Statistisk sentralbyrå
Statistics Norway

What can we do with the quality-adjusted labor input data?

An explanation with examples

Gang Liu

TALL SOM FORTELLER
NOTATER / DOCUMENTS
2023/23

In the series Documents, documentation, method descriptions, model descriptions and standards are published.

Published: 26 May 2023

ISBN 978-82-587-1741-3 (electronic)
ISSN 2535-7271 (electronic)

Symbols in tables	Symbol
Category not applicable Figures do not exist at this time, because the category was not in use when the figures were collected.	.
Not available Figures have not been entered into our databases or are too unreliable to be published.	..
Confidential Figures are not published to avoid identifying persons or companies.	:
Decimal punctuation mark	.

Preface

This document is a follow-up work after a Eurostat Grant project (EU project 2019/NO/IGA - DLV-874652) for improving productivity accounts at Statistics Norway was completed in December 2020. The document has demonstrated how the quality-adjusted labor input data can be applied for economic analysis in general, and for growth accounting practice in particular.

The author wants to thank Kristian Gimming for his great help by providing the quality-adjusted labor input data for the period 2015-2018. Valuable comments from Trude Nygård Evensen and Kristian Gimming are very much appreciated.

Statistisk sentralbyrå, 19 May 2023

Lasse Sandberg

Abstract

This document, by using examples, aims to demonstrate how the quality-adjusted labor input data can be applied for economic analysis in general, and for growth accounting in particular. For instance, such data can be used to improve the estimation of multifactor productivity indicators, and to restore the internal consistency of measuring labor productivity across aggregation levels in the Norwegian national accounts. By constructing meaningful indexes based on such data, the growth of labor input and quality over time can be identified and better understood, at both aggregate and industry level. Given the crucial importance of the quality-adjusted labor input data, the document concludes that it is time for Statistics Norway to compile and publish such data together with other official statistics on a more regular basis.

Contents

1. Introduction

Labor input is one of the essential production factors that are used by almost all production activities defined by the System of National Accounts (see United Nations, 2009; Eurostat, 2013).[1] A good measure of labor input is, therefore, of vital importance for economic analysis in general, and for growth accounting in particular, based on national accounts data.

For a period, labor input had been measured by simple headcounts of employed persons. Although still in use somewhere, the measure of labor input by headcounts is bound to mask changes in average hours worked that are caused by many factors including the evolution of part-time work or the effect of variations in overtime, absence from work or shifts in normal hours, etc.

Nowadays it has been recommended internationally that hours actually worked should be the target statistical variable for measuring labor input, while hours paid and full-time equivalent persons can provide reasonable alternatives in this regard. It has also been recognized that quality-adjusted labor input could serve as an even better measure for the purpose of productivity analysis (United Nations, 2009; Eurostat, 2013).

As widely acknowledged, using hours actually worked as labor input assumes implicitly that each hour worked is of the same quality, regardless of the differences in qualifications and skill levels of the labor employed. On the contrary, the quality-adjusted labor input measure takes into account that each hour worked by a highly skilled person will produce more volume (i.e., more quantity and/or higher quality of output) than each hour worked by an unskilled worker.

Hours actually worked are often measured as the aggregate number of total hours worked during the period in employee and self-employment jobs by national statistics institutes.[2] Hours actually worked measured as such have been used for many years for compiling, among others, labor productivity indicators at Statistics Norway. The annual statistics of hours actually worked and the corresponding labor productivity by industry are published in Table 09174 (*Wages and salaries, employment and productivity, by industry*) in the Statbank, an online databank at Statistics Norway.[3]

On the other hand, quality-adjusted labor input data was constructed only occasionally at Statistics Norway, for example, one was compiled for the period 2008-2014. In addition, as a one-time product, the 2008-2014 quality-adjusted labor input data has not been updated due to limited resources. Fortunately, in connection with a Eurostat Grant project (EU project 2019/NO/IGA - DLV-874652) for improving productivity accounts at Statistics Norway, a new quality-adjusted labor input dataset for the period 2015-2018 was recently assembled.

Different from the previous vintage of the 2008-2014 dataset, the new dataset has widely exploited a new data source, namely, a novel data reporting system that has been introduced in Norway since 2015, offering, among others, a resumed opportunity for compiling high quality labor statistics, including the quality-adjusted labor input data that are internally in consistent with the Norwegian national accounts.

Constructing the quality-adjusted labor input statistics is very data- and resource-demanding. For example, as a minimum, time series of hours actually worked, broken down by different quality indicators have to be available, alongside the corresponding statistics for average compensation,

[1] One well-known exception is the provision of owner-occupied housing services where only housing services are compensated as the sole production factor.
[2] Although conceptually clear, different national statistics institutes have different practices for measuring hours worked, which may raise the issue of international comparability (see e.g., Ahmad *et al*., 2003; Ward *et al*., 2018).
[3] See https://www.ssb.no/statbank/table/09174/.

also by the same indicators. Measurement problems are compounded if further breakdown by industry is sought. However, the quality-adjusted labor input data can have a wide application.

The purpose of this paper is to showcase the application of quality-adjusted labor input data by using as examples the two established vintage datasets for two subperiods, i.e., 2008-2014 and 2015-2018. Knowing how quality-adjusted labor input data can be applied will facilitate the decision-making about whether such data should be compiled at all, on a regular basis or just occasionally, and in what frequency (e.g., annual or quarterly data), etc. at Statistics Norway.

The rest of the paper is structured as follows. Section 2 first elaborates on the importance of quality-adjusting labor input for better measurement. How to construct meaningful indexes of labor input and quality at industry level is then introduced, followed by a brief discussion on the newly assembled quality-adjusted labor input dataset for the period 2015-2018. In Section 3, the application of quality-adjusted labor input data is presented for improving the estimation of multifactor productivity growth, and for removing the inconsistency in measuring labor productivity across aggregation levels at Statistics Norway. Some new growth accounting results based on the new 2015-2018 data are also reported in this section. Section 4 and Section 5 demonstrate how quality-adjusted labor input data can be used to offer further insights about the change of labor input and quality at the aggregate and industry level respectively over the period 2008-2018 in the market economy of mainland Norway. Section 6 concludes.

2. Quality-adjusted labor input

2.1. Quality-adjusting labor input

Labor input measure reflecting changes in labor quality due to changes in the composition of labor force has a long history. The concept was pioneered by Denison (1962) and Jorgenson and Griliches (1967). This approach combines hours for workers with different labor quality characteristics (such as sex, age, and educational attainment of the labor force in concern),[4] using the corresponding hourly wage as weights, into a constant quality volume index, in parallel to its price counterpart of constant quality price index, of labor input.[5]

Quality-adjusting labor input into the one with constant quality has later become a standard practice applied for compiling labor input for growth accounting by many internationally leading national statistics institutes, such as Australian Bureau of Statistics, Bureau of Labor Statistics in the US, Statistics Canada, Statistics Netherlands, Office for National Statistics in the UK, Statistics Denmark, Statistics Sweden, and Statistics Finland.[6]

Recently, with the purpose of improving the conventional measure of labor input for comparative analysis, the European Commission launched a QALI (Quality-Adjusted Labor Inputs) project and the results from the project were already published as experimental statistics at Eurostat.[7]

Although 'hours worked' is the 'natural' unit for measuring the quantity of labor input for one particular worker during a period, it is not suitable for measuring heterogenous hours supplied by different workers as labor input. From an economic point of view, hours from different workers are heterogenous rather than homogenous because their marginal products differ.

Workers are hired only until their marginal price (that is, their wages) is equal to the marginal revenue expected to result from their production. As a result, observed wages, for example, indicate that an hour of an experienced worker with advanced education is not the same as an hour from a young and less-educated worker. Thus, hours should be disaggregated by the characteristics of individual workers to generate a constant quality index of labor input that would better account for substitution among different types of labor.

Analogous to the concept of capital services in the neoclassical capital theory (see Jorgenson, 1963; Christensen and Jorgenson, 1969, 1970), labor input can be regarded as labor services that are generated by human capital embodied in the labor force in concern, in parallel to the capital services that are generated by conventional fixed capital. Different from capital services, the unit cost of labor services is observed wages, while that of capital services is often, however, not observable.

Since human capital developed and embodied in the labor force varies across different types of labor, the productivity of various types of labor (such as low- versus high-skilled workers) will thus

[4] The use of 'sex' as one labor quality characteristic for classifying labor input is only to reflect average labor earnings differential between sex, it does not necessarily imply that productivity or 'quality' of women is lower than men. In fact, this earnings differential may only reflect a combination of lower labor force participation, lower employment and lower wages for women than for men, due to historical and institutional settings.

[5] The constant quality price index, or more commonly, the quality-adjusted price index, is a term with which national accountants are more acquainted.

[6] For those interested in detailed information of national quality-adjusted labor input statistics, please go to the official websites of the national statistics institutes.

[7] See https://ec.europa.eu/eurostat/web/experimental-statistics/qali.

differ.[8] This heterogeneity must be taken into account when analyzing the productivity and the actual contribution of labor input to output growth, similarly to that capital services generated by differential capital assets should be treated differently for measuring capital input.

2.2. Indexes of labor input and quality

Suppose that the labor force can be divided into different types by some quality characteristics. These selected labor quality characteristics, such as sex, age, educational attainment, and occupation, etc., are both theoretically reasonable and practically tractable factors that will determine the labor productivity of each labor type.[9]

Assume that the volume of labor input in an industry *j* is a Törnqvist index of the individual labor types in industry *j*:

$$\Delta \ln L_{j,t} = \sum_s \sum_a \sum_e \bar{v}^L_{s,a,e,j,t} \Delta \ln L_{s,a,e,j,t}, \quad (1)$$

where $L_{j,t}$ is the aggregate labor input volume in industry *j* at time *t*, $L_{s,a,e,j,t}$ is the labor input of the labor type with sex '*s*', age '*a*', and educational attainment '*e*' in industry *j* at time *t*.

In this paper, $\Delta x = x_t - x_{t-1}$ denotes the period (e.g., annual) change of variable *x* between *t-1* and *t*, such that $\Delta \ln x$ indicates the logarithmic growth rate of variable *x*.

The value share of each individual labor type in industry *j* (indexed with the subscript '*s*, *a*, *e*, *j*') in the value of total labor compensation in industry *j* at time *t* is defined as:

$$v^L_{s,a,e,j,t} = \frac{P^L_{s,a,e,j,t} L_{s,a,e,j,t}}{\sum_s \sum_a \sum_e P^L_{s,a,e,j,t} L_{s,a,e,j,t}}, \quad (2)$$

where $P^L_{s,a,e,j,t}$ is the price of labor input of type '*s*, *a*, *e*, *j*' in industry *j* at time *t*. Note that the sum of value shares over all labor types within the industry *j* is unity.

The two-period average value share $\bar{v}^L_{s,a,e,j,t}$ is then defined as:

$$\bar{v}^L_{s,a,e,j,t} = (v^L_{s,a,e,j,t} + v^L_{s,a,e,j,t-1})/2 \, . \quad (3)$$

Equation (1) indicates that the growth rate of the labor volume index in industry *j* is a weighted average of the growth rates of the labor input provided by its individual labor types in industry *j*. Diewert (1976) has shown that the constant quality index numbers of labor input as defined by the superlative Törnqvist index form in (1) is exact for a translog function of labor input.[10]

To quantify the impact of substitution among different types of labor input, labor input provided by a specific type of labor at time *t* is assumed to be proportional to hours worked by this type at time *t*:

[8] For more general discussions on how human capital is developed, composed and what kind of benefits, including improved labor productivity, can be generated through human capital investment, please refer to Liu and Fraumeni (2014, 2016).
[9] Practical tractability is an important requirement for choosing labor quality characteristics for empirical measurement work. For instance, one may argue that each individual person is created with unique characteristic and should be treated as such. However, this view is apparently impossible to implement in practice, even if it is philosophically attractive.
[10] 'Superlative' index numbers are those that can be directly derived from functional forms that provide a second-order approximation to an arbitrary, twice differentiable linear homogenous function, covering a wide range of utility, production, distance, cost or revenue functions. A 'superlative' index is called 'exact' if it can be directly derived from a particular functional form. For example, Törnqvist index is exact for the translog flexible functional form, and Fisher index is exact for a quadratic functional form.

(4) $$L_{s,a,e,j,t} = q_{s,a,e,j} H_{s,a,e,j,t} \ ,$$

where the constant of proportionality $q_{s,a,e,j}$ transforms hours worked $H_{s,a,e,j,t}$ into flows of labor services $L_{s,a,e,j,t}$.

The symbol $q_{s,a,e,j}$ is used to denote the fixed quality of hours of a given labor type. It is assumed that labor services for each type of hours worked are the same at all points of time, i.e. $q_{s,a,e,j}$ is not index by *t*. Though debatable, this assumption is also frequently taken for measuring capital input, where each unit of capital, measured in constant quality units, provides the same flow of capital services over time.

Under the assumption given in (4), the labor input index in (1) may be expressed in terms of hours worked:

(5) $$\Delta \ln L_{j,t} = \sum_s \sum_a \sum_e \bar{v}^L_{s,a,e,j,t} \Delta \ln H_{s,a,e,j,t},$$

where the term $\Delta \ln H_{s,a,e,j,t}$ indicates the growth of hours actually worked by labor type '*s*, *a*, *e*, *j*' in industry *j* over the two-period *t* and *t*-1.

As workers are assumedly paid their marginal productivities, the weighting procedure as shown in (5) ensures that an individual labor type which has a higher price also has a larger influence in the labor 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.

Given the volume of labor input index by (5), the corresponding constant quality price index of labor input for industry *j*, $P^L_{j,t}$, can be derived by applying the product test in index number theory (Frisch, 1930), i.e., by dividing the total labor compensation in industry *j* by the volume of labor input. The total labor compensation in industry *j* is:

(6) $$P^L_{j,t} L_{j,t} = \sum_s \sum_a \sum_e P^H_{s,a,e,j,t} H_{s,a,e,j,t},$$

where $P^H_{s,a,e,j,t}$ is the price of one hour worked received by labor type '*s*, *a*, *e*, *j*" in industry *j* at time *t*.

Based on (5) and (6), any normalization can be chosen for the indexes. Let the price index $P^L_{j,t}$ to be set at unity in the base year *b*, then the volume of labor input at time *b* will be equal to the total value of labor compensation in industry *j* at time *b*.

Formally, the labor quality index of industry *j*, $Q_{j,t}$, as measured by the contribution of substitution among the various types of labor input in industry *j*, can be defined as the ratio between the volume of labor input $L_{j,t}$ to the number of total hours worked in industry *j*, $H_{j,t}$, then the growth rate of labor quality can be expressed as:

(7) $$\Delta \ln Q_{j,t} = \Delta \ln L_{j,t} - \Delta \ln H_{j,t}$$

$$= \sum_s \sum_a \sum_e \bar{v}^L_{s,a,e,j,t} \Delta \ln H_{s,a,e,j,t} - \Delta \ln H_{j,t},$$

where

(8) $$H_{j,t} = \sum_s \sum_a \sum_e H_{s,a,e,j,t}.$$

Recall that the assumption of proportionality between labor input and hours worked for individuals as given in (4) implies that observations on the constant $q_{s,a,e,j}$ are not necessarily required. In addition, $Q_{j,t}$ is indexed by *t* even though the quality of each specific type of labor input $q_{s,a,e,j}$ is

constant over time, because the aggregate labor quality index in industry *j* incorporates the impact of substitution between heterogenous types of labor input in the industry.

The growth rate of labor quality given in (7) is the difference between weighted and unweighted growth rates of hours worked in industry *j*, and it basically reflects the change in labor composition over time. For instance, if only proportions of each labor type change, while keeping total hours worked unchanged in an industry, then the impact on the growth of labor input will be reflected only by the change of labor composition. Equation (7) also indicates that the growth of labor input volume $L_{j,t}$ incorporates growth in hours worked $H_{j,t}$, and improvements in labor quality $Q_{j,t}$.

2.3. The new quality-adjusted labor input dataset

By considering the quality differences of labor input, the quality-adjusted labor input data are important statistics that can be used for addressing a number of interesting issues by many.

Quality-adjusting labor input in the Norwegian national accounts was once implemented for the period 2008-2014. The quality indicators then used relate to two variables: sex and educational attainment of the labor force by industry. The one-time product was published in the Statbank as Table 10585 (*Compensation and employees, by industry, education, and sex 2008 – 2014*)[11], and was later incorporated for compiling a Norwegian KLEMS database (see Liu, 2017), based on which a series of economic analyses were published accordingly (see Liu, 2018, 2019, 2020a). Due to limited resources, the quality-adjusted labor input data, however, has not been updated on a regular basis at Statistics Norway.

Recently, in connection with a Eurostat Grant project (EU project 2019/NO/IGA - DLV-874652) for establishing an experimental growth and productivity database at Statistics Norway, a new vintage of quality-adjusted labor input dataset for the period 2015-2018 was compiled, based on a new data reporting system that has been introduced in Norway since 2015.[12]

This new data source offers a good opportunity for compiling high quality labor statistics in the Norwegian national accounts compilation system. In particular, there exists possibility for constructing the statistics of labor inputs that could be cross-classified not only by sex and educational attainment as done in the 2008-2014 vintage of labor input data, but also by age and occupation.

Table 1. Classification of labor input for each industry

Labor quality characteristics	Number of Categories	Categories
Sex	2	Male; Female
Age (group)	3	15/16-29; 30-49; 50+
Education	5	Primary and lower secondary education
		Upper secondary education, general programs
		Upper secondary education, vocational programs
		Tertiary education, lower degree
		Tertiary education, higher degree

Source: Statistics Norway

Age is frequently used as a proxy indicator to reflect working experiences due to e.g., on-the-job training while the latter is one of the most important channels for human capital development (see e.g., Liu and Fraumeni, 2014, 2016). Moreover, occupation is often employed to directly identify new job creation, which is also important information for analysis related to digitalization and

[11] See https://www.ssb.no/en/statbank/table/10585/.

[12] *A-ordning* in *Norwegian*. See https://www.skatteetaten.no/en/business-and-organisation/employer/the-a-melding/about-the-a-ordning/about-a-ordningen/.

globalization that prevail in today's economy.

Although the work for incorporating quality-adjusted labor input cross-classified by age, gender, educational attainment, and occupation into the labor accounts has been placed on the priority agenda at Statistics Norway, the unexpected breakout of Covid-19 finally led to an experimental vintage of labor input data that are only cross-classified by sex, age, and educational attainment for the period 2015-2018.

As shown in Table 1, the three selected labor quality characteristics in the new dataset, sex, age (group), and education, have 2, 3, and 5 detailed categories, respectively, implying that for each industry, there are 2 × 3 × 5 = 30 types of labor input. Note that the original number of categories for educational attainment is six, including one category of 'Unknown education'. For our purpose, this category is merged with 'Primary and lower secondary education'. To some extent, this is justified by the observation that for most industries, labor compensation per hour in the category of 'Unknown education' is in general either close to that for the category of 'Primary and lower secondary education', or lower than those for higher (than 'Primary and lower secondary education') categories.

Table 2. Industries and sectors in the market economy of mainland Norway

Industry		Sector (aggregate of industries)												
Code	Description	NR23FN	NRLKNR_NR23IND	NR23FN_AV	NR23JORD	NR23FISK	NR23BERG	NR23ELGV	NR23BOA	NR23FN_PT	NR23VAH	NR23ITR	NR23IKT	NR23FIN
2301	Agriculture, Hunting	x		x	x									
2302	Forestry	x		x	x									
2303	Fishing	x		x		x								
2304	Aquaculture	x		x		x								
2305	Mining and quarrying	x		x			x							
2307	Service activities incidental to oil and gas	x								x				
2310	Food, beverage and tobacco industry	x	x											
2312	Processing and preservation of fish etc.	x	x											
2313	Textile, clothing and leather goods industry	x	x											
2315	Timber and wood products, excluding furniture	x	x											
2316	Manufacture of paper and paper products	x	x											
2317	Printing and reproduction of recorded recordings	x	x											
2318	Manufacture of coal and refined petroleum products	x	x											
2319	Manufacture of chemical raw materials	x	x											
2320	Manufacture of chemical products	x	x											
2321	Pharmaceutical raw materials and preparations	x	x											
2322	Manufacture of rubber and plastic products	x	x											
2323	Manufacture of other non-metallic mineral products	x	x											
2324	Manufacture of basic metals	x	x											
2325	Fabricated metal, except machinery and equipment	x	x											
2326	Manufacture of computer and electronic products	x	x											
2327	Manufacture of electrical equipment	x	x											
2328	Manufacture of other machinery and equipment	x	x											
2329	Manufacture of motor vehicles and vehicles etc.	x	x											
2330	Construction of ships and boats	x	x											
2331	Construction of oil platforms and modules	x	x											
2332	Manufacture of furniture and other industrial products	x	x											
2333	Repair and installation of machinery and equipment	x	x											
2335	Production of electricity	x		x				x						
2336	Distribution and trading of electricity	x		x				x						
2337	Gas and hot water supply	x		x				x						
2338	Water supply, drainage and waste disposal	x								x				
2341	Development of construction projects	x		x					x					
2342	Construction activities	x		x					x					
2344	Wholesale and retail trade, repair of motor vehicles	x								x	x			
2346	Rail and other land transport with passengers	x								x		x		

Industry		Sector (aggregate of industries)												
Code	Description	NR23FN	NRLKNR_NR23IND	NR23FN_AV	NR23JORD	NR23FISK	NR23BERG	NR23ELGV	NR23BOA	NR23FN_PT	NR23VAH	NR23ITR	NR23IKT	NR23FIN
2347	Freight transport by road	x								x		x		
2350	Domestic shipping	x								x		x		
2351	Air transport	x								x		x		
2352	Storage and other services related to transportation	x								x		x		
2353	Post and distribution business	x								x		x		
2356	Accommodation and catering activities	x								x				
2358	Publishing	x								x			x	
2361	Telecommunications	x								x			x	
2362	Services related to ICT and information services	x								x			x	
2364	Financing and insurance activities	x								x				x
2367	Real estate activities	x								x				
2370	Technical consulting, auditing, etc.	x								x				
2372	Research and Development	x								x				
2373	Marketing, other professional and technical services	x								x				
2377	Business services	x								x				
2385	Education and training	x								x				
2386	Health services	x								x				
2387	Nursing and care services, kindergartens and AKS	x								x				
2390	Artistic activities, sports and leisure activities, etc.	x								x				
2394	Other private services, organizations, etc.	x								x				
2397	Paid work in private households	x								x				

Source: Statistics Norway. Notes: 'x' stands for 'included'

NR23FN	=	Market activities in mainland Norway (excluding housing services)
NRLKNR_NR23IND	=	Industrial activities
NR23FN_AV	=	Other goods production industries in mainland Norway
NR23JORD	=	Agriculture and forestry
NR23FISK	=	Fishing and aquaculture
NR23BERG	=	Mining and quarrying
NR23ELGV	=	Electricity and district heating and gas
NR23BOA	=	Building development and construction
NR23FN_PT	=	Private services in mainland Norway (excluding housing services)
NR23VAH	=	Wholesale/retail trade, repair of motor vehicles
NR23ITR	=	Domestic transport
NR23IKT	=	Information and communication technology
NR23FIN	=	Financing and insurance activities

In this paper, we will focus on the market economy of mainland Norway, since it is the chosen concept for which the productivity indicators in the Statbank at Statistics Norway are published.[13] The market economy of mainland Norway consists of 57 industries that are used at the Norwegian quarterly national accounts. The corresponding codes and short descriptions of these industries, as well as the sectors are listed in Table 2. It is worth mentioning here that the term of 'sector' used in Table 2 and throughout the paper refers to an 'aggregate of industries', it is not necessarily the same as an 'institutional sector' as defined in the System of National Accounts (see United Nations, 2009; Eurostat, 2013).

If each industry as shown in Table 2 is treated differently, i.e., if 'employment by industry', or 'industry' in short, is also regarded as one quality characteristic of the labor force, the total types of labor input will become 30 × 57 = 1710 types of labor in the market economy of mainland Norway.

[13] For a more elaborated definition and discussion of the market economy of mainland Norway, see Liu (2017, 2020a).

3. Growth accounting

With the quality-adjusted labor input data available, at least two works can be undertaken as regards updating the current growth accounting practices at Statistics Norway: first, the estimation of multifactor productivity (*MFP*) can be improved; second, the measurement inconsistency of average labor productivity (*LP*) across aggregation levels can be removed.

3.1. Improving the estimation of MFP

According to the current methodology behind the published growth accounting statistics at Statistics Norway,[14] the growth rate of value-added generated by an industry *j* can be accounted for by applying the following equation:

$$\Delta \ln Z_j = \bar{v}_{K,j}^{Z} \Delta \ln K_j + \bar{v}_{L,j}^{Z} \Delta \ln H_j + \Delta \ln MFP_j^{Z}, \quad (9)$$

where Z_j is the volume of industry *j*'s value-added, $\bar{v}_{K,j}^{Z}$, and $\bar{v}_{L,j}^{Z}$ are the period average share of capital (K_j) and labor (H_j) input in the nominal value-added of industry *j*, respectively. MFP_j^{Z} is the value-added-based multifactor productivity of industry *j*.[15] Note that the subscript of time *t* has been suppressed in (9) and we shall do the same for the following equations unless the specific context requires time *t* to be referred to explicitly to avoid misunderstanding.

The value-added share of capital and labor input is defined as:

$$v_{K,j}^{Z} = \frac{P_j^K K_j}{P_j^Z Z_j}, \quad (10)$$

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

where P_j^K and P_j^L are the price indexes of capital (K_j) and labor (H_j) input in industry *j*, respectively, while P_j^Z is the (implicit) price index of value-added of industry *j*. The two-period average value share is then defined as:

$$\bar{v}_{K,j}^{Z} = (v_{K,j,t}^{Z} + v_{K,j,t-1}^{Z})/2 , \quad (11)$$

$$\bar{v}_{L,j}^{Z} = (v_{L,j,t}^{Z} + v_{L,j,t-1}^{Z})/2 .$$

Equation (9) indicates that the growth rate of valued-added of industry *j* can be attributed to the contributions from primary factor inputs (capital and labor) and the *MFP*. With data for value-added and primary factors ready, the growth of *MFP* is estimated residually as:

$$\Delta \ln MFP_j^{Z} = \Delta \ln Z_j - \bar{v}_{K,j}^{Z} \Delta \ln K_j - \bar{v}_{L,j}^{Z} \Delta \ln H_j . \quad (12)$$

Note that the labor input of industry *j* in (12) is currently measured as the sum of total hours worked in the industry (H_j), regardless of the quality differences between hours worked by people with higher and those with lower education or skills. As discussed in Section 2, this does not make sense.

If $\Delta \ln H_j$ in (12) is replaced by (the quality-adjusted labor input) $\Delta \ln L_j$ as defined in (5), and using (7),

[14] The methodology and the associated statistics are published at https://www.ssb.no/nasjonalregnskap-og-konjunkturer/statistikker/nr/tilleggsinformasjon/produktivitetsendringer-for-naringer/.

[15] In the current methodology at Statistics Norway, the term of total factor productivity (TFP) is used to refer in fact to multifactor productivity (MFP).

(12) becomes:

$$\Delta \ln MFP_j^Z = \Delta \ln Z_j - \bar{v}_{K,j}^Z \Delta \ln K_j - \bar{v}_{L,j}^Z \Delta \ln H_j - \bar{v}_{L,j}^Z \Delta \ln Q_j. \quad (13)$$

Comparing (12) with (13) shows immediately that the current estimate of the *MFP* growth by (12) is biased owing to that the last item on the right-hand side of (13) is missing.

The biasedness to the estimate of MFP growth due to the absence of the change in labor composition could be either upward or downward, depending on whether $\Delta \ln Q_j$ is positive or negative. Previous studies have found that the change of labor composition in Norwegian industries varied across industries and had both positive and negative values over the period 1997-2014 (see Liu, 2017, 2018).

In Table 3, the growth accounting results for the market economy of mainland Norway over the period 2015-2018 based on the new quality-adjusted dataset are presented. The growth accounting results for a number of sectors as listed in Table 2 are reported in Appendix A.

Table 3. Growth accounting for the market economy of mainland Norway (%)

	2015-2016	2016-2017	2017-2018	Average (2015-2018)
Value added	0.53	4.69	4.66	3.28
Hours worked	-1.26	-0.18	1.44	-0.01
Aggregate labor productivity	1.80	4.88	3.21	3.29
Reallocation	0.60	-0.22	-0.18	0.06
Industry-weighted labor productivity	1.20	5.10	3.39	3.22
Contribution from				
Other capital per hour	0.85	1.17	0.85	0.96
Hardware capital per hour	-0.06	0.16	0.24	0.11
Software capital per hour	0.32	0.31	0.23	0.29
R&D capital per hour	0.10	0.22	0.04	0.12
Labor composition	-0.07	0.19	0.11	0.08
MFP	0.06	3.04	1.92	1.67

Source: Author's own calculations. Note: Excluding housing services.

As shown in Table 3, the estimated annual average growth rate of MFP was 1.67 per cent over 2015-2018. Without quality-adjusted labor input data, this value would have been estimated upward-biased as 1.75 per cent, because the annual average contribution of labor composition was 0.08 per cent over the same period. For the periods 2016-2017 and 2017-2018, the estimated MFP growth would have been upward-biased as well, if labor input data are not quality-adjusted.

However, with no quality-adjusted labor input data, the estimated MFP growth would have been downward-biased for the period 2015-2016, and even worse, the estimated MFP growth would have been negative because the annual contribution from labor composition was -0.07 per cent, a negative value, but in terms of absolute value, being larger than 0.06 per cent, the estimated MFP growth by using the quality-adjusted labor input data.

As shown in Appendix A, different from others, only the three sectors coded as ELGV ('Electricity and district heating and gas' in Table A6), IKT ('Information and communication technology' in Table A11), and FIN ('Financing and insurance activities' in Table A12) had negative values of annual average contribution from labor composition over the period 2015-2018. A careful look at these tables finds that the relatively large (in terms of absolute value) negative value of labor composition contribution that occurred in 2015-2016 is the main reason.

The sector ELGV consists of KNR2335 (Production of electricity), KNR2336 (Distribution and trading of electricity), and KNR2337 (Gas and hot water supply); the sector IKT comprises KNR2358

(Publishing), KNR2361 (Telecommunications), and KNR2362 (Services related to ICT and information services); and the sector FIN has KNR2364 (Financing and insurance activities). Further investigation into the constituent industries of the three sectors gives rise to the following finding: it is primarily the abrupt reduction of hours worked by workers with non-tertiary education during 2015-2016 that led to the (large in terms of absolute value) negative value of the change of labor composition.

There is another event that might have also contributed profoundly to the change of labor composition between 2015 and 2016 in the mainland Norway, i.e., the substantial decline in oil prices in 2014/2015 and its aftermath, which had resulted in a large amount of highly educated people with high wages in the oil-related industries (mostly in the mainland Norway) losing their jobs.

Recall that the new data reporting system (*A-ordning*) was introduced in 2015 for the first time in Norway, thus the 2015 data had relatively lower quality than those after 2015 in general. Moreover, in any case, the new vintage of quality-adjusted labor input data for the period 2015-2018 is featured with experimental character. Therefore, all the examples and explanations as presented in the paper should be taken with due caution, they are mainly to demonstrate how the quality-adjusted labor input data can be applied, without paying excessive attention to giving sensible interpretations to the estimated results.

3.2. Restoring consistency of LP across aggregation levels

As pointed out in Liu (2020b), there exists an internal inconsistency of measuring average labor productivity (*LP*) across aggregation levels in the current growth accounting practice at Statistics Norway. According to the current method, the value-added based average labor productivity at the industry level (LP_j^Z) is measured as the value-added divided by total hours worked in industry *j*:

$$LP_j^Z = \frac{Z_j}{H_j}. \tag{14}$$

However, at the sector level (and up to the entire economy level as well), the value-added based average labor productivity (LP_S^Z) is measured as the sector value-added (Z_S) divided by sector labor input (L_S) as:

$$LP_S^Z = \frac{Z_S}{L_S}. \tag{15}$$

The sector value-added (Z_S) is defined by:

$$\Delta \ln Z_S = \sum_{j \in S} \bar{v}_{Z,j}^S \Delta \ln Z_j, \tag{16}$$

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

$$v_{Z,j}^S = \frac{P_j^Z Z_j}{\sum_{j \in S} P_j^Z Z_j}. \tag{17}$$

The sector labor input (L_S) is defined as:

$$\Delta \ln L_S = \sum_{j \in S} \bar{v}_{L,j}^S \Delta \ln H_j, \tag{18}$$

where $\bar{v}_{L,j}^S$ is period average share of labor compensation of industry *j* in the total labor compensation in sector *S*, and

(19) $$v_{L,j}^{S} = \frac{P_j^L H_j}{\sum_{j \in S} P_j^L H_j}.$$

Note that L_S given by (18) is an index, rather than hours worked, i.e.

(20) $$L_S \neq H_S = \sum_{j \in S} H_j.$$

As such, the sector labor productivity as currently defined in (15) at Statistics Norway is not consistent across levels of aggregation (see (14)). However, the conventional way, also applied at the lower-level industries at Statistics Norway,[16] is to define labor productivity in an economic production unit as the volume of output divided by the corresponding *hours worked* in the unit.

One primary justification for using L_S instead of H_S for measuring the sector labor productivity in (15) is that if 'industry' is treated as one quality characteristic, then aggregation of undifferentiated labor input across detailed industries can provide some form of implicit differentiation. For instance, as the index given by (18) is weighted by labor compensation, hours worked by high wage industry count more than hours worked by low wage industry. The weighting scheme as shown in (19) can therefore be used to capture labor heterogeneity via the wage differentials across industries, in order to partially compensate for the lack of quality-adjusted labor input data, such as the data discussed and applied in this paper.

However, even if 'industry' can be considered as a quality characteristic for the labor force,[17] it is one but only one of many quality characteristics that determine the marginal productivity of various types of labor input. With the quality-adjusted labor input cross-classified by more quality characteristics, it is no longer needed to remain the inconsistency of measuring average labor productivity across aggregation levels in the current growth accounting practice at Statistics Norway.

With the quality-adjusted labor input data incorporated, the contribution from labor quality to the average labor productivity growth of industry *j* can be explicitly and directly measured. Assuming constant returns to scale, the total compensation of labor and capital will exhaust the value-added of industry *j*, i.e.

(21) $$P_j^Z Z_j = P_j^K K_j + P_j^L H_j,$$

then the two shares defined in (10) sum to unity, and (13) can be reorganized as:

(22) $$\Delta \ln LP_j^Z = \bar{v}_{K,j}^Z \Delta \ln KI_j + \bar{v}_{L,j}^Z \Delta \ln Q_j + \Delta \ln MFP_j^Z.$$

where $KI_j = \frac{K_j}{H_j}$ is capital intensity (capital services per hour) in industry *j*.

Finally, by following the convention and most important, to be consistent across levels of aggregation, the suggested sector labor productivity, $\widehat{LP_S^Z}$, should be measured as:[18]

(23) $$\widehat{LP_S^Z} = \frac{Z_S}{H_S}.$$

[16] Each of the quarterly-national-accounts industry as listed in Table 2 consists of several lower-level industries that are so-called annual-national-accounts industries in the Norwegian national accounts system.
[17] Also see subsection 4.2 and footnote 19.
[18] For further discussion on how to account for the contribution of various components including change of labor composition from each industry to the growth of the aggregate sector labor productivity (as given in (23)), please refer to Liu (2020b).

4. Labor input and quality at aggregate level

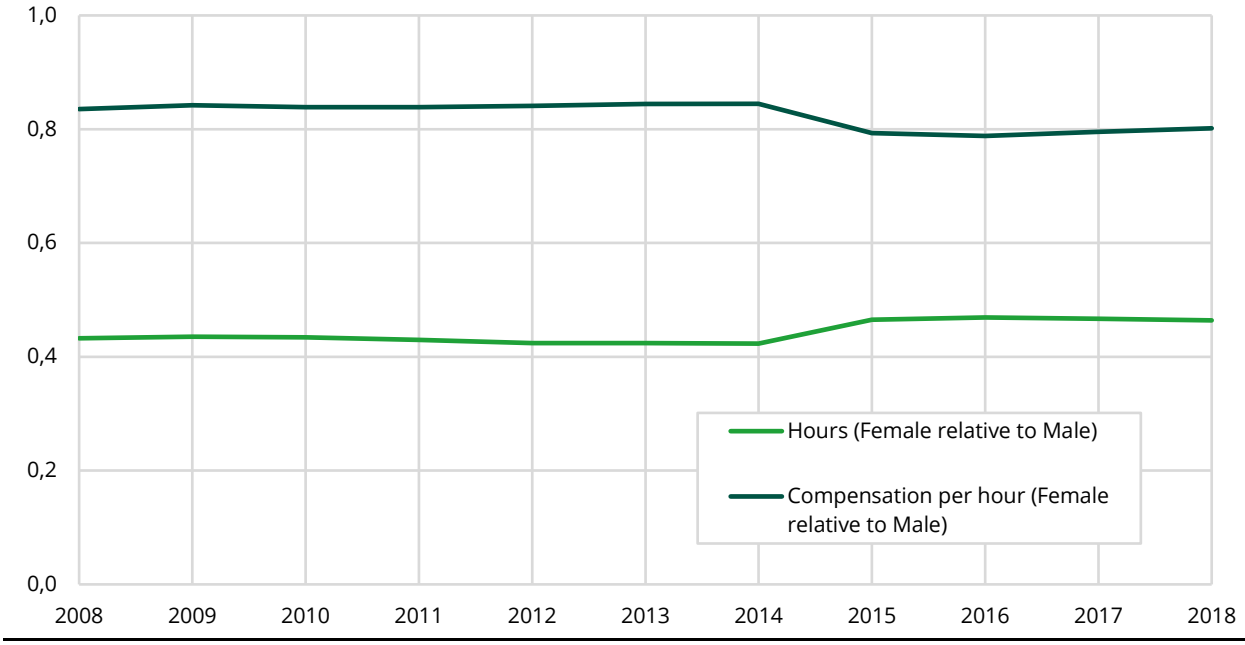
The quality-adjusted labor input data can also be applied for analyzing the effects of substitution among quality components of labor input at the aggregate level. In the following, let us first have a brief look at hours worked and compensation per hour by the selected quality characteristics in the market economy of mainland Norway over the years.

4.1. Hours and compensation per hour by quality

Sex

Total hours worked and compensation per hour for females relative to males are displayed for the period 2008-2018 in Figure 1. As shown, both ratios (over 0.4 and 0.8, respectively) were quite stable and had almost indiscernible changes over the observed years. There was a slight shift between the two subperiods of 2008-2014 and 2015-2018, most likely owing to that the quality-adjusted labor input data of the two subperiods are different vintages.

Figure 1. Hours and compensation per hour, Female relative to Male



Source: Author's own calculations.

Age

Because no age dimension was applied for the quality-adjusted labor input series for the subperiod 2008-2014, hours worked and compensation per hour of age groups (15/16-29 and 30-49) relative to that of age group (50+) is reported in Table 4 only for the subperiod 2015-2018.

Table 4. Hours and compensation per hour relative to Age (50+)

Year	Hours			Compensation per hour		
	Age (15/16-29)	Age (30-49)	Age (50+)	Age (15/16-29)	Age (30-49)	Age (50+)
2015	0.704	1.634	1.000	0.638	0.933	1.000
2016	0.685	1.573	1.000	0.606	0.927	1.000
2017	0.666	1.533	1.000	0.601	0.919	1.000
2018	0.664	1.521	1.000	0.604	0.914	1.000

Source: Author's own calculations.

Table 4 shows that both hours worked and compensation per hour of age group (15/16-29) were the lowest among the three selected age groups. While hours worked of age group (30-49) was larger, its compensation per hour, however, was lower, than those of age group (50+). Over the years of 2015-2018, for either of the two age groups (15/16-29 and 30-49), both hours worked and compensation per hour had been decreasing relative to those of age group (50+), which might indicate that senior people had been working longer and gaining more relative to their younger counterparts in the market economy of mainland Norway over the observed recent years.

Educational attainment

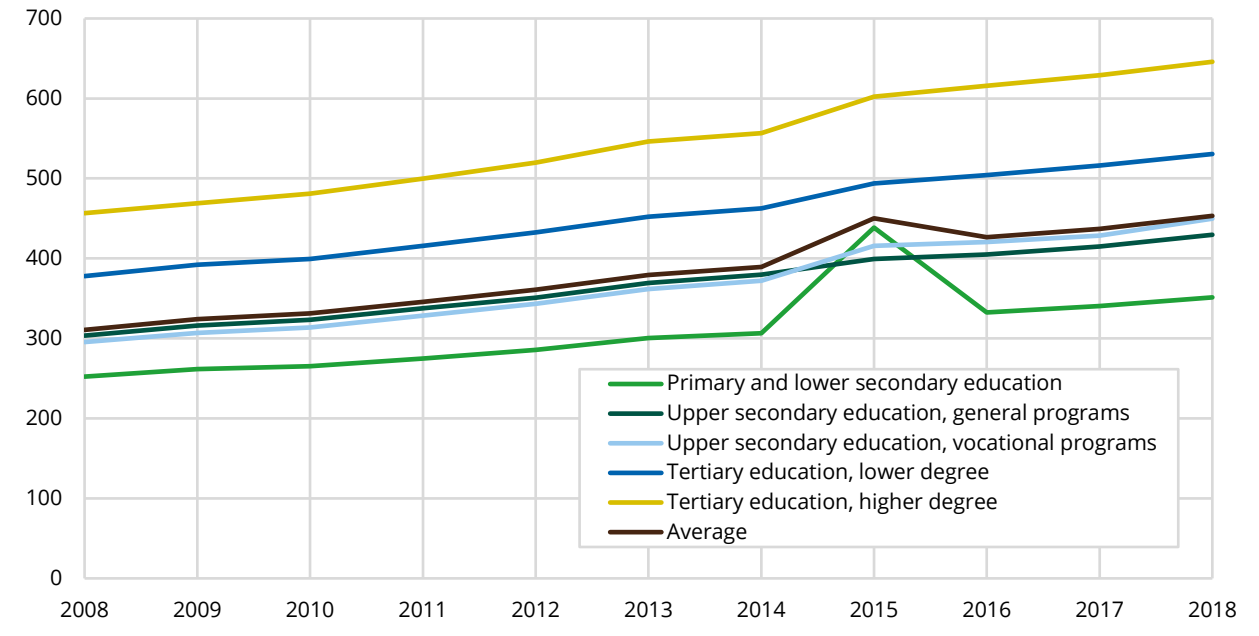
Table 5 presents the distribution of hours worked across the 5 selected educational attainment levels over the period 2008-2018. The share of 'Upper secondary education, vocational programs' had been the largest among all educational categories up to 2014. From 2016, although decreasing every year, it was still the second largest category during the period 2015-2018, just after the share of 'Primary and lower secondary education'.

Table 5. Share of hours worked by educational attainment in the market economy of mainland Norway

Year	Primary and lower secondary education	Upper secondary education, general programs	Upper secondary education, vocational programs	Tertiary education, lower degree	Tertiary education, higher degree	SUM
2008	0.262	0.182	0.317	0.172	0.067	1.000
2009	0.251	0.179	0.320	0.178	0.072	1.000
2010	0.249	0.174	0.320	0.181	0.075	1.000
2011	0.250	0.169	0.320	0.184	0.078	1.000
2012	0.249	0.163	0.320	0.187	0.081	1.000
2013	0.254	0.158	0.318	0.188	0.082	1.000
2014	0.255	0.153	0.317	0.190	0.086	1.000
2015	0.352	0.133	0.262	0.172	0.081	1.000
2016	0.289	0.142	0.288	0.189	0.092	1.000
2017	0.290	0.138	0.287	0.190	0.095	1.000
2018	0.291	0.133	0.285	0.192	0.098	1.000

Source: Author's own calculations.

Figure 2. Compensation per hour by educational attainment in the market economy of mainland Norway (NOK/hour)



Source: Author's own calculations.

The share of 'Upper secondary education, general programs' had the similar magnitude with that of

'Tertiary education, lower degree' at the beginning of the period 2008-2018. Ove the years, different between the two was that the former had been decreasing, while the latter increasing. Over the same period, the share of 'Tertiary education, higher degree' had kept increasing, resulting in its share from less than 7% in 2008 becoming close 10% in 2018.

The compensation per hour over 2008-2018 for the five educational attainment categories together with the (weighted) average of them are displayed in Figure 2. First, it seems that higher educational levels had received higher compensation per hour in general, however, the compensation per hour for the two upper secondary educational attainment levels were very close, and the compensation per hour for 'Upper secondary education, vocational programs' was slightly lower during 2008-2014, while it was higher during 2015-2018, than that for 'Upper secondary education, general programs'. This observation might be due to that data from the two subperiods 2008-2014 and 2015-2018 come from two different vintages.

Second, compensation per hour for all educational attainment levels increased over the period 2008-2018; third, differences of compensation per hour among different educational attainment levels were slightly increasing as visualized in Figure 2.

However, there is one exception here: the compensation per hour of 'Primary and lower secondary education' in 2015 seems to be an outlier in Figure 2. The reason could be that it might not be appropriate to merge 'Unknown education' category with the category of 'Primary and lower secondary education', and esp. for the period 2015-2018. Nonetheless, further investigations are needed.

4.2. Aggregation

The method of aggregation varies and the one chosen in this subsection is in accordance with a well-defined aggregate production possibility frontier (PPF) or aggregate production function (PF). This choice implies that the indexes constructed in this subsection ignore the 'industry' dimension, but it is consistent with expressing GDP as an aggregate production function such as $Y_t = A_t F(K_t, L_t)$ as employed by the current growth accounting practice at Statistics Norway.[19]

First, the hours worked across industries for each type of heterogenous labor are aggregated, which is the sum over all industries for a specific type '*s*, *a*, *e*':

(24) $$H_{s,a,e,t} = \sum_j H_{s,a,e,j,t}.$$

The price of each labor type '*s*, *a*, *e*', $P^L_{s,a,e,t}$, is the average price over all industries and is implicitly defined by:

(25) $$P^L_{s,a,e,t} H_{s,a,e,t} = \sum_j P^H_{s,a,e,j,t} H_{s,a,e,j,t}.$$

Then the index of aggregate labor input, L_t, is expressed as a Törnqvist index over all types of labor, in parallel to (5), but without industry dimension:[20]

(26) $$\Delta \ln L_t = \sum_s \sum_a \sum_e \bar{v}^L_{s,a,e,t} \Delta \ln H_{s,a,e,t},$$

[19] See footnote 13.

[20] An aggregate index of labor input that regards 'industry' as another quality characteristic can also be constructed, but such a labor input index is not appropriate for a well-defined aggregate production possibility frontier or an aggregate production function. We will not dwell on this issue in this paper.

where the value share of each labor type '*s*, *a*, *e*' is:

(27) $$v^L_{s,a,e,t} = \frac{P^L_{s,a,e,t}H_{s,a,e,t}}{\sum_s \sum_a \sum_e P^L_{s,a,e,t}H_{s,a,e,t}},$$

and the two-period average value share $\bar{v}^L_{s,a,e,t}$ is then defined as:

(28) $$\bar{v}^L_{s,a,e,t} = (v^L_{s,a,e,t} + v^L_{s,a,e,t-1})/2\ .$$

Note that the sum of value shares defined by (27) over all labor types within the total economy is unity.

Similar to the industry definition (see (7)), the quality index of aggregate labor input can be defined as:

(29) $$\Delta \ln Q_t = \Delta \ln L_t - \Delta \ln H_t,$$

where aggregate hours are:

(30) $$H_t = \sum_s \sum_a \sum_e H_{s,a,e,t}.$$

Then the price of aggregate labor input, P^L_t, is implicitly defined by:

(31) $$P^L_t L_t = \sum_s \sum_a \sum_e P^L_{s,a,e,t}H_{s,a,e,t}.$$

Table 6. Labor input of the market economy of mainland Norway

Year	Price	Quantity (in 2008 prices)	Labor compensation (NOK, million)	Quality	Compensation per hour (NOK/hour)	Hours (million)
2008	1.000	808 194.0	808 194.0	1.000	310.70	2 601
2009	1.039	782 447.0	812 700.0	1.005	324.06	2 508
2010	1.059	781 216.6	827 444.8	1.007	331.30	2 498
2011	1.104	793 108.0	875 852.4	1.009	345.91	2 532
2012	1.151	811 804.5	934 072.7	1.011	361.07	2 587
2013	1.210	813 174.5	983 541.7	1.011	379.49	2 592
2014	1.240	824 547.9	1 022 324.4	1.012	389.53	2 625
2015	1.455	781 044.4	1 136 551.9	0.998	450.07	2 525
2016	1.363	780 174.3	1 063 591.1	1.009	426.52	2 494
2017	1.394	780 034.5	1 087 446.7	1.011	436.88	2 489
2018	1.444	792 835.1	1 144 524.2	1.013	453.23	2 525

Source: Author's own calculations.

Using equations (24) through (31),[21] the aggregate indexes for the market economy of mainland Norway are reported in Table 6. The second and third columns are the price and volume indexes of aggregate labor input, P^L_t and L_t. The product of these two is the value of total labor compensation given in the fourth column. The year of 2008 is chosen as the base year, then the volume indexes are in terms of base year kroners. Thus, prices in 2008 are normalized to 1, and the aggregate volume index in 2008 is equal to the value of total labor compensation in 2008, namely, L_{2008} = 808194 million kroners.

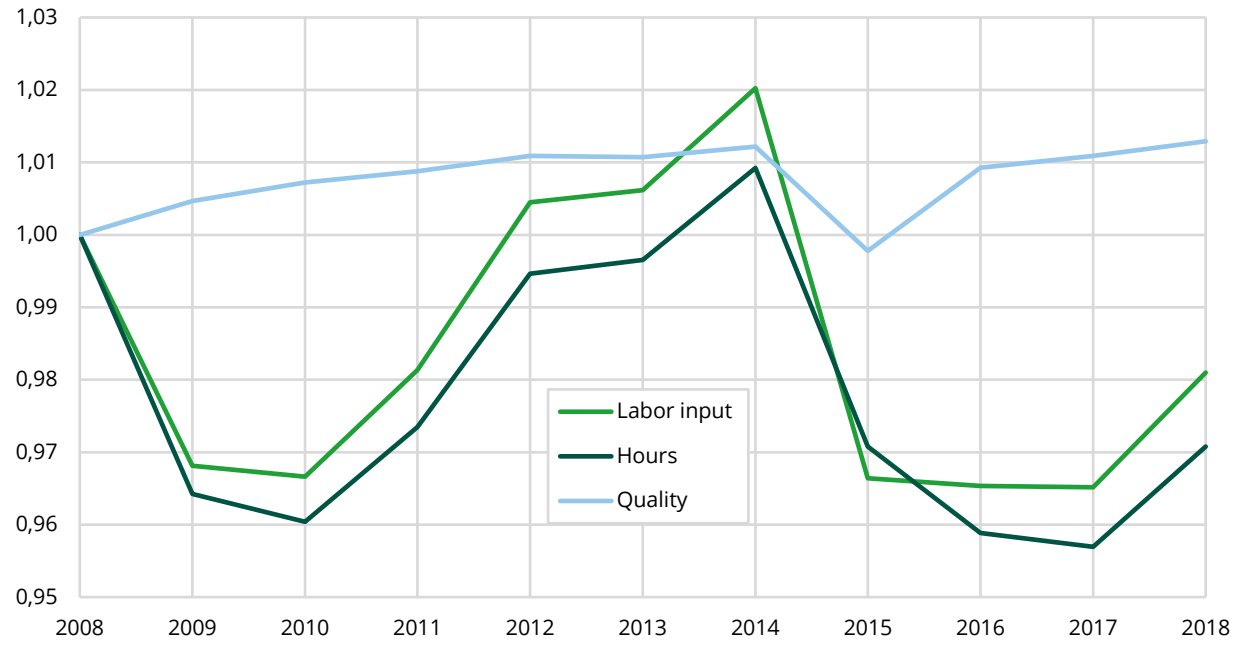
The quality index of aggregate labor input, given by Q_t in (29) and with normalization of Q_{2008} equal 1, is given in the fifth column in Table 6. Average compensation per hour (NOK/hour) and total hours

[21] Because the vintage of 2008-2014 data has no 'age (group)' as one quality characteristic, unless stated otherwise, all the aggregate indexes of labor input are calculated without '*a*' dimension when applying equations (24) through (31) in this paper.

worked in the market economy of mainland Norway are listed in the last two columns in Table 6, respectively.

Figure 3 displays the indexes of aggregate labor input, total hours, and aggregate labor quality, all normalized at unity in 2008. Clearly, there was an abrupt shift/break from 2014 to 2015 since the estimates for 2008-2014 and 2015-2018 come from two different vintages of quality-adjusted labor input data.

Figure 3. Labor input and hours in the market economy of mainland Norway, 2008-2018



Source: Author's own calculations. Note: All indexes are normalized at unity in 2008.

However, if ignoring the shift/break for the moment, it is also clear from Figure 3 that the aggregate labor input grew faster or decreased slower than total hours worked for most of the years during 2008-2018, and the aggregate labor quality had kept growing, albeit gradually, over the period 2008-2018 for the market economy of mainland Norway.

4.3. Decomposition of indexes

To analyze the effects of substitution among quality dimensions of labor input at the aggregate level, we follow the approach by Jorgenson *et al*. (2005) to construct partial indexes of aggregate labor input, incorporating only a subset of the quality characteristics of the labor force.

To form a partial volume index, hours worked and the corresponding value shares over some of the quality characteristics are summed and a Törnqvist index over the remaining characteristics is formed. For instance, a partial index of aggregate labor input corresponding to sex is defined as:

(32) $$\Delta \ln L_t(s) = \sum_s \bar{v}^L_{s,t} \Delta \ln\left(\sum_a \sum_e H_{s,a,e,t}\right),$$

where

(33) $$\bar{v}^L_{s,t} = (v^L_{s,t} + v^L_{s,t-1})/2\ ,$$

and

(34) $$v^L_{s,t} = \sum_a \sum_e v^L_{s,a,e,t}.$$

Analogous to (32), partial indexes for each selected quality characteristic can be defined as $L_t(s)$, $L_t(a)$, $L_t(e)$, where each index captures substitution among the characteristic chosen, but ignores other substitutions. For instance, the partial index $L_t(s)$ as defined by (32) captures substitution between the two sexes but fails to reflect substitution among age and education within each gender category. These partial indexes involving only a single characteristic are referred to as a first-order index.

Similarly, a second-order index is a partial index involving two quality characteristics. The second-order index for sex and education, for example, is defined as:

(35) $$\Delta \ln L_t(s,e) = \sum_s \sum_e \bar{v}^L_{s,e,t} \Delta \ln\left(H_{s,e,t}\right),$$

where

(36) $$H_{s,e,t} = \sum_a H_{s,a,e,t}.$$

Higher-order indexes can be defined in a similar way.[22]

To identify contributions to the growth of aggregate labor quality from changes in the composition of hours worked by sex, age, and educational attainment, the first-order contribution of each quality characteristic to the growth of aggregate labor quality is defined in the following. For example, the contribution of sex to aggregate labor quality, $Q_t(s)$, is the difference between the growth rates of the first-order partial index of aggregate labor input and hours worked:

(37) $$\Delta \ln Q_t(s) = \Delta \ln L_t(s) - \Delta \ln H_t.$$

The first-order contribution of age and of education ($Q_t(a)$ and $Q_t(e)$) can be defined analogously. Similarly, the growth rate of the second-order contribution of each pair of quality characteristics can be defined as the difference between the growth rates of the corresponding partial index of aggregate labor input and hours worked, less the sum of the growth rates of the two first-order contributions. For example, the second-order contribution of sex and education, $Q_t(s,e)$, takes the form:

(38) $$\Delta \ln Q_t(s,e) = \Delta \ln L_t(s,e) - \Delta \ln H_t - \Delta \ln Q_t(s) - \Delta \ln Q_t(e).$$

This index reflects the impact of changes in the composition of hours worked by sex and education on the growth of aggregate labor quality, excluding the first-order effect of these two individual characteristics.[23]

By summing the growth rates of contributions to aggregate labor quality of all orders for a given set of quality characteristics, the growth rate of the index of aggregate labor quality corresponding to those characteristics can be obtained. For example, it can be shown by reorganizing (38) as:

(39) $$\Delta \ln L_t(s,e) - \Delta \ln H_t = \Delta \ln Q_t(s,e) + \Delta \ln Q_t(s) + \Delta \ln Q_t(e),$$

i.e., the growth rate for the contribution of sex and education is the difference between the growth rate of the partial index of labor volume $L_t(s,e)$ and hours worked H_t .

[22] If 'industry' is regarded as another quality characteristic, there are one fourth-order index, four third-order indexes, six second-order indexes, and four first-order indexes.
[23] If 'industry' is regarded as another quality characteristic, there are one fourth-order contribution, four third-order contributions, six second-order contributions, and four first-order contributions.

The index of aggregate labor quality given in (29) tracks the changes in the sex-age-education composition of the economy ignoring the industry dimension. As a matter of fact, it is also a partial index corresponding to all three selected characteristics, and can be represented as the product of the contributions of all orders:

(40) $$\Delta \ln Q_t = \Delta \ln Q_t(s,a,e) + \Delta \ln Q_t(s,a) + \Delta \ln Q_t(s,e) + \Delta \ln Q_t(a,e)$$
$$+\Delta \ln Q_t(s) + \Delta \ln Q_t(a) + \Delta \ln Q_t(e) = \Delta \ln L_t - \Delta \ln H_t.$$

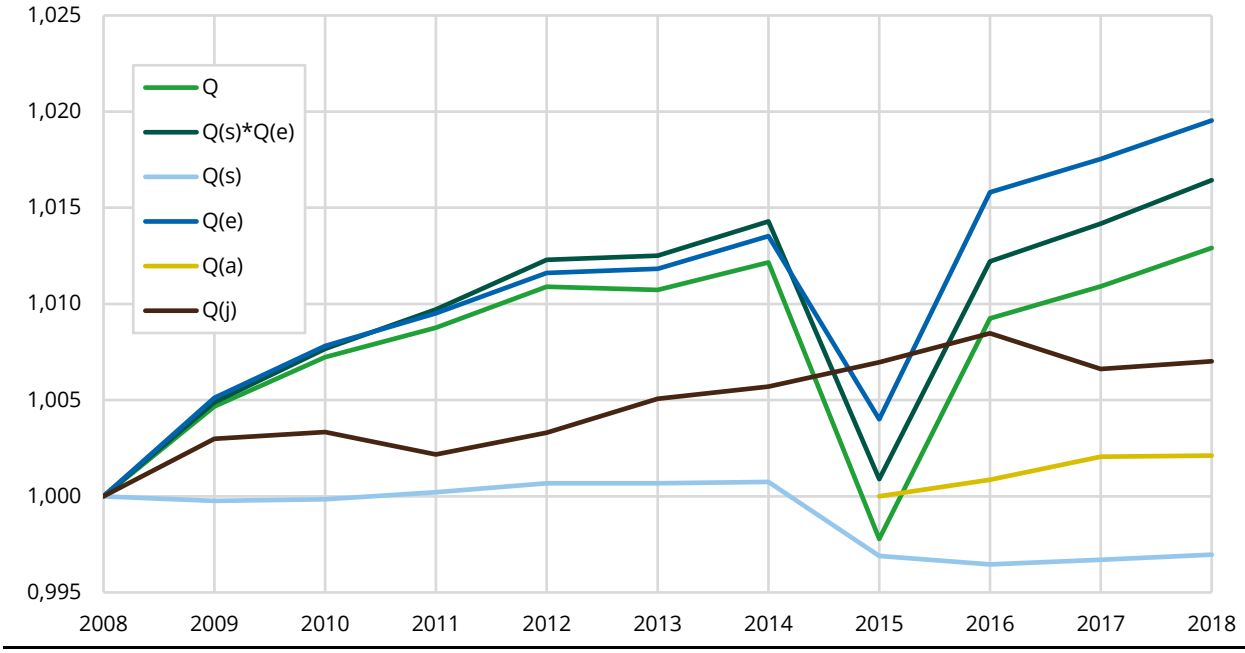
If the second and third order terms in (40) are ignored, the product of all three first-order contributions can be regarded as a first-order approximation to the aggregate quality index. That is, the first-order approximation to Q_t can be written as:

(41) $$Q_t^1 = Q_t(s)Q_t(a)Q_t(e).$$

Figure 4 displays the aggregate labor quality Q_t, four first-order partial quality indexes, $Q_t(s)$, $Q_t(a)$, $Q_t(e)$, $Q_t(j)$, over the period 2008-2018, all normalized at unity in 2008 except for $Q_t(a)$ which is normalized at unity in 2015. Note that the aggregate labor quality is calculated without the 'age (group)' dimension of '*a*', since only '*s*' and '*e*' are two common quality characteristics shared by the two data vintages of 2008-2014 and 2015-2018.[24] As a result, the aggregate labor quality index is in fact calculated by using (39) instead of (40), and the first-order approximation to this aggregate labor quality index is the product of $Q_t(s)$ and $Q_t(e)$, i.e. $Q_t^1 = Q_t(s) * Q_t(e)$, which is also plotted in Figure 4.

First, it is not surprising that there was a break between 2014 and 2015, simply because the data of 2008-2014 and 2015-2018 are two different vintages. Leaving the break for the moment, the first-order contribution of sex $Q_t(s)$, which ignores the interaction with other quality characteristics, seems to have no discernible change over 2008-2018. The first-order contribution of age $Q_t(a)$, starting from 2015, had increased gradually until 2017, and levelled off since then.

Figure 4. Aggregate quality and first order approximation, 2008-2018



Source: Author's own calculations. Note: All indexes are normalized at unity in 2008, except that Q(a) is normalized at unity in 2015.

[24] Also see footnote 20.

On the other hand, the first-order contribution of education $Q_t(e)$, had grown significantly over the period 2008-2018. Moreover, the aggregate labor quality index Q_t as shown in Figure 4 seems to be dominated by the contribution from education. If 'industry' is regarded as one quality characteristic of labor force, the first-order contribution of 'industry', $Q_t(j)$, had increased, esp. over the first subperiod of 2008-2014. This index reflects somehow the importance of reallocation of hours worked among industries.

As shown in Figure 4, the aggregate labor quality index Q_t had increased significantly over the period 2008-2018, and it was closer to its first-order approximation, i.e., $Q_t(s) * Q_t(e)$, and in particular, over the first subperiod 2008-2014.

Table 7 presents annual average growth rates of aggregate labor input, quality, and hours worked for the entire period 2008-2018, as well as for the two subperiods, 2008-2014 and 2015-2018, in the market economy of mainland Norway. The first-order contributions from sex and education are also reported in the table. With the strong assumption that the two vintage datasets of 2008-2014 and 2015-2018 are comparable, the results as presented in Table 7 may be interpreted as follows. Over the whole period 2008-2018, the annual average growth rate of labor input was 0.39 per cent, to which labor quality contributed 0.30 percentage points, accounting for 77%, while hours worked contributed only 0.09 percentage points, accounting for the remaining 23%. Among the quality characteristics, the first-order quality index from education contributed 0.32 percentage points, dominating the whole contribution from labor quality, while the first-order contribution from sex was very small, only 0.01 percentage points.

Table 7. Growth rates of aggregate labor input, quality, and hours (%)

	2008-2018	2008-2014	2015-2018
Value-added in the market economy of mainland Norway	2.27	1.77	3.28
Aggregate labor			
Labor input	0.39	0.33	0.50
Labor quality	0.30	0.20	0.50
Hours	0.09	0.13	-0.01
First-order aggregate labor quality indexes			
Q(s)	0.01	0.01	0.00
Q(e)	0.32	0.22	0.51

Source: Author's own calculations. Note: Average annual growth rates for 2008-2018 is a geometric mean of those of 2008-2014 and 2015-2018.

As a matter of fact, the first-order contribution from sex had almost no change from 2008-2014 to 2015-2018. However, over the same two subperiods, despite a decrease in the growth rate of hours worked, the growth rates of aggregate labor input, quality, and the contribution from education had all increased in the market economy of mainland Norway.

5. Labor input and quality at industry level

5.1. Hours and compensation per hour by industry

Using 2018 as an example, this subsection will provide a snapshot of hours worked and compensation per hour by industry in the market economy of mainland Norway, similar information could have been drawn for all the observed years.

Figure 5 displays the percentage share of each of the 57 industries (listed in Table 2) in the total hours actually worked in the market economy of mainland Norway in 2018. The range of share is from 0.04 per cent for KNR2337 (Gas and hot water supply) to 17.63 per cent for KNR2344 (Wholesale and retail trade, repair of motor vehicles). The median share is 0.66 per cent for KNR2372 (Research and Development). The five industries with largest share of hours worked as shown in Figure 5 are, by descending order in value, KNR2344 (Wholesale and retail trade, repair of motor vehicles), KNR2342 (Construction activities), KNR2377 (Business services), KNR2370 (Technical consulting, auditing, etc.), and KNR2356 (Accommodation and catering activities), all being typically labor-intensive industries.

The five industries with least share of hours worked are, by ascending order in value, KNR2337 (Gas and hot water supply), KNR2318 (Manufacture of coal and refined petroleum products), KNR2397 (Paid work in private households), KNR2321 (Pharmaceutical raw materials and preparations), and KNR2316 (Manufacture of paper and paper products). Except for KNR2397 which is in fact a tiny 'industry', all the other four industries are typically capital-intensive.

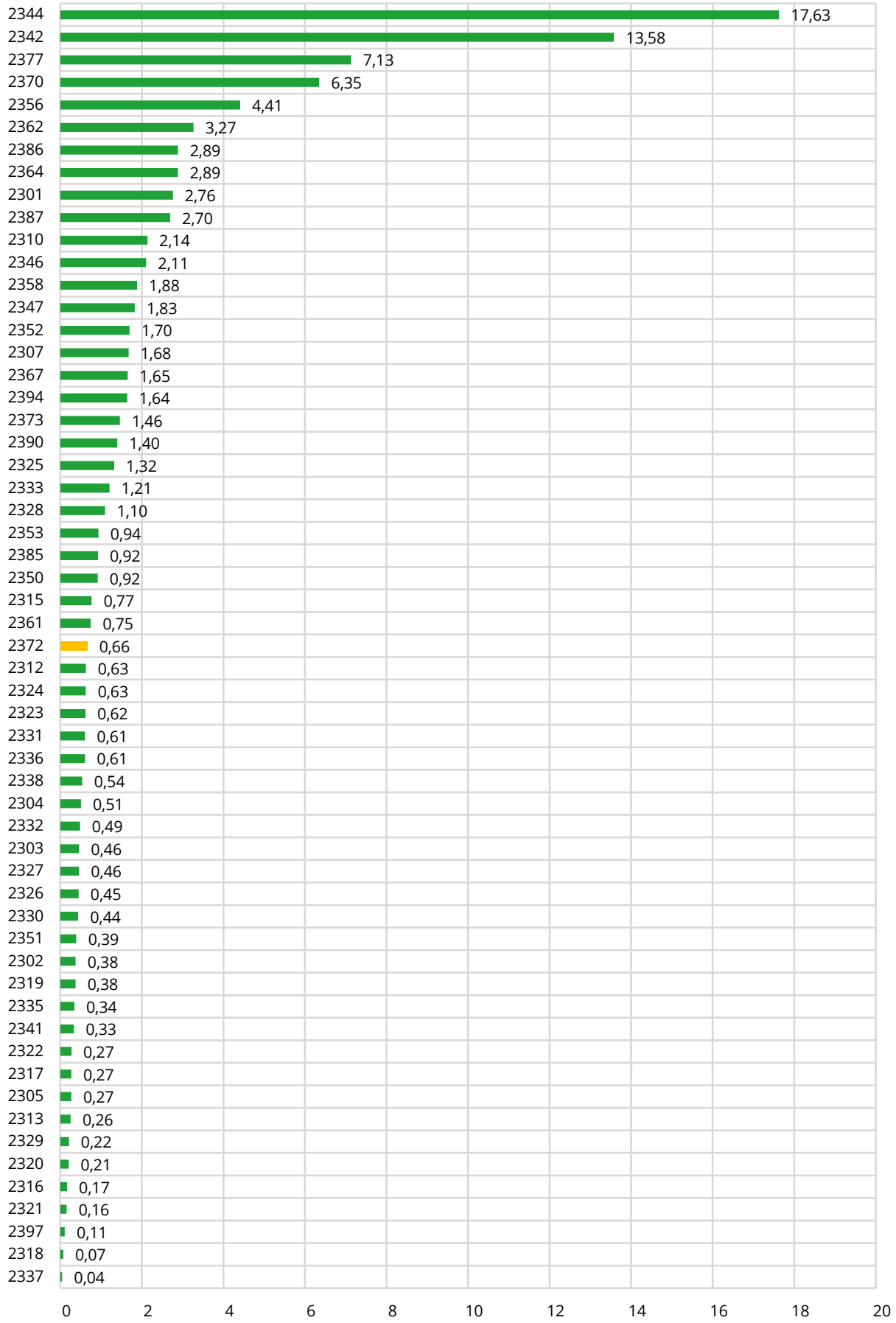
Figure 6 displays the female percentage share of hours actually worked in each of the 57 industries in the market economy of mainland Norway in 2018. The minimum share is 6.14 per cent for KNR2342 (Construction activities), while the maximum share is 79.30 per cent for KNR2387 (Nursing and care services, kindergartens and AKS). The median share is 23.37 per cent for KNR2335 (Production of electricity), implying hours worked by males dominating in most of the industries in the market economy of mainland Norway in 2018.

However, there are some female-labor-intensive industries, for example, the industries with female share larger than 50% are, by descending order in value, KNR2387 (Nursing and care services, kindergartens and AKS), KNR2394 (Other private services, organizations, etc.), KNR2397 (Paid work in private households), KNR2386 (Health services), KNR2356 (Accommodation and catering activities), KNR2321 (Pharmaceutical raw materials and preparations), and KNR2313 (Textile, clothing and leather goods industry). All these industries are traditionally those into which females would first enter when leaving home for market activities.

At the other end of spectrum, a few industries with more than 90% hours worked coming from males in 2018 are, by ascending order in value, KNR2342 (Construction activities), KNR2303 (Fishing), KNR2347 (Freight transport by road), and KNR2333 (Repair and installation of machinery and equipment).

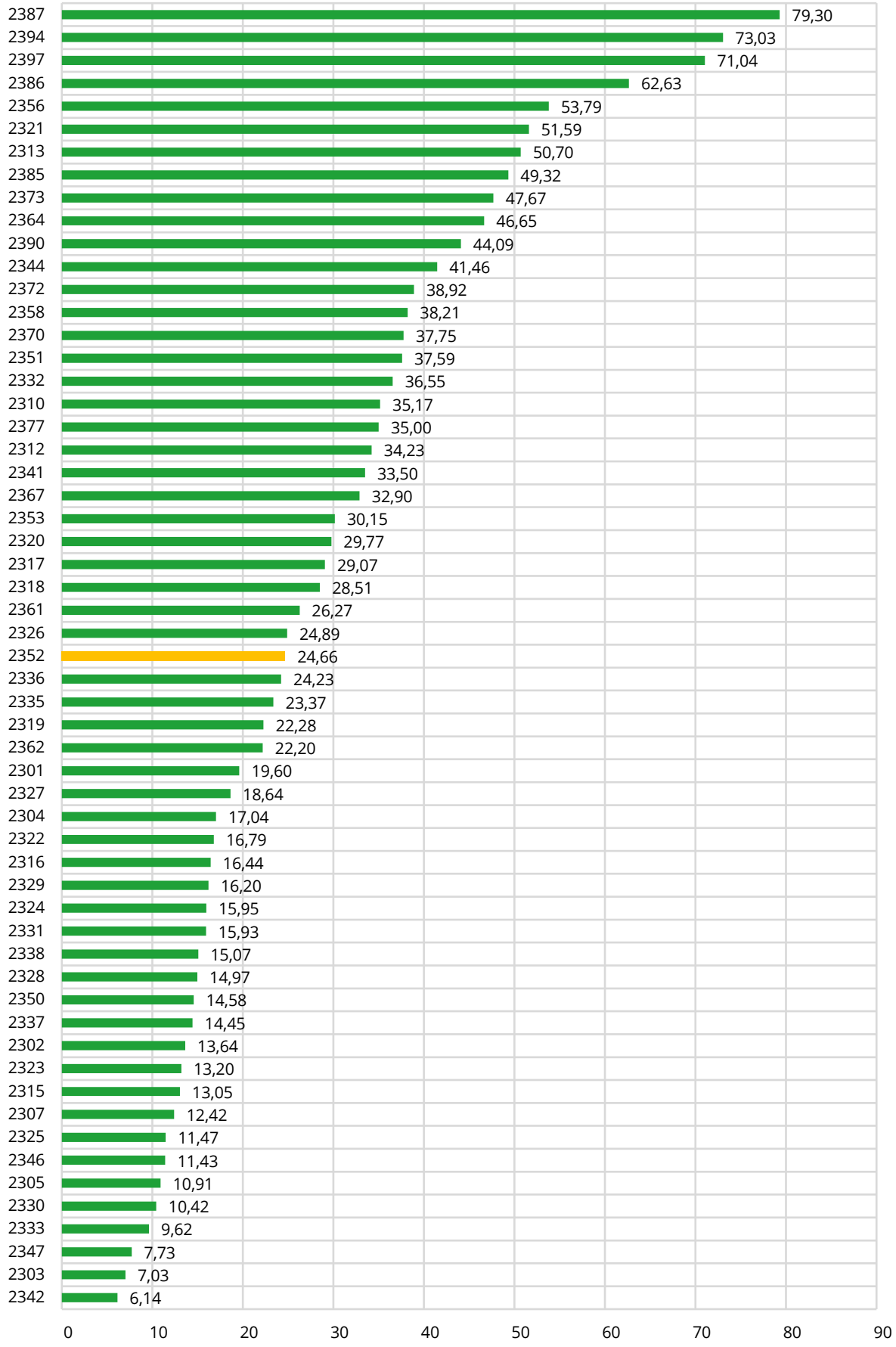
Figure 7 displays the percentage share of hours worked by three age groups in each of the 57 industries in the market economy of mainland Norway in 2018. The industries are arranged by descending order in the share of age group (50+) in each industry. The five industries with largest share of hours by age (50+) are KNR2303 (Fishing), KNR2302 (Forestry), KNR2346 (Rail and other land transport with passengers), KNR2335 (Production of electricity), and KNR2301 (Agriculture, Hunting), three of them are traditional primary industries. The five industries with lowest share of hours by age (50+) are KNR2356 (Accommodation and catering activities), KNR2304 (Aquaculture), KNR2377

Figure 5. Hours share by industry in 2018 (%)



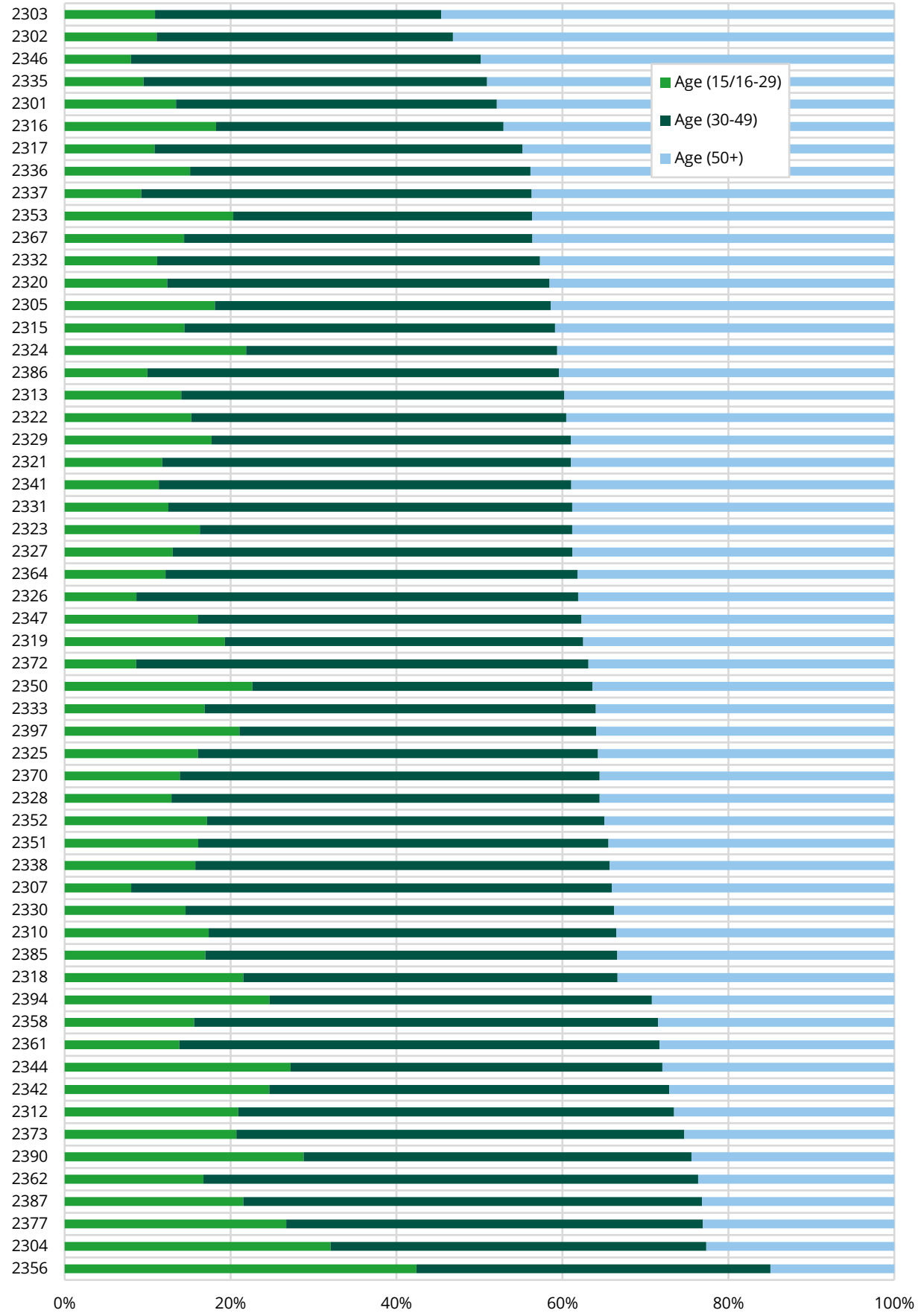
Source: Author's own calculations.

Figure 6. Female hours share across industries in 2018 (%)



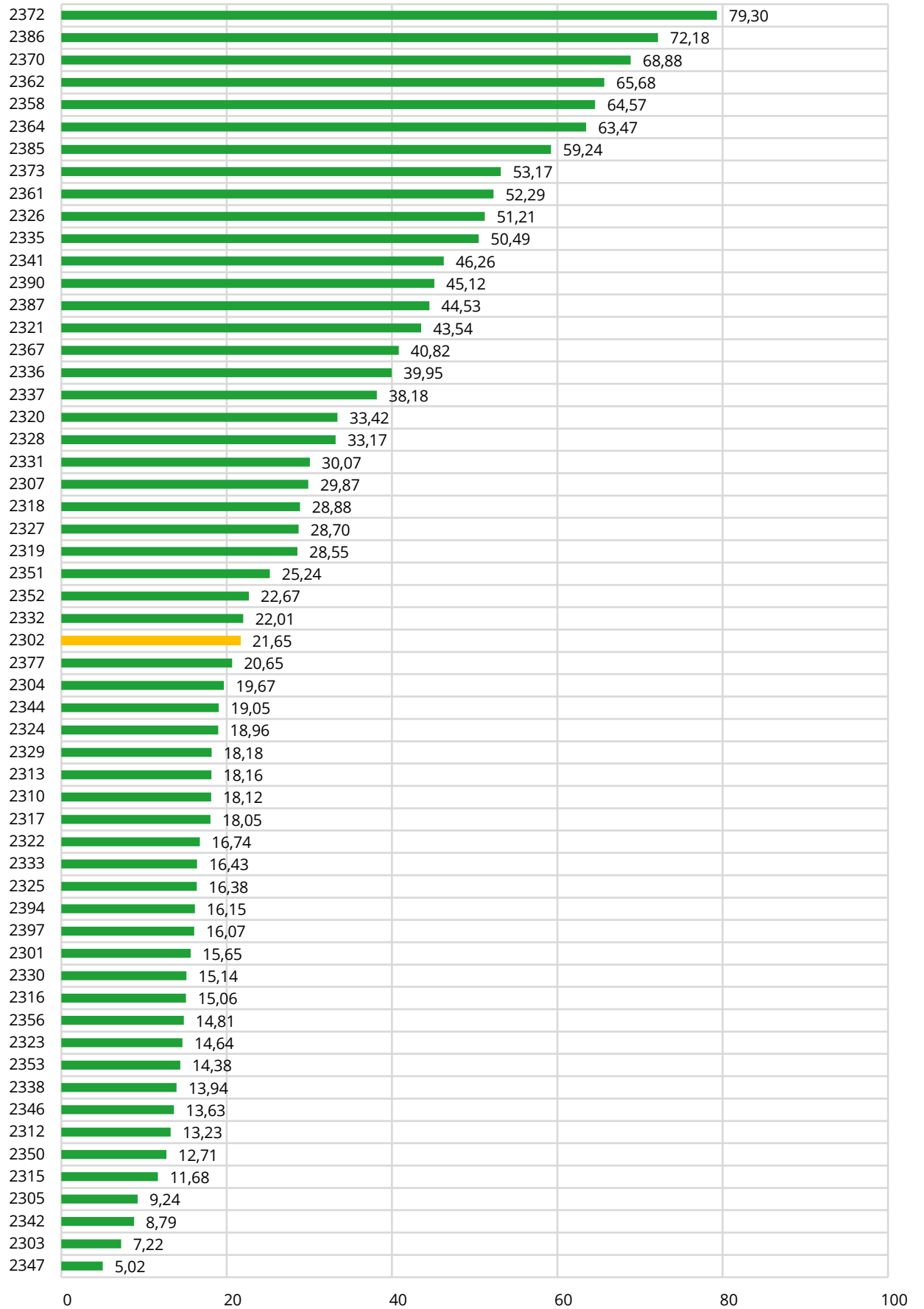
Source: Author's own calculations.

Figure 7. Hours share of labor by age group across industries in 2018



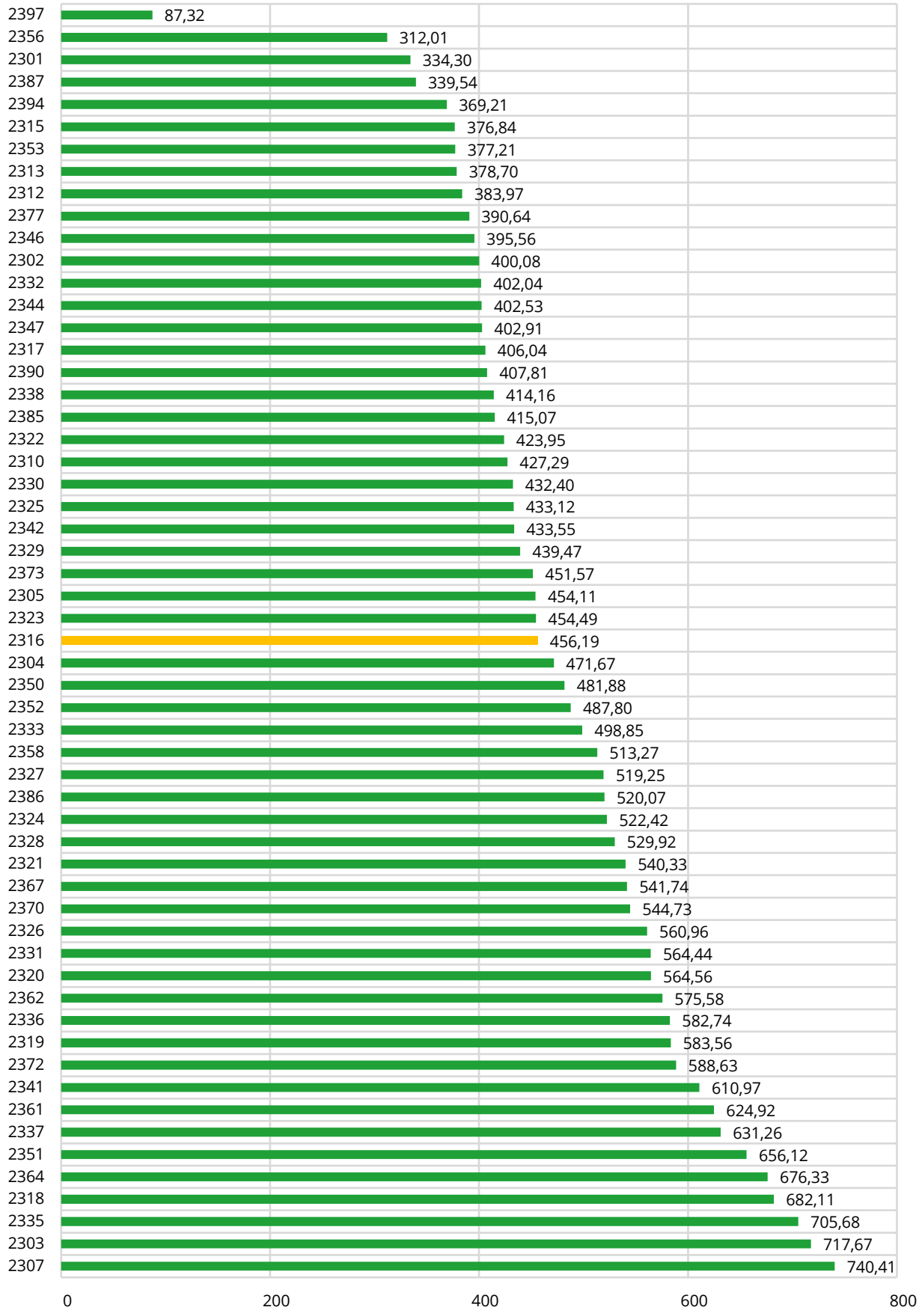
Source: Author's own calculations.

Figure 8. Hours share of labor with tertiary education (both lower and higher degree) across industries in 2018 (%)



Source: Author's own calculations.

Figure 9. Compensation per hour by industry in 2018 (NOK/hour)



Source: Author's own calculations.

(Business services), KNR2387 (Nursing and care services, kindergartens and AKS), and KNR2362 (Services related to ICT and information services).

Besides sex and age, educational attainment level is another important quality characteristic selected in the paper. Figure 8 displays the percentage share of hours worked by workers with tertiary education (both lower and higher degree) in each of the 57 industries in the market economy of mainland Norway in 2018. The minimum share is 5.02 per cent for KNR2347 (Freight transport by road), while the maximum share is 79.30 per cent for KNR2372 (Research and Development). The median share is 21.65 per cent for KNR2302 (Forestry). The industries with the tertiary education share larger than 60% are, by descending order in value, KNR2372 (Research and Development), KNR2386 (Health services), KNR2370 (Technical consulting, auditing, etc.), KNR2362 (Services related to ICT and information services), KNR2358 (Publishing), and KNR2364 (Financing and insurance activities). All these industries demand workers with higher education and long training.

On the other hand, a few industries with less than 10% hours from workers with tertiary education in 2018 are, by ascending order in value, KNR2347 (Freight transport by road), KNR2303 (Fishing), KNR2342 (Construction activities), and KNR2305 (Mining and quarrying), reflecting that there was relatively low education threshold for entering these industries.

In Figure 9, average compensation per hour for each of the 57 industries in the market economy of mainland Norway in 2018 is reported. The range of average industry compensation per hour is from 87.32 NOK/hour for KNR2397 (Paid work in private households) to 740.41 NOK/hour for KNR2307 (Service activities incidental to oil and gas). The median is 456.19 NOK/hour for KNR2316 (Manufacture of paper and paper products).

In Table 6, we have reported the average compensation per hour for the market economy of mainland Norway being 453.23 NOK/hour in 2018. This is a weighted average of the industry compensation per hour as shown in Figure 9. A simple average of the industry compensation per hour as shown in Figure 9 is 484.91 NOK/hour. The industries with average labor compensation per hour larger than 600 NOK/hour in 2018 are KNR2307 (Service activities incidental to oil and gas), KNR2303 (Fishing), KNR2335 (Production of electricity), KNR2318 (Manufacture of coal and refined petroleum products), KNR2364 (Financing and insurance activities), KNR2351 (Air transport), KNR2337 (Gas and hot water supply), KNR2361 (Telecommunications), and KNR2341 (Development of construction projects). The five industries with lowest average compensation per hour are, by ascending order in value, KNR2397 (Paid work in private households), KNR2356 (Accommodation and catering activities), KNR2301 (Agriculture, Hunting), KNR2387 (Nursing and care services, kindergartens and AKS), and KNR2394 (Other private services, organizations, etc.), with the last industry having compensation per hour being just half of the maximum that was enjoyed by KNR2307 (Service activities incidental to oil and gas) in 2018.

More detailed information about hours worked and compensation per hour by industry that could be further cross-classified by sex, age, and education can also be obtained from the quality-adjusted labor input datasets.

5.2. Change of labor input by industry

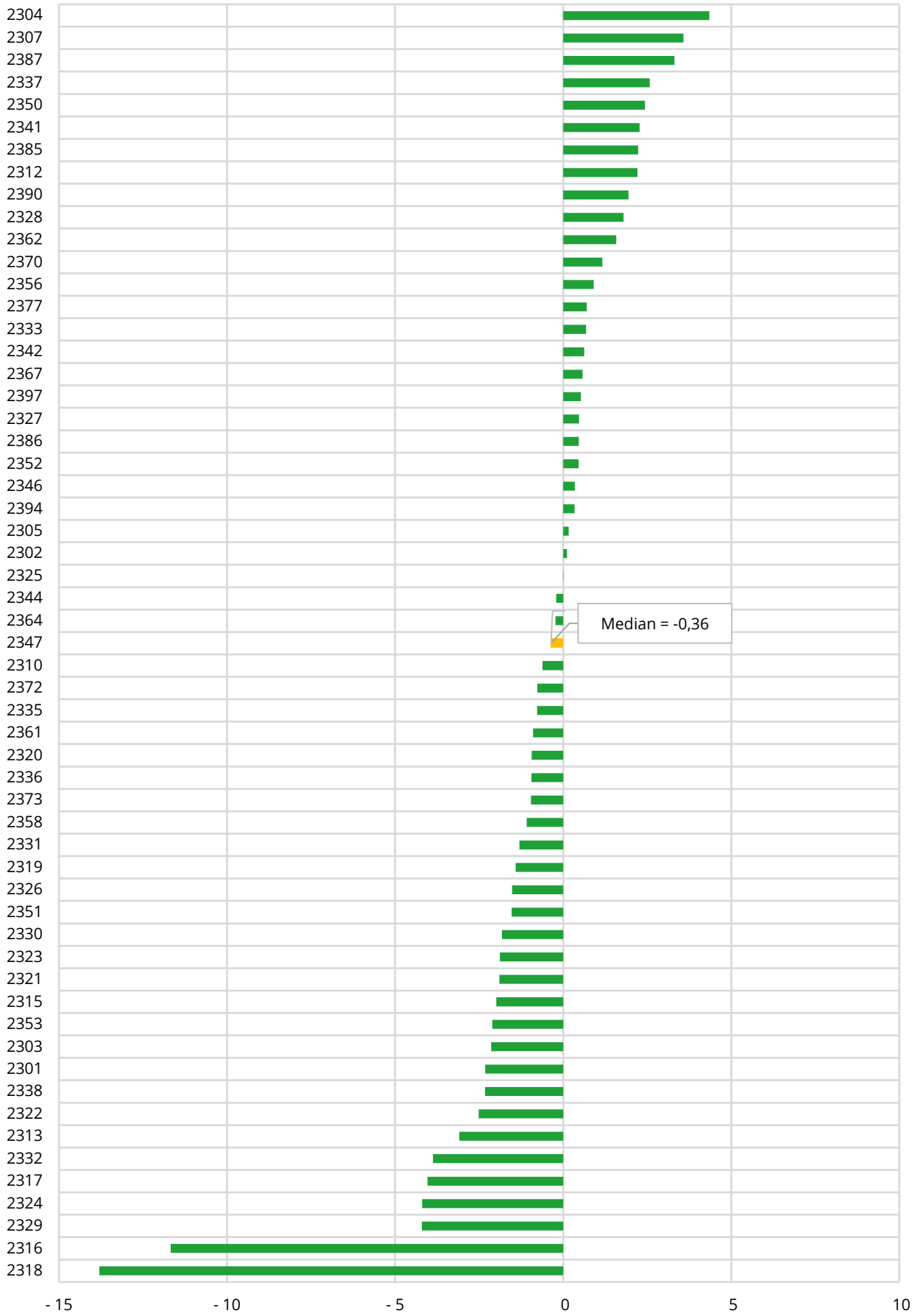
By using the indexes of industry labor input as defined in Section 2, the estimated results are reported in Table 8 for the growth rate of labor input for each of the 57 industries in the market economy of mainland Norway. The average annual growth rates both for the entire period 2008-2018 and for the two subperiods 2008-2014 and 2015-2018, as well as the change between the two subperiods are reported.

Table 8. Growth of labor input by industry (%)

Industry	2008-2018	2008-2014	2015-2018	Change between 2008-2014 and 2015-2018
2301	-2.32	-3.54	0.16	3.70
2302	0.11	0.23	-0.11	-0.33
2303	-2.14	-3.20	0.01	3.22
2304	4.35	6.90	-0.58	-7.48
2305	0.17	0.08	0.34	0.26
2307	3.58	5.21	0.40	-4.81
2310	-0.62	-1.11	0.39	1.50
2312	2.21	3.22	0.21	-3.01
2313	-3.09	-4.45	-0.32	4.13
2315	-1.99	-3.01	0.09	3.11
2316	-11.67	-17.19	0.50	17.69
2317	-4.03	-5.84	-0.31	5.53
2318	-13.80	-19.40	-1.40	18.00
2319	-1.41	-2.24	0.27	2.52
2320	-0.94	-0.89	-1.03	-0.13
2321	-1.90	-2.82	-0.04	2.78
2322	-2.52	-3.96	0.45	4.41
2323	-1.89	-2.83	0.03	2.87
2324	-4.20	-6.31	0.17	6.48
2325	0.00	-0.13	0.27	0.41
2326	-1.52	-2.20	-0.13	2.07
2327	0.47	0.47	0.46	-0.01
2328	1.80	2.59	0.23	-2.36
2329	-4.21	-6.42	0.37	6.78
2330	-1.82	-3.72	2.08	5.79
2331	-1.30	-1.36	-1.19	0.17
2332	-3.87	-5.87	0.25	6.12
2333	0.68	0.92	0.21	-0.72
2335	-0.78	-1.06	-0.20	0.87
2336	-0.94	-0.83	-1.17	-0.34
2337	2.58	4.86	-1.84	-6.70
2338	-2.33	-3.67	0.41	4.07
2341	2.27	3.39	0.07	-3.32
2342	0.63	0.81	0.26	-0.55
2344	-0.21	-0.50	0.38	0.88
2346	0.35	0.44	0.15	-0.29
2347	-0.36	-0.55	0.02	0.56
2350	2.43	3.62	0.10	-3.52
2351	-1.53	-2.47	0.37	2.84
2352	0.46	0.48	0.42	-0.06
2353	-2.11	-3.05	-0.21	2.84
2356	0.90	1.37	-0.03	-1.40
2358	-1.09	-1.37	-0.53	0.84
2361	-0.90	-1.57	0.46	2.02
2362	1.58	2.80	-0.81	-3.61
2364	-0.23	-0.26	-0.18	0.08
2367	0.58	0.67	0.38	-0.29
2370	1.16	2.02	-0.53	-2.55
2372	-0.77	-0.68	-0.95	-0.27
2373	-0.96	-1.22	-0.44	0.78
2377	0.70	1.01	0.08	-0.94
2385	2.23	3.70	-0.63	-4.33
2386	0.46	0.72	-0.05	-0.76
2387	3.31	4.83	0.33	-4.51
2390	1.94	3.08	-0.30	-3.38
2394	0.34	0.26	0.51	0.26
2397	0.52	1.59	-1.57	-3.16
Mean	-0.73	-1.03	-0.07	0.96
Median	-0.36	-0.55	0.08	0.26

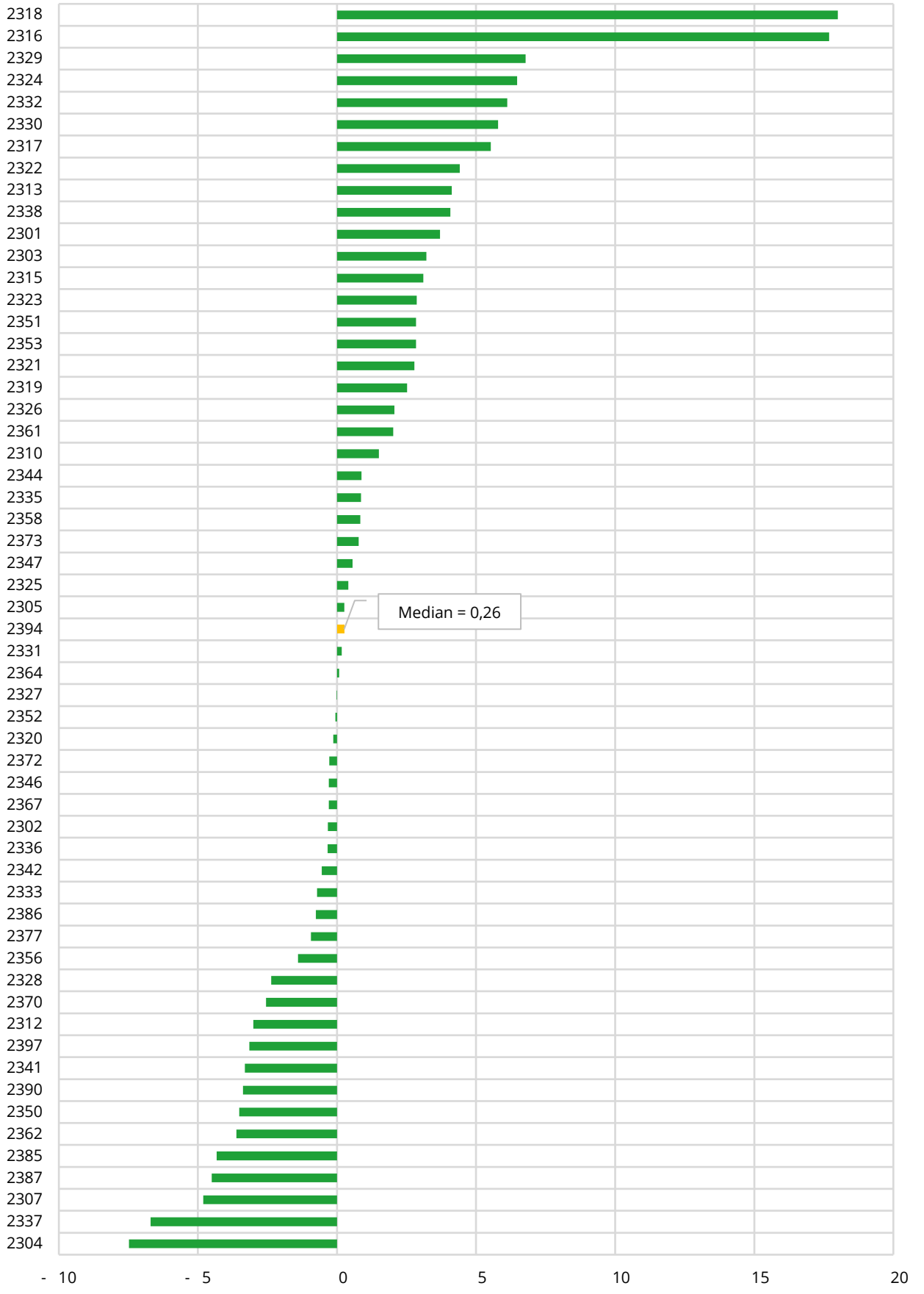
Source: Author's own calculations. Note: Average annual growth rates for 2008-2018 is a geometric mean of those of 2008-2014 and 2015-2018.

Figure 10. Growth in labor input by industry (%), 2008-2018



Source: Author's own calculations. Note: Average annual growth rates for 2008-2018 is a geometric mean of those of 2008-2014 and 2015-2018.

Figure 11. Change in labor input growth (%), 2015-2018 less 2008-2014



Source: Author's own calculations.

Figure 10 displays the percentage annual average growth rate in labor input by industry over the period 2008-2018. The change of the labor input growth rate between the two subperiods 2008-2014 and 2015-2018 by industry is displayed in Figure 11. The percentage annual average growth rate in labor input by industry over the subperiod 2008-2014 is reported in Figure B1, and that over the subperiod 2015-2018 in Figure B2 in Appendix B.

The median value in Figure 10 is -0.36 per cent for KNR2347 (Freight transport by road), indicating that there are relatively more industries having negative growth rates over the entire period 2008-2018. On the contrary, the median value in Figure 11 is 0.26 per cent for KNR2394 (Other private services, organizations, etc.), implying that more industries have accelerated labor input growth (or reduced labor input decrease) between the two subperiods 2008-2014 and 2015-2018.

It is interesting to observe that the four industries with largest growth rates over the period 2008-2018 are those having least growth changes over the two subperiods 2008-2014 and 2015-2018, they are KNR2304 (Aquaculture), KNR2307 (Service activities incidental to oil and gas), KNR2387 (Nursing and care services, kindergartens and AKS), and KNR2337(Gas and hot water supply). On the other hand, the four industries with least growth rates over the entire period are those having largest growth changes over the two subperiods, they are KNR2318 (Manufacture of coal and refined petroleum products), KNR2316 (Manufacture of paper and paper products), KNR2329 (Manufacture of motor vehicles and vehicles etc.), and KNR2324 (Manufacture of basic metals).

All these observations point to that something must have happened with these industries over the two subperiods 2008-2014 and 2015-2018. However, to understand whether it is due to real changes or just due to data quality deficiency, further investigation is needed. For instance, a preliminary examination on the two industries with largest growth changes, i.e., KNR2318 and KNR2316, shows that KNR2318 experienced two abnormal decreases of labor input by around 70 per cent over 2008-2009 and 13 per cent over 2010-2011; while for KNR2316, its value-added seemed to be less than labor compensation over the period 2009-2011.

Using the indexes of industry labor input as defined in Section 2, Table 9 presents the growth rate of labor input from workers with tertiary education (both lower and higher degree) for each of the 57 industries in the market economy of mainland Norway. The average annual growth rates both for the entire period 2008-2018 and for the two subperiods 2008-2014 and 2015-2018, as well as the change between the two subperiods are also reported in Table 9.

Figure 12 displays the percentage annual average growth rate in labor input from workers with tertiary education (both lower and higher degree) by industry over the period 2008-2018. The change of the growth rate between the two subperiods 2008-2014 and 2015-2018 by industry is displayed in Figure 13.

The median value in Figure 12 is 0.72 per cent for KNR2397 (Paid work in private households), and only four out of total 57 industries had negative growth rates over 2008-2018, they are, by ascending order in value, KNR2318 (Manufacture of coal and refined petroleum products), KNR2316 (Manufacture of paper and paper products), KNR2321 (Pharmaceutical raw materials and preparations), and KNR2351 (Air transport).

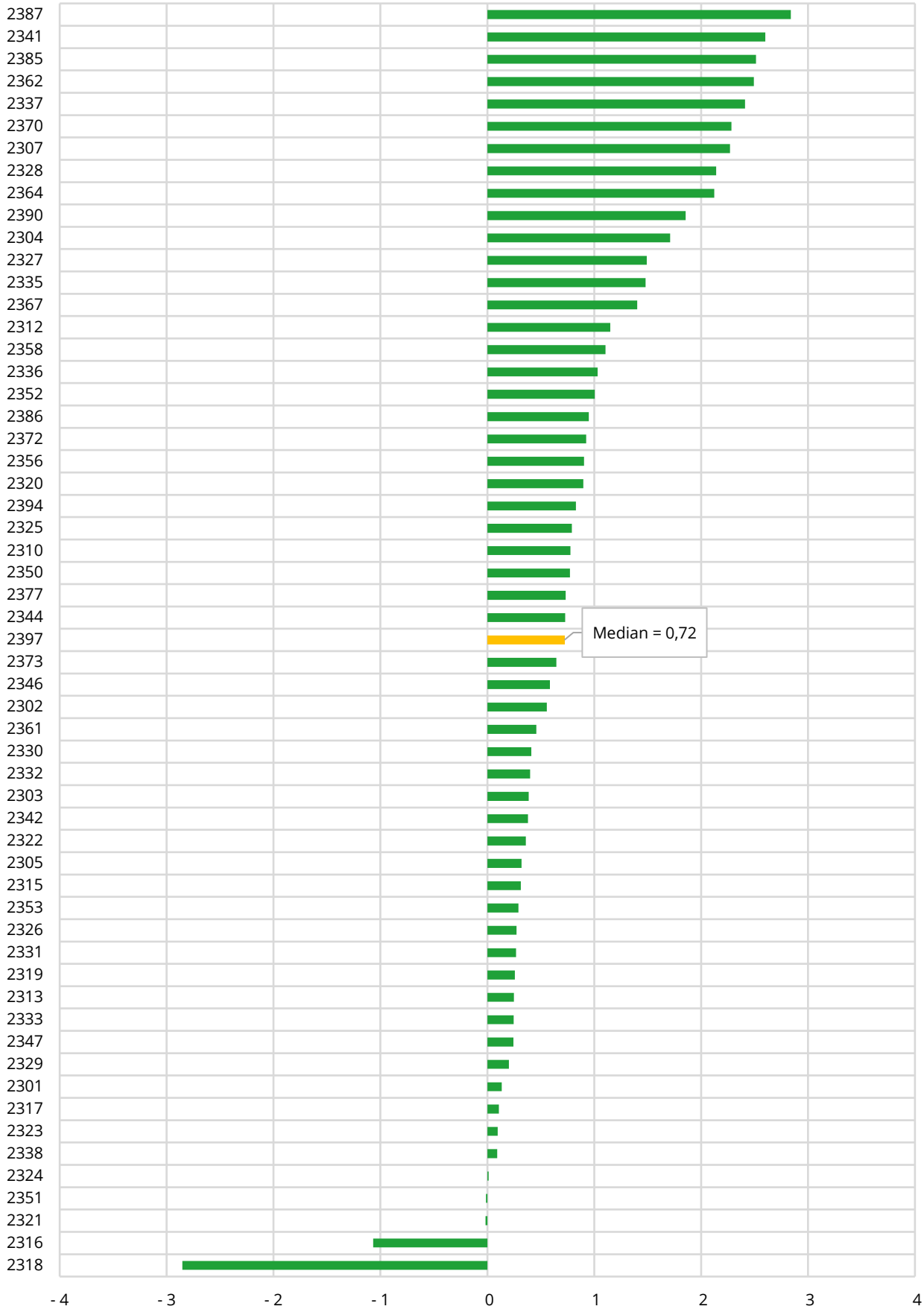
The median value in Figure 13 is 0.70 per cent for KNR2377 (Business services), and forty-eight out of total 57 industries have accelerated labor input growth (or reduced labor input decrease) between the two subperiods 2008-2014 and 2015-2018. Clearly, having more and more labor input from workers with tertiary education does not concentrate on a few industries, on the contrary, it is a widely observed phenomena over the period 2008-2018 in the market economy of mainland Norway.

Table 9. Growth of labor input with tertiary education (both lower and higher degree) by industry (%)

Industry	2008-2018	2008-2014	2015-2018	Change between 2008-2014 and 2015-2018
2301	0.13	-0.01	0.42	0.42
2302	0.56	0.74	0.18	-0.57
2303	0.39	0.15	0.86	0.71
2304	1.71	2.03	1.07	-0.96
2305	0.32	0.17	0.62	0.45
2307	2.27	2.41	1.99	-0.41
2310	0.78	0.53	1.27	0.74
2312	1.15	1.44	0.56	-0.88
2313	0.25	-0.37	1.50	1.87
2315	0.31	0.06	0.81	0.75
2316	-1.07	-2.84	2.57	5.41
2317	0.11	-0.48	1.29	1.77
2318	-2.85	-5.16	1.92	7.08
2319	0.26	-0.72	2.24	2.96
2320	0.90	0.67	1.36	0.69
2321	-0.02	-1.10	2.18	3.27
2322	0.36	-0.06	1.20	1.26
2323	0.10	-0.19	0.68	0.87
2324	0.01	-0.82	1.70	2.53
2325	0.79	0.79	0.79	0.01
2326	0.27	-0.53	1.91	2.44
2327	1.49	1.42	1.63	0.21
2328	2.14	2.73	0.98	-1.74
2329	0.20	-0.51	1.65	2.16
2330	0.41	0.22	0.79	0.56
2331	0.27	1.18	-1.53	-2.71
2332	0.40	-0.20	1.60	1.80
2333	0.25	0.41	-0.08	-0.48
2335	1.48	0.54	3.39	2.86
2336	1.03	0.48	2.15	1.67
2337	2.41	2.77	1.69	-1.08
2338	0.09	-0.44	1.17	1.61
2341	2.60	2.65	2.50	-0.15
2342	0.38	0.32	0.50	0.18
2344	0.73	0.37	1.44	1.07
2346	0.58	0.52	0.70	0.18
2347	0.24	0.23	0.26	0.03
2350	0.77	0.72	0.88	0.17
2351	-0.01	-0.63	1.25	1.88
2352	1.00	0.78	1.44	0.66
2353	0.29	-0.05	0.98	1.03
2356	0.91	0.85	1.02	0.17
2358	1.11	0.31	2.71	2.40
2361	0.46	-0.58	2.56	3.14
2362	2.49	2.13	3.22	1.09
2364	2.12	1.20	4.00	2.80
2367	1.40	1.04	2.14	1.10
2370	2.28	2.07	2.71	0.64
2372	0.93	-0.12	3.04	3.15
2373	0.64	-0.05	2.05	2.11
2377	0.73	0.50	1.20	0.70
2385	2.51	2.59	2.36	-0.24
2386	0.95	0.85	1.16	0.31
2387	2.84	3.00	2.51	-0.49
2390	1.86	2.32	0.94	-1.38
2394	0.83	0.75	0.99	0.24
2397	0.72	0.52	1.13	0.61
Mean	0.81	0.48	1.48	0.99
Median	0.72	0.48	1.29	0.70

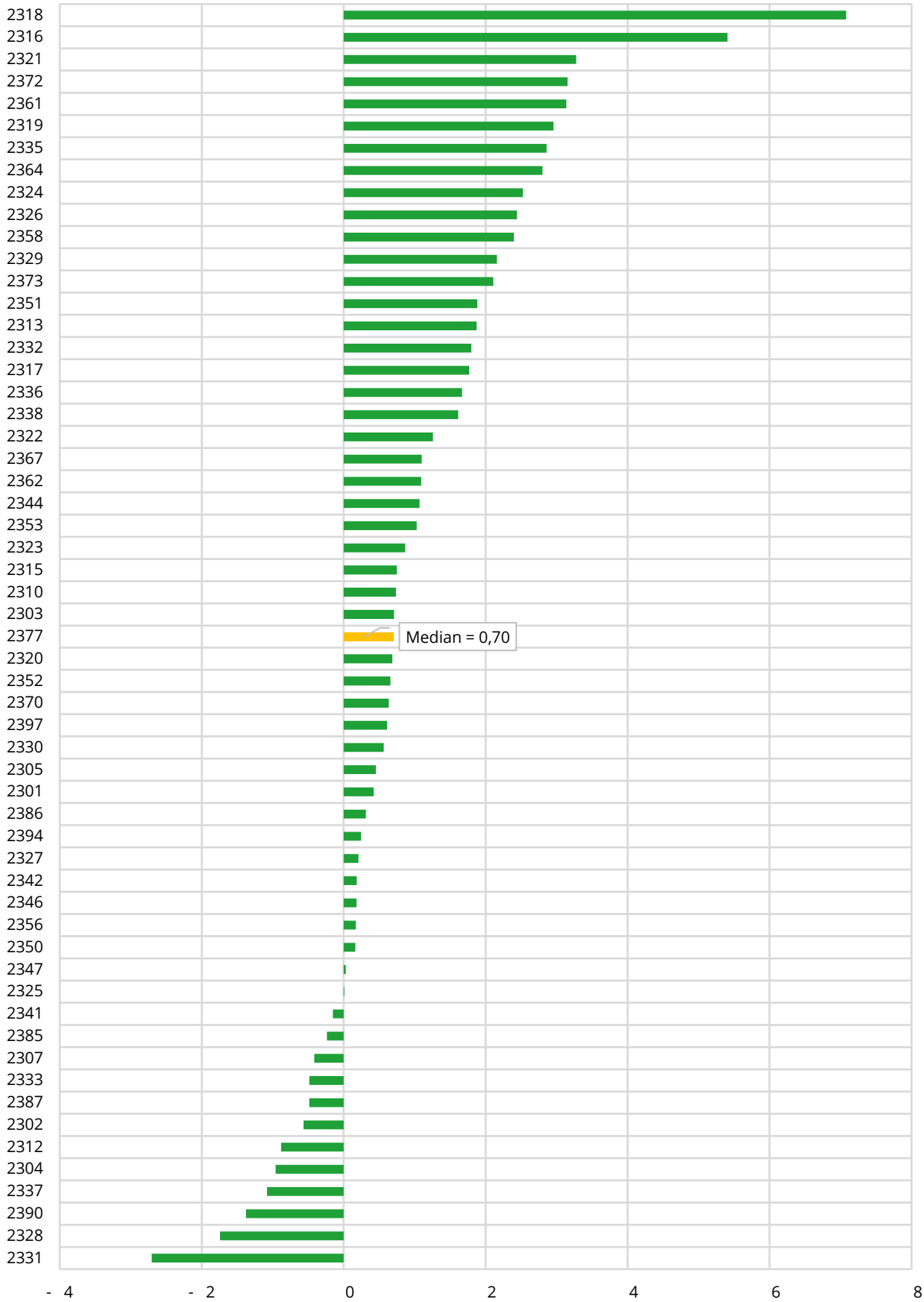
Source: Author's own calculations. Note: Average annual growth rates for 2008-2018 is a geometric mean of those of 2008-2014 and 2015-2018.

Figure 12. Growth of labor input with tertiary education (both lower and higher degree) by industry (%), 2008-2018



Source: Author's own calculations. Note: Average annual growth rates for 2008-2018 is a geometric mean of those of 2008-2014 and 2015-2018.

Figure 13. Change in growth of labor input with tertiary education (both low and high degree) by industry (%), 2015-2018 less 2008-2014



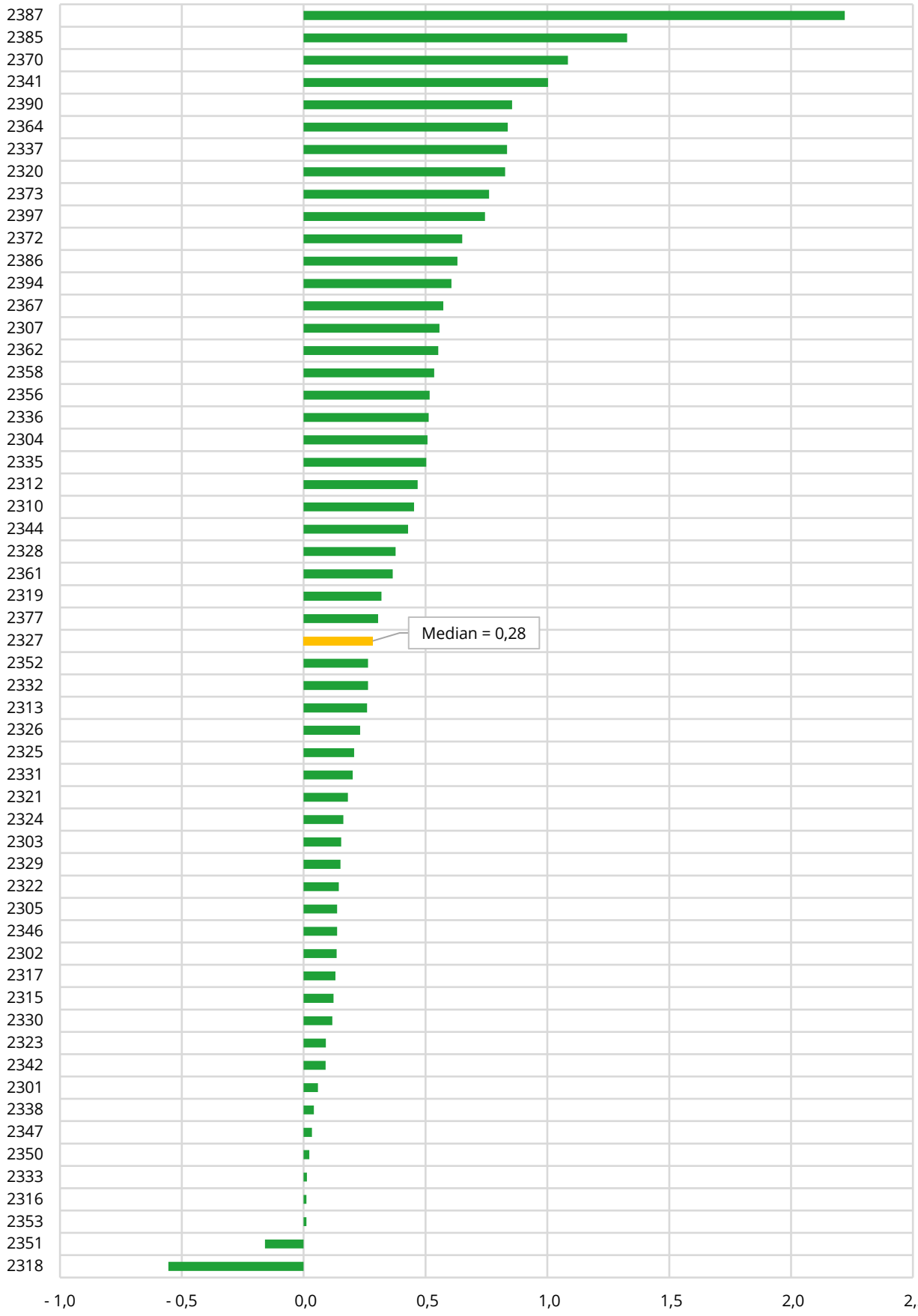
Source: Author's own calculations.

Table 10. Growth of female labor input with tertiary education (both lower and higher degree) by industry (%)

Industry	2008-2018	2008-2014	2015-2018	Change between 2008-2014 and 2015-2018
2301	0.06	-0.02	0.22	0.25
2302	0.14	0.16	0.09	-0.06
2303	0.15	0.11	0.24	0.12
2304	0.51	0.43	0.66	0.23
2305	0.14	0.13	0.15	0.02
2307	0.56	0.68	0.31	-0.37
2310	0.45	0.37	0.61	0.24
2312	0.47	0.61	0.18	-0.43
2313	0.26	0.06	0.66	0.61
2315	0.12	0.06	0.26	0.20
2316	0.01	-0.46	0.96	1.43
2317	0.13	-0.11	0.62	0.73
2318	-0.56	-1.15	0.65	1.81
2319	0.32	0.09	0.79	0.70
2320	0.83	0.84	0.80	-0.04
2321	0.18	-0.45	1.45	1.89
2322	0.14	0.11	0.22	0.11
2323	0.09	0.00	0.27	0.27
2324	0.16	-0.09	0.66	0.74
2325	0.21	0.21	0.21	0.00
2326	0.23	0.16	0.37	0.21
2327	0.28	0.27	0.31	0.04
2328	0.38	0.59	-0.05	-0.65
2329	0.15	0.02	0.42	0.40
2330	0.12	0.11	0.14	0.03
2331	0.20	0.61	-0.62	-1.23
2332	0.26	-0.02	0.83	0.85
2333	0.01	0.08	-0.11	-0.19
2335	0.50	0.30	0.92	0.62
2336	0.51	0.31	0.92	0.60
2337	0.83	0.87	0.77	-0.10
2338	0.04	-0.18	0.49	0.67
2341	1.00	1.01	1.00	-0.01
2342	0.09	0.06	0.15	0.08
2344	0.43	0.28	0.72	0.44
2346	0.14	0.11	0.19	0.08
2347	0.03	0.01	0.07	0.06
2350	0.02	-0.04	0.14	0.18
2351	-0.16	-0.40	0.33	0.73
2352	0.26	0.22	0.36	0.14
2353	0.01	-0.12	0.27	0.38
2356	0.52	0.51	0.53	0.02
2358	0.54	0.21	1.19	0.98
2361	0.37	0.14	0.82	0.68
2362	0.55	0.40	0.86	0.46
2364	0.84	0.52	1.47	0.94
2367	0.57	0.44	0.84	0.40
2370	1.08	0.95	1.36	0.41
2372	0.65	0.25	1.45	1.20
2373	0.76	0.45	1.39	0.94
2377	0.31	0.21	0.50	0.29
2385	1.33	1.23	1.51	0.28
2386	0.63	0.38	1.13	0.74
2387	2.22	2.27	2.13	-0.13
2390	0.86	0.89	0.79	-0.09
2394	0.61	0.56	0.70	0.14
2397	0.74	0.78	0.67	-0.12
Mean	0.39	0.28	0.61	0.33
Median	0.28	0.21	0.62	0.24

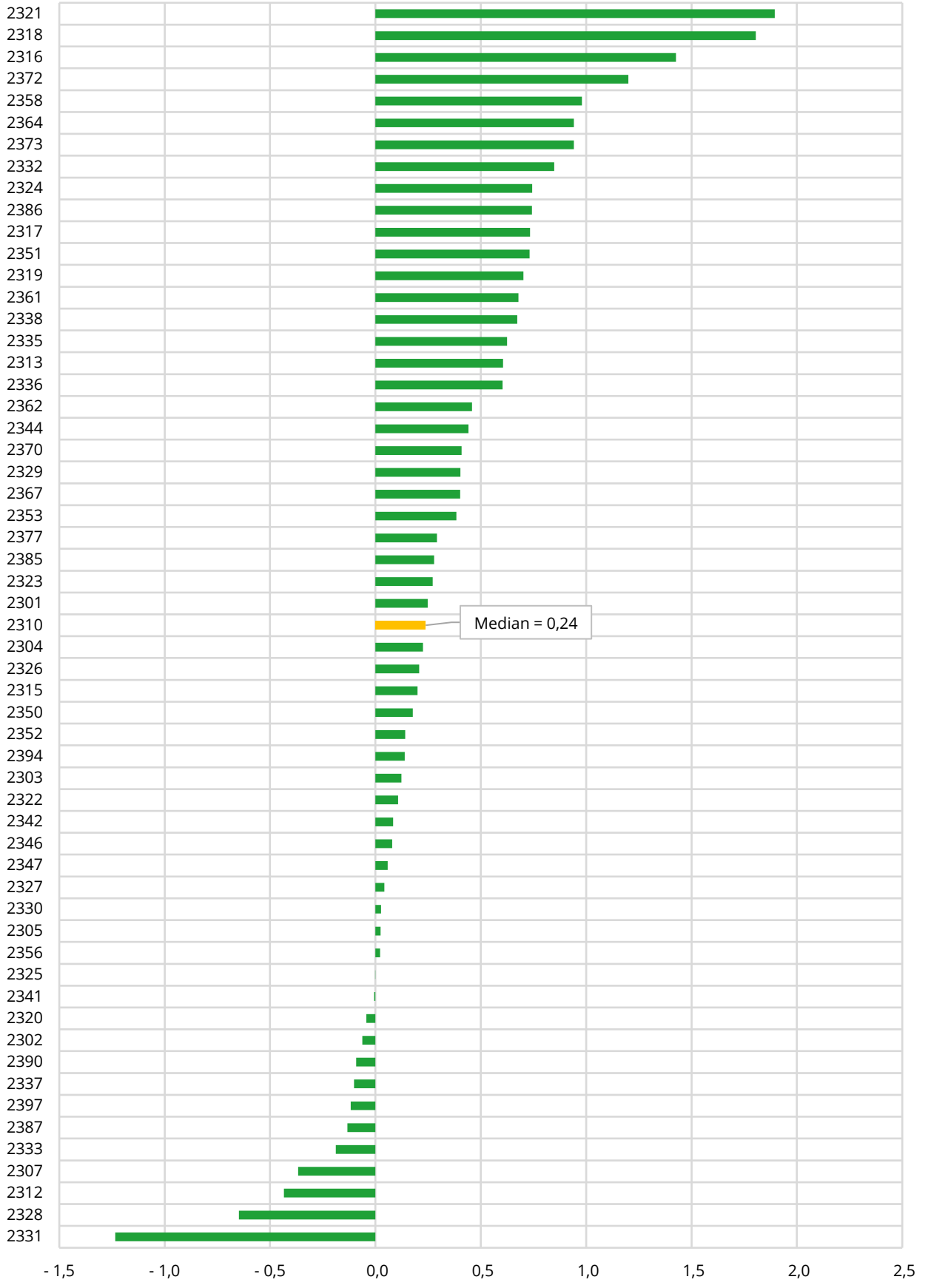
Source: Author's own calculations. Note: Average annual growth rates for 2008-2018 is a geometric mean of those of 2008-2014 and 2015-2018.

Figure 14. Growth of female labor input with tertiary education (both lower and higher degree) by industry (%), 2008-2018



Source: Author's own calculations. Note: Average annual growth rates for 2008-2018 is a geometric mean of those of 2008-2014 and 2015-2018.

Figure 15. Change in growth of female labor input with tertiary education (both lower and higher degree) by industry (%), 2015-2018 less 2008-2014



Source: Author's own calculations.

By applying the indexes of industry labor input as defined in Section 2, Table 10 presents the growth rate of labor input from female workers with tertiary education (both lower and higher degree) for each of the 57 industries in the market economy of mainland Norway. The average annual growth rates both for the entire period 2008-2018 and for the two subperiods 2008-2014 and 2015-2018, as well as the change between the two subperiods are also reported in Table 10.

Figure 14 displays the percentage annual average growth rate in labor input from female workers with tertiary education (both lower and higher degree) by industry over the period 2008-2018. The change of the growth rate between the two subperiods 2008-2014 and 2015-2018 by industry is displayed in Figure 15.

The median value in Figure 14 is 0.28 per cent for KNR2327 (Manufacture of electrical equipment), and only two out of total 57 industries had negative growth rates over 2008-2018, they are, by ascending order in value, KNR2318 (Manufacture of coal and refined petroleum products), and KNR2351 (Air transport). The median value in Figure 15 is 0.24 per cent for KNR2310 (Food, beverage and tobacco industry), and forty-five out of total 57 industries had accelerated labor input growth (or reduced labor input decrease) between the two subperiods 2008-2014 and 2015-2018. Clearly, having more and more labor input from female workers with tertiary education did not concentrate on a few industries, on the contrary, it is a widely observed phenomena over the period 2008-2018.

However, by comparing Table 10 with Table 9 (see last two rows in tables), both the mean and median values of the growth rates over the period 2008-2018, as well as of the growth changes between the two subperiods 2015-2018 and 2008-2014, for females are less than those for males and females combined, implying that hours worked by male workers with tertiary education had grown even faster than those by their female counterparts over the observed periods in the market economy of mainland Norway.

In Appendix B, the growth rate of labor input from workers with lower degree tertiary education for each of the 57 industries in the market economy of mainland Norway is presented in Table B1. The average annual growth rates both for the entire period 2008-2018 and for the two subperiods 2008-2014 and 2015-2018, as well as the change between the two subperiods are also reported in Table B1. Similar information for workers with higher degree tertiary education are presented in Table B2, and those for female workers with lower degree tertiary education, as well as female workers with higher degree tertiary education, are reported in Table B3 and Table B4 in Appendix B, respectively.

5.3. Change of labor quality by industry

Applying the indexes of industry labor quality as defined in Section 2, Table 11 reports the estimated results for the growth rate of labor quality for each of the 57 industries in the market economy of mainland Norway. The average annual growth rates both for the entire period 2008-2018 and for the two subperiods 2008-2014 and 2015-2018, as well as the change between the two subperiods are reported.

Figure 16 displays the percentage annual average growth rate of labor quality in each of the 57 industries over the period 2008-2018. The change of the growth rate between the two subperiods 2008-2014 and 2015-2018 by industry is displayed in Figure 17. The percentage annual average growth rate in labor quality by industry over the subperiod 2008-2014 is displayed in Figure C1, and that over the subperiod 2015-2018 in Figure C2 in Appendix C.

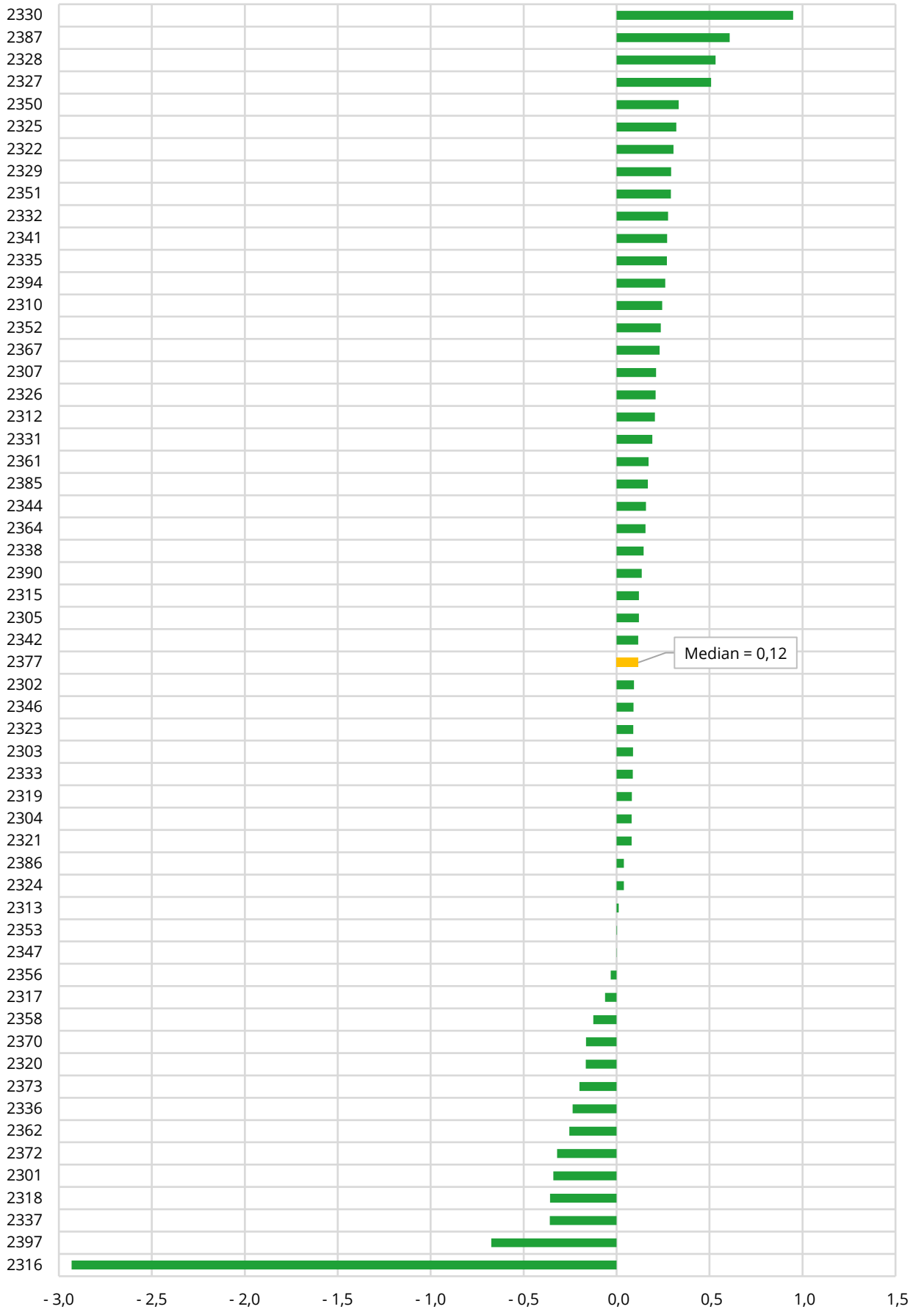
The median value in Figure 16 is 0.12 per cent for KNR2377 (Business services), and forty-three out of total 57 industries had positive growth rates over 2008-2018. The median value in Figure 17 is 0.00 per cent for KNR2341 (Development of construction projects), implying that the number of industries having accelerated labor quality growth (or reduced labor quality decrease) is about the

Table 11. Growth of labor quality by industry (%)

Industry	2008-2018	2008-2014	2015-2018	Change between 2008-2014 and 2015-2018
2301	-0.34	-0.60	0.18	0.77
2302	0.09	0.16	-0.04	-0.21
2303	0.09	0.12	0.02	-0.10
2304	0.08	0.13	-0.01	-0.13
2305	0.12	0.00	0.36	0.36
2307	0.21	0.07	0.50	0.43
2310	0.25	0.17	0.40	0.23
2312	0.21	0.20	0.22	0.03
2313	0.01	0.02	-0.01	-0.04
2315	0.12	0.12	0.11	-0.01
2316	-2.93	-4.66	0.62	5.28
2317	-0.06	0.03	-0.25	-0.28
2318	-0.36	0.16	-1.38	-1.54
2319	0.08	-0.03	0.30	0.33
2320	-0.17	0.25	-0.99	-1.24
2321	0.08	0.09	0.06	-0.03
2322	0.31	0.23	0.45	0.22
2323	0.09	0.08	0.10	0.02
2324	0.04	-0.03	0.18	0.21
2325	0.32	0.32	0.33	0.02
2326	0.21	0.23	0.17	-0.06
2327	0.51	0.48	0.56	0.08
2328	0.53	0.51	0.58	0.08
2329	0.29	0.24	0.40	0.16
2330	0.95	0.30	2.26	1.96
2331	0.19	0.55	-0.51	-1.06
2332	0.28	0.29	0.25	-0.04
2333	0.09	0.02	0.21	0.19
2335	0.27	0.37	0.08	-0.29
2336	-0.24	0.20	-1.11	-1.32
2337	-0.36	0.06	-1.20	-1.26
2338	0.14	-0.01	0.45	0.46
2341	0.27	0.27	0.27	0.00
2342	0.12	0.02	0.31	0.29
2344	0.16	0.05	0.38	0.34
2346	0.09	0.05	0.16	0.11
2347	0.00	-0.03	0.07	0.11
2350	0.33	0.37	0.26	-0.11
2351	0.29	0.23	0.41	0.18
2352	0.24	0.15	0.42	0.27
2353	0.00	0.07	-0.14	-0.21
2356	-0.03	-0.06	0.03	0.09
2358	-0.12	0.07	-0.51	-0.58
2361	0.17	-0.04	0.59	0.63
2362	-0.25	-0.08	-0.60	-0.52
2364	0.15	0.32	-0.17	-0.48
2367	0.23	0.15	0.40	0.25
2370	-0.16	0.00	-0.48	-0.48
2372	-0.32	-0.04	-0.87	-0.83
2373	-0.20	-0.11	-0.38	-0.27
2377	0.12	0.02	0.31	0.28
2385	0.17	0.53	-0.55	-1.07
2386	0.04	0.08	-0.04	-0.12
2387	0.61	0.71	0.40	-0.31
2390	0.14	0.32	-0.23	-0.55
2394	0.26	0.13	0.52	0.38
2397	-0.67	-0.23	-1.56	-1.34
Mean	0.05	0.05	0.04	-0.01
Median	0.12	0.12	0.17	0.00

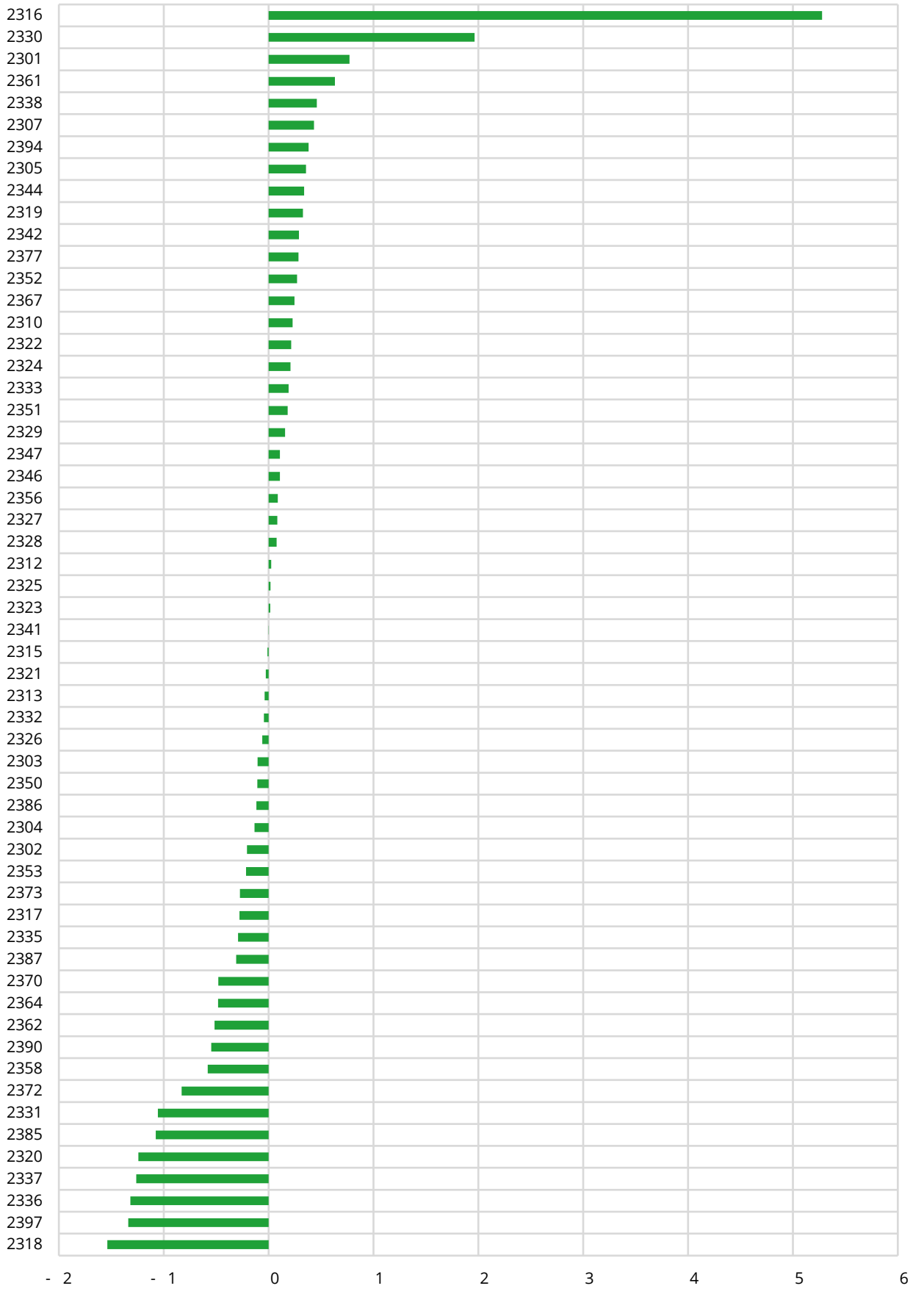
Source: Author's own calculations. Note: Average annual growth rates for 2008-2018 is a geometric mean of those of 2008-2014 and 2015-2018.

Figure 16. Growth in labor quality by industry (%), 2008-2018



Source: Author's own calculations. Note: Average annual growth rates for 2008-2018 is a geometric mean of those of 2008-2014 and 2015-2018.

Figure 17. Change in labor quality growth (%), 2015-2018 less 2008-2014



Source: Author's own calculations.

same as that of industries having decreased labor quality growth (or increased change rate of labor quality reduction) between the two subperiods 2008-2014 and 2015-2018.

By comparing Table 11 with Table 8 (see last two rows in tables), both the mean and median values of the labor quality growth rates are, though in small magnitude, positive and larger than those of the labor input growth rates over the same periods, the latter being all negative except for the median value during the subperiod 2015-2018. However, both the mean and median values of the labor quality growth change are less than those of the labor input growth change between the two subperiods 2008-2014 and 2015-2018. As a matter of fact, the former values are nearly zero in magnitude.

For those interested in more detailed information, analyses can be further made by applying the quality-adjusted labor input data, for instance, to show the labor input and/or labor quality growth of workers with higher education and in a certain age group by industry, or more generally, of workers with a variety of cross-classified quality characteristics of the labor force in the market economy of mainland Norway over the observed years.

6. Conclusions

This paper aims to demonstrate how the quality-adjusted labor input data can be applied for economic analysis in general, and for growth accounting practice in particular, by means of examples.

Using the recently compiled quality-adjusted labor input dataset for the period 2015-2018, combined with previous one for the period 2008-2014, the paper showcases the use of the quality-adjusted labor input data for improving the estimation of multifactor productivity indicators, and for restoring the internal consistency of measuring labor productivity across aggregation levels in the Norwegian national accounts.

By constructing meaningful indexes of labor input and quality, at both aggregate and industry level, the paper also shows the application of these indexes for identifying and understanding the growth of labor input and quality over the period 2008-2018, as well as the change of growth over the two subperiods 2008-2014 and 2015-2018, in the market economy of mainland Norway.

Plenty of interesting results are derived by means of the quality-adjusted labor input data in this paper. However, it is the methodologies, rather than the derived results *per se*, that are the focus of this paper. Given that the quality-adjusted labor input data for the two subperiods 2008-2014 and 2015-2018 are two different vintages, the estimated results, esp. those regarding the comparison of the two subperiods, should be interpreted with due caution.

Nonetheless, several general patterns appear to be informing. For instance, education had become the dominant factor in improving the quality of labor force. In addition, quality enhancement in labor input had been a wide-spread phenomenon across the industries in the market economy of mainland Norway over the observed period 2008-2018.

Moreover, some estimated results are also signaling the need for checking the quality of original data. For instance, for a number of industries over several years, value-added are found to be less than labor compensation, which merits further investigation.

It is worth mentioning that the application examples of the quality-adjusted labor input data as presented in this paper are never meant to be exhaustive. In fact, such data are important statistics *per se* that can be used widely for addressing many interesting issues. Here are just two more examples: such data can be applied for analyzing new job creation related to digital economy and globalization, and for forecasting the composition of labor force by quality characteristics in the future.

Given the crucial importance of the quality-adjusted labor input data, we conclude that it is time for Statistics Norway to compile and publish such data together with other official statistics in the Statbank on a more regular basis.

References

Ahmad, N., F. Lequiller, P. Marianna, D. Pilat, P. Schreyer, and A. Wölfl (2003), "Comparing Labor Productivity Growth in the OECD Area: The Role of Measurement", *OECD Statistics Working Papers*, 2003/5, OECD Publishing. doi: 10.1787/838342850485

Christensen, L. R. and D. W. Jorgenson (1969), 'The Measurement of U.S. Real Capital Input, 1929-1967', *Review of Income and Wealth*, Series 15, December 1969, pp. 293-320.

Christensen, L. R. and D. W. Jorgenson (1970), 'U.S. Real Product and Real Factor Input, 1929-1967', *Review of Income and Wealth*, Series 16, March 1970, pp. 19-50.

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

Diewert, W. E. (1976), 'Exact and Superlative Index Numbers', *Journal of Econometrics* 4, no. 2 (May): 115-146.

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

Frisch, R. (1930), 'Necessary and Sufficient Conditions Regarding the Form of an Index Number which Shall Meet Certain of Fisher's Tests', *American Statistical Association Journal* 25, 397-406.

Jorgenson, D. W. (1963), 'Capital Theory and Investment Behavior', *American Economic Review*, Vol. 53, No. 2, pp. 247-259.

Jorgenson, D. W. and Z. Griliches (1967), 'The Explanation of Productivity Change', *Review of Economic Studies* 34, no. 99 (July), 249-280.

Jorgenson, D. W, M. Ho, and K. Stiroh (2005), *Productivity, Volume 3: Information Technology and the American Growth Resurgence*, The MIT Press.

Liu, G. and B.M. Fraumeni (2014), 'Human capital measurement: a bird's eye view', Chapter 3 in UNU-IHDP and UNEP, *Inclusive Wealth Report 2014: Measuring progress toward sustainability*, Cambridge: Cambridge University Press.

Liu, G. and B.M. Fraumeni (2016), 'Human capital measurement: country experiences and international initiatives', in D. W. Jorgenson, K. Fukao and M. P. Timmer (ed.), *The World Economy - Growth or Stagnation*, Cambridge University Press.

Liu, G. (2017), 'The Norwegian KLEMS Growth and Productivity Accounts 1997-2014', *Documents*, 2017/38, Statistics Norway.

Liu, G. (2018), 'Industry origins of aggregate growth in the market economy of mainland Norway 1997-2014', *Internal Documents*, 2019/11, Statistics Norway.

Liu, G. (2019), 'Structural Change and Productivity in the Market Economy of Mainland Norway: 1997-2014', *International Productivity Monitor*, No. 36, Spring, pp. 79-109.

Liu, G. (2020a), 'Growth origins and patterns in the market economy of mainland Norway, 1997-2014', Ch.9 in B. M. Fraumeni (ed.), *Measuring Economic Growth and Productivity – Foundations, KLEMS Production Models, and Extensions*, Academic Press, An imprint of Elsevier.

Liu, G. (2020b), 'On the measurement of productivity growth in the Norwegian National Accounts', *Documents*, 2020/20, Statistics Norway.

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

Ward, A., M. B. Zinni, and P. Marianna (2018), 'International productivity gaps: Are labor input measures comparable?', OECD Statistics Working Papers, 2018/99.

Appendix A: Growth accounting for selected sectors in the market economy of mainland Norway

Table A1. Growth accounting for NRLKNR_NR23IND (%)

	2015-2016	2016-2017	2017-2018	Average (2015-2018)
Value added	0.08	-1.82	8.23	2.06
Hours worked	1.90	-2.87	0.97	-0.02
Labor productivity	-1.82	1.05	7.27	2.08
Contribution from				
Other capital per hour	0.51	0.53	0.29	0.44
Hardware capital per hour	-0.33	-0.04	0.08	-0.10
Software capital per hour	0.12	0.12	-0.02	0.08
R&D capital per hour	-0.10	0.38	-0.08	0.07
Labor composition	0.36	0.09	0.16	0.21
MFP	-2.38	-0.03	6.84	1.39

Source: Author's own calculations. Note: NRLKNR_NR23IND = Industrial activities.

Table A2. Growth accounting for NR23FN_AV (%)

	2015-2016	2016-2017	2017-2018	Average (2015-2018)
Value added	3.90	12.05	3.60	6.42
Hours worked	-3.38	1.48	1.89	-0.03
Labor productivity	7.28	10.56	1.71	6.45
Contribution from				
Other capital per hour	2.69	2.17	2.44	2.43
Hardware capital per hour	-0.06	-0.04	-0.11	-0.07
Software capital per hour	0.19	0.13	0.18	0.17
R&D capital per hour	0.21	0.10	0.07	0.12
Labor composition	0.39	0.01	-0.03	0.12
MFP	3.85	8.20	-0.84	3.68

Source: Author's own calculations. Note: NR23FN_AV = Other goods production industries in mainland Norway.

Table A3. Growth accounting for NR23JORD (%)

	2015-2016	2016-2017	2017-2018	Average (2015-2018)
Value added	6.28	4.97	-10.93	0.30
Hours worked	1.82	-2.23	0.42	-0.01
Labor productivity	4.46	7.20	-11.34	0.32
Contribution from				
Other capital per hour	0.07	0.54	-0.06	0.19
Hardware capital per hour	0.00	0.02	0.00	0.01
Software capital per hour	0.00	0.00	0.00	0.00
R&D capital per hour	0.01	0.01	0.00	0.00
Labor composition	0.59	-0.33	0.13	0.13
MFP	3.79	6.97	-11.40	-0.01

Source: Author's own calculations. Note: NR23JORD = Agriculture and forestry.

Table A4. Growth accounting for NR23FISK (%)

	2015-2016	2016-2017	2017-2018	Average (2015-2018)
Value added	6.44	56.87	-2.19	20.66
Hours worked	-8.22	4.15	4.07	-0.17
Labor productivity	14.66	52.72	-6.26	20.83
Contribution from				
Other capital per hour	12.92	6.21	2.87	7.03
Hardware capital per hour	0.00	0.00	0.00	0.00
Software capital per hour	0.00	0.00	0.00	0.00
R&D capital per hour	1.66	0.52	0.37	0.80
Labor composition	0.07	0.00	-0.05	0.00
MFP	0.01	46.00	-9.45	13.00

Source: Author's own calculations. Note: NR23FISK = Fishing and aquaculture.

Table A5. Growth accounting for NR23BERG (%)

	2015-2016	2016-2017	2017-2018	Average (2015-2018)
Value added	6.61	-10.76	2.35	-0.48
Hours worked	-1.34	-1.55	2.89	-0.02
Labor productivity	7.95	-9.22	-0.53	-0.46
Contribution from				
Other capital per hour	0.99	0.23	-0.62	0.21
Hardware capital per hour	0.04	0.09	0.25	0.13
Software capital per hour	0.02	0.06	0.24	0.11
R&D capital per hour	0.11	0.10	-0.02	0.06
Labor composition	0.51	0.09	0.02	0.21
MFP	6.28	-9.79	-0.40	-1.18

Source: Author's own calculations. Note: NR23BERG = Mining and quarrying.

Table A6. Growth accounting for NR23ELGV (%)

	2015-2016	2016-2017	2017-2018	Average (2015-2018)
Value added	-7.83	15.06	8.67	5.75
Hours worked	0.77	0.01	-0.78	0.00
Labor productivity	-8.60	15.05	9.45	5.75
Contribution from				
Other capital per hour	-0.75	5.00	6.62	3.84
Hardware capital per hour	0.30	0.15	-0.26	0.04
Software capital per hour	0.82	0.48	0.68	0.66
R&D capital per hour	-0.04	0.06	0.00	0.01
Labor composition	-0.80	0.13	0.12	-0.16
MFP	-8.13	9.22	2.29	1.36

Source: Author's own calculations. Note: NR23ELGV = Electricity and district heating and gas.

Table A7. Growth accounting for NR23BOA (%)

	2015-2016	2016-2017	2017-2018	Average (2015-2018)
Value added	6.60	2.58	4.33	4.38
Hours worked	-4.60	2.35	2.25	-0.05
Labor productivity	11.20	0.23	2.08	4.43
Contribution from				
Other capital per hour	2.13	0.53	1.14	1.26
Hardware capital per hour	-0.20	-0.12	-0.11	-0.14
Software capital per hour	0.06	0.06	0.06	0.06
R&D capital per hour	0.04	0.02	0.03	0.03
Labor composition	0.81	0.01	-0.10	0.23
MFP	8.36	-0.26	1.05	2.99

Source: Author's own calculations. Note: NR23BOA = Building development and construction.

Table A8. Growth accounting for NR23FN_PT (%)

	2015-2016	2016-2017	2017-2018	Average (2015-2018)
Value added	-1.20	4.11	4.58	2.47
Hours worked	-1.28	-0.13	1.41	-0.01
Labor productivity	0.07	4.24	3.18	2.48
Contribution from				
Other capital per hour	0.39	1.00	0.47	0.62
Hardware capital per hour	-0.01	0.25	0.38	0.20
Software capital per hour	0.40	0.41	0.29	0.37
R&D capital per hour	0.11	0.23	0.06	0.13
Labor composition	-0.29	0.26	0.15	0.04
MFP	-0.52	2.09	1.83	1.12

Source: Author's own calculations. Note: NR23FN_PT = Private services in mainland Norway (excluding housing services).

Table A9. Growth accounting for NR23VAH (%)

	2015-2016	2016-2017	2017-2018	Average (2015-2018)
Value added	1.85	3.54	2.95	2.78
Hours worked	1.17	-0.49	-0.68	0.00
Labor productivity	0.68	4.02	3.63	2.78
Contribution from				
Other capital per hour	0.11	0.54	0.85	0.50
Hardware capital per hour	0.13	0.52	-0.07	0.19
Software capital per hour	0.49	0.22	0.67	0.46
R&D capital per hour	0.02	0.10	0.05	0.06
Labor composition	0.10	0.39	0.37	0.29
MFP	-0.17	2.25	1.75	1.28

Source: Author's own calculations. Note: NR23VAH = Wholesale/retail trade, repair of motor vehicles.

Table A10. Growth accounting for NR23ITR (%)

	2015-2016	2016-2017	2017-2018	Average (2015-2018)
Value added	-10.81	3.00	5.62	-1.18
Hours worked	1.98	-2.65	0.66	-0.02
Labor productivity	-12.79	5.64	4.96	-1.16
Contribution from				
Other capital per hour	-0.14	0.19	-0.02	0.01
Hardware capital per hour	-0.15	-0.03	0.01	-0.06
Software capital per hour	0.33	0.07	0.31	0.24
R&D capital per hour	0.03	0.04	0.02	0.03
Labor composition	0.26	0.13	0.09	0.17
MFP	-13.14	5.24	4.55	-1.54

Source: Author's own calculations. Note: NR23ITR = Domestic transport.

Table A11. Growth accounting for NR23IKT (%)

	2015-2016	2016-2017	2017-2018	Average (2015-2018)
Value added	0.94	3.82	8.20	4.30
Hours worked	-3.08	0.40	2.68	-0.03
Labor productivity	4.02	3.43	5.52	4.33
Contribution from				
Other capital per hour	-0.34	1.20	-0.30	0.18
Hardware capital per hour	0.12	1.03	1.04	0.73
Software capital per hour	0.78	1.65	1.25	1.23
R&D capital per hour	0.67	0.88	0.40	0.65
Labor composition	-0.97	0.20	-0.03	-0.27
MFP	3.76	-1.54	3.17	1.80

Source: Author's own calculations. Note: NR23IKT = Information and communication technology.

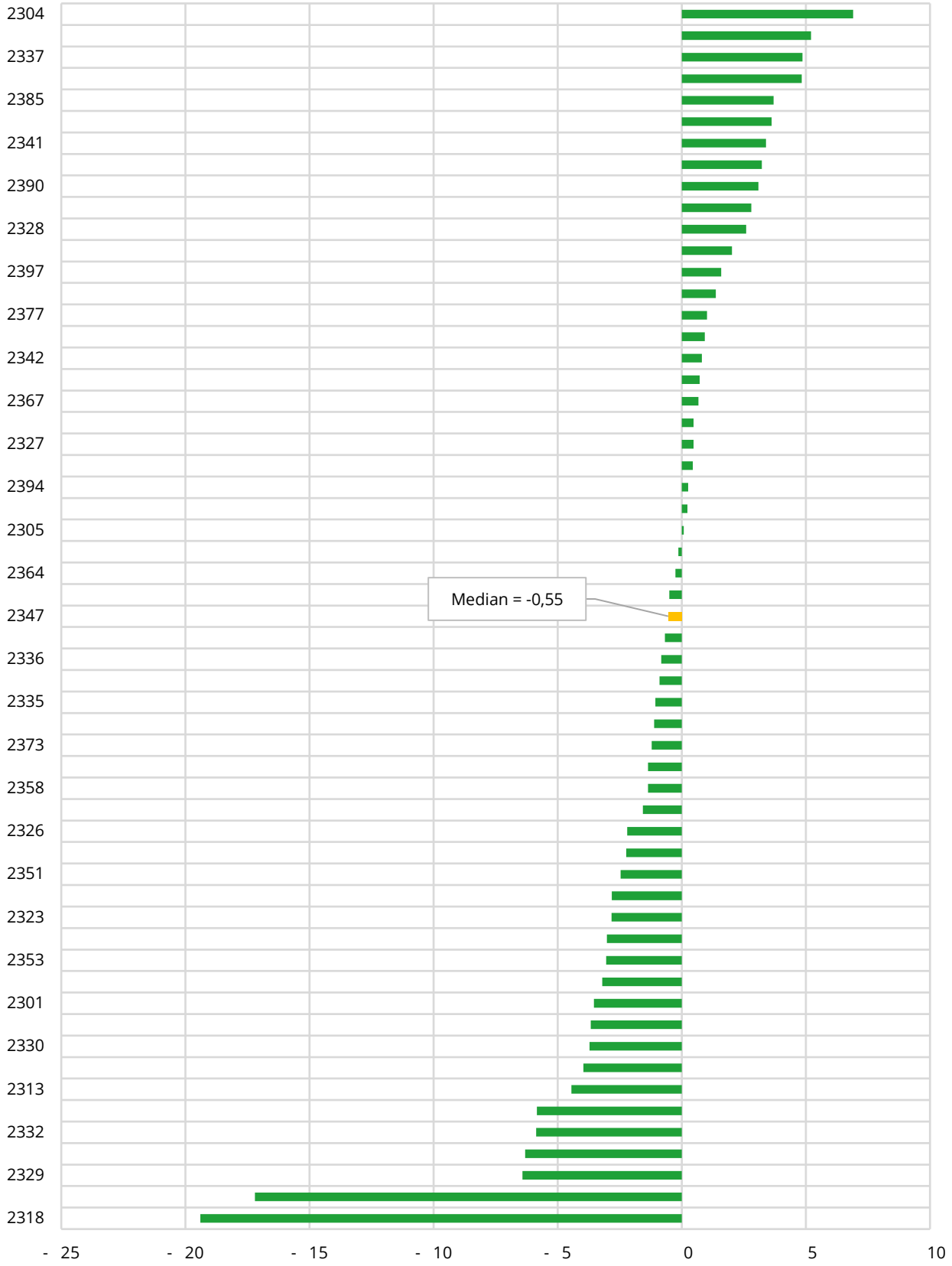
Table A12. Growth accounting for NR23FIN (%)

	2015-2016	2016-2017	2017-2018	Average (2015-2018)
Value added	1.00	7.90	4.75	4.59
Hours worked	2.31	-1.89	-0.43	-0.02
Labor productivity	-1.32	9.78	5.18	4.60
Contribution from				
Other capital per hour	-1.91	0.80	0.44	-0.21
Hardware capital per hour	-0.62	0.05	2.07	0.51
Software capital per hour	0.09	0.63	-0.58	0.05
R&D capital per hour	-0.26	0.48	0.13	0.12
Labor composition	-0.67	0.28	0.17	-0.07
MFP	2.06	7.54	2.96	4.21

Source: Author's own calculations. Note: NR23FIN = Financing and insurance activities

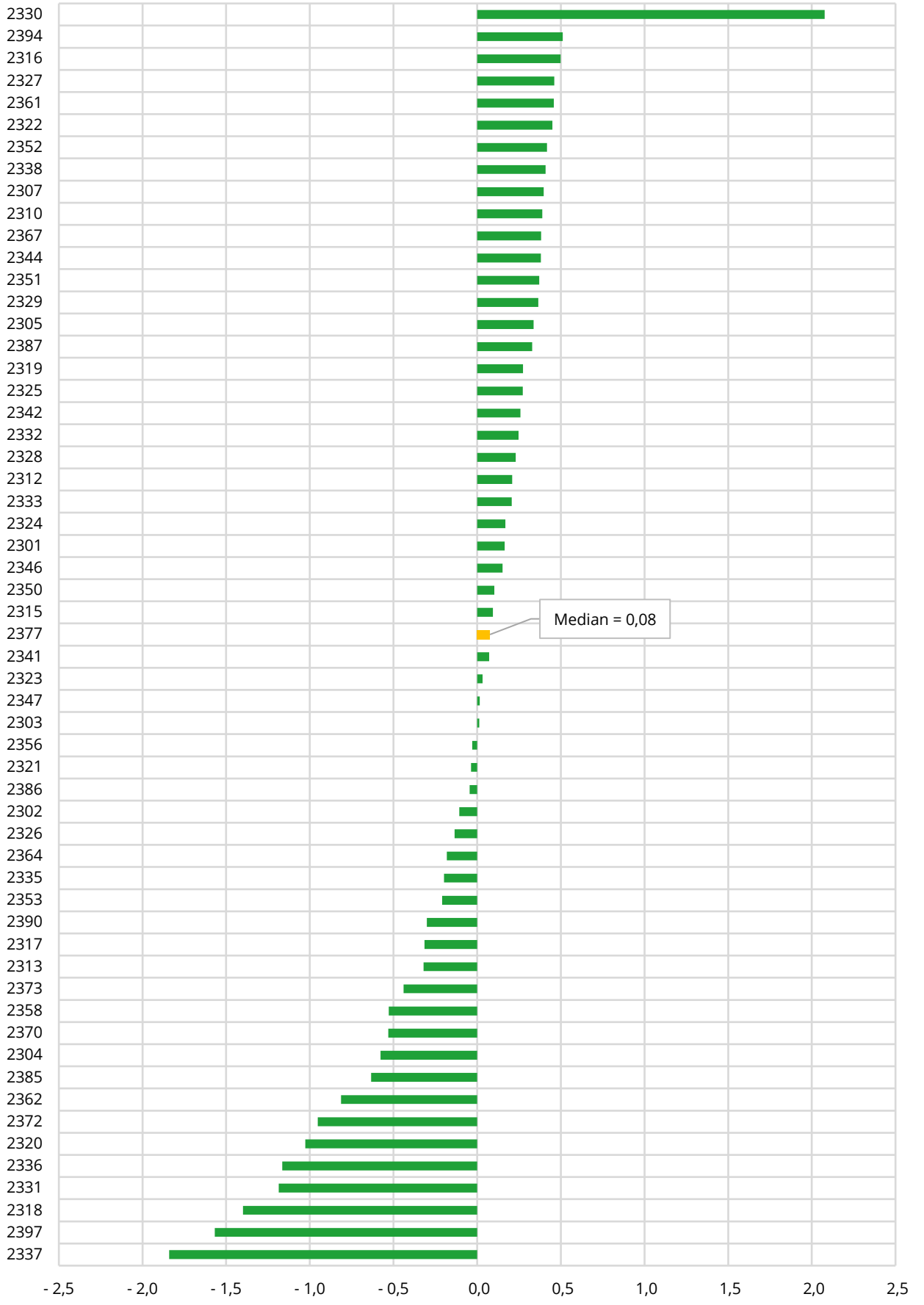
Appendix B: Growth in labor input by industry

Figure B1. Growth in labor input by industry (%), 2008-2014



Source: Author's own calculations.

Figure B2. Growth in labor input by industry (%), 2015-2018



Source: Author's own calculations.

Table B1. Growth of labor input with tertiary education (low degree) by industry (%)

Industry	2008-2018	2008-2014	2015-2018	Change between 2008-2014 and 2015-2018
2301	0.08	-0.05	0.35	0.40
2302	0.36	0.43	0.23	-0.20
2303	0.26	0.07	0.65	0.58
2304	1.03	1.28	0.51	-0.77
2305	0.09	0.02	0.22	0.20
2307	1.00	1.18	0.63	-0.55
2310	0.35	0.21	0.62	0.41
2312	0.69	0.91	0.27	-0.64
2313	0.01	-0.47	1.00	1.47
2315	0.18	-0.02	0.57	0.60
2316	-0.85	-1.62	0.70	2.33
2317	0.00	-0.47	0.94	1.41
2318	-1.41	-2.54	0.89	3.43
2319	0.03	-0.34	0.78	1.12
2320	0.14	-0.04	0.50	0.55
2321	-0.27	-0.71	0.61	1.32
2322	0.11	-0.12	0.57	0.69
2323	-0.02	-0.15	0.24	0.39
2324	-0.16	-0.57	0.67	1.24
2325	0.36	0.33	0.43	0.10
2326	-0.03	-0.44	0.79	1.24
2327	0.72	0.71	0.73	0.01
2328	0.91	1.27	0.19	-1.07
2329	0.08	-0.32	0.89	1.21
2330	0.18	0.04	0.48	0.44
2331	-0.03	0.03	-0.14	-0.17
2332	0.13	-0.32	1.03	1.36
2333	0.11	0.22	-0.11	-0.32
2335	0.31	-0.11	1.16	1.27
2336	0.27	0.00	0.83	0.83
2337	1.23	1.46	0.79	-0.66
2338	-0.01	-0.35	0.68	1.03
2341	1.48	1.71	1.03	-0.68
2342	0.22	0.19	0.28	0.09
2344	0.46	0.21	0.94	0.73
2346	0.37	0.32	0.47	0.15
2347	0.17	0.17	0.18	0.02
2350	0.58	0.57	0.61	0.04
2351	-0.23	-0.64	0.58	1.22
2352	0.61	0.46	0.91	0.45
2353	0.14	-0.16	0.75	0.91
2356	0.60	0.56	0.69	0.12
2358	0.56	0.00	1.70	1.70
2361	0.03	-0.51	1.13	1.65
2362	1.04	1.00	1.11	0.11
2364	0.81	0.33	1.76	1.42
2367	1.07	0.91	1.41	0.50
2370	0.59	0.60	0.59	-0.01
2372	-0.04	-0.22	0.33	0.55
2373	0.22	-0.25	1.15	1.40
2377	0.36	0.18	0.73	0.55
2385	1.42	1.56	1.13	-0.43
2386	0.07	0.03	0.15	0.12
2387	2.48	2.58	2.28	-0.30
2390	1.16	1.50	0.48	-1.02
2394	0.45	0.39	0.57	0.18
2397	0.64	0.61	0.69	0.08
Mean	0.37	0.20	0.71	0.50
Median	0.26	0.07	0.67	0.44

Source: Author's own calculations. Note: Average annual growth rates for 2008-2018 is a geometric mean of those of 2008-2014 and 2015-2018.

Table B2. Growth of labor input with tertiary education (high degree) by industry (%)

Industry	2008-2018	2008-2014	2015-2018	Change between 2008-2014 and 2015-2018
2301	0.05	0.04	0.07	0.03
2302	0.20	0.32	-0.05	-0.36
2303	0.13	0.08	0.21	0.13
2304	0.69	0.75	0.57	-0.19
2305	0.23	0.15	0.40	0.26
2307	1.27	1.23	1.37	0.14
2310	0.43	0.32	0.65	0.33
2312	0.46	0.54	0.29	-0.25
2313	0.24	0.10	0.51	0.40
2315	0.14	0.09	0.24	0.15
2316	-0.18	-1.19	1.87	3.06
2317	0.11	-0.01	0.35	0.36
2318	-1.23	-2.35	1.04	3.39
2319	0.24	-0.37	1.46	1.82
2320	0.77	0.72	0.87	0.16
2321	0.30	-0.32	1.57	1.89
2322	0.25	0.07	0.63	0.56
2323	0.12	-0.04	0.44	0.47
2324	0.18	-0.25	1.03	1.28
2325	0.43	0.46	0.37	-0.09
2326	0.37	-0.09	1.30	1.38
2327	0.78	0.71	0.93	0.22
2328	1.26	1.47	0.84	-0.63
2329	0.13	-0.18	0.76	0.94
2330	0.23	0.19	0.31	0.12
2331	0.38	1.19	-1.22	-2.41
2332	0.28	0.13	0.57	0.44
2333	0.15	0.20	0.03	-0.17
2335	1.21	0.65	2.34	1.68
2336	0.76	0.49	1.32	0.83
2337	1.21	1.35	0.93	-0.42
2338	0.11	-0.09	0.49	0.58
2341	1.13	0.96	1.48	0.52
2342	0.16	0.13	0.22	0.10
2344	0.27	0.16	0.50	0.34
2346	0.22	0.21	0.23	0.03
2347	0.07	0.07	0.08	0.01
2350	0.19	0.15	0.27	0.12
2351	0.23	0.01	0.67	0.66
2352	0.40	0.32	0.54	0.22
2353	0.15	0.11	0.23	0.12
2356	0.30	0.29	0.33	0.05
2358	0.56	0.32	1.04	0.72
2361	0.45	-0.06	1.49	1.55
2362	1.46	1.14	2.11	0.98
2364	1.33	0.87	2.27	1.40
2367	0.34	0.14	0.73	0.60
2370	1.69	1.48	2.13	0.65
2372	0.97	0.11	2.71	2.60
2373	0.44	0.22	0.91	0.69
2377	0.37	0.32	0.47	0.15
2385	1.10	1.04	1.23	0.18
2386	0.88	0.82	1.01	0.19
2387	0.36	0.42	0.24	-0.18
2390	0.71	0.83	0.47	-0.36
2394	0.38	0.36	0.43	0.06
2397	0.08	-0.09	0.44	0.53
Mean	0.46	0.29	0.78	0.49
Median	0.34	0.20	0.57	0.26

Source: Author's own calculations. Note: Average annual growth rates for 2008-2018 is a geometric mean of those of 2008-2014 and 2015-2018.

Table B3. Growth of female labor input with tertiary education (low degree) by industry (%)

Industry	2008-2018	2008-2014	2015-2018	Change between 2008-2014 and 2015-2018
2301	0.02	-0.04	0.16	0.21
2302	0.07	0.09	0.02	-0.07
2303	0.09	0.06	0.15	0.09
2304	0.28	0.26	0.32	0.07
2305	0.08	0.09	0.07	-0.03
2307	0.22	0.33	0.00	-0.33
2310	0.22	0.19	0.30	0.11
2312	0.29	0.38	0.12	-0.26
2313	0.14	-0.03	0.48	0.51
2315	0.09	0.03	0.21	0.18
2316	-0.07	-0.29	0.36	0.65
2317	0.08	-0.13	0.50	0.64
2318	-0.25	-0.53	0.32	0.85
2319	0.09	0.00	0.27	0.27
2320	0.29	0.37	0.13	-0.24
2321	-0.13	-0.38	0.37	0.74
2322	0.08	0.06	0.11	0.05
2323	0.02	-0.03	0.13	0.16
2324	0.01	-0.09	0.21	0.30
2325	0.13	0.13	0.12	-0.01
2326	0.06	0.03	0.13	0.10
2327	0.13	0.13	0.14	0.01
2328	0.17	0.33	-0.14	-0.47
2329	0.07	-0.01	0.22	0.23
2330	0.05	0.04	0.07	0.03
2331	0.06	0.22	-0.25	-0.47
2332	0.14	-0.08	0.58	0.66
2333	0.02	0.05	-0.06	-0.11
2335	0.10	0.01	0.30	0.29
2336	0.19	0.07	0.42	0.34
2337	0.32	0.38	0.19	-0.20
2338	-0.02	-0.15	0.24	0.39
2341	0.63	0.71	0.48	-0.23
2342	0.05	0.04	0.08	0.04
2344	0.28	0.18	0.48	0.30
2346	0.08	0.07	0.10	0.04
2347	0.03	0.01	0.06	0.05
2350	-0.02	-0.06	0.05	0.10
2351	-0.23	-0.45	0.21	0.67
2352	0.17	0.14	0.22	0.08
2353	-0.03	-0.15	0.22	0.37
2356	0.36	0.36	0.37	0.01
2358	0.25	0.02	0.70	0.68
2361	0.12	0.00	0.35	0.35
2362	0.18	0.13	0.28	0.15
2364	0.38	0.22	0.69	0.47
2367	0.42	0.33	0.60	0.27
2370	0.34	0.31	0.42	0.11
2372	0.02	-0.07	0.19	0.26
2373	0.35	0.14	0.77	0.63
2377	0.13	0.05	0.28	0.23
2385	0.62	0.58	0.70	0.12
2386	-0.04	-0.13	0.15	0.27
2387	1.95	1.96	1.92	-0.04
2390	0.50	0.54	0.42	-0.12
2394	0.34	0.32	0.39	0.07
2397	0.75	0.99	0.28	-0.71
Mean	0.19	0.14	0.29	0.16
Median	0.12	0.06	0.22	0.11

Source: Author's own calculations. Note: Average annual growth rates for 2008-2018 is a geometric mean of those of 2008-2014 and 2015-2018.

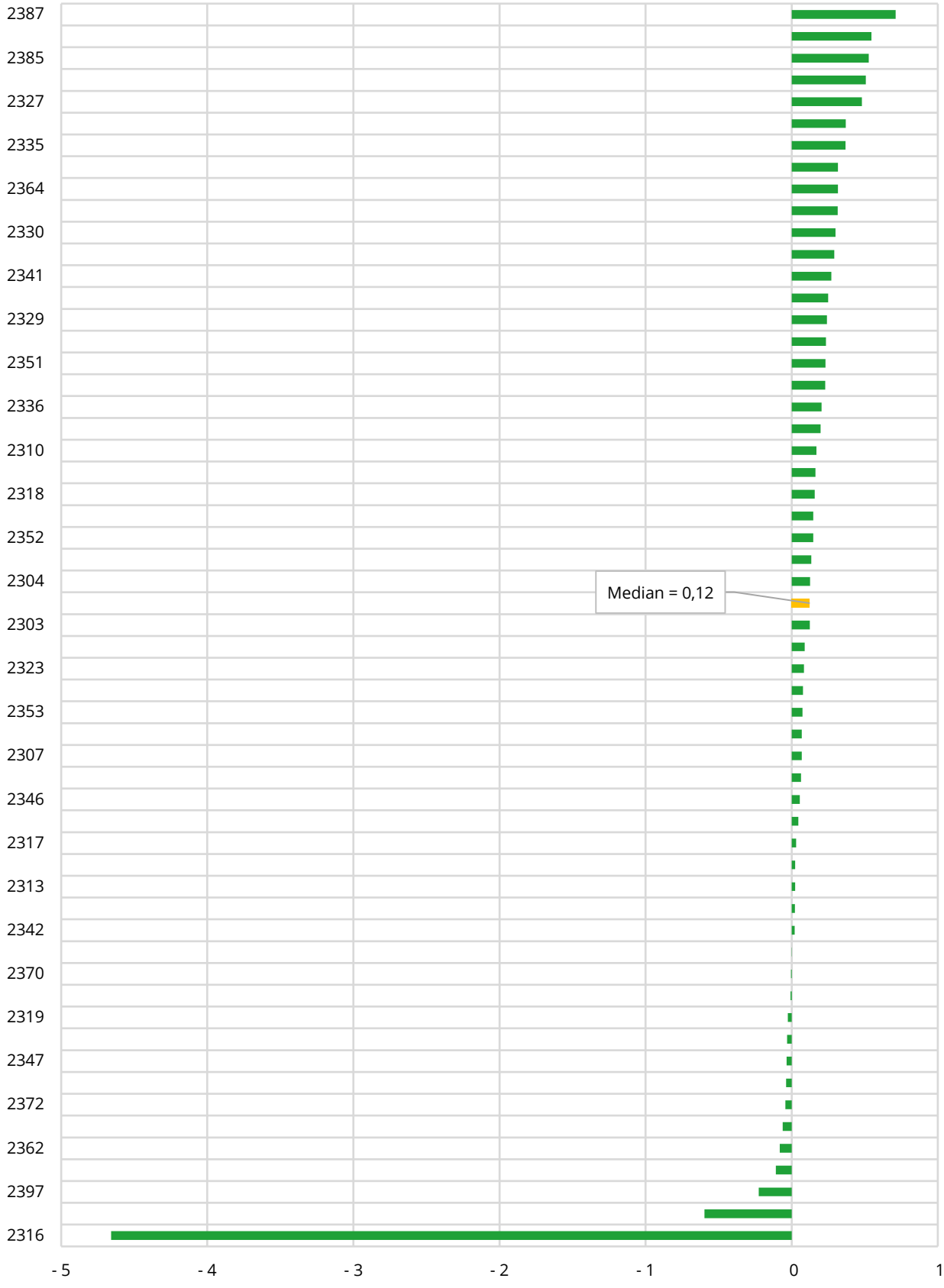
Table B4. Growth of female labor input with tertiary education (high degree) by industry (%)

Industry	2008-2018	2008-2014	2015-2018	Change between 2008-2014 and 2015-2018
2301	0.03	0.02	0.06	0.04
2302	0.07	0.07	0.08	0.01
2303	0.06	0.05	0.09	0.04
2304	0.23	0.18	0.34	0.16
2305	0.05	0.04	0.09	0.05
2307	0.33	0.34	0.31	-0.03
2310	0.23	0.19	0.32	0.13
2312	0.18	0.24	0.06	-0.18
2313	0.12	0.09	0.18	0.09
2315	0.04	0.03	0.05	0.02
2316	0.08	-0.17	0.60	0.78
2317	0.05	0.02	0.12	0.10
2318	-0.29	-0.60	0.33	0.94
2319	0.23	0.09	0.52	0.43
2320	0.54	0.47	0.67	0.20
2321	0.32	-0.06	1.08	1.14
2322	0.07	0.05	0.11	0.06
2323	0.07	0.03	0.14	0.11
2324	0.15	0.01	0.45	0.45
2325	0.08	0.08	0.09	0.01
2326	0.17	0.13	0.24	0.11
2327	0.15	0.14	0.18	0.04
2328	0.21	0.27	0.09	-0.18
2329	0.08	0.02	0.20	0.17
2330	0.07	0.07	0.07	0.00
2331	0.15	0.40	-0.36	-0.76
2332	0.12	0.06	0.25	0.19
2333	0.00	0.02	-0.05	-0.08
2335	0.40	0.29	0.63	0.34
2336	0.33	0.24	0.50	0.26
2337	0.52	0.48	0.58	0.10
2338	0.06	-0.03	0.25	0.28
2341	0.37	0.30	0.52	0.22
2342	0.04	0.02	0.06	0.04
2344	0.15	0.10	0.24	0.14
2346	0.06	0.04	0.09	0.04
2347	0.01	0.00	0.01	0.01
2350	0.04	0.02	0.09	0.07
2351	0.07	0.05	0.12	0.07
2352	0.10	0.08	0.14	0.06
2353	0.04	0.03	0.05	0.02
2356	0.16	0.15	0.16	0.01
2358	0.29	0.19	0.49	0.31
2361	0.25	0.14	0.47	0.33
2362	0.37	0.27	0.58	0.31
2364	0.46	0.30	0.78	0.48
2367	0.16	0.11	0.24	0.13
2370	0.74	0.64	0.94	0.30
2372	0.63	0.32	1.26	0.94
2373	0.41	0.31	0.62	0.31
2377	0.18	0.16	0.22	0.07
2385	0.71	0.66	0.81	0.15
2386	0.67	0.51	0.98	0.47
2387	0.27	0.31	0.21	-0.09
2390	0.36	0.35	0.37	0.02
2394	0.27	0.24	0.31	0.07
2397	-0.01	-0.20	0.39	0.59
Mean	0.21	0.15	0.32	0.18
Median	0.15	0.10	0.24	0.10

Source: Author's own calculations. Note: Average annual growth rates for 2008-2018 is a geometric mean of those of 2008-2014 and 2015-2018.

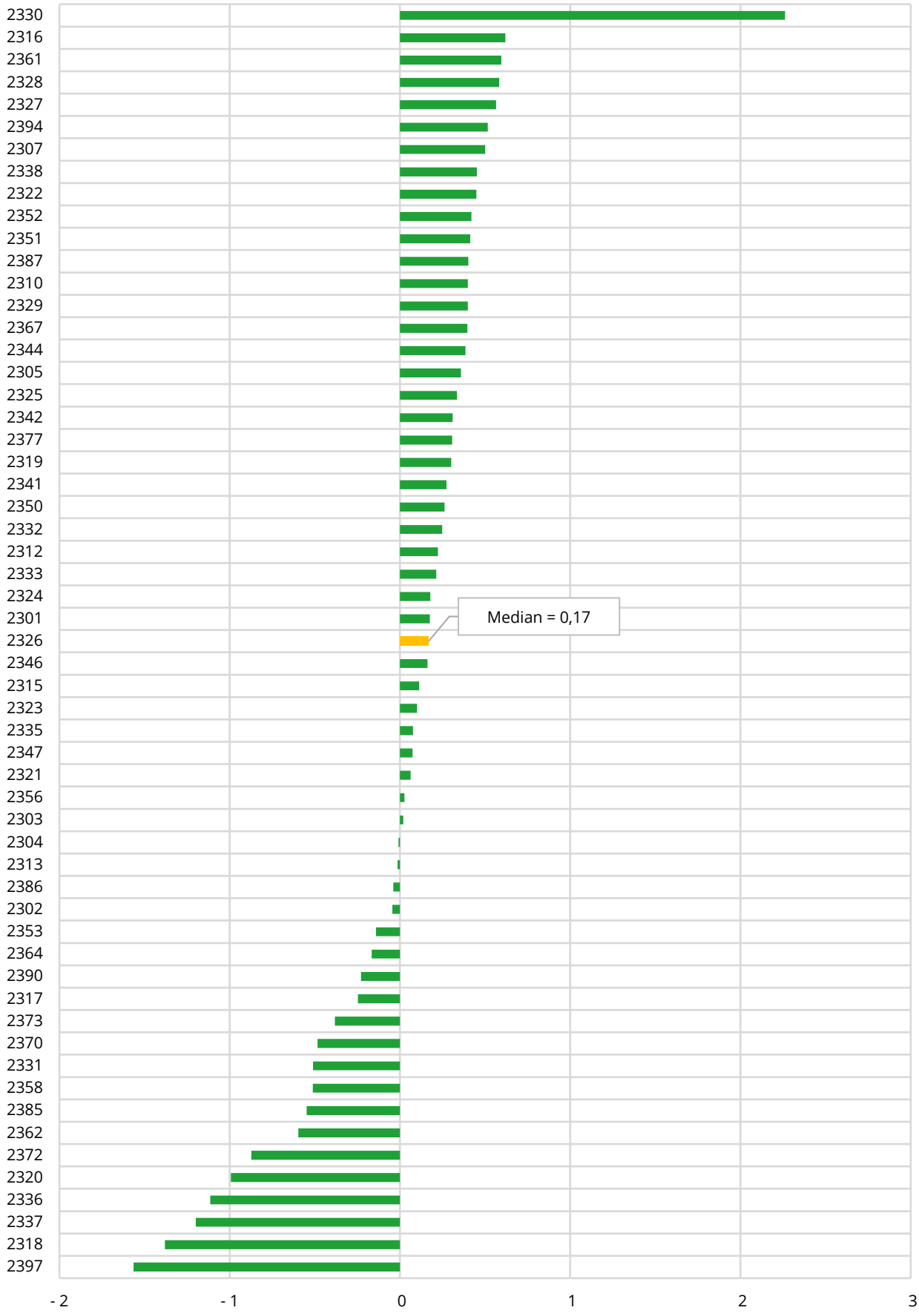
Appendix C: Growth in labor quality by industry

Figure C1. Growth in labor quality by industry (%), 2008-2014



Source: Author's own calculations.

Figure C2. Growth in labor quality by industry (%), 2015-2018



Source: Author's own calculations.