

The composition of labour input: Sensitivity testing and results for productivity analysis

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Abstract / Résumé

Composition Adjusted-Labour Input (CALI) measures account for workers' differences in skills and productive capacity. This study reviews the most relevant literature to have produced CALI estimates to date and presents a generic approach to produce CALI measures for 21 countries. It finds that education and age (proxy for work experience) are two key workers' characteristics to be included in CALI measures, with additional workers characteristics having a more limited impact. Replacing a traditional measure of labour input, such as hours worked, with a measure of CALI in the growth accounts leads to a significant downward revision in multifactor productivity (MFP) growth in countries that experience large changes in the composition of labour.

Keywords: labour input, hours worked, growth accounts, productivity, multifactor productivity (MFP).

JEL codes: E1, E24, E26.

La mesure du facteur travail corrigée par la composition de la main d'œuvre (CALI) prend en compte les différences de compétences et de capacité de production des travailleurs. Cette étude examine les publications les plus pertinentes ayant produit des estimations de CALI à ce jour et présente une approche générique permettant de produire des mesures de CALI pour 21 pays. Elle conclut que l'éducation et l'âge (proxy de l'expérience professionnelle) sont deux caractéristiques clés des travailleurs à inclure dans les mesures de CALI, tandis que les autres caractéristiques des travailleurs ont un impact plus limité. Le remplacement d'une mesure traditionnelle du facteur travail, par exemple les heures travaillées, par une mesure de CALI dans les comptes de croissance entraîne une révision à la baisse significative de la croissance de la productivité multifactorielle (PMF) dans les pays qui ont connu d'importants changements dans la composition du facteur travail.

Mots clés : facteur travail, heures travaillées, comptabilité de la croissance, productivité, productivité globale des facteurs (PGF).

Codes JEL : E1, E24, E26.

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The composition of labour input: Sensitivity testing and results for productivity analysis

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1. Introduction

1. Human capital, defined as the stock of knowledge, skills and other personal characteristics embodied in people, contributes to the productive capacity of the workforce and, as such, constitutes a key input into the production process (Romer, 1989; OECD, 2001; Coe et al., 2009; Fraumeni, 2012; OECD/APO, 2022). The evidence shows that the potential for productivity gains arising from human capital are much greater from improvements in the “quality” than in the “quantity” component (Égert et al., 2022). This is reinforced by OECD work on *The Human Side of Productivity*, which highlights the importance of workforce composition in terms of skills, management capacity and diversity (Criscuolo et al., 2021).

2. However, traditional measures of labour input used in productivity analysis, such as employment and hours worked, only account for the number of workers, jobs or the total number of hours worked, treating all workers identically. These measures ignore heterogeneity among workers with potentially vastly different skills as well as differences in their contributions to output and productivity. Indeed, workers with different skills are not perfect substitutes and firms recognise this distinction by paying different wages. For this reason, in productivity analysis, a more accurate estimation of the contribution of labour to production requires accounting for both the number of hours worked (or employment) and the composition of the workforce, that is a measure of *Composition Adjusted-Labour Input* (CALI).

3. CALI measures facilitate an understanding of whether, over time, the composition of the workforce changes, i.e. whether there is an increase or decrease in the average “quality” of the labour force. An increase in the average “labour quality” implies that a composition-adjusted measure of labour would rise faster than an unadjusted measure. A comparison of an adjusted and unadjusted measure of labour input yields a measure of compositional change, which can offer insights into the growth in a country’s human capital over time.

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4. While a measure of CALI is a useful tool to better measure labour input, it can also play an important role in productivity analysis and growth accounting in some countries. In the growth accounting framework, multifactor productivity (MFP) growth is estimated as the residual growth in output that cannot be explained by the rate of change in the services of labour and capital inputs. When unadjusted measures of labour input are replaced by CALI, a larger share of output growth is attributed to the factor “labour”, providing an improved understanding of the sources of economic growth and reducing the unexplained share of output growth captured by growth in MFP.

5. There have been many attempts to produce measures of CALI, almost all of which follow the approach originally developed by Jorgenson and Griliches (1967). The economic literature has also referred to these measures as either *Labour Services* or *Quality Adjusted-Labour Input (QALI)* indices. However, irrespective of nomenclature, each approach makes use of different data sources and chooses different workers’ characteristics (and/or different granularities of those workers’ characteristics) to distinguish between different types of workers.

6. This paper reviews the most relevant studies and approaches to produce CALI estimates and presents a generic approach to produce CALI measures for 21 countries, including Canada, selected countries in the European Union, the United Kingdom, and the United States for the period 2004-2018. On this basis, the study tests the sensitivity of CALI estimates to the selection of workers’ characteristics and how the inclusion of some of them might impact the comparability of CALI across countries. It then assesses trends in the evolution of CALI across the sample of countries between 2004-2018. Finally, it assesses the impact on MFP growth estimates of replacing total hours worked with a CALI measure.

7. The main findings of the paper are as follows:

- Education and age (proxy for work experience) are the two key workers’ characteristics to be considered for the construction of CALI measures, with additional workers’ characteristics having a more limited impact. Indeed, while education is likely to be the primary factor determining a worker’s productive capacity at an early age, work experience is likely to become an increasingly important factor as a worker ages. The inclusion of gender in the set of workers’ characteristics yields minimal changes in the growth rate of CALI as compared with the age-education CALI measure. Occupation appears to hold some explanatory power in the measurement of CALI, especially when combined with educational attainment. Accounting for education and occupation simultaneously may help to account for skills mismatches (i.e. a misalignment between workers’ qualifications and their role and tasks), which may diminish the contribution of the composition of labour to CALI growth. The broad industry of work seems to be less relevant, adding little or no explanatory power to the CALI measure in addition to education and age.
- While patterns vary across countries, CALI was found to fall during or immediately after the 2008-2009 global recession, reflecting the substantial drop in total hours worked resulting from the sudden increase in unemployment rates. However, changes in the composition of the workforce had a counterbalancing effect over the same period. Indeed, during times of crisis businesses tend to retain more skilled and experienced workers (i.e. labour hoarding), while shedding labour and/or reducing hours worked among lower-skilled workers, resulting in an increase in the average skill level of those in employment.
- For all countries covered in this study, the evidence shows that the use of CALI in the growth accounts as opposed to traditional measures of labour input reduces measured MFP growth – although for some countries by a limited amount – and increases the role of labour as a source of economic growth.

8. The paper is organised as follows. Section 2. reviews the measurement of CALI in the economic literature. Section 3. describes the methodology and the challenges when using wages as a proxy for productivity. Section 4 describes the data sources. Section 5. presents an analysis of the sensitivity of CALI measures to the selection of worker characteristics. Section 6 examines the evolution of CALI across time

in the selected countries. Section 7. highlights the impact of accounting for changes in labour composition in the measurement of MFP. Section 8. concludes.

2. The measurement of CALI in the literature

Methodological approaches in existing studies

9. The need to account for the number of hours worked and the skills and characteristics of the workforce was laid out in the Measuring Productivity OECD Manual (OECD, 2001), and subsequently in the System of National Accounts 2008 (2008 SNA) (United Nations et al., 2009).² These documents stipulate that the measure of labour input used in growth accounts should properly account for the heterogeneity of labour, necessarily differentiating between hours worked by persons with different characteristics. This is particularly important in the context of ongoing changes in labour markets in response to “mega-trends” such as digitalisation, technological change, globalisation, the transition to a low-carbon economy, and population ageing (OECD, 2019).

Accounting for workers’ heterogeneity

10. The construction of a measure of labour inputs that accounts for both the quantity and the quality of labour requires the aggregation of hours worked by different types of workers (quantities of different types of inputs) weighted by their relative marginal products commonly proxied by their relative wages (prices of the different types of inputs) (Ho and Jorgenson, 1999; OECD, 2001).

11. Jorgenson and Griliches (1967) explored compositional adjustments to labour input in the United States relying on a Divisia index³ of total labour services that weighted hours worked by different categories of workers using their relative shares of total labour compensation. Their method set up the conceptual and measurement basis of the approaches currently adopted by several national statistical offices (NSOs), international organisations and researchers to measure labour services (Reilly et al., 2005; Bureau of Labor Statistics, 1993 and 2007; Australian Bureau of Statistics, 2015; Eurostat, 2016; Nomura and Akashi, 2017; Vries and Erumban, 2017; Stehrer et al., 2019; Sgaravatti, 2020; Fukao et al., 2021).

12. The approach applied by Jorgenson and Griliches (1967) is rooted in the economic theory of production and linked to the growth accounting framework widely used for productivity measurement. It offers a consistent approach that integrates the theory of the firm, index number theory and national accounts, facilitating the regular production and update of productivity series (OECD, 2001). A distinct characteristic of this method, given its roots in index number theory, is that it measures the average change in the level of labour services provided by all workers engaged in production rather than the level of the labour services itself. As such, it differs from other approaches to measure the level of human capital, such as the lifetime income approach developed by Jorgenson and Fraumeni (1989, 1992a, 1992b), the cost-based approach introduced by Kendrick (1976), and the indicator-based approach accounting for school enrolments, years of schooling and adult literacy developed by Barro and Lee (1993, 2001, 2013, 2021).

13. The Bureau of Labor Statistics (BLS) was one of the first NSOs to invest in such a measurement exercise (BLS, 1993). The BLS approach considered a limited number of workers’ characteristics, namely

² The 2025 SNA goes even beyond by recommending the inclusion of new tables on labour (i.e. Labour accounts) to accompany the sequence of economic accounts. These tables should focus on four dimensions: jobs, person, hours, payments, including demographic breakdowns by gender, age and educational attainment in the case of persons.

³ A Divisia index is a continuous-time index designed to measure changes in the aggregate value of a group of economic variables over time, using information on quantities and prices of the different economic variables or sub-components. In practice, it is often approximated by other indices like the Törnqvist index.

education and work experience, to identify the impact of changes in specific workers' characteristics on productivity growth, rather than creating a comprehensive measure where direct contributions from – and interaction effects across – different workers' traits would be harder to disentangle. Given the persistent gender wage gap, the BLS calculated an adjusted labour input measure separately for women and men. The BLS used the Törnqvist index to aggregate the changes in hours worked by different types of workers. The current BLS approach maintains most of the features of the original, using the Current Population Survey (CPS), Current Employment Statistics (CES) and National Compensation Survey (NCS) to produce adjusted labour input for the private business sector in the United States (BLS, 2007).

14. Nowadays, there exist different approaches to the compositional adjustment of labour input, particularly when it comes to accounting for different combinations of workers' characteristics. This reflects, in part, conceptual differences, but also the availability of the necessary microdata and the sample sizes therein. Table A.1 in Annex A details the methods used by several NSOs and research bodies to compute CALI measures, including the data sources used in each approach.

15. Some approaches venture to account for several workers' traits. Jorgenson et al. (1987), for example, used up to five categories (age, education, employment class, occupation, and sex) to classify workers in the United States. More recent approaches account for educational attainment, age, sex and employment status (Nomura and Akashi, 2017; Fukao et al., 2021). Other approaches rely on a slightly slimmed-down set of characteristics, namely age, education and gender, at a more or less detailed industry breakdown (BLS, 2007; Stehrer et al., 2019; Cabbanes et al., 2013; Australian Bureau of Statistics - ABS, 2015; Sgaravatti, 2020; Bontadini et al., 2023). The approach applied in Statistics Canada also includes a reduced number of workers' characteristics, namely education, age and employment status, but expressly excludes gender as this does not necessarily capture productivity differences between women and men (Gu et al., 2002; Baldwin et al., 2007, Section -1202732272.351). Other approaches differentiate between an even smaller number of characteristics and classify workers only according to their education and age (Schwerdt and Turunen, 2007; Eurostat, 2016; Amores et al., 2021), or just their educational attainment (Vries and Erumban, 2017). The measurement of CALI in the literature has not accounted for other factors contributing to or affecting changes in human capital over time, such as workers' health, lifelong learning, and on-the-job training.

16. Most studies include both education and age to classify workers into different groups. In many of these studies, the education groupings are defined in line with the International Standard Classification of Education (ISCED) 1997 or 2011, as described in OECD et al. (2015), often aggregated into high, medium and low education. This is the case in studies that cover a set of countries, in particular EU countries, and use multi-country microdata surveys, such as the EU-LFS and other EU microdata (Eurostat, 2016; Schwerdt and Turunen, 2007; Stehrer et al., 2019, Amores et al., 2021; Bontadini et al., 2023). Other studies, however, introduced different and sometimes more detailed classifications of educational attainment, which are not necessarily aligned with the ISCED but reflect the information available in the national microdata sources used (Jorgenson et al., 1987; Reilly et al., 2005; ABS, 2015; Nomura and Akashi, 2017; Sgaravatti, 2020).

17. Work experience is recognised as an important mechanism to expand skills and increase productivity and life-long earnings (Zveglic et al., 2019; Madgavkar et al., 2022; Ribaldo and Nabella, 2023). For instance, senior workers may possess characteristics that are key to the companies' success, such as having a wider professional network, being able to provide training and guidance, and possessing institutional knowledge that allows them to easily solve problems arising with relatively low frequency (Skirbekk, 2004). To measure work experience, most studies producing CALI measures use age as a proxy for working experience and group workers into several age-range groups. This measure of work experience implicitly assumes that workers have been continuously engaged in the labour force throughout their adult lives, which will not be the case for many individuals, in particular for women, who more regularly interrupt their working lives due to childbearing and rearing. This assumption also rules out shifts in the performance of active workers due to sickness and health problems (Boles et al., 2004), which tend to

increase as a worker ages (Section -1202732272.351). Some more complex approaches to measuring work experience attempt to adjust for these factors. The ABS (2009), for example, constructs a measure of “potential years of experience” which is taken as a person’s age, minus five, minus years of education, with one additional year subtracted for each child up to a cap of five years for women. This approach is not adopted here, partly owing to the lack of availability of all the necessary variables across data sources.

18. As regards other dimensions, Jorgenson and Griliches (1967) and Jorgenson et al. (1987) recognised the desirability of disaggregating labour input not only by the industry of work, but also by the occupational and demographic characteristics of the workforce. Later, Lavoie and Roy (1998) and OECD (1998) also exploited the occupation of workers to better capture changes in the composition of labour. Lavoie and Roy (1998) claimed that the classification of workers according to their industry of work differs substantially from a classification based on the tasks these workers perform. They also argued that the occupation-based approach reveals the degree of heterogeneity of the high-skilled group (i.e. workers with high education levels). Bosler et al. (2017) found that while education and experience are the most relevant predictors to determine wage differentials across workers, occupations are the next best variable in terms of explanatory power. Even though education and occupation are likely to be correlated, the use of these two characteristics may capture to some extent the impact of over or under-qualification of workers (skill mismatches).

Weights

19. Regardless of the number of characteristics considered, all CALI measures require the weighting of total hours worked by each group by their respective relative marginal productivity, which is not directly observed. Under specific conditions – i.e. competitive input and product markets – labour of a certain type will continue to be hired up until the point where the cost of an additional unit of labour is equal to the additional revenue generated by that unit of labour. As such, most approaches weigh the hours worked of each group by the share of each workers group in total wages (Section -1202732272.351).

20. As recommended in OECD (2001), most of these studies use the Törnqvist index to aggregate hours worked by workers’ groups. Only the Eurostat’s QALI database (Eurostat, 2016; Amores et al., 2021), the EU KLEMS project (Stehrer et al., 2019, Bontadini et al., 2023) and the growth accounts produced by the Office for National Statistics (ONS) of the United Kingdom (Korhonen, 2020; Sgaravatti, 2020), scale the data on hours worked and wages, classified by workers’ characteristics using microdata, to national accounts aggregates before constructing the Törnqvist index. This is highly desirable, as the benchmarking against total hours worked and total labour compensation in the national accounts could be seen as a way to improve the consistency of the resulting CALI measure with the other elements in the growth accounts, which are typically estimated using national accounts data. This benchmarking exercise can be seen as a first step towards the reconciliation between micro and macro data sources.

21. Given the nature of the operation, the construction of a CALI measure generally requires the use of many different data sources. Most approaches use some combination of household surveys (e.g. labour force surveys, LFS), administrative sources, enterprise earnings surveys and population censuses, occasionally in combination with national accounts (Table A.1 in Annex A). Most notable for this study are the approaches of the Eurostat’s QALI Database and the EU KLEMS project, which use the European Labour Force Survey (EU-LFS), the European Structure of Earnings Survey (EU-SES) and national accounts as the foundation of their approaches (Eurostat, 2016; Stehrer et al., 2019; Bontadini et al., 2023).

Key findings

22. In general, the replacement of the volume of hours worked with a measure of CALI in the growth accounting framework increases the role of labour and hence decreases the extent of measured MFP growth. Starting with the original studies, Jorgenson and Griliches (1967) found that the replacement of a volume measure of hours worked by a CALI measure reduces the proportion of output growth accounted

for by MFP in the United States over the period 1945-1965, from 16% to just 3%. The evidence presented by BLS (1993) points to a 1.3% annual increase in adjusted labour input for the private sector of the United States between 1948 and 1990, with the contribution of labour composition being 0.3% per year. This implies that changes in the composition of the workforce, driven particularly by the marked growth in educational attainment, accounted for around 9% of labour productivity growth between 1948 and 1990.

23. In the United Kingdom, the results show that changes in the composition of labour make a mostly positive contribution to overall growth in CALI between 2008 and 2019 (Korhonen, 2020; Sgaravatti, 2020). Similarly, ABS (2019, 2022) indicates that quality adjusting hours worked puts a downwards pressure on MFP growth in Australia. Between 1995-1996 and 2021-2022, MFP growth in Australia measured on a CALI basis grew 9.5 percentage points less than MFP measured on an hours worked basis (ABS, 2022).

24. Measuring labour input purely through the total volume of hours worked is also a significant underestimate in the case of selected South Asia economies (Nomura and Akashi, 2017). Between 1970 and 2015 growth in labour composition ranges from 0.7% per year for Bangladesh to 1.9% in Nepal. Changes in labour composition explained between 27% and 46% of labour input growth in the economies in question over that period, implying a downward revision in measured MFP growth from 0.4 to 1.1 percentage points per year when accounting for changes in labour composition in addition to those in the volume of hours worked.

3. Methodology

The standard approach

25. The construction of a CALI measure involves aggregating hours worked by different groups of workers with potentially different skills weighted by their respective relative productivity. However, the latter is not directly observable, and is typically approximated by observable hourly wages. When firms are price-takers and behave as cost-minimising producers, the labour services of a worker will be hired up to the point where the cost of an additional hour equals the additional revenue that this generates when engaged in production. This equality implies that the relative productivity of the average worker in each workers' group can be approximated by the share of the respective group in total wages. In practice, there are conceptual challenges in using wages as a proxy for marginal productivity (discussed in Section - 1202732272.351).

26. This requires the construction of two matrices that classify hours worked and total wages by different groups of workers, respectively, according to a set of characteristics or skills. These matrices are built using microdata, typically including labour force surveys, and whenever relevant and available, business surveys and administrative sources (Section 2.).

27. While various indexes can be used to aggregate the hours worked across the workers' groups, OECD (2001) recommends the use of the Törnqvist index, which is also the index used by most NSOs, international bodies and researchers to construct CALI measures. One advantage of this index is that it uses time-varying weights. The Törnqvist volume index of total labour services is defined as a weighted geometric average of growth rates of hours worked (h) of different workers' groups (i) between two consecutive periods (t and $t - 1$), where the weights are the labour cost shares (w) of the different groups (i):

$$\frac{CALI_t}{CALI_{t-1}} = \prod_i \left(\frac{h_{i,t}}{h_{i,t-1}} \right)^{\frac{1}{2}(v_{i,t} + v_{i,t-1})} \quad \text{Equation 1}$$

where $v_{i,t} = \frac{w_{i,t} * h_{i,t}}{\sum_{i=1}^N w_{i,t} * h_{i,t}}$ is the share of workers' group i in total wages in t , $w_{i,t}$ is the average hourly wages of workers in group i in t , $h_{i,t}$ is the number of total hours worked of workers' group i in t , $i = 1, \dots, N$, and N is the total number of workers' groups.

28. Therefore, the growth rate of labour services can be calculated as:

$$\ln\left(\frac{CALI_t}{CALI_{t-1}}\right) = \sum_{i=1}^N \frac{1}{2} (v_{i,t} + v_{i,t-1}) \ln\left(\frac{h_{i,t}}{h_{i,t-1}}\right) \quad \text{Equation 2}$$

29. The change in labour composition (LQ) between t and $t - 1$ (also commonly referred as the growth rate of "labour quality") is derived by removing the growth of the volume of hours worked from the growth of total labour services:

$$\begin{aligned} \ln\left(\frac{LQ_t}{LQ_{t-1}}\right) &= \ln\left(\frac{CALI_t}{CALI_{t-1}}\right) - \ln\left(\frac{H_t}{H_{t-1}}\right) \\ &= \sum_{i=1}^N \frac{1}{2} (v_{i,t} + v_{i,t-1}) \ln\left(\frac{h_{i,t}}{h_{i,t-1}}\right) - \ln\left(\frac{H_t}{H_{t-1}}\right) \end{aligned} \quad \text{Equation 3}$$

where $H_t = \sum_{i=1}^N h_{i,t}$ is the total number of hours worked by all workers in the economy in t and $h_{i,t}$ is the number of total hours worked of workers in group i in t .

30. When the total volume of hours worked is used as a measure of labour input, hence disregarding differences across workers, MFP growth can be estimated as follows:

$$\begin{aligned} \text{Standard MFP growth} \\ &= \ln\left(\frac{Q_t}{Q_{t-1}}\right) \\ &\quad - \left[S_{L,t} \ln\left(\frac{H_t}{H_{t-1}}\right) + S_{K,t} \ln\left(\frac{KSER_t}{KSER_{t-1}}\right) \right] \end{aligned} \quad \text{Equation 4}$$

where Q_t is the total volume of output (value added) in t , $KSER_t$ is the volume of total capital services in t , $S_{L,t} = \frac{1}{2} (s_{L,t} + s_{L,t-1})$, $S_{K,t} = \frac{1}{2} (s_{K,t} + s_{K,t-1})$, and $s_{L,t} = \frac{\sum_{i=1}^N w_{i,t} h_{i,t}}{\sum_{i=1}^N w_{i,t} h_{i,t} + uK}$ and $s_{K,t} = \frac{uK}{\sum_{i=1}^N w_{i,t} h_{i,t} + uK}$ are the shares of labour and capital in total production costs, respectively, where uK represents the total value of capital services priced with the user costs of capital (Schreyer et al., 2003; APO/OECD, 2021).

31. The introduction of CALI in the growth accounts generates estimates of MFP growth that exclude the contribution of changes in labour composition, as follows:

$$\begin{aligned} \text{Adjusted MFP growth} \\ &= \ln\left(\frac{Q_t}{Q_{t-1}}\right) \\ &\quad - \left\{ S_{L,t} \left[\ln\left(\frac{LQ_t}{LQ_{t-1}}\right) + \ln\left(\frac{H_t}{H_{t-1}}\right) \right] \right. \\ &\quad \left. + S_{K,t} \ln\left(\frac{KSER_t}{KSER_{t-1}}\right) \right\} \end{aligned} \quad \text{Equation 5}$$

32. Whenever the distribution of total hours worked ($i \sum_{i=1}^N h_{i,t}$) and total wages ($\sum_{i=1}^N w_{i,t} h_{i,t}$) across workers' groups derived from microdata sources is benchmarked to total hours worked (H_t) and total labour compensation ($W_t H_t$) obtained from the national accounts, the value of total wages across different groups matches that of total labour compensation obtained from national accounts, so that $S_{L,t}$ and $S_{K,t}$ are the same in both the standard and the adjusted MFP growth estimates.⁴ The introduction of a CALI measure in the growth accounts explicitly accounts for the contribution of changes in labour composition to output growth (i.e. labour quality), improving, in theory, the accuracy of measured MFP growth:

$$\begin{aligned} & \text{Standard MFP growth} - \text{Adjusted MFP growth} \\ &= S_{L,t} \ln \left(\frac{LQ_t}{LQ_{t-1}} \right) \end{aligned} \quad \text{Equation 6}$$

Constructing different CALI measures

33. This study compiles and analyses five different CALI measures built using different microdata sources (Section 4.) for 21 countries, including Canada, selected EU countries, the United Kingdom and the United States, over the period 2004-2018.⁵

34. The first CALI measure is constructed by grouping workers according only to their educational attainment. Education is often identified as one of the most important contributors to human capital and determinants of productivity differentials across workers (Bosler et al., 2017; Amores et al., 2021). Education is typically measured as the educational attainment of an individual, i.e. the degree or level of completed education. This study, motivated partly by the information available, groups workers by educational attainment following the ISCED 1997 and 2011 into high-education (ISCED 1997 5-6, ISCED 2011 5-8), medium-education (ISCED 1997 and 2011 3-4), and low-education (ISCED 1997 and 2011 0-2). While for the EU countries and the United Kingdom the microdata sources report the information on educational attainment in line with the ISCED, for Canada and the United States it was necessary to build a correspondence between the ISCED and the information available in the STATCAN LFS and the CPS of the United States. The correspondence tables in question can be made available upon request.

35. While higher levels of education generally correlate with increased productivity, the field of study also plays a crucial role. Workers with studies that provide technical and specialised skills, such as Science, Technology, Engineering, and Mathematics (STEM), often earn significantly more than their peers in non-STEM fields (Even et al., 2023) and are more productive (Cammeraat et. al., 2024). However, the educational attainment accounted for in CALI measures, captures only the highest degree of education obtained by an individual, overlooking differences in fields of study and their specific impacts on workers' productivity. The microdata sources used in this study do not allow accounting for these differences. Similarly, the microdata used only provide a view of changes in the "quantity" of education (i.e. highest level attained) and not the "quality" of education over time. Future research may explore variations in the quality of education across countries and over time, for example, by examining the potential of the OECD's Programme for International Student Assessment (PISA), which evaluates students' abilities across various school subjects.

⁴ The distribution of wages across workers' groups derived from microdata sources is benchmarked to total labour compensation in national accounts rather than the wage bill to match the national accounts aggregates used to compile the weights of labour and capital inputs in the growth accounts of the OECD Productivity Database.

⁵ It is important to acknowledge that the CALI estimates presented in this paper may not be as timely as desired. This reflects the fact that some of the microdata used in this study are currently accessible up to the year 2018. This is the case, for instance, of the EU Structure of Earnings Survey (EU SES), which is conducted every four years. Indeed, EU SES data for the year 2022 will be accessible approximately two years after the end of the reference year, i.e. in December 2024, following Eurostat's dissemination schedules.

36. The second CALI measure, which is used as a benchmark in the paper, accounts for age in addition to educational attainment. Beyond education, age acts as a proxy for work experience and on-the-job training, another important factor driving productivity differentials across workers (Bosler et al., 2017; Amores et al., 2021). While education is likely to be the primary factor determining a worker's productive capacity at an early age, work experience is likely to become an increasingly important factor as a worker ages. As shown in Section 2. , education and age are the established cornerstones of most approaches producing CALI measures. Age groups have been classified as follows: 16-29, 30-49, 50+. The age groupings used were chosen to ensure representativeness across groups for all countries, to align with those typically followed in the literature, and to match aggregated age variables used in the various microdata sources. This results in a total of nine workers' groups.

37. The third measure of CALI accounts for gender. This step serves to establish whether, based on available data, the gender dimension holds any power in explaining productivity differences, as compared with education and age alone. By extension, this helps to evaluate whether gender can be comfortably excluded in estimates of CALI across countries. Indeed, gender pay gaps often reflect discrimination between women and men in the workplace, as well as differences in self-selection, negotiation behaviour and risk aversion, as opposed to actual productivity differences (Section -1202732272.351). Adding gender, in addition to education and age, creates a total of 18 groups of workers.

38. The fourth measure of CALI tests the relevance of the industry of work in addition to age and education, as a relatively simple way to differentiate workers. If industry is used as one of the workers' characteristics in the construction of CALI measures, changes in hours worked in industries that pay above-average wages will receive a larger weight than those recorded in industries that pay below-average wages (OECD, 2001). Sgaravatti (2020) builds a CALI measure for the United Kingdom accounting for education, age, gender, and industry of work, including the latter to capture inherent differences in skills and productivity that exist between industries. The use of the industry of work to differentiate across workers allows these measures, albeit imperfectly, to capture changes in the composition of the workforce. Therefore, the fourth measure of CALI creates four more categories defined according to the ISIC Rev. 4 (A – Agriculture, B to F – Industry plus Construction, G to N – Market Services, and O to U – Non-Market Services), creating a total of 36 groups. The industry groupings reflect the maximum number of industries that can be considered while ensuring the representativeness of the resulting groups in all countries and distinguishing between key economic activities.

39. The fifth and final measure of CALI tests the use of occupational skill levels in addition to education and age. The skill level of an occupation is associated with the level of complexity of tasks performed, following ILOSTAT (2020) but excluding armed forces which tasks are specific and are not covered by most microdata sources. These comprise high-skill occupations – including managers, professionals and technicians and associate professionals; medium-skill occupations – including clerical support workers, service and sales workers, skilled agriculture, craft and related trade workers, and plant and machine operators; and low-skill occupations – including elementary occupations, which comprise street sales, cleaning, labourers in mining, construction or manufacturing, among other occupations.

40. For the final three measures, each additional characteristic is introduced to the age-education measure one at a time. This approach ensures the representativeness of each of the workers' groupings: the larger the number of workers' characteristics, the larger the number of groupings, the smaller the sample of individuals in each group, and the higher the probability to run into confidentiality and reliability issues.

41. For each measure the total number of hours worked per year is calculated as the average usual hours worked per person each year multiplied by the number of persons employed in each group of workers. The shares of hours worked by each group are then used to scale hours worked by each group to the total hours worked used in the growth accounts and sourced from the OECD Productivity Statistics

database. For each CALI measure, estimates of average wage per hour are combined with the estimated total hours worked to create annual earnings for the specified groups of workers.

Main challenges regarding the use of wages as a proxy of productivity

42. There are many challenges associated with the use of relative wages as a proxy for workers' relative productivity. Factors including technological change, digitalisation, increasing investment in intangible assets, and the expansion of global value chains have been identified as the principal drivers of the decoupling between real median compensation and aggregate productivity (Schwellnus et al., 2017; OECD, 2018). These drivers are also likely behind the increasing divergence in both productivity and wages between firms observed globally and even within two-digit industries within countries (Andrews et al., 2016; Berlingieri et al., 2017).

43. Market imperfections constitute an important challenge, as they may cause a divergence between relative wages and relative productivity. Besides, pay gaps across workers represent additional challenges. Wage gaps are prevalent across many countries to varying degrees, in particular between women and men but not only, as they may be also driven by ethnicity, origin, place of residence, among other workers characteristics. These gaps may impact cross-country comparisons to the extent that they vary across countries and/or shift across time in individual countries, for example, in line with labour market policy changes.

Wage setting practices

44. The hypothesis that the wage rate corresponds to the marginal productivity of hiring one additional worker (or hour worked) relies on standard but still unrealistic assumptions, such as perfect competition, constant returns to scale, symmetric information, homogeneous agents, and the absence of market frictions.

45. These assumptions are violated whenever firms retain control in determining wages and working conditions, in contrast to competitive markets where they must pay workers the "market rate", in line with their productivity. Similarly, the search costs incurred by workers when seeking better job opportunities may deter workers from switching jobs, providing employers with bargaining power. Workers are then unable to profit from competition among potential employers to raise wages to their level of productivity. Under these conditions, gaps in firms' pay reflect not only variations in productivity across firms, but also differences in wage-setting power.

46. Labour market concentration, often used as a measure of monopsony in labour markets (Langella and Manning, 2021), influences wage-setting practices applying downward pressure on wages (OECD, 2021). On average, in a sample of 15 OECD countries, just over 16% of workers in 2019 found themselves in labour markets that were at least moderately concentrated, and about 10% worked in highly concentrated labour markets (Araki et al., 2022). A 10% increase in labour market concentration in a small group of European countries has been associated with a decline in daily wages of 0.2%- 0.3% between 2010 and 2019 (Araki et al., 2022).

47. Low rates of voluntary job mobility have been associated with the transmission of productivity gaps across firms to pay disparities (Criscuolo et al., 2022). Workers consider not only wages but also working conditions when evaluating jobs and job offers, and are often willing to exchange a potential wage increases for improved employment terms and conditions (Mas and Pallais, 2017; Taber and Vejlín, 2020; Kesternich et al., 2021). Besides wages, housing and commuting costs are also likely to influence workers decisions (Ziemann et al., 2023). More centralised collective bargaining and higher minimum wages appear to weaken the pass-through of productivity to wage premia by limiting the scope of low-performing firms to compete while offering low wages (Criscuolo et al., 2022).

48. An additional deviation from the equality of wages and productivity is the presence of asymmetric information (Van Biesebroeck, 2015). When a worker's productivity is unobservable, other characteristics are used by employers as proxies for productivity. Education and working experience are typical traits used by workers to "signal" their productivity levels. In addition, to address this information asymmetry, employers may also decide to make wages conditional on workers' output, induce competition among workers for promotion, or pay efficiency wages – i.e. wages exceeding the average "market rate".

49. Firm performance play an important role in explaining aggregate wage inequality. Many country-specific studies have revealed large cross-firm differences in average pay for workers with similar qualifications (Card, Heining and Kline, 2013; Song et al., 2018). Rather than being exclusively determined by workers' characteristics, wages are driven to a significant extent by firm performance as workers and firms bargain over their share of productivity-related rents. Evidence for a subset of OECD countries shows that two-thirds (65%) of the difference in average wages across firms is explained by differences in firm wage premia, which are independent from the workforce characteristics and depend exclusively on the characteristics of the firm (Criscuolo et al., 2020). The remaining third (35%) in between-firm wage inequality can be attributed to the characteristics of the workforce and hence workers sorting, i.e. the sorting of high (low) skilled workers into high (low) paying firms.

Health, age and productivity

50. Wage rates may also deviate from workers' productivity whenever active workers experience performance shifts due to sickness and health problems (Boles et al., 2004). In addition, wages tend to increase with workers' seniority (i.e. with increasing age) independently of productivity increases (Lazear, 1979). If wages and workers' productivity changed with age at a different pace (all other things being equal), this would raise concerns for the use of age as one of the characteristics by which workers are grouped for the construction of CALI measures. However, empirical studies on the effect of age on productivity and wages find mixed results on the existence of an age-related wage-productivity gap (André et al., 2024). While some studies found that wages increase with age while productivity does not keep pace (Aubert and Crépon, 2003; Ilmakunnas and Maliranta, 2005; Dostie, 2011), others do not find any evidence indicating an overpayment of older workers (van Ours and Stoeldraijer, 2011; Mahlberg et al., 2013; Kampelmann et al., 2018). Understanding how workers' productivity changes with age is challenging due to difficulties associated with the measurement of a workers' productivity and selection bias (older workers may remain in the workforce because of good health) (Goldin et al., 2024). Börsch-Supan (2013) and André et al. (2024) provide a thorough review of empirical studies analysing the age-productivity relationship. They stress that even in a work environment requiring substantial physical strength, declining productivity with age can be compensated for by characteristics that appear to increase with age and that are hard to measure directly (e.g. experience, leadership, ability to operate well in high pressure situations).

Gender pay gaps

51. Women face a number of challenges in the labour market, recorded through gaps in employment, working time and wages, among other measures (Ciminelli et al., 2021; OECD, 2023a). These gaps interact with one another, influencing the overall impact. For example, the greater tendency of women to take career breaks or to work in part-time jobs often leads to slower wage progression and lower hourly wages compared with men. In the estimation of CALI, the inclusion of gender among the dimensions considered to assign workers into different groups is intended to capture pay differentials associated to these differences in career paths whenever these reflect productivity differentials between women and men.

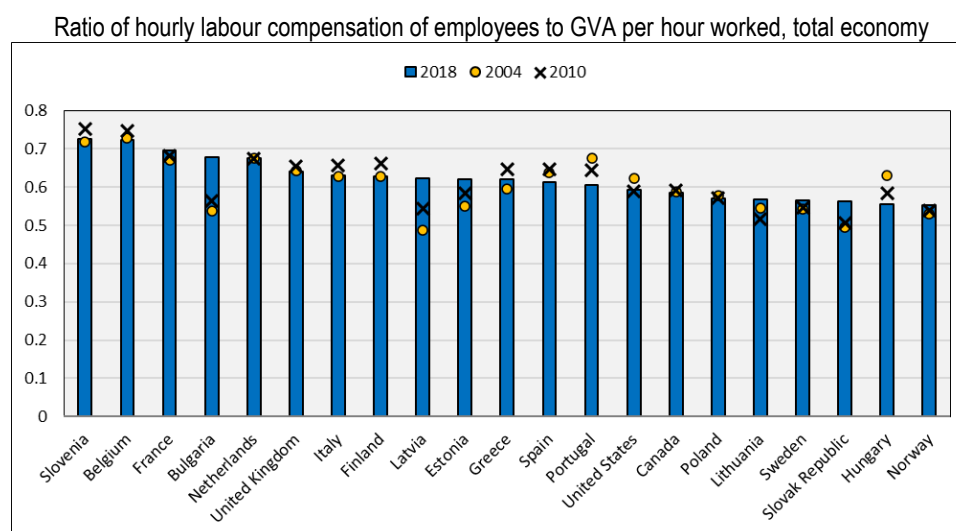
52. However, gender pay gaps may also reflect discrimination in hiring practices, as well as differences in workers' behaviour or risk aversion, thereby depressing women's wages and violating the assumption

that women are paid according to their relative productivity. Many studies show that women with otherwise identical qualifications as men are less likely to be hired (Moss-Racusin et al., 2012; Reuben, Sapienza and Zingales, 2014; Jessen et al., 2019) and when they are selected for specific job positions, they are often offered lower wages than men (Neumark, Bank and Van Nort, 1996; Correll, Benard and Paik, 2007). Differences in negotiation behaviour, propensity to compete, and risk aversion between women and men, instead, appear to explain only about 10% to 15% of the gender wage gap, after controlling for other worker and job characteristics (Le Barbanchon et al., 2019; Ciminelli et al., 2021).

53. Challenges in measuring the contribution of demand-side and supply-side factors in gender pay gaps and differences in the magnitude of these gaps across countries may introduce cross-country differences in CALI measures that account for gender. In addition, empirical evidence presented for Canada in the early 2000s indicates that the exclusion of the gender dimension from CALI measures has a minimal impact when estimating the growth in a country's labour services (Gu et al., 2002). The sensitivity analysis presented in Section 5. of this study reinforces this finding for a wider set of countries using more recent data. Therefore, taking these considerations together, it is considered desirable to exclude the gender dimension when constructing CALI measures for a large set of countries as way to limit the impact of cross-country differences in demand-side and supply-side barriers to women in the labour market.

54. Despite the challenges outlined above, this paper follows the existing literature and, due to the lack of alternative measures of workers' productivity, uses relative wages as a proxy for relative productivity in measuring CALI. The ratio of hourly labour compensation for employees to hourly labour productivity serves as a rough indicator of the magnitude of the disparities. This ratio, ranging from 0.5 to 0.8 across countries, appears to exhibit stability over time, suggesting a relatively modest impact on CALI growth rates (Figure 1).

Figure 1. Wages to labour productivity ratio



Source: OECD Annual National Accounts Statistics.

4. Data sources

55. The analysis covers 21 countries: Belgium, Bulgaria, Canada, Estonia, Finland, France, Greece, Hungary, Italy, Latvia, Lithuania, the Netherlands, Norway, Poland, Portugal, Romania, the Slovak Republic, Spain, Sweden, the United Kingdom and the United States.

56. For EU countries and the United Kingdom, hours worked and wages are sourced from the European Union Labour Force Survey (EU-LFS) and the European Union Structure of Earnings Survey (EU-SES), respectively, covering the period 2004-2018. For the United States, the matrices of hours worked and wages are constructed for the period 2004-2018 using the Current Population Survey, which constitutes the primary source of monthly labour force statistics in this country. For Canada, this study relies on Canada's Labour Force Survey, so that, as for the United States, a single data source can be used to cross-classify both hours worked and total wages across workers with different traits over the period 2004-2018. For all countries, usual hours as opposed to actual hours are used to compile the hours worked matrix, as the former tend to be more stable over time and better correspond to the hours for which wages are paid. Total hours worked and total labour compensation are sourced from the OECD Productivity Statistics database and the OECD National Accounts Statistics database, and then used to scale the distributions of hours worked and wages obtained from the microdata sources.

57. As regards the estimation of hourly wages, these are estimated using information on gross earnings available in the different microdata sources (EU-SES for countries in the European Union and the United Kingdom and the labour force surveys in the cases of Canada and the United States). Annex B provides further information about the different microdata sources as well as the exact variables used for each country to construct measures of total annual hours worked and hourly wages for each country.

58. Unlike some of the approaches described in Section 2. , the exercise described here limits the number of categories within each worker characteristic to improve the sample size of the eventual cross-classified workers' groups. This is especially important in a study that covers a range of countries, including smaller countries for which 500 or 1 000 groups might prove impractical or yield unusably small sizes for certain groups. As such, and by the same token as the Eurostat's QALI database (Eurostat, 2016), harmonisation across countries takes priority over granularity in accounting for heterogeneity. This approach, while necessary to analyse the sensitivity of cross-country estimates of CALI to changes in the included workers' characteristics, should be understood as complementary to estimates produced by countries. National administrations, and especially NSOs, have access to a range of detailed data sources that should allow for more precise calculations based on a wider range of dimensions facilitating country specific analysis.

5. Sensitivity of CALI to the selection of workers' characteristics

Comparing different CALI measures

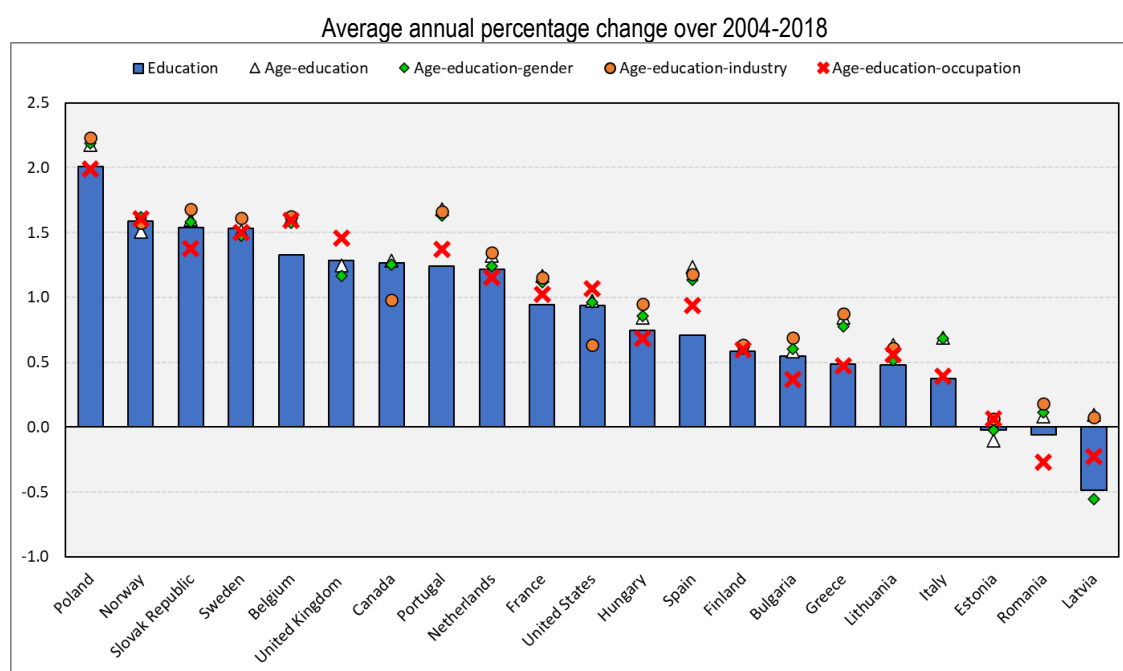
59. The highest average growth rate in CALI was recorded in Poland, Norway, the Slovak Republic, Sweden and Belgium, partly driven by the rapid growth in total hours worked experienced in these countries (Figure 2). Growth rates for the five CALI measures are well aligned with one another, with a standard deviation averaging 0.1 percentage point across the countries for which all measures are estimated. The greatest difference is observed in Latvia and Spain, where the standard deviation among the annual growth rates of CALI estimates over the entire period is 0.3 and 0.2 percentage point, respectively. The analysis of CALI measures over time presented in Annex C confirms the close alignment in the annual evolution of the five CALI measures for all countries included in the study.

60. Accounting for age (a proxy for work experience) in addition to educational attainment increases the average annual growth rate of CALI over the period 2004-2018 in 80% of the countries included in the sample. Indeed, work experience and on the job training have been noted as important determinants of workers' performance and lifetime earnings (Section -1202732272.351).

61. The countries recording the largest increase (between 0.3 and 0.6 annual percentage growth) in the average annual growth rate of CALI when accounting for age in addition to education are Latvia, Greece, Italy, Portugal, and Spain. These countries experienced relatively greater increases in the share of senior (older) workers and a relatively larger declines in the share of younger workers in the employed population (Figure 3). This partly reflects persistently high and increasing youth unemployment rates (Figure 4) and a temporary increase in the share of young adults neither employed, nor in formal education or training (NEET) following the financial crisis. In addition, it may be indicative of difficulties in the transition from education to work (Eichhorst and Neder, 2014). Relatively high long-term unemployment rates of adults (medium and high-aged individuals) with upper secondary, post-secondary non-tertiary, and tertiary education may also dampen the power of education alone to explain productivity differences across workers within these countries (OECD, 2022b).

62. Considering the relevance of accounting for age (as a proxy for work experience) in measuring CALI, the age-education CALI measure is henceforth used below as the benchmark against which this study assesses the sensitivity of CALI to the addition of further worker characteristics.

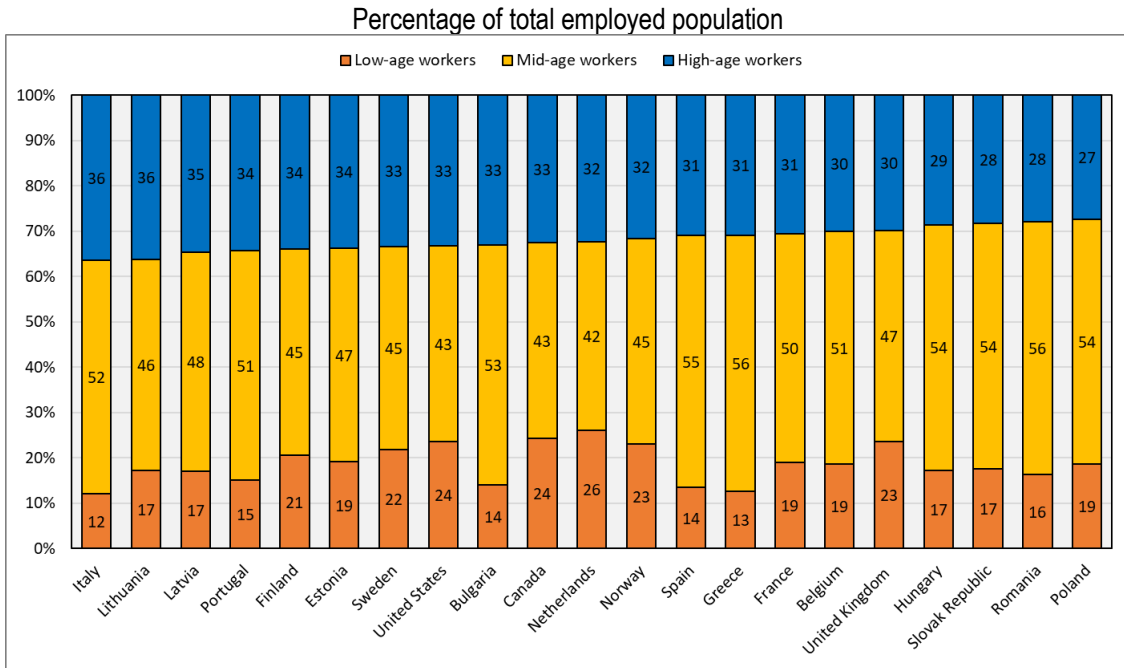
Figure 2. Annual average growth of CALI



Note: Data for the United Kingdom correspond to 2004-2014; data for the age-education-industry for the United States correspond to 2004-2017.

Source: Authors estimates based on EU-LFS, EU-SES, STATCAN LFS, CPS and OECD Productivity Statistics (database).

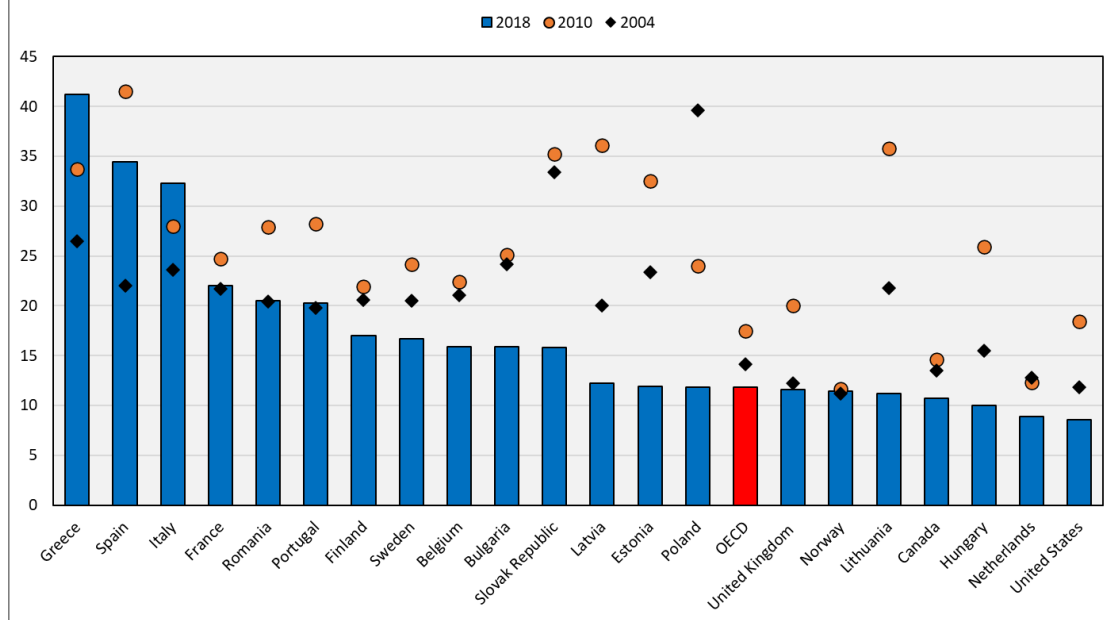
Figure 3. Persons employed by age in 2018



Source: Authors estimates based on EU-LFS, EU-SES, STATCAN LFS, CPS and OECD Productivity Statistics (database).

Figure 4. Youth unemployment rates

Young unemployed individuals aged 15-24 years, as percentage of total labour force in the same age group



Source: OECD Short-term labour market statistics and Eurostat database.

63. The inclusion of gender in the set of workers' characteristics yields minimal changes in the growth rate of CALI as compared with the age-education CALI measure (Figure 2) in almost all countries included in this study. This confirms the evidence presented for Canada by Gu et al. (2002) (Sections -1202732272.351 and -1202732272.351). Latvia is a notable exception, with lower growth in CALI when distinguishing between men and women workers' groups, likely explained by the relatively high and increasing gender wage gap. Indeed, Latvia recorded one of the highest gender wage gaps in the European Union and the OECD in 2020 and is one of the six OECD countries whose gap grew between 2000 and 2020 (OECD, 2022a). The gender wage gap has been increasing in Latvia since 2000, with the median wages of men being 22.3% higher than those of women in 2020. While some of the gap can be explained by career choices made by women, recent evidence points to the comparatively large role of discrimination in determining Latvia's gap (Ciminelli et al., 2021; OECD, 2022a), even with labour legislation dictating equal pay for work of equal value. Balancing the evidence, this study recommends the exclusion of a gender dimension when constructing CALI measures, as the expected impact on results is minimal and it is preferred to avoid distortions in cross-country comparisons of the indicator.

64. Similarly, the classification of workers according to their industry of work, in addition to their educational attainment and age, has a limited effect on the growth of CALI as compared with the age-education measure (Figure 2).

65. However, accounting for workers' occupation appears to have some impact on CALI measurement, resulting in lower annual growth rates than the age-education measure in the majority of countries (Figure 2). The average annual growth rate of the age-education-occupation CALI measure is substantially lower in the cases of Romania (-0.3% compared with 0.1%, respectively), Greece (0.5% compared with 0.8%), Latvia (-0.2% compared with 0.1%), Portugal (1.4% compared with 1.7%) and Spain (0.9% compared with 1.2%).

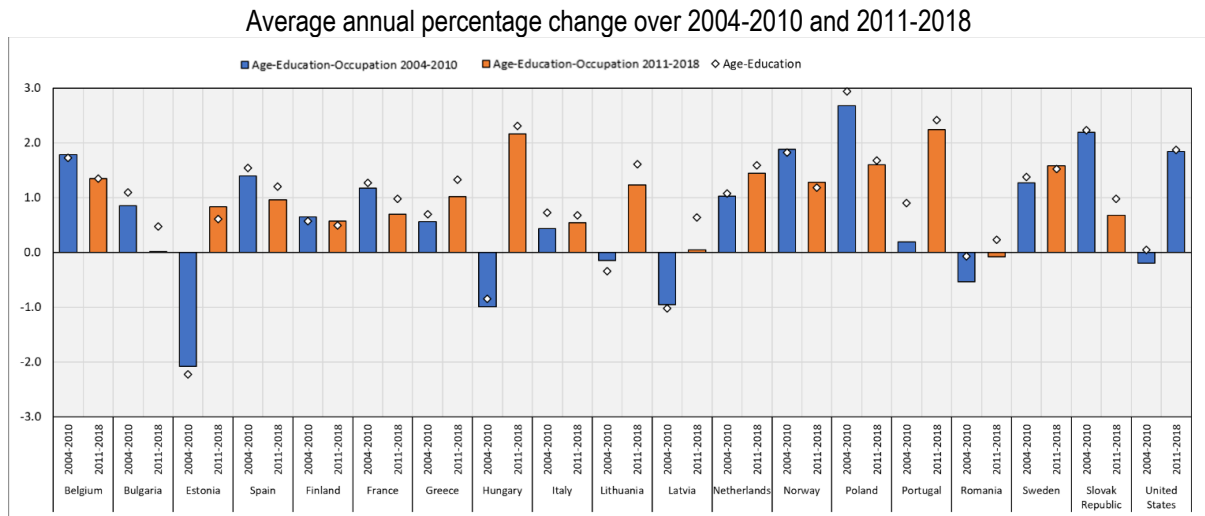
66. The downward bias introduced when accounting for occupation points to a potential, if small, overestimation of the labour quality component when occupation is overlooked. One possible interpretation is that measures of labour services which account for workers' educational attainment, but ignore workers' occupation, may fail to capture the existence of skill mismatches. In other words, the workforce in a given country could be increasing in its average level of educational attainment and work experience, but not be allocated to correspondingly skilled jobs.⁶ Another explanation could be the existence of obstacles in the reallocation of labour.

67. The implementation of a new classification for occupation in 2011 (i.e. from ISCO 1988 to ISCO 2008, Annex B) could also impact the interpretation of the estimates. As a sense check,

68. presents the comparison of the two CALI measures for the periods before and after 2011, excluding any break in the estimates presented for each period. Again, for most countries, the CALI measure that accounts for occupation in addition to age and education shows slightly lower growth than the age-education CALI measure, suggesting that the former may better capture, where they exist, the role of skills mismatches.

⁶ The measurement of skills mismatches requires however more detailed information than that used in the construction of CALI measures. Skills mismatches can be measured in several ways, either through workers' self-assessment or by comparing information on workers' field of study, skill proficiency scores and skills use in the occupations (Robst, 2007, Adalet McGowan and Andrews, 2015, 2017; Pellizzari and Fichen, 2017; Brun-Schammé and Rey, 2021), each with advantages and disadvantages and out of the scope of this study.

Figure 5. Age-Education CALI vs. Age-Education-Occupation CALI



Note: Data are not presented for the United Kingdom as data for this country are available for shorter time period (2004-2014).
 Source: Authors estimates based on EU-LFS, EU-SES, STATCAN LFS, CPS and OECD Productivity Statistics (database).

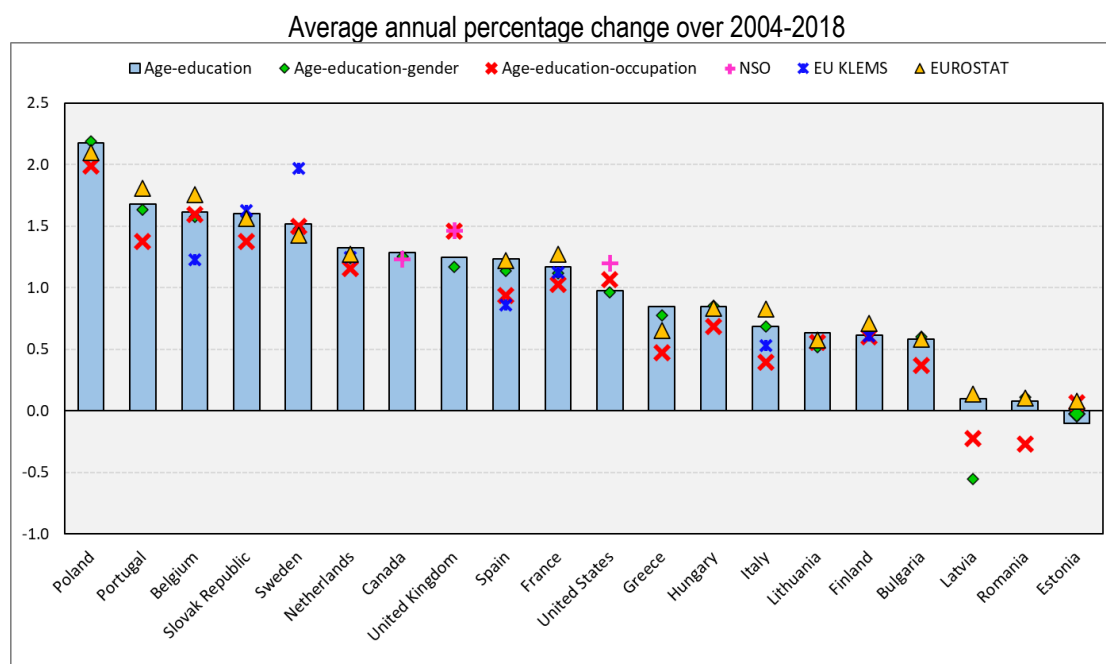
Comparison of CALI estimates with existing estimates

69. One important question is whether CALI estimates are sensitive to other specifications of workers’ characteristics and to the use of different data sources. Several NSOs and international organisations have constructed estimates of CALI. Figure 6 compares the CALI measures calculated in this paper with estimates built by Eurostat (Eurostat, 2016; Amores et al., 2021), EU KLEMS (Stehrer et al., 2019, Bontadini et al., 2023) and selected NSOs. The similarities between the methodology implemented in this study and that of the Eurostat’s QALI database are reflected in the broad alignment of the benchmark CALI measure with those produced by Eurostat. Both account for differences in the educational attainment and age of workers based on broadly equivalent data sources and methodology. Similarly, in the majority of countries where comparisons are feasible, the CALI estimates computed here using age, education and gender are broadly aligned with those released in the EU KLEMS database for the same period of analysis. Differences between the CALI measure accounting for age, education and gender and the EU KLEMS estimates are more important for Belgium and Sweden, reflecting the use of additional data sources for these countries in the EU KLEMS project.

70. Country specific estimates of CALI, such as those produced by the NSOs of Canada, the United Kingdom, and the United States, also have key methodological differences to the approach adopted in this study. For example, both the BLS (BLS, 1993; BLS, 2007) and the ONS (Sgaravatti, 2020) approaches classify workers by gender, as well as education and age, and notably the BLS uses much more granular age groupings than this study. In addition, both national authorities combined information from several microdata sources to compute their CALI estimates, which is also the case for Canada (Table A.1 in Annex A). Beyond the usual dimensions of education and work experience, the Canadian approach also divides workers based on their employment status (i.e. employed or self-employed) (Gu et al., 2002; Baldwin et al., 2007). Considering the methodological differences, the CALI estimates accounting for age and education presented in this study and those produced by the NSOs are reasonably aligned.

71. The methodological differences between the CALI estimates presented as part of this study and those produced by NSOs do not necessarily translate into substantial differences, particularly when the latter are compared with the age-education, the age-education-gender, and the age-education-occupation measures. This suggests that CALI estimates produced by international organisations, could serve to fill CALI data gaps in countries not yet producing these measures and act as a reference point for future approaches at the national level. These estimates can also provide a reasonable basis for international comparisons.

Figure 6. Comparing CALI estimates across different data sources



Note: Data for the United Kingdom correspond to 2004-2014; Norway is excluded from this graph as there are no NSOs, EU KLEMS or EUROSTAT estimates. CALI measures produced in the present study using education only and age, education and industry, are excluded from this graph for the sake of simplicity.

Source: Authors estimates based on EU-LFS, EU-SES, STATCAN LFS, CPS, OECD Productivity Statistics (database), EUROSTAT QALI's database, EUKLEMS & INTANProd - Release 2023, Statistics Canada, ONS and BLS.

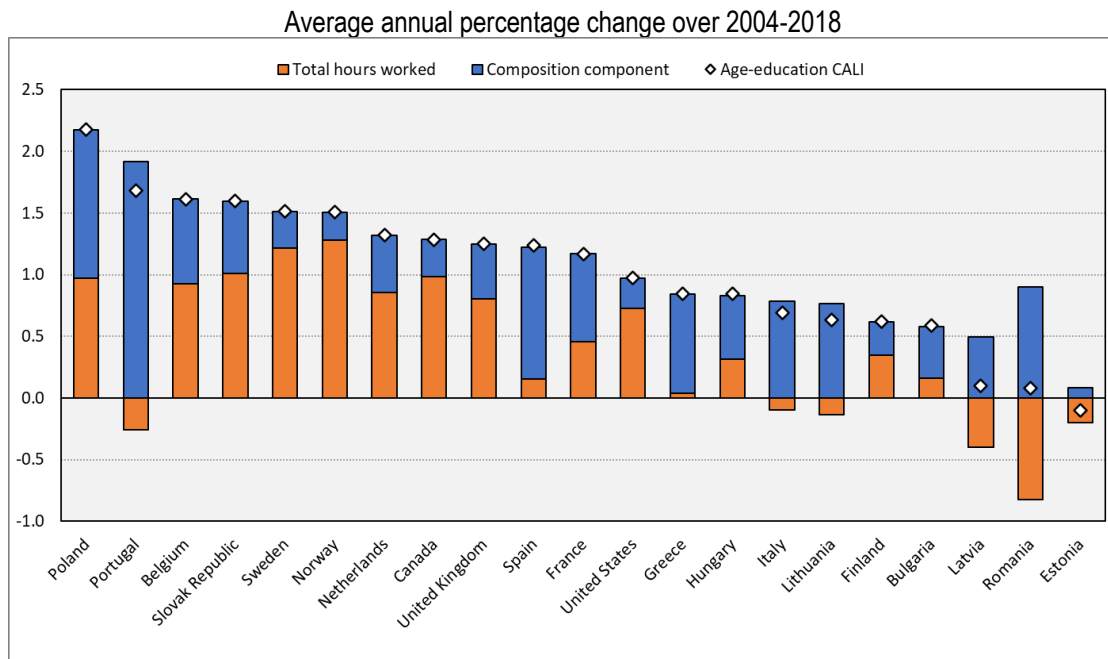
6. Analysing the evolution of CALI

72. The present section analyses the evolution and drivers of CALI over time using benchmark CALI measure (i.e. constructing on the basis of workers’ educational attainment and age).

73. Decomposing labour services into the volume of hours worked and the composition component contributes to better understanding changes in the accumulation of human capital in an economy (OECD, 2001). Growth in the composition of labour (or labour quality) is found to make a positive contribution to labour services in all countries between 2004 and 2018 (Figure 7). In other words, using a CALI measure as opposed to total hours worked leads to an increase in the average growth rate of labour input over the period 2004-2018 in all countries. The greatest contributions from changes in labour composition, and hence the largest increases in the average growth rate of labour input, are observed in Portugal, Poland and Spain, where the labour composition component grew by 1.9%, 1.2% and 1.1%, respectively, well above the average for countries for which data are available (0.6%). In a few countries, including Estonia, Latvia, Portugal and Romania, accounting for the composition of the workforce changes the sign of growth in labour input from negative to positive, as compared with that suggested by the volume of hours worked.

74. The period under analysis includes the 2008-2009 recession, which had a substantial impact on the labour markets of all the countries covered. During a recession and often in the years that follow, the compositional effect of CALI measures tends to be higher, pointing to an increase in the average skill level of those in employment (i.e. an increase in labour quality), as firms tend to shed labour and/or reduce hours worked among lower-skilled workers, while hoarding higher-skilled individuals (Leitner and Stehrer, 2012; APO/OECD, 2021). Figure 8 and Annex D confirm this reasoning, showing an increase in the composition component in most countries during the great recession (Figure 8), which counterbalanced the decline in total hours worked and cushioned the fall in CALI.

Figure 7. Growth in the age-education CALI measure and its components



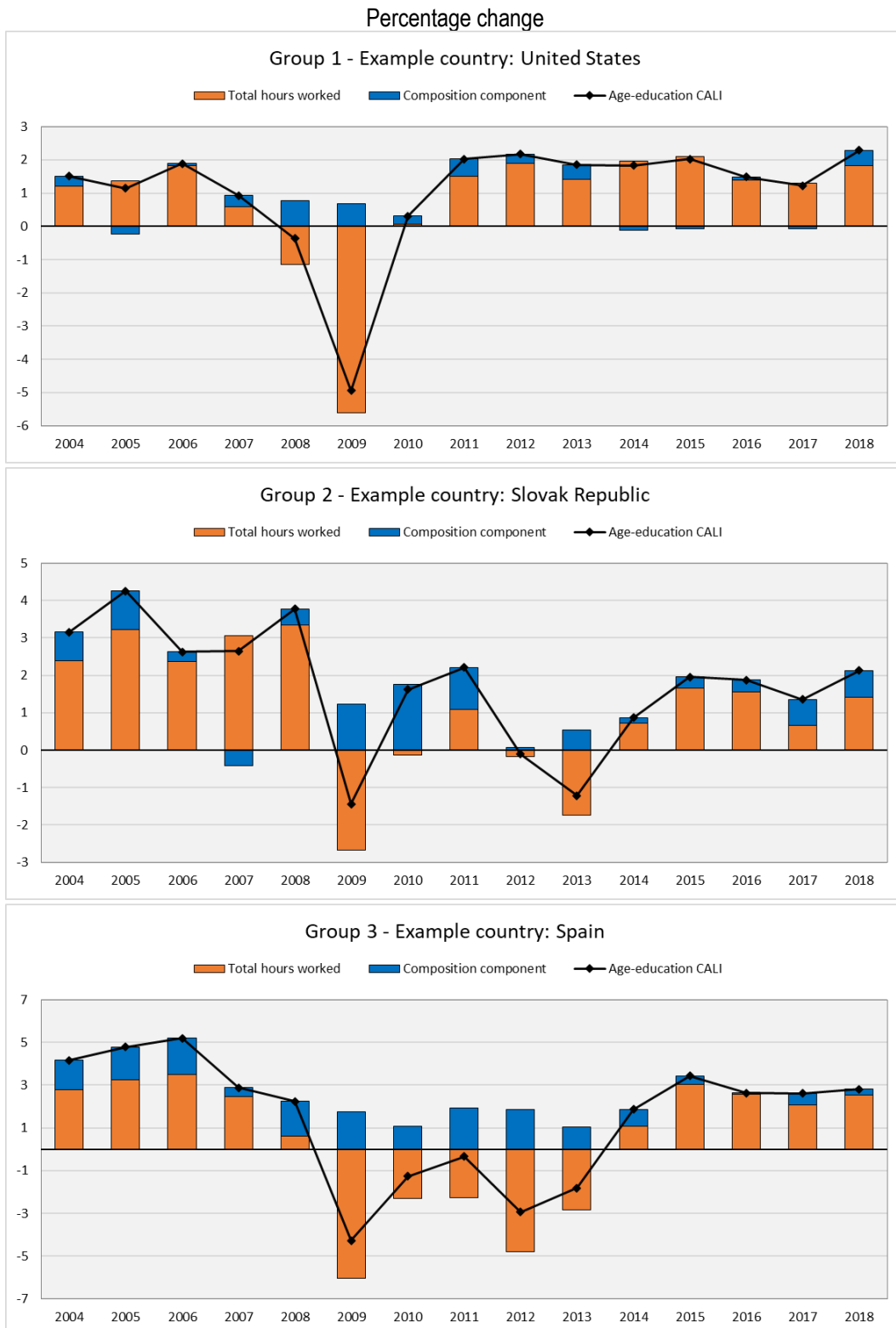
Note: Data for the United Kingdom corresponds to 2004-2014.

Source: Authors estimates based on EU-LFS, EU-SES, STATCAN LFS, CPS and OECD Productivity Statistics (database).

75. The growth rate of CALI fell during or right after the great recession in all countries, reflecting the substantial drop in total hours worked resulting from the sudden increase in unemployment rates (Annex D). However, CALI growth behaved differently across countries in the years that follow 2008-2009 recession. Countries can be categorised into three broad groups based on the evolution of CALI over time (Figure 8, Annex E):

- In a first group of countries, including Canada, Estonia, the United Kingdom, and the United States, CALI growth fell sharply during or right after the great recession but quickly recovered to pre-crisis rates, remaining stable over time. The recovery and stability in CALI growth coincides with stable growth rates in total hours worked.
- The second group of countries includes Belgium, Finland, France, Norway, the Slovak Republic, and Sweden. In these countries, CALI growth declined dramatically during or right after the recession, recovered quickly and declined again a few years after, reflecting similar movements in total hours worked and the resurgence in the unemployment rate (Annex D).
- The third group of countries includes Bulgaria, Greece, Hungary, Italy, Latvia, Lithuania, the Netherlands, Poland, Portugal, Romania, and Spain. In these countries, CALI growth fell during or right after the recession, and remained depressed in the years that followed, reflecting lower (negative) growth in total hours worked as result of persistently higher unemployment rates (Annex D).

Figure 8. Growth in age-education CALI and its components in selected countries over time

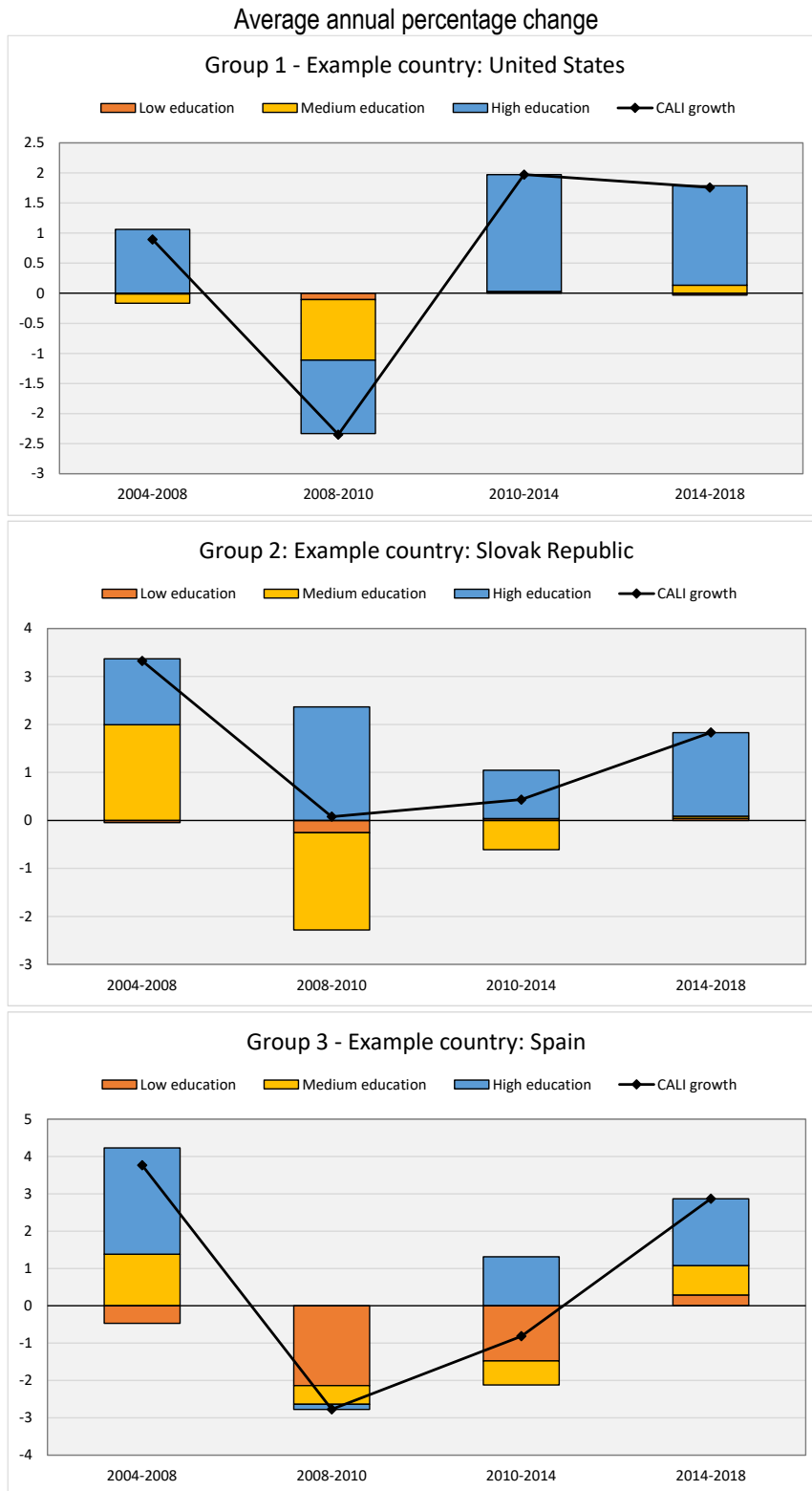


Source: Authors estimates based on EU-LFS, EU-SES, CPS and OECD Productivity Statistics (database).

76. Analysing the contributions of workers with different levels of educational attainment and different ages helps to identify some of the factors driving the evolution of CALI over time. Such a disaggregation reveals that during the great recession, less educated and younger workers in all countries covered in this study contributed negatively to CALI growth (Figure 9, Figure 10 and Annex F). This suggests that firms shed labour and/or reduced hours worked among lower skilled and less experienced workers during economic downturns.

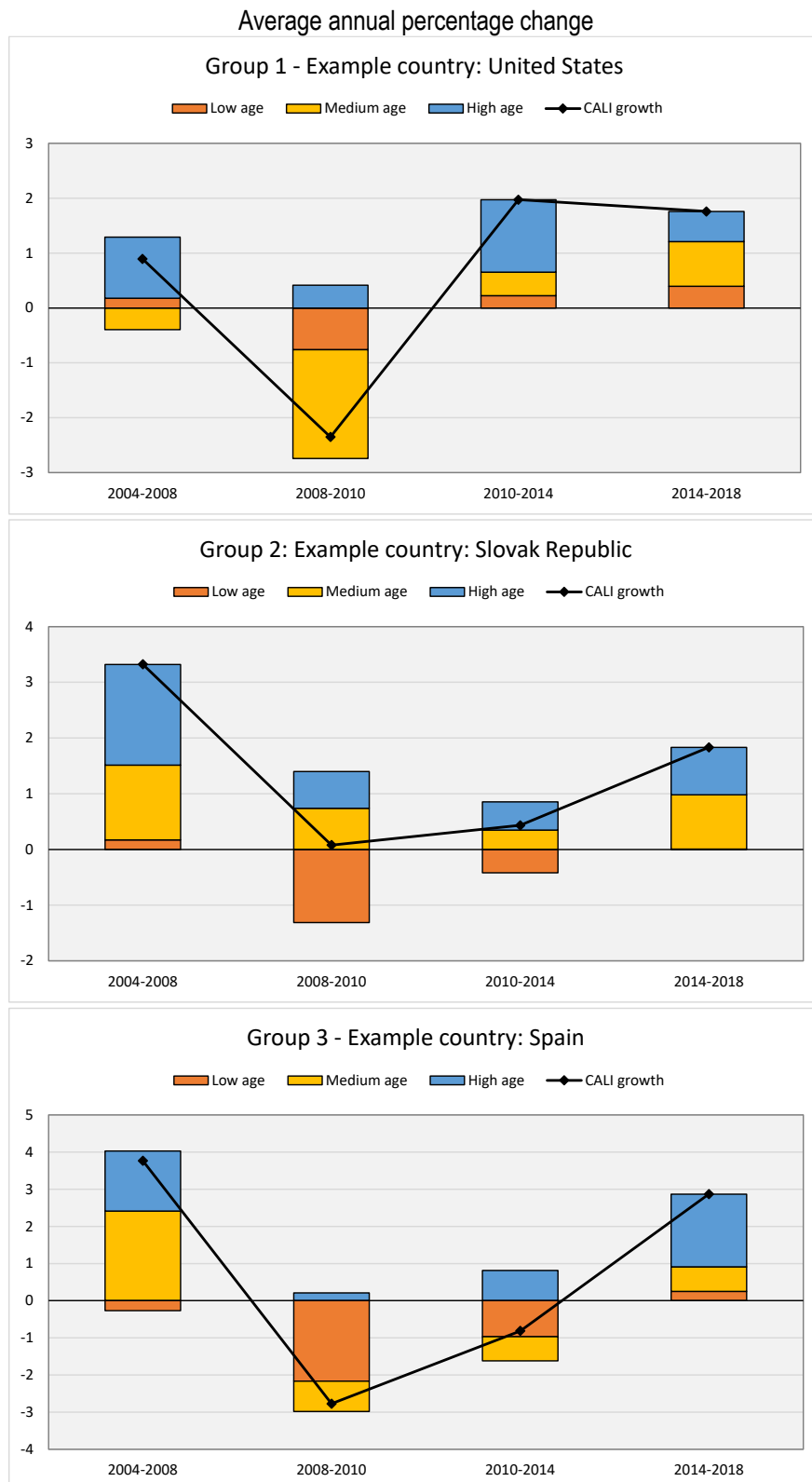
77. In most countries where CALI growth declined during the recession and recovered rapidly after (i.e. countries in groups 1 and 2), the post-financial crisis recovery in CALI growth was mostly sustained by the contribution of high-educated workers, who made up for the negative or limited contributions from their medium-educated and low-educated peers (Figure 9 and Annex F). Similarly, older workers were the major contributors to CALI growth in the aftermath of the recession in these countries (Figure 10 and Annex F). However, in many countries where CALI growth remained below pre-crisis rates for several years (group 3), high-educated workers counterbalanced the negative or limited contribution made by their low-educated peers in the aftermath of the recession (Figure 9 and Annex F). In addition, workers in the medium and high age ranges contributed positively to CALI growth in these countries, making up for the minor or negative contribution from young workers. This is likely reflective of the higher weight received by older workers in the construction of CALI, given their increasing share in total employment. Indeed, medium and high age workers accounted for between 70% and 80% of total employment in 2004 across included countries, and between 75% and 90% in 2018. Low-skilled young workers in these countries (e.g. Greece, Italy, Portugal, and Spain) were particularly exposed to job losses (Livanos et al., 2012) and were at higher risk of long-term inactivity and exclusion (Scarpetta et al., 2010).

Figure 9. Contributions to age-education CALI growth from workers with different education attainment, selected countries



Source: Authors estimates based on EU-LFS, EU-SES, CPS and OECD Productivity Statistics (database).

Figure 10. Contributions to age-education CALI growth from workers of different age, selected countries



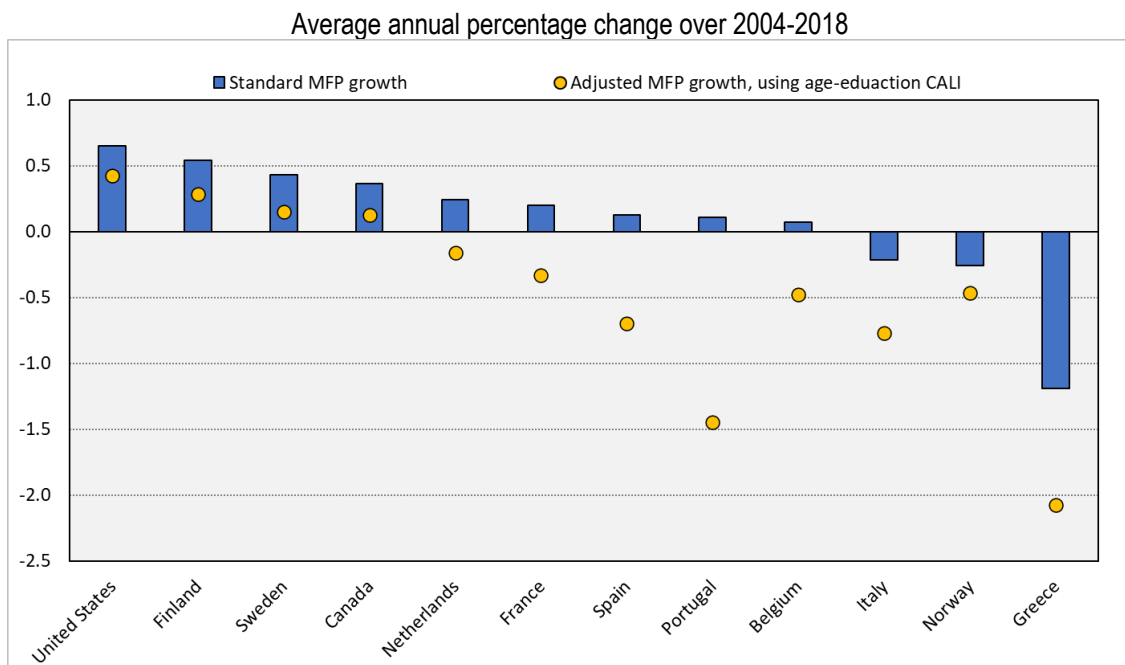
Source: Authors estimates based on EU-LFS, EU-SES, CPS and OECD Productivity Statistics (database).

7. The impact of CALI on MFP growth

78. Accounting for changes in labour composition in the growth accounts allows for a more accurate indication of the contribution of labour to production and a better appreciation of the sources of growth (OECD, 2001). The use of composition-adjusted measures of labour input, as opposed to traditional measures, generally leads to a larger share of output growth being attributed to labour and a smaller share to MFP growth. These revisions in MFP growth appear broadly comparable in scale to those observed when substituting net capital stocks with a measure of capital services in the growth accounting framework (Schreyer, 2004).

79. For all countries, measured MFP growth is revised downwards when the CALI measure is introduced into the growth accounts, suggesting that labour plays a larger role as a source of output growth than previously understood (Figure 11). While the revision to average annual MFP growth over 2004-2018 remains small in most countries, the impact on measured MFP growth may be relevant in countries that have experienced larger improvements in labour quality. A significant downward revision in average MFP growth ranging between 0.8% and 1.6% per year is found in Greece, Portugal and Spain, which is equivalent to a cumulative downward revision ranging between 10 and 20 percentage points in the MFP index over the whole period of analysis (Figure 12 and Annex G). This reflects the large increases in labour quality in these countries between 2004 and 2018. In Portugal, the standard MFP index was stable between 2004 and 2018, while the adjusted MFP index lost 20 percentage points over the same period. By contrast, the impact on MFP growth is smaller in Norway and the United States (a downward revision in average annual MFP growth close to 0.2%), as these countries experienced smaller changes in the composition of labour over the period of analysis (Figure 7).

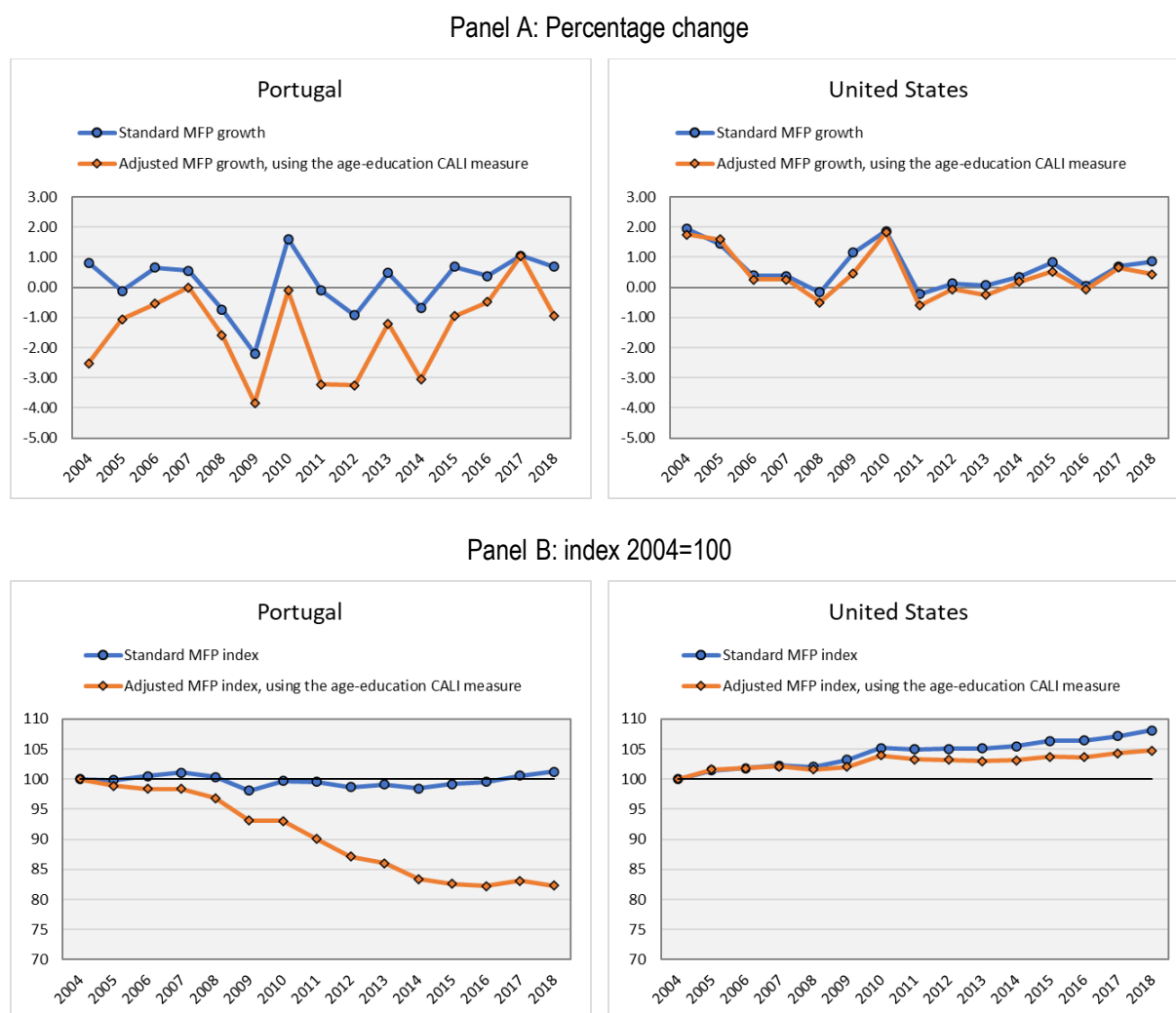
Figure 11. MFP growth using total hours worked (Standard MFP growth) and the age-education CALI measure (Adjusted MFP growth)



Note: The graph shows all countries in this study with available Standard MFP growth data in OECD Productivity Database. Data for the United Kingdom corresponds to 2004-2014.

Source: Authors estimates based on EU-LFS, EU-SES, STATCAN LFS, CPS and OECD Productivity Statistics (database).

Figure 12. Standard and adjusted MFP growth in Portugal and the United States



Source: Authors estimates based on EU-LFS, EU-SES, CPS and OECD Productivity Statistics (database).

8. Conclusions

80. This study presents one of the more comprehensive assessments of the compilation of CALI, in terms of both country coverage and workers' characteristics, while providing important insights to ensure the international comparability of this indicator. Measuring labour input solely through the volume of hours worked ignores potential changes in the skills and capabilities of the workforce over time. Composition-adjusted measures of labour input address this oversight by differentiating hours worked according to a set of workers' characteristics assumed to dictate their productive capacity.

81. Using a generic approach and different microdata sources, the study builds five CALI measures for selected OECD countries and assesses the magnitude of their differences. Educational attainment and age (as a proxy for years of experience), i.e. the baseline CALI measure in this study, emerge as the two essential workers' characteristics to consider when investigating the contribution of labour input to output growth. Occupation also appears to hold some explanatory power. When combined with educational attainment, occupation may help to account for skills mismatches that may diminish the contribution of workers whose qualifications are misaligned with their role and tasks. Nonetheless, this interpretation

requires some caution and deserves further analysis. The broad industry of work seems to be less relevant, adding little or no explanatory power to the CALI measure in addition to education and age. Similarly, the inclusion of gender as a dimension yields minimal changes to the growth rate of the CALI measure.

82. The use of wages as a proxy for productivity in the estimation of CALI remains controversial, especially where workers are classified according to their gender. Indeed, gender pay gaps often reflect discrimination between women and men in the workplace, as well as differences in self-selection, propensity to compete, negotiation behaviour and risk aversion.

83. Methodological differences between CALI measures presented as part of this study and those produced by NSOs do not necessarily translate into substantial differences in CALI estimates, particularly when the estimates account for age-education and age-education-occupation, at least in the cases of the United Kingdom and the United States. This suggests that CALI measures produced by international organisations could serve to fill CALI data gaps in countries not yet producing these measures and act as a reference point for future approaches at the national level. These estimates may also provide a reasonable basis for international comparisons.

84. The average growth rate of labour input increases across all countries when using a CALI measure as opposed to a traditional measure, e.g. total hours worked. The growth rate of CALI fell during or right after the 2008-2009 global recession in all countries, reflecting the substantial drop in total hours worked resulting from the sudden increase in unemployment rates. However, deconstructing CALI growth over time in each country reveals the counterbalancing effect of changes in the composition of the workforce over the same period. Indeed, during times of crisis businesses tend to retain more skilled and experienced workers (i.e. labour hoarding), while shedding labour and/or reducing hours worked among lower-skilled workers, resulting in an increase in the average skill level of those in employment.

85. For all countries covered in this study, the use of a CALI measure in the growth accounts as opposed to traditional measures of labour input, increases the role of labour as a source of economic growth and reduces measured MFP growth – although for many countries by a limited amount. The impact on MFP growth is especially pronounced in those countries that have experienced large changes in labour quality over the period of analysis.

86. Overall, the replacement of traditional measures of labour input with those accounting for changes in the composition of the workforce can help to improve our understanding of changes in human capital over time, as well as in MFP growth. NSOs are typically best placed to produce CALI measures, as they benefit from access to a much wider range of data sources, sometimes confidential, and have the expertise to address representative biases to maximise the quality of their estimates. Such an exercise comes at the cost of timeliness and resources and necessitates access to microdata sources. Therefore, decisions regarding the calculation and introduction of such a measure into the growth accounting framework will depend on the expected changes in the composition of the workforce overtime and/or the cost of producing CALI measures.

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Annex A. Summary of studies measuring CALI

Table A.1. Methods, dimensions and data sources used in the literature to compile CALI measures

Dimension / Study	Jorgerson and Griliches (1967)	Jorgerson, Gollop and Fraumeni (1987) ⁽¹⁾	BLS (1993) ⁽²⁾	BLS (2007)	Baldwin et al., (2007)	Fukao et al. (2007), Fukao et al. (2021)	Schwerdt and Turunen (2007)	Cabannes, Montaut and Pionnier (2013)	ABS (2015)	Eurostat (2016), Amores et al. (2021)	The Conference Board (TED) (2017)	Nomura and Akashi (2017)	EU KLEMS (Stehrer et al., 2019, Bontadini et al., 2023)	Sgaravatti (2020) ⁽⁴⁾
Education	8 categories	5 categories	7 categories	7 categories	4 categories	4 categories	3 categories	3 categories (employees only)	4 categories	3 categories	3 categories	4-10 categories	3 categories	6 categories
Age	-	8 categories	72 categories	72 categories	7 categories	11 categories	6 categories	4 categories (employees only)	5 categories	3 categories	-	11 or 12 categories per country	3 categories	3 categories
Sex	Males only	Male, female	Calculated separately by sex ⁽³⁾	Calculated separately by sex ⁽³⁾	-	Male, female	Calculated separately by sex ⁽³⁾	Male, female (employees only)	Male, female	-	-	Male, female	Male, female	Male, female
Employment class	-	Employees, self-employed	-	-	Employees, self-employed	Full-time employees, Part-time employees, Self-employed workers	-	Employees, self-employed	-	-	-	Employees, own-account workers and unpaid family workers	-	-
Total groups	8 groups	1600 groups	Males: 504, Females: 4032	1008 groups	56 groups	264 groups	36 groups	25 groups	40 groups	9 groups	3 groups	264-720 groups	18 groups	360 groups
Industry breakdown	-	51 industries	-	3 aggregates + 18 manufacturing industries	139 industries	3 aggregates + 108 industries	-	-	16 industries + 2 aggregates	A*10 and A*21	-	-	A*20 (M-N combined)	10 industries
Benchmarking to national accounts	Not specified	Not specified	Not specified	Not specified	Not specified	Not specified	Not specified	Yes, using hours worked	Not specified	Yes, using hours worked	Not specified	Not specified	Yes, using employment	Yes, using hours worked
Countries and period covered	United States, 1945-1965	United States, 1948-1979	United States, 1948-1990	United States, since 1987	Canada, since 1961	Japan, 1994-2018	12 euro area countries, 1983-2005	France, 1979-2010	Australia, since 1995	EU 27, 2002-2019	96 countries, since 2000	Bangladesh, Bhutan, India, Nepal, Pakistan, Sri Lanka, 1970-2015	EU 27, United Kingdom, Norway, Japan, United States, since 1995	United Kingdom, since 1994
Data sources	Not specified	Census of Population, CPS, Bureau of Census statistics, Survey of Current Business	CPS, Census, Social Security and IRS records	CES, CPS and NCS	Survey of Consumer Finance, LFS, Survey of Labour and Income Dynamics, Population Census	Pop. Census, Employment Status Survey, LFS, Establishment and Enterprise Census, Monthly Labour Survey, Basic Survey on Wage Structure.	ECHP, EU-LFS, LIS, GSOEP	LFS, DADS, National Accounts	IDS, SIHC, LFS and National Accounts	EU-LFS, EU-SES, EU-SILC, National Accounts	Intl. databases e.g. Eurostat, OECD, ILO, World IO and KLEMS	Mostly population and housing census and LFS.	EU-LFS, EU-SES, EUKLEMS, National Accounts	LFS, ASHE, Hours data from Productivity Statistics

Note: (1) Jorgerson, Gollop and Fraumeni (1987) also account for ten categories of occupation; (2) BLS (1993) accounts also for marital status and children (women only); (3) CALI is computed for men and women separately, hence they compute two measures of CALI; (4) Sgaravatti (2020) also accounts for the industry of work when classifying workers into different groups.

Source: Authors' elaboration.

Annex B. Data sources and data manipulation

The construction of the hours worked and wages matrices, i.e. hours worked and wages cross-classified across groups of workers with different skills, relies on the use of different microdata sources. For EU countries and the United Kingdom, hours worked and wages are sourced from the European Union Labour Force Survey (EU-LFS) and the European Union Structure of Earnings Survey (EU-SES), respectively. For Canada and the United States, the matrices of hours worked and wages are constructed using the Canadian Labour Force Survey (STATCAN LFS) and the Current Population Survey (CPS), respectively, with the latter being the primary source of monthly labour force statistics in the United States. For all countries included in this study, total hours worked and total labour compensation sourced from the OECD Productivity Statistics database and the OECD National Accounts Statistics database⁷ are used to benchmark the distributions of hours worked and wages obtained from the microdata sources.⁸ The exact variables used from each microdata source are detailed in Table A.1.

The EU-LFS is a large household survey⁹ yielding quarterly results on employment, unemployment, labour force participation of people aged 15 or over, as well as detailing their individual characteristics such as age, sex, educational attainment, employment status, occupation, industry, and hours worked, among many other variables. The survey covers the 27 EU member states plus candidate countries, countries that are part of the European Free Trade Area (EFTA) and, until Q3 2020, the United Kingdom. The EU LFS data used covers the period 2004-2018 for all countries.

⁷ In the OECD Productivity Statistics database, the preferred source for total hours worked data is countries' national accounts, which are presented in the OECD National Accounts Statistics database. However, since January 2019, hours worked for Austria, Estonia, Finland, Greece, Latvia, Lithuania, Poland, Portugal, Sweden and the United Kingdom available in the OECD Productivity Statistics database and OECD Employment and Labour Market Statistics database are estimated by the OECD Secretariat with a "simplified" component method based on EU LFS data, with the aim to limit self-reporting bias and improve the international comparability of these series (Ward et al., 2018).

⁸ For the EU countries and the United Kingdom, the variable for gross annual earnings in the reference year, sourced from the EU-SES, is adjusted wherever a full-time employee has worked less than 52 weeks, to properly reflect annual earnings.

⁹ The EU-LFS covered 1.5 million individuals across the EU in 2018.

Table B.1. Description of variables sourced from microdata sources

		EU-LFS	EU-SES	STATCAN-LFS	CPS of the United States	OECD Productivity Database
Country of Residence		country	-	-	-	LOCATION
Country of Work		-	country	-	-	-
Year		year	year	survyear	hryear4	_TIME_
Education	Before e	hat97lev	b25	educ90	peeduca	-
	From e	hat11lev	b25	educ	peeduca	-
Age	Before a	age	b22_class	age_12	peage	-
	From a	age	b22_class	age_12	prtage	-
Industry	Before i	na111d	nace	naics_18	primind1	-
	From i	nace1d	nace	naics_18	primind1	-
Occupation	Before o	is881d	b23	nocs_01_47	peio1ocd	-
	From o	isco1d	b23	nocs_01_47	peio1ocd	-
Hours worked		hwusual*(365/7)	(b32*b31)/4.35	utothrs*(365/7)	(pehrusl1+pehrusl2) *(365/7)	T_HRSTO
Earnings		-	b41	hrlyearn	prernwa	-

Notes: e = 2014 for the EU-LFS, e = 2017 for the STATCAN-LFS, a = 2013 for the CPS of the United States, i = 2008 for the EU-LFS, and o = 2011 for the EU-LFS.

Variables used for hours worked calculations are defined as follows: hwusual = usual weekly hours of work; b32 = number of hours paid during the reference month; b31 = number of weeks to which gross annual earnings relate; utothrs = usual hours per week at all jobs; pehrusl1 = usual hours per week at main job; pehrusl2 = usual hours per week worked in other jobs.

Variables used for earnings calculations are defined as follows: b41 = total gross annual earnings in the reference year; hrlyearn = usual hourly wages; prernwa = weekly earnings.

Source: Authors' elaboration.

The EU-SES is a large enterprise survey run on a four-yearly basis (2002, 2006, 2010, 2014 and 2018) providing harmonised information on the level of remuneration and characteristics of employees - e.g. educational attainment, age, sex and occupation – and of the enterprises – e.g. industry, size and location within the country. The information refers to enterprises with at least ten employees operating in all areas of the economy except agriculture, forestry and fishing, and public administration, in EU member states, EFTA countries and the United Kingdom. For workers employed in these industries, this paper uses the average annual earnings in the total economy (i.e. average annual earnings across all industries for which data are available). In addition, the EU SES provides information only on employees, excluding self-employed workers. Therefore, it is assumed that the self-employed worker earns the average wage of an employee with the same characteristics (e.g. age, education, gender, industry, occupation). Earnings in the EU-SES are originally reported as gross annual earnings in the reference year including all bonuses and non-salary benefits. From this information, it is possible to derive hourly earnings by dividing gross annual earnings by annual hours worked (calculated as described in Table B.1), cross-classified by the same selected workers' characteristics as the groups formed for annual hours worked. Given the periodicity of the data it was necessary to interpolate between the available years. Without any evidence to indicate a more complex path, the chosen approach was linear interpolation, which is also the approach taken by Eurostat (2016) – i.e. drawing a straight line between the available EU-SES data points for different years. The 2007-2009 financial crisis makes the linear interpolation of wages particularly imperfect between 2006 and 2010; however, the impact of the crisis is partly captured when scaling the microdata wage structure to the national accounts. In addition, for some waves/countries of this survey, information on skill and industry has not been reported for some or all workers. In those cases where only some of the workers reported the information, it is adopted the structure of available data on earnings by skill/age.

The CPS is conducted by the United States Census Bureau using a probability selected sample of around 60 000 occupied households and covering all 50 states. The survey collects information from individuals aged 15 or older that are not in the armed forces, an institution (e.g. prison), a long-term care hospital or a nursing home. The CPS comprises information on various labour force indicators, including all of the worker characteristics required to classify hours worked and earnings by workers' traits – i.e. employment status, age, sex, educational attainment, occupation and industry of work. However, the occupational classifications used in the CPS do not directly align with the International Standard Classification of Occupations 2008 (ISCO08), making some adjustment necessary for the sake of this sensitivity test. To create an occupational breakdown consistent with ISCO08, a three-stage concordance table was used, first aligning the CPS classification with the 2010 Standard Occupational Classification System (SOC10) used by the BLS in the United States, and then aligning SOC10 with ISCO08.¹⁰

The Canadian LFS is a monthly household survey carried out by Statistics Canada (STATCAN) with the principal objective of determining the employment status of the working age population. The STATCAN-LFS collects data on hours worked, earnings and the worker characteristics necessary to compute all the CALI measures included in this study. The primary challenge of working with the STATCAN-LFS is to properly align the national classification of occupations with the International Standard Classification of Occupations 2008, ISCO08 (ILO 2020), which are needed to classify workers according to the tasks and duties undertaken in their job. The classification system used in the STATCAN-LFS is consistent with the National Occupational Classification for Statistics (NOC-S) 2006 and NOC 2011. This is not an issue in itself when viewing the Canadian data in isolation but does bring some challenges when aligning the Canadian data with the ISCO for cross-country comparisons. While concordance tables do exist between NOC-S 2006 and NOC 2011, many of the NOC-S 2006 occupation categories are split in the NOC 2011 version, making it impossible to cleanly convert some of these categories into ISCO08 for direct comparison with the other countries the sample without making significant judgement calls.¹¹

In all the LFS listed above, hours worked are originally reported in terms of both actual and usual weekly hours of work in the reference week. In this paper, usual hours as opposed to actual hours are used to compile the hours worked matrix, as the former tend to be more stable over time and better correspond to the hours for which wages are paid. As reported in Table B.1, usual weekly hours worked sourced from the EU-LFS, STATCAN-LFS and the CPS are converted into annual estimates by multiplying them by 365/7. For Canada and the United States, hourly earnings are readily available in the STATCAN-LFS and CPS, respectively. Annual earnings are then calculated by multiplying hourly earnings by annual hours worked. For countries in the European Union and the United Kingdom, annual earnings are available in the EU-SES. Annual earnings are then divided by total annual hours paid to estimate a measure of hourly earnings for a given year. Total annual hours paid for these countries are obtained by multiplying the number of hours paid during the reference month by the number of weeks to which the gross annual earnings relate and then dividing this by 4.35.¹²

Using data from labour force surveys (LFS) (EU-LFS, STATCAN LFS, CPS) brings with it one important consistency problem. The sampling structure of the LFS is based on households, irrespective of their country of work. However, labour input data in the national accounts and used in productivity analyses (needs to) reflect the activities of workers in the national territory (i.e. in resident institutional units). Therefore, there is a discrepancy in the definition of surveyed workers between the LFS and the national accounts. The approach adopted here is to assume that incoming workers not captured in the LFS for a given country have the same characteristics as resident workers. This seems to be a reasonable

¹⁰ The concordance tables elaborated by the authors are available upon request.

¹¹ The concordance tables elaborated by the authors are available upon request.

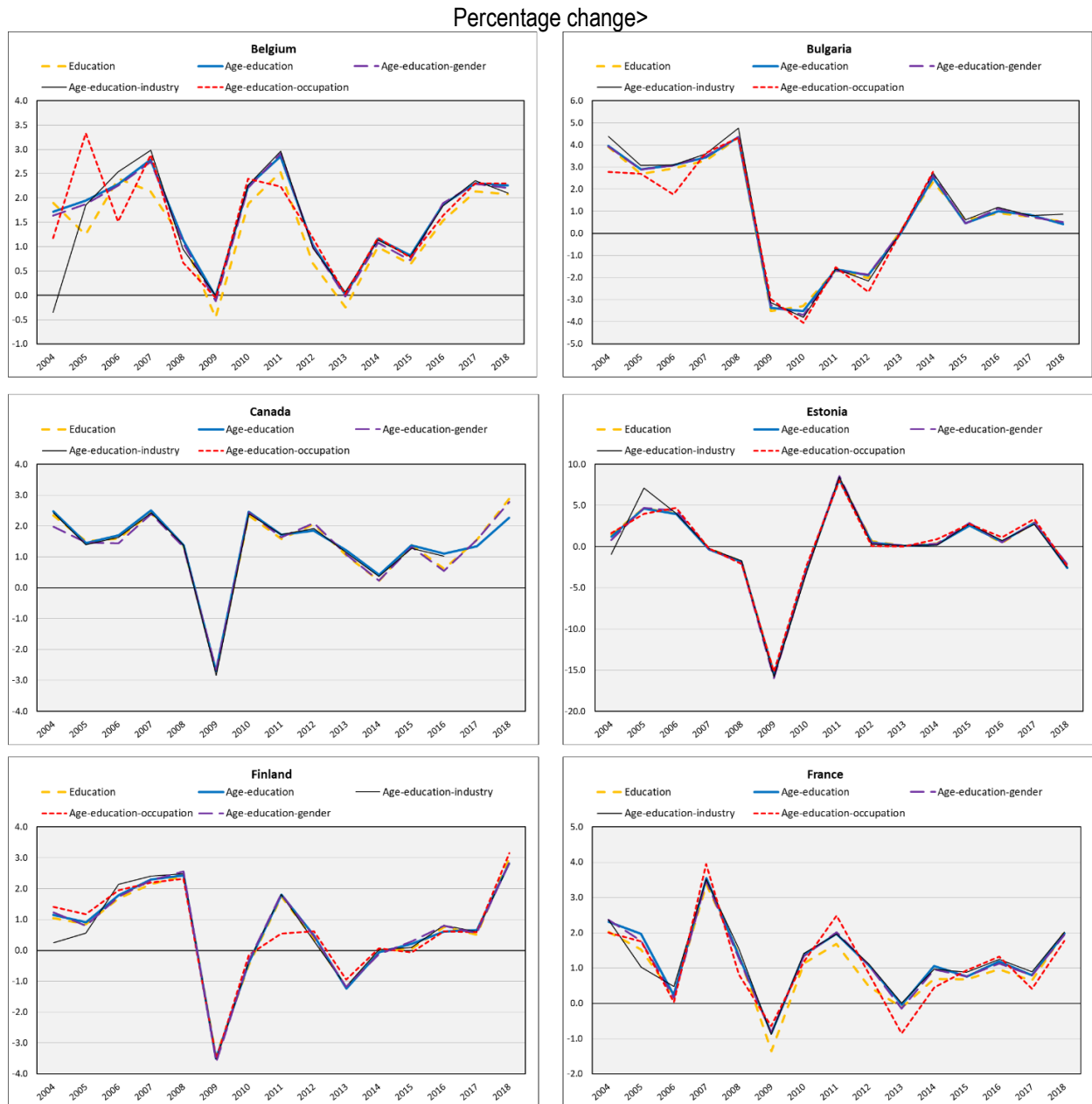
¹² The factor 4.35 is the average number of weeks within a month (365 days per year / 7 days per week / 12 months per year).

assumption as, for the most part, the share of resident workers in most countries tends to be close to 100% (Eurostat, 2016).

Another important challenge arises from changes in individual country surveys, which can impact the comparability of data through time, especially for EU countries and the United Kingdom when multiple surveys are combined to produce the EU-LFS (Eurostat, 2016). For instance, population censuses are generally revised on a regular basis, meaning the sample weights used to make a wide range of estimations may change as well. Other inconsistencies in the time series may arise due to changes in the reference periods, often when countries transition to a quarterly continuous survey, or due to countries modifying their sample designs and/or changing the content or the order of their questionnaire in order to improve the quality of results. Further to this, there are sometimes divergences of national definitions of employment and European ones (Eurostat, 2020). For example, in Portugal, the persons on sick leave, maternity or paternity leave, or paid parental leave are always considered as employed, regardless of the length of the absence. These types of differences can create inconsistencies in cross-country comparisons of employment measures calculated from the EU-LFS. That being said, recent changes introduced in EU-LFS definitions with the entry into force of the Integrated European Social Statistics (IESS) regulation are expected to improve comparability across countries, though the effects depend to some extent on Eurostat and country-by-country revision policies.

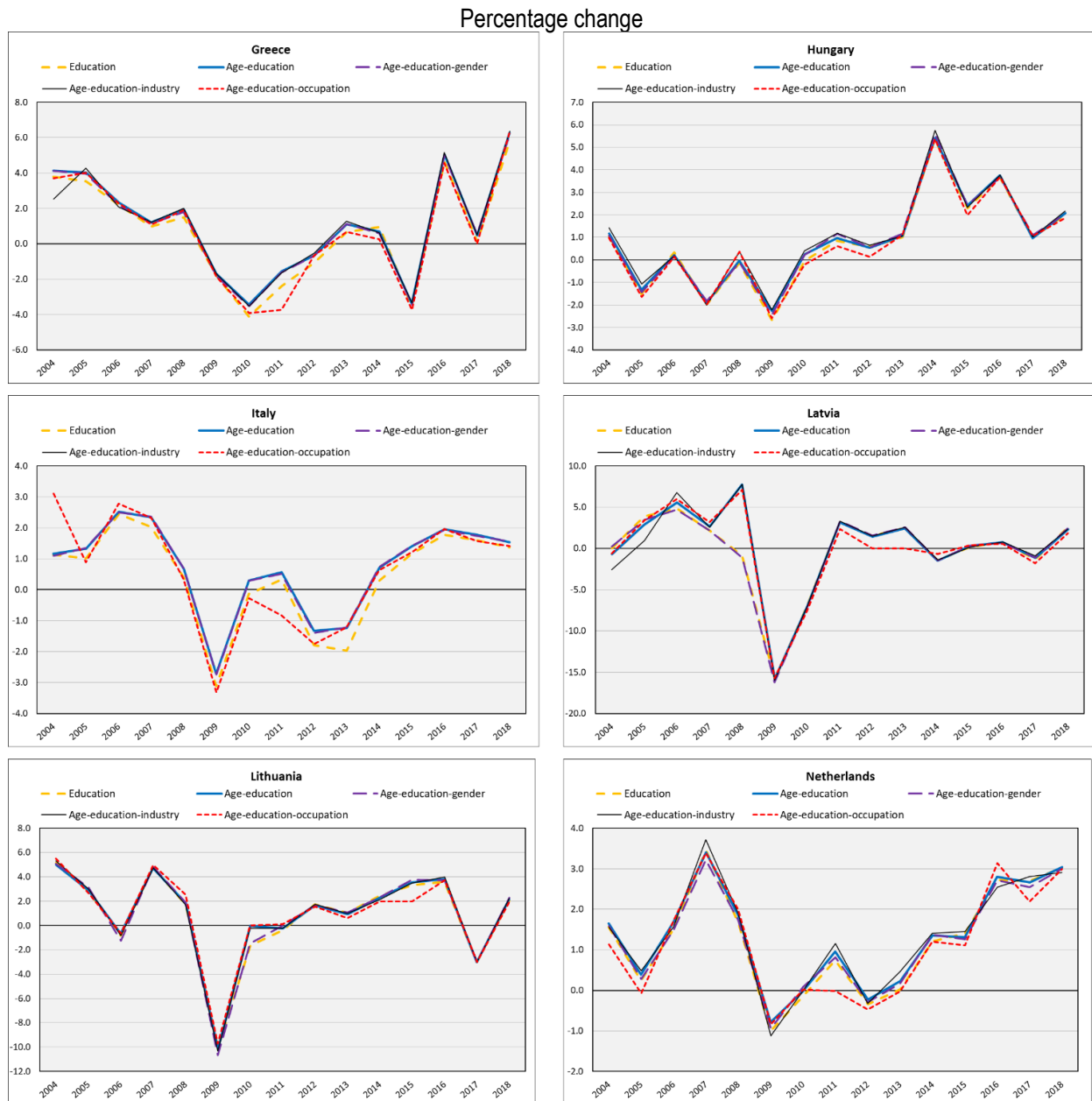
Annex C. Evolution of CALI over time

Figure C.1. Evolution of different CALI measures over time, selected countries (1)



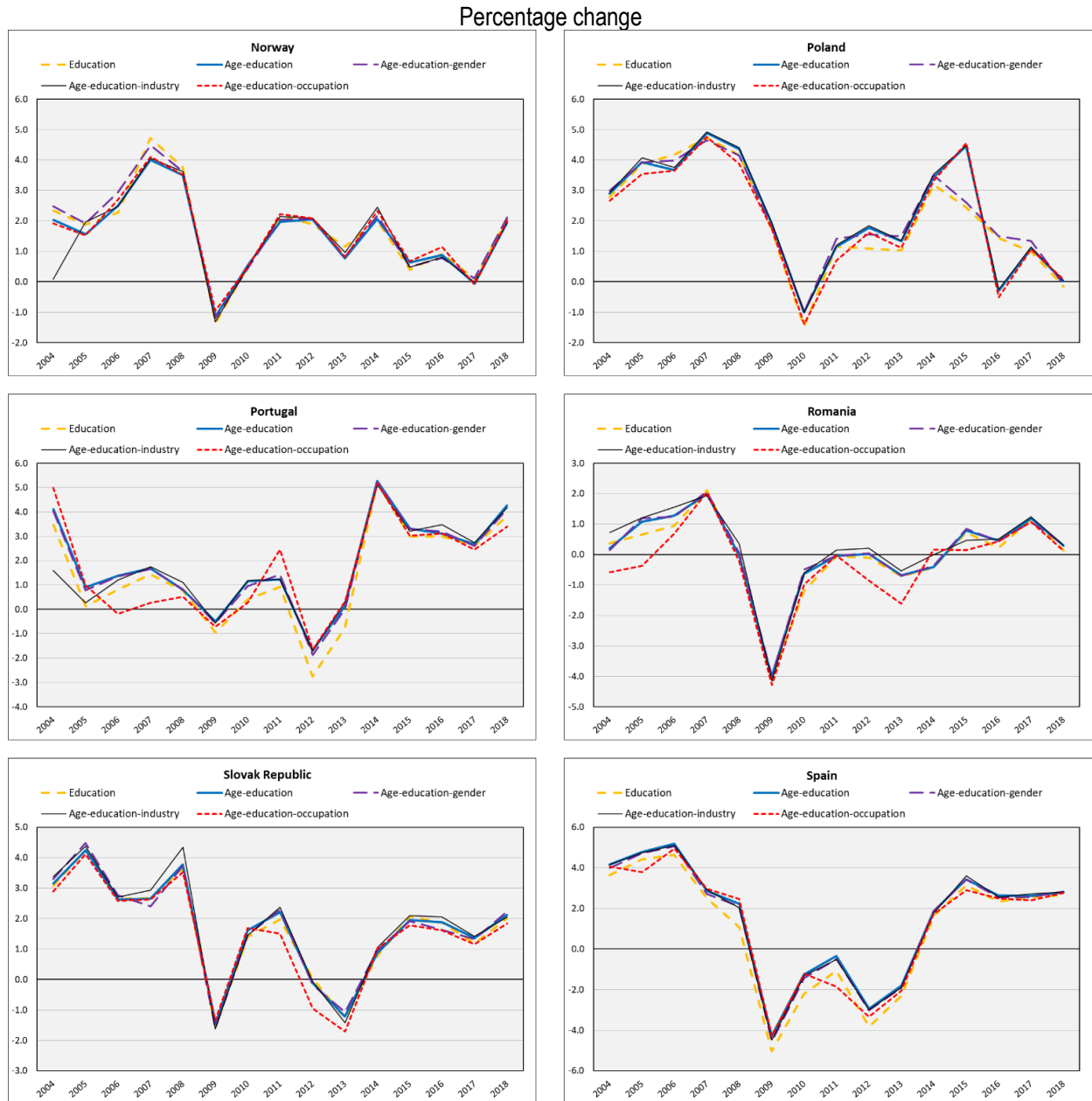
Source: Authors' calculations.

Figure C.2. Evolution of CALI over time, selected countries (2)



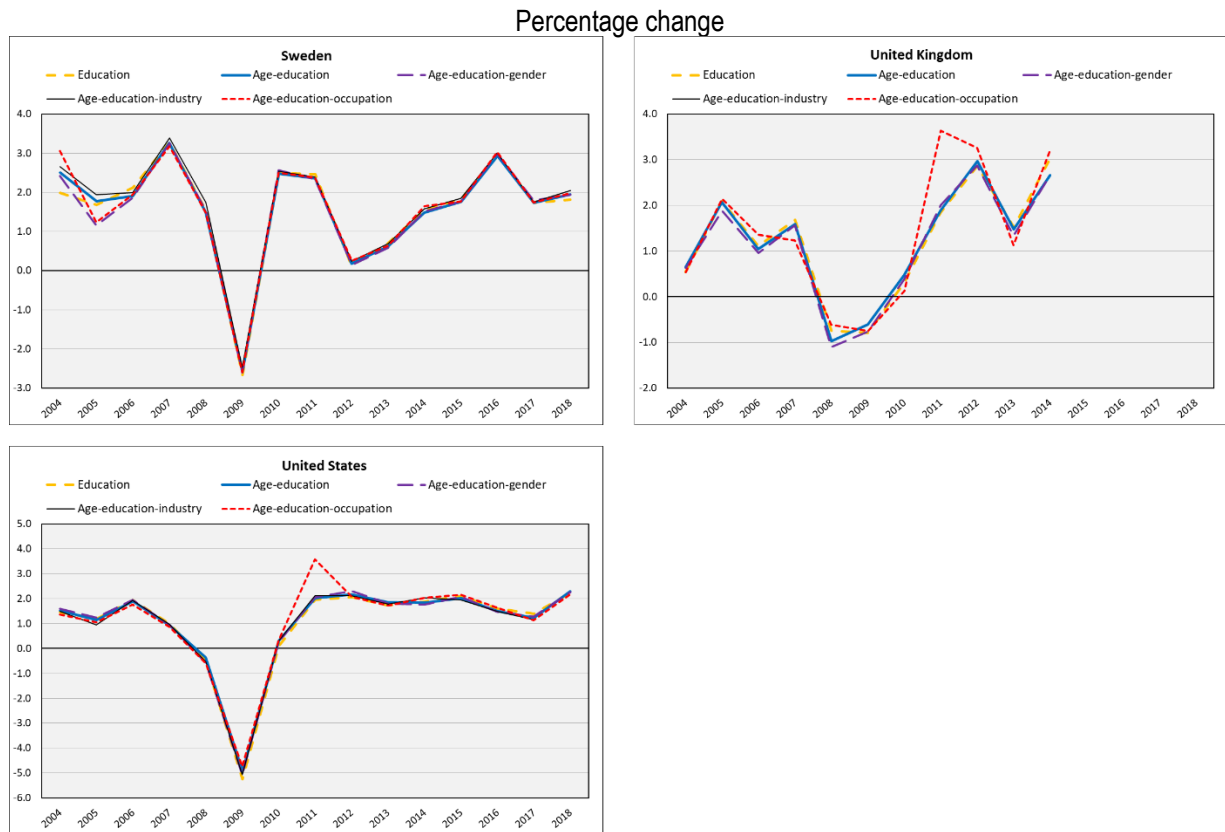
Source: Authors' calculations.

Figure C.3. Evolution of CALI over time, selected countries (3)



Source: Authors' calculations.

Figure C.4. Evolution of CALI over time, selected countries (4)



Source: Authors' calculations.

Annex D. Unemployment rates over time

Table D.1. Unemployment rates

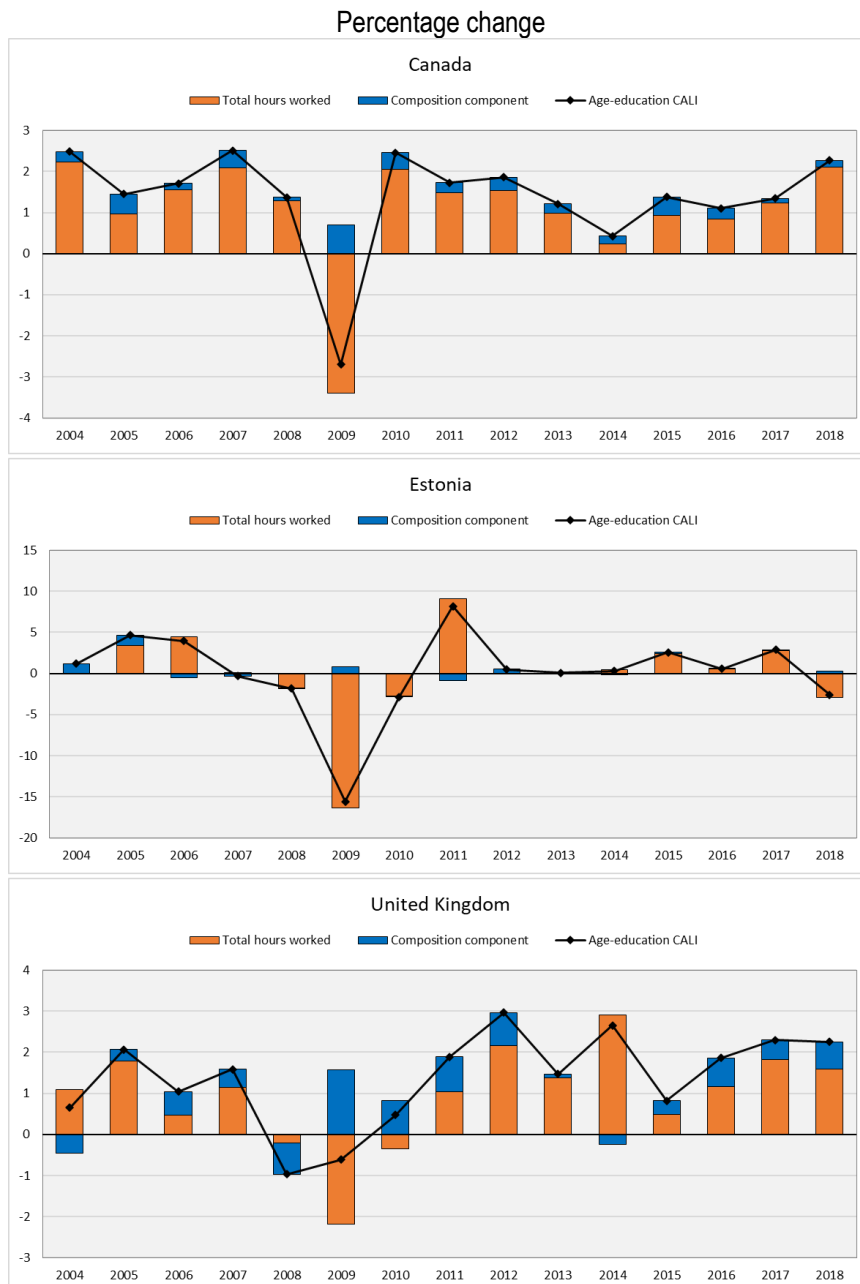
Unemployed persons as percentage of total labour force

	Country	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Group 1	Canada	6.2	6.3	8.5	8.2	7.6	7.4	7.2	7.0	6.9	7.0	6.4	5.8
	Estonia	4.6	5.5	13.5	16.6	12.4	9.9	8.5	7.3	6.4	6.8	5.8	5.4
	United Kingdom	5.3	5.7	7.6	7.9	8.1	8.0	7.6	6.2	5.4	4.9	4.4	4.1
	United States	4.6	5.8	9.3	9.6	9.0	8.1	7.4	6.2	5.3	4.9	4.4	3.9
Group 2	Belgium	7.5	7.0	8.0	8.4	7.2	7.6	8.6	8.7	8.7	7.9	7.1	6.0
	Finland	6.9	6.4	8.4	8.5	8.0	7.8	8.3	8.8	9.5	8.9	8.8	7.4
	France	8.0	7.4	9.1	9.3	9.2	9.8	10.3	10.3	10.4	10.1	9.4	9.0
	Norway	2.7	2.9	3.5	4.0	3.6	3.5	3.9	3.8	4.7	4.9	4.4	4.0
	Slovak Republic	11.2	9.6	12.1	14.4	13.6	13.9	14.1	13.1	11.5	9.7	8.1	6.5
	Sweden	6.3	6.4	8.5	8.8	8.0	8.2	8.2	8.1	7.6	7.2	6.9	6.5
Group 3	Bulgaria	6.9	5.6	8.0	11.3	12.3	13.3	13.9	12.4	10.1	8.6	7.2	6.2
	Greece	8.4	7.8	9.8	13.0	18.1	24.8	27.8	26.7	25.0	23.9	21.8	19.7
	Hungary	7.4	7.8	9.7	10.8	10.7	10.6	9.6	7.5	6.5	4.9	4.1	3.5
	Italy	6.2	6.8	7.9	8.5	8.5	10.9	12.4	12.8	12.0	11.8	11.3	10.6
	Latvia	6.1	7.8	17.6	19.5	16.2	15.0	11.9	10.8	9.9	9.6	8.7	7.4
	Lithuania	4.3	5.8	13.8	17.8	15.4	13.4	11.8	10.7	9.1	7.9	7.1	6.2
	Netherlands	5.3	4.8	5.4	6.1	6.1	6.8	8.2	8.4	7.9	7.0	5.9	4.9
	Poland	9.6	7.0	8.1	10.0	10.0	10.4	10.6	9.2	7.7	6.3	5.0	3.9
	Portugal	9.6	9.2	11.2	12.6	13.5	16.6	17.2	14.7	13.0	11.5	9.2	7.2
	Romania	6.4	5.6	8.4	9.0	9.1	8.7	9.0	8.6	8.4	7.2	6.1	5.3
	Spain	8.2	11.3	17.9	19.9	21.4	24.8	26.1	24.5	22.1	19.7	17.2	15.3

Source: OECD Short-term labour market statistics and Eurostat database.

Annex E. The evolution of CALI and its components over time

Figure E.1. Growth in age-education CALI and its components: other countries in group 1



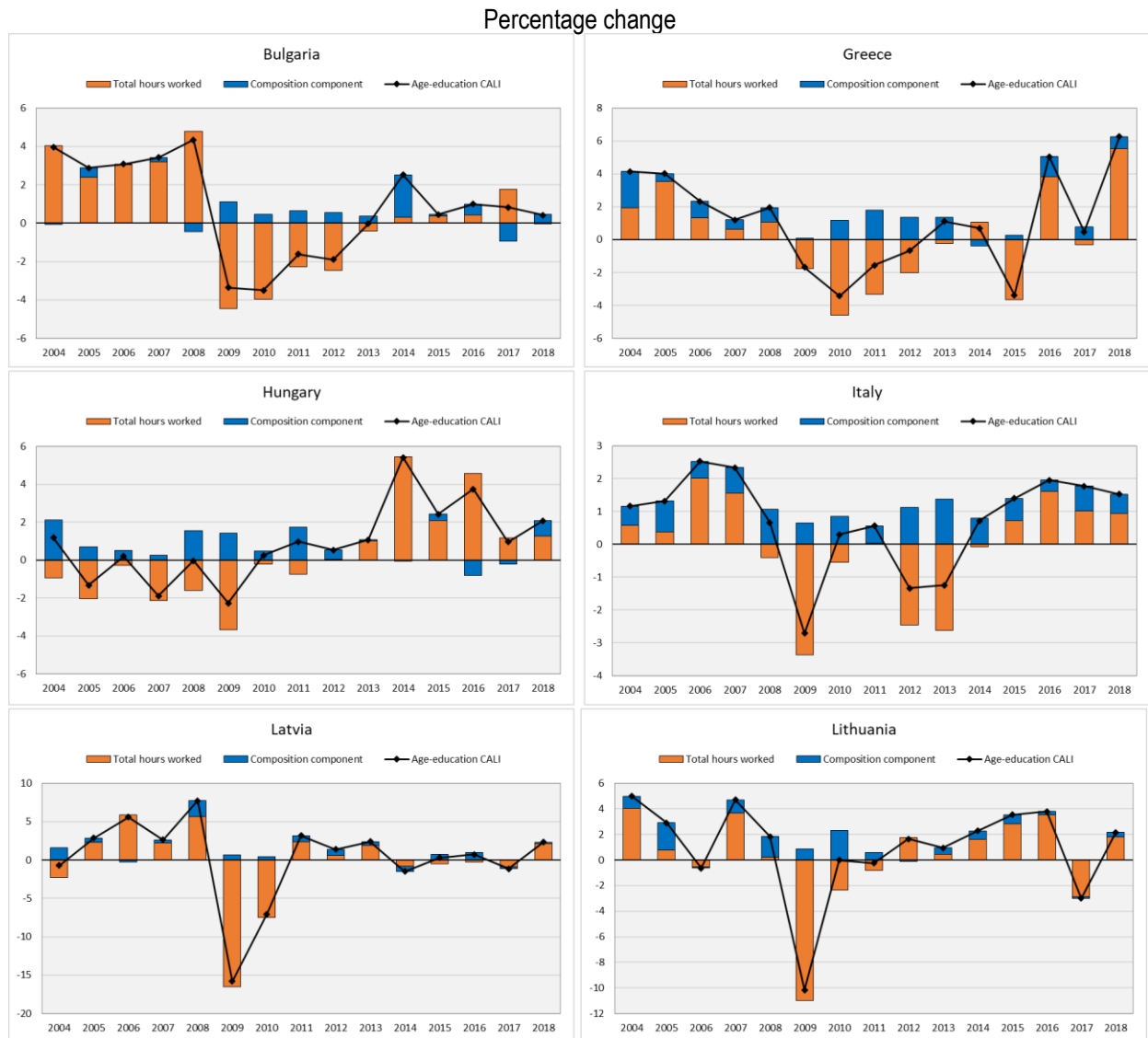
Source: Authors' estimates based on EU-LFS, EU-SES, STATCAN LFS, and OECD Productivity Statistics (database).

Figure E.2. Growth in age-education CALI and its components: other countries in group 2



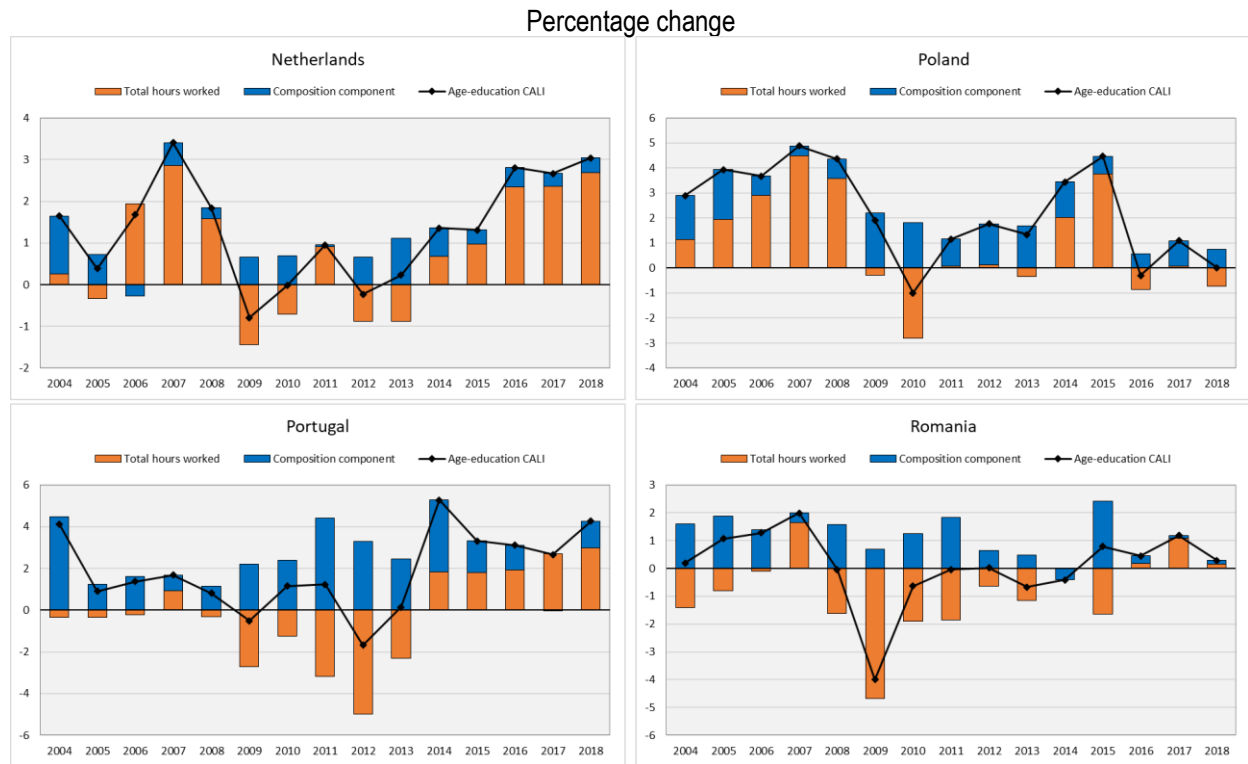
Source: Authors estimates based on EU-LFS, EU-SES and OECD Productivity Statistics (database).

Figure E.3. Growth in age-education CALI and its components: other countries in group 3 (1)



Source: Authors estimates based on EU-LFS, EU-SES and OECD Productivity Statistics (database).

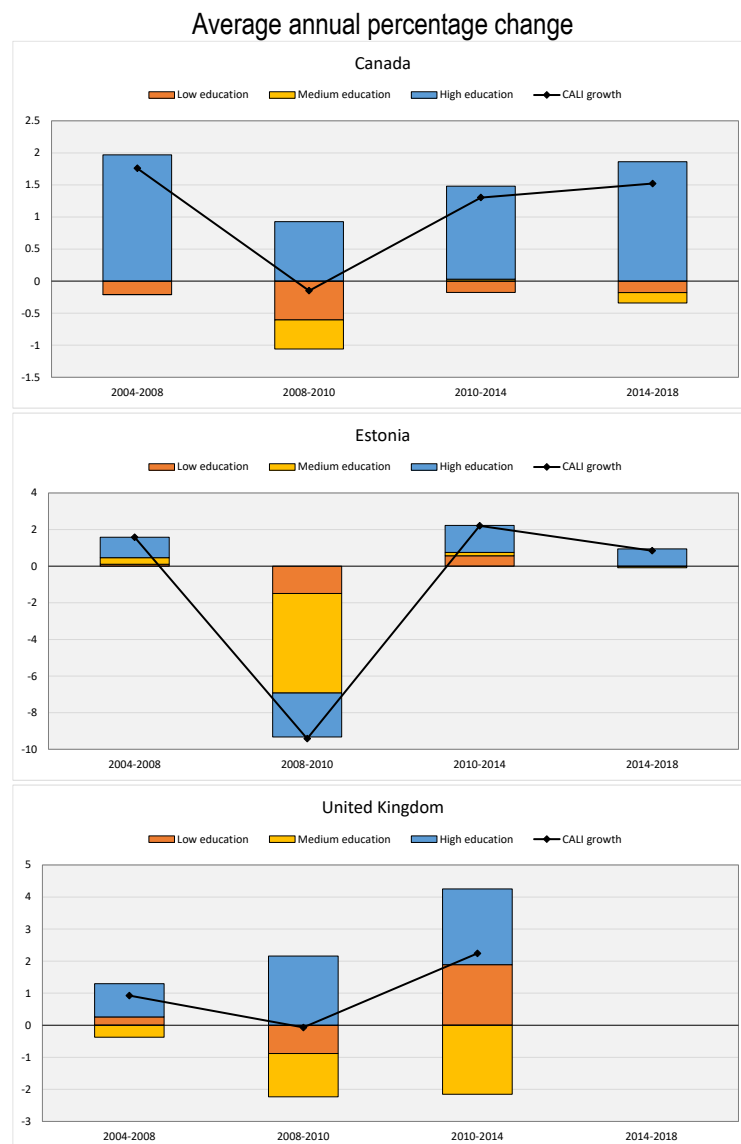
Figure E.4. Growth in age-education CALI and its components: other countries in group 3 (2)



Source: Authors estimates based on EU-LFS, EU-SES and OECD Productivity Statistics (database).

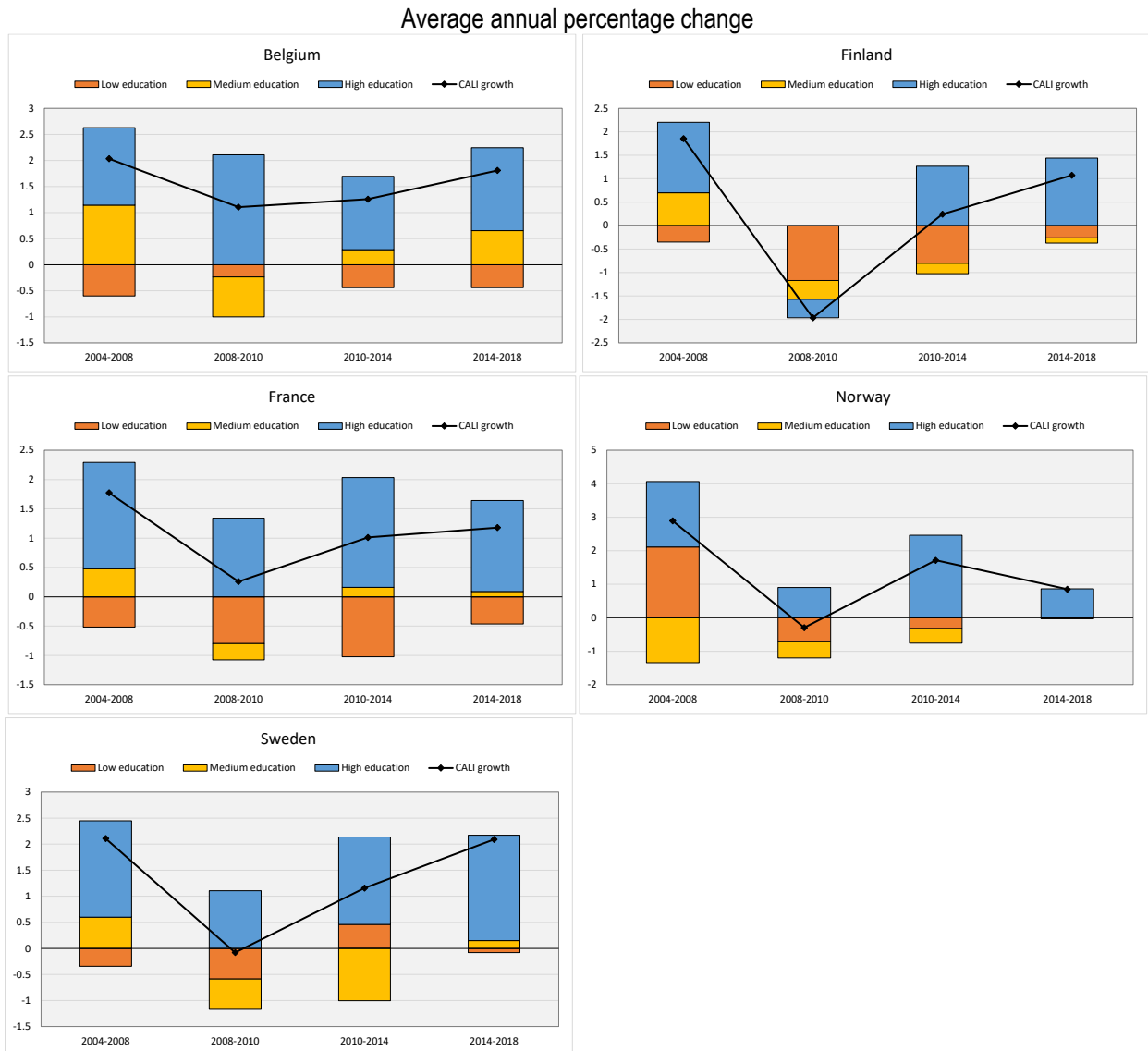
Annex F. Contributions to age-education CALI growth from workers with different levels of educational attainment and age

Figure F.1. Contributions to age-education CALI growth from workers with different education attainment (group 1)



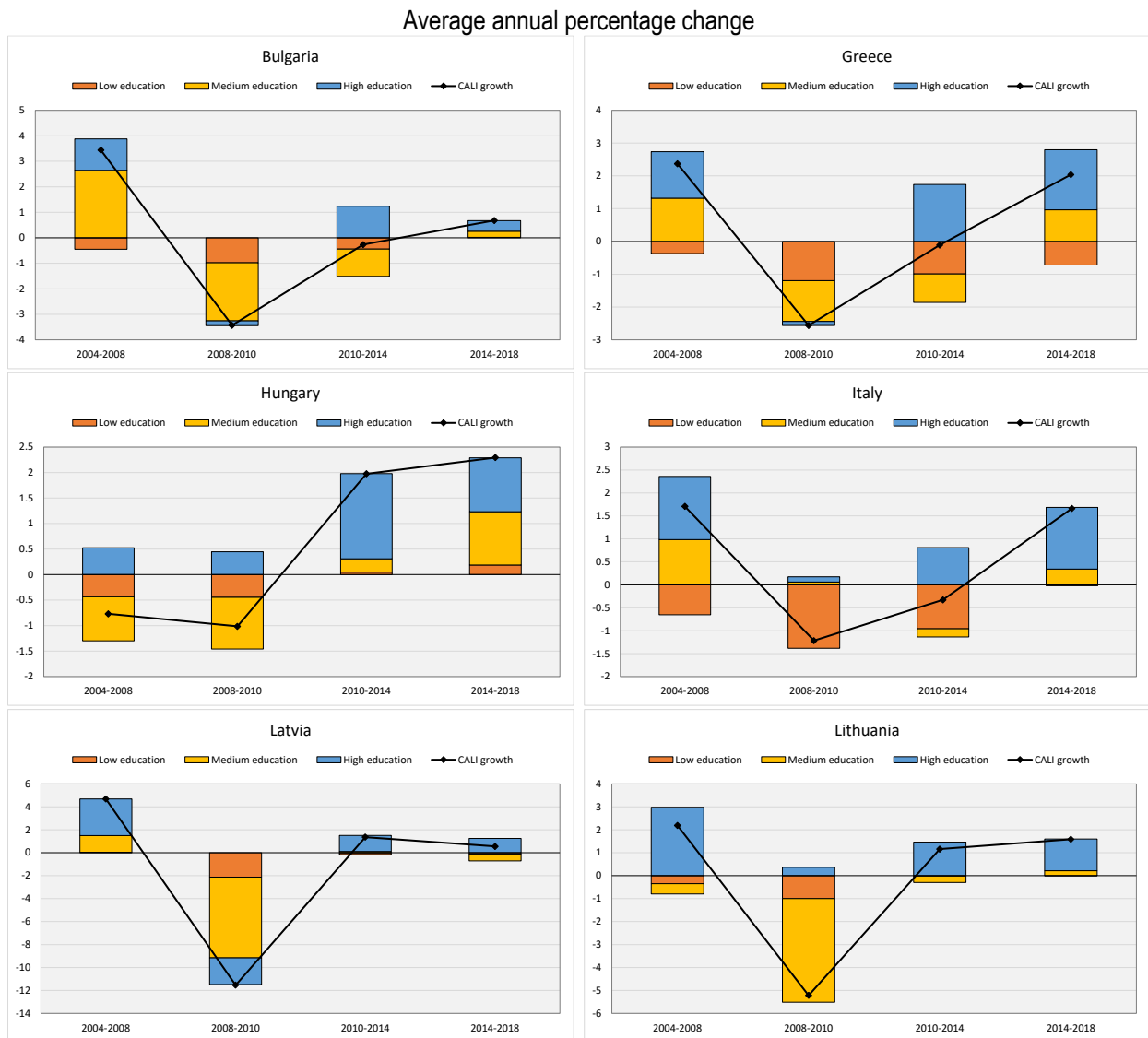
Source: Authors estimates based on EU-LFS, EU-SES, STATCAN LFS, and OECD Productivity Statistics (database).

Figure F.2. Contributions to age-education CALI growth from workers with different education attainment (group 2)



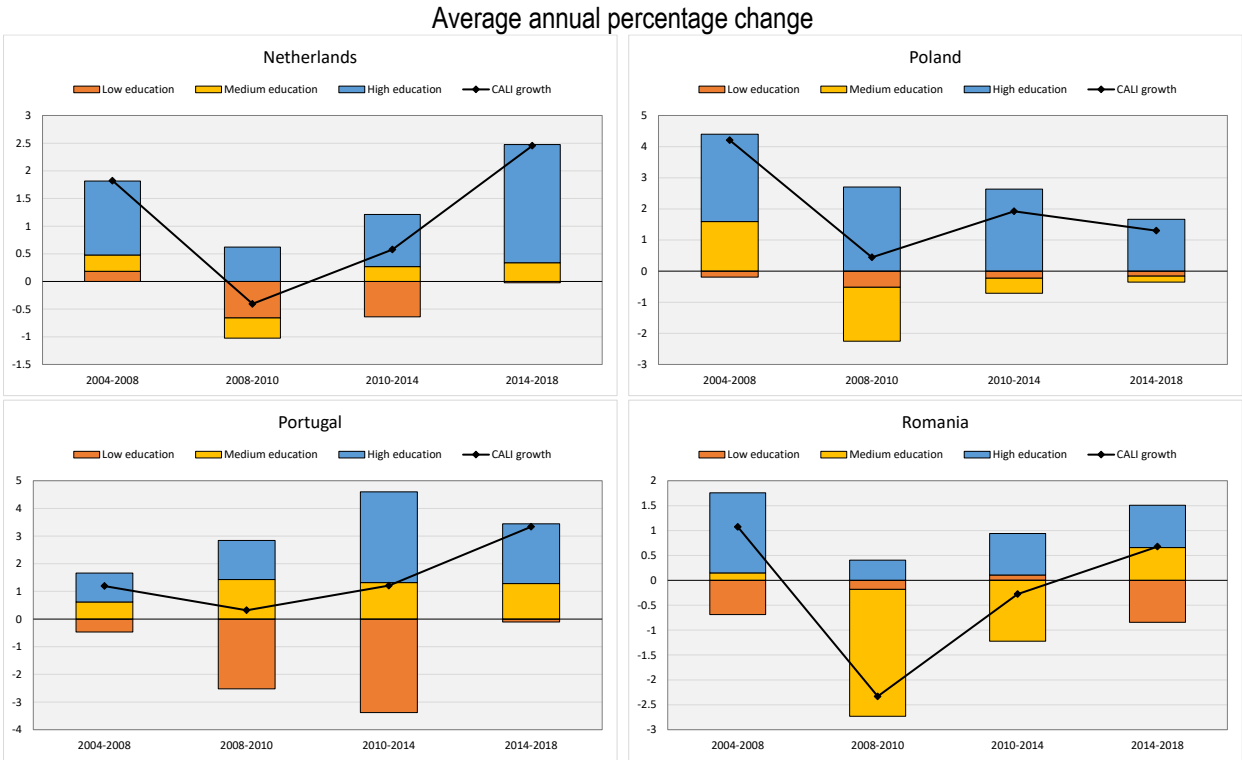
Source: Authors estimates based on EU-LFS, EU-SES and OECD Productivity Statistics (database).

Figure F.3. Contributions to age-education CALI growth from workers with different education attainment (group 3) (1)



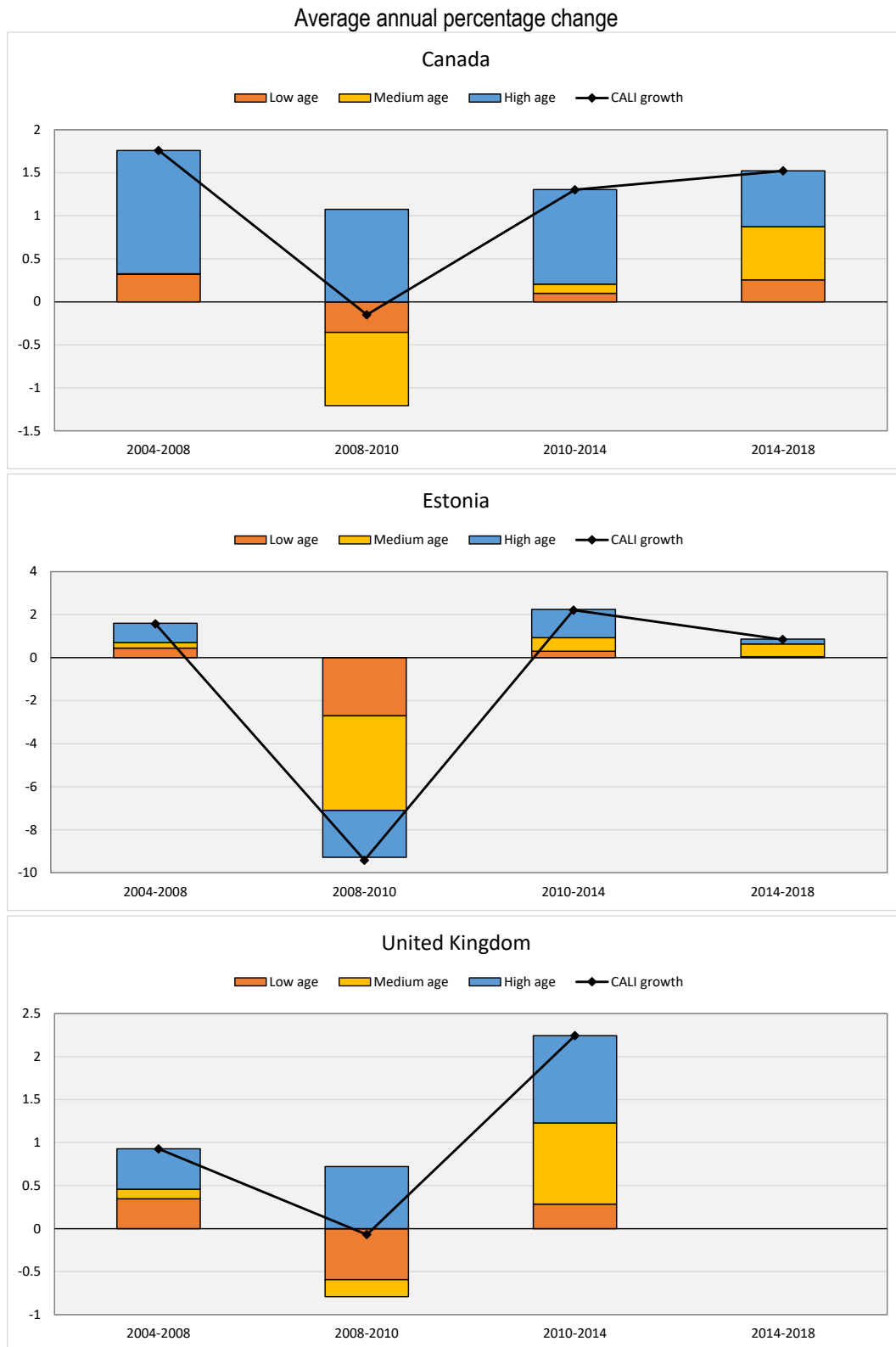
Source: Authors estimates based on EU-LFS, EU-SES and OECD Productivity Statistics (database).

Figure F.4. Contributions to age-education CALI growth from workers with different education attainment (group 3) (2)



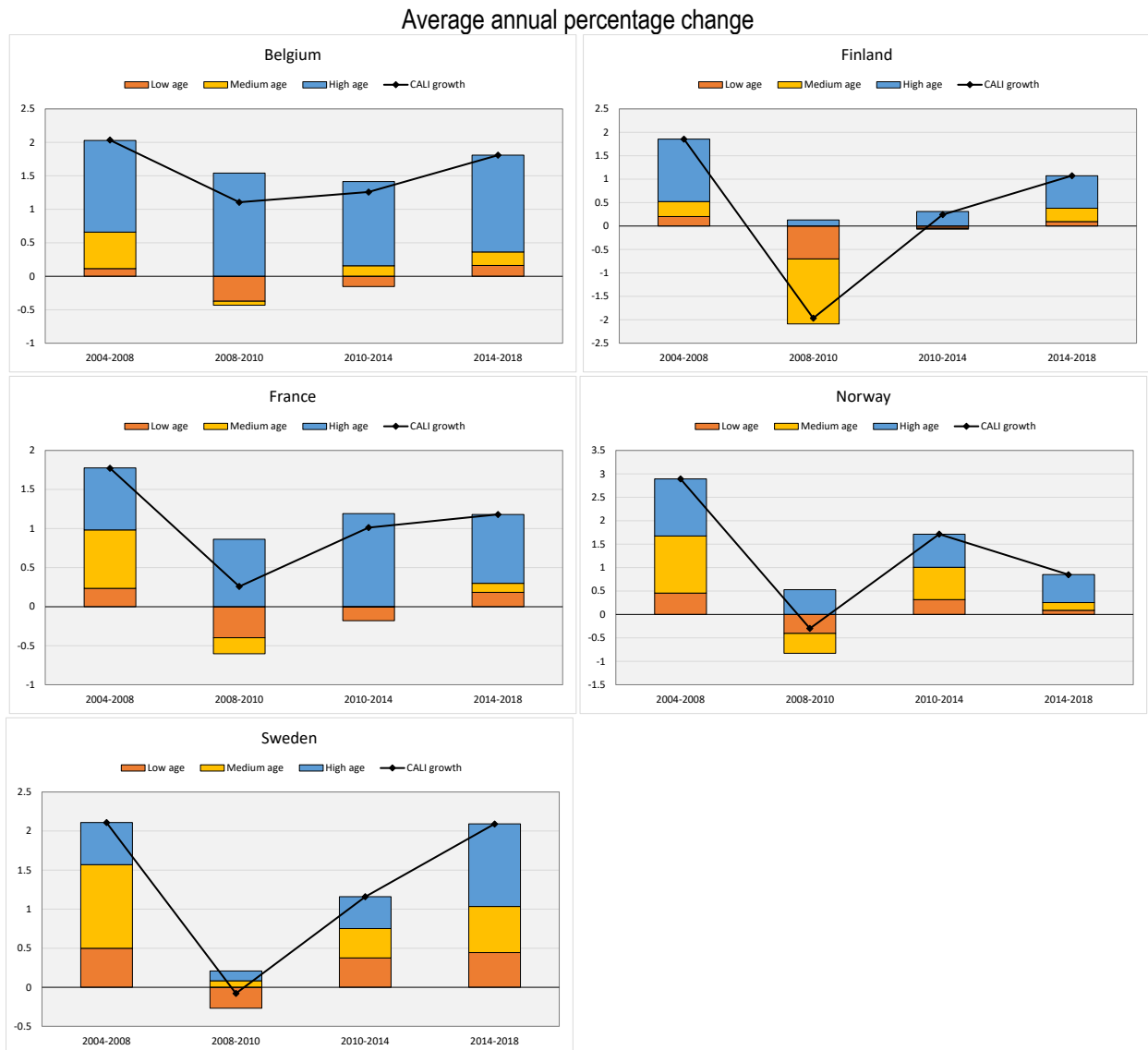
Source: Authors estimates based on EU-LFS, EU-SES and OECD Productivity Statistics (database).

Figure F.5. Contributions to age-education CALI growth from workers of different age (group 1)



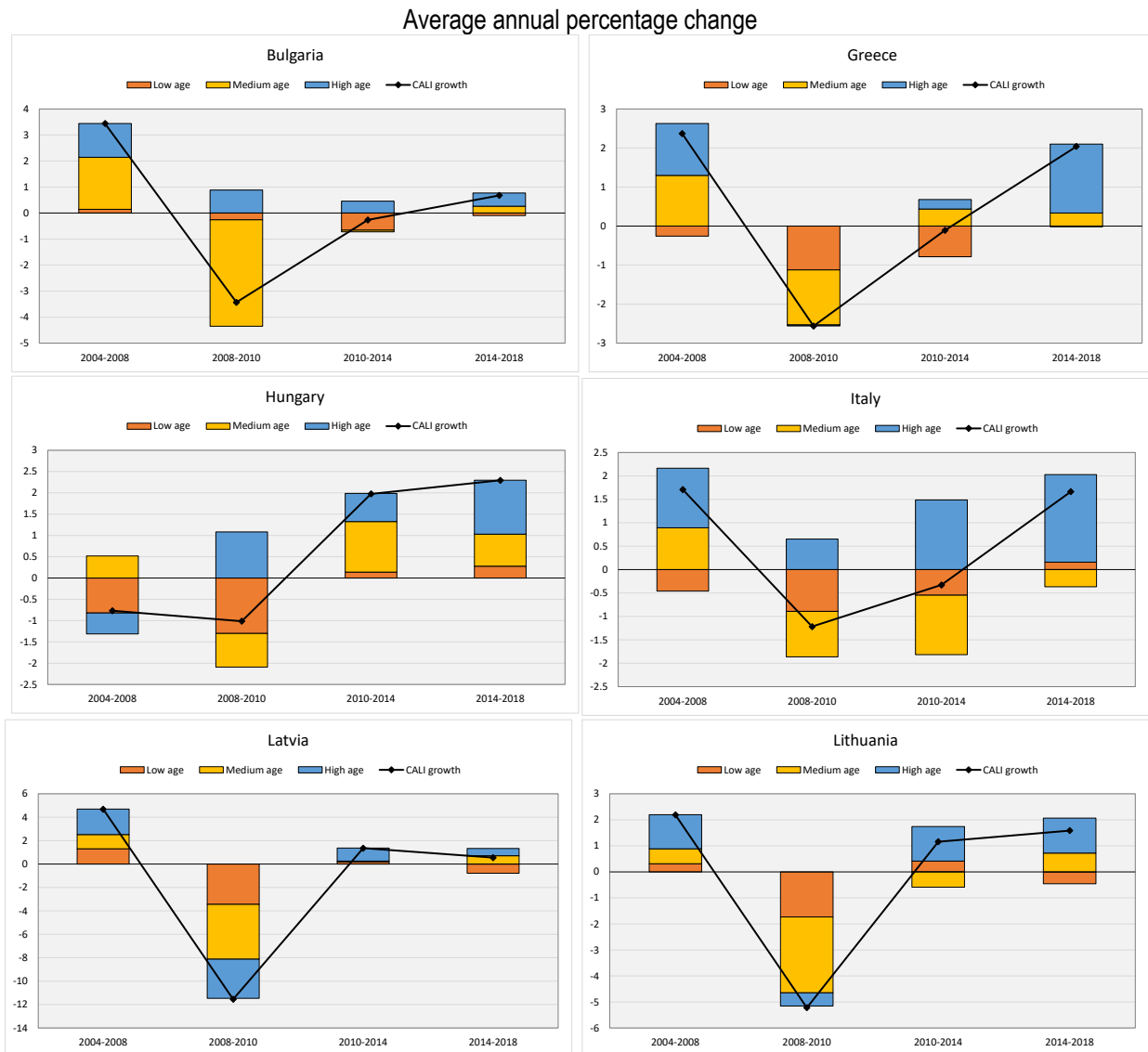
Source: Authors estimates based on EU-LFS, EU-SES, STATCAN LFS, and OECD Productivity Statistics (database).

Figure F.6. Contributions to age-education CALI growth from workers of different age (group 2)



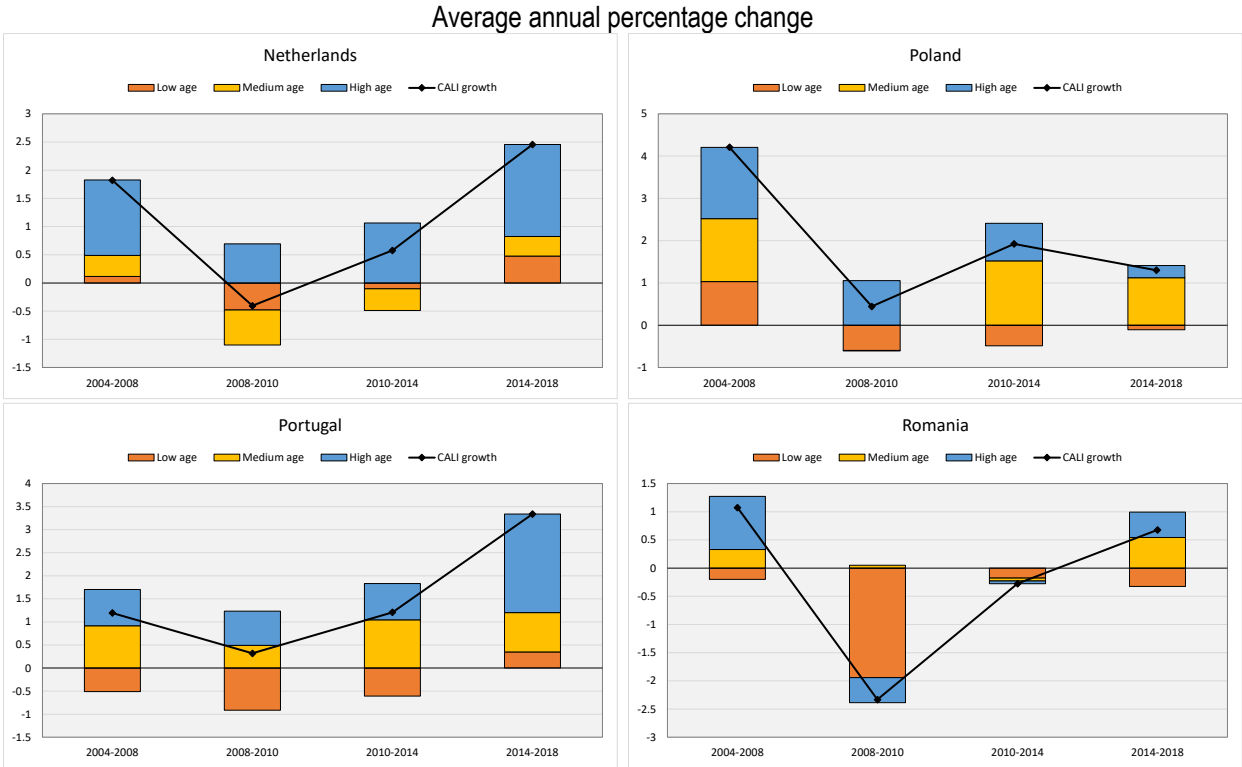
Source: Authors estimates based on EU-LFS, EU-SES and OECD Productivity Statistics (database).

Figure F.7. Contributions to age-education CALI growth from workers of different age (group 3) (1)



Source: Authors estimates based on EU-LFS, EU-SES and OECD Productivity Statistics (database).

Figure F.8. Contributions to age-education CALI growth from workers of different age (group 3) (2)

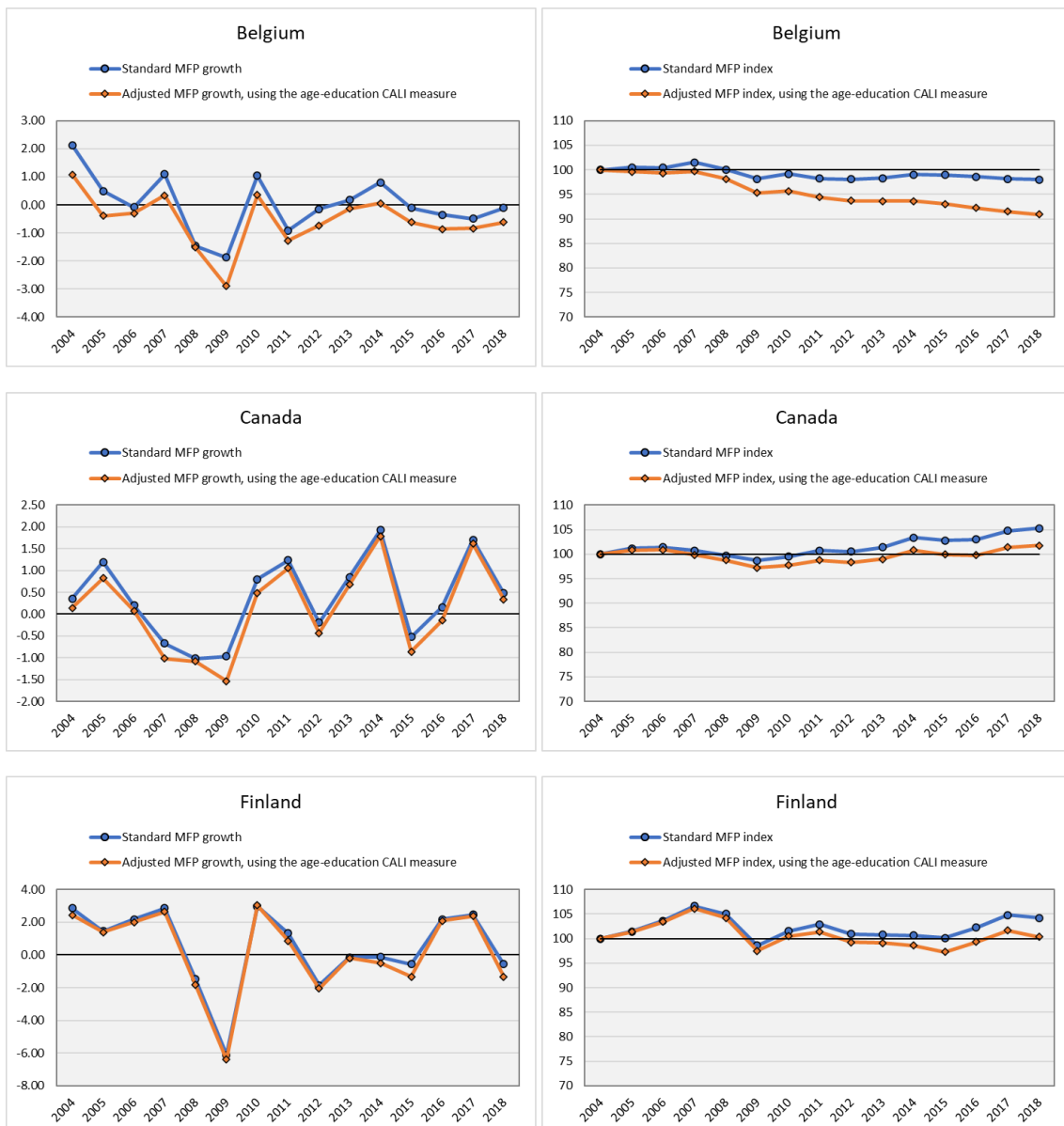


Source: Authors estimates based on EU-LFS, EU-SES and OECD Productivity Statistics (database).

Annex G. Standard and adjusted MFP growth

Figure G.1. Standard and adjusted MFP growth (1)

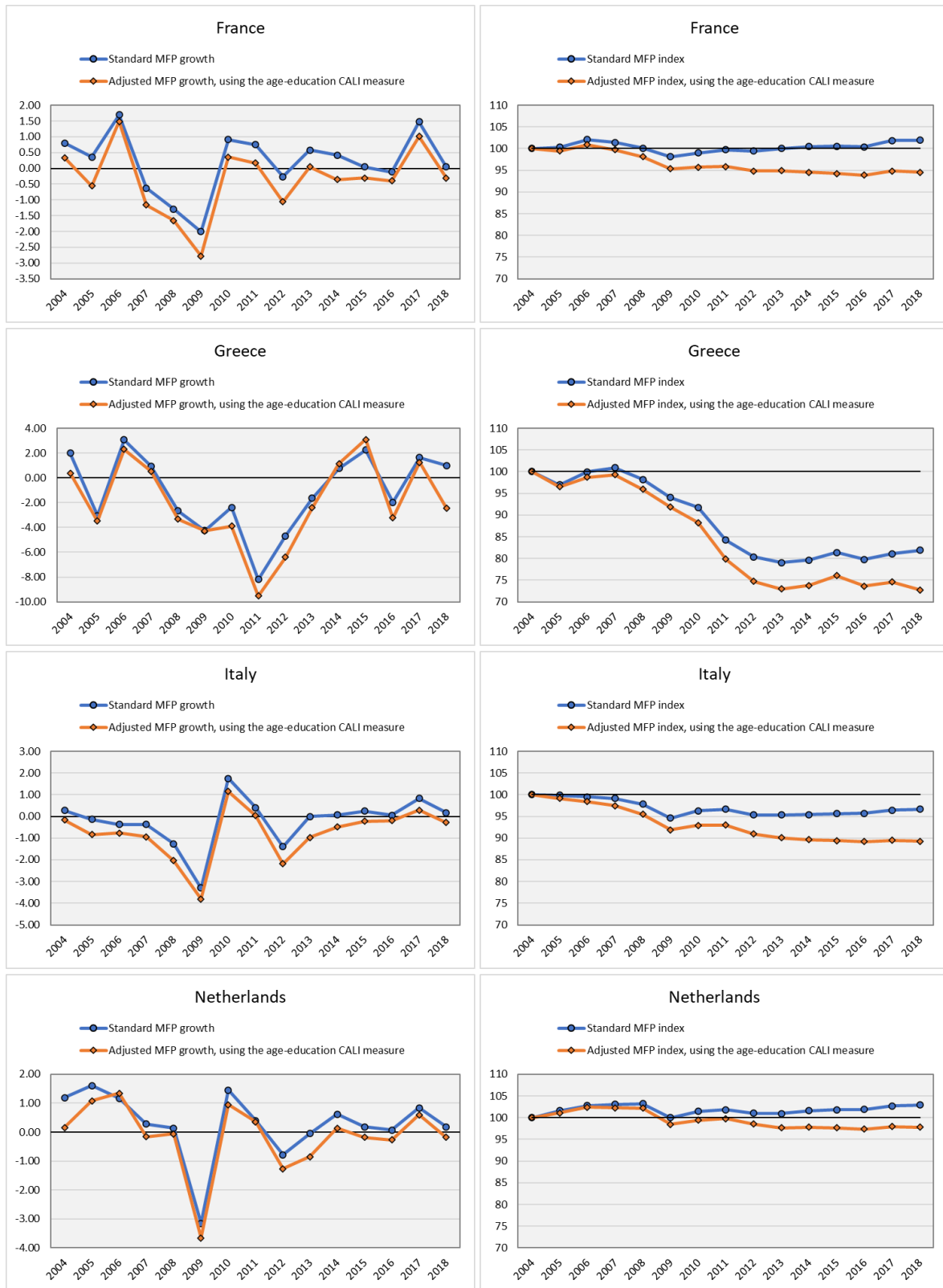
Percentage growth rate (left-hand side) and index 2004=100 (right-hand side)



Source: Authors' calculations.

Figure G.2. Standard and adjusted MFP growth (2)

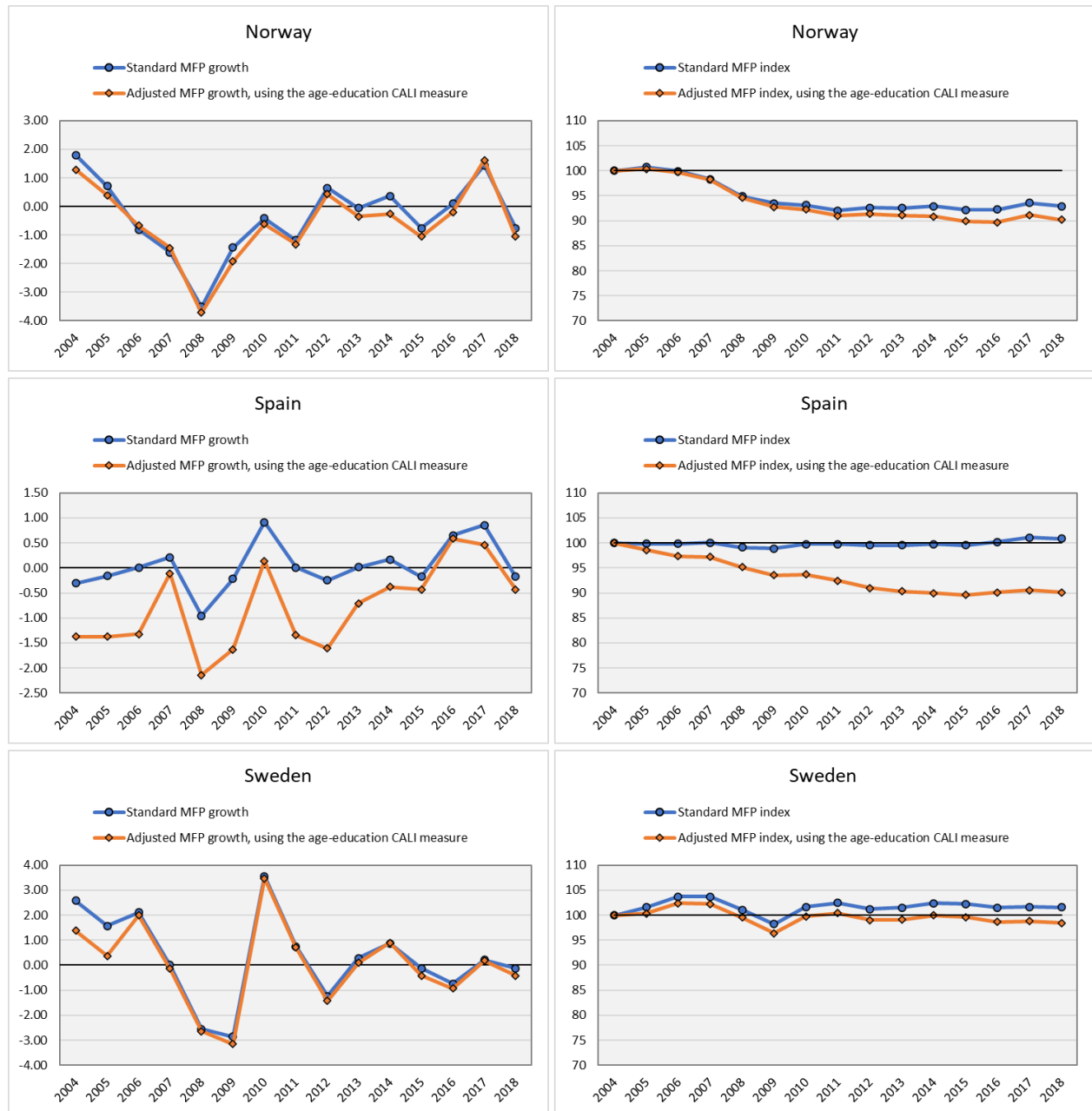
Percentage growth rate (left-hand side) and index 2004=100 (right-hand side)



Source: Authors' calculations.

Figure G.3. Standard and adjusted MFP growth (3)

Percentage growth rate (left-hand side) and index 2004=100 (right-hand side)



Source: Authors' calculations.