UNIVERSITY of York

Discussion Papers in Economics

No. 26/02

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Abstract

This paper constructs new measures of effective labour input in the UK economy. Unlike previous studies, which focus on the aggregate effect of labour quality on output, it analyses the contributions of factors such as human capital and industrial structure separately. Using data from the ONS and HMRC, numbers of employees and hours worked are weighted by labour costs, used as an indicator of their marginal productivity. The results underline the importance of investment in training and education. They also show that the reallocation of employment towards lower-productivity industries has reduced labour productivity, while regional migration has increased it. This approach provides a useful framework for analyzing structural change in the labour market and for monitoring the effect of government policy.

Keywords

Divisia index; Törnqvist index; labour quality; productivity measurement; labour composition; sectoral reallocation; United Kingdom; growth accounting; effective labour input.

JEL Classifications: E24,J24,O47,C43.

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1 Introduction

Measures of labour quality have long been used in productivity analysis. A large body of work, beginning with Jorgenson and Griliches (1967) and developed for the United Kingdom by the Office for National Statistics (ONS (2025)), uses quality-adjusted labour input to help explain the growth in output per hour. Compositionally-Adjusted Labour Input (CALI) series are based on the observation that in a properly functioning economy, profit maximization should keep labour costs close to marginal productivity, showing the effect on output of marginal changes in the number of hours worked. Thus, instead of giving every hour the same weight and simply adding them up, these measures use a weighted average, that gives these changes a weight that depends upon their hourly cost to the employer.

These studies use a detailed grid that classifies workers in terms of various educational, occupational, demographic and other characteristics. They show the combined effect that these influences upon the composition of the labour force have upon aggregate productivity. Figure 1 shows the ONS CALI analysis for the UK, revealing how the quantity of labour input (the index of hours worked in the economy) and the CALI index of labour input (in hours equivalent) have increased since 1994. The ratio between the two is known as composition, a basic measure of quality. This is depicted by the red line in Figure 2.

Such analysis is valuable for understanding long-run productivity trends, but does not reveal the separate effects of educational, industrial and other changes in the structure of the labour force. The ONS CALI studies show that improvements in the quality of the labour force have been the major source of productivity improvement in the UK since the financial crisis. However, although this largely seems to be due to the increased participation of better-educated and better-paid workers, we lack a specific estimate of this effect. We also lack estimates of the separate effects of changes in industrial and demographic composition.

This paper takes a different approach. Rather than focusing on the overall impact of labour quality on output, its primary aim is to distil the effect of these various influences from the detailed data set. So, for example, we use the standard wage-weighted approach to marginal productivity to estimate the effect of flows of labour between different industrial sectors in each period, assuming that percentage changes in hours worked in each industry are equally spread across all employers in that industry. This gives a specific estimate of the effect of changes in industrial composition on the quality of the national labour force, which is independent of demographic and other influences. Similarly, we find the specific effect of changes in labour force qualifications, independently of industrial, demographic and other influences and then the effect of demographic changes, independently of educational and industrial changes.

We can in principal estimate the overall improvement in labour quality by adding up these separate estimates. The appendix shows that this piecemeal approach can be formalized using a model in which the percentage change in hours worked in each group in the grid is explained by the percentage change in educational, industrial and demographic factors. These factors are constructed by averaging the change in hours in each industry, educational band, and demographic group respectively.

The drawback of this approach, compared to the use of a detailed grid as the ONS and others do, is that we need to assume that average changes in hours in each educational, industrial and demographic group are spread evenly across all the employers in that group. However, the advantage is that the numbers used to construct the factors are much larger than the numbers in the grid. This splits the UK labour force into 360 categories, many of which are naturally very small and prone to measurement error. The new approach should thus be more robust in this respect.

Figure 2 shows how these two estimates compare and provides a useful cross-check. These estimates drift apart initially, and then run in parallel before converging towards the end of the period. Nevertheless, they show a similar picture. Both suggest that quality improved temporarily during the Covid epidemic. Section 3 shows that this is largely due to the large fall in the hours worked in low productivity sectors like hospitality.

Ultimately, no grid can be fully comprehensive in its scope and detail. There are important differential effects even within the finely-defined categories used in these studies.[1] It is also difficult to allow for all of the relevant factors. For example, the ONS is typical of national statistical agencies in overlooking the effect of important changes in regional structure. To investigate the regional effect and provide a check on the ONS-based estimates of industrial composition, the paper reports the results of a second study. This uses a dataset complied from Pay As You Earn (PAYE) tax returns by His Majesty's Revenue and Customs (HMRC) and ONS (HMRC (2026)). These data report the number of workers and average pay in different industries and regions as well a combined industrial-regional grid. They are available on a monthly basis and more timely than the CALI data set and are currently available for the period June 2014 to December 2025. Figure 3 shows that the sum of the separate industrial and contributions matches the aggregate quality measure from the combined grid closely until the Covid epidemic. As with the ONS CALI shown in Figure 2, converge toward the end of the period.

The paper proceeds as follows. The next section, supported by the appendix, outlines and motivates the methodology. Section 3 then uses the ONS CALI quality

[1] Take for example the educational category HQ5 that covers first degrees and equivalent qualifications. At one end of the spectrum, studies of the payback to university degrees reveal that the range from around zero for creative arts and languages to more than £250k for women and £500k for men studying law, economics and medicine (Britton, Deard, Van der Erve, and Waltmann (2020)).

dataset to estimate the contributions of different influences from 1994 to mid-2024. HMRC pay and payroll data are used in the subsequent section to estimate the industrial and regional contributions since June 2015 in a monthly time-frame. Section 4 concludes with a summary and suggestions for further research in this area.

2 Productivity and the composition of the labour force

Productivity holds the key to economic growth. It is normally measured as output per hour worked. It can increase naturally through technical progress as new discoveries are made and new working methods are adopted. It can be increased by investing in new machines and in education and training. As we have argued elsewhere Santos Monteiro, Smith, and Spencer (2020) investment in equipment has knowledge spillover effects which also boost productivity. Last but not least, productivity increases as factors of production capital and labour move from low productivity activities like agriculture to high productivity activities like manufacturing.

These compositional effects are particularly important in developing economies, but can also be an important influence on the growth of developed economies like the UK. The potential for this gain depends upon differences in productivity across the various educational, industrial and other groups. Tables 1 and 2 show output per hour at a disaggregated, bespoke industrial level in 2024, while Figure 4 ranks the sectoral differences. Mining and quarrying tops the list, boosted by North Sea oil. In the low productivity group, we find distribution, accommodation, as well as food and drink services, with productivity levels at a fraction of the UK average. It is no surprise that these industries have been exposed to the recent increase in employer National Insurance Contributions (NICs) and the minimum wage.[2] Residential care,

[2] In her first budget of October 2024, the Chancellor increased employers' National Insurance Contributions (NICs) as part of an emergency package to restore control of the public finances. Effective the following April, their contribution rate was increased from 13.8 to 15% and the secondary thresh-

social work and postal and courier services are also found in this low productivity tail.

These average hourly productivity figures would show the impact on GDP of changes in hours worked if output in each activity moved in line. However, economies of scale and movements in the capital/labour ratio are likely to disturb such relationships. An alternative measure of the impact is given by labour compensation: the average cost of wages, salaries and payroll taxes per hour. These are also shown in Figure 4. In a properly functioning, frictionless economy, profit maximization should keep labour compensation close to marginal productivity, showing the effect on output of marginal changes in the number of hours worked. The differences between these average and marginal measures reflect capital/labour ratios, being extreme in the case of mining and quarrying but minimal in low value-added services.

This idea motivates the construction of Divisia indices, which weight percentage changes in the hours worked in different industries by hourly labour costs, taken as a measure of marginal productivity. These methods have long been used to produce chain-linked measures of prices and output, and more recently the money supply[3]. They are also used to measure labour inputs. As noted, the ONS has published a CALI index for the years 1994-2024, and our first series, discussed in the next section, uses their data to analyze the contributions of different sectors.

3 The ONS CALI data-based measures

This section uses the ONS quarterly CALI data set to estimate the contributions of different types of worker to labour quality. The data set takes the form of a matrix

old, the level at which NICs starts being levied on employers, was reduced from £9,100 to £5,000 a year. The National Living Wage is the statutory minimum that applies to workers aged 21 and over, also rose by 6.7 that month. The increases for 18- to 20-year-olds and 16- to 17-year-olds and apprentices under 25, were larger, 19 and 16% respectively.

[3] Divisia measures of the money supply, such as Hancock (2005), use interest rates paid on different types of bank account to estimate their marginal 'moneyness' relative to cash.

that allocates hours worked in each quarter (by both employees and self-employed) and hourly compensation rates, into 360 categories, differentiating workers in terms of education, gender, age and industry. We aggregate these data and split the UK labour force separately into (a) 6 groups by qualification, (b) 2 by gender, (c) 3 groups by age, and (d) by 19 industrial sectors. These averages are then used to estimate the separate effects of these four types of composition and their component groups, as explained in the appendix.

3.1 Human capital

Investment in human capital is a major source of growth in any developed economy and this has certainly been the case in the UK over the last 30 years. This effect is revealed in Figure 5, which shows the first of these indices, the quarterly qualification-adjusted labour input index. This is built up from six national qualification bands: HQ1 to HQ6. Recall that the contribution of each band is estimated under the assumption that in any quarter, the average change in hours worked in the band is spread evenly over industrial and demographic sub-groups, allowing its average hourly compensation to represent its marginal hourly productivity.

This input index is shown alongside the standard labour force measure, which reports the average weekly hours worked in the economy in each quarter. This comparison shows that giving workers marginal value weight corresponding to their compensation, rather than just counting them all in with the same value as in the standard labour force measure, has the effect of greatly increasing the estimate of the contribution that labour makes to GDP. Dividing this input index by the labour force gives a labour composition index , a measure of the change in the quality of the labour force due to changes in educational composition, shown in Figure 6. This suggests that investment in human capital has increased the effective labour force by

16% since the mid 1990s. Almost all of this contribution was made after 2008.

Figure 7 separates this effect into the effect of changes in hours worked by workers in the six different bands. The series in the panels on the left hand side show hours worked by different bands since 1994 as a share of the UK total. The central panels show labour costs in each band, specifically compensation per hour, relative to the UK average. As the appendix explains, multiplying these hours and labour cost figures gives the share of each band's remuneration relative to the UK total, which determines the effect of the growth in its hours on labour input and hence GDP. The contribution that they make to the labour quality index are shown in the panels on the right hand side. This figure reveals a sustained increase in the number workers with university degrees or equivalent, which now make up 40% of the labour force. Although workers in these two bands experience a sustained fall in relative compensation over the period, this is from a relatively high level, and their contribution is equivalent to a 12% increase in the effective hours worked in the economy. The increasing share of graduates in the workforce is mirrored by a fall in the share of less qualified people. Specifically, the decline in the share of unqualified workers adds another 3% to the number of effective hours worked. The GDP effect shown in Figure 6 follows by multiplying the quality effect of each of the six bands shown in Figure 7 by its total compensation as a share of money GDP, as explained in the appendix.

3.2 Demographic composition

This mirroring effect is most apparent in the case of the gender composition of the labour force, where the growth in hours worked by women is obviously matched by a fall in the share of men. Historically, men have been better remunerated than women, although as Figure 10 shows, the gap has been closing. Discrimination could distort the relationship between wage and marginal product upon which this methodology depends. With this *caveat*, Figure 8 suggests that increased female participation has on this measure reduced the effective hours worked in the economy by 0.9% and GDP by 0.6% over the last twenty years. On the other hand, the increase in the share of more experienced older workers has increased labour quality by 1.8% over this period, adding 1% to GDP.

3.3 Industrial composition

Historically, changes in industrial structure have had a major effect on composition and productivity. In particular, the demise of the coal mining industry and the long term decline in the share of jobs in manufacturing have been a drag on UK productivity, since remuneration and productivity in these sectors has been relatively high. The effects of industrial composition have been relatively muted in recent years, but Figure 14, which shows the quarterly industrial composition effect, suggests that this reduced the effective labour input by 1.8% and GDP by 1% between 1994 and 2019. It suggests that composition has added to productivity and GDP since then, with the Covid epidemic providing a temporary boost. The overall effect of industrial composition over the period 1994-2024 was to reduce quality by just 0.7%, but this small number disguises a more interesting sectoral pattern.

Figure 15 shows the basic series used in this index. The figure arranges the data for the 19 SIC2007 sectors into five groups. The first is a group of five low productivity industries. The second is a group of three large industries that have been in decline historically. The third is a group of three largely public sector activities. Finally, the last two groups show the remaining private sector activities.

Taking these in turn, the chart in the top central position shows that compensation in the hospitality sector has consistently been about 60% of the UK average, with compensation in distribution at around 80%. Unfortunately this level of aggregation does not distinguish between retail and wholesale activities within distribution, and as Table 2 shows, value-added in retail is significantly lower than in wholesale activities. Employment in hospitality has been growing, exerting a consistent drag, reducing effective UK labour input by 1.3%. Compensation in agriculture has been lowest of all the SIC sectors, but has moved up noticeably since the millennium. This sector has been in long-term decline, releasing low productivity labour to the rest of the economy. Although this is now a very small part of the economy it provided a temporary boost to composition during the first decade of the millennium. The industries in the second group have also been in decline, but remuneration and productivity in these sectors is relatively high, accounting for the drag that they have imposed on UK productivity shown in the right hand panel. The decline in manufacturing employment stands out, and is on a much larger scale than in the other two sectors. The lower panel suggests that, despite its large size, this industry subtracted less than 1% from the effective UK labour force.

Within the public sector workers in the third group, those in education and administration enjoy a relatively high level of compensation, but the former have seen their position eroded over the last twenty years. The increase in employment in education and health & social care stand out, and the relatively high level of productivity in the education sector means that this has boosted the quality of the UK labour force by 0.8%. This is in addition to the improvement stemming from the more qualified workforce discussed in section 3.1. With compensation close to the national average in health & social care, this has had little effect on UK productivity. Public administration has lost jobs over this period, but this appears to have had little effect on productivity.

Within the fourth group, professional and scientific activities have been growing strongly, but with compensation surprisingly close to the national average in this data set, this has had little effect on productivity. The PAYE data analyzed in the next section indicates however, that this industry has nevertheless made a positive contribution over the last decade. Employment in real estate activities has also grown strongly, and with compensation relatively high in this sector, this has boosted productivity, despite this sector's very small size. Turning to the last group, administration has been growing rapidly, partly because administrative activities within industries like manufacturing have been re-allocated to this sector. With compensation just below the national average, this apparently reduced the effective labour force by another 1%. The growth in information and communication since the millennium has had exactly the opposite effect given its relatively high level of compensation.

4 The PAYE based measures

In view of the recent problems with the coverage of the Labour Force Survey, economists are increasingly relying upon Pay As You Earn (PAYE) tax returns, aggregated and published by HMRC (HMRC (2026)), to monitor wage costs and employment. They are available since June 2014 for the number of workers (not hours) as well as mean and median pay for each category. In principle, these data cover rather than just survey the labour force, but exclude groups like the self-employed. Also, 'pay' as recorded by the HMRC, excludes costs like payroll taxes. Nevertheless, these data provide a useful check on the recent behavior of the ONS CALI-based series discussed in the previous section. Moreover, they are more granular, available on a more timely monthly basis, with a regional (UK, NUTS 1, 2 and 3 areas and local authorities) as well as an industrial breakdown.[4]

In this paper I use a grid of pay and payroll observations for the SIC2007 industrial sectors in each of the 12 standard UK regions (NUTS 1) since the finer geographical

[4] Other tables report the age (though not gender) structure of the workforce.

breakdown (NUTS 2 and 3) is naturally more noisy. Figure 17 shows the resulting labour input index alongside the PAYE total labour force numbers. We can think of these as effective workforce (rather than hours) indices. The changes in quality indicated by this regional/industrial grid are shown as the black line in Figure 3. This exercise shows the combined effect of industrial and regional labour market flows.

The PAYE data is also available on a more aggregate basis, for SIC2007 industrial sectors and the standard UK regions. This conveniently allows me to separate the industrial and regional effects and to see how well their sum approximates the combined effect shown in Figure 3, providing another test of the piecemeal approach. The industrial component is shown by the red line and the regional component by the green line. Their sum tracks the combined effect remarkably well until the Covid epidemic, which throws it temporary off course. However, the two series move back into line nicely as the economy recovers. The rest of this section discusses the industrial and regional contributions in detail.

4.1 Industrial composition

I first discuss the contribution of flows of workers between different industries at the level of the UK economy, isolating them from regional shifts. This exercise is comparable to that for the ONS CALI index in the previous section, which uses the same 19 SIC sectors. It gives the industrial component depicted by the red line in Figure 3. This also suggests that the deterioration due to industrial composition has reversed since 2018, adding 0.15% to quality over the full period. Figure 18 shows the HMRC industrial data and their contributions to this index. These are broadly similar to those shown by the ONS CALI-based analysis for the last ten years in Figure 15. Consistent with that analysis, the more stable pattern of employment in the so-called declining industries means that they have had a negligible impact on labour productivity over the last decade. Employment in the electricity and gas industries has recently been increasing, improving labour quality. The monthly data for hospitality shown in the first column track the effect of the Covid lockdown more sharply than in the quarterly data, but again suggest that the fall in employment and pay had the effect of boosting productivity temporarily, reversing the drag on productivity seen earlier..

Although the overall impact of industrial composition has been small, adding just 0.1% to quality on this measure since 2014, this disguises some significant changes in the components. For example, employment in the health & social work and in the professional and scientific sector have both been growing strongly over this period. The relatively low wages in the former means that this has reduced labour quality by 0.5% while high wages in the latter suggests that this has increased quality by 0.8%. Differential productivity effects have also been significant over the last two years. Since December 2023, employment in hospitality has fallen by 3.9%, 0.28% of the UK workforce. However, this analysis of the PAYE data suggests that this has reduced UK labour inputs by just 0.15%. In contrast, employment in ICT has as fallen by 5.0%. This is just 0.2% of the UK workforce, since employment in this industry is relatively small. However, because of the high productivity of ICT workers, this has reduced labour inputs by 0.36%.

4.2 Regional composition

I next analyze the contribution of flows of workers between different regions, isolating them from industrial shifts. This gives the regional component shown in Figure 3, which suggests that, apart from the temporary effect of the Covid epidemic, regional migration has improved labour quality, adding 0.3% over the period. Figure 19 shows the regional data and their contributions to this component, and tells a very simple story. Labour has migrated to London and the South East and this has improved quality given their higher wage structures. This has improved quality by 1.2% over the last decade, partly offset by the expanding labour force in lower productivity regions. Surprisingly, the growth in the share of the labour force employed in the West Midlands and the North West, which include relatively successful conurbations, has reduced labour quality. Scotland has seen a fall in its share of the labour force, but its impact has been cushioned by its relatively high wage structure, closer to the national average.

4.3 Industrial effects by region

The finer grid allows these industrial contributions to be analyzed at a regional level. These effects are similar to those in the whole economy, although their scale is inevitably much smaller, and monthly variations in the data, especially the wage data, are more noisy. Hospitality has a negative impact in all regions. However, some marked regional effects are evident. Figure 20 shows the breakdown for Scotland, where the depletion of the North Sea fields is evident in the mining and quarrying component. This deterioration is partly offset by improvements in the professional, scientific, information and communication industries, and since 2020, in public administration. In contrast the mining and quarrying sector makes very little contribution to the Welsh economy now, as shown in Figure 21. The contribution of manufacturing is more important in Wales, as it is in Northern Ireland (Figure 22) and the West Midlands (Figure 24). In London (Figure 23), professional services, finance and information and communication each add about $\frac{1}{4}$% to the labour composition index. Indeed, health and social work is relatively well-paid in the capital, and this sector also makes a positive contribution. Results for the other 8 regions are available upon request.

5 Conclusion

This paper shows how various compositional effects on labour force quality can be distilled from more detailed data sets. Although the aggregation employed to do this loses information on interaction effects between different factors, this also offers a check on the standard approach, which could be prone to measurement error. When we do this using the ONS CALI data labour force input data, we see that the improvement in quality over the last twenty years has been entirely due to investment in human capital. The increase in the share of more highly qualified people, and in particular the share of graduates, has increased the effective number of hours worked in the economy by 16%. Other compositional effects have largely cancelled each other out. The increasing share of older, better paid workers in the labour force added 1.8%, while this analysis suggests that the increasing share of women subtracted 0.9%.

Industrial composition reduced labour quality by just 0.7% over the period. The effect of the falling share of employment in manufacturing has been relatively muted, reducing quality by less than 1%. More of a surprise, we find that the growth of the hospitality industry over this period reduced labour productivity by 1.3%. Increased employment in administrative and support services, partly due to reclassification of activities in manufacturing and other industries, subtracted another 1%. The hospitality industry also stands out from the perspective of the more recent HMRC data. The effects of the Covid epidemic are much more pronounced here given its finer granularity. The shutdown of this industry provided a temporary boost to labour productivity, yet it has nevertheless reduced the quality of the UK labour force by 0.7% since 2014. The growth in health and social work reduced this by another 0.4%. To set against this, employment in professional and scientific services increased quality by 0.8% and that in information and communication by another

0.5%. Employment in education was relatively flat over this period and thus made a negligible contribution.

The regional classification of the PAYE data allows us to estimate its effect on labour quality and GDP growth, arguably a gap in the ONS's CALI analysis. It is perhaps not surprising to find that the growth of the labour force in London and the South East has improved quality by 1.2 since 2014, although this has been largely offset by growth in lower productivity English regions, notably the West Midlands. However, this study leaves many questions open for future research. Some of these are hampered by data availability. For example, it would be useful to have a further breakdown by gender of the PAYE data, to allow an the effect of increased female participation in the labour force to be assessed.

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6 Appendix: Divisia quality measures for labour

This Appendix outlines and motivates the methodology used in this paper. The first part shows how the Divisia methodology works in a continuous time setting and explains the separable approach. The second part describes the discrete time Törnqvist approximations used in practical work.

Divisia measures

First, suppose for simplicity that there are just two ways of classifying workers, by say industry, with index $i = 1, ..., I$, and region $j = 1, ..., K$. Let the average wage for workers in industry i and region j in period t be $w_{i,j,t}$ and the total hours they work $h_{i,j,t}$. With a comprehensive $i \times j$ grid of data, the instantaneous change in the Divisia index L_t at time t is defined as:

$$d \ln L_t = \sum_i \sum_j s_{i,j,t} d \ln h_{i.j,t}.$$

where $s_{i,j,t}$ is the nominal labour cost share of workers of type j in industry i at time t:

$$s_{i,j,t} = \frac{w_{i,j,t} \times h_{i,j,t}}{\sum_i \sum_j w_{i,j,t} \times h_{i,j,t}}.$$

Similarly we can use this methodology to construct a labour composition index G by dividing the hours worked by different types of worker by the total:

$$d \ln G_t = \sum_i \sum_j s_{i,j,t} d \ln g_{i.j,t}, \quad \text{where: } g_{i,j,t} = \frac{h_{i,j,t}}{\sum_i \sum_j h_{i,j,t}},$$
$$G_t = G_0 \exp[\int_0^t d \ln G_s ds]$$

These measures differ from a simple sum measures because they capture the productivity effects of shifts in composition toward high- or low-wage groups. More relevant for this paper is the partial contribution $G_{i,j,t}$ to the composition index of workers in industry i and region j :

$$d \ln G_{i,j,t} = s_{i,j,t} d \ln g_{i.j,t}. \tag{1}$$

6.1 Separability

Now suppose that instead of an $i \times j$ classification grid we have two separate classifications, first by industry and second by region. We observe the relative hours worked in industry i, which is $g_{i,t} = \Sigma_j g_{i,j,t}$, and the average wage: $w_{i,t} = (\Sigma_j w_{i,j,t} \times g_{i,j,t})/g_{i,t}$. Similarly, we observe the relative hours worked in region j, $g_{j,t} = \Sigma_i g_{i,j,t}$, and their average wage: $w_{j,t} = (\Sigma_i w_{i,j,t} \times g_{i,j,t})/g_{j,t}$. We can look at the effect of industrial or regional shifts by aggregation, which means assuming that changes in hours worked are evenly spread across all employers in each sub-sector. Consider for example the effect of a small change in the relative hours worked in an industry i under this assumption. This will change all workers' hours in the same proportion, no matter which region they work in: $d \ln g_{i,j,t} = d \ln g_{i,t}$. Substituting this into (1) and summing over regions gives the quality effect of this industry:

$$d \ln G_{i,t} = \sum\nolimits_j s_{i,j,t} d \ln g_{i.j,t} = \ s_{it} d \ln g_{i,t}, \quad where : s_{it} = \sum\nolimits_j s_{i,j,t},$$
$$G_{i,t} = G_{i,0} \exp[\int_0^t d \ln G_{i,s} ds].$$

The *partial* effect of variations in industrial employment on the economy-wide quality index under this assumption can then be calculated by summing over industries to get $\Sigma_i d \ln G_{i,t}$. Similarly,the average contribution of employment in region j to the quality index, assuming all workers' hours move in the same proportion $d\ln g_{i,j,t} = d\ln g_{j,t}$ is:

$$d\ln G_{j,t} = s_{j,t} d\ln g_{j,t}, \quad where \quad s_{j,t} = \sum_i s_{i,j,t}.$$
$$G_{j,t} = G_{j,0} \exp[\int_0^t d\ln G_{j,s} ds].$$

and summing over regions gives the effect of variations in regional employment: $\Sigma_j d\ln G_{j,t}$.

This argument could be used to justify the partial analysis of a single type of composition, industrial or regional. It can also be used to analyze the effect of multiple influences in a situation where we only have separate classifications rather than an $i \times j$ classification grid (as in our study of the PAYE data). Finally, this type of aggregation can be used to separate out the effect of multiple influences even when we do have such a classification grid (as in our study of the CALI data). One way to justify this is to suppose that the change in hours worked by workers in any industry i and region j largely depends upon the relevant industrial and regional averages:

$$d\ln g_{i.j,t} = \ s_{it} d\ln g_{i,t} + s_{j,t} d\ln g_{j,t} + r_{i.j,t}$$

where $r_{i.j,t}$ is a residual that allows for idiosyncratic effects. In other words, we use the industrial and regional averages as observable factors with known coefficients. We can then approximate the change in the overall quality of labour (1) by adding up a series of separate industrial, regional (and perhaps other) contributions:

$$d\ln G_t \simeq \sum_i s_{it} d\ln g_{i,t} + \sum_j s_{j,t} d\ln g_{j,t}.$$

The degree of approximation will depend upon industrial and regional cross-effects as well as purely idiosyncratic effects, but this piecemeal approach will give the same result as a $i \times j$ grid if the relative hours of workers of type i, j is the simple product of the industry and regional factors:

$$g_{i,j,t} = g_{i,t} g_{j,t}.$$

In this model, changes in $g_{i,t}$ do not affect $g_{j,t}$ or vice versa. Note that this system 'adds up' properly because:

$$\sum_i \sum_j g_{i,j,t} = \sum_i \sum_j h_{i,j,t} = 1.$$

and thus:

$$g_{i,t} = \Sigma_j g_{i,j,t} = \Sigma_j g_{i,t} g_{j,t} = g_{i,t} \Sigma_j g_{j,t} = g_{i,t} \Sigma_j \Sigma_i g_{i,j,t} = g_{i,t},$$

$$g_{j,t} = \Sigma_i g_{i,j,t} = \Sigma_i g_{i,t} g_{j,t} = g_{j,t} \Sigma_i g_{j,t} = g_{j,t} \Sigma_j \Sigma_i g_{i,j,t} = g_{j,t}.$$

6.2 The Törnqvist index

The Törnqvist index, which gives the discrete time approximation labour input index for two consecutive periods $t-1$ and t, is:

$$\ln L_t - \ln L_{t-1} = \sum_i \left(\tfrac{1}{2}(s_{i,t} + s_{i,t-1}) \times \big(\ln h_{i,t} - \ln h_{i,t-1} \big) \right),$$

where the nominal labour cost share of industry i at time t as;

$$s_{i,t} = \frac{w_{i,t} \times h_{i,t}}{\sum_k w_{k,t} \times h_{k,t}},$$

and where $w_{i,t}$ is compensation per hour and $h_{i,t}$ is hours worked. Note that this share is the product of the share of hours worked in the whole economy ($q_{i,t} = h_{i,t}/\sum_k h_{k,t}$) shown in the first panel of the contribution figures and the relative wage ($r_{i,t} = w_{i,t}/\bar{w}_t$, where $\bar{w}_t = \sum_k w_{k,t} \times h_{k,t}/\sum_k h_{k,t}$) shown in the second panel:

$$s_{i,t} = \frac{w_{i,t} \times h_{i,t}}{\sum_k w_{k,t} \times h_{k,t}} = r_{i,t} \times q_{i,t}.$$

Next we use the cost shares to value the percentage changes in hours in each sector and add them up to get the percentage change in the index:

$$\ln L_t - \ln L_{t-1} = \sum_i \left(\tfrac{1}{2}(s_{i,t} + s_{i,t-1}) \times \big(\ln h_{i,t} - \ln h_{i,t-1}\big)\right).$$

Finally, we exponentiate and chain these period-to-period growth rates in the sectoral contributions and the index to obtain their levels. These measures differ from a simple sums of hours, because productivity effects shifts in composition toward high- or low-wage groups are captured. The change in the simple sum hours N can be represented as:

$$\ln N_t - \ln N_{t-1} = \sum_i \left(\tfrac{1}{2}(r_{i,t} + r_{i,t-1}) \times (\big(\ln h_{i,t} - \ln h_{i,t-1}\big))\right),$$

and the contribution to the quality index $G = L/N$ of sector i in period t is calculated as:

$$\ln G_{i,t} - \ln G_{i,t-1} = \tfrac{1}{2}((s_{i,t} + s_{i,t-1}) - (r_{i,t} + r_{i,t-1})) \times (\big(\ln h_{i,t} - \ln h_{i,t-1}\big)).$$

Figures and tables

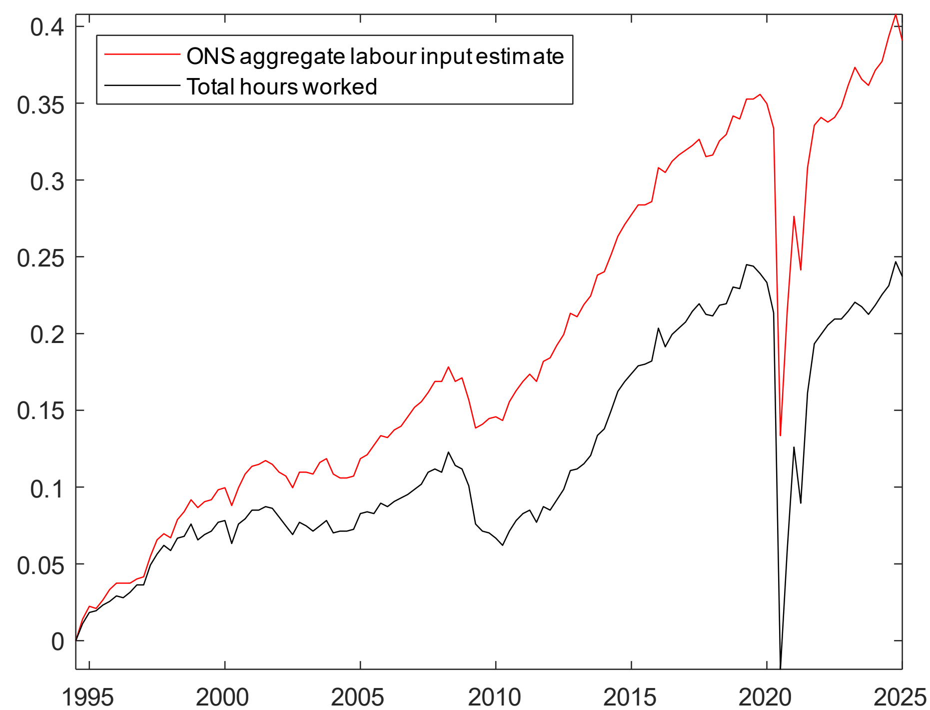
Table 1: Output per hour in high productivity activities (č)

Mining and quarrying related activities	442.0
Real estate activities	315.0
Insurance, reinsurance and pension funding, except compulsory social security	256.5
Manufacture of basic pharmaceutical products and pharmaceutical preparations	218.4
Water transport	214.3
Electricity, gas, steam, air conditioning supply	123.8
Financial service activities, except insurance and pension funding	105.1
Manufacture of coke and refined petroleum products	95.10
Water collection, treatment and supply	94.58
Manufacture of beverages and tobacco products	92.27
Programming and broadcasting activities	88.43
Scientific research and development	88.05
Rental and leasing activities	87.68
Telecommunications	86.61
Manufacture of motor vehicles, trailers and semi-trailers	79.53
Travel agency, tour operator and other reservation service and related activities	78.57
Information service activities	74.93
Activities auxiliary to financial services and insurance activities	74.25
Sewerage, waste management and remediation activities	64.76
Manufacture of computer, electronic and optical products	64.10
Advertising and market research	62.68
Civil engineering	55.95
Manufacture of other transport equipment	54.69
Office administrative, office support and other business support activities	52.17
Manufacture of chemicals and chemical products	51.93
Publishing activities	51.54
Manufacture of machinery and equipment not elsewhere classified	51.26
Legal and accounting activities	50.61
Manufacture of wearing apparel and leather goods	47.81
Public administration and defence; compulsory social security	46.04
Motion picture, video and television programme production, etc	45.75
Whole Economy	44.25

Table 2: Output per hour in low productivity activities (č)

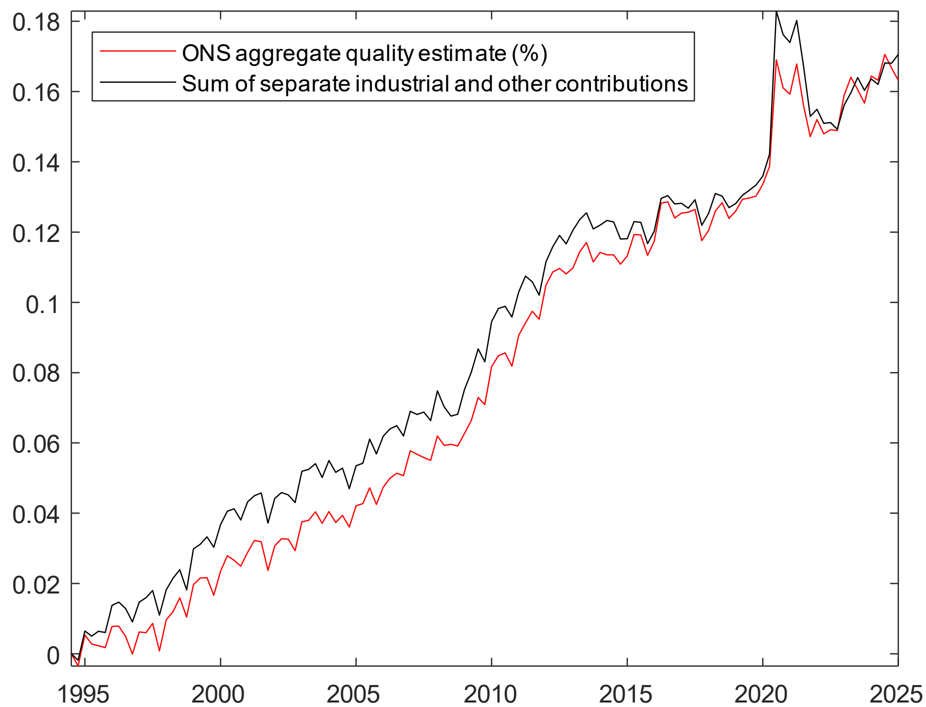
Whole Economy	44.25
Manufacture of paper and paper products	42.73
Repair and installation of machinery and equipment	42.35
Computer programming, consultancy and related activities	41.50
Wholesale trade, except of motor vehicles and motorcycles	41.38
Manufacture of fabricated metal products, except machinery and equipment	40.98
Education	40.03
Manufacture of other non-metallic mineral products	39.94
Gambling and betting activities	39.55
Veterinary activities	38.62
Manufacture of electrical equipment	38.25
Manufacture of food products	37.66
Manufacture of basic metals	37.34
Specialised construction activities	36.76
Mining support service activities	35.46
Printing and reproduction of recorded media	34.90
Other personal service activities	34.55
Human health activities	34.04
Construction of buildings	31.92
Warehousing and support activities for transportation	31.55
Other manufacturing	31.16
Wholesale and retail trade and repair of motor vehicles and motorcycles	29.95
Manufacture of textiles	29.31
Air transport	28.30
Creative, arts and entertainment activities	27.88
Architectural and engineering activities; technical testing and analysis	27.65
Retail trade, excluding motor vehicles and motorcycles	27.58
Manufacture of rubber and plastic products	27.57
Activities of membership organisations	27.32
Accommodation	27.13
Manufacture of furniture	26.73
Other professional, scientific and technical activities	25.77
Residential care activities	25.75
Postal and courier activities	25.59
Land transport and transport via pipelines	25.29
Manufacture of wood and of products of wood and cork, except furniture	24.92
Social work activities without accommodation	24.26
Activities of head offices; management consultancy activities	23.29
Sports activities and amusement and recreation activities	22.40
Repair of computers and personal and household goods	21.89
Forestry and logging and fishing and aquaculture	21.25
Crop and animal production, hunting and related service activities	20.91
Food and beverage service activities	20.09
Employment activities	18.56
Libraries, archives, museums and other cultural activities	16.30
Services to buildings and landscape activities	13.62
Activities of households as employees	11.33
Security and investigation activities	10.24

Figure 1: ONS measure of labour input



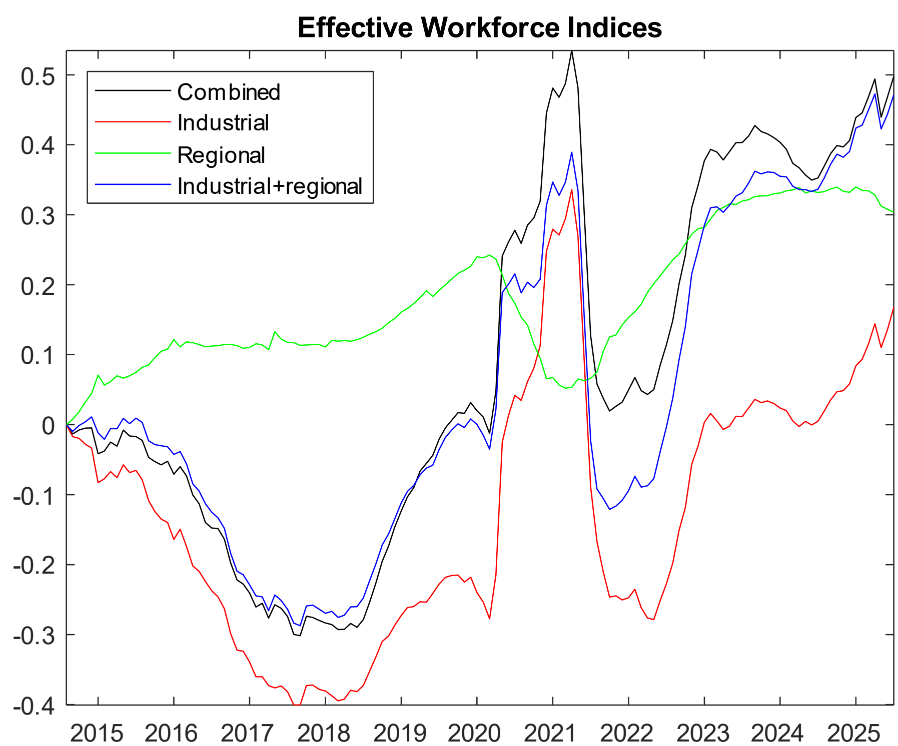
This figure compares the logatithm of the ONS labour input index with that of the the standard workforce measure, which is based on a simple count of the number of hours worked in the economy.

Figure 2: Comparison of aggregate and disaggregate labour input estimates from the ONS data



This Figure compares the logarithm of the ONS aggregate labour quality index (the difference of the two series in Figure 1) with the sum of the logarithms of the separate industrial, educational and demographic contributions shown in subsequent figures.

Figure 3: Comparison of aggregate and disaggregate labour input estimates from the HMRC PAYE data



The growth of the effective workforce indicated by the PAYE regional/industrial grid are shown as the black line. Separating out the industrial and regional effects gives the red and green lines respectively. Combining them gives the blue line. Comparing this with the black line shows how well they approximate the combined grid estimate, providing a test of the partial approach.

Figure 4: Hourly value added and compensation in 2024

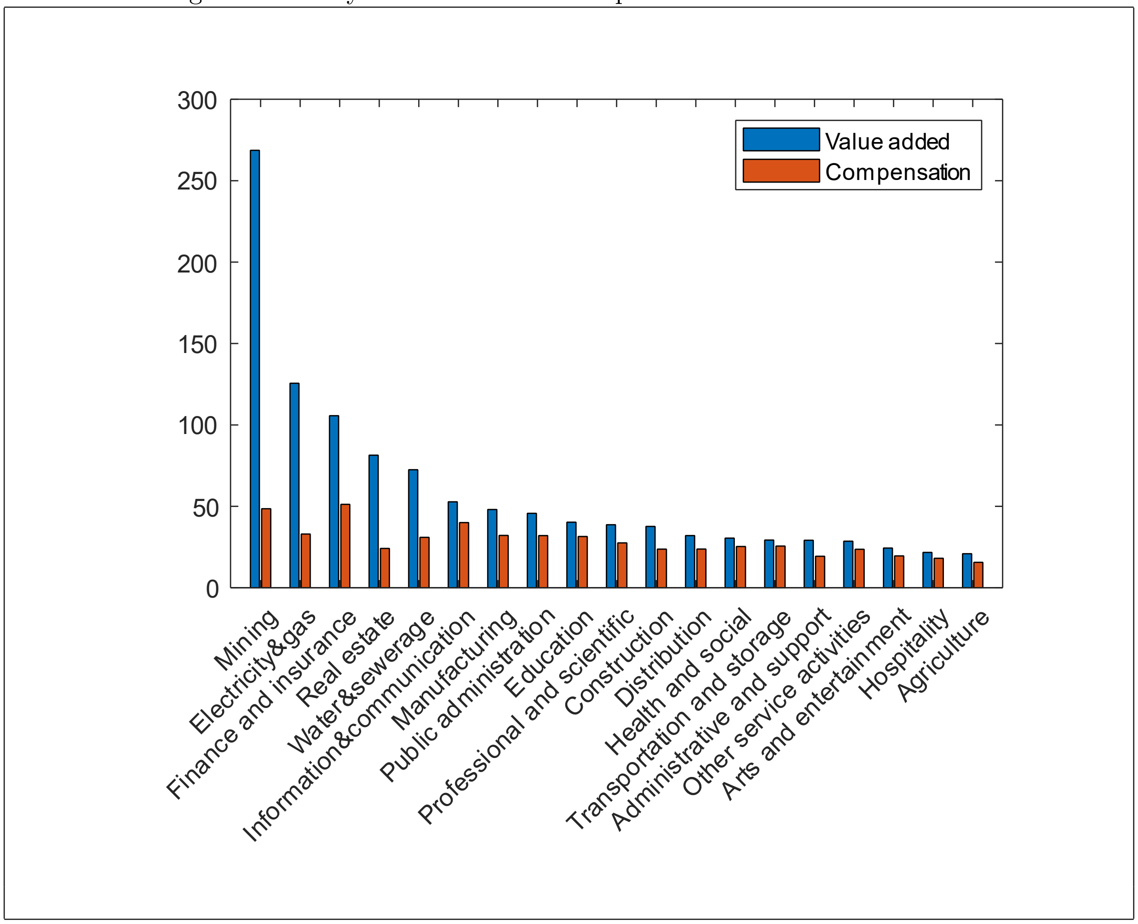
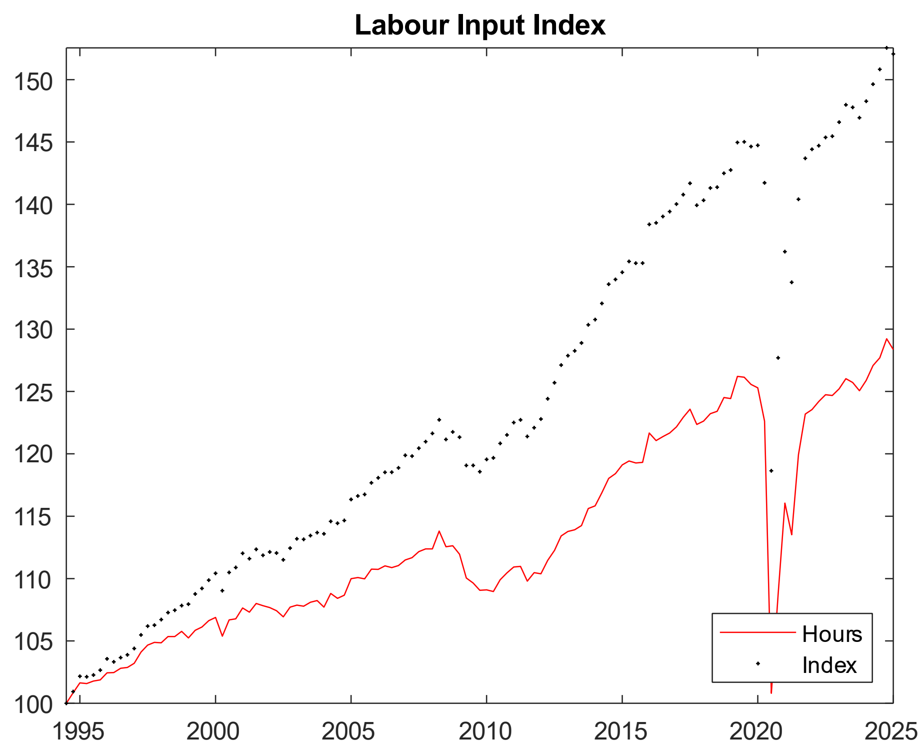
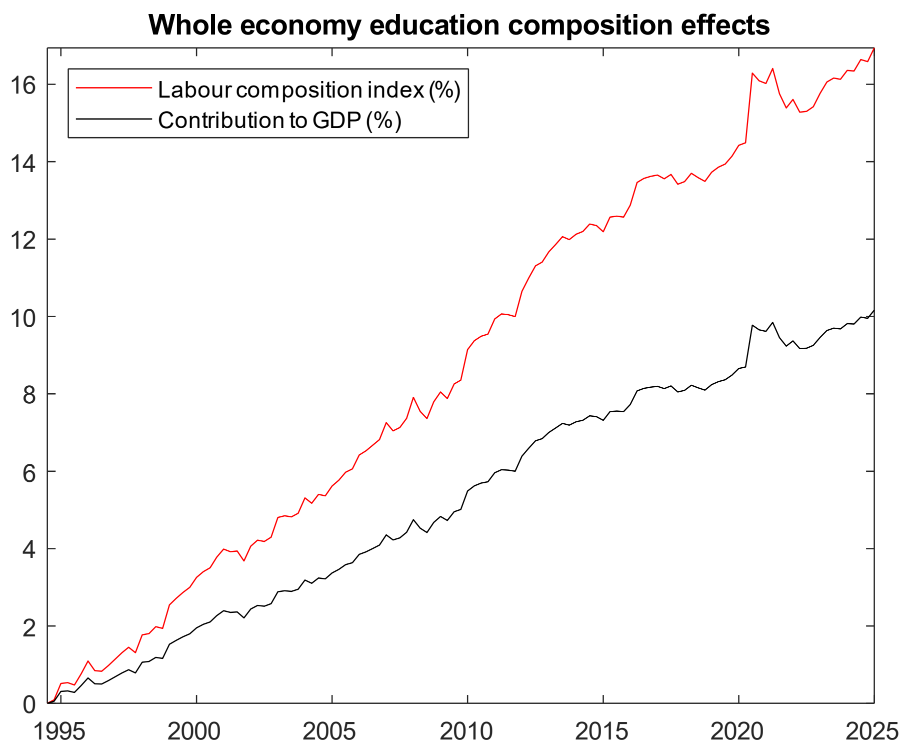


Figure 5: Labour input estimates for education and training



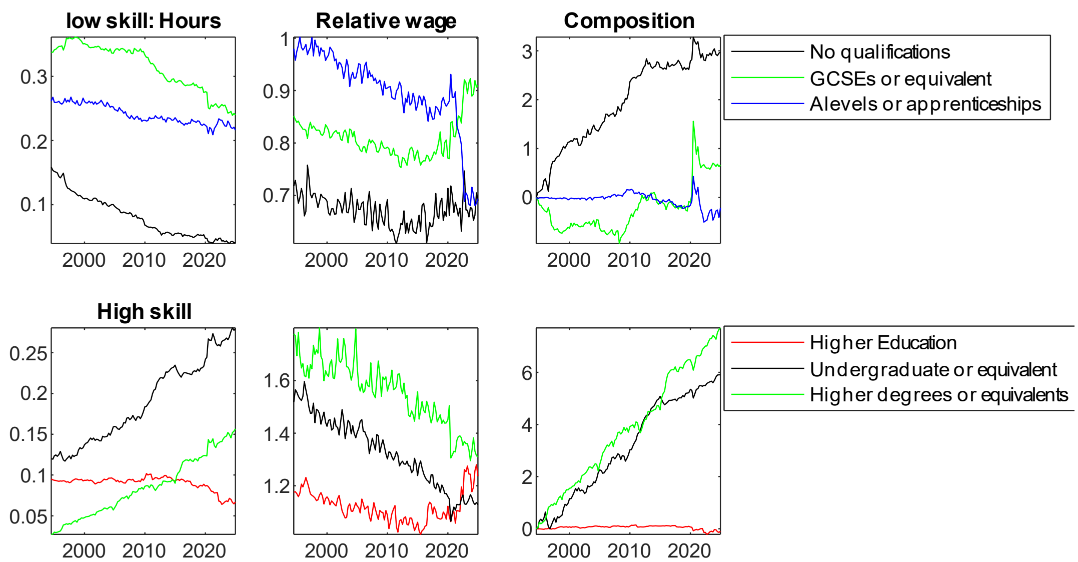
This figure compares the qualification-weighted labour input index with the standard workforce measure, which is based on a simple count of the number of hours worked in the economy.

Figure 6: Estimated effect of education and training on labour quality and GDP



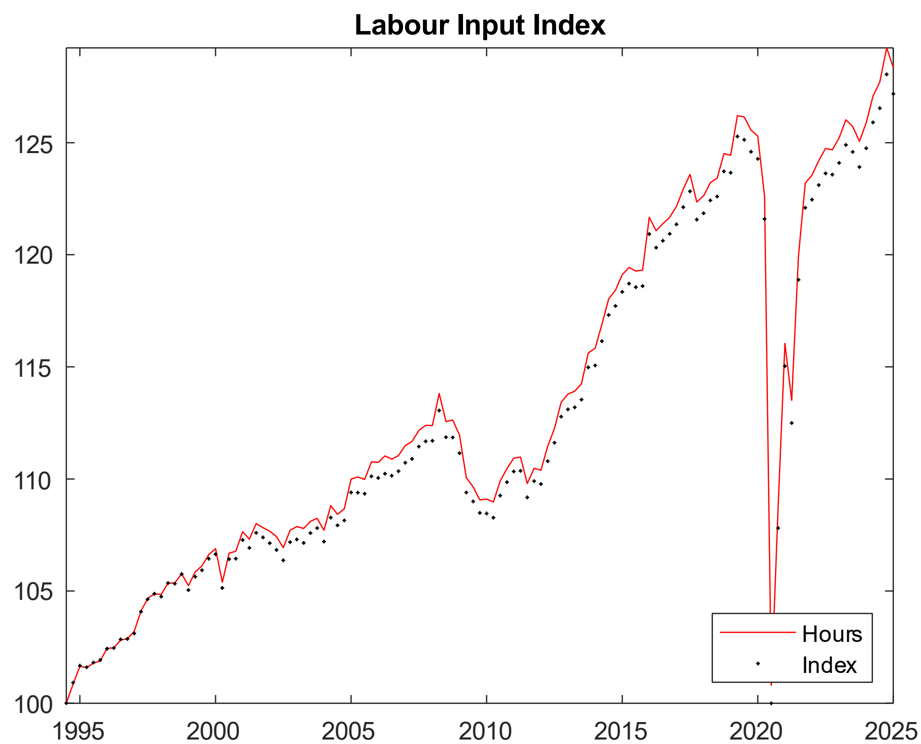
The labour composition index is found by dividing the labour input measure in the previous chart by the standard workforce measure. This is the basic measure of quality used in the literature. The GDP effect follows by multiplying the quality effect each of the components shown in the next chart by its total compensation as a share of money GDP, as explained in the appendix.

Figure 7: Sectoral contributions to the education and training composition index



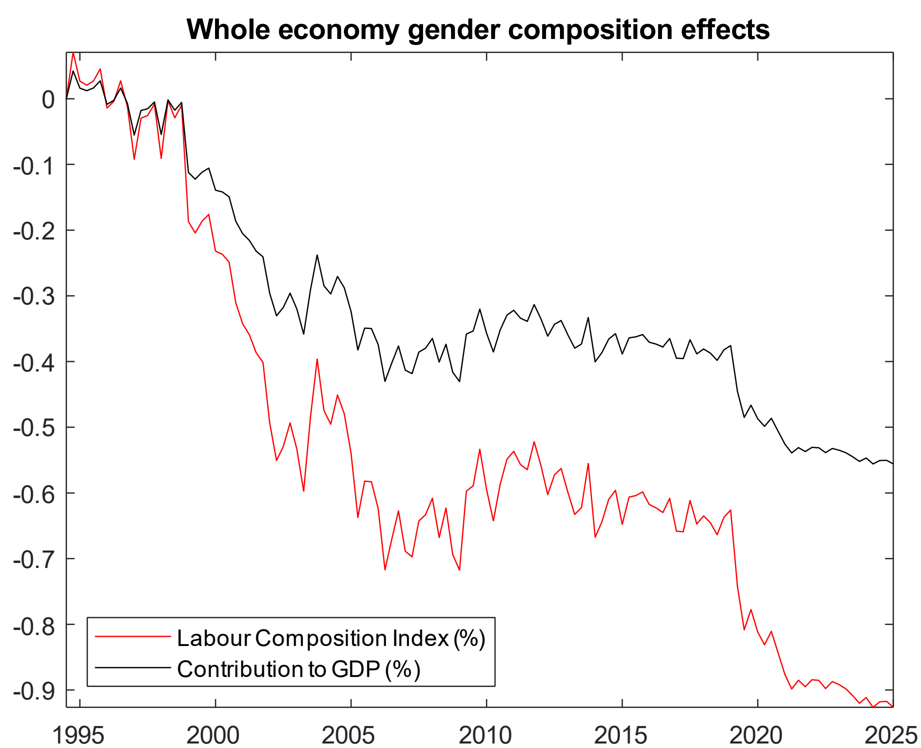
The left hand panel in this figure shows the ONS data for hours worked in each sector as a share of the total. The central panel shows average compensation per employee in each sector, relative to the national average. These determine the contributions that these groups of workers respectively make to the LCI, as explained in the appendix. These contributions are shown in the right hand panel.

Figure 8: Labour input estimates for gender composition



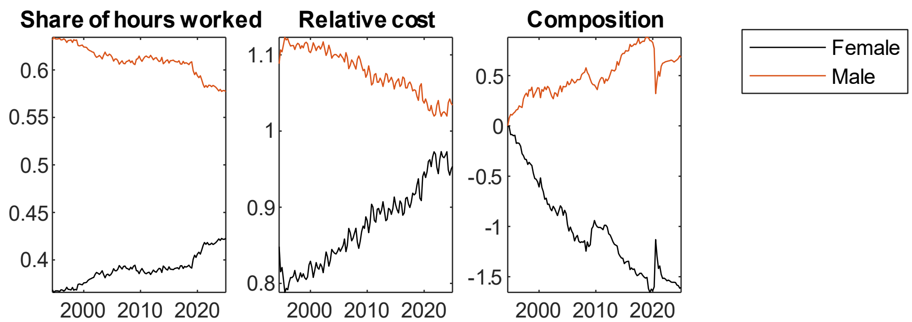
This figure compares the gender-weighted labour input index with the standard workforce measure, which is based on a simple count of the number of hours worked in the economy.

Figure 9: Estimated effect of gender composition on labour quality and GDP



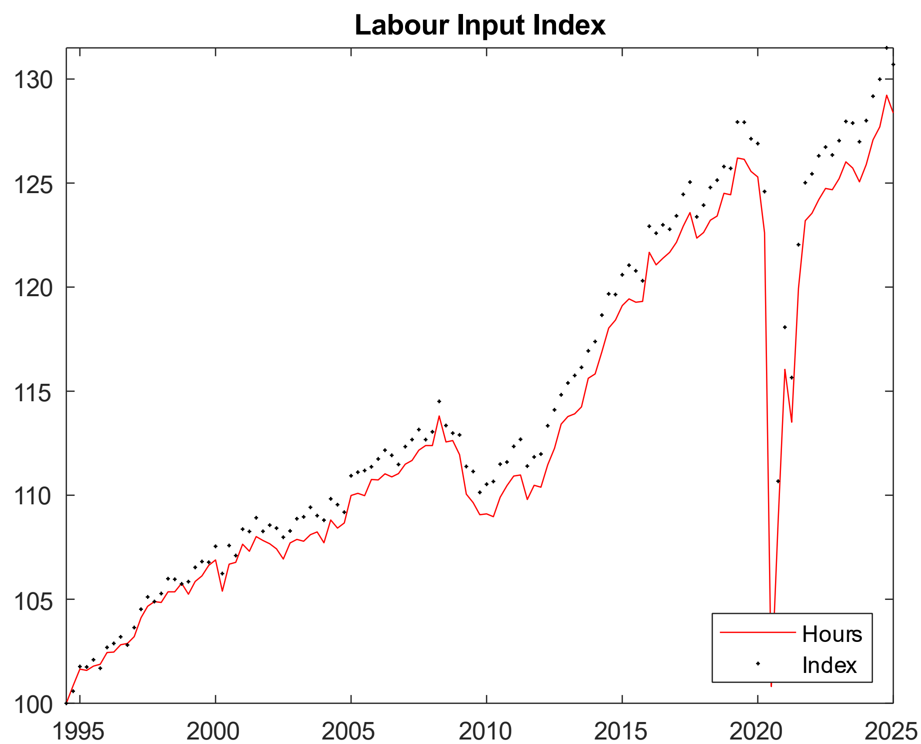
See notes to figure 6.

Figure 10: Sectoral contributions to gender composition



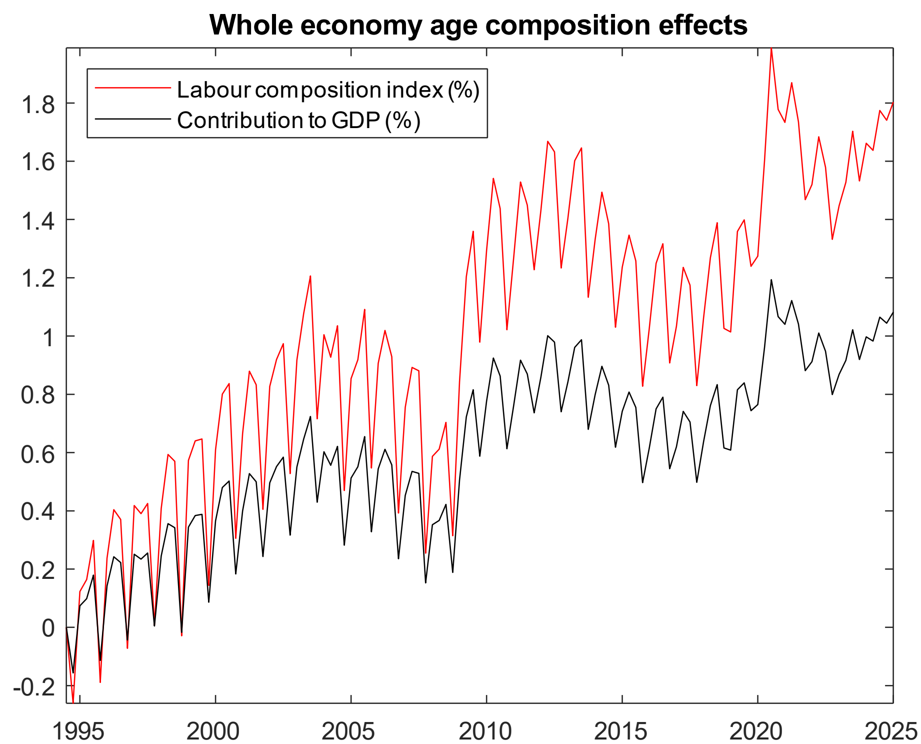
See notes to figure 7.

Figure 11: Labour input estimates for age composition



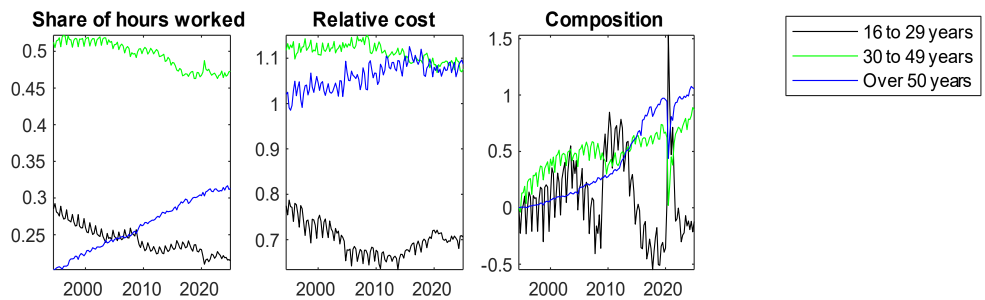
See notes to figure 5.

Figure 12: Estimated effect of age composition on labour quality and GDP



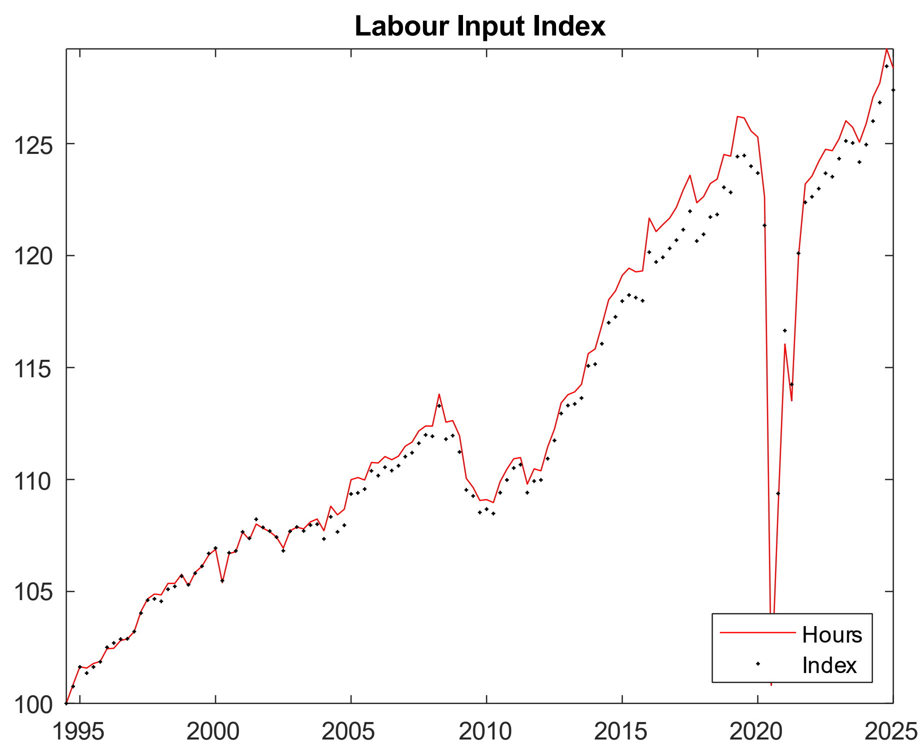
See notes to figure 6.

Figure 13: Sectoral contributions to age composition



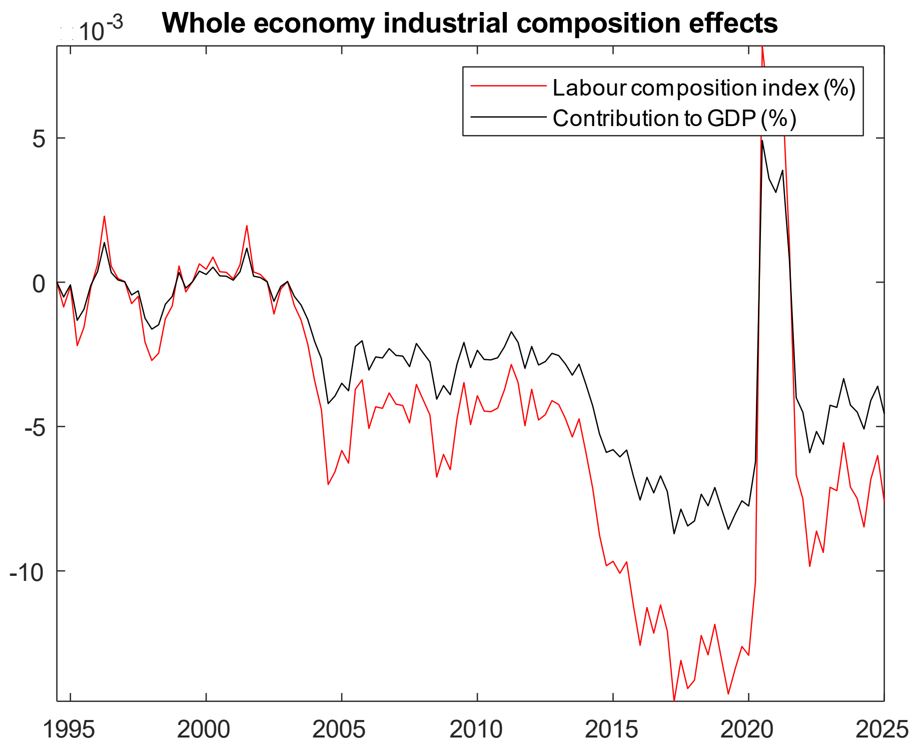
See notes to figure 7.

Figure 14: Labour input estimates for industrial composition



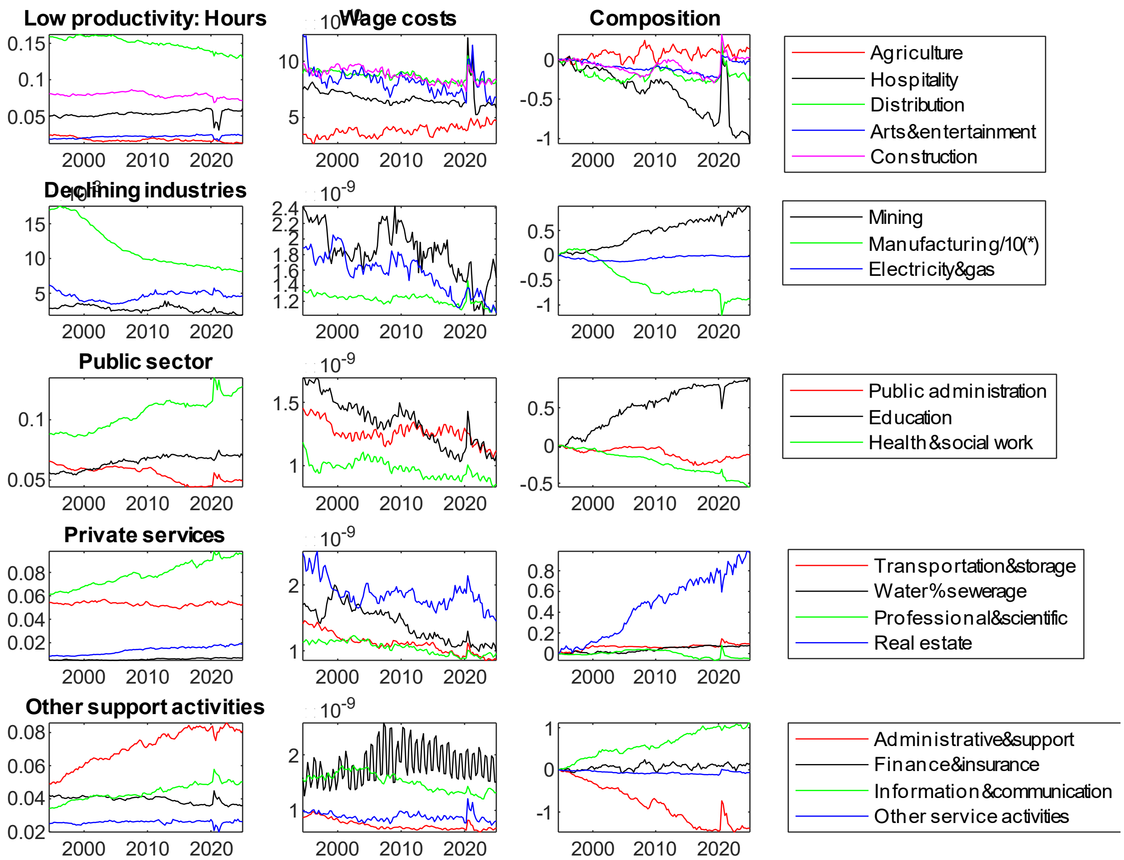
See notes to figure 5.

Figure 15: Estimated effect of industrial structure on labour quality and GDP



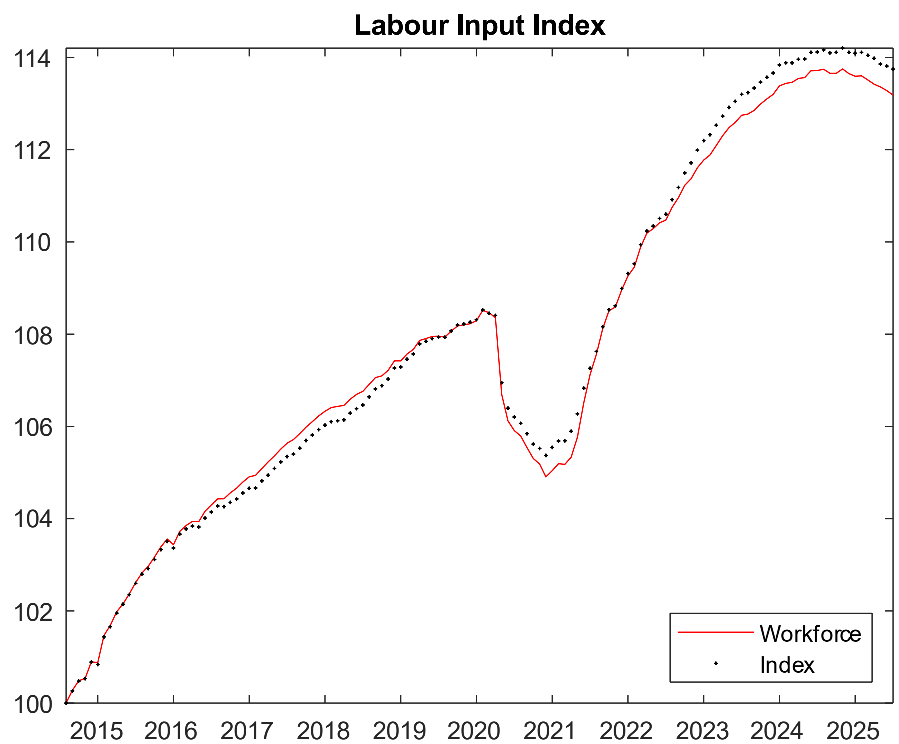
See notes to figure 6.

Figure 16: Sectoral contributions to industrial composition



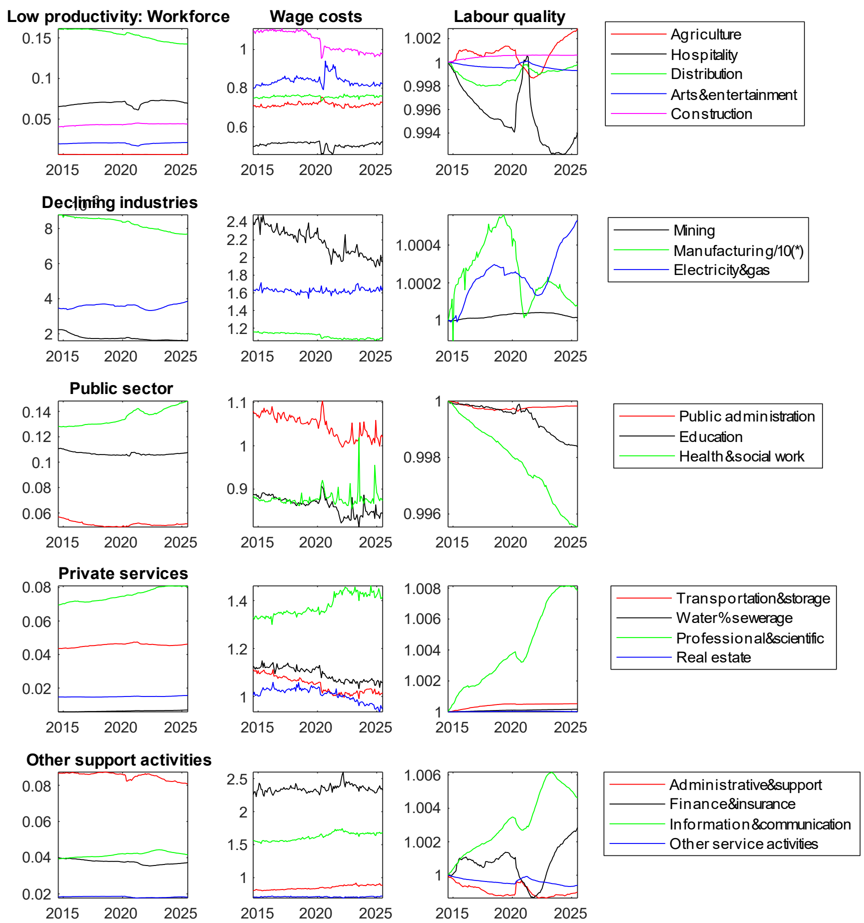
See notes to figure 7.

Figure 17: Labour input index estimates from the HMRC payroll data



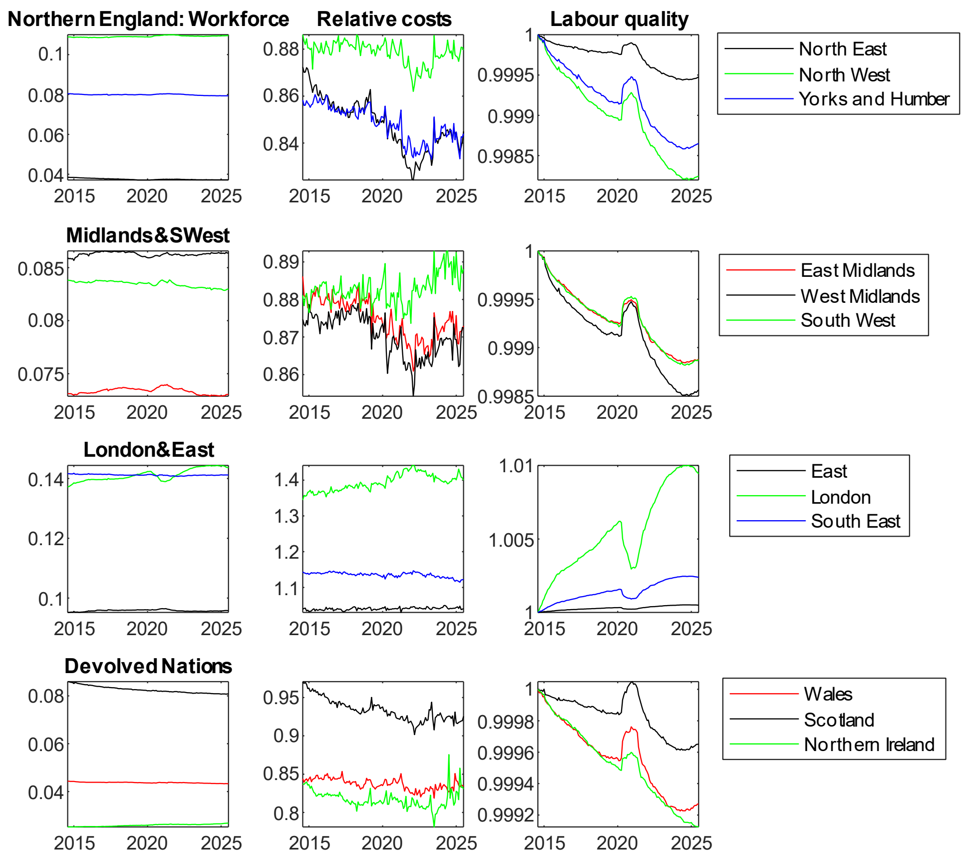
This Index shows the labour input index measure constructed from the regional×industrial PAYE data. This is compared with the standard workforce measure based on a simple count of the number of employes covered by the PAYE system.

Figure 18: Industrial composition effects in the whole economy PAYE data



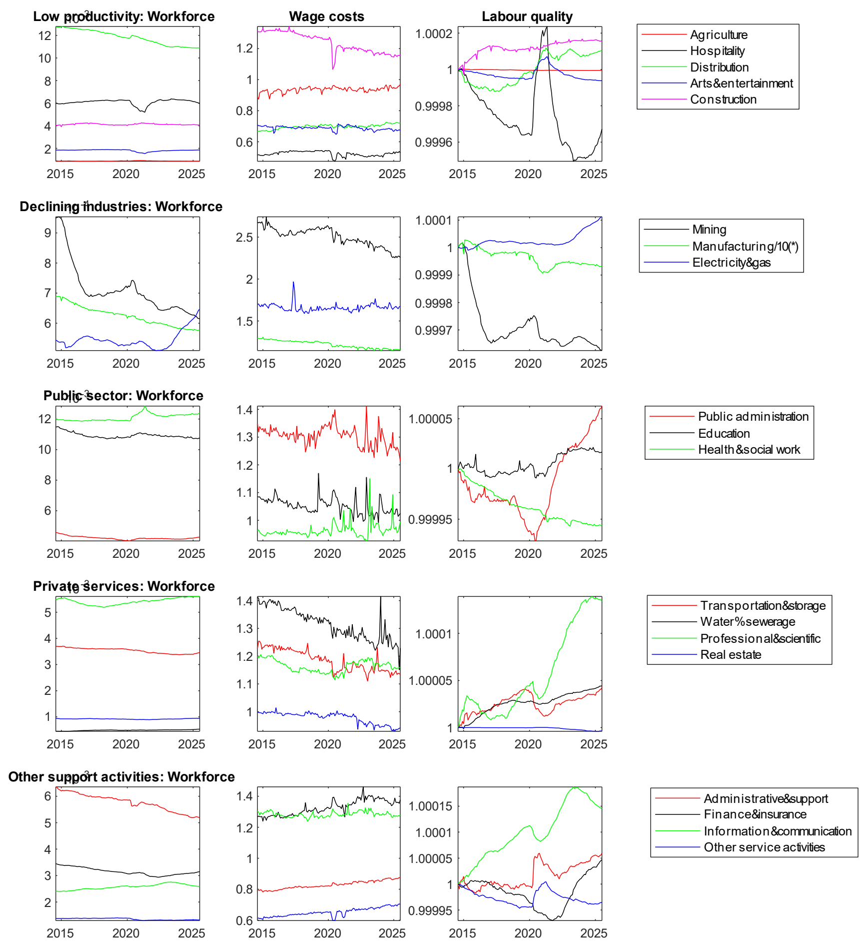
The left hand panel in this figure shows PAYE data for employment in each sector as a share of the total. The central panel shows PAYE wage costs per employee in each sector, relative to the average. The contribution that these industries make to the labour quality index are shown in the right hand panel.

Figure 19: Regional estimates from the HMRC data



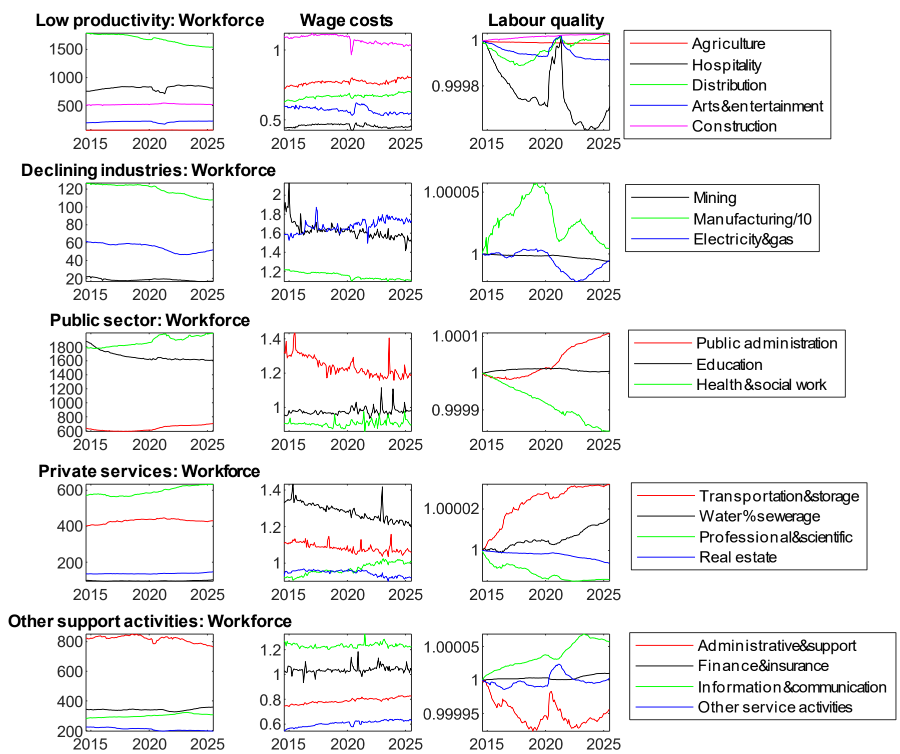
The left hand panel in this figure shows PAYE data for employment in each region as a share of the total. The central panel shows PAYE wage costs per employee in each region, relative to the average. The contribution that these regions make to the labour quality index are shown in the right hand panel.

Figure 20: Sectoral effects in the PAYE data for Scotland



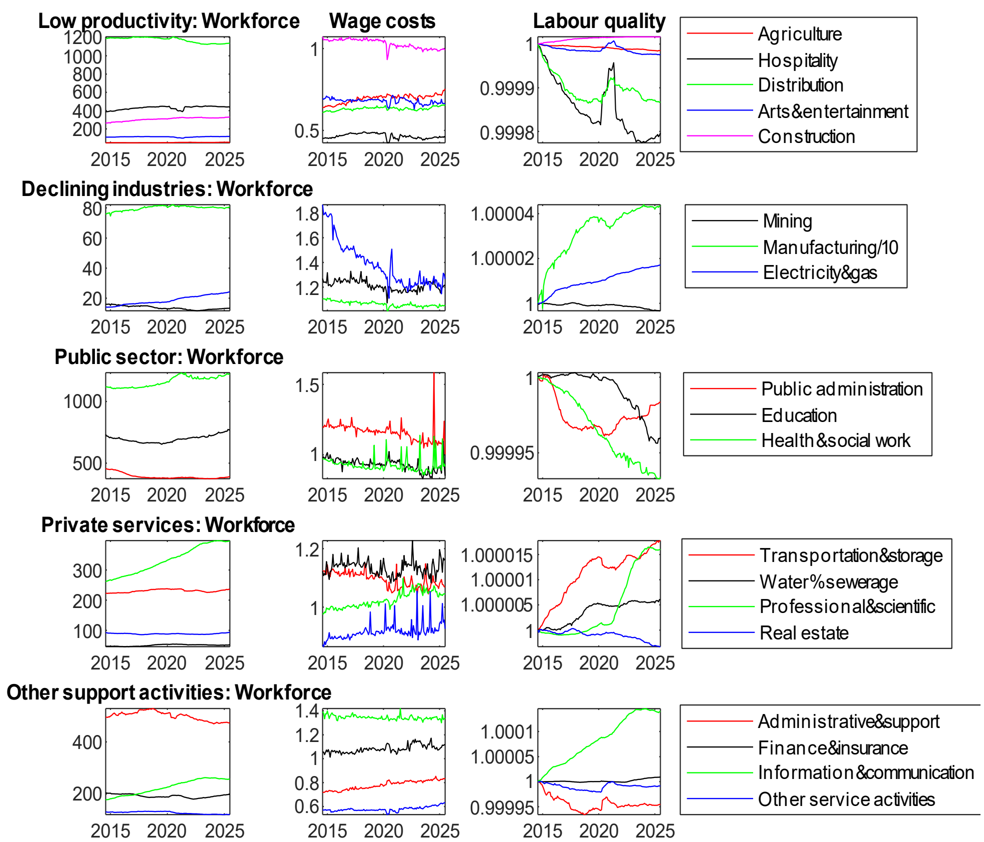
The top panel of this figure shows the contribution that these industries make to the regional/industrial labour composition index in Figure 3. The left hand panel shows PAYE data for employment in each Scottish sector as a share of the total. The central panel shows PAYE wage costs per employee in each of these, relative to the average. The contribution that these industries make to the labour quality index are shown in the right hand panel.

Figure 21: Sectoral effects in the PAYE data for Wales



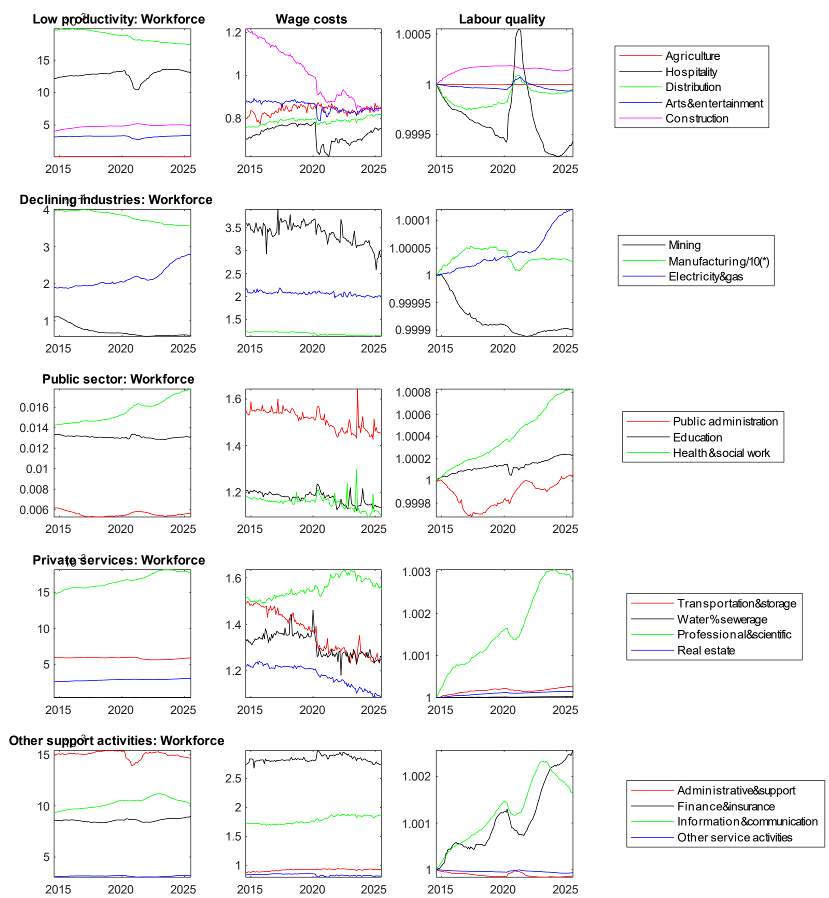
The top panel of this figure shows the contribution that Welsh industries make to the regional/industrial labour composition index in Figure 3. See notes to Figure 20.

Figure 22: Sectoral effects in the PAYE data for Northern Ireland



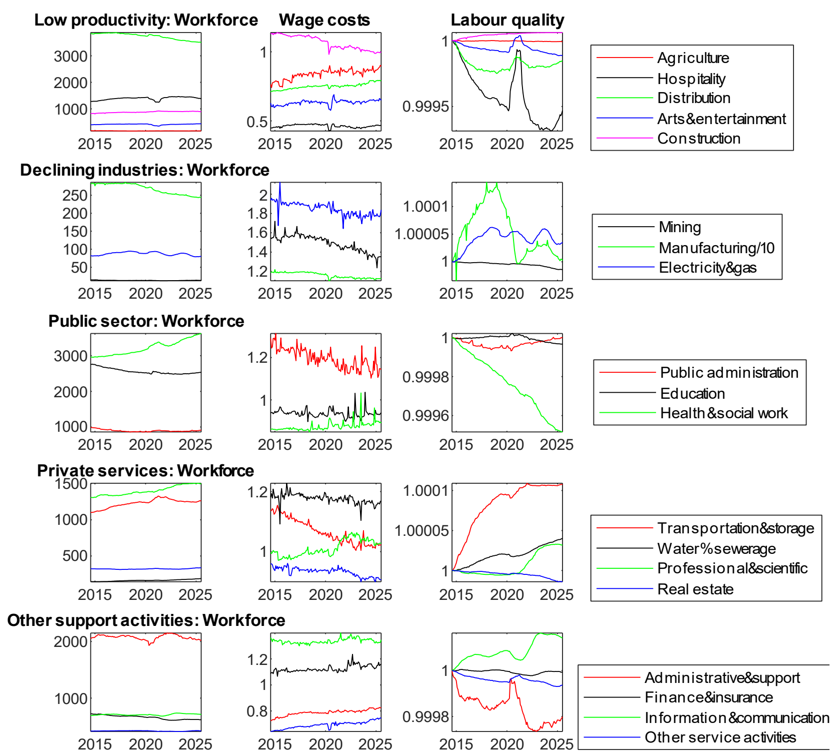
The top panel of this figure shows the contribution that Northern Irish industries make to the regional/industrial labour composition index in Figure 3. See notes to Figure 20.See notes to Figure 20.

Figure 23: Sectoral effects in the PAYE data for London



The top panel of this figure shows the contribution that London's industries make to the regional/industrial labour composition index in Figure 3. See notes to Figure 20.

Figure 24: Sectoral effects in the PAYE data for the West Midlands



The top panel of this figure shows the contribution that industries in the West Midlends make to the regional/industrial labour composition index in Figure 3. See notes to Figure 20.