The Norwegian KLEMS Database: 1997-2014

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Abstract

This paper documents the theoretical methodologies and practical compilation procedures for constructing the Norwegian KLEMS database 1997-2014. This database comprises output, intermediate input, labor, capital, and multi-factor and labor productivity accounts for each disaggregated industry, all being organized within the modern growth accounting framework.

For each account, some results and analyses are presented with the purpose of showing the richness of the whole database. The database can be used not only for productivity analysis, but also for undertaking empirical and theoretical research in many other areas, such as skill creation, capital development, technological progress, R&D activities, as well as economic growth more generally.

Contents

1. Introduction

This paper aims to describe the general methodologies and the practical compilation procedures that have been employed for constructing the Norwegian KLEMS Growth and Productivity Accounts database. The Norwegian KLEMS database provides detailed production input measures including various categories of capital (K), labor (L), energy (E), materials (M) and services (S), as well as the output measure, at the disaggregated industry level, for the period of 1997-2014. Based on these measures, useful statistical indicators are further derived as regards economic growth, productivity, employment creation, capital formation and technological change in the Norwegian economy.

The variables in the Norwegian KLEMS database are organized by means of the modern growth accounting methodology, which has a long history dating back to a seminal article by Jorgenson and Griliches (1967), and was further grounded in economic theory by Diewert (1976) and Caves *et al*. (1982). Later, the modern growth accounting methodology was placed in a more general input-output framework by Jorgenson *et al*. (1987), and was applied more recently in Jorgenson *et al*. (2005). The framework of the modern growth accounting also becomes an international standard now (see Schreyer, 2001, 2009).

The major advantage of the modern growth accounting methodology is that it is well-founded in the neo-classical production theory, and therefore offering a clear conceptual framework, within which the interactions among different variables in the growth accounts can be analyzed in an internally consistent way.

In addition, by recognizing that productivity, and therefore one-hour labor services from various types of labor (such as low- versus high- skilled labor) differ, the KLEMS database takes account of this heterogeneity of labor force in measuring contribution of labor to output growth. However, the current productivity statistics as published at Statistics Norway do not account for such differences and measure labor input only by the total hours worked, regardless of the labor type.

Moreover, in the Norwegian KLEMS database, the Tornquist index, one of the superlative indices (see Diewert, 1976), is widely applied for aggregation across products and industries, which offers the possibility for making less-biased measurement of the contribution from input factors to output growth. On the contrary, aggregation to higher levels in the current productivity statistics as published at Statistics Norway is carried out by merely summing up the Laspeyres volumes from lower levels.

The Norwegian KLEMS database is meant to be used primarily for analyzing productivity trend over time in Norway at the detailed disaggregated industry level. However, since this database is almost fully comparable with the well-known EU KLEMS database (see O'Mahony and Timmer, 2009; Timmer, *et al*. 2010), it can be well utilized for comparative analyses with other EU member countries, and even with non-EU countries by making use of the WORLD KLEMS Initiative[1].

Besides productivity analysis, the Norwegian KLEMS database can also serve for undertaking empirical and theoretical research in many other areas, such as in skill creation, capital development, technological progress and R&D activities, as well as in economic growth more generally. Arguably, policy interventions that are drawn upon the research results from these studies should be more fact-based and thus target-oriented.

[1] See http://www.worldklems.net/index.htm.

Last but not the least, the construction of the Norwegian KLEMS database will also facilitate the systematic production of high quality statistics in general, and of national accounts, growth and productivity statistics in particular, by following the methodologies of national accounts and input-output analysis, which is of more significance for routine works at Statistics Norway.

The rest of the document is structured as follows. Section 2 describes the coverage of the current Norwegian KLEMS database in terms of the time span, the detailed industry classification and the corresponding aggregation levels. Section 3 gives out the general growth accounting methodology that is the organizing principle underlying the construction of the whole database.

Then, the compilation of the various component accounts in the database is discussed, i.e. the output and intermediate input account (Section 4), labor input account (Section 5) and capital input account (Section 6) are discussed in turn. In Section 7, decomposition of labor productivity growth into detailed components is presented. Section 8 describes the methodology for aggregation and for identifying the industry origin of economic growth in Norwegian economy. In each of the above-mentioned sections, except for Section 2, a number of analysis results will be provided as well. Section 9 concludes.

2. Database coverage

The time span for the current, also the first, version of the Norwegian KLEMS database only covers the period 1997-2014,[2] which is determined primarily by the availability of data, in particular, of the detailed labor inputs data at Statistics Norway. Before 1997, it is hard to find the data of labor inputs that can be cross-classified by various types needed for our purpose, although labor inputs (actual hours worked in total and by gender, labor compensation in total) are available. On the contrary, all other inputs (such as intermediate inputs and capital inputs) and output data needed are available back to 1970 in the current annual Norwegian National Accounts (NNA) database.

In the annual NNA database, the classification of industries is an aggregated version of NACE rev.2[3], specifying around 150 industries (see Simpson and Todsen, 2012), while in the quarterly NNA, these 150 industries are further aggregated to a total of 79 industries (see Korsnes, 2014). Due to data limitation, the 79 industries are considered as the lowest disaggregated industry level in the Norwegian KLEMS database.

In the current version of the Norwegian KLEMS database, the focus has been put on the market economy, with non-market activities being excluded.[4] Non-market activities consist mainly of the central and local government activities, which are typically non-market services, such as education, health, defense, and public administration etc.
To mitigate the impact on the analysis of Norwegian economy due to price volatility of raw oil and natural gas in the international market, three industries, i.e. the Norwegian offshore industry extracting raw oil and natural gas (KNR2306), the pipeline transport of raw oil and natural gas (KNR2348), and the maritime

[2] In the current version of the Norwegian KLEMS database, all source data were drawn before July 2017, after when changes/updates may take place for the databases applied. For instance, annual Norwegian National Accounts database will be updated in August 2017 for data of the period of 2007-2014.
[3] The term NACE is derived from the French *Nomenclature statistique des activités économiques dans la Communauté européenne*, which is the Statistical classification of economic activities in the European Community. NACE rev.2 is a (second) revised classification and was adopted at the end of 2006.
[4] This does not mean that non-market activities are not important for productivity analysis; it only reflects data limitation at the current stage. Non-market activities may be taken into account in the next version of the KLEMS database.

transport (KNR2349), are usually excluded from the total Norwegian economy, leading to a term of the so-called mainland-Norway economy.

Table 2.1 Industries/Sectors in market economy in mainland Norway (without housing services)

Industries		Sectors	
Code	Description	Abbreviation	Description
KNR2326	Computer and electronics	ELECOM	ICT production (including Electrical machinery manufacturing and post and communication services)
KNR2327	Electrical equipment		
KNR2353	Post and distribution		
KNR2361	Telecommunication		
KNR2362	Information services		
KNR2310	Food products, beverages and tobacco	MexElec	Manufacturing (excluding Electrical machinery)
KNR2312	Fish farming		
KNR2313	Textiles, wearing apparel, leather		
KNR2315	Manufacture of wood and wood products		
KNR2316	Wood processing		
KNR2317	Graphic production		
KNR2318	Production of coal and refined petroleum		
KNR2319	Chemical raw goods		
KNR2320	Chemical products		
KNR2321	Production of pharmaceutical products		
KNR2322	Rubber and plastic products		
KNR2323	Other chemical and mineral products		
KNR2324	Metal raw goods		
KNR2325	Metal products		
KNR2328	Machinery and equipment		
KNR2329	Production of transport equipment		
KNR2330	Building of ships		
KNR2331	Building of oil platforms and modules		
KNR2332	Other industry production		
KNR2333	Repair/installation of machinery/equipment		
KNR2301	Agriculture, Hunting	OtherG	Other production (including Agriculture, mining, utilities and construction)
KNR2302	Forestry		
KNR2303	Fishing		
KNR2304	Aquaculture		
KNR2305	Mining and quarrying		
KNR2335	Production of electricity		
KNR2336	Transport and sale of electricity		
KNR2337	Other energy, district heating and gas		
KNR2341	Building development		
KNR2342	Construction		
KNR2344	Wholesale/retail trade, repair of motor v.	DISTR	Distribution (including Trade and transportation)
KNR2346	Passenger transport		
KNR2347	Goods transport		
KNR2350	Domestic maritime transport		
KNR2351	Air transport		
KNR2352	Services connected to transport		
KNR2307	Service activities incidental to oil and gas	FINBU	Finance and business services (excluding housing services)
KNR2358	Publishing business		
KNR2364	Financial services		
KNR2367	Managing real estate		
KNR2370	Architecture/legal/accounting/consulting		
KNR2372	Research and Development		
KNR2373	Marketing/veterinary and other services		
KNR2377	Leasing, travel and other business services		
KNR2338	Water supply, sewerage, waste	PERS	Personal services (including Hotels, restaurants and community, social and personal services)
KNR2356	Hotel and restaurant		
KNR2385	Education/training		
KNR2386	Health services		
KNR2387	Social welfare services		
KNR2390	Cultural/sports/leisure activities		
KNR2394	Membership and other private activities		
KNR2397	Paid household works		

Source: Statistics Norway and EU KLEMS database (www.euklems.net)

Since residential properties do not contribute in any direct way to production productivity gains, the industries that provide owner-occupied housing services (KNR2368), as well as private renting (KNR2369), are also excluded from the current version of the KLEMS database.
Finally, we end up with a market economy in mainland Norway (without housing services) as our focus. And the market economy defined as such comprises 57

industries (with codes like KNR23xx). The names and the corresponding codes of these 57 industries (which are also used in the quarterly NNA) are listed in Table 2.1.

Quite often, aggregating the disaggregated industries to higher level sectors or even to the total economy is needed. To this end, the 6 sectors that make up the total market economy in mainland Norway are defined as follows: ICT production (5 industries), Manufacturing (20 industries), Other production (10 industries), Distribution (6 industries), Finance and business services (8 industries), Personal services (8 industries).

Roughly speaking, the last three sectors, i.e. Distribution, Finance and business services, and Personal services, are so-called service sectors. However, there are a few industries that are usually considered as service industries are nonetheless allocated in the non-service sectors. For example, the industry of Information services (KNR2362) is in ICT production sector, and that of Repair/installation of machinery/equipment (KNR2333) is in Manufacturing sector. With this in mind, the services sectors include in general around 40% industries in total.

In order to be useful for comparable analysis, the sector classification applied in the Norwegian KLEMS database is in accordance with that applied in the EU KLEMS database (see O'Mahony and Timmer, 2009; Timmer, *et al.* 2010). The detailed description and the corresponding abbreviations of these sectors are listed in Table 2.1.

3. Multi-factor productivity

3.1. Methodology

This section will introduce the general methodology used to develop the measures of industry-level multi-factor productivity (MFP) growth, both of gross output-based and of value added-based. As mentioned, this methodology follows the modern growth accounting framework as developed by Dale Jorgenson and associates as outlined in Jorgenson, *et al*. (1987, 2005). It is based on production possibility frontiers where industry gross output is a function of capital, labor, intermediate inputs and the level of technology, the latter being indexed by time, *T*.

Each industry, indexed by *j*, can produce a set of products and purchases a number of distinct intermediate inputs, capital service inputs, and labor service inputs. The production function is given by:

(1) $$Y_j = F_j\left(X_j, K_j, L_j, T\right),$$

where Y_j is an index of output, X_j is an index of intermediate inputs (either purchased from domestic industries or imported), K_j is an index of capital service flows, and L_j is an index of labor service flows. Under the assumptions of constant returns to scale and competitive markets, the value of output is equal to the value of all inputs:

(2) $$P_j^Y Y_j = P_j^X X_j + P_j^K K_j + P_j^L L_j,$$

where P_j^Y, P_j^X, P_j^K, and P_j^L denote the price (index) of output, intermediate inputs, capital services and labor services, respectively. For the brevity of notation, the time subscript in all variables in (1) and (2) is suppressed, and we will do so in all the following equations whenever possible, so long as there is no misunderstanding.

Under the standard assumptions of profit maximizing behavior, competitive factor markets, full input utilization, and using the translog functional form common in such analyses, the gross output-based MFP (A^Y) growth can be defined as follows:

(3) $$\Delta \ln A_j^Y \equiv \Delta \ln Y_j - \bar{v}_{X,j}^Y \Delta \ln X_j - \bar{v}_{K,j}^Y \Delta \ln K_j - \bar{v}_{L,j}^Y \Delta \ln L_j,$$

i.e. the MFP growth is derived as the real growth of output minus a weighted growth of different inputs.

In equation (3), $\Delta x = x_t - x_{t-1}$ denotes the period change of variable *x* between *t-1* and *t* such that $\Delta \ln x$ indicates logarithmic growth rates of variable *x*, and $\bar{v}$ is the two period average share of the corresponding input (indicated by subscript *X*, *K*, and *L*) in the nominal value of output (indicated by superscript *Y*). The value share (v) of each input is defined as follows:

(4) $$v_{X,j}^Y = \frac{P_j^X X_j}{P_j^Y Y_j}, \quad v_{K,j}^Y = \frac{P_j^K K_j}{P_j^Y Y_j}, \quad v_{L,j}^Y = \frac{P_j^L L_j}{P_j^Y Y_j},$$

and the period average share as

(5) $$\bar{v}_{X,j}^Y = \frac{1}{2} * \left(v_{X,j,t}^Y + v_{X,j,t-1}^Y\right), \quad \bar{v}_{K,j}^Y = \frac{1}{2} * \left(v_{K,j,t}^Y + v_{K,j,t-1}^Y\right), \quad \bar{v}_{L,j}^Y = \frac{1}{2} * \left(v_{L,j,t}^Y + v_{L,j,t-1}^Y\right).$$

Under the assumption of constant returns to scale to all inputs, the value share of all inputs adds up to unity:

(6) $$v_{X,j}^Y + v_{K,j}^Y + v_{L,j}^Y = 1.$$

Equation (6) allows the observed value shares to be used in the estimation of MFP growth in equation (3). This assumption is common in the growth accounting literature (see e.g. Schreyer, 2001). Alternatively, one can undertake the growth accounting without the imposition of constant returns to scale and use cost shares, rather than revenue shares to weight input growth rates (see, e.g. Basu, Fernald, and Shapiro 2001).

Rearranging (3) yields the standard growth accounting decomposition of output growth into the revenue-share weighted growth of inputs and the residual MFP growth:

(7) $$\Delta \ln Y_j \equiv \bar{v}_{X,j}^Y \Delta \ln X_j + \bar{v}_{K,j}^Y \Delta \ln K_j + \bar{v}_{L,j}^Y \Delta \ln L_j + \Delta \ln A_j^Y.$$

Each item of the right-hand side of (7) indicates the proportion of output growth accounted for (contributed by) growth in intermediate inputs (*X*), capital services (*K*), labor services (*L*) and the MFP growth (representing technical change). The latter (MFP growth) cannot be directly measured and is derived as a residual as in (3).

In order to decompose growth at higher levels of aggregation, a more restrictive industry value-added function should be defined, giving the quantity of industry j's value added (Z_j) as a function of only capital (K_j), labor (L_j) and technology (T) as:

$$(8) \qquad Z_j = G_j(K_j, L_j, T).$$

The nominal value of value added is:

$$(9) \qquad P_j^Z Z_j = P_j^K K_j + P_j^L L_j,$$

where P_j^Z is the price (index) of value added. The crucial assumption made here is that the gross output production function as shown in (1) is separable between value-added (generated by using the primary inputs only, i.e. capital and labor), and intermediate inputs such that (1) can be rewritten as:

$$(10) \qquad Y_j = F_j\left(X_j, G_j(K_j, L_j, T)\right).$$

Under the same assumptions as for gross output, industry value added growth can be decomposed into the contribution of capital, labor and the value added based MFP (A^Z), which is defined as:

$$(11) \qquad \Delta \ln A_j^Z \equiv \Delta \ln Z_j - \bar{v}_{K,j}^Z \Delta \ln K_j - \bar{v}_{L,j}^Z \Delta \ln L_j,$$

where $\bar{v}_{K,j}^Z$, and $\bar{v}_{L,j}^Z$ are the period average share of capital and labor in nominal value added, respectively. The value share of each input is defined as follows:

$$(12) \qquad v_{K,j}^Z = \frac{P_j^K K_j}{P_j^Z Z_j}$$

$$v_{L,j}^Z = \frac{P_j^L L_j}{P_j^Z Z_j},$$

such that they sum to unity. In order to define the quantity of value added and remain consistent with the gross output function (1), the quantity of value added needs to be defined implicitly from a Tornqvist expression for gross output:

$$(13) \qquad \Delta \ln Z_j = \frac{1}{\bar{v}_{Z,j}^Y}\left(\Delta \ln Y_j - \left(1 - \bar{v}_{Z,j}^Y\right)\Delta \ln X_j\right),$$

where $\bar{v}_{Z,j}^Y$ is the period average share of value added in gross output. The corresponding price index of value added (P_j^Z) is also defined implicitly to make the following value identity hold:

$$(14) \qquad P_j^Z Z_j = P_j^K K_j + P_j^L L_j = P_j^Y Y_j - P_j^X X_j.$$

If the value added quantity and price are defined in this way, the MFP measured for gross output by (3) (i.e. gross output based MFP), and the MFP as measured for value added by (11) (i.e. value added based MFP) are proportional to each other with the ratio of gross output over value added as the factor of proportion (Bruno, 1984):

(15) $$\Delta \ln A_j^Z = \frac{1}{\bar{v}_{Z,j}^Y} \Delta \ln A_j^Y .$$

Note that the MFP growth measured on a value added function is essentially based on the assumption that technical change only has an impact on the use of capital and labor. Put simply, any improvements in the use of intermediate inputs will thus end up in the measure of value added-based MFP, which is quite a restrict assumption.

3.2. Some results

For better understanding, it is useful to provide some results generated by applying the modern growth accounting methodology as discussed above. We pick up one industry (KNR2310: Manufacturing of food products, beverages and tobacco) as an example, showing that how the MFP growth of this industry between 1997 and 2014 is calculated by following (3), which derives the MFP growth rate as a residual.

In Table 3.1, the gross output growth in KNR2310 is decomposed into the growth of factor inputs and the MFP growth, by means of equation (7). Moreover, Table 3.1 also provides further decomposition (of factor inputs into respective detailed components) results, i.e. intermediate inputs are decomposed into Energy, Materials, and Services, labor inputs into Hours worked and Labor composition, and capital inputs into ICT (Information and Communication Technology), R&D (Research and Development), and Others (including all other capital assets excluding ICT and R&D).

The methodology of these further decompositions will be described in the following sections (Section 4 on intermediated input, Section 5 on labor inputs and Section 6 on capital inputs).

Table 3.1 Gross output based MFP growth for industry KNR2310 (manufacturing of food products, beverages and tobacco), 1997-2014

	Average share in gross output (%)	Volume growth rate (%)	Contribution to growth rate in gross output (%)
Gross output	100.0	1.1	1.1
Intermediate inputs	80.0	0.3	0.2
Energy	0.6	-0.5	0.0
Materials	59.8	0.4	0.2
Services	19.6	-0.7	-0.1
Labor input	15.2	-0.4	-0.1
Hours worked	15.2	-0.3	-0.1
Labor composition	15.2	-0.1	0.0
Capital input	4.8	1.7	0.1
ICT	0.4	6.0	0.0
R&D	0.4	2.9	0.0
Others	3.9	1.0	0.0
MFP (gross output based)		0.9	0.9

Notes: Contribution of inputs is calculated as the value share of input times the volume growth rate. Shares are averaged over 1997 and 2014. Volume growth rates are annual compound growth rates over the period 1997-2014. Numbers may not sum exactly due to rounding.

Source: Calculations are based on the Norwegian KLEMS database, July 2017.

The first column in Table 3.1 gives the average share of each input in gross output. In the industry KNR2310, intermediate inputs, in particular, Materials play a dominant role, taking up more than half of the total cost. Labor input is also important, while the cost share of capital input is relatively low, only accounting for around 5% of the total cost.

The cost shares are used to weight the volume growth rate of each individual input given in the second column in Table 3.1. Between 1997 and 2014 production in this industry has increased by an average annual growth rate of 1.1 percent, but labor input has declined during the same period. Both the growth rates of Hours worked and Labor composition are negative, implying that the contracting labor force was composed of less productive workers by the end of the period in this industry.

Although intermediate inputs in total has increased, its components of Energy and Services have decreased, which, however, are counterbalanced by increased use of Materials, the dominant input in the industry.

Over the period 1997-2014, total capital input including all its detailed components (i.e. ICT, R&D, and Others) has increased. In particular, the use of ICT capital increased strongly.

The estimated positive MFP growth indicates that all inputs (intermediate, capital and labor) were used in a more efficient way in the production process in this industry over the observed period. As mentioned, the average annual growth rate of 0.9 percent is calculated as the growth of output minus the weighted growth of inputs (see equation (3)).

The rightmost column in Table 3.1 provides the contribution of each input and MFP to the growth in output, which is the product of the corresponding component in the first and second columns. In general, the increase in output is mainly due to the more efficient use of inputs, represented by the positive MFP growth. The contribution of labor input is roughly counterweighed by that of capital input over the observed period 1997-2014.

Table 3.2 Value added based MFP growth for industry KNR2310 (manufacturing of food products, beverages and tobacco), 1997-2014

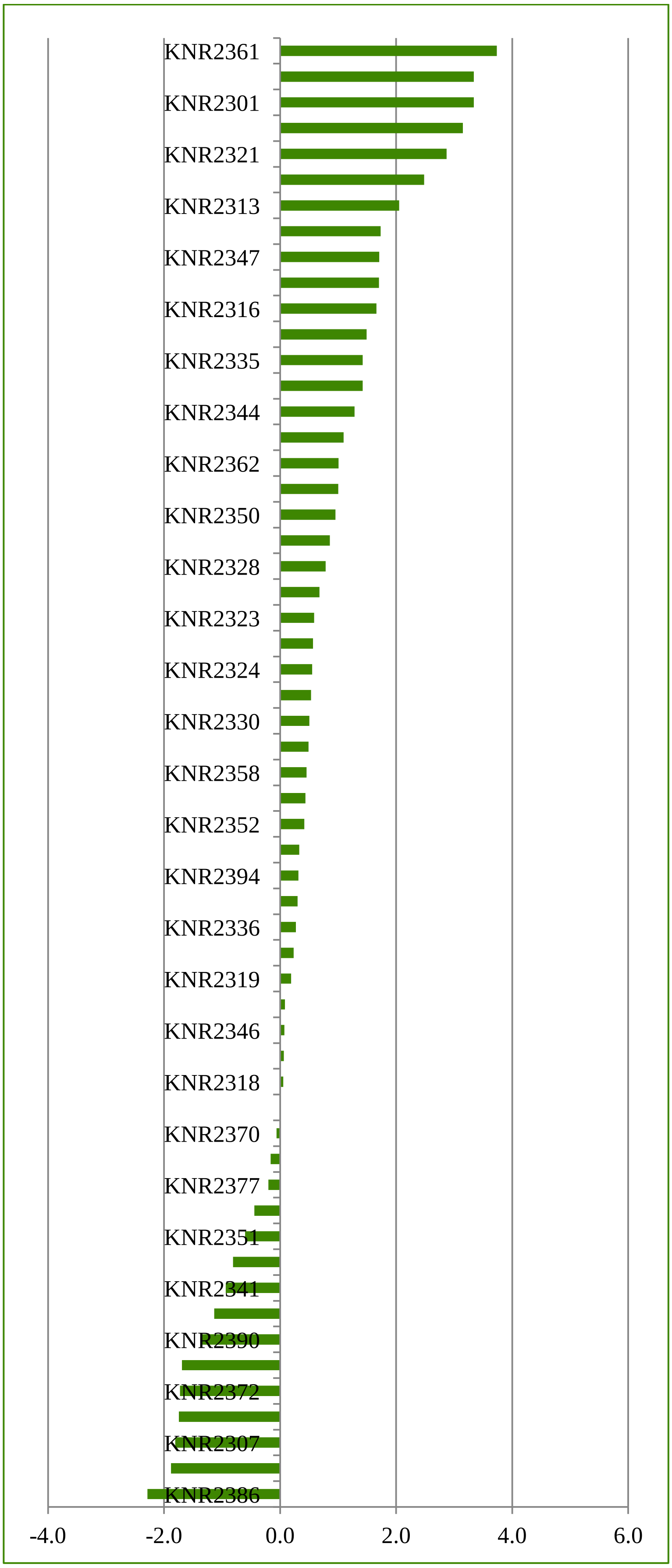
	Average share in gross output (%)	Volume growth rate (%)	Contribution to growth rate in value added (%)
Valued added	100.0	4.4	4.4
Labor input	76.5	-0.4	-0.3
Hours worked	76.5	-0.3	-0.3
Labor composition	76.5	-0.1	-0.1
Capital input	23.5	1.7	0.4
ICT	2.1	6.0	0.1
R&D	2.1	2.9	0.1
Others	19.3	1.0	0.2
MFP (value added based)		4.3	4.3

Notes and Source: See Table 3.1.

Using the same industry (KNR2310), Table 3.2 provides a decomposition of growth in value added, and the corresponding value added based MFP growth by means of equation (11). Value added is dominated by labor input, accounting for almost 80 percent of total value added. The volume growth rate of value added is derived on the basis of growth in intermediated inputs and output, as represented by equation (13).

Similar with Table 3.1, Table 3.2 shows that growth in labor input is negative, while that in capital input is positive, and their contributions to the overall growth of value added are almost offset with each other, leading to the estimated growth rate of MFP almost equal to that of the total value added.

Figure 3.1 Growth rates of MFP (gross output based) by industry, market economy in mainland Norway, 1997-2014 (%)



Notes: Annual compound growth rates.
Source: Calculations are based on the Norwegian KLEMS database, July 2017.

Note that the calculation of value added based MFP growth follows (11), which relies on the assumption that all technical change only takes place in the use of labor and capital, and not in the use of all inputs as is the case for gross output based MFP calculation.

As reflected by (15), due to the low share of value added in output (roughly 20 percent), value added based MFP growth is much higher than gross output based MFP growth, i.e. 4.3 versus 0.9 percent, as shown in Table 3.1 and Table 3.2.

In Figure 3.1, we provide a ranking of technical change in the 57 industries in the market economy in mainland Norway, measured by growth in gross output based MFP over the period 1997-2014. It shows that 41 out of 57 industries have positive MFP growth rates, and 29 industries with positive MFP growth rates belong to Manufacturing/Other goods production sectors, and the rest 12 are from service sectors.

As shown in Figure 3.1, MFP growth rates are highest in industries such as KNR2361 (Telecommunication), KNR2303 (Fishing), KNR2301 (Agriculture, Hunting), KNR2320 (Chemical products), KNR2321 (Production of pharmaceutical products), KNR2364 (Financial services), and KNR2313 (Textiles, wearing apparel, leather), with annual average growth rates all being larger than 2 percent. Among these industries, only one (KNR2364) is service industry.

Also shown in Figure 3.1, one industry (KNR2397: Paid household works) has zero MFP growth rate by construction.[5] In total, there are 15 industries having negative MFP growth rates, among which, 4 industries belong to either Other goods production sector (i.e. KNR2342: Construction; KNR2302: Forestry; and KNR2341: Building development) or Manufacturing sector (KNR2317: Graphic production), and the rest 11 industries are from service sectors.

For instance, the 5 industries with lowest (negative) growth rates (at the bottom of Figure 3.1) are all service industries, i.e. KNR2386 (Health services), KNR2385 (Education/training), KNR2307 (Service activities incidental to oil and gas), KNR2387 (Social welfare services), and KNR2372 (Research and Development).

That negative MFP growth rates are frequently found in service sectors may reflect the inherent limitation to innovation in these service sectors, as suggested by Baumol's cost-disease hypothesis (Baumol, 1967), but it may also be due to measurement problems that are notoriously associated with the measurement of services output (e.g. Griliches, 1992; Sichel, 1997; Triplett and Bosworth, 2004).

4. Output and intermediate input

4.1. Methodology

In order to make a coherent set of industry-level productivity estimates which cover the aggregate economy, one needs a consistent set of inter-industry transaction accounts. This methodology was introduced by Jorgenson, *et al.* (1987).

We define the quantity of output in industry j as an aggregate of a number of distinct outputs (indexed by i). Using the Tornqvist index as before yields:

(16) $$\Delta \ln Y_j = \sum_i \bar{v}_{i,j}^{Y} \Delta \ln Y_{i,j},$$

[5] For KNR2397 (Paid household works), it is assumed that labor is the only input and equals the output from this industry, thus leading to the productivity growth in this industry being zero.

where $\bar{v}_{i,j}^{Y}$ is the period average share of product *i* in the total nominal value of output, and $Y_{i,j}$ is the volume of product *i* produced by industry *j*.

The value share of the product *i* is defined as follows:

(17) $$v_{i,j}^{Y} = \frac{P_{i,j}^{Y} Y_{i,j}}{P_j^{Y} Y_j} = \frac{P_{i,j}^{Y} Y_{i,j}}{\sum_i P_{i,j}^{Y} Y_{i,j}},$$

where $P_{i,j}^{Y}$ is the price received by industry *j* for selling product *i*.

Note that the weight applied to each product *i* produced by industry *j* should be seen from the producer's perspective, i.e. it should reflect marginal revenue products. This means that the value share as shown in (17) should be evaluated from the producer's point of view and thus excludes all taxes from the value of output, but includes product subsidies. This is the basic prices concept as defined and recommended in the System of National Accounts (e.g. United Nations, 2009; Eurostat, 2013).

The aggregate intermediate input quantity index for industry *j*, X_j as shown in (1), is defined analogously as a Tornqvist volume index of various individual intermediate inputs (indexed by *x*):

(18) $$\Delta \ln X_j = \sum_x \bar{v}_{x,j}^{X} \Delta \ln X_{x,j},$$

where the weights are given by the period average shares of each individual input *x* in the value of total intermediate input compensation, such that the sum of shares over all individual intermediate input is unity. The term $\Delta \ln X_{x,j}$ indicates the volume growth of intermediate input *x* used by industry *j* over the period.

The value share of each individual input *x* used by industry *j* is defined as:

(19) $$v_{x,j}^{X} = \frac{P_{x,j}^{X} X_{x,j}}{P_j^{X} X_j} = \frac{P_{x,j}^{X} X_{x,j}}{\sum_x P_{x,j}^{X} X_{x,j}},$$

where $P_{x,j}^{X}$ is the price paid by industry *j* for using intermediate product *x*.

Different from output evaluation, the inputs used by industry *j* should be valued at purchasers' prices and should reflect the marginal cost paid by the user. Therefore, the prices as shown in (19) should include taxes, and exclude subsidies, on products paid by the user (non-deductible VAT included). Margins on trade and transport should also be included.

For many applications it is useful to group intermediate inputs into different broad groups. For example, total intermediate inputs can be classified into three subgroups, energy (E), materials (M) and services (S), such that

(20) $$\Delta \ln X_j = \bar{v}_{E,j}^{X} \Delta \ln X_j^{E} + \bar{v}_{M,j}^{X} \Delta \ln X_j^{M} + \bar{v}_{S,j}^{X} \Delta \ln X_j^{S}.$$

This breakdown of intermediate inputs can be used for extending the growth accounting exercises, but also convey interesting information as regards changing patterns in intermediate consumption (see e.g. Jorgenson *et al*., 2005).

In (20) $\bar{v}_{E,j}^{X}$ is the period average share of energy products (E) in total intermediate input costs in industry *j*, and $\bar{v}_{M,j}^{X}$, $\bar{v}_{S,j}^{X}$ are similarly defined for materials (M) and services (S), respectively. The input volume growth of E, M and S is defined in terms of their respective components as:

$$\Delta \ln X_j^E = \sum_{x \in E} \bar{v}_{x,j}^E \Delta \ln X_{x,j},$$

(21)
$$\Delta \ln X_j^M = \sum_{x \in M} \bar{v}_{x,j}^M \Delta \ln X_{x,j},$$

$$\Delta \ln X_j^S = \sum_{x \in S} \bar{v}_{x,j}^S \Delta \ln X_{x,j},$$

with weights $\bar{v}_{x,j}^E$ being the period average share of energy product *x* in total energy costs (E) in industry j, summing to unity over all energy input products. Weights for materials (M) ($\bar{v}_{x,j}^M$) and services (S) ($\bar{v}_{x,j}^S$) are defined analogously.

4.2. Compilation

In the Norwegian National Accounts (NNA) compilation system, around 950 products are defined according to the European Union's main product standard CPA (Classification of Products by Activities), either with a link to the CPA-codes or as aggregates of the CPA-codes. As an integral part of the NNA system, the time-series of Norwegian Supply and USE Tables (SUTs) in both current and constant prices provide a consistent set of inter-industry transaction accounts for our purpose (Simpson and Todsen, 2012).

In addition, detailed valuation classes employed by the Norwegian SUTs include information for each product on product's basic value (code 10), taxes on products (code 11), subsidies on products (code 12), retail and wholesale trade and transport margins in basic value (code 14), taxes on product related to trade margins (paid by the traders) (code 15), subsidies on product related to trade margins (paid to the traders) (code 16), non-deductible value added tax (code 17), investment levy or sales tax (if relevant) (code 18), and product's purchaser's value (code 19).

The last valuation class (code 19) for a product is equivalent to the product's purchaser's price which reflects the marginal cost paid by the user (see e.g. United Nations, 2008; Eurostat, 2013). It is calculated as the sum of all the other value classes as mentioned above, i.e. 19 value = 10 value + 11 value + 12 value + 14 value + 15 value + 16 value + 17 value + 18 value.[6] Clearly, information drawn from the Norwegian SUTs allows the calculation of the output from industry in basic prices and the inputs used by industry in purchaser's prices.

As mentioned before, the 57 industries we choose as the lowest disaggregated industry level in the Norwegian KLEMS database are simply aggregated from about 150 industries in the Norwegian SUTs. Ideally, for each of the 57 industries, decomposing gross output should be carried out on a sectoral output measure which excludes intra-sectoral deliveries of intermediate inputs (see Gollop, 1979).[7] Due to data limitation, however, the exclusion work has not been done for the current version of the Norwegian KLEMS database.

In the Norwegian KLEMS database, total intermediate inputs are also grouped into three broad groups: Energy (E), Materials (M) and Services (S). Energy inputs are defined as all energy mining products (code 050000 to code 060058), oil refining products (code 191000 to code 192420) and electricity and gas products (code 351107 to code 353000).

[6] Note that subsidies (i.e. 12 value, and 16 value) enter the summation with negative sign.
[7] However, value added decomposition does not require sectoral output measure because value added, by definition, is independent of the vertical integration of firms/lower level industries.

All services (products from code 33xxxx and above) are included in S, as well as some of the (technically) aggregated products (code 000016, code 000026 to code 000050, code 000150 to code 000379).[8] As a result, all the remaining products are classified as materials (M).

Strictly speaking, trade and transport margins (14 value + 15 value + 16 value) which are included in product's purchasers' prices (19 value) are one type of services product, i.e. trade and transportation product. If trade and transportation product is treated as a separate product, the trade and transportation margins on all other products should be reallocated to this product. Notice that the reallocation will only affect the relative contributions of E, M and S to gross output growth, but not the other growth accounting variables.

Formally, the following approach is taken in the Norwegian KLEMS database. We make a distinction between the intermediate products as delivered by the producing industry to the use industry, valued at purchasers' prices minus trade and transportation margins (i.e. 19 value – 14 value – 15 value – 16 value = 10 value + 11 value + 12 value + 17 value + 18 value), and the trade and transportation services, valued at the margins (i.e. 14 value + 15 value + 16 value). This approach is the same as taken in Jorgenson, *et al*. (1987, 2005).

There are a few exceptions. For four industries (KNR2328, KNR2330, KNR2331 and KNR2333), and over a number of years (from 2002 to 2014), because trade and transportation margins cannot be separated, we still use purchase prices including trade and transportation margins as the prices of the products used by these industries for the specified years.

4.3. Some results

In Figure 4.1 we have ranked the 57 industries in the market economy in mainland Norway on the basis of growth of gross output volumes over the period 1997-2014.

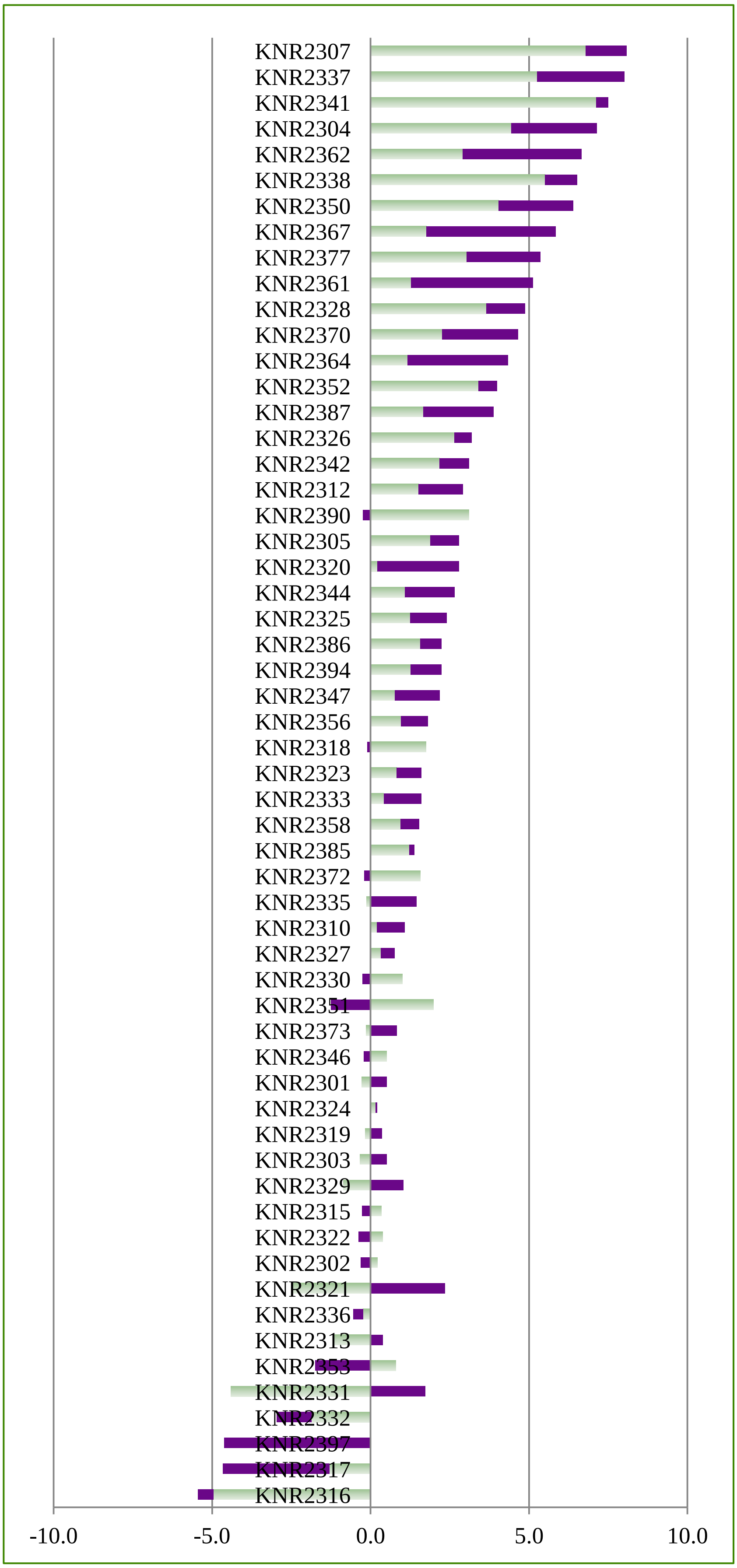
Among the 57 industries, there are 10 industries that have negative gross output growth rates. Ranked from the lowest growth rates up, they are KNR2316 (Wood processing), KNR2317 (Graphic production), KNR2397 (Paid household works), KNR2332 (Other industry production), KNR2331 (Building of oil platforms and modules), KNR2353 (Post and distribution), KNR2313 (Textiles, wearing apparel, leather), KNR2336 (Transport and sale of electricity), KNR2321 (Production of pharmaceutical products), and KNR2302 (Forestry).

Of the 47 industries that have positive gross output growth rates, 10 industries have the highest annual average growth rates, all larger than 5%. Ranked from the lowest growth rates up, they are: KNR2361 (Telecommunication), KNR2377 (Leasing, travel and other business services), KNR2367 (Managing real estate), KNR2350 (Domestic maritime transport), KNR2338 (Water supply, sewerage, wastes), KNR2362 (Information services), KNR2304 (Aquaculture), KNR2341 (Building development), KNR2337 (Other energy, district heating and gas), and KNR2307 (Service activities incidental to oil and gas).

By comparing the top ten fast-growing industries with the top ten fast-contracting industries in Norway over the period 1997-2014, it seems that the former are mainly from service sectors, while the latter are mainly from Manufacturing and/or Other goods production sectors.

[8] For definitions of (technically) aggregated products, see Simpson and Todsen (2012). And for all product codes applied by the NNA, see Amdal and Sagelvmo (2017).

Figure 4.1 Growth rates of gross output by industry, 1997-2014 (%)



Notes: Annual compound growth rates of gross output volumes by industry. In dark, the contribution of growth in value added and, in light, the contribution of growth in intermediate inputs.
Source: Calculations are based on the Norwegian KLEMS database, July 2017.

Also in Figure 4.1, the growth of gross output volume is further decomposed into the respective contribution by the growth of intermediate inputs (light) and that of value added (dark) by following (13).

In general, the correlation between the growth of gross output and either the value added growth, or the intermediate input growth is high, with the sample correlation coefficient being 0.71 and 0.87, respectively.

However, in some industries, the contribution of intermediate input is much higher than from value added (such as KNR2341: Building development; KNR2338: Water supply, sewerage, waste), while in some other industries, the opposite is true (e.g. KNR2320: Chemical products; KNR2364: Financial services).

5. Labor input

5.1. Methodology

From user's perspective, labor is one of the essential inputs used by common production process. The aim of the labor input accounts is to estimate total labor inputs used by industry so that it reflects the actual changes in the amount and quality of labor inputs over time and across industries.

From supplier's perspective, labor inputs can be regarded as labor services generated by human capital embodied in labor forces working in industry. Since human capital developed varies across different types of labor, the productivity of various types of labor (such as low- versus high-skilled) will differ.

Standard measures of labor input, such as the numbers employed or hours worked, will not account for such differences. Hence it is important to have measures of labor input which take the heterogeneity of the labor force into account in analyzing productivity and the contribution of labor input to output growth.

We follow the approach taken by Jorgenson *et al*. (1987) and assume that aggregate labor services are a translog function of the services delivered by individual types. It is further assumed that the flow of labor services for each labor type is proportional to hours worked, and workers are paid their marginal productivities.

In the Norwegian KLEMS database, the labor force is subdivided into different types based on various characteristics that are considered to be important factors determining the corresponding labor productivity by each labor type, such as age, gender and educational attainment.

Thus, the corresponding index of the aggregate labor services input L is a translog quantity index of individual types, indexed by l, and given by

(22) $$\Delta \ln L_j = \sum_l \bar{v}_{l,j}^L \Delta \ln H_{l,j},$$

where the weights are given by the period average shares of each labor type l in the value of total labor compensation in industry j, such that the sum of shares over all labor types within the industry j is unity. The term $\Delta \ln H_{l,j}$ indicates the growth of actual hours worked by labor type l in industry j over the period.

The value share of each individual labor input type l is defined as:

(23) $$v_{l,j}^{L} = \frac{P_{l,j}^{L} H_{l,j}}{P_{j}^{L} L_{j}} = \frac{P_{l,j}^{L} H_{l,j}}{\sum_{l} P_{l,j}^{L} H_{l,j}},$$

where $P_{l,j}^{L}$ is the price of one hour worked received by labor type *l* in industry j.

As we assume that marginal revenues are equal to marginal costs, the weighting procedure ensures that an input which has a higher price also has a larger influence in the input index. For example, a doubling of hours worked by a high-skilled worker gets a bigger weight than a doubling of hours worked by a low-skilled worker.

In this way, aggregation as shown in (22) takes into account the changing composition of the labor force. Typically, a shift in the share of hours worked by low-skilled workers to high-skilled workers will lead to a growth of labor services which is bigger than the growth in total hours worked, as long as wages per hour worked of low-skilled workers are lower than those of high-skilled workers. We refer to this difference as the labor composition effect.

Let H_j indicate total hours worked by all types of labor in industry j, i.e. $H_j = \sum_l H_{l,j}$, then we can further decompose the change in labor inputs as shown in (22) as follows:

(24) $$\Delta \ln L_j = \sum_l \bar{v}_{l,j}^{L} \Delta \ln \frac{H_{l,j}}{H_j} + \Delta \ln H_j = \Delta \ln LC_j + \Delta \ln H_j.$$

The first term on the right-hand side indicates the change in labor composition, and the second term indicates the change in total hours worked. It can easily be seen that if only proportions of each labor type change, while keeping total hours worked unchanged, then the impact on the growth of labor input will be reflected only by the change of labor composition, defined as $\Delta \ln LC_j$.

An alternative further decomposition of (22) is to classify labor types into different labor groups, such as those by low (LE), middle (ME) and high (HE) educational attainment. Then (22) becomes:

(25) $$\Delta \ln L_j = \bar{v}_{LE,j}^{L} \Delta \ln L_j^{LE} + \bar{v}_{ME,j}^{L} \Delta \ln L_j^{ME} + \bar{v}_{HE,j}^{L} \Delta \ln L_j^{HE},$$

with $\bar{v}_{LE,j}^{L}$ being the period-average labor compensation share of workers with low education level in total labor costs in industry j, and $\bar{v}_{ME,j}^{L}, \bar{v}_{HE,j}^{L}$ similarly for middle and high educational levels, respectively.

The volume growth of labor input by low, middle and high educational levels is defined as

(26) $$\begin{aligned} \Delta \ln L_j^{LE} &= \sum_{l \in LE} \bar{v}_{l,j}^{LE} \Delta \ln L_{l,j}, \\ \Delta \ln L_j^{ME} &= \sum_{l \in ME} \bar{v}_{l,j}^{ME} \Delta \ln L_{l,j}, \\ \Delta \ln L_j^{HE} &= \sum_{l \in HE} \bar{v}_{l,j}^{HE} \Delta \ln L_{l,j}, \end{aligned}$$

where $\bar{v}_{l,j}^{LE}$ being the period-average labor compensation share of labor type *l* in total labor costs of those with low educational level in industry j, and $\bar{v}_{l,j}^{ME}, \bar{v}_{l,j}^{HE}$ similarly for labor type of middle and high educational levels in industry j, respectively. Each set of weights just mentioned should sum to unity.

5.2. Compilation

Formally, in the Norwegian KLEMS database, we cross-classify hours worked and the corresponding labor compensation by age, educational attainment, employment class, and gender into 48 labor categories, i.e. 3 * 4 * 2 * 2 types in total (see Table5.1).

Table 5.1 Classification of labor force for each industry

Dimension	Number of categories	Categories
Age	3	Young (15/16-29), Middle (30-49), Elder (50 and above)
Education	4	Low, Intermediate, High S (short), High L (Long)
Employment class	2	Employees, Self-employed
Gender	2	Male, Female

The four education categories are defined as follows: Low = Primary and lower secondary education (*Grunnskoleutdanning* in Norwegian) + Unknown education (*Uoppgitt/ukjent* in Norwegian); Intermediate = Upper secondary education, general programs (*Videregående allmennfaglig- og økonomisk- og administrativ utdanning* in Norwegian) + Upper secondary education, vocational programs (*Videregående fagutdanning* in Norwegian); High S (Short) = Tertiary education, lower degree (*Universitet- og høyskoleutdanning, lavere nivå* in Norwegian); High L (Long) = Tertiary education, higher degree (*Universitet- og høyskoleutdanning, høyere nivå* in Norwegian).

For the period 2008-2014, data are available for each industry on number of employed persons, actual hours worked, wages/salaries, and labor compensation, all cross-classified by education and gender, for employees. While for self-employed, only data on number of employed persons and actual hours worked are available.

By assuming that the self-employed could have earned the same labor compensation per hour as the employees, data on actual hours worked and the corresponding labor compensation in each industry for both the employees and self-employed can be derived, again, cross-classified by education and gender, but not yet by age categories.

In order to generate data for each industry on actual hours worked and the corresponding labor compensation, cross-classified by age, education, employment class and gender, two further assumptions are made: First, population age (Young, Middle, and Elder) distribution by gender and education, for which annual data are extracted from StatBank at Statistics Norway,[9] is assumed to be the same as that for hours worked across all industries in each year.

Second, the ratios among average monthly wages for employees by gender and age, for which annual data are also extracted from StatBank at Statistics Norway, are assumed to be the same as those for labor compensation across all educational levels in each year. The availability and relative richness of data on average monthly wages for employees for different industries (or broader industry groups) allows us to apply the industry-specific ratios to all the industries in our database. For the period 1997-2007, data are only available for each industry on actual hours worked by gender and employment class, and total (for Males and Females as a whole) labor compensation for employees. To obtain data as needed for our purpose, further steps have to be taken.

First, for each industry (or broader industry group), a gender ratio of labor compensation is derived from data on average monthly wages by gender, which,

[9] See https://www.ssb.no/statistikkbanken/ .

again, are drawn from StatBank. Applying this ratio to the total labor compensation leads to labor compensation for Males and Females, respectively.

Second, apply the ratios of labor compensation by education, derived from average monthly wages by education. And within each education category, apply the ratios of labor compensation by age (derived from average monthly wages by age) to labor compensation by gender. All the ratios are generated from the StatBank.

Finally, by assuming that population distribution by age, gender and education (from StatBank) is the same as that for hours worked, data on actual hours worked and the corresponding labor compensation cross-classified by age, education, employment class and gender over the period 1997-2007 can be finally obtained.

5.3. Some results

In Table 5.2 an example is given to demonstrate the calculation of the growth in labor services for one industry KNR2307 (Service activities incidental to oil and gas) over the period 1997-2014. For better exposition, data are given for 12 types of labor only, by summing both the actual hours worked and the corresponding labor compensation over the gender and employment class dimensions.

Table 5.2 Labor services growth for industry KNR2307 (Service activities incidental to oil and gas), 1997-2014

	Hours worked (Millions)			Share in labor compensation (%)			Contribution to labor services growth (%)
	1997	2014	Annual growth (%)	1997	2014	Average	
Low, Young	1.3	2.7	4.2	6.4	3.1	4.7	0.2
Low, Middle	1.3	1.7	1.4	10.3	2.8	6.5	0.1
Low, Elder	2.0	2.6	1.7	15.6	4.9	10.3	0.2
Intermediate, Young	1.4	5.8	8.6	6.9	7.2	7.0	0.6
Intermediate, Middle	2.4	10.6	9.2	18.5	19.0	18.7	1.7
Intermediate, Elder	2.2	14.1	11.5	17.9	29.2	23.5	2.7
High S, Young	0.5	1.8	7.6	3.0	2.5	2.7	0.2
High S, Middle	0.9	4.4	9.4	8.9	8.7	8.8	0.8
High S, Elder	0.5	3.7	12.0	5.4	8.5	7.0	0.8
High L, Young	0.1	0.7	14.7	0.4	1.1	0.8	0.1
High L, Middle	0.4	3.3	13.4	3.8	7.2	5.5	0.7
High L, Elder	0.3	2.3	13.0	3.0	5.8	4.4	0.6
Residual							0.0
All workers	13.4	53.8	8.5	100.0	100.0	100.0	8.8

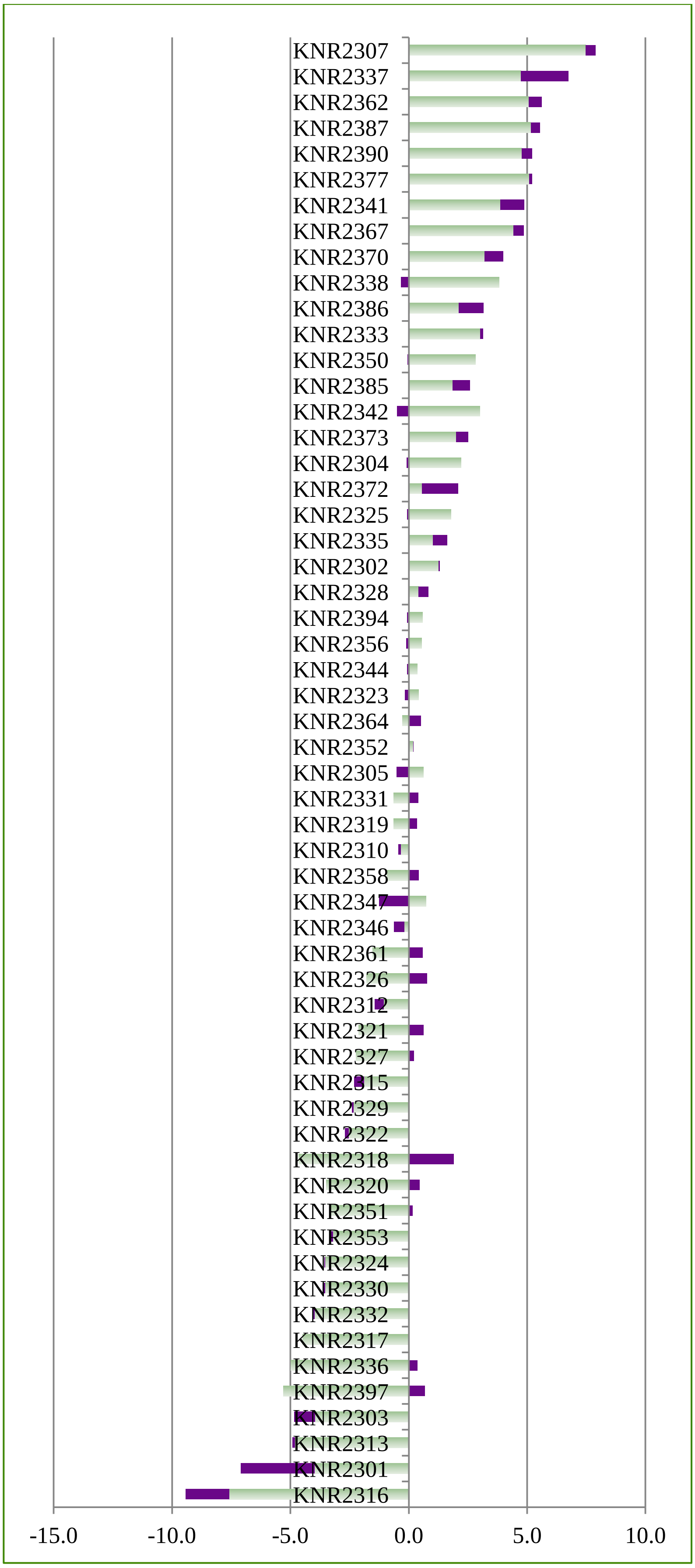
Notes: Contribution of labor types calculated as the average share of input times the volume growth rate. Numbers may not sum exactly due to rounding. Residual includes effects of shifts in Male and Female shares.
Source: Calculations are based on the Norwegian KLEMS database, July 2017.

Table 5.2 provides the total hours worked by labor type and the corresponding share in total labor compensation. Although workers with Intermediate education and aged Middle and above dominate the labor force in this industry, higher growth of hours worked has been found for workers with higher education over the period 1997-2014, compared with their counterparts with lower education levels (see the third column in Table 5.2).

By multiplying the average share in labor compensation with the growth rate in hours worked, the contribution of each labor type to growth in labor services is calculated. This is given in the rightmost column of Table 5.2. Total hours worked in this industry (KNR2307) increased at a rate of 8.5 percent per year on average, while labor services increased at 8.8 percent annually.

The difference of 0.3 percent per year on average is due to the change in the composition of the labor force in this industry, which indicates that higher education workers (thus with higher productivity) increased their hours worked, while hours worked by workers with lower education (thus lower productivity) decreased in the same industry.

Figure 5.1 Growth rates of labor input by industry, 1997-2014 (%)



Notes: Annual compound growth rates. In light, the growth in hours worked and, in dark, the contribution of changes in labor composition.
Source: Calculations are based on the Norwegian KLEMS database, July 2017.

Figure 5.1 provides an overview of the growth in labor services by industry in the market economy in mainland Norway over the period 1997-2014.The 57 industries are ranked according to their average annual growth rate of labor services input in each industry.

Generally speaking, slightly more than half of the total 57 industries (29 industries) having positive annual growth rate of labor services. The industries with highest (larger than 5 percent per year on average) growth of labor services over the period 1997-2014, ranked from the highest growth rate down, are KNR2307 (Service activities incidental to oil and gas), KNR2337 (Other energy, district heating and gas), KNR2362 (Information services), KNR2387 (Social welfare services), KNR2390 (Cultural/sports/leisure activities), and KNR2377 (Leasing, travel and other business services).

Of the 57 industries, 28 industries have negative annual growth rate of labor services. The industries with lowest (less than -5 percent per year on average) growth of labor services over the same observed period, ranked from the lowest growth rate up, are KNR2316 (Wood processing), KNR2301 (Agriculture, Hunting), KNR2313 (Textiles, wearing apparel, leather), KNR2303 (Fishing), KNR2397 (Paid household works), KNR2336 (Transport and sale of electricity), KNR2317 (Graphic production), KNR2332 (Other industry production).

In terms of the labor services input growth over the observed period 1997-2014, it is clear that at least the fast-growing industries are mainly from the services sectors, on the contrary, the quick-contracting industries are largely from Manufacturing and Other goods production sectors.

In general, the correlation between the growth of labor services and that of hours worked is quite high, with the sample correlation coefficient being 0.98. This is partly due to that for most industries the contribution from the change in labor composition is rather small, if compared with that from the growth of hours worked.

6. Capital input

6.1. Methodology

This section provides a description of the methodologies employed to estimate capital services by industry. The theoretical methodologies are drawn from the analysis developed by Jorgenson and Griliches (1967), and outlined in Jorgenson, *et al*. (1987).

As for labor, various types of capital have different productivities when used in industry production. To account for this heterogeneity the user-cost approach is employed, based on which capital input is measured as capital services, rather than as capital stock as conventionally used for growth accounting (e.g. Solow, 1970; Kuznets, 1976).

But different from labor input where labor services (rather than human capital that generate such services) are observable, capital services are not directly observable. Therefore, for the measurement of capital services, we need capital stock estimates for detailed assets and the shares of capital remuneration in total output value.

The most commonly employed approach in capital stock measurement is the Perpetual Inventory Method (PIM). According to the PIM, capital stock is defined as a weighted sum of past investments with weights given by the relative efficiencies of capital goods at different ages (industry subscripts are suppressed for convenience):

(27) $$S_{k,t} = \sum_{\tau=0}^{\infty} \theta_{k,\tau} I_{k,t-\tau},$$

with $S_{k,t}$ being the capital stock for a particular asset type k at time t, $\theta_{k,\tau}$ the efficiency of this capital good k of age τ relative to the efficiency of a new capital good, and $I_{k,t-\tau}$ the investment in period t-τ. An important implicit assumption here is that the services by assets of different vintages are perfect substitutes for each other.[10]

Implementing equation (27) requires specifying for each asset type a particular pattern of age-efficiency. Based mainly on practical grounds the geometric pattern is applied, which implies that a given vintage of investment loses a fixed percentage of its productive capacity each year.

Given the geometric pattern of age-efficiency profile for each asset type, the corresponding age-price profile, which defines the depreciation rate of the asset, will also be of geometric pattern. Then it is relatively easier to make estimates of the depreciation rate based on observations in asset market.

Hence with a given constant rate of depreciation δ_k, different for each asset type, we get $\theta_{k,t} = (1-\delta_k)^t$, and it follows that the capital stock of a particular asset k at time t, $S_{k,t}$, is given by

(28) $$S_{k,t} = \sum_{\tau=0}^{\infty}(1-\delta_k)^{\tau} I_{k,t-\tau} = S_{k,t-1}(1-\delta_k) + I_{k,t}.$$

For the aggregation of capital services over the different asset types, it is assumed that aggregate services are a translog function of the services of individual assets. It is further assumed that the flow of capital services by each asset type k, $K_{k,t}$ is proportional to its stock $S_{k,t}$, independent of both asset type k and time t, i.e. $K_{k,t} = \mu * S_{k,t}$, where μ is a constant.

Then the corresponding index of capital services input K_t can be defined as a translog quantity index of individual assets in a particular industry by

(29) $$\Delta \ln K_t = \sum_k \bar{v}_{k,t}^K \Delta \ln K_{k,t} = \sum_k \bar{v}_{k,t}^K \Delta \ln S_{k,t},$$

where weights are given by the period average shares of each asset component in the value of total capital compensation, i.e. $\bar{v}_{k,t}^K = \frac{1}{2} * \left(v_{k,t}^K + v_{k,t-1}^K\right)$, and $v_{k,t}^K = \frac{P_{k,t}^K K_{k,t}}{\sum_k P_{k,t}^K K_{k,t}} = \frac{P_{k,t}^K S_{k,t}}{\sum_k P_{k,t}^K S_{k,t}}$, , with $P_{k,t}^K$ being the price of capital services from asset type k, also called the rental price, or user cost of capital.

In this way, the aggregation as shown in (29) takes into account the widely differentiated marginal products from the heterogeneous stock of assets. The rental price, or user cost of capital, can be estimated using the standard approach grounded in the arbitrage equation derived from neo-classical theory of investment, introduced by Jorgenson (1963) and Jorgenson and Griliches (1967) as follows.

In equilibrium, an investor is indifferent between two alternatives: buying a unit of capital at investment price $P_{k,t}^I$, collecting a rental fee and then selling the depreciated asset for $(1-\delta_k)P_{k,t+1}^I$ in the next period, or earning a nominal rate of

[10] For discussions on this assumption, please refer to Jorgenson, *et al*. (1987).

return, i_t , on a different investment opportunity. In the absence of taxation the equilibrium condition can be rearranged, yielding the cost-of-capital equation:

(30) $$P^K_{k,t} = i_t P^I_{k,t-1} + \delta_k P^I_{k,t} - \left(P^I_{k,t} - P^I_{k,t-1}\right).$$

This formula shows that the rental price is determined in combination by the nominal rate of return, the rate of economic depreciation and the asset specific capital gains.

Equation (30) can also be rewritten as

(31) $$P^K_{k,t} = r_{k,t} P^I_{k,t-1} + \delta_k P^I_{k,t}.$$

with $r_{k,t}$ being the real rate of return, defined as the nominal rate of return adjusted for asset-specific capital gains:

(32) $$r_{k,t} = i_t - \left(\frac{P^I_{k,t}}{P^I_{k,t-1}} - 1\right).$$

The asset revaluation term can be derived from the investment price indices. The rate of depreciation is identical to the rate used in the construction of the capital stock estimates in (28) because, as mentioned before, in the case of geometric depreciation, the age-price and age-efficiency profile follow the same geometric pattern. To calculate the rental price, the only unknown variable in (31) is the nominal rate of return, i_t.

The nominal rate of return can be estimated in two different ways. The first approach is the residual, or ex-post approach, which estimates the rate of return as a residual given the value of capital compensation from the national accounts, depreciation and the capital gains. The second is the ex-ante approach, which is based on some exogenous value for the rate of return, for example interest rates on government bonds.

Following the ex-post approach, the nominal rate of return is assumed to be the same for all assets in an industry, but is allowed to vary across industries. It is derived as a residual as follows:

(33) $$i_{j,t} = \frac{P^K_{j,t} K_{j,t} + \sum_k \left(P^I_{k,j,t} - P^I_{k,j,t-1}\right) S_{k,j,t} - \sum_k P^I_{k,j,t} \delta_{k,j} S_{k,j,t}}{\sum_k P^I_{k,j,t-1} S_{k,j,t}},$$

where the first term in the numerator, $P^K_{j,t} K_{j,t}$, is the total capital compensation in industry *j*, which under constant returns to scale can be derived as value added minus labor compensation, i.e. as gross operating surplus.
Apparently, the attractive property of the ex-post approach is that it ensures complete consistency between income and production accounts by assuming that the total value of capital services for each industry equals its compensation for all assets, thus generating an internal rate of return that exhausts capital income and is consistent with constant returns to scale assumption.

Despite the advantages for the ex-post approach, there are also reasons to opt for the ex-ante measure as well. For instance, the ex-post approach has some weaknesses: first, the gross operating surplus contains compensation for all assets, including those not covered in the SNA, leading to an overestimated rate of return; second, the assumptions, such as equalization of rates of return across all assets in an industry, are rather strong; and third, such endogenously calculated rate of return is volatile and can result in negative rental prices.

On the other hand, the rate of return by the ex-ante approach is much less volatile and does not need strong assumptions. However, the main problem with this approach is what to be chosen as the exogenous rate of return. In addition, resorting to information outside the SNA is usually needed.

A number of studies have shown that in practice, the choice for the ex-ante or ex-post measure does not make a big difference: growth rates of capital services appear to be almost similar for both approaches, at both the aggregate economy and the industry level (e.g. Erumban, 2004; Schreyer, 2004; Oulton, 2005; Baldwin and Gu, 2007). However, estimates for MFP growth can be rather different, depending on whether the ex-post or ex-ante measure is used (e.g. Schreyer, 2004; Baldwin and Gu, 2007).

Given the above discussions, we finally decide that the ex-post approach be employed in the current version of the Norwegian KLEMS database. In the next phase, experimentation will be taken based on the ex-ante measure in order to investigate the sensitivity of the corresponding results.

To analyze the separate impact on total capital services growth by ICT (Information and Communication Technologies), R&D (Research and Development) and Others (All other capital assets excluding ICT and R&D), asset types are allocated to three groups: ICT assets (indicated by IT), R&D asset (indicated by RD), and Others (indicated by OA), such that

(34) $$\Delta \ln K_j = \bar{v}^K_{IT,j} \Delta \ln K^{IT}_j + \bar{v}^K_{RD,j} \Delta \ln K^{RD}_j + \bar{v}^K_{OA,j} \Delta \ln K^{OA}_j,$$

with $\bar{v}^K_{IT,j}$ being the period-average share of ICT assets in total capital compensation in industry *j*, and $\bar{v}^K_{RD,j}, \bar{v}^K_{OA,j}$similarly for R&D and Others, respectively.

The volume growth of ICT, R&D and Others is defined as

$$\Delta \ln K^{IT}_j = \sum_{k \in IT} \bar{v}^{IT}_{k,j} \Delta \ln K_{k,j},$$

(35) $$\Delta \ln K^{RD}_j = \sum_{k \in RD} \bar{v}^{RD}_{k,j} \Delta \ln K_{k,j},$$

$$\Delta \ln K^{OA}_j = \sum_{k \in OA} \bar{v}^{OA}_{k,j} \Delta \ln K_{k,j},$$

where $\bar{v}^{IT}_{k,j}$ being the period-average share of ICT asset *k* in total ICT capital costs in industry *j*, and $\bar{v}^{RD}_{k,j}, \bar{v}^{OA}_{k,j}$ similarly for R&D and Others, respectively, so long as each set of weights sums to unity.
Alternative decomposition of total capital services growth is also possible. For instance, if we define a quantity index of capita stock in industry *j* as:

(36) $$\Delta \ln S_t = \sum_k \bar{v}^S_{k,t} \Delta \ln S_{k,t},$$

where weights are given by the period-average share of each component in the value of capital compensation, i.e. $\bar{v}^S_{k,t} = \frac{1}{2} * \left(v^S_{k,t} + v^S_{k,t-1}\right)$, and $v^S_{k,t} = \frac{P^I_{k,t} S_{k,t}}{\sum_k P^I_{k,t} S_{k,t}}$, , with $P^I_{k,t}$ being the price of capital investment for asset type *k*.

Then, a quality index for industry *j*, Q_j can be defined as:

(37) $$\Delta \ln Q_j = \Delta \ln K_j - \Delta \ln S_j = \sum_k \bar{v}^K_{k,t} \Delta \ln S_{k,t}, - \sum_k \bar{v}^S_{k,t} \Delta \ln S_{k,t},$$

where the use is made of (29) and (36).

As shown in (37), the quantity indexes of capital services K_j and capital stock S_j both aggregate the same asset quantity $S_{k,t}$ by means of Tornqvist indexes. However, the key difference between them is the use of services prices versus asset prices in the respective weights. Since larger weights are placed on assets with higher marginal products in the index of capital services K_j, growth in capital quality reflects therefore substitutions towards those assets with relatively high capital services and marginal products.

6.2. Compilation

In the Norwegian National Accounts (NNA) system, there are about 40 detailed asset types that make up broad asset groups classified by the SNA (e.g. United Nations, 2009; Eurostat, 2013). In particular, three asset types are regarded as ICT capital that is focused in the Norwegian KLEMS database: Office and computing equipment, Communications equipment, and Software.

However, two important asset types, land and inventories, are missing in the NNA. Changes of inventories have been conventionally merged with statistical discrepancy and are not separately estimated in the NNA (see Simpson and Todsen, 2012). Although some experimental work was recently carried out, trying to make separate estimates of changes in inventories (Todsen and Eikill, 2017), the results have not yet been incorporated in the official NNA database.

Similarly, work has also been done recently at Statistics Norway for incorporating land into the balance sheet of the NNA (see Liu, 2016). However, the current estimates of land value are by broad group of industries and institutional sectors, rather than by detailed disaggregate industry. Moreover, due to data limitation, the current estimates of land value only start from 2011.

As a result, inventories and land as assets are excluded from the current Norwegian KLEMS database. Nonetheless, to have a complete capital accounts, inventories and land should also be taken into consideration, as capital compensation in the national accounts includes the user costs of these assets as well.

Although one might argue that changes in inventories are short-term cycles without trends over longer periods of time, so the exclusion of inventories may not bias the growth accounting results. For land, this is probably not true. Even if one might argue that at the total economy level the amount of land used does not change much, at the industry level this assumption is indefensible.

Moreover, the exclusion of land may also have certain impact on the estimates of rate of return. However, given the current data availability at the industry level, the issues resulted from the exclusion of land and inventories can only be investigated as further research topic in the future.

In the NNA compilation system, long time series of gross fixed capital formation (GFCF) for different assets exist, dating back to 1970, which enables the estimation of capital stock for each asset by following the Perpetual Inventory Method (PIM).[11]

The data sources for the GFCF are often the same as for output and intermediate inputs, and include, among others, Structural Business Statistics, construction

[11] To be able to start the PIM estimates for capital stock and depreciation in the same year, the GFCF series have been extrapolated backwards, in some cases back to 1870.

statistics, central and local government accounts, etc. In general, data quality for the GFCF is not as good as for output and intermediate inputs. The price index for the GFCF of an asset is a weighted average of the price indexes of products that make up each asset type. The data sources include, e.g. construction cost indexes for residential buildings and roads, price indexes for new detached houses, etc.

A key assumption in computation of capital services as outlined above is that investment should be measured in constant-quality efficiency units. Only under this assumption, different vintages of each asset can be treated as perfect substitutes in production. Correspondingly, constant-quality price indices are required for each asset type, in particular, for those which are subject to rapid technological change and improvements in quality, such as ICT assets.

To this end, new methodologies such as hedonic or high-frequency matched model to derive the quality adjusted deflators should be adopted, especially, for ICT assets. However, although some works as regards price index compilation have been done for improving both data sources and methodologies by taking the quality change into consideration, quality adjustment for price indexes in general is still a challenge at Statistics Norway, and therefore, further research along this line should be encouraged.

The PIM and geometric depreciation are applied to all assets for each industry, and the associated service lives vary by industry, institutional sector and asset type. The choice of service lives is based on expert advices, other countries' estimates, as well as empirical estimates drawn from recent survey questionnaires (see Barth, *et al*., 2016). In addition, the application of geometric depreciation is regarded as being empirically supported, conceptually correct and easy to implement in practice.

In Table 6.1, the average geometric deprecation rate by asset type is presented. The depreciation rate (δ) is derived by using the assumption that δ =2/L, where L is the average service lives.

As mentioned above, the ex-post approach to calculate an internal rate of return is chosen in the current Norwegian KLEMS database. The rate of return in each industry can be determined by using (33), and subsequently, this rate is used to calculate the capital service prices as shown in (30) or (31).

Incidentally, the implied rental prices of capital services can be negative. Negative rental prices are not necessarily inconsistent in theory (see e.g. Berndt and Fuss 1986), but can also be an indication of empirical problems in the estimation of labor and capital compensation shares, or in the investment deflators applied.

When compiling the Norwegian KLEMS database, it is found that most negative rental prices are caused by very low, or even negative capital compensation in some industry for some years, which are related to over-adjustment of the labor compensation of the self-employed, e.g. in agriculture industry.

Labor compensation of the self-employed is not registered in the NNA. Thus an imputation has to be made by assuming that the compensation per hour of self-

Table 6.1 Geometric depreciation rate by asset type

Asset type	Depreciation rate up to 2003	Depreciation rate after 2003
008100 (Residential building)	0.03	0.025
008108 (Residential building, own account investment)	0.02	0.025
008180 (Transaction cost for used residential building)	0.2	0.2
008190 (Transaction cost for land)	0.02	0.2

008200 (Commercial building)	0.033	0.04
008208 (Commercial building, own account investment)	0.04	0.04
008290 (Transaction cost for commercial building)	0.2	0.2
008300 (Land improvement)	0.0456	0.05
008308 (Land improvement, own account investment)	0.0443	0.05
008310 (Railway, including suburban railway and bridges)	0.0369	0.04
008320 (Electricity transmission lines)	0.055	0.06
008328 (Electricity transmission lines, own account investment)	0.041	0.06
008330 (Electricity production equipment)	0.0266	0.03
008338 (Electricity production equipment, own account investment)	0.0266	0.03
008340 (Road and street)	0.0333	0.035
008348 (Road and street, own account investment)	0.0329	0.035
008350 (Other equipment)	0.0343	0.08
008358 (Other equipment, own account investment)	0.0288	0.08
008370 (Shaft for oil and gas extraction)	0.0954	0.08
008378 (Shaft for oil and gas extraction, own account investment)	0.0953	0.08
008380 (Oil platform, rig, and module)	0.0981	0.08
008388 (Oil platform, rig, and module, own account investment)	0.097	0.08
008389 (Removal cost for oil and gas devices)	1	1
008390 (Oil and gas pipes)	0.0406	0.05
008398 (Oil and gas pipes, own account investment)	0.0406	0.05
008410 (Ship and boat)	0.0967	0.1
008420 (Plane and helicopter)	0.1058	0.1
008430 (Car, station wagon)	0.2045	0.13
008440 (Bus)	0.219	0.2
008450 (Trucks and other pickups)	0.2194	0.2
008460 (Occupational rental car)	0.2157	0.2
008470 (Locomotive, passenger and goods carrier)	0.0551	0.06
008508 (Machine and equipment, own account investment)	0.0617	0.05
008510 (Machine used for agriculture and forestry)	0.1351	0.15
008520 (Machine and equipment for quarrying and industry)	0.1173	0.15
008530 (Machine and equipment for electricity and gas works)	0.0476	0.05
008540 (Machine and equipment for construction activities)	0.1972	0.2
008550 (Machine and equipment for other industries)	0.1451	0.2
008560 (Office and computing equipment)	0.4921	0.45
008570 (Communications equipment)	0.1322	0.2
008590 (Weaponry)	0.1	0.1
008710 (Exploration for oil, gas and mineral)	0.1117	0.1
008718 (Exploration for oil, gas and mineral, own account investment)	0.1118	0.1
008720 (Research and development)	0.2	0.2
008728 (Research and development, own account investment)	0.2	0.2
008740 (Software and database)	0.5	0.5
008748 (Software and database, own account investment)	0.5	0.5
008760 (Literary and artistic originals)	0.5	0.5
008768 (Literary and artistic originals, own account investment)	0.5	0.5
008790 (Other fixed, intangible assets)	0.5	0.5
008990 (Antiques, art objects, and other valuables)	0.0001	0.0001

Source: The Norwegian National Accounts Database, Statistics Norway

employed is equal to that of employees (see Section 5.2). This assumption is made at the industry level and can be crude for some industries if earnings of self-employed and employees vary widely. As a result, labor compensation is sometimes higher than value added, so that capital compensation, which is defined as the residual, becomes negative.

Negative rental prices of capital services breakdown the aggregation framework and therefore need to be dealt with accordingly. In the Norwegian KLEMS database, as in the EU KLEMS database, the rental price is forced to be non-negative, i.e. setting it to zero in case where it is negative. Then the calculated total capital services in an industry are treated as total capital compensation, and the original total labor compensation is accordingly adjusted in this industry.
Ideally taxes should be included to account for differences in tax treatment of the different asset types and different legal forms (e.g. household, corporate and non-corporate). The capital service price formulas as outlined above should then be adjusted to take these tax rates into account (see Jorgenson and Yun, 1991).

However this refinement would require detailed data on capital tax allowances and rates by industry and year, which is beyond the scope of this database. However, available evidence for major European countries shows that the inclusion of tax rates has only a very minor effect on growth rates of capital services and MFP (Erumban, 2008).

6.3. Some results

Using the industry KNR2310 (manufacturing of food products, beverages and tobacco) as an example, the calculation results of capital services growth are presented in Table 6.2.

Table 6.2 Capital services growth for industry KNR2310 (manufacturing of food products, beverages and tobacco), 1997-2014

	Average annual growth of capital stock (%)	Share in capital compensation (%)			Contribution to capital services growth (%)
		1997	2014	Average	
ICT	6,0	10,3	7,2	8,7	0,5
R&D	2,9	8,2	9,7	8,9	0,3
Others	1,0	81,6	83,1	82,3	0,9
Total	1,7	100,0	100,0	100,0	1,7

Notes: Contribution of each asset group is calculated as the compensation share weighted sum of the volume growth rate of the stocks. Numbers may not sum exactly due to rounding.
Source: Calculations are based on the Norwegian KLEMS database, July 2017.

The first column in Table 6.2 gives the average annual volume growth rates of the stock of each asset group considered in this document (ICT, R&D and Others) between 1997 and 2014. The estimates indicate that the use of ICT assets has strongly increased (6.0 per cent annually), while the stock of other assets including more traditional capital has increased with much lower growth rate (1.0 per cent annually).

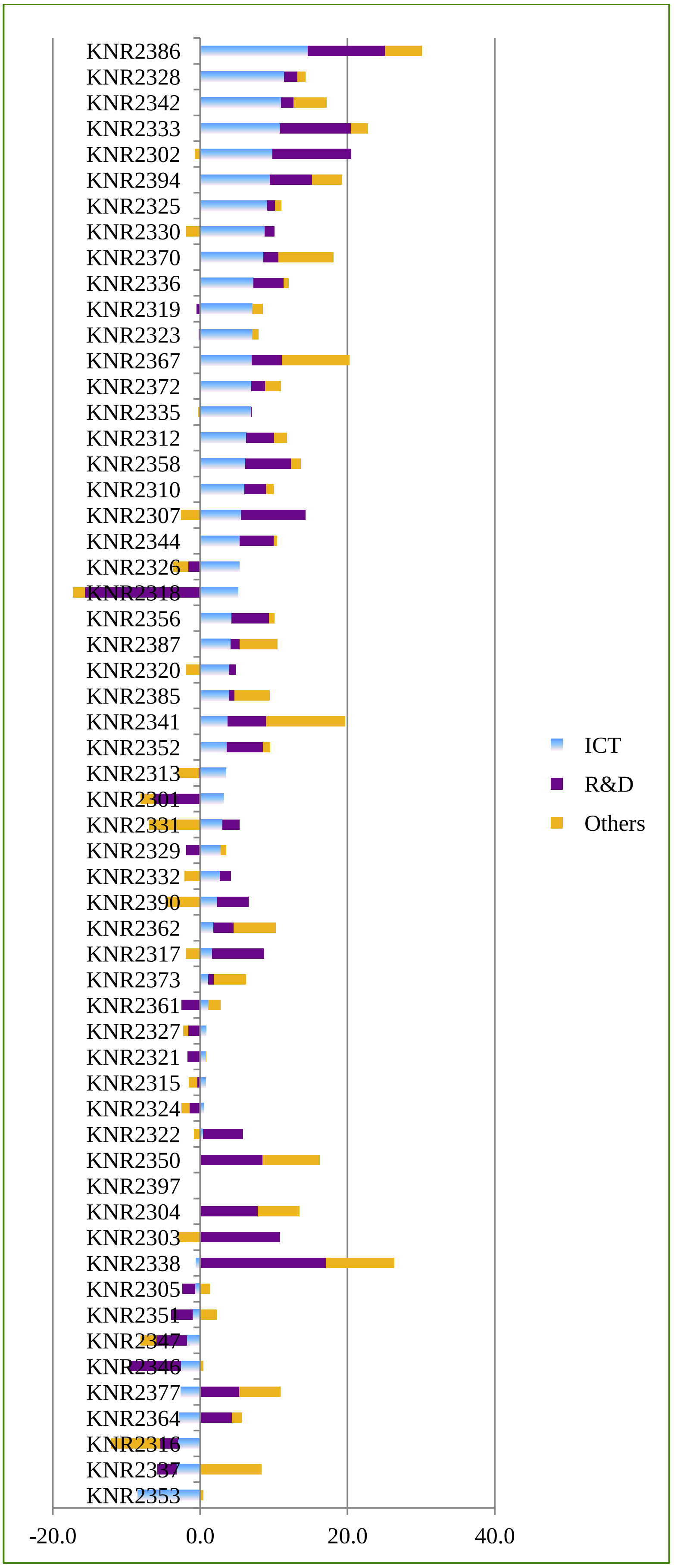
As a result, even if the average share of ICT assets in total capital compensation in this industry is much smaller, compared with that of other assets, the contribution of ICT capital to the growth of total capital services in this industry is more than half than that of other assets.

As for R&D, its annual average growth rate is lower than the simple average among the three capital groups (ICT, R&D and Others). But by multiplying it by its average share in total capital compensation, which is larger than that for ICT capital, the contribution of R&D to the growth of total capital services in this industry becomes roughly equal to that of ICT capital.

The importance of ICT assets in production can be seen in many other industries in the market economy in mainland Norway. Figure 6.1 gives the annual average volume growth rates of capital services by asset group (i.e. ICT, R&D, and Others) and by industry between 1997 and 2014. The total 57 industries are ranked according to their annual average growth rate of ICT capital services.

As shown in Figure 6.1, among the 57 industries, there are 47 industries having non-negative annual growth rate of ICT capital services, 39 industries having non-negative annual growth rate of R&D capital services, and 37 industries having non-negative annual growth rate of other assets capital services over the period 1997-2014.

Figure 6.1 Growth rates of capital services by asset group and industry, 1997-2014 (%)



Notes: Annual compound growth rates.
Source: Calculations are based on the Norwegian KLEMS database, July 2017.

Note that in order to obtain the contribution to the growth of total capital services from the three capital groups (i.e. ICT, R&D and Others) in each industry, the annual growth rate of capital services of the three capital groups as shown in Figure 6.1 has to be multiplied by the respective share of each asset group in total capital compensation in the industry (see Table 6.2).

Likewise, in order to obtain the respective contribution to the growth of total output (either gross output or valued added) by these asset groups, the annual average growth rate of capital services of the three capital groups from Figure 6.1 should be multiplied by the corresponding capital compensation share of each asset group in the value of total output.

7. Labor productivity

7.1. Methodology

Labor productivity is an important indicator which helps to better understand the development of living standards, because income per capita in an economy varies directly with labor productivity, such as value added per hour worked.

Labor productivity is defined as quantity index of output divided by quantity index of labor input. Since two output concepts exist in the Norwegian KLEMS database, i.e. gross output which includes intermediate inputs and value added which does not, there are two types of labor productivity accordingly: the gross output based, and the value added labor productivity.

The gross output based labor productivity for industry *j* is defined as $y_j = \frac{Y_j}{H_j}$, i.e. gross output volume per hour worked. Inserting equation (24) into (7) and making rearrangement yields:

$$(38) \qquad \Delta \ln y_j = \bar{v}^Y_{X,j} \Delta \ln x_j + \bar{v}^Y_{K,j} \Delta \ln k_j + \bar{v}^Y_{L,j} \Delta \ln LC_j + \Delta \ln A^Y_j,$$

where $x_j = \frac{X_j}{H_j}$, and $k_j = \frac{K_j}{H_j}$ are intermediate input density (intermediate input per hour worked), capital density (capital services input per hour worked), respectively.

Similarly, the value added based labor productivity for industry *j* is defined as $z_j = \frac{Z_j}{H_j}$, i.e. value added output volume per hour worked. Inserting equation (24) into (11) and making rearrangement yields:

$$(39) \qquad \Delta \ln z_j = \bar{v}^Z_{K,j} \Delta \ln k_j + \bar{v}^Z_{L,j} \Delta \ln LC_j + \Delta \ln A^Z_j.$$

By inserting equation (20) and (34) into (38), we obtain a growth decomposition of gross output-based labor productivity into its various components:

$$(40) \qquad \Delta \ln y_j = \bar{v}^Y_{E,j} \Delta \ln x^E_j + \bar{v}^Y_{M,j} \Delta \ln x^M_j + \bar{v}^Y_{S,j} \Delta \ln x^S_j + \bar{v}^Y_{IT,j} \Delta \ln k^{IT}_j + \bar{v}^Y_{RD,j} \Delta \ln k^{RD}_j + \bar{v}^Y_{OA,j} \Delta \ln k^{OA}_j + \bar{v}^Y_{L,j} \Delta \ln LC_j + \Delta \ln A^Y_j,$$

where $x^E_j = \frac{X^E_j}{H_j}$, $x^M_j = \frac{X^M_j}{H_j}$, $x^S_j = \frac{X^S_j}{H_j}$, $k^{IT}_j = \frac{K^{IT}_j}{H_j}$, $k^{RD}_j = \frac{K^{RD}_j}{H_j}$, and $k^{OA}_j = \frac{K^{OA}_j}{H_j}$ are volume per hour of Energy (E), Material (M), Services (S), ICT, R&D, and other capitals, respectively.

The right hand side of (40) shows the contribution to labor productivity growth from various factors. The first factor is the contribution of intermediate inputs deepening, which reflects the impact of more intermediate–intensive production on labor productivity. The total contribution from intermediate inputs deepening can be further decomposed into the deepening of three disaggregate intermediate inputs, namely, Energy (E), Material (M), and Services (S).

The second contribution factor is that of capital deepening where more or better capital makes labor more productive. This can be further decomposed into the ICT, R&D, and other capital deepening, respectively.

The third contribution factor to labor productivity growth is from changes of labor composition, e.g. an increase in the share of workers in labor force with relatively high wages and marginal products will raise average labor productivity for the industry. The last contribution factor is MFP growth, which contributes to labor productivity point-for-point.

Finally, inserting (20) and (34) into (39) leads to a similar growth decomposition of value added labor productivity into its various components:

(41) $$\Delta \ln z_j = \bar{v}^Z_{IT,j}\Delta \ln k^{IT}_j + \bar{v}^Z_{RD,j}\Delta \ln k^{RD}_j + \bar{v}^Z_{OA,j}\Delta \ln k^{OA}_j + \bar{v}^Z_{L,j}\Delta \ln LC_j + \Delta \ln A^Z_j .$$

Labor productivity is a partial productivity measure. As clearly shown in (40) and (41), it reflects the joint influence of a host of factors, such as the combined effects of changes in capital inputs, intermediate inputs and overall productivity. Thus it is easily misinterpreted as technical change or as the productivity of the individuals in the labor force.

In comparison with gross output based labor productivity, the growth rate of value added based labor productivity is less dependent on any change in the substitution between intermediate inputs and labor, or the degree of vertical integration. For example, when outsourcing takes place and labor is replaced by intermediate inputs, gross output based labor productivity rises as a consequence of outsourcing; while value added based labor productivity tends to be less sensitive, because outsourcing leads to a fall in both value added and labor input.

7.2. Some results

In Table 7.1, a decomposition of gross output based labor productivity growth into intermediate input and capital deepening, changes of labor composition, and MFP growth is presented. This is for industry KNR2310 (manufacturing of food products, beverages and tobacco) over the period 1997-2014. Note that the intermediate inputs are further decomposed into Energy (E), Materials (M), and Services (S), and capital into ICT, R&D, and Others. All calculations are based on (40).

Table 7.1 Labor productivity growth (gross output based) for industry KNR2310 (manufacturing of food products, beverages and tobacco), 1997-2014

	Average share in gross output (%)	Growth rate of volume per hour (%)	Contribution to growth rate in gross output per hour (%)
Gross output	100.0	1.4	1.4
Intermediate inputs	80.0	0.6	0.5
Energy	0.6	-0.2	0.0
Materials	59.8	0.7	0.4
Services	19.6	-0.4	-0.1
Labor input	15.2		
Hours worked	15.2		
Labor composition	15.2	-0.1	0.0

Capital input	4.8	2.0	0.1
ICT	0.4	6.4	0.0
R&D	0.4	3.2	0.0
Others	3.9	1.4	0.1
MFP (gross output based)		0.9	0.9

Notes: Contribution of inputs is calculated as the share of input times the volume growth rate. Shares are averaged over 1997 and 2014. Volume growth rates are annual compound growth rates over the period 1997-2014. Numbers may not sum exactly due to rounding.

Source: Calculations are based on the Norwegian KLEMS database, July 2017.

Recall Table 3.1 which shows how MFP growth is calculated for the same industry (KNR2310). Since hours worked in this industry contracted over the period 1997-2014 (at annual growth rate of -0.3 per cent on average), labor productivity growth can be calculated as: volume growth rate of gross output (1.4 per cent) – growth rate of hours worked (-0.3 per cent) = 1.4 per cent.

Table 7.2 presents a similar decomposition of value added based labor productivity growth for the same industry (KNR2310), by using (41).

Table 7.2 Labor productivity growth (value added based) for industry KNR2310 (manufacturing of food products, beverages and tobacco), 1997-2014

	Average share in gross output (%)	Growth rate of volume per hour (%)	Contribution to growth rate in value added per hour (%)
Valued added	100.0	4.7	4.7
Labor input	76.5		
Hours worked	76.5		
Labor composition	76.5	-0.1	-0.1
Capital input	23.5	2.0	0.5
ICT	2.1	6.4	0.1
R&D	2.1	3.2	0.1
Others	19.3	1.4	0.3
MFP (value added based)		4.3	4.3

Notes and Source: See Table 7.1.

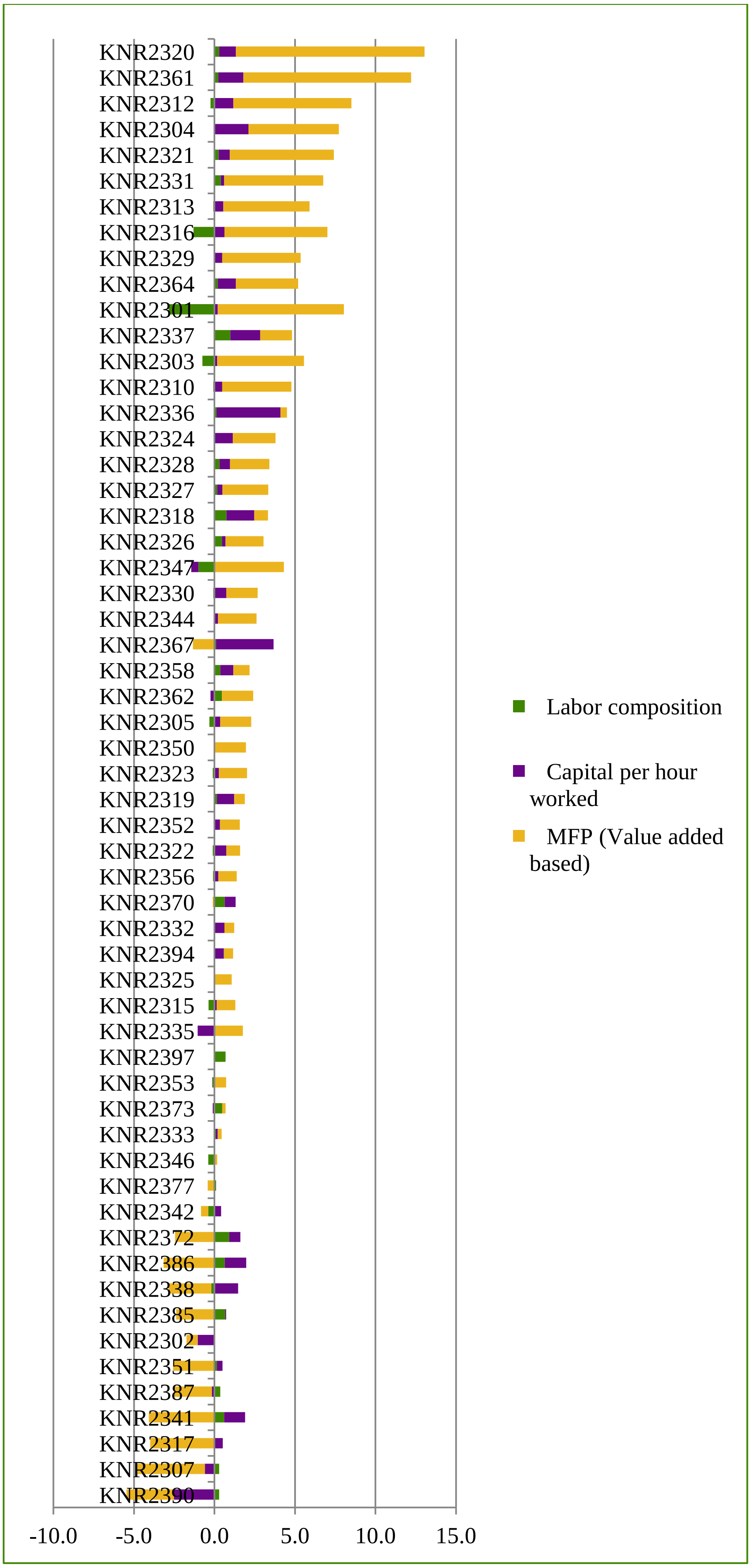
Basically, the main messages drawn from Table 7.1 and Table 7.2 are similar as those from Table 3.1 and Table 3.2 in Section 3, respectively.

In Figure 7.1 we provide a decomposition of labor productivity growth (value added per hour worked) in the 57 industries for the market economy in the mainland Norway over the period 1997-2014.

Based on (41) the growth in value added per hour worked is divided into the contribution of growth in labor composition, capital services per hour worked, and the change in productivity of these inputs as measured by the growth in MFP.

Industries are ranked from highest to lowest growth rate in labor productivity. Of the total 57 industries, 43 industries have positive labor productivity growth. The industries with highest (all higher than 5 per cent annually) growth rate, ranked from highest growth rate down, are: KNR2320 (Chemical products), KNR2361 (Telecommunication), KNR2312 (Fish farming), KNR2304 (Aquaculture),

Figure 7.1 Growth rates of labor productivity (value added based) by industry, 1997-2014 (%)



Notes: Annual compound growth rates.
Source: Calculations are based on the Norwegian KLEMS database, July 2017.

KNR2321 (Production of pharmaceutical products), KNR2331 (Building of oil platforms and modules), KNR2313 (Textiles, wearing apparel, leather), KNR2316

(Wood processing), KNR2329 (Production of transport equipment), KNR2364 (Financial services), and KNR2301 (Agriculture, Hunting). Except for KNR2364 which is a service industry, all are from either Manufacturing or Other goods production sector.

There are 14 industries having negative labor productivity growth over the observed period, among which, only 4 (KNR2317: Graphic production; KNR2341: Building development; KNR2302: Forestry; and KNR2342: Construction) are from Manufacturing or Other goods production sector, the rest 10 industries all belong to services sector. It might reflect that services sectors are usually labor-intensive and its development might need more and more labor input, if compared with Manufacturing or Other goods production sectors.

Growth in the use of inputs (capital services and labor composition) typically contributed no more than 2 percentage points to growth in labor productivity. Also for industries that have negative labor productivity growth, most of them still increased the use of inputs (capital services and labor composition).

Based on data from Figure 7.1, it has been found that the correlation between the annual growth of labor productivity and the MFP growth is quite high, with the sample correlation coefficient being equal 0.94. However, the correlation between the labor productivity growth and the changes of either labor composition or capital intensity is rather low. In other words, differences in growth rates of labor productivity across industries were mainly driven by differences in the growth of MFP over the period 1997-2014.

8. Aggregation and decomposition

8.1. Methodology

Up to now we have outlined the methodologies as regards how to measure the performance of individual industries in terms of their outputs, inputs, and productivity growth. However, for various reasons, interests from the academia, government, or even the public are frequently shown on the performance of aggregate economy and/or sectors.

There are several approaches to obtain measures of aggregate output, inputs and productivity growth, based on exactly the same underlying detailed industry level data and the derived industry-specific indicators of performance. These approaches differ in the restrictiveness of their assumptions made and thus give rise to different estimates of aggregate economic growth and conclusions of the sources of economic growth.

The first approach, most restrictive, is an aggregate production function, the second, less restrictive, is an aggregate production possibility frontier, and the third, least restrictive, is a direct aggregation across industries.[12]

The third approach, i.e. the direct aggregation across industries approach is taken in constructing the Norwegian KLEMS database. Based on this approach, the contribution of each industry to aggregate growth is given by industry growth multiplied by industry shares of value added.

[12] For comprehensive discussion on the three aggregation approaches, please refer to Jorgenson, *et al*. (2005).

Suppose the volume of aggregate value added is denoted as *GDP*, such that the aggregate nominal value of *GDP* is simply the sum over nominal value added in all industries:

(42) $$P^{GDP}GDP = \sum_j P_j^Z \, Z_j,$$

where P^{GDP} is the price index of *GDP*. The volume growth of *GDP* is then defined as a Tornqvist index that is weighted industry value added volume growth as follows:

(43) $$\Delta \ln GDP = \sum_j \bar{v}_{Z,j}^{GDP} \Delta \ln Z_j,$$

where $\bar{v}_{Z,j}^{GDP}$ is the period average share of industry *j* in nominal value of aggregate value added, and

(44) $$v_{Z,j}^{GDP} = \frac{P_j^Z Z_j}{\sum_j P_j^Z Z_j}.$$

Then we define total aggregate hours worked (*H*) as the sum of industry hours worked over all industries: $H = \sum_j H_j$, and the corresponding aggregate labor productivity as $\frac{GDP}{H}$.

Since industry value added based labor productivity is defined as $z_j = \frac{Z_j}{H_j}$, as shown in Stiroh (2002), the aggregate labor productivity growth can be decomposed into industry contributions as follows:

(45) $$\Delta \ln \frac{GDP}{H} = \sum_j \bar{v}_{Z,j}^{GDP} \Delta \ln z_j + \left(\sum_j \bar{v}_{Z,j}^{GDP} \Delta \ln H_j - \Delta \ln H\right)$$

$$= \sum_j \bar{v}_{Z,j}^{GDP} \Delta \ln z_j + R.$$

The term in brackets in (45) is the reallocation of hours (*R*) and reflects differences in the share of an industry in aggregate value added and its share in aggregate hours worked. This term will be positive when industries with an above-average labor productivity level show positive employment growth or when industries with below-average labor productivity have declining employment shares.

Based on (45), we define the contribution of industry *j* to overall aggregate labor productivity growth as:

(46) $$CTLP_{LP,j} = \bar{v}_{Z,j}^{GDP} \Delta \ln z_j \, .$$

By inserting (41) into (45), we have

(47) $$\Delta \ln \frac{GDP}{H} = \sum_j \bar{v}_{Z,j}^{GDP} \big(\bar{v}_{IT,j}^{Z} \Delta \ln k_j^{IT} + \bar{v}_{RD,j}^{Z} \Delta \ln k_j^{RD} + \bar{v}_{OA,j}^{Z} \Delta \ln k_j^{OA} +$$
$$vL,jZ\Delta\ln LCj+\Delta\ln AjZ+R \, .$$

In this way, the contribution of various inputs and MFP growth from each industry to aggregate labor productivity growth can be calculated.
We define the contribution of ICT capital deepening in industry *j* to aggregate labor productivity growth as:

(48) $$CTLP_{IT,j} = \bar{v}_{Z,j}^{GDP} * \left(\bar{v}_{IT,j}^{Z} \Delta \ln k_j^{IT}\right) = \bar{v}_{IT,j}^{GDP} \Delta \ln k_j^{IT},$$

which is the growth of ICT capital per hour worked in industry *j* weighted by the share of ICT capital compensation in industry *j* in aggregate nominal value added ($\bar{v}^{GDP}_{IT,j}$). The weight itself is the product of the share of industry *j* in aggregate value added ($\bar{v}^{GDP}_{Z,j}$) and the share of ICT capital compensation in industry *j*'s value added ($\bar{v}^{Z}_{IT,j}$).

Similarly, we define the contribution to aggregate labor productivity growth from R&D, and Other assets deepening in industry *j* respectively as:

(49) $$CTLP_{RD,j} = \bar{v}^{GDP}_{Z,j} * \left(\bar{v}^{Z}_{RD,j} \Delta \ln k^{RD}_{j}\right) = \bar{v}^{GDP}_{RD,j} \Delta \ln k^{RD}_{j},$$

(50) $$CTLP_{OA,j} = \bar{v}^{GDP}_{Z,j} * \left(\bar{v}^{Z}_{OA,j} \Delta \ln k^{OA}_{j}\right) = \bar{v}^{GDP}_{OA,j} \Delta \ln k^{OA}_{j},$$

which are the growth of R&D, and Other assets per hour worked in industry *j* weighted by the respective share of R&D and Other assets compensation in industry *j* in aggregate nominal value added.

Then, the contribution to aggregate labor productivity growth from labor compositional change is defined as:

(51) $$CTLP_{LC,j} = \bar{v}^{GDP}_{Z,j} * \left(\bar{v}^{Z}_{L,j} \Delta \ln LC_{j}\right) = \bar{v}^{GDP}_{L,j} \Delta \ln LC_{j},$$

which is the growth of labor services per hour worked in industry *j* weighted by the share of labor compensation in industry *j* in aggregate nominal value added ($\bar{v}^{GDP}_{L,j}$). Again, the weight is the product of the share of industry *j* in aggregate value added ($\bar{v}^{GDP}_{Z,j}$) and the share of labor compensation in industry *j*'s value added ($\bar{v}^{Z}_{L,j}$).

Finally, the contribution to aggregate labor productivity growth from industry *j*'s MFP growth is defined as:

(52) $$CTLP_{MFP,j} = \bar{v}^{GDP}_{Z,j} \Delta \ln A^{Z}_{j},$$

which is the growth of MFP in industry *j* weighted by the share of industry *j* in aggregate value added.

8.2. Some results

In Table 8.1, the decomposition of aggregate labor productivity growth is given for the market economy in mainland Norway by following the methodology discussed above. In addition, the growth accounting results for major sectors that constitute the aggregate market economy are also presented. There are three panels in Table 8.1, representing the decomposition results for the entire observed period 1997-2014 (upper panel), and for the two sub-periods, i.e. 1997-2005 (middle panel) and 2005-2014 (lower panel), respectively.

The first column of Table 8.1, which is the sum of the second and third columns, indicates the growth of aggregate value added volume, i.e. *GDP* for the aggregate market economy, and sector valued added for major sectors. The second column gives the growth of hours worked, and the third the aggregate labor productivity growth. The other columns (from the fourth to the rightmost) provide detailed decomposition results of aggregate labor productivity into its various components by following (47).

Table 8.1 Growth accounting for aggregate market economy and sectors (%)

	Growth rate of	Value added contribution from	Labor productivity contribution from

	value added	Hours worked	Labor productivity	Labor composition	ICT per hour	R&D per hour	Other assets per hour	MFP	Real location
	1= 2+3	2	3=4+5+6+7 +8	4	5	6	7	8	
1997-2014									
Market economy	3.1	0.9	2.2	0.0	0.2	0.0	0.4	1.4	0.2
ICT production	5.3	0.4	4.9	0.3	0.4	-0.1	0.2	4.1	
Manufacturing	2.3	-0.9	3.3	0.0	0.2	0.1	0.4	2.6	
Other goods	1.5	0.5	1.0	-0.4	0.1	0.0	0.1	1.2	
Distribution	2.6	0.4	2.3	-0.1	0.1	0.0	0.1	2.2	
Finance & Business	4.6	2.9	1.6	0.3	0.1	0.1	0.8	0.3	
Personal	1.2	2.1	-0.9	0.2	0.1	0.0	0.2	-1.5	
1997-2005									
Market economy	3.3	0.2	3.2	0.2	0.4	0.0	0.7	1.7	0.2
ICT production	5.1	-0.2	5.3	0.2	0.9	-0.1	0.3	4.1	
Manufacturing	0.7	-1.8	2.5	0.2	0.5	0.0	0.6	1.2	
Other goods	1.9	-0.4	2.4	-0.1	0.2	0.0	0.7	1.6	
Distribution	4.0	0.3	3.7	0.2	0.4	0.0	0.2	2.8	
Finance & Business	5.5	2.4	3.1	0.2	0.2	0.0	1.4	1.5	
Personal	0.3	0.7	-0.4	0.2	0.4	0.0	0.7	-1.7	
2005-2014									
Market economy	2.8	1.5	1.3	-0.1	0.0	0.1	0.1	1.1	0.2
ICT production	5.3	0.9	4.4	0.4	-0.1	0.0	0.1	4.0	
Manufacturing	3.7	-0.1	4.2	-0.2	-0.1	0.1	0.2	4.1	
Other goods	1.1	1.3	-0.1	-0.7	0.1	0.0	-0.3	0.8	
Distribution	1.4	0.5	0.9	-0.4	-0.2	0.0	0.0	1.5	
Finance & Business	3.7	3.3	0.4	0.4	0.0	0.1	0.5	-0.6	
Personal	1.8	3.3	-1.5	0.3	-0.1	0.0	-0.3	-1.4	

Notes: Numbers may not sum exactly due to rounding.
Source: Calculations are based on the Norwegian KLEMS database, July 2017.

The rightmost column shows the reallocation effect as defined in (45). The results indicate that for the period as a whole (1997-2014), and for the two sub-periods (1997-2005, and 2005-2014) as well, the reallocation of labor between industries had a positive impact (0.2 per cent per year on average) on aggregate labor productivity growth as hours worked were reallocated to industries with higher levels of labor productivity, primarily to Finance and business sector (such as KNR2307 (Service activities incidental to oil and gas), and KNR2377 (Leasing, travel and other business services)), and Personal services sector (such as KNR2387 (Social welfare services), and KNR2390 (Cultural/sports/leisure activities)).

Results in Table 8.1 also indicate that labor productivity growth for the market economy as a whole had declined from the first sub-period (1997-2005) to the second (2005-2014) (from 3.2 to 1.3 per cent per year on average). This is also true for most of the major sectors as shown in Table 8.1, except for the Manufacturing sector whose labor productivity had actually increased over the period, from 2.5 to 4.2 per cent per year on average.

In terms of the contribution to aggregate labor productivity growth, changes of labor composition contributed very little (almost 0 per cent) for the entire market economy over the whole period 1997-2014, while from the first sub-period (1997-2005) to the second (2005-2014), this contribution had declined (from 0.2 to - 0.1 percent per year on average).
For the major sectors as listed in Table 8.1 and over the two sub-periods, the contribution from changes of labor composition had also declined for the Manufacturing, Other goods production and Distribution sectors, while had

increased for the other three sectors: i.e. ICT production, Finance and Business services, and Personal services.

Concerning the contribution to aggregate labor productivity growth from capital deepening, measured by the growth of capital services per hour worked, Table 8.1 shows that for both the entire market economy and all the major sectors over the two sub-periods, the contribution by R&D per hour was non-decreasing, while that from either ICT capita per hour or Other assets per hour had declined.

When considering the contribution to aggregate labor productivity growth from MFP growth, which is point-for-point, it is found that the change pattern of MFP growth for the entire market economy and the major sectors over the two sub-periods is almost the same as that for the aggregate labor productivity growth. The only exception is that MFP growth for the Personal services sector had increased (from -1.7 to -1.4 per cent), while its labor productivity growth had declined (from -0.4 to -1.5 per cent) over the two sub-periods.

Overall, it is clear that aggregate labor productivity growth was mainly driven by MFP growth, which is consistent with the findings that are drawn from observations on individual industries (see Section 7).

From the perspective of the so-called knowledge economy, attention might be directed towards the summed contributions of four factors as shown in Table 8.1: changes in labor composition (Column 4), mostly driven by greater demand for skilled (higher productivity) workers; direct impact from investments in ICT (Column 5); and that from R&D investments (Column 6); as well as MFP growth (Column 8).[13]

As shown in Table 8.1, the combined contribution of these four factors to aggregated labor productivity growth accounted for 73 per cent (1.6/2.2) of aggregate labor productivity growth over the whole observed period 1997-2014. For the sub-period 1997-2005, and 2005-2014, the combined contributions accounted for 72 and 85 per cent, respectively.

The importance of an industry or sector in explaining differences in aggregate labor productivity growth does not only depend on its productivity growth rate, but also on its value share in aggregate valued added. By following (46), the contribution of each major sector to aggregate labor productivity growth is measured and the results are presented in Table 8.2.

The results are given for six broad sectors that make up the total market economy in mainland Norway. Based on the average share in value added and the sector growth in labor productivity, the contribution of each sector to aggregate labor productivity growth is derived and shown in the lowest section of Table 8.2.

For instance, over the period 1997-2014, the contribution to aggregate labor productivity growth by the sector of Finance and Business services is 0.5 percentage points, which is among the highest compared to those from other sectors. However, this is not because growth in this sector is particularly high. In fact, the labor productivity growth of this sector is just 1.7 per cent per year, which is lower than average, but due to its large share of value added in the market economy (28.2 per cent), its contribution is substantially high.

Table 8.2 Sector contributions to aggregate labor productivity

	1997-2014	1997-2005	2005-2014

[13] Note that the MFP growth might include the impact of intangible investments such as organizational changes related to the use of ICT and R&D activities.

Average share in aggregate value added (%)			
ICT production	7.5	8.1	7.1
Manufacturing	16.0	17.8	14.5
Other goods	17.3	16.6	18.0
Distribution	22.2	23.4	21.2
Finance & Business	28.2	25.2	31.0
Personal	8.7	9.0	8.4
Market economy	100.0	100.0	100.0
Growth in labor productivity (%)			
ICT production	4.8	5.3	4.3
Manufacturing	3.2	2.5	3.8
Other goods	1.0	2.4	-0.2
Distribution	2.2	3.7	0.9
Finance & Business	1.7	3.1	0.4
Personal	-1.0	-0.4	-1.5
Market economy			
Contribution to market economy labor productivity growth (%)			
ICT production	0.4	0.4	0.3
Manufacturing	0.5	0.4	0.6
Other goods	0.2	0.4	0.0
Distribution	0.5	0.9	0.2
Finance & Business	0.5	0.8	0.1
Personal	-0.1	0.0	-0.1
Reallocation effect	0.2	0.2	0.2
Market economy	2.2	3.2	1.3

Notes: Numbers may not sum exactly due to rounding.
Source: Calculations are based on the Norwegian KLEMS database, July 2017.

On the other hand, labor productivity growth in ICT production sector is much higher (4.8 per cent per year on average), but as its share in value added is only small (7.5 per cent), its contribution to aggregate labor productivity growth is only 0.4 per cent.

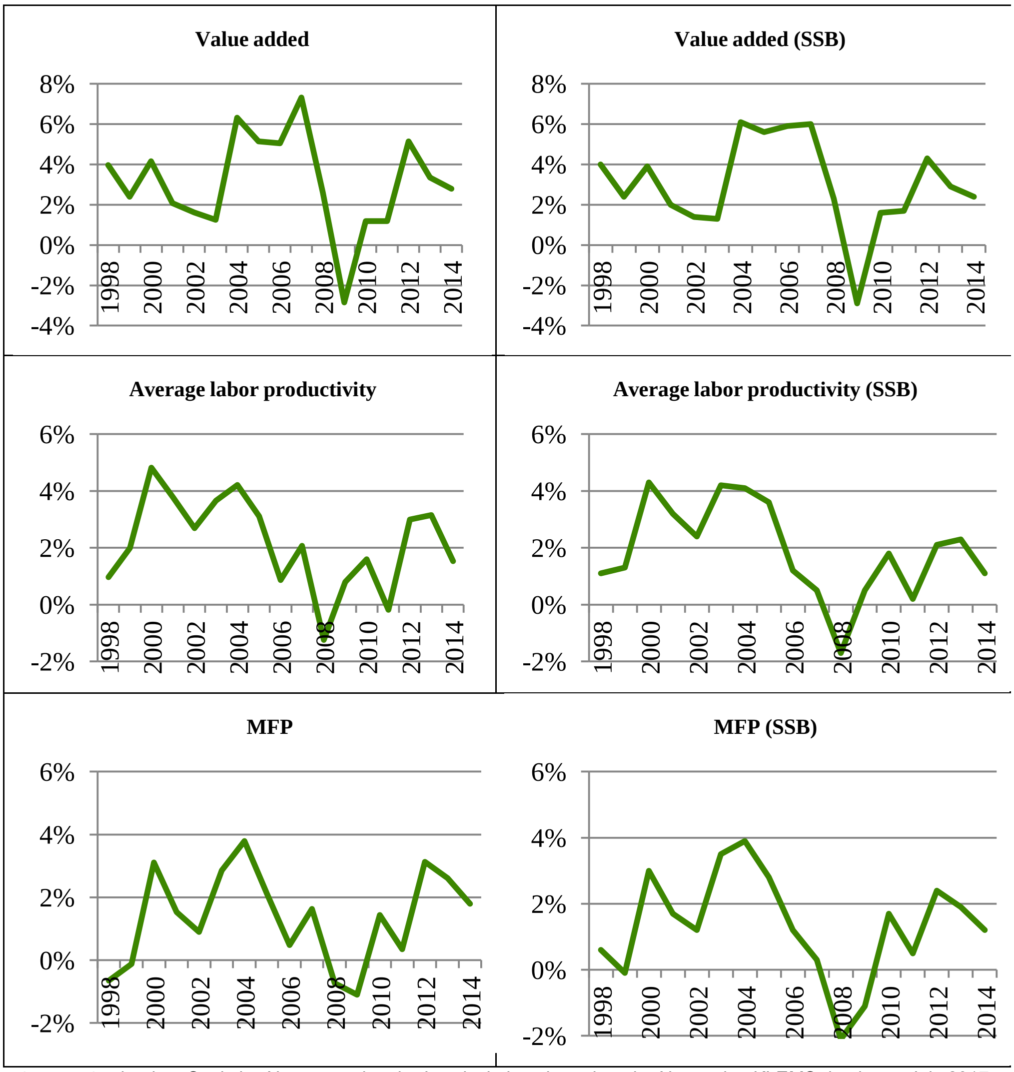
Besides the contribution to aggregate labor productivity growth by industry/sector labor productivity growth, the contribution by various capital deepening, changes of labor composition, as well as MFP growth can be analyzed by following the methodologies as shown in (48) – (52), so that aggregate labor productivity growth can be traced to the individual industry origins as the sources of economic growth.

Finally, it is interesting to compare the aggregate results drawn from the KLEMS database with those from the current practices at Statistics Norway, because the former is based on the direct aggregation across industries approach (with less restrictive assumptions), and the latter is based on an aggregate production function approach (with highly restrictive assumptions), while both of them use the same datasets as inputs.

For the whole market economy at mainland Norway, Figure 8.1 presents a comparison of the aggregated annual growth rate of value added, average labor productivity and (value added based) multi-factor productivity (MFP) based on the two different aggregation approaches. Figures in the left panels are from the KLEMS database, while those in the right panels (indicated with SSB) are drawn from the current practices at Statistics Norway.

In general, the annual estimates (and the reflected trend over time) of the aggregate growth based on the two different aggregation approaches are rather similar. The general similarity between the results somehow provides evidence in favor of the current practices at Statistics Norway. In other words, the restrictive assumptions or hypotheses (e.g. all industry value added functions are identical) taken by the aggregate production function approach are not rejected in a significant way.

Figure 8.1 Comparison of aggregate results (growth rate in percentage)



Source: Statbank at Statistics Norway and author's calculations based on the Norwegian KLEMS database, July 2017

However, other research has found that analyses by using the aggregate production function approach may be suitable for long-term growth, while for shorter periods, this approach can be seriously misleading (see e.g. Jorgenson, 1990). Looking at Figure 8.1, it is easy to find that there are some differences of estimated results in some years, for example, in 2004, 2007, discrepancies are substantial.

Moreover, despite the similar aggregate results based on the two different approaches, there is no guarantee that disaggregated industry level estimates are also similar. Thus, given that the direct aggregation across industries approach is a bottom-up approach with less restrictive assumptions being made, this approach should be taken as the favorite one for analyses based on the Norwegian KLEMS database, in particular, when undertaking analyses at the disaggregated industry level.

9. Conclusions

This paper documents both the theoretical methodologies and the practical compilation procedures as regards the construction of the Norwegian KLEMS database over the period 1997-2014, based mainly on official statistics including annual Norwegian national accounts data. The database consists of five accounts (i.e. output and intermediate input, labor, capital, and multi-factor and labor productivity accounts) at disaggregated industry level, all being organized within the modern growth accounting framework.

The intermediate inputs are classified into Energy (E), Materials (M) and Services (S), the labor inputs are decomposed into hours worked and changes of labor composition, and the capital inputs are further grouped into ICT (Information and Communication Technology), R&D (Research and Development), and Others (including all other capital assets excluding ICT and R&D). These further classifications make it possible for the decomposition of productivity growth for each industry into various detailed components.

For each account, some results and analyses are presented with the purpose of showing the richness of the whole KLEMS database. For instance, it is found that over the period 1997-2014, 41 out of 57 industries have positive (gross output based) MFP growth, and most of them belong to Manufacturing/Other goods production sectors. On the contrary, most of the industries with negative MFP growth are from services sectors.

In terms of measured gross output volume growth, it is found that the top ten fast-growing industries are mainly from service sectors, while the top ten fast-contracting industries are mainly from Manufacturing and/or Other goods production sectors over the period 1997-2014.

The finding just mentioned above is also valid in terms of estimated labor services input growth for the industries. In other words, over the same period 1997-2014, the fast-growing industries are mainly from services sectors, while the fast-contracting industries are largely from Manufacturing and Other goods production sectors.

Based on the analysis results, it is confirmed that over the period 1997-2014, the aggregate labor productivity growth for the whole market economy at mainland Norway, as well as for the main sectors, was principally driven by MFP growth, which is also consistent with the findings that are drawn from observations on individual industries.

Over the two observed sub-periods (from 1997-2005 to 2005-2014), the growth of value added for the total market economy at mainland Norway decreased despite an increase in total hours worked, leading to a slow-down of the aggregate labor productivity growth.

Further decomposition analysis demonstrates that all components that contribute to the aggregate labor productivity growth decreased over the two sub-periods, some even changed their contributions from positive to negative ones (such as labor composition, ICT intensity). The only exception is R&D intensity component, which slightly increased its contribution over the two sub-periods.

By comparing aggregate results from the Norwegian KLEMS database with those from the current practices at Statistics Norway, it is found that the displayed growth trend over time of aggregate value added, labor productivity, and (value added based) MFP is rather similar, offering supportive evidence for the application of an aggregate production function approach as currently taken at Statistics Norway.

However, for analysis staring from disaggregated industry level, a bottom-up approach with less restrictive assumptions being made, such as the direct aggregation across industries approach as now taken by the Norwegian KLEMS database, is arguably more favorable.

With the Norwegian KLEMS database ready, more research can be undertaken, not only for productivity analysis, but also for empirical and theoretical studies in many other areas, such as in skill creation, capital development, technological progress, R&D activities, as well as in economic growth more generally.

References

Amdal, N. and I. Sagelvmo (2017), 'Grouping standard for products in the Norwegian National Accounts', unpublished document, Statistics Norway.

Baldwin, J. R. and W. Gu (2007), 'Multi-Factor Productivity in Canada: An Evaluation of Alternative Methods of Estimating Capital Services', *Canadian Productivity Review*, 9, pp.1-53.

Barth, N., A. Cappelen, T. Skjerpen, S. Todsen, and T. Åbyholm (2016), 'Expected service lives and depreciation profiles for capital assets: Evidence based on a survey of Norwegian firms', *Journal of Economic and Social Measurement* 41 (2016), 329–369.

Basu, S., J. G. Fernald and M. D. Shapiro (2001), 'Productivity Growth in the 1990s: Technology, Utilization, or Adjustment? ' Carnegie-Rochester Conference Series on Public Policy, 55, 117-166.

Baumol, W. J. (1967), 'Macroeconomics of Unbalanced Growth: The Anatomy of Urban Crisis', *American Economic Review*, 57(3), pp.415-26.

Berndt, E. R. and M. A. Fuss (1986), 'Productivity Measurement with Adjustments for Variations in Capacity Utilization and Other Forms of Temporary Equilibrium', *Journal of Econometrics*, 33, 7-29.

Bruno, M. (1984), 'Raw Materials, Profits, and the Productivity Slowdown', *The Quarterly Journal of Economics*, Vol. 99, No. 1 (Feb., 1984), pp. 1-30

Caves, D. W., L. R. Christensen and W. E. Diewert (1982), 'The Economic Theory of Index Numbers and the Measurement of Input, Output, and Productivity', *Econometrica*, 50(6), pp. 1392-414.

Diewert, W. E. (1976), 'Exact and Superlative Index Numbers', *Journal of Econometrics*, 4, pp. 114-45.

Erumban, A. A. (2004), 'Twenty Ways to Aggregate Capital: Does it Really Matter for a Study of Economic Growth? ', Paper presented at the 28th general conference of the International Association for Research in Income and Wealth, Cork , Ireland , August 2004.

Erumban, A. A. (2008), 'Rental Prices, Rates of Return, Capital Aggregation and Productivity: Evidence from EU and US', *CESifo Economic Studies*, 54(3), pp. 499-533.

Eurostat (2013), *European System of Accounts 2010.*

Gollop, F. (1979), 'Accounting for Intermediate Input: the Link between Sectoral and Aggregate Measures of Productivity', in *Measurement and Interpretation of Productivity*, National Academy of Sciences, Washington, DC, pp. 318-33.

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

Jorgenson, D. W. (1963), 'Capital Theory and Investment Behavior', *American Economic Review*, 53(2), pp. 247-259.

Jorgenson, D. W. (1990), 'Productivity and Economic Growth', in E. R. Berndt and Triplett eds. *Fifty Years of Economic Measurement,* Studies in Income and Wealth, Volume 54, The University of Chicago Press.

Jorgenson, D. W. and Z. Griliches (1967), 'The Explanation of Productivity Change', *Review of Economic Studies*, 34(3), pp. 249-83.

Jorgenson, D. W. and K.-Y. Yun (1991), *Tax Reform and the Cost of Capital*, Oxford University Press, New York.

Jorgenson, D. W., F. M. Gollop and B. M. Fraumeni (1987), *Productivity and U.S. Economic Growth*, Harvard Economic Studies, Cambridge, MA.

Jorgenson, D. W., M. S. Ho and K. J. Stiroh (2005), *Information Technology and the American Growth Resurgence*, MIT Press, Cambridge, MA.

Kuznets, S. (1971), *Economic Growth of Nations*, Harvard University Press, Cambridge, MA.

Korsnes, K. (2014), 'Quarterly National Accounts – Methods and sources of the quarterly national accounts compilations for Norway December 2013', *Documents*, 2014/2, Statistics Norway.

Liu, G. (2016), 'Including land as a balance sheet item in the Norwegian National Accounts', *Documents*, 2016/01, Statistics Norway.

O'Mahony, M. and M. P. Timmer (2009), 'Output, Input and Productivity Measures at the Industry Level: the EU KLEMS Database', *Economic Journal*, 119(538), pp. F374-F403.

Oulton, N. (2005), 'Ex ante versus ex post measures of the user cost of capital', EUKLEMS working paper Nr. 5, August 2005.

Schreyer, P. (2001), *OECD Productivity Manual: A Guide to the Measurement of Industry-Level and Aggregate Productivity Growth*, Organization for Economic Co-operation and Development, Paris.

Schreyer, P. (2004), 'Measuring Multi-Factor Productivity when Rates of Return are Exogenous', paper prepared for the SSHRC International Conference on Index Number Theory and the Measurement of Prices and Productivity.

Schreyer, P. (2009), *Measuring Capital - OECD Manual*, Second Edition, Organization for Economic Co-operation and Development, Paris,

Sichel, D. E. (1997), 'The Productivity Slowdown: Is a Growing Unmeasurable Sector the Culprit?', *Review of Economics and Statistics*, 79(3), pp.367-70.

Simpson, L. H. and S. Todsen (2012), 'Norwegian Methodology for Supply-Use and Input-Output Tables', Internal Documents, 31/2012, Statistics Norway.

Solow, R.M. (1970), *Growth Theory: An Exposition*, Oxford University Press, New York.

Stiroh, K. J. (2002), 'Information Technology and the US Productivity Revival: What Do the Industry Data Say?', *American Economic Review*, 92(5), pp.1559-76.

Timmer, M. P., R. Inklaar, M. O'Mahony and B. Van Ark (2010), *Economic Growth in Europe – A Comparative Industry Perspective*, Cambridge University Press.

Todsen, S. and K. O. Eikill (2017), 'Sources to changes in inventory in the Norwegian National Accounts', Document 2017/13, Statistics Norway.

Triplett, J. E. and B. P. Bosworth (2004), *Productivity in the U.S. Services Sector: New Sources of Economic Growth*, Brookings Institution, Washington, DC.

United Nations (2009), *System of National Account 2008.*