift-share analysis results in more detail the shift-share analysis itself is not taken to the sector level. The processes are studied directly on the sector level developments in the country level analysis. This methodology is thought to suit best explaining the country level findings. And secondly does it prevent from searching for the proper level of aggregation to study the growth that results from reallocation of labor. The equation is:

$$\sum_{q=1}^{Q} \frac{y_{iq}^{1} - y_{iq}^{0}}{y_{q}^{0} Q} = \sum_{q=1}^{Q} \frac{\left(S_{iq}^{1} - S_{iq}^{0}\right) y_{iq}^{0}}{y_{q}^{0} Q} + \sum_{q=1}^{Q} \frac{\left(y_{iq}^{1} - y_{iq}^{0}\right)\left(S_{iq}^{1} - S_{iq}^{0}\right)}{y_{q}^{0} Q} + \sum_{q=1}^{Q} \frac{\left(y_{iq}^{1} - y_{iq}^{0}\right) S_{iq}^{0}}{y_{q}^{0} Q} \qquad (13)$$

By equation 13 the average country growth contribution of the separate sectors is calculated and decomposed into an average contribution of the static-shift effect, the interaction, and the intra-sector growth. This basically refers to the averages of the sector contributions that are calculated with the conventional shift-share equation, eq. 11. The sum of the average contributions is therefore equal to the averages presented in table 5, chapter 4. The results are found in table 10.

The static shift effect is determined by the initial level of the labor productivity and the change in labor share. The averages in column I therefore present a picture of what is happening in the sectors by the reallocation of labor, independent of the size of the economy of the EU member countries.
Table 10 shows negative growth contributions of static-shift in agriculture, manufacturing and mining. This corresponds to the development of the labor shares, as are studied in the previous subsection. All three sectors show a decrease in labor share.
This same observation is made, but then for the positive contributions, for the trade sector and the real estate sector. Both show an increase in labor share.

Although processes can be different within the individual country, it is this shift of labor from agriculture, mining and manufacturing towards services, and also to construction, that causes the positive contribution of the static-shift growth on country level throughout the period. Especially when the large contribution of the real estate sector is considered.
This shift towards services is usually associated with a decrease in labor productivity. But also the study of the sector level frontiers has clearly shown that the average productivity levels are above average in these sectors.

Table 10: The average contribution of static-shift, the intra-sector productivity growth and the interaction to the total growth in the EU-15, 1985 to 1995, and EU-25, 1995 to 2005. Based on the sector contributions in the EU-member countries.

Sector	Period	I	II	III	Total
Extraction					
Agriculture	85-95*	-1.23%	-0.54%	1.80%	0.03%
	95-05**	-1.18%	-0.28%	0.37%	-1.09%
Mining	85-95	-0.52%	-0.55%	0.68%	-0.40%
	95-05	-0.30%	-0.24%	0.56%	0.02%
Transformative					
Manufacturing	85-95	-1.97%	-1.30%	9.69%	4.41%
	95-05	-3.65%	-5.39%	11.38%	2.34%
Construction	85-95	0.55%	0.09%	4.04%	4.68%
	95-05	1.40%	-0.75%	-0.51%	0.15%
Distributive services					
Trade	85-95	1.41%	-0.03%	3.28%	4.67%
	95-05	1.44%	-0.28%	-0.75%	0.42%
Transportation	85-95	0.20%	0.00%	0.48%	0.68%
	95-05	-0.02%	-0.11%	0.01%	-0.11%
Producer services					
Financial intermediation	85-95	2.01%	-0.60%	-0.13%	1.27%
	95-05	0.35%	-0.07%	0.61%	0.90%
Real estate	85-95	11.76%	-4.91%	2.44%	9.29%
	95-05	9.33%	-3.58%	-4.87%	0.87%

* n = 15 (EU-15)
** n = 25 (EU-25)

5.4 Summary and conclusions of the sector level analysis

In this chapter the 'technological change' is studied on sector level, and, qualitatively, related to the country level findings. Further are the shift-share findings studied in more detail.

The first step of the analysis of technological change is the estimation of the sector frontier. This frontier is, like the country frontier, made up out of the best practice labor productivity levels of the technologies operated.
The results of the frontier estimation show that from the eight sectors four sectors show hardly any innovation. All four have in common that the frontier top lies above the country level frontier and that the dominant process is capital intensification. Only in the mining sector this is rewarded with additional potential for all countries. In transportation this is rewarded with additional potential for countries operating at moderate capital intensities. And in the other sectors only the very low capital intensity countries are rewarded.
Two sectors show a raise in the frontier until the mid 1990s, the trade sector and agricultural sector. Both have frontiers lower than the country level frontier. The countries in the trade sector operate close to the frontier that is enveloping all production plans.
The last two sectors, construction and manufacturing show innovation throughout the period. In manufacturing the frontier is somewhat above the country level. Further countries operate close to the frontier in this sector and innovation is present at high capital intensities.

A specific characteristic of the construction sector is the difference between the sources in the first, assimilation, and the second, capital intensification.

The development of the country level frontier cannot directly be derived from the sector level developments as both the shares of labor and the specific sector distributions within countries affect the country-sector relation. But it can be roughly estimated from the previous results and the shares of labor.
The four sectors that are innovative in the first period, 1985 to 1995, cover around 70% of the EU labor share and therefore dominate the country frontier. The process of capital intensification as is shown in the non-innovative sectors, is already visible at the frontier. Capital intensification is at the frontier faster than the increase of the labor productivity.
For the second period it is argued that the dominant capital intensification without innovativeness results in the lack of innovativeness on the country frontier.

The second step in analysis is the study of 'technological change' by the regression on the sources of growth decomposition.
From the results is concluded that the convergence present on country level is only found in the sector agriculture and in the first period within the financial intermediation sector. Within the other 6 sectors no convergence is significantly estimated. An explanation might be that the disaggregation to sector level intersects the balanced country set up.
The significant relation in the assimilation regression, which is not found on country level, is present in five sectors in the first period, and in three in the second. This result indicates that on sector level the relative distance to the frontier is more important to explain growth.
The largest contribution to growth is realized by creating spillover potential. Significant results are found in all sectors except for manufacturing and construction in the first period. Except for the trade sector the results are, comparable with the country level results, determined by a small part of the countries that operate less capital intensive. In the regression this is shown from the extreme R^2. These results cannot easily be generalized for the EU but show that the NMS are increasing their potential. Within the trade sector and the transportation sector growth from creating spillover potential is positively related to the level of schooling.
The results from innovativeness, not significant on country level, are less interesting to study further as they are closely related to the frontier movement itself. Although in manufacturing not significant, it is important to mention that the level of schooling is positively related to the growth from local innovativeness. Being highly educated partly explains the high growth from local innovation.

In the last part of this chapter the shift-share findings on country level are directly studied through the results of the sectors.
The findings might differ for individual countries, but on EU-level the shift from agriculture, mining and manufacturing towards services and construction results in the positive contribution from the inter-sector growth as has been found on sector level. Positive because these last sectors show higher labor productivity levels.

Conclusions and discussion

This chapter describes the most important conclusions that can be drawn from this study, and it provides a discussion on the research that is combined with recommendations for further research.

6.1 Conclusions

This study directly refers to the prime objectives of the EU, labor productivity growth and becoming a knowledge based economy. It therefore contributes to EU policy considerations on these points. The central question of this study is:

To what extent have 'structural change' and 'technological change' contributed to growth of labor productivity in the EU member countries in the period 1985 to 2005

Technological change is assessed with the growth decomposition in relation to the production frontier. The growth decomposition explains growth from the country performance in the assimilation of knowledge, capital intensification and innovativeness.
The results of the country level analysis show that, during the total period under study, 1985 to 2005, creating spillover potential is the main source of growth. The capital intensification that is fuelling this process seems unrelated to labor productivity growth or innovativeness in the period 1995 to 2005. In the first period, 1985 to 1995, the frontier is raised, indicating innovative activity in the EU member countries.
The introduction of the NMS in 1995 adjusts the frontier to new, less capital intensive, but efficient technologies. Because labor productivity growth in this period is clearly concentrated in the NMS, these develop to competitors for the former low performers in the EU. Further the rate of capital intensification in most NMS shows, that these are not stuck in low potential technologies.

To explain the country development in more detail from the country-sector relation, the analysis is extended to sector level. The results of this sector level analysis show that innovation is only of influence in manufacturing and construction throughout the period. In the trade and agricultural sector innovation is shown until the mid-1990s, but in the producer services, mining and transportation only until the mid-1980s. The sectors that are innovative until the mid-1980s and mid-1990s make up 70% of the labor share in the EU and the absence of innovativeness in the period 1995-2005 is explainable from this.
Comparable to the country level it is found that capital intensification is also on sector level the dominant process. Most markedly in the sectors showing no innovation.

The level of schooling is added to the analysis to further explain the performance of countries. The results show that schooling is only significant in the sector level analysis. Growth from innovativeness is positively related to the level of schooling in manufacturing, and to growth from creating spillover potential in trade and transportation. In these sectors a high level of schooling of the workforce is important to growth. In all other regressions no significant results are found.

From these results it is clear that the 'technological change', especially in the second period, is primarily the result of capital intensification. This capital intensification points at a shift towards new technology. But the lack of innovativeness and growth in this second period, indicates that countries did not make the necessary adjustments to benefit fully from the new technologies, yet. As a result the assimilation performance and innovative power in countries are too low which results in low growth and unused potential.

A, to my knowledge, totally new development is the additional study of the shift of labor share between sectors in relation to 'technological change'. The results of the shift-share analysis point out that within countries a shift towards the services sectors is present. And especially towards the sector real estate, renting of machinery and equipment, and business activities. An expected result in the EU where services sectors are gaining importance.
The unexpected outcome is that this shift positively contributes to labor productivity growth. Services sectors are usually associated with low levels of labor productivity, but the productivity frontiers in these sectors show labor productivity levels above country level. Most of the countries newly admitted to the EU, which operate at low productivity levels, show high labor productivity growth and the largest contribution from the shift of labor share between sectors. This is a shift out of agriculture, mining and manufacturing towards services, and especially real estate, renting of machinery and equipment, and business activities.
In the first period these countries are Portugal, Greece and Spain, and in the second period the NMS. Although some countries stay behind, Lithuania for instance. These countries are apparently not able to attract foreign direct investment and grow from this.

The synthesis between the literatures on 'technological change', analyzed with the growth decomposition, and 'structural change', analyzed with the shift-share analysis, is initiated in this study. The results of the correlation analysis between both analyses show that in the period 1985 to 1995, a significant correlation is found between the assimilation of knowledge spillovers and the intra-sector growth. This result is in line with the assumptions that assimilation and intra-sector growth are closely related processes.
In the second period, 1995 to 2005, the static-shift is correlated to growth from creating spillover potential. This is in line with the SBTC-argument that technological change results in changed demand for labor. But the sign at the correlation is, unexpectedly, positive. Indicating that capital intensification attracts labor or that labor shifts towards sectors showing higher labor productivity levels. The second option is in line with the shift-share findings. These results indicate that the assumptions on the relation between the growth decomposition and the shift-share analysis are partly confirmed. This can mean that the relation might not be robust and time independent. Further study is necessary.

6.2 Discussion

There are several points of discussion that somewhat limit the findings of this study or that are valuable to further develop the framework of analysis.

For the 'technological change' analysis data on only half of the EU countries is available. The cause of this is that it is not compulsory to all countries to deliver capital formation data and some countries keep this data confidential. Although some countries outside this subset,

Belgium and Luxembourg, show higher labor productivity in specific sectors, it is still thought that the results on the 'technological change' analysis are representative for the EU. In further studies on the EU the use of a larger data set to verify the findings, is recommended.

In the analysis countries are positioned relative to the frontier. But otherwise than from 'technological appropriateness' the country's efficiency is not explained.
The level of schooling has been used in this study to explain, if only partly, the differences in the country performance. But on country level no significant results are found. This might be the result of an absent relation, the number of countries available to this study or the concept used.
From literature other methods to incorporate schooling are known. Best results are found from levels that are (internationally) comparable (Barro, 2001, a.o.). But it might be useful to look for measures which are more specifically related to production itself. The introduction of knowledge and skills via services and intermediate goods for example.

It is found that countries show a far faster increase in capital intensity than in labor productivity, especially in the second decade under study, 1995-2005. This investment seems irrational unless it promises a large potential that has not been realized yet. Think of potential in IT-capital stock (Bresnahan, Brynjolfsson & Hitt, 2002, Piatkowski, 2003).
In this study the producer durables and the IT-capital stock are used to construct the capital intensity of production. Using the framework to study the different efficiencies of capital input would add to further development of 'technological appropriateness'. Spillovers are only interesting when these spillovers are from productive capital.

The sector level development is studied using the country level methodology. This choice in the research design results in valuable insights of the sector level development but it restricts the study of the sector-country relation. Because this country-sector relation is affected by the sector distributions within the individual countries.
For further study and further development of the framework (statistical) methods should be developed to indicate this relation quantitatively.

In this study a first attempt is made to initiate a convergence between literature on 'technological change' and 'structural change'. The correlation analysis used just partly confirms the assumptions. The expected relations are between static-shift and creating potential, because capital intensification, the process of which creating potential is the result, changes the demand for labor. And between intra-sector growth and growth from assimilation, as both are expected to be related processes. Further research is necessary to find out whether shift of labor is mostly intra sector shift and therefore no relation can be found. Or that a time-lag is interfering with the analysis because using the possibilities of the new technology also requires organizational changes which are difficult and time consuming (Bresnahan, Brynjolfsson & Hitt, 2002).

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Appendices

A: Country availability

Overview of availability of countries to country and sector analysis on both parts of the framework.

Part of framework	1985 to 1995	1995 to 2005
Growth decomposition*	AUT, DNK, ESP, FIN, GER**, ITA, NLD, UK	AUT, CZE, DNK, ESP, FIN, GER**, ITA, NLD, PRT***, SVN, SWE, UK
Structural Change****	EU-15	EU-2005

* For the Growth Decomposition 12 European countries are available for the period of 1995 to 2005. Eight of them are available for the period 1985 to1995. The restriction to the dataset is partly the result that some small economies can't provide, especially the capital stock, data, but also due to confidentiality issues. This concerns data on France, Hungary, Ireland and Luxembourg.

** Germany takes a special position as after the fall of the Iron Curtain East- and Western Germany merged into Germany in 1990. Because of the small amount of countries and Germany as important country in the European Union data before and after merge are harmonized. For VA and hours this has been done on beforehand by the EU KLEMS project. For Human Capital and Capital stock data, 1991 is available on both Germany and Western-Germany. The data on Western-Germany are imputed on Germany for 1985-1990 after first harmonizing to the level of Germany 1991.

*** On sector level the human capital data are not available on Portugal as its level of aggregation differs from other countries.

**** The structural change analysis is based on value added and hours worked. Which are available on all countries.

B: Sectors and activities

The sectors used in this study are presented in the column *sector*.
The sector is build from the activities in the third column.

no	Sector	Activity	Description
1	Agriculture	AtB	Agriculture hunting forestry, Fishing
2	Mining	C	Mining quarrying
3	Manufacturing	15t16	Food products, beverages, tobacco
3	Manufacturing	17t19	Textiles and textile products, leather, footwear
3	Manufacturing	20	Wood, products of wood and cork
3	Manufacturing	21t22	Pulp, paper and paper products; printing publishing reproduction
3	Manufacturing	23	Coke, refined petroleum products, nuclear fuel
3	Manufacturing	24	Chemical and chemical products
3	Manufacturing	25	Rubber and plastic products
3	Manufacturing	26	Other non metallic mineral products
3	Manufacturing	27t28	Basic metals; fabricated metal products
3	Manufacturing	29	Machinery nec
3	Manufacturing	30t33	Electrical and optical equipment
3	Manufacturing	34t35	Transport equipment
3	Manufacturing	36t37	Manufacturing nec; recycling
3	Manufacturing	E	Electricity, gas and water supply
4	Construction	F	Construction
5	Trade	50	Sale, maintenance and repair of motor vehicles and motorcycles
5	Trade	51	Wholesale trade and commission trade, excluding motor vehicles
5	Trade	52	Retail trade, repair of household goods
5	Trade	H	Hotels and restaurants
6	Transportation	60t63	Transport and storage
6	Transportation	64	Post and telecommunication
7	Financial intermediation	J	Financial intermediation
8	Real estate	70	Real estate activities
8	Real estate	71t74	Renting of Machinery and Equipment and other business activities

C: Variables

The equations to construct the variables used in the analyses are presented in this appendix. The EU KLEMS PPP is available on the industry level as presented in appendix B, all aggregates are therefore constructed from this level. Industries LtQ, Community Social and Personal Services are not taken into account.
Variable names from the EU KLEMS dataset are used.

Value Added
The PPP conversion executed according to formula 8.2 and 8.3 from the EUKLEMS methodology (Timmer et. al, 2007: 51). This PPP also incorporates the exchange rate to the Euro for non-Eurozone-countries.

$$VA_{c,tot} = \sum_{i=1}^{n} VA_{i,tot} = \sum_{i=1}^{n} \frac{VA_i}{VA\_QI_i \cdot PPP_i} \left[1995 - German - Euro\right]$$

$VA_{c,\,tot}$: Total Value Added of a country [1995 German Euro]
$VA_{i,\,tot}$: Total Value Added of an industry [1995 German Euro]
VA_i: Gross Value Added in industry i at current basic prices
VA_QI_i: Gross Value Added volume index, 1995 = 1
PPP: PPP for gross output expressed in national currency per German Euro

Labor Productivity
In this study labor productivity is defined as value added per hour worked for persons engaged in the economic activity.

$$(y)_{c,tot} = \frac{VA_{c,tot}}{H\_EMP_{c,tot}} \left[1995 - German - Euro \big/ hour\right]$$

y: Labor productivity of a country [1995 German Euro/hour]
$VA_{c,\,tot}$: Total Value Added of a country [1995 German Euro]
$H\_EMP_{c,\,tot}$: Total hours worked by persons engaged

Capital intensity
According to Los & Timmer in this study technologies are indexed from producer durables only, as producer durables are most interesting from a technology perspective (Los & Timmer, 2005: 522). This concept is closest estimated by using Machinery and Equipment and IT from the EU KLEMS database.

Similar to the calculation of value added the capital intensity on aggregate level is built from the 26 industries. In the database capital stock data are available in 1995 local currency and are used in calculations in this way. According to the methodology used for the Euro zone countries capital stock data for countries outside the Euro zone are converted to the Euro by the fixed official conversion rate of EuroStat.

$$c = \frac{\sum_{i=1}^{n} K\_ICT + K\_Traeq + K\_Omach}{\sum_{i=1}^{n} H\_EMP} [1995\_Euro/Hour]$$

c: Capital intensity (1995 Euro/hour)
K_ICT: ICT assets (Real fixed capital stock, 1995 prices)
K_Traeq: Transport Equipment (Real fixed capital stock, 1995 prices)
K_Omach: Other Machinery and Equipment (Real fixed capital stock, 1995 prices)
H_EMP: Total hours worked by persons engaged

Level of schooling
In this framework share of hours of middle and high educated workforce will be used. Within the EU KLEMS this is as a harmonized classification available.

$$ls_{c,ls} = \frac{\sum_{i=1}^{n} (H\_HS_i + H\_MS_i) \cdot H\_EMP_i}{H\_EMP_c}$$

$ls_{c,ls}$: Share in total hours of medium and high educated labor
H_HS_i: Share of hours worked by high-skilled persons engaged in industry i
H_MS_i: Share of hours worked by medium-skilled persons engaged in industry i
H_EMP_i: Total hours worked by persons engaged in industry i
H_EMP_c: Total hours worked by persons engaged

D: Labor productivity and capital intensity, per sector

		AUT	BEL	DNK	ESP	FIN	FRA	GER	GRC	IRL	ITA	LUX	NLD	PRT	SWE	UK
	EU-15 Country level															
	y	18.12	34.88	23.25	21.92	16.3	23.94	23.4	11.1	23.31	22.13	64.84	33.2	7.48	24.68	18.34
	GR	2.76%	1.71%	3.49%	1.71%	5.01%	1.75%	2.68%	2.15%	0.02%	2.89%	-1.31%	-0.24%	5.82%	2.31%	2.27%
	c	15.34		15.92	7.17	11.36		12.44			11.33		14.09			13.94
	GR	2.44%		4.68%	2.68%	4.23%		4.13%			4.06%		1.68%			-0.91%
Extraction	*Agriculture*															
	y	6.14	15.78	17.43	6.11	3.74	6.80	5.61	3.01	8.34	5.03	12.21	17.21	1.55	10.85	7.42
	GR	2.35%	3.09%	2.29%	5.23%	4.82%	5.39%	5.97%	2.67%	0.56%	3.96%	3.94%	0.25%	5.74%	3.26%	3.87%
	c	10.5		4.7	3.44	7.44		11.82			5.85		10.9			12.78
	GR	0.81%		4.83%	3.34%	2.12%		3.76%			5.29%		3.02%			0.12%
	Mining															
	y	19.51	16.18	203.53	25.84	25.62	43.71	20.65	8.92	30.38	79.61	39.36	1114.85	14.23	20.39	57.96
	GR	2.68%	11.93%	-1.88%	3.60%	1.52%	3.20%	4.62%	5.03%	1.55%	-0.42%	0.49%	-4.54%	-1.30%	2.90%	9.58%
	c	68.2		210.13	19.85	21.46		28.6			40.07		284.61			64.23
	GR	2.73%		2.20%	4.18%	2.67%		5.02%			5.49%		-0.32%			5.97%
``Transformative	***Manufacturing***															
	y	16.30	29.92	16.80	26.14	22.56	2.86	20.67	8.37	36.32	24.15	31.35	23.22	5.49	27.19	16.70
	GR	3.64%	3.31%	5.22%	1.47%	4.76%	3.20%	3.95%	3.04%	-0.63%	2.81%	1.60%	3.59%	6.63%	2.53%	4.31%
	c	26.47		16.9	15.69	18.7		19.09			22.27		24.23			22.03
	GR	2.97%		4.70%	2.31%	5.07%		4.48%			4.09%		3.47%			0.15%
	Construction															
	y	21.60	27.32	12.90	17.53	10.54	12.55	14.71	13.71	18.23	17.43	21.40	18.11	5.53	11.46	11.30
	GR	3.01%	2.50%	6.37%	3.22%	9.41%	5.04%	3.68%	4.00%	-0.19%	4.73%	1.10%	2.24%	8.90%	6.05%	3.70%
	c	6.58		10.24	2.15	4.46		5.63			8.44		5.95			2.34
	GR	0.05%		5.07%	0.40%	4.47%		1.30%			-0.46%		-2.21%			-2.08%
Distributive services	*Trade*															
	y	12.46	24.72	18.53	13.92	11.10	14.88	15.49	10.16	13.86	10.88	26.93	20.17	5.45	12.43	9.98
	GR	2.15%	1.01%	2.40%	1.17%	4.84%	2.97%	2.03%	-1.34%	-0.35%	2.16%	-0.35%	-0.25%	4.40%	2.31%	1.72%
	c	6.37		8.82	1.62	5.16		3.59			3.23		5.01			5.19
	GR	0.95%		4.93%	4.37%	4.80%		5.44%			4.60%		1.63%			-0.36%
	Transportation															
	y	21.81	27.83	25.77	27.91	26.76	32.76	24.04	10.43	21.63	26.43	114.25	53.28	22.75	37.33	29.30
	GR	0.03%	1.74%	2.28%	-0.12%	1.60%	0.03%	0.96%	0.67%	0.33%	-0.33%	-5.01%	-1.02%	2.11%	0.54%	0.64%

	c	33.34		40.54	16.58	28.95		15.83			21.43		33.70			35.27
	GR	3.08%		4.64%	4.62%	1.72%		5.92%			5.34%		1.71%			-1.22%
Producer services	*Financial intermediation*															
	y	39.41	60.87	34.40	44.90	20.53	31.77	34.88	46.84	68.41	41.98	257.51	59.20	34.49	51.34	36.45
	GR	1.98%	-0.29%	3.11%	1.20%	6.19%	3.73%	1.13%	-4.01%	-1.80%	2.77%	-6.00%	0.06%	1.91%	0.66%	0.98%
	c	11.61		6.59	5.96	6.97		4.38			8.52		5.15			5.65
	GR	4.72%		7.95%	7.33%	7.17%		7.38%			5.28%		7.19%			8.16%
	Real estate															
	y	53.29	93.79	59.29	103.89	38.29	44.12	91.01	89.51	39.37	96.01	201.88	58.30	74.80	51.66	30.10
	GR	-8.90%	-10.42%	-6.06%	-13.27%	-1.98%	-2.94%	-12.35%	-20.83%	-5.66%	-13.23%	-10.71%	-1.92%	-9.79%	-2.71%	0.37%
	c	6.93		7.99	4.46	4.52		18.55			6.34		6.18			5.00
	GR	9.23%		8.12%	3.59%	6.57%		4.52%			1.93%		3.92%			3.96%

y: labor productivity (1995 Euro / hour)
c: capital intensity (1995 Euro / hour)
GR: annual average growth rate

E: Country efficiencies per sector

The country efficiency is defined as the relative distance to the frontier.
In the table the efficiencies are presented for the years 1985, 1995 and 2005 relative to the frontiers of these years.

Efficiency		AUT	CZE	DNK	ESP	FIN	GER	ITA	NLD	SVN	SWE	UK
Country level	1985	0.546		0.700	1.000	0.567	0.767	0.771	1.000			0.557
	1995	0.685	1.000	0.946	0.992	0.772	0.878	0.848	0.930	1.000	0.893	0.729
	2005	0.674	0.576	0.912	0.644	0.704	0.995	0.837	0.889	0.232	0.848	0.662
Extraction												
Agriculture	1985	0.352		1.000	1.000	0.215	0.322	0.289	0.988			0.426
	1995	0.353	0.374	0.997	0.563	0.276	0.464	0.34	0.803	1.000	0.684	0.497
	2005	0.293	0.232	0.602	0.428	0.303	0.470	0.314	0.560	0.288	0.576	0.464
Mining	1985	0.087		0.252	1.000	0.789	0.334	0.730	1.000			0.278
	1995	0.074	1.000	0.164	0.342	0.298	0.186	0.290	0.656	0.327	0.153	0.355
	2005	0.101	0.586	0.231	0.382	0.194	0.247	0.235	0.739	0.256	0.149	0.633
Transformative												
Manufacturing	1985	0.642		0.643	1.000	0.863	0.791	0.924	0.889			0.639
	1995	0.617	0.230	0.758	0.827	0.960	0.814	0.842	0.875	0.121	1.000	0.697
	2005	0.669	0.629	0.971	0.773	0.829	1.000	0.953	0.961	0.683	0.858	0.895
Construction	1985	1.000		0.597	1.000	0.561	0.717	0.807	0.839			0.625
	1995	0.985	1.000	0.812	0.992	0.951	0.730	0.931	0.791	0.310	0.699	0.674
	2005	0.976	0.608	0.65	0.499	0.652	0.991	0.715	0.666	0.217	0.578	0.562
Distributive services												
Trade	1985	0.618		0.919	1.000	0.55	0.883	0.645	1.000			0.495
	1995	0.732	0.390	0.982	1.000	0.83	0.915	0.668	0.955	1.000	0.697	0.588
	2005	0.659	0.319	0.852	0.659	0.677	0.901	0.589	0.828	0.259	0.600	0.511
Transportation	1985	0.414		0.484	1.000	0.579	1.000	0.753	1.000			0.550
	1995	0.388	1.000	0.573	0.596	0.556	0.534	0.453	0.852	0.399	0.746	0.586
	2005	0.388	0.514	0.551	0.367	0.535	0.486	0.418	0.812	0.260	0.661	0.459
Producer services												
Financial intermediation	1985	0.666		0.581	0.758	0.347	1.000	0.709	1.000			0.616
	1995	0.716	0.369	0.700	0.755	0.568	0.582	0.826	0.888	1.000	0.817	0.599
	2005	0.835	0.367	0.696	0.706	0.740	0.865	0.86	0.922	0.170	0.930	0.625
Real estate	1985	0.513		0.571	1.000	0.369	0.876	0.924	0.561			0.290
	1995	0.545	0.712	0.681	0.587	0.42	0.716	0.878	0.366	1.000	0.496	0.298
	2005	0.313	0.300	0.456	0.391	0.318	0.502	0.56	0.292	0.413	0.418	0.227

F: Sector level growth contribution from assimilation

The contribution to labor productivity growth from assimilation of knowledge spillovers, *assimilation*, for the periods 1985-1995 and 1995-2005. On country level, and for the individual sectors.

Assimilation		AUT	CZE	DNK	ESP	FIN	GER	ITA	NLD	SVN	SWE	UK
EU-country	85-95	1.25		1.35	0.99	1.36	1.14	1.10	0.93			1.31
	95-05	0.98	0.58	0.96	0.65	0.91	1.13	0.99	0.96	0.23	0.95	0.91
Extraction												
Agriculture	85-95	1.00		1.00	0.56	1.28	1.44	1.18	0.81			1.17
	95-05	0.83	0.62	0.60	0.76	1.10	1.01	0.92	0.70	0.29	0.84	0.93
Mining	85-95	0.85		0.65	0.34	0.38	0.56	0.40	0.66			1.28
	95-05	1.37	0.59	1.41	1.12	0.65	1.33	0.81	1.13	0.78	0.97	1.78
Transformative												
Manufacturing	85-95	1.02		1.25	1.00	1.16	1.07	0.95	1.02			1.26
	95-05	1.04	0.75	1.20	0.77	0.86	1.20	1.10	1.04	0.68	0.86	1.15
Construction	85-95	0.99		1.36	0.99	1.70	1.02	1.15	0.94			1.08
	95-05	0.99	0.61	0.80	0.50	0.69	1.36	0.77	0.84	0.70	0.83	0.83
Distributive services												
Trade	85-95	1.18		1.07	1.00	1.51	1.04	1.04	0.96			1.19
	95-05	0.90	0.82	0.87	0.66	0.82	0.99	0.88	0.87	0.26	0.86	0.87
Transportation	85-95	0.94		1.18	0.60	0.96	0.53	0.60	0.85			1.07
	95-05	1.00	0.51	0.96	0.62	0.96	0.91	0.92	0.95	0.65	0.89	0.78
Producer services												
Financial intermediation	85-95	1.08		1.21	1.00	1.64	0.58	1.17	0.89			0.97
	95-05	1.17	1.00	0.99	0.94	1.30	1.49	1.04	1.04	0.17	1.14	1.04
Real estate	85-95	1.06		1.19	0.59	1.14	0.82	0.95	0.65			1.03
	95-05	0.57	0.42	0.67	0.67	0.76	0.70	0.64	0.80	0.41	0.84	0.76

G: Sector level growth contribution from creating potential

The contribution to labor productivity growth from the creation of potential for knowledge spillovers, *potential*, for the periods 1985 to 1995 and 1995 to 2005. On country level, and for the individual sectors.

Potential		AUT	CZE	DNK	ESP	FIN	GER	ITA	NLD	SVN	SWE	UK
Country level	85-95	1.00		1.00	1.16	1.21	1.11	1.17	1.02			0.94
	95-05	1.00	2.49	1.00	1.22	1.00	1.00	1.00	1.00	4.88	1.00	1.10
Extraction												
Agriculture	85-95	1.00		1.12	2.92	1.00	1.00	1.00	1.00			1.00
	95-05	1.00	2.29	1.00	1.15	1.00	1.00	1.00	1.00	3.47	1.00	1.00
Mining	85-95	1.48		1.29	3.35	2.39	2.55	2.28	0.99			2.08
	95-05	1.03	4.22	1.09	1.26	1.32	1.40	1.29	1.03	2.06	1.92	0.74
Transformative												
Manufacturing	85-95	1.03		1.01	0.94	1.03	1.03	1.03	1.02			0.96
	95-05	1.01	0.48	1.04	1.03	1.03	1.03	1.03	1.03	1.42	1.11	1.03
Construction	85-95	1.00		1.00	1.02	1.09	1.03	1.00	0.96			0.97
	95-05	1.00	2.67	1.00	1.16	1.08	1.04	1.00	1.07	1.14	1.00	1.21
Distributive services												
Trade	85-95	1.01		1.05	1.12	1.04	1.16	1.19	1.01			1.00
	95-05	1.08	1.36	1.00	1.26	1.02	1.07	1.09	1.10	4.11	1.07	1.15
Transportation	85-95	1.01		1.00	1.47	1.14	1.74	1.48	1.00			1.01
	95-05	1.00	2.47	1.00	1.22	1.00	1.14	1.00	1.00	1.39	1.07	1.06
Producer services												
Financial intermediation	85-95	1.00		1.00	1.00	1.00	1.55	1.00	1.06			1.00
	95-05	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	4.67	1.00	1.00
Real estate	85-95	1.00		1.00	1.00	1.00	1.00	1.00	1.00			1.00
	95-05	1.00	2.38	1.00	1.00	1.00	1.00	1.00	1.00	1.07	1.00	1.00

H: Sector level growth contribution from local innovativeness

The contribution to labor productivity growth from local innovation, *innovation*, for the periods 1985 to1995 and 1995 to 2005. On country level, and for the individual sectors.

Innovation		AUT	CZE	DNK	ESP	FIN	GER	ITA	NLD	SVN	SWE	UK
Country level	85-95	1.05		1.05	1.03	1.00	1.03	1.04	1.03			1.02
	95-05	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Extraction												
Agriculture	85-95	1.26		1.12	1.03	1.26	1.26	1.26	1.26			1.26
	95-05	1.02	1.00	1.02	1.00	1.02	1.02	1.02	1.02	1.34	1.02	1.02
Mining	85-95	1.04		1.00	1.25	1.29	1.12	1.06	1.00			1.00
	95-05	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.03
Transformative												
Manufacturing	85-95	1.37		1.33	1.23	1.35	1.35	1.36	1.36			1.27
	95-05	1.01	1.00	1.00	1.03	1.00	1.00	1.00	1.00	1.00	1.00	1.02
Construction	85-95	1.37		1.39	1.36	1.39	1.38	1.39	1.38			1.39
	95-05	1.16	1.01	1.13	1.03	1.11	1.11	1.13	1.11	1.01	1.13	1.04
Distributive services												
Trade	85-95	1.04		1.14	1.00	1.04	1.02	1.00	1.01			1.00
	95-05	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.10	1.00	1.02
Transportation	85-95	1.06		1.06	1.13	1.07	1.19	1.09	1.06			1.03
	95-05	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Producer services												
Financial	85-95	1.13		1.13	1.13	1.13	1.25	1.13	1.07			1.13
intermediation	95-05	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Real estate	85-95	1.00		1.00	1.00	1.00	1.00	1.00	1.00			1.00
	95-05	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

I: Labor shares per sector

The share of labor is defined as the share of labor, in hours, in the total of the eight sectors. This means that the shares in the sectors under study count up to 100%. The labor shares are presented for the years 1985, 1995 and 2005.

	Agriculture			Mining			Manufacturing			Construction		
Country	***1985***	***1995***	***2005***	***1985***	***1995***	***2005***	***1985***	***1995***	***2005***	***1985***	***1995***	***2005***
AUT	13.87%	10.76%	8.54%	0.49%	0.32%	0.22%	30.34%	26.51%	21.97%	8.96%	10.67%	9.08%
BEL	4.31%	3.21%	2.75%	0.95%	0.17%	0.12%	35.42%	28.94%	23.75%	7.85%	9.17%	8.61%
CYP		17.21%	13.23%		0.17%	0.17%		19.46%	14.43%		12.01%	13.22%
CZE		8.76%	5.04%		2.17%	1.07%		34.02%	34.67%		12.85%	11.91%
DNK	9.40%	6.89%	5.13%	0.26%	0.23%	0.17%	30.02%	29.47%	22.67%	9.30%	9.18%	10.72%
ESP	21.39%	11.56%	7.76%	0.84%	0.47%	0.28%	26.80%	24.96%	21.26%	9.03%	11.98%	17.97%
EST		15.29%	7.61%		1.60%	1.28%		33.95%	33.38%		7.06%	10.84%
FIN	20.10%	15.93%	10.30%	0.45%	0.37%	0.35%	28.62%	27.47%	25.39%	11.55%	9.94%	12.31%
FRA	15.48%	10.14%	7.82%	0.47%	0.32%	0.18%	27.47%	24.83%	20.62%	10.81%	10.71%	10.99%
GER	7.67%	4.91%	3.81%	1.32%	0.71%	0.36%	37.99%	31.80%	28.83%	10.57%	12.50%	8.87%
GRC	31.11%	23.10%	15.08%	1.09%	0.57%	0.48%	26.75%	22.87%	20.00%	8.12%	8.26%	11.05%
HUN		11.44%	7.04%		1.25%	0.52%		35.31%	32.15%		8.49%	11.34%
IRL	21.29%	16.40%	8.93%	0.97%	0.60%	0.56%	26.61%	26.95%	20.99%	8.15%	9.54%	18.35%
ITA	14.96%	10.00%	7.42%	0.28%	0.24%	0.21%	30.07%	29.88%	25.87%	8.16%	8.48%	9.74%
LTU		23.43%	17.75%		0.36%	0.33%		30.67%	27.88%		9.00%	12.44%
LUX	5.55%	2.79%	1.96%	0.35%	0.20%	0.14%	31.71%	22.04%	15.12%	11.28%	14.76%	13.52%
LVA		17.32%	6.64%		0.46%	0.23%		32.98%	26.46%		6.22%	10.94%
MLT		4.04%	3.88%		0.72%	0.52%		34.63%	26.49%		10.32%	9.44%
NLD	8.84%	6.69%	6.14%	0.23%	0.22%	0.18%	27.81%	22.27%	18.05%	8.76%	9.19%	9.72%
POL		25.70%	27.94%		2.90%	1.59%		29.13%	25.11%		7.54%	5.81%
PRT	25.46%	18.72%	15.55%	0.37%	0.41%	0.41%	27.58%	27.91%	23.10%	11.17%	11.94%	14.01%
SVK		13.08%	6.01%		1.18%	0.54%		36.48%	33.48%		9.68%	9.88%
SVN		21.61%	14.49%		1.11%	0.56%		36.02%	34.29%		7.35%	10.04%
SWE	8.53%	6.93%	4.95%	0.60%	0.42%	0.33%	34.49%	31.93%	29.19%	10.84%	9.10%	9.95%
UK	4.45%	3.64%	2.55%	1.75%	0.46%	0.38%	31.21%	25.10%	17.91%	10.70%	10.89%	10.97%

	Trade			Transportation			Financial intermediation			Real estate renting and business activities		
Country	***1985***	***1995***	***2005***	***1985***	***1995***	***2005***	***1985***	***1995***	***2005***	***1985***	***1995***	***2005***
AUT	27.12%	29.06%	30.20%	8.90%	9.59%	9.31%	3.78%	4.13%	4.00%	6.54%	8.96%	16.69%
BEL	24.83%	25.28%	24.89%	11.97%	11.52%	11.25%	5.85%	5.79%	5.01%	8.82%	15.92%	23.63%
CYP		32.61%	37.66%		8.51%	9.24%		4.80%	5.59%		5.21%	6.47%
CZE		22.37%	23.70%		8.73%	9.17%		1.85%	2.01%		9.26%	12.43%
DNK	26.00%	26.53%	27.78%	10.83%	11.02%	10.96%	4.77%	4.78%	4.32%	9.40%	11.90%	18.25%
ESP	26.41%	30.77%	30.79%	8.03%	7.88%	7.74%	3.21%	3.34%	2.60%	4.29%	9.04%	11.59%
EST		21.13%	23.13%		13.46%	12.26%		1.39%	1.45%		6.11%	10.05%
FIN	20.91%	21.38%	23.38%	9.16%	11.28%	11.06%	3.04%	3.01%	2.17%	6.17%	10.61%	15.05%
FRA	22.40%	24.29%	25.33%	7.69%	8.30%	9.04%	4.21%	4.43%	4.28%	11.47%	16.97%	21.74%
GER	22.86%	25.52%	26.95%	8.61%	8.40%	8.07%	4.11%	4.64%	4.76%	6.86%	11.53%	18.36%
GRC	18.69%	27.34%	30.90%	9.25%	9.02%	9.54%	1.44%	2.66%	3.20%	3.55%	6.19%	9.75%
HUN		22.78%	26.26%		12.60%	10.30%		3.04%	2.78%		5.09%	9.61%
IRL	25.69%	26.37%	25.27%	7.41%	6.30%	7.95%	3.56%	4.76%	5.93%	6.34%	9.08%	12.02%
ITA	29.24%	30.28%	29.65%	8.00%	8.43%	8.87%	3.24%	3.17%	2.91%	6.06%	9.52%	15.33%
LTU		21.19%	25.74%		9.10%	8.72%		1.86%	1.49%		4.40%	5.65%
LUX	27.77%	26.81%	23.30%	8.73%	9.20%	10.20%	8.48%	12.74%	13.79%	6.13%	11.47%	21.97%
LVA		20.52%	31.59%		13.45%	12.70%		2.44%	3.42%		6.61%	8.02%
MLT		28.72%	32.65%		11.04%	10.66%		4.60%	4.55%		5.92%	11.82%
NLD	26.82%	28.46%	27.71%	9.59%	9.13%	9.20%	5.31%	4.87%	5.01%	12.64%	19.15%	24.00%
POL		20.78%	21.83%		6.99%	6.54%		2.08%	2.53%		4.87%	8.65%
PRT	26.50%	28.77%	33.04%	4.66%	4.61%	4.96%	1.99%	2.29%	1.80%	2.28%	5.35%	7.12%
SVK		19.47%	27.82%		10.27%	8.46%		1.77%	2.07%		8.08%	11.74%
SVN		17.93%	19.37%		6.68%	7.66%		1.96%	2.87%		7.35%	10.71%
SWE	22.93%	23.74%	24.17%	10.52%	10.98%	10.29%	2.62%	3.03%	3.04%	9.46%	13.89%	18.07%
UK	26.14%	28.10%	29.08%	8.91%	8.89%	9.26%	4.55%	5.18%	5.26%	12.28%	17.75%	24.59%