The weak link between productivity and wages in London: Evidence from firms and local labour markets (2004-2014)

A Report for the Greater London Authority

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Executive Summary

This report offers empirical evidence on the impact of labour productivity on wages at the firm and at the local labour market levels (Travel-To-Work-Area, TTWA) in Great Britain (GB), with a focus on firms based in London and within the local labour markets composing the Greater London Authority: London and Slough and Heathrow (S&H).

The aim of this report is to offer evidence to ground policies that aim to foster productivity recovery, including in areas that top the productivity and wages distribution such as London, stimulate wage growth and living standards more generally, without increasing inequality within and between areas.

Greater London Authority: a glance on wage and productivity
London had the highest average hourly nominal wage and labour productivity distributions, both in 2004 and 2014. Slough and Heathrow is positioned close to London in 2004, although it dropped several places in 2014.

London and Slough and Heathrow experience a large increase in labour productivity between 2004-2014. In London, this is coupled with a similar positive change in average nominal wages, whereas in Slough and Heathrow average nominal wages increase less than in most other Travel-to-Work-Areas in Great Britain.

London is one of the few Travel-to-Work-Areas where we observe a rise of both labour productivity and wages.

The impact of productivity on wages in firms
There is no evidence that firms in GB share gains in productivity with the average worker by increasing real wages. The rent-sharing effect of productivity gains is on average very small, with no statistically significant difference for firms based in London, despite such effect is slightly larger in London-based firms.

There are sectoral differences in the impact of labour productivity on wages in firms. In GB, only firms in professional services experience a (tiny) increase in wages as a result of increases in productivity. In London, beyond professional services, firms in the financial sector experience a tiny increase of real wages as a result of productivity gains. The opposite occurs in London-based manufacturing firms, where changes in productivity have led to a lower than average change in real wages. Because the data include the years of the financial crisis, the negative effect may be also due to stagnant wages during the productivity dip.

The impact of productivity on wages in local labour markets
Within the local labour market, there is some evidence that the average and median worker benefit from productivity increases:
- A £1 increase in labour productivity results in a £0.28 increase in average nominal wages and in a £0.35 increase in median nominal wages: the effect is small, and points to a decoupling between productivity and wage growth in GB within labour markets.

- The statistical evidence on the impact of labour productivity changes on wage changes is however weak, which confirms the descriptive analysis.
- The London labour market follows this pattern but Slough and Heathrow labour market shows a different pattern, with productivity leading to a more marginal increase in nominal wages.
- Across GB Travel-to-Work-Areas, we find a stronger impact of productivity on median than on average wages. This is also true for London, different from what was concluded from descriptive evidence in Figure 5. However, a word of caution is necessary when inspecting the coefficients estimated for London Travel-to-Work-Areas, as these results are derived from only two observations.
- A stronger impact of productivity on median rather than average wages shows that productivity gains do not necessarily increase wage inequality in labour markets.
- However, our results show a decoupling between productivity and wage growth within labour markets.

Key findings and policy recommendations

The evidence shows that the impact of labour productivity on wages at the firm and at the local labour market levels differs in firms based in London and within the local labour markets composing the Greater London Authority: London and Slough and Heathrow.

Within a general context of stagnant productivity in GB, we find a decoupling between productivity and wage growth. Evidence of a rent-sharing effects is weak, and it involves the median more pronouncedly, rather than the average wages. This implies that productivity gains do not necessarily increase wage inequality in labour markets.

The key findings in our report indicate that a sustained productivity growth is a necessary but not a sufficient condition to achieve increases in living standards, neither in GB, nor in London. The good news is that median wages seem to have gained more than average wages from productivity (although this is less clear in the London Travel-to-Work-Area). Policies should focus on how to increase the elasticity between productivity and median wages, so to achieve both a more productive and inclusive economy.

1. Focusing on innovation incentives for firms and public investments in Research and Development (R&D) and innovation might be a more effective strategy to increase living standards than focusing on productivity alone, which might also be achieved by cutting labour costs. In parallel, and not less important, tools to support innovation diffusion should be prioritised, to maximise benefits of innovation and reduce asymmetries across local labour markets in both labour productivity and wages.

2. There is no automatic trickle-down effect, but policy at both national and local levels should aim at creating the conditions for it to occur. Supporting London's innovative sectors as identified in the Local Industrial Strategy Report is important for wage trends and job quality. These are digital services, advanced urban services, life sciences, cultural and creative activities and environmental services (GLA, 2020). However, this must be accompanied by policies that increase the inclusion of parts of the population currently excluded from entrepreneurship opportunities, curbs market concentration, and favours redistribution of innovation rents.

3. Firms need to invest in formal training, skills upgrading and life-long learning to make innovation more inclusive.

4. Focusing on the principles of inclusive and sustainable growth, the Government must maintain employment schemes that allow workers to benefit from innovation outcomes at firm and local labour market levels while avoiding premature austerity measures that might be counter-cyclical in the aftermath of the pandemic.

5. Promoting inclusion that is innovation- and wage-progression friendly is something that policies should pursue. This is also something that would go beyond the hyper-focus on productivity that has recently dominated the policy debate in the UK.

In sum, a comprehensive policy framework to achieve an inclusive post-crises recovery, based on higher living standards for low skilled workers and the occupational categories at the bottom of the wage distribution, or those currently excluded from the job market of innovative activities, should go beyond productivity. It should ensure innovation in, and structural changes of, local labour markets by leveraging on inclusion as a tool, rather than considering inclusion as a constraint or simply an objective; mitigate the effects of digital transformations on labour markets by ensuring life-long learning and soft skills enhancement where the share of low skilled is particularly important; and prioritise employment protection and jobs quality in a recession context. A comprehensive, place-based policy approach should also involve social partners and ensure that alternative work arrangements such as self-employed and gig workers are protected similarly to paid labour. Finally, policy should mitigate the detrimental effects on inequality caused by the fact that superstar firms and megacities are innovating but not redistributing effectively or allowing effective diffusion.

1. Introduction

The UK has suffered from a stagnant productivity recovery after the 2008 financial crisis (Blundell et al., 2014), coupled with a flat real wage growth (Valero and Van Reenen, 2019), a sluggish growth of the nominal wage rate and an increase in income inequality (Joyce and Xu, 2019). This trend was partly counterbalanced by the observation that employment has been at its highest peak since the crisis (76% in 2019 in the UK), due to an increase in self-employment (Ciarli et al., 2020), new contractual arrangements and firms 'hoarding' labour – perhaps at lower wages or reduced number of hours – rather than making workers redundant (Crawford et al., 2013; Valero and Van Reenen, 2019).

Productivity growth plays a central role in increasing economic wealth. Although at the firm level productivity does not contribute to a great extent to an increase in wages (Card et al., 2018), there is evidence that it does contribute to wage changes at the level of the local labour market (Hornbeck and Moretti, 2019). However, due to reduced labour shares (Karabarbounis and Neiman, 2014), a divergence between productivity and wage growth has been observed across most OECD countries (Berlingieri et al., 2017). The UK is not an exception, with the decoupling between productivity and wages contributing to increased wage inequality (Machin, 2016). With the UK suffering a poor productivity performance (as with many OECD countries) over at least two decades (Crawford et al., 2013), it is important to better understand the extent to which efforts to increase productivity across the UK (Balawejder and Monahan, 2020) will lead to improved standards of living in terms of increased wages (Hawking, 2019). In addition, to achieve a sustainable growth, it is important to better understand the conditions under which productivity growth leads to an increase in wages, without increasing inequality.

Regional differences in the UK, in terms of both productivity and wages (Haldane, 2017, 2018a 2018b; D'Costa and Overman, 2014), and evidence that firm innovation may have unequal impact on employment across regions (Ciarli et al., 2018a and 2018b) pose an additional challenge, but also an opportunity to better understand the micro, regional and sectoral variations of the productivity-wages nexus. Urban wage premia, the concentration of high-skilled and high-education workers in large urban agglomerations, and the favourable sectoral specialisation of London and the South East of the UK, may contribute to both productivity's and wages' positive performances.

Within this context, it is of pivotal importance that sectoral and industrial policies that aim to foster productivity recovery (Balawejder and Monahan, 2020), including in areas that top the productivity and wages distribution such as London, are able to stimulate wage growth and living standards more generally, without increasing inequality (within and between areas). To inform such policies, evidence on the impact that productivity has on wages and inequality within firms and in local labour markets, in London and in the UK, is needed.

This report provides solid evidence to this aim. Based on a large set of matched data on productivity and wages over 2004-2014, it estimates the impact of labour productivity on wages at the firm and at the local labour market levels (Travel-To-Work-Area, TTWA) in Great Britain (GB). The report offers evidence on whether such impact differs in firms based in London and within the local labour markets composing the Greater London Authority: London and Slough and Heathrow (S&H) (Figure A).

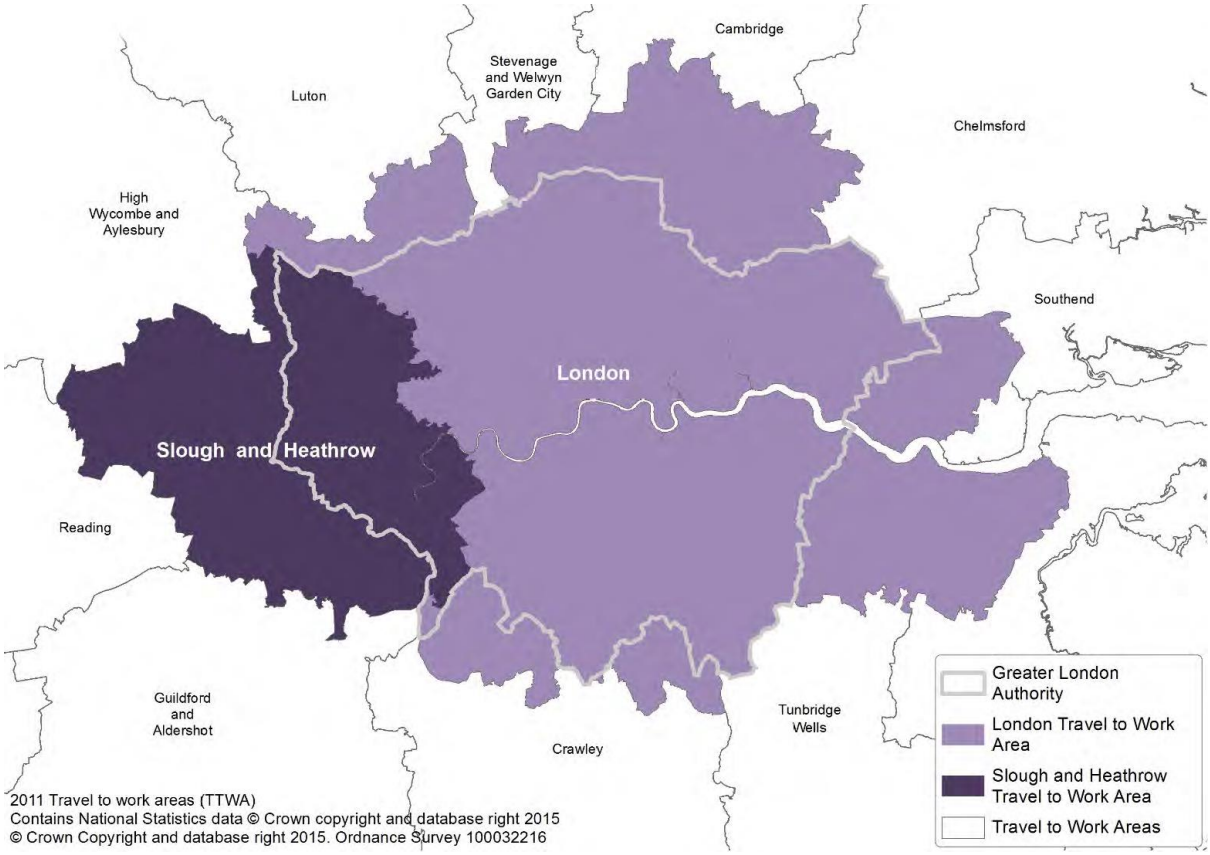


Figure A: The Greater London Authority, London and Slough and Heathrow Travel To Work Areas

Source: GLA, 2020

Our results can be useful to provide an additional perspective on the problems of the North-South divide, and the Northern 'left behind places', with policies that aim at redistributing the benefits of productivity to a wider population, including sectors and occupations that have been hit the hardest from stagnant growth and post-crisis dips, regardless of where they are located, being particularly welcome. This implies that our report is particularly relevant to highlight the uneven distribution of productivity gains also *within* London TTWAs, and to extend the traditional rationale of 'levelling up' not only across local labour markets in the UK, but also within each of the TTWAs, which might be highly uneven.

The remainder of the report is structured as follows. Section 2 provides an overall glance at the descriptive evidence on the levels and changes of productivity and nominal wages across the TTWAs in GB, and positions the two London TTWAs in the national context, over the 2004-2014 time span. Section 3 offers a brief, selected review of the relevant literature. Section 4 discusses the data and empirical strategy, at the firm and TTWA levels. Section 5 describes the estimations results at the two levels of analysis. Section 6 summarises the key results, while Section 7 provides the policy recommendations that can be devised from our evidence.

2. Background Evidence

Figure 1 plots the distribution of labour productivity (LP) (panel (a)) and average hourly nominal wages (panel (b)) across Great Britain's (GB) Travel to Work Area (TTWAs), which are local labour markets. Both confirm stark differences across GB regions, over the 2000-2014 period. in both years. The London TTWAs top the distribution for both indicators, and are followed by a few local labour markets with high LP and wages. Next there are a large number of "average" local labour markets, followed by a tail of quite a few local labour markets at the bottom of the distribution.

Figure 2 shows that, as expected, the two indicators are correlated: TTWAs with higher LP also tend to show higher average wages. However, the slope of the relationship has flattened between 2004 and 2014, suggesting that the relationship between productivity and wages has weakened across GB, as discussed in the literature (Pessoa and Van Reenen, 2013; Machin, 2016). There are two mechanisms that explain this decoupling.

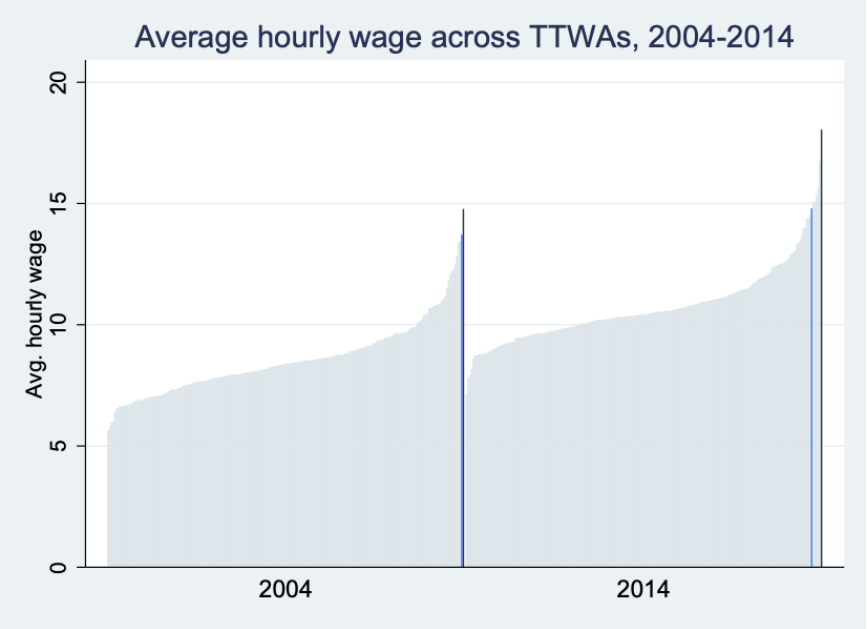
First, the average ten-year change of productivity across TTWA has been higher than the change of nominal wages. We show this in Figure 3 for all GB TTWAs. Second, the pattern differs across TTWAs, with some experiencing high increases in productivity, although not in wages. The two London TTWAs follow very different patterns. The London TTWA experiences high LP and high wage increases. In Slough and Heathrow, instead, the similarly high increase in LP is not accompanied by an equally high increase in wages. On the contrary, wages in Slough and Heathrow increase less than most other GB TTWAs.

We show this more systematically in Figure 4. Panel (a) plots the relationship between the initial level of LP and its change between 2004-1014, across TTWAs. It offers strong evidence that the TTWAs with higher productivity (because of their sectoral structure, capability to innovate, adoption of innovation, and presence of high skills), build on their advantages and further increase their LP. In other words, there has been no levelling up, or better, catching up, in LP: laggard regions are even more behind, relatively speaking, in relation to LP. As noted, both London TTWAs are at the top of the high LP TTWAs.

Against this backdrop, wages have been levelling up, or better, TTWAs with low average nominal wages have seen a higher increase than TTWAs with high nominal wages (panel (b)). Slough and Heathrow is a typical example, being the second TTWA in terms of nominal wages in 2004, and amongst those that experiences the lowest increase between then and 2014. The London TTWA, instead, is an exception, being one of the few that have a high wage in 2004 and a large increase between then and 2014.

In sum, against the evidence of increasing income inequality we observe a reduction in wage inequality across UK labour markets. As we discuss later, this may imply that increasing LP differences may be fuelling inequality, but not through wages, which remain low even where LP increases.

(a) Productivity

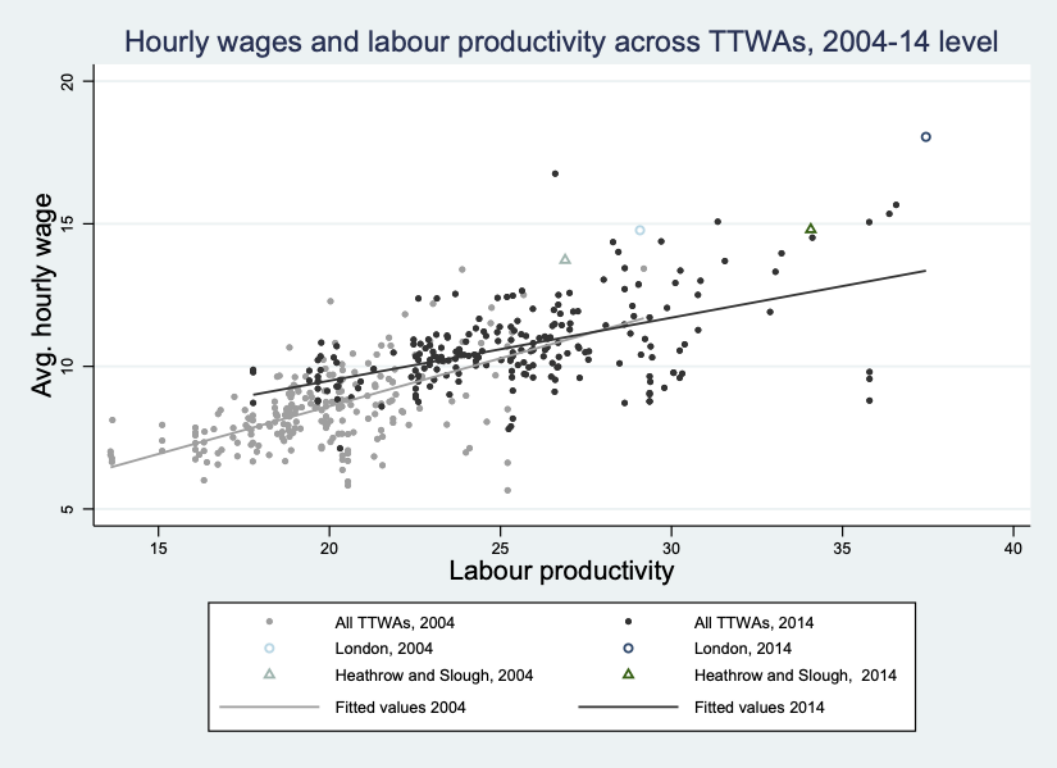


(b) Nominal wages

Note: Labour productivity is measured as nominal GVA per hours worked, excluding rental income. TTWA sorted from low to high productivity (a) and average hourly nominal wage (b). Black vertical line: London TTWA; blue vertical line: Slough and Heathrow TTWA.

Figure 1: Distribution of labour productivity and nominal average wages across GB TTWAs: 2004 and 2014

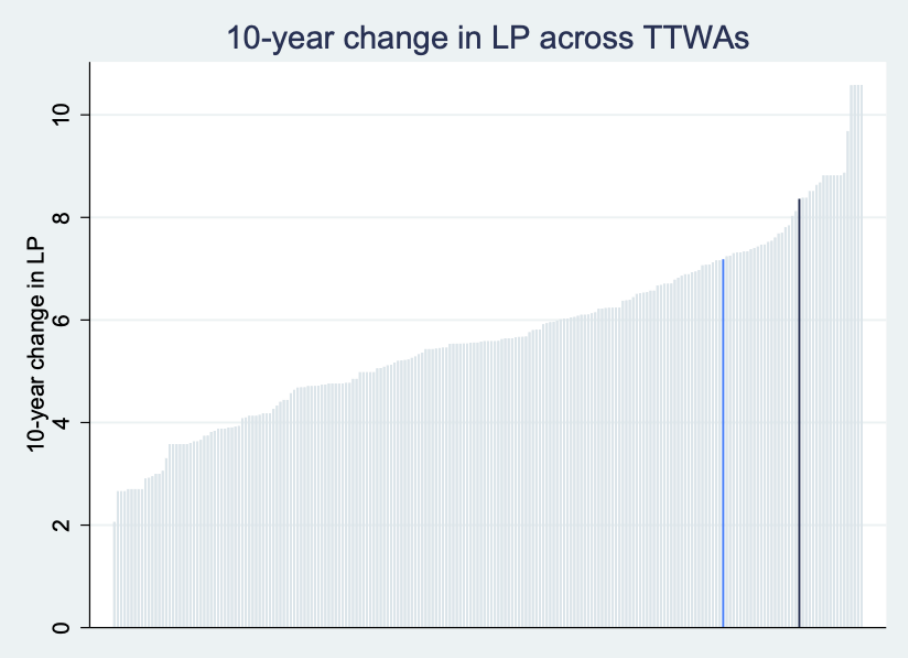
Source: Our calculations based on data from the ONS regional and sub-regional productivity tables and ASHE



Note: Labour productivity is measured as nominal GVA per hours worked, excluding rental income. The two lines plot the linear fit between LP and wages, in 2004 (lighter grey) and 2014 (darker black). Hollow circles: London TTWA; hollow triangles: Slough and Heathrow TTWA.

Figure 2: Correlation between LP and nominal average wages (2004 and 2014)

Source: Our calculations based on data from the ONS regional and sub-regional productivity tables and ASHE.



(a) Productivity

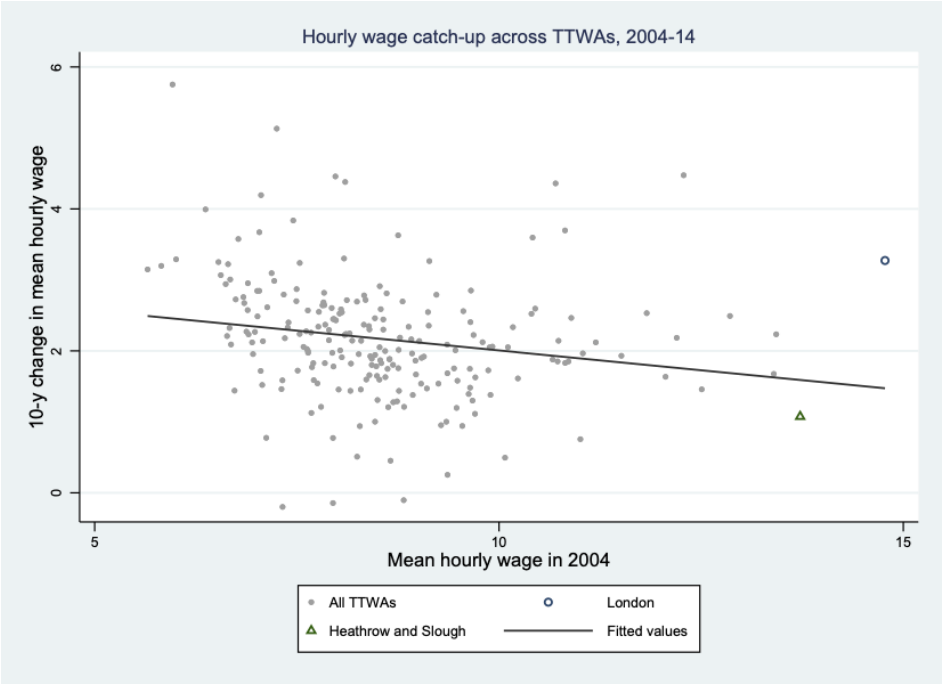
(b) Nominal wages

Note: Labour productivity is measured as nominal GVA per hours worked, excluding rental income. TTWA sorted from low to high productivity growth (a) and average hourly nominal wage growth (b). Black vertical line: London TTWA; blue vertical line: Slough and Heathrow TTWA.

Figure 3: 10-year changes of labour productivity and nominal average wages across GB TTWAs (20014-14)

Source: Our calculations based on data from the ONS regional and sub-regional productivity tables and ASHE

(a) Productivity



(b) Nominal wages

Note: Labour productivity is measured as nominal GVA per hours worked, excluding rental income. The two lines plot the linear fit between the level of LP (a) and wages (b) in 2004 and their 10-year change. Hollow circles: London TTWA; hollow triangles: Slough and Heathrow TTWA.

Figure 4: Relationship between the initial level of labour productivity and nominal wages and the 10-year change (2004-2014)

Source: Our calculations based on data from the ONS regional and sub-regional productivity tables and ASHE

(a) Average nominal wages

(b) Median nominal wages

Note: Labour productivity is measured as nominal GVA per hours worked, excluding rental income. The two lines plot the linear fit between the 10-year change in LP and average (a) or median (b) wages between 2004-2014. Hollow circles: London TTWA; hollow triangles: Slough and Heathrow TTWA.

Figure 5: Relationship between 10-year change in labour productivity and nominal wages across GB TTWAs (2004-2014)

Source: Our calculations based on data from the ONS regional and sub-regional productivity tables and ASHE

As a result of the overall lower increase in wages than in LP, and the contrasting catching up dynamics of LP and wages, we do not observe a strong correlation between LP and wages across TTWAs. We plot this in Figure 5 in relation to both average and median wages. The figure shows a relatively flat slope for both the average and the median wage. It also shows two other important pieces of evidence. First, the change in average wages (£2.16 per hour) is larger than the change in the median wage (£1.63 per hour). Because the average is higher than the median wage, this suggests that, against the discussed reduced wages inequality across TTWAs, within TTWAs wage inequality has increased.

However, the slope of the relationship between LP and wages is very similar for the average and the median. Because the average wage is higher than the median wage, this suggests that it is not the increase in LP that has contributed to this within TTWA inequality: the wages of the workers in the 50th percentile changes as much as that of the average wage (which is higher).

The two examples of the London TTWAs come in handy again here. London is well above the fitted line in plot (a), being one of the few TTWAs that experienced both a high increase in LP and a high increase in average wages over 2004-2014, suggesting a positive relationship between LP and wages in this area. However, London is very close to the fitted line in plot (b), suggesting that the wages of the median worker have not increased as much as that of the, better paid, average worker. This suggests an increase in inequality within London over the same period, related to the LP increase. Slough and Heathrow, instead, is well below the fitted line in plot (a), suggesting, as noted, that the increase in LP was not accompanied by an increase in wages. However, it is quite close to the fitted line in plot (b), suggesting that, although even median wages have not increased as much as LP, they have increased by a rate similar to the average, thus not leading to an increase in inequality.

3. Background literature

The relationship between labour productivity gains (or losses), i.e., the growth (or decline) of output or value added per hour worked or worker, and wages within firms is referred to as a 'rent-sharing' mechanism (Blanchflower et al., 1996; Manning, 2011; see also Card et al., 2018, for a review). The rent-sharing elasticity is the response of wages to productivity changes, and it indicates how much of the productivity gains/losses are accrued/incurred by workers.

Firms might want to share part of their productivity gains with workers for a series of reasons. First, firms might pay wage premia to highly performing workers, or to attract highly skilled workers (efficiency wages) (Van Reenen, 1996; Lazear, 1986, 2000). Second, firms might also want to adapt wages to productivity to share risks due to market uncertainty, in the case of both positive and negative demand shocks. Third, firms might be induced to pay productivity premia when workers have a high degree of bargaining power, for instance due to unionisation. Finally, in the case of positive shocks to industry level productivity (between firms), firms might prefer to increase wages to retain high skilled workers (Carlsson et al., 2016).

At firm level, there is a large literature that investigates the rent sharing mechanism. Card et al. (2018) offer a comprehensive review of these contributions. Reviewing studies that employ different data, methods, identification strategies and country coverage, they show the stylised

fact that the rent sharing elasticity is typically low, ranging between 0.5% and 1.5% since after the 2008 crisis.

For the UK, Ciarli et al. (2018c) find a very small rent sharing mechanism, in line with other recent studies (for instance, Juhn et al., 2018 for the US; Matano and Naticchioni, 2017 for Italy). They find significant industry heterogeneity: the positive elasticity of wages to productivity is concentrated in some services (i.e., wholesale and retail trade, professional services) rather than the manufacturing sector.

The evidence may be explained by the behaviour of real wages and productivity in Great Britain (GB)[1] since the 2008 financial crisis, both stagnating and sticking to their pre-crisis levels (Haldane, 2017, 2018a, 2018b; Valero and Van Reenen, 2019). The lack of rent sharing might be mainly due to a lack of productivity growth. Blundell et al. (2014) show that the 2008 financial crisis, compared to previous recessions, caused real wages to fall consistently in response to the productivity slump, while containing the losses in employment, and featuring a record high employment rate (see also Valero and Van Reenen, 2019). Crawford et al. (2013) document firm strategies to hoard labour, and changes contractual forms to part-time or alternative work arrangements as a result of the recession; this has been associated to a fall in weekly wages.

Much less investigated is the relationship between productivity and wages in labour markets (Hornbeck and Moretti, 2019), accounting for the impact that firms may have outside their organisation, in attracting workers and firms in the same or related sectors, and increasing competition.

Substantial evidence shows that wages are tied to urban premia (D'Costa and Overman, 2014; Overman, 2019) and geographical agglomeration of activities (Powell et al., 2002; Echeverri-Carroll and Ayala, 2009; Meliciani and Savona, 2014), which might affect labour market dynamics (Korpi, 2007; Matano and Naticchioni, 2017; Berger and Frey, 2016), jobs (Moretti, 2011), and wage distribution (Lee, 2011; Lee and Rodriguez-Pose, 2012).

In the presence of agglomeration forces, do increases in productivity in a given labour market lead to an increase in wages?

In aggregate, at the national level, Pessoa and Van Reenen (2014) show that total remuneration in GB follows productivity quite closely, even during the long term stagnation of productivity (Castle et al., 2020), when real wages experience a 1% fall between 2008 and 2014 (while increasing by 1.3% between 2001 and 2008) (Cribb and Joyce, 2015). We have no evidence on whether this relationship holds across different local labour markets.

For the US, Hornbeck and Moretti (2019) estimate the impact of total factor productivity growth in manufacturing across metropolitan statistical areas on employment, earnings and house prices (rents). They find that both employment and earnings increase substantially in the long term as a consequence of Total Factor Productivity (TFP) growth. Earnings increase by a substantial 1.45% over 20 years for a 1% in TFP (over the first 10 years). The increase of purchasing power is lower.

[1] We remind that the data refers to Great Britain only rather than the whole UK, and excludes Northern Ireland, due to data availability.

The other estimate that we found is from Italian regions (larger than local labour markets), where Martini and Giannini (2020) find a lower elasticity of 0.28 between productivity and nominal wages, when considering regional changes and spillovers from other regions using a co-integration analysis.

In sum, although the empirical literature shows some heterogeneity in the wage-productivity elasticity across different levels of analysis and countries, a stylised fact emerging from it is that this is overall quite low.

4. Econometric analysis

4.1. Empirical strategy: Key aims and findings

Against the descriptive evidence of the weak link between LP and wages across TTWAs, where the two London TTWAs are exceptions (albeit in opposite directions), in this report we estimate the causal effect of changes in LP on wages, in GB and London, comparing within-firms' effects and between firms at the level of a local labour market (TTWA). We first study this relationship at firm level. We estimate the impact of yearly firm level productivity changes on their real average wage. This provides evidence on the extent to which firms share the rents produced by a productivity increase with their workers (through wages). Next, we estimate the impact of a 5- and (alternatively) 10-year productivity change in a TTWA on the 5- and 10-year change in nominal wages in the same TTWA. This provides evidence of productivity increases improving workers' payments across the local labour market, irrespective of which firms/sectors may generate them.

The empirical strategy employed here is based on a demanding data matching procedure that ensures representativeness of the main variables at the TTWA level, and on a sample of employees matched with their employers, representative at the national level. Similar exercises at the firm level, using matched employer-employee data, are now established, and evidence already exists for the UK (Ciarli et al., 2018c). Here, our methodological and empirical contribution consists in providing estimates over a longer time period starting well before the recession, in 2004, a more accurate measure of capital investment, and a comparison with what happens across local labour markets.

Earlier work estimating the impact of LP on wages in local labour markets in the US relies on the census of firms and workers (Hornbeck and Moretti, 2019). To our knowledge, for the UK there is no firm level data that allows the estimation of a statistically representative value for labour productivity for local labour markets (TTWAs). To address this data limitation, we use recently produced ONS estimates of value added for NUTS2 and NUTS3 regions. We transform those estimates at TTWA level by using the geographical intersections between NUTS regions and TTWAs, and using employment of firms located in these areas as weights. This allows us to compare the wage-productivity nexus at the firm and local labour market level.

To obtain robust causal estimates of the effect of LP on wages, the empirical analysis employs instrumentation strategies (IV) appropriate to both the chosen level of analysis: a shift-share IV strategy for the TTWA level analysis (Bartik, 1991); and a Total Factor Productivity (TFP) IV strategy (Carlsson et al., 2016) based on the Levinsohn-Petrin (2003) estimation routine for

the firm-level analysis. At firm level, we use a conservative estimation strategy, controlling for matched employer-employee fixed effects and year fixed effects.

We find that, at the firm level, as expected from the literature on countries with similar labour market institutions, the sharing of labour productivity gains with the workers (rent-sharing) is overall small, with an estimated elasticity of 0.006. On average, this implies that an increase in a firm's LP by 10% translates into a 0.06% increase in the average individual wage. At the firm level, the evidence does not confirm a "London effect": although the wage elasticity to labour productivity is almost the double in the London TTWA with respect to the rest of GB, the difference is not statistically significant. Also, in Heathrow and Slough, despite the descriptive picture on the potential negative relationship between LP and wage changes in the TTWA, the causal relationship is not statistically different from the rest of GB at the firm level.

When considering sectoral specificities, the productivity-wage sharing in London (not in Slough and Heathrow) is positive only in financial services and professional activities, and negative in manufacturing. This confirms that a London idiosyncrasy occurs for financial services, that shows a higher impact of labour productivity on wages relative to the rest of GB, and for manufacturing, that shows a lower impact of labour productivity on wages relative to the rest of GB (where rent sharing is not statistically significant).

How does this translate at the level of the labour market, where productive firms may attract other productive firms, create new well-paid jobs, and attract more skilled labour?

At the TTWA level, the magnitude of the elasticity of *average* wages to productivity changes is substantially larger than at firm level, but is weakly statistically significant, meaning that it occurs in some TTWAs and over certain periods only, but it is not a particularly strong pattern (as shown in Figure 5). A £1 larger increase in labour productivity over the 2004-2014 period results in an £0.26 increase in average wages. The magnitude of the elasticity of *median* wages to productivity changes is very similar to that for average wages (as discussed in relation to Figure 5), but the relationship is statistically stronger and more robust. This is an important result, because it suggests that, although wages are weakly related to LP, the latter does increase wage inequality.

At the TTWA level, we do not find that LP has a stronger (weaker) impact on average (median) wages in London than in the rest of GB (as the descriptive evidence above may suggest). We do find, however, that in Slough and Heathrow, LP has almost no impact on the change in average wage, and a smaller impact on the change in the median compared to the rest of GB (albeit larger than on the average wage). The TTWA level effects for London, however, need to be interpreted with caution as, due to the data structure, they are based on one single observation per TTWA.

In the next sections, we detail the analysis of the impact of labour productivity on wages within firms and beyond firms, in the local labour market (TTWA). In the remainder of this section, we describe the data and the empirical strategy employed at both levels, in turn. The empirical and methodological contribution is in the estimation of statistically representative labour productivity at the TTWA level, which allows the estimation of benefits of productivity increases for labour markets.

4.2. Firm-level Analysis

We perform a micro-econometric analysis to estimate the effect of productivity at the firm level on wages at the individual level between 2004-2014. This analysis will inform whether productivity gains in a certain firm are shared with the employees working in that firm (i.e., rent sharing).

We estimate the following equation:

$$\ln(real\_w)_{ifsat} = a + \beta_1 \ln(LP)_{fsat} + \beta_2 \ln(LP)_{st} + \beta_3 \ln(LP)_{at} + \beta_4 tenure_{ifsat} + \beta_5 ft_{ifsat} + \beta_6 age_{ifsat} + \gamma_{if} + \delta_t + \varepsilon_{it} \quad (1)$$

where:

- $\ln(real\_w)_{ifsat}$ is the (log) real hourly wage earned by worker *i*, in firm *f*, which operates in industry *s* (SIC 2007 2 digit), in TTWA *a*, in year *t*;
- $\ln (LP)_{fsat}$ denotes the (log) real labour productivity of firm f;
- $\ln (LP)_{st}$ denotes the (log) mean labour productivity in industry *s*;
- $\ln (LP)_{at}$ denotes the (log) mean labour productivity in TTWA *a*;
- we include sector- and TTWA-level productivity, to distinguish whether the changes in wages are due to productivity gains in the specific firm (rent sharing), or if they are common to the whole industry (e.g., because of improved trade conditions or because of tight labour markets), or local labour market (e.g., because workers benefit from an increase in wealth generated by firms in different industries);
- $tenure_{ifsat}$, ft_{ifsat} and age_{ifsat} denotes individual level variables for the tenure of the worker, full-time job status, and the age;
- γ_{if} are a set of worker-firm fixed effects, that is each match between a worker and a firm, to control for specific features of these matches that do not vary through time, such as sorting;
- δ_t are a set of year fixed effect;
- ε_{it} is the residual.

The mean industry and TTWA LP variables are constructed as weighted averages of firm level LP, with the share of a firm's employment in an industry or TTWA used as weights.[2]

To account for the peculiarity of the London labour market, and its size in relation to the rest of the UK, we also explored the hypothesis that the impact of productivity on wages could differ in London, relative to the rest of GB. For this, we introduced an interaction term with an identifier for the London TTWAs[3]:

$$\ln(real\_w)_{ifsat} = a + \beta_1 \ln(LP)_{fsat} + \beta_{11} \ln(LP)_{fsat} * London_a + London_a + \beta_2 \ln(LP)_{st} + \beta_3 \ln(LP)_{at} + \beta_4 tenure_{ifsat} + \beta_5 ft_{ifsat} + \beta_6 age_{ifsat} + \gamma_{if} + \delta_t + \varepsilon_{it} \quad (2)$$

[2] The employment shares used as weights have been constructed with data from the Business Structure Database (BSD).
[3] We add separate dummies for the London TTWA and the Heathrow and Slough TTWA.

Instrumental variable approach

The relationship between LP and wages could suffer from various sources of endogeneity. This might be due to unobservable factors affecting both wages and LP, or to reverse causality that might occur in the case of an increase in wages (for instance due to a rise in the minimum wage) that pushes firms to increase their productivity (Rizov et al., 2016). To reduce the likelihood that the estimation results are biased by any of these forms of endogeneity, we also estimated Two Stage Least Squares (2SLS) models. This implied constructing an instrumental variable for LP changes at the firm level, which can account for LP, but is not influenced by wages.

As an instrument for firms' labour productivity, we estimate firms' technical productivity (total factor productivity - TFP), exploiting the Levinsohn-Petrin (Levinsohn and Petrin, 2003; Petrin and Levinsohn, 2004) estimation routine (Carlsson et al., 2016). The idea behind this strategy is that capital investment is more lumpy (Doms and Dunne, 1998) than labour hiring, and is therefore less likely to be influenced, at least in the short term, by changes in the minimum wage. The estimation of TFP is performed with data on firms' value added, employment, capital stocks and intermediate inputs.[4] The estimation is performed by 2-digit SIC 2007 industries. Importantly, the estimation of firms' TFP necessitates information on their capital stock, which need to be constructed by exploiting data of firms' investments, which we aggregated with the perpetual inventory method (PIM) (Dey-Chowdhury, 2008).

We exploited the estimated firm TFP also to construct IV variables for the industry level and TTWA level LP variables. These latter have been constructed as weighted averages of firm level TFP, with a firms' employment share in an industry or TTWA used as weights.

Data

We exploited data on hourly wages from the Annual Survey of Hours and Earning,[5] from which we constructed the employee's hourly wage as the ratio of (basic) pay over (basic) hours worked. Data on firms' labour productivity are obtained from the Annual Responded Database X (ARDx) survey.[6] Both the wages and the labour productivity are in real terms and have been deflated by use of, respectively, the Consumer Price Index (CPI) and the producer price index (PPI). The unit of measurement of wages is pounds sterling per hour worked, and the unit for labour productivity is thousands of pounds sterling per worker. The final sample of analysis includes 69,014 workers employed in 10,205 firms.

4.3. Travel-To-Work-Area Level of Analysis

We assess how changes in labour productivity in a given area result in changes in nominal wages, and whether the labour productivity-wages relationship differs in London, relative to the rest of the UK. This analysis informs on whether average productivity changes in an area

[4] All data are available in the ARDx survey. All monetary variables have been deflated with the available price indexes, to obtain variables in real terms.

[5] Office for National Statistics (2020). Annual Survey of Hours and Earning, 1997-2020: secure Access. [data collection]. 17th edition. UK Data Service. SN: 6689. http://doi.org/10.5255/UKDA-SN-6689-16

[6] Office for National Statistics. Virtual Microdata Laboratory (VML), University of the West of England, Bristol. (2017). *Annual Respondents Database X, 1998-2015: Secure Access.* [data collection]. *4th Edition.* Office for National Statistics, [original data producer(s)]. UK Data Service. SN: 7989, http://doi.org/10.5255/UKDA-SN-7989-4

(not linked to a particular firm or sector) translate into an increase in wages for all workers in the same area (not in a particular form or sector).

The lowest level of geographical disaggregation allowing the meaningful exploration of the effect of productivity on wages, is the Travel-to-Work-Area (TTWA). A lower than TTWA level of disaggregation, for instance at the local authority district (NUTS3) level, would not allow us to correctly capture local-area effects, due to the impact of commuting of workers across the various NUTS3 areas. For London, in particular, there would be several NUTS3 areas over which people move when going to work, such that it would not be possible to attribute changes in wages to changes in productivity that occurred in a certain NUTS3 area.

A higher than TTWA level of disaggregation would not allow us to capture the specificities of local effects: changes in wages at NUTS1 level result from what happens in several, different, labour markets.

The TTWA has been designed such that "of the resident economically active, at least 75% actually work in the area, and also, of everyone working in the area, at least 75% actually live in the area" (ONS, 2016). For these reasons we decided to focus on the TTWA as our preferred level for the local-area analysis.

OLS estimation and main variables

To study the relationship between changes in productivity and wages, we estimate the following equation:

$$\Delta y_{it} = a + \beta \Delta LP_{it} + \gamma_t + \varepsilon_{it} \qquad (3)$$

where Δy_{it} denotes the change in mean nominal wages in TTWA *i* in period *t* relative to period *t-1*; ΔLP_{it} denotes the change in labour productivity in TTWA *i* in period *t* relative to period *t-1*; γ_t are a set of time dummies; ε_{it} is the residual. The coefficient $\beta$is a measure of how much an increase in labour productivity, in an average TTWA between *t* and *t-1*, results in increases of wages in the same time frame.

To explore the differential effect of productivity on wages in London, we interact the LP variable with an identifier for the London TTWAs:

$$\Delta y_{it} = a + \beta \Delta LP_{it} * London_i + \gamma_t + \varepsilon_{it} \qquad (4)$$

Where $London_i$ can be either 0 or 1.[7] Due to data availability, we perform the analysis over the 2004-2014 period and for Great Britain (i.e., excluding Northern Ireland TTWAs). More in detail, we study the impact of a change in labour productivity between 2004 and 2014 (10-year period) over a change in nominal wages over the same 10 years. In addition to the 10-year period, we also analyse shorter term (stacked) changes over 5-year periods, before/during and after the financial crisis.[8]

[7] Similar to the firm-level analysis, we add separate dummies for the London TTWA and the Heathrow and Slough TTWA.

[8] The time dummies can only be used in the models exploiting 5-year changes, where we have two observations for each TTWA.

Measurement of wages and labour productivity at TTWA level

The focus on the TTWA poses some measurement challenges, when using the micro data available in the UK Office of National Statistics (ONS). This is because the firm level data available to compute labour productivity (i.e., that include a measure of value added) are representative at the sectoral and national level, but not at TTWA level. In addition, we were not able to find data that allow us to measure real wage (TTWA deflators).

To measure TTWA wages, we aggregated wages at the TTWA-year level starting from individual level wage information available in the ASHE survey.[9] We constructed hourly wages by taking the ratio of pay over hours worked, and computed both the mean and the median wage in each TTWA and year. We explore the effect of labour productivity changes on both the average and the median wage. A positive relationship between productivity and average wages does not allow us to distinguish whether it is top or bottom wages that are increasing. A positive relationship between productivity and median wages, instead, suggests that the wage of the worker in the middle of the wage distribution increases with labour productivity, i.e., not only the top wages.

To measure labour productivity (LP) we used the recently produced data from the *ONS Regional and Sub-regional productivity tables* available for NUTS1-3 levels. From these we extracted the tables on "Nominal GVA per hours worked without rental income": we believe the latter to be the correct productivity measure to exploit in our context, because it allowed us to exclude the disproportionately higher rental incomes earned in London.[10]

NUTS geographical units are defined over administrative boundaries; these differ from labour markets as discussed above. One of the novel contributions of this work is how we tackled this issue: we exploited the productivity tables at the lowest level of aggregation, NUTS3, and then converted the NUTS3 productivity data to obtain labour productivity data at TTWA level.

We performed the NUTS3-TTWA conversion of the productivity measures in two different ways. Both methods rely on the calculation of weights that allow us to distribute to the TTWA(s) the productivity of the NUTS3 that fall within the TTWA area(s). To compute such weights, therefore, we needed data on a measure of economic activity that could be accurately mapped to all TTWAs, all the NUTS3 areas, and all the areas of partial intersection of the TTWAs with the NUTS3 areas. For the first method, we constructed employment-based weights, for the second we constructed population-based weights. Conceptually, therefore, the two methods are similar; in practice, they require very different data for the calculation of the weights.[11]

The employment-based weights method exploits detailed data on the local-units (i.e., plants) belonging to enterprises based in the UK, available in the Business Structure Database (BSD). The BSD provides data on virtually all UK businesses, their level of employment, sector of activity, and their location at both the TTWA and the NUTS levels. We began by collecting information on the TTWA and NUTS3 of all the local units in a certain year. We selected the 2015 data from the BSD, because for 2015 the BSD provides 5-digit NUTS3 codes. Then, we

[9] Office for National Statistics (2020). Annual Survey of Hours and Earning, 1997-2020: secure Access. [data collection]. 17th edition. UK Data Service. SN: 6689. http://doi.org/10.5255/UKDA-SN-6689-16

[10] For robustness, we also experiment with the GVA per hours worked that includes rental income.

[11] We explain both methods in this section, but we only show results obtained with employment weights, due to the close similarity of the findings.

made sure that the TTWA definition was compatible across the data sources.[12] Next, we converted the NUTS3 classification in the ONS productivity tables to that in the 2015 BSD data[13]. Finally, we computed the employment weights $\sigma_{j,TTWA,NUTS3}$ as the ratio of the employment of local-units in sector *j* located in the intersection of a TTWA and NUTS3 area, over the employment of local-units in sector *j* located in the TTWA. These weights were then used to convert the NUTS3 level to the TTWA level labour productivity[14] as follows[15]:

$$LP_{TTWA,t} = \sum_{j,NUTS3} \sigma_{j,TTWA,NUTS3} * LP_{j,NUTS3,t} \quad (5)$$

To get a better sense of how this conversion works, consider, for example, a TTWA that cuts across three different NUTS3 areas. In the simplest case, the employment in each of these NUTS3 areas, within the TTWA, is one third of the total TTWA employment. In this simplified example, the labour productivity of the TTWA is constructed by adding the labour productivity of each of the NUTS3 areas divided by three. However, it might be the case that each NUTS3 cuts across several TTWAs, so that its level of labour productivity is used several times, in each of the TTWAs in which it is present, weighted by the employment of firms in the intersection between the NUTS3 and that TTWA.

The population-based weights, which we used as an alternative to the employment-based weights, are constructed as follows. We first created a map tracing the intersections between NUTS3 and TTWAs. For each TTWA we identified which NUTS3 areas compose it, in parts or in full (where in full means that a NUTS3 is entirely included in a TTWA, while in part means that a NUTS3 pertains to more than one TTWA). This allowed us to construct the population-based weights as the proportion of a NUTS3 population lives in a TTWA. The population data were obtained from "*The spatial distribution of population in 2002, United Kingdom of Great Britain & Northern Ireland*", extracted from WorldPop[16], and arranged in ArcGIS to provide a count of the population living in each TTWA, and each intersection of

[12] We converted the TTWA definition from the 2001 version (in the 2015 BSD data) to the 2011 version (in the ASHE data), by use of lower-layer super-output areas (LSOA) boundaries that can be mapped directly to the TTWAs. The 2001 LSOAs are available across different years of the BSD. We extracted the mapping of 2001 LSOAs to 2011 TTWAs from the 2016 BSD data, and merged this to the 2015 BSD data (using LSOAs as a matching variable) thereby bringing the 2011 TTWAs definition in the 2015 BSD data.

[13] The ONS productivity tables report data at the 2018 version of the NUTS3 areas, while the 2015 BSD data contains the 2012 version of the NUTS3 areas. As the 2012 NUTS3 are more aggregated that the 2018 NUTS3, with each of the former mapping exactly to the one or more of the latter (for England, Wales, and Scotland), we aggregated the ONS data at the level of the 2012 NUTS3 areas.

[14] We carefully evaluated the possibility of constructing the TTWA-level productivity measure with alternative data. The ONS Annual Respondents Database X (ARDx) allows to compute a firm level labour productivity measure but, due to the sampling frame of the ARDx, the aggregation of this measure would not be correct because the data are not representative at the TTWA level. The ONS Business Structure Database (BSD) includes data for the population of UK firms, satisfying the representativeness criterion, but does not allow the computation of a correct labour productivity measure, lacking data on the use of intermediate inputs.

[15] We constructed the employment-based weights with a sectoral dimension, to be able to convert labour productivity figures both at the TTWA level and the TTWA-sector level. The former was our main dependent variable, the latter would be exploited in our instrumentation strategy.

[16] www.worldpop.org - School of Geography and Environmental Science, University of Southampton; Department of Geography and Geosciences, University of Louisville; Departement de Geographie, Université de Namur) and Center for International Earth Science Information Network (CIESIN), Columbia University (2018). Global High Resolution Population Denominators Project - Funded by The Bill and Melinda Gates Foundation (OPP1134076). https://dx.doi.org/10.5258/SOTON/WP00645

NUTS3 with TTWA areas. The share of the population in the intersection as a total of a TTWA area is the weight $\rho_{TTWA,NUTS3}$.

We used both the employment and the population-based weights to construct alternative measures of labour productivity, and used both in estimation. The empirical results were found to be very similar, and we decided to only show the results based on the employment weights in this report.[17]

Instrumental variable estimation

Similar to the firm level analysis, for the TTWA level analysis we also exploited an instrumental variable (IV) approach to reduce endogeneity concerns due to possible reverse causality between labour productivity and wages.

The IV strategy at the firm level differs from the IV strategy at the TTWA level. We followed a relatively standard approach in the literature and instrumented the LP with a shift-share instrumental variable (IV): the shift-share IV exploits the nationwide change in LP at the industry level. This latter is then distributed to the TTWA level by using the initial period (2002 data) industry composition of TTWAs, i.e., the gross-value added (GVA) share of each industry in each TTWA.[18] This instrumentation strategy implies that TTWA changes in LP are going to be explained by nationwide changes in LP that are not due to TTWA level shocks that could be correlated with TTWA level wages. The exogeneity of the IV variable rests on the assumption that the GVA shares computed with data at the beginning of the observation period are exogenous to the outcome variable (the wage changes).

To implement this instrumentation strategy, we proceeded as follows. For each year in the data, we first computed the nationwide industry LP that would be used to predict LP changes at the local level. To further support the exogeneity of the shift-share IV, we constructed the nationwide industry-year LP separately for each TTWA, by aggregating the TTWA-industry-year to industry-year LP and excluding each time the TTWA of interest. In other words, we only used aggregate variation in LP that is also external to the relevant TTWA.

We then computed the change in the nationwide industry-year LP over, alternatively, 10- and 5-year changes: i.e., for 10-year changes:

$$\Delta LP_{-i,j} = LP_{-i,j,2014} - LP_{-i,j,2004} \quad (6)$$

where j denotes SIC2007 2-digit industries, *i* denotes TTWA and *t* denotes the year. The subscript -*i* indicates that the LP changes are TTWA specific, as we excluded the relevant TTWA when aggregating the LP to the national level.

Next, we constructed the share of GVA of each 2-digit industry in each TTWA w_{ij}, using 2002 data.[19] Finally, we constructed the instrument z_i for each TTWA as the weighted sum of a sector's j LP changes, where the weights correspond to the GVA shares.

[17] The results with the population weights are available upon request from the authors.
[18] This shift-share instrumentation strategy was originally developed by Bartik (1991) and Blanchard and Katz (1992).
[19] We can exploit 2002 data for the GVA shares as the ONS LP tables span from 2002 to 2014.

$$z_i = \sum_j w_{ij}\, \Delta LP_{-i,j} \quad (7)$$

Aggregation across the various industries in a TTWA converts the nationwide LP to the TTWA level.

The calculation of this IV necessitates data on LP by industry and TTWA. We constructed the latter by extracting GVA data from the *ONS Regional gross-value added reference tables*; these provide GVA at the SIC-2007 2-digit industry and NUTS3 level,[20] and employment data from the BSD at the industry-TTWA level. We finally obtained the relevant LP measure as the ratio of GVA over employment.

Finally, we used data on all the TTWAs in Great Britain, except for Newton Steward, for which we did not have data on our instrumental variable.

The results of the estimations are provided in the next section.

5. The impact of productivity gains on wages across firms and local labour markets

5.1. Within firm wages

In this section we present results of the estimation of firm labour productivity level on the hourly wage of its employees: the extent to which firms share an increase in the output per worker with their workers. Because workers in a company may also benefit from productivity increases in other firms in the same industry (LP_SIC) or local labour market (LP_TTWA), we also include changes at these two levels. These results also allow the comparison of how local gains are shared across firms, if at all. Table 1 presents the results for all sectors, and for the whole country (introducing an interaction dummy for firms located in the London TTWAs (London, and Slough and Heathrow (S&H))). We present only results from 2SLS estimations here. OLS results (and their comparison with the 2SLS) are discussed in the Appendix.

In Table 1, we find that, on aggregate, higher LP at the firm level leads to higher (average) wages of their workers (col. 1-4). This result is robust to controlling for the industry and TTWA mean LP. These controls, though, are not significant, suggesting that wages do not change in relation to changes in other firms in the same industry or TTWA. Results then seem to confirm that wage differences are mainly linked to differences in firm productivity (Card et al., 2018; Song et al., 2019). The effect at firm level, however, is economically small, with an estimated elasticity of at most 0.006, i.e., on average, an increase in firm's LP by 10% translates into a 0.06% increase in individual wages.

At firm level we do not find a different productivity-wage relationship in London, nor in the London TTWA (col. 2), or for the S&H TTWA (col. 3), relative to the rest of GB. When we include them together we find a premium for firms in London, suggesting an increase in wage by approximately 0.1% for a 10% increase in firm productivity. However, this is significant

[20] The GVA data at the NUTS3 level were converted to the TTWA level by use of the same population weights described above.

only at the 15% level, and contradicts the negative coefficient in col. 2 (when a dummy only for London firms is introduced). Taken together, results suggest that the relationship between firm productivity and wages does not differ substantially between London and the rest of GB (and is positive in London as well as in the UK). In other words, we do not find a London premium between 2004-2014: the average worker in London TTWAs does not benefit from productivity increases more than workers in other parts of GB.

Table 1: Impact of firm-level productivity on workers' wages, aggregate sample

	(1)	(2)	(3)	(4)
Dep var.	Ln(hourly wage)			
Estimator	2SLS	2SLS	2SLS	2SLS
Sample	All			
Ln(LP)	0.00630**	0.00534**	0.00560***	0.00448**
	(0.00261)	(0.00257)	(0.00210)	(0.00193)
Ln(LP_SIC)	-0.00136	-0.00121	-0.00256	-0.00242
	(0.0106)	(0.0105)	(0.00993)	(0.00984)
Ln(LP_TTWA)	0.00216	0.00202	0.00203	0.00189
	(0.00832)	(0.00820)	(0.00827)	(0.00816)
London		0.00586		-0.00973
		(0.00470)		(0.0169)
Ln(LP)*London		-0.00466		0.00679#
		(0.0170)		(0.00464)
Heath. & Slough			-0.100	-0.0980
			(0.0903)	(0.0894)
Ln(LP)* Heath. & Slough			0.0216	0.0220
			(0.0217)	(0.0213)
Worker-Firm FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
N	283588	283588	283588	283588

Note: all estimated models include controls for the workers' tenure, age, and full-time status. Standard errors clustered at the 2-digit SIC 2007 industry level in parentheses: # p<0.15, * p<0.10, ** p<0.05, *** p<0.01.

In Table 2 we further explore whether the positive effect of firm productivity on wages differs if the econometric equations are estimated separately on the subsamples of firms located in London and those located in the rest of GB. While the exercise is analogous to exploiting the interaction term, as done in Table 1 (cols. 2-4), results in Table 2 provide a more precise estimation of the impact of firm productivity gains within London.

The 2SLS results confirm the existence of a positive and causal effect of productivity on wages in the rest of GB and London, but not in S&H. The estimated elasticity for London is about twice as large as that for the rest of the UK, with a 10% increase in labour productivity leading

to a 0.1% increase in wages in London. Recall, however, that the *difference* between the effect for the rest of GB and London is not statistically significant, as shown in Table 1.

Table 2: impact of firm-level productivity on workers' wages

Rest of GB and London subsamples

	(1)	(2)	(4)
Dep var.	Ln(hourly wage)	Ln(hourly wage)	Ln(hourly wage)
Estimator	2SLS	2SLS	2SLS
Sample	Rest of GB	London	Heathrow & Slough
Ln(LP)	0.00434**	0.00984**	-0.00531
	(0.00194)	(0.00406)	(0.0218)
Ln(LP_SIC)	0.00233	-0.0238#	0.00211
	(0.0101)	(0.0153)	(0.0189)
Ln(LP_TTWA)	0.000679	0.00805	-0.0373
	(0.00733)	(0.0200)	(0.0338)
Worker-Firm FE	Y	Y	Y
Year FE	Y	Y	Y
N	230702	38085	10831

Note: all estimated models include controls for the workers tenure, age, and full-time status. Standard errors clustered at the 2-digit SIC 2007 industry level in parentheses: # p<0.15, * p<0.10, ** p<0.05, *** p<0.01.

Because productivity, labour relationships and compensation change substantially across types of activities, Table 3 presents the results obtained from estimating the same relationship presented in Table 1, separately on 10 macro-sectoral groups.[21]

We find that results differ substantially across sectors for the entire country, London TTWAs, and for the difference between the two. We provide here a summary of those results.

First, in most sectors we do not observe the average small positive impact of labour productivity on firm wages. We find a positive and statistically significant impact of LP on wages only in the professional services activities sector, with a magnitude about three times as large as that of the aggregate sample. Professional services seem to drive the aggregate positive estimation of rent sharing discussed above. In construction, and to some extent in other services, an increase in productivity in the average firm in the industry has a positive impact on wages in all other firms in that sector, except in the trade sector. However, in the hospitality sector, the positive impact comes from the average firm in the TTWA, which drives wages upwards in all sectors.

[21] Manufacturing, SIC-2007 codes: 10 to 33; Construction, SIC-2007 codes: 41, 42, 43; Wholesale and retail trade, SIC-2007 codes: 45, 46, 47; Transport, SIC-2007 codes: 49, 50, 51, 52, 53; Hotel and restaurants, SIC 2007 codes: 55, 56; Information and communication, SIC 2007 codes: 58, 59, 60, 61, 62, 63; Financial services, SIC 2007 codes: 64, 65, 66; Professional activities, SIC 2007 codes: 68, 69, 70, 71, 72, 73, 74; Business services, SIC 2007 codes: 77, 78, 79, 80, 81, 82; Other services, SIC 2007 codes: 90, 91, 92, 93, 94, 95, 96.

Table 3: Impact of firm-level productivity on workers' wages, by macro-sectors

	(1)	(2)	(3)	(4)	(5)	(6)
Estimator	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS
Sample	Manufacturing		Construction		Wholesale and retail trade	
Ln(LP)	0.0102	0.0121	0.00162	0.00168	0.0000511	-0.000528
	(0.0111)	(0.0121)	(0.00476)	(0.00344)	(0.00225)	(0.00264)
Ln(LP_SIC)	0.0379	0.0391	**0.0308***	**0.0295#**	-0.00756	-0.00765
	(0.0712)	(0.0733)	**(0.0101)**	**(0.0106)**	(0.00520)	(0.00529)
Ln(LP_TTWA)	0.00672	0.00683	0.000601	0.00104	**-0.00495#**	**-0.00482#**
	(0.0131)	(0.0128)	(0.0262)	(0.0251)	**(0.00207)**	**(0.00207)**
London		0.176*		0.0204		**0.0366#**
		(0.101)		(0.0358)		**(0.0136)**
Ln(LP)*London		**-0.0351***		-0.000731		-0.00728
		(0.0194)		(0.0104)		(0.00443)
Heath. & Slough		0.198		**-0.106****		-0.102
		(0.214)		**(0.0211)**		(0.0950)
Ln(LP)*Heath. & Slough		-0.0512		0.00605		0.0337
		(0.0409)		(0.00736)		(0.0318)
Worker-Firm FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
N	46805	46805	9548	9548	93248	93248

Table 3, continued.

	(7)	(8)	(9)	(10)	(11)	(12)
Estimator	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS
Sample	Transport		Hotels and restaurants		Information and communication	
Ln(LP)	0.00724	0.00727	0.00125	0.00113	-0.00443	-0.322
	(0.0223)	(0.0129)	(0.00324)	(0.00436)	(0.125)	(2.870)
Ln(LP_SIC)	0.00291	0.0111	0.00189	0.00221	-0.0511	-0.0359
	(0.0317)	(0.0451)	(0.0102)	(0.00986)	(0.0595)	(0.170)
Ln(LP_TTWA)	-0.0283	-0.0284	**0.00460****	0.00388	-0.213	-0.0225
	(0.0281)	(0.0266)	**(0.000243)**	(0.00145)	(0.824)	(1.466)
London		-0.00606		-0.0808		-6.026
		(0.0562)		(0.0620)		(54.67)
Ln(LP)*London		0.00851		0.0232		1.295
		(0.0145)		(0.0187)		(11.70)
Heath. & Slough		0.0553		0.217		1.347
		(0.259)		(0.350)		(11.68)
Ln(LP)* Heath. & Slough		-0.0211		-0.0706		-0.296
		(0.0608)		(0.111)		(2.523)
Worker-Firm FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
N	38042	38042	12407	12407	25352	25352

Table 3, continued.

	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(30)
Estimator	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS
Sample	Financial services		Professional activities		Business services		Other services	
Ln(LP)	-0.000953	-0.00155	**0.0171****	0.0127	-0.00472	-0.00612	-0.00709	-0.00951
	(0.00339)	(0.00331)	**(0.00532)**	(0.00897)	(0.00908)	(0.00710)	(0.0120)	(0.0167)
Ln(LP_SIC)	0.0125	0.0134	0.00711	0.00621	0.00826	0.00808	**-0.0220#**	**-0.0222#**
	(0.00626)	(0.00647)	(0.00605)	(0.00537)	(0.00944)	(0.00913)	**(0.0123)**	**(0.0122)**
Ln(LP_TTWA)	-0.00357	-0.00438	0.00340	0.00329	-0.0106	-0.0106	0.0188	0.0184
	(0.00615)	(0.00501)	(0.00849)	(0.00836)	(0.00740)	(0.00721)	(0.0124)	(0.0129)
London		-0.0162		-0.00638		-0.0269		-0.0513
		(0.0127)		(0.0508)		(0.0738)		(0.0740)
Ln(LP)*London		**0.00524*****		0.0115		0.00709		0.00694
		(0.000446)		(0.0110)		(0.0226)		(0.0203)
Heath. & Slough		**0.0793****		-0.255		-0.00386		-0.0210
		(0.0169)		(0.328)		(0.143)		(0.0360)
Ln(LP)* Heath. & Slough		**0.00143#**		0.0657		-0.00161		0.00580
		(0.000613)		(0.0767)		(0.0383)		(0.0106)
Worker-Firm FE	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y
N	3362	3362	27367	27367	15740	15740	8906	8906

Note: all estimated models include controls for the workers tenure, age, and full-time status. Standard errors clustered at the 2-digit SIC 2007 industry level in parentheses: # p<0.15, * p<0.10, ** p<0.05, *** p<0.01.

With respect to London, we find some differences in firm behaviour. The London interaction is found to be negative in manufacturing[22] (col. 2) and positive in financial services (col. 14). When compared to the average affect, this result suggests that an increase in LP in manufacturing in London has led to a small reduction in wages. This has to be taken together with the evidence that the level of wages is economically and statistically significantly higher in London, as suggested by the London dummy term in col. 2, and may be suggestive of a smaller reduction in wages during the recession following the 2007 financial crisis. In other words, in manufacturing, in London, an increase in productivity resulted in lower increases in wages, although (or because) on average all wages in London manufacturing are higher than the rest of the UK. Instead, in financial services firms in London share a small part of the productivity increases with employees' wages, unlike what is observed in the rest of the UK.

[22] Notice that the manufacturing sector is also the one for which the computation of productivity is most reliable, from an accounting perspective.

Real wages are not higher than in the rest of the country, but productivity increases are rewarded with higher increases in wages, on average.

In S&H, however, we do not find a difference in firm behaviour in relation to rent sharing. It should be noted, though, that when we introduce the London TTWAs dummies, the positive impact of LP on wages disappears.

5.2. Local Labour Market Wages

The results discussed in Section 5.1 suggest that there is evidence of small within firm rent-sharing. In this section we discuss results estimating changes in the average wage, across all firms, as a function of TTWA productivity growth, over a longer period of time. As discussed in the introduction, in the aggregate, we expect to observe a positive relationship between productivity and the compensation of labour, as an increase in productivity may attract more productive firms, and more skilled workers.

The tables below present the results from estimating the effect of 10- or 5-year productivity changes at the TTWA level on 10- or 5-year wage changes in the same TTWA. This analysis will inform whether productivity gains in a certain local labour market were shared with the employees working in that local area, independently from the firm/sector that is responsible for the productivity gains. We present four sets of results, based on 10- and 5-year changes in productivity on both average and median wages.

Table 4 presents the estimation results for 10-year changes. We only present the results of the IV estimations in this section (for a comparison between the non-instrumented (OLS) and instrumented (2SLS) equations we refer the reader to the Appendix).

On aggregate, across GB, in columns 1-4 we show that a larger increase in productivity at the TTWA level leads to a larger increase in the mean wage at the TTWA level, but with this result being only weakly statistically significant (far below the conventional levels). The magnitude of the coefficient suggests that, on average, a £1 larger increase in LP over the 10-year period results in an £0.26 larger increase in mean wages.

The relationship between LP and average wages in London is the same as in the rest of GB (cols 2 and 4), whereas in S&H TTWA the relationship is substantially weaker: a £1 larger increase in LP over the 10-year period in S&H results in an £0.04 larger increase in mean wages (cols 2 and 4).[23] Note also the lack of significance for the LP coefficient in column 4 when introducing interaction terms for both London and S&H: this may suggest that the aggregate effect estimated in column 1 is particular to some outlier TTWAs (see also Figure 5).

Results are similar, but more robust across TTWAs, when we consider the relationship with the median wage (cols 5-8). The 2SLS coefficients are very similar in magnitude, and more statistically significant. This result suggests a positive story, partially contradicting the widespread evidence of an overall increase in inequality in the UK: that productivity gains are more regularly translating into wage increases for workers with lower than average wages (as the median wage is lower than the mean wage).

[23] Results on the London differential relationship should be taken cautiously when using the 10-year change, because they are based on one single observation (TTWA).

As for the average wage, results do not differ for the London TTWA with respect to the rest of GB (cols 6 and 8), but the gains are significantly smaller in the S&H TTWA. On a positive note, in S&H median wages increase more than average wages in response to a 10 year increase in LP (cols 7-8). A £1 larger increase in LP over the 10-year period in S&H results in an £0.17 larger increase in mean wages.

Table 4: The effect of productivity on wages at the TTWA area level, 10-year changes

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Mean wage				**Median wage**			
Dep var	Δ10 Hourly wage				Δ10 Hourly wage			
Estimator	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS
Δ10LP	0.260##	0.231	0.270##	0.243	0.260*	0.283##	0.265*	0.289##
	(0.176)	(0.204)	(0.178)	(0.207)	(0.156)	(0.189)	(0.158)	(0.192)
Δ10LP * London		0.0594		0.0548		-0.0466		-0.0489
		(0.0657)		(0.0668)		(0.0615)		(0.0629)
Δ10LP * Heath. & Slough			-0.208***	-0.202***			-0.0992***	-0.104***
			(0.0657)	(0.0441)			(0.0345)	(0.0419)
N	217	217	217	217	217	217	217	217

Note: Labour productivity is measured as nominal GVA per hours worked, excluding rental income. Robust standard errors clustered at the TTWA level in parentheses. # p<0.20, ## p<0.15, * p<0.10, ** p<0.05, *** p<0.01

Table 5 presents the results from exploiting stacked changes over two 5-year periods (2004-2009 and 2009-2014), implying a doubling of the number of observations that can be used in analysis (two for each TTWA). Importantly, in the 5-year changes equations we can also include controls for the time period (a period FE), capturing any shock common to all the TTWAs in the 5-year spans.

Results differ slightly between equations using the mean and the median wage as dependent variables, but do not differ from those discussed above in relation to the 10-year period. We find a positive effect of productivity on both the mean and the median wage. However, the aggregate productivity-wages relationship remains weakly insignificant for the mean wage (cols 1-4), while it becomes more statistically significant for the median wage (cols 5-8). This latter result suggests a causal effect of productivity changes on median wage changes, but not on the average wage.

The results with respect to the London TTWAs are almost the same as those discussed above: no different for the London TTWA in relation to the rest of GB (same gain in average (not robust) and median wages (more robust)), and smaller impact in S&H with respect to the rest of the UK. However, a word of caution is again necessary when inspecting the coefficients estimated for London TTWAs. Although when using 5-year changes we can instrument the *Δ5 (LP) * London* interaction with its IV variable, due to the data structure, instrumentation produces a (very) large first-stage F-statistic and does not allow the estimation of the non-interacted London dummy (because of collinearity with the IV variable).

Table 5: The effect of productivity on wages at the TTWA area level, 5-year changes.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Mean wage				**Median wage**			
Dep var	Δ5 Hourly wage				Δ5 Hourly wage			
Estimator	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS
Δ5 (LP)	0.280#	0.252	0.291#	0.267	0.348**	0.384*	0.354**	0.392*
	(0.208)	(0.245)	(0.210)	(0.248)	(0.171)	(0.215)	(0.173)	(0.219)
Δ5 (LP) * London		0.0560		0.0503		-0.0740		-0.0771
		(0.0828)		(0.0840)		(0.0737)		(0.0752)
Δ5LP * Heath. & Slough			-0.243***	-0.239***			-0.123***	-0.130***
			(0.0373)	(0.0438)			(0.0320)	(0.0402)
N	434	434	434	434	434	434	434	434

Standard errors in parentheses
# p<0.20, ## p<0.15, * p<0.10, ** p<0.05, *** p<0.01

6. Summary of the findings

Our findings confirm the extant weak evidence of productivity changes leading to wages changes in the UK. Within firms, there is little evidence of rent sharing, that is, only a very small share (at best 0.006%) of firm productivity gains are transferred to employees in terms of higher wages. This does not exclude that premia may be distributed, e.g., bonuses on top of base wages (we have data on wages only). However, this would make little difference to the average worker. The productivity-wages nexus in the London TTWA (although not in S&H) seems to be only slightly higher: a 10% increase in productivity yields to a 0.1% increase in wages, but such a difference, i.e., compared to the rest of GB, is not statistically significant.

When we distinguish by macro sectors, we confirm a weakly positive productivity-wage link only in professional services across GB. In the London TTWA, the evidence seems to reflect the peculiarity of its industrial composition. First, productivity growth is negatively related to wages growth in manufacturing (although wages are substantially higher than in other sectors). This may be due to manufacturing firms deciding not to reduce wages, in a set of industrial activities that have seen productivity dwindling more than in the service industries. Second, productivity leads to increases in wages in financial services, where firms enjoy a comparative advantage and manage to attract more skilled workers. We find no results specific to S&H.

If within-firm productivity gains do not lead to higher wages, do other workers in the same local labour market gain from an average productivity increase across all firms in the area?

Although we find an economically significant positive relationship between productivity and wages across GB TTWAs, the relationship is statistically weak (as one would have inferred from Figure 5). A 100% increase in productivity over five years yields a 35% gain in median wages. This estimate appears to be lower (about 26%) and less precise when we consider a longer 10-year period (most likely because the longer period includes the effect of the crisis, 2009-2014). The good news is that the relationship with median wages is more robust than

with average wages, suggesting that it is not the productivity-wage dynamics that is responsible for increasing inequality, within TTWAs, in GB.

The London TTWA also experiences a positive impact in wages over the 5-year period, but not S&H, where there is almost no gain in wages from productivity growth (see also Figures 3 and 5). Although in London average wages have grown more than median wages (Figure 5), we do not find that this is a result of increases in productivity. This suggests that in London productivity gains tend to benefit all workers, even though wage differences are increasing. Due to the data constraints, the estimation results for London at the TTWA level should be taken with great caution.

In summary, the descriptive evidence and the causal estimates suggests that differences in LP across GB grew substantially between 2004-14, with London TTWAs leading them. At the same time, wage differences across TTWAs have been shrinking, but have been increasing within TTWAs. This implies that changes in LP translate only partially to changes in wages: the link is weaker at the firm than at the TTWA level, where productivity gains are distributed among workers to some extent. The stronger impact of LP on median than average wages, and the opposite catching up dynamics of LP and wages across TTWAs, suggests that LP has not contributed to an increase in wage inequality, within and across TTWAs, through wages. However, the weak relationship between LP and wages suggests that LP might be contributing to income inequality via market concentration and reduced labour and wahe shares (Autor et al., 2020; Song et al., 2019).

7. Conclusions and policy implications

A persistently sluggish productivity growth in GB would threaten a full growth recovery from the previous and present crises that might percolate to wages. However, our findings show that the levels and growth rates of wages are relatively decoupled from productivity changes.

The report offers evidence that balances the narrative around a persistent North-South divide in the UK: the presence of a “London premium” of firm wage elasticity to LP is not supported by our findings, except in the financial services firms.

In the current context of double-dip crisis affecting the UK, relying on such a feeble link is clearly not enough for a solid prospect to get out of the crisis in a sustainable and inclusive manner. In addition, the effects of Brexit and the Covid-19 pandemic might further erode the already weak link between productivity and wages.

The key message of our work is that a sustained productivity growth is a necessary, but no longer a sufficient condition to achieve a broad increase in living standards. We show that wages have been catching up over the time span considered, although productivity has not.

Amidst issues of productivity mismeasurement, productivity stagnation and productivity-wage decoupling, we suggest that it is important to enlarge the policy perspective beyond productivity and centre the narrative around innovation, inclusion and redistribution policies, to make the recovery sustainable and its effects persistent.

A few established policy tools to tackle the productivity-wage decoupling, and the increases in wage and productivity dispersion, are based on institutional factors, such as strengthening bargaining regimes, employment protection legislation, and the role of the minimum wage (see Berlingieri et al., 2017 for a multi-country study). Further evidence is needed to establish how such policies can support increases in productivity while increasing wages and living standards for all workers in London.

Our findings on the specific characteristics of London-based firms and the London TTWAs need also to be interpreted in the light of the contradiction between the 'secular stagnation' (sluggish productivity growth) despite a 'secular innovation' within the new technological paradigm of the fourth industrial revolution, which has great potential for productivity increases not yet realised (Brynjolfsson et al, 2017; Haldane, 2017).

We suggest five broad policy considerations centred around the role of innovation as a potential engine of productivity growth, and the recent push for inclusive innovation and growth policies, especially at level of city councils (Lee, 2019).

Policy recommendation 1:
Focusing on innovation incentives for firms and public investments in Research and Development (R&D) and innovation might be a more effective strategy to increase living standards than focusing on productivity alone, which might also be achieved by cutting labour costs. In parallel, and not less important, tools to support innovation diffusion should be prioritised, to maximise benefits of innovation and reduce asymmetries across local labour markets in both labour productivity and wages.

Innovative firms pay comparatively higher wages, and an innovation rent-sharing mechanism is at work, mostly to non-routinised, highly paid jobs (Ciarli et al., 2018c), but to some extent also to low skilled workers (Aghion et al., 2020). At a regional level, there is evidence that focusing on innovation increases wages of mid-skilled workers (Lee and Clarke, 2019). This does not happen automatically, though, and is linked to the conditions and the industrial structure of the local labour market context (Ciarli et al., 2018a and 2018b, McCann et al., 2021): in contexts with high levels of non-routine jobs, such as London, there is evidence that an increase in innovation activities benefits employment levels and quality (Ciarli et al., 2018a and 2018b).

Policy recommendation 2:
There is no automatic trickle-down effect, but policy at both national and local levels should aim at creating the conditions for it to occur. Supporting London's innovative sectors as identified in the London Industrial Strategy Evidence Base is important for wage trends and job quality. These are digital services, advanced urban services, life sciences, cultural and creative activities and environmental services (GLA, 2020). However, this must be accompanied by policies that increase the inclusion of parts of the population currently excluded from entrepreneurship opportunities, curbs market concentration, and favours redistribution of innovation rents.

Wages benefit from an urban premium, the sectoral composition of local labour markets in high value added activities, and from agglomeration economies (Meliciani and Savona, 2015; Balland et al., 2020). London seems to be in an advantageous position, both in terms of its sectoral specialisation in high skilled sectors such as professional services as well as arts and

creative industries (Siepel et al., 2020), and of urban agglomeration and spatial spillovers (Duranton and Puga, 2020). In the current context of stagnation and potential post-Brexit and post-Covid stagflation these advantages might be eroded, therefore, a concerted vision of both industrial and innovation policies is needed to maintain London's comparative advantages (McCann et al., 2021).

However, our evidence shows that London premia do not necessarily trickle down to workers. There is evidence that only occupational categories in a few sectors benefit from productivity and innovation (Ciarli et al, 2018c; Lee and Clarke, 2019), and that as innovation concentrates more and more in cities and firms, it can contribute to furthering inequality (Autor et al, 2020; Feldman et al, 2021; Song et al, 2019). Our evidence suggests that in local labour markets LP has a similar effect on the median and the average wage. Exclusion is then more a matter of who accesses non-routine job opportunities, and non-wage income. Policymakers need to investigate this further, in order to design innovation policies that not only lead to shared benefits across workers, but also to less concentration, more turnover and more social mobility opportunities for the many that are occupied in marginal (albeit essential) jobs and left behind (Bell et al, 2019 Aghion et al, 2019), particularly in the post-pandemics context (Savona, 2020).

Policy recommendation 3:
Firms need to invest in formal training, skills upgrading and life-long learning to make innovation more inclusive.

Empirical evidence has shown that innovative firms pay higher wages: R&D intensive firms share innovative rents, although favouring particularly high-wage, non-routinised workers (Van Reenen, 1996); software capital-intensive firms also favour wage progression, again particularly at the top end of the wage distribution (Barth et al., 2020). In general, if innovative firms favour wage progression, support to innovation should be accompanied by complementary investments to make routinised jobs and low skilled workers catch up in terms of skills, hence the importance of firm investments in on-the-job training and skill upgrading. Incentives to invest in on-the-job training and soft skills will have to come from job retention policies and firm re-investments of innovation premia that can also be distributed to vulnerable workers (HLG, 2019).

Policy recommendation 4:
Focusing on the principles of Inclusive and Sustainable Growth, the Government must maintain employment schemes that allow workers to benefit from innovation outcomes at firm and local labour market levels while avoiding premature austerity measures that might be counter-cyclical in the aftermath of the pandemic.

The level and quality of employment should be maintained as a priority, in a context that often over-emphasises the role of productivity performance in driving wage gains, in the absence of convincing evidence (Compagnucci et al., 2018).

Policy recommendation 5:
Promoting inclusion that is innovation- and wage-progression friendly is something that policies should pursue. This is also something that would go beyond the hyper-focus on productivity that has recently dominated the policy debate in the UK.

It has been shown that more inclusion is conducive of more innovation, so that a virtuous circle between redistributive policies that favour inclusion and innovation performance might be created (Bell et al., 2019; Ciarli et al., 2021; Saha and Ciarli, 2018). Innovation might in turn increase further inclusion via wage premia and wage progression.

In sum, a comprehensive policy framework to achieve an inclusive post-crises recovery, based on higher living standards for low skilled workers and the occupational categories at the bottom of the wage distribution, or those currently excluded from the job market of innovative activities, should go beyond productivity. It should ensure innovation in, and structural changes of, local labour markets (Ciarli et al., 2021) by leveraging on inclusion as a tool, rather than considering inclusion as a constraint or simply an objective; mitigate the effects of digital transformations on labour markets (HLG, 2019) by ensuring life-long learning and soft skills enhancement where the share of low skilled is particularly important (Aghion et al., 2020); and prioritise employment protection and jobs quality in a recession context. A comprehensive, place-based policy approach (Evenhuis et al., 2021) should also involve social partners and ensure that alternative work arrangements such as self-employed and gig workers are protected similarly to paid labour (Ciarli et al., 2020, HLG, 2019). Finally, policy should mitigate the detrimental effects on inequality caused by the fact that superstar firms and megacities are innovating but not redistributing effectively or allowing effective diffusion. Our findings show that LP does not seem to increase wage inequality but might still affect income and wealth inequality through the effects of capital concentration.

There is no silver bullet recipe to address the shortfall of productivity in GB while also raising living standards of low wage workers. However, if the main priority is to increase living standards and wellbeing through wage progressions, policy might need to concentrate on a concerted effort of innovation and industrial policy built on measures to include excluded talents and redistribute the innovation rents.

This is all the more so in the aftermath of the Covid-19 pandemic and requires an immense effort to avoid a triple dip recession. Along the lines put forward by Bloom et al. (2019), it is important to build an institutional architecture, arguably even at the local level, to mitigate what has been labelled as a "Policy Attention Deficit Disorder" (Bloom et al., 2019). This consists of the damaging effects of uncertainty, lack of infrastructural investments and long-term investments in physical and human capital. Innovation policy should be prioritised, and London is in the best position to attract and support innovative human capital (Bloom et al., 2019). This is equally needed for public services and, in the case of London, for advanced urban services and local public services (GLA, 2020).[24]

[24] In relation to this, there is a need to revise the methodological approach to measuring productivity in non-manufacturing sectors. The mismeasurement of services' productivity is a long-term issue (Grassano and Savona, 2021) and one that is being affected by the increasing digitalisation of the economies (HLG, 2019). As London and S&H, and more generally in the UK, the share of these activities is substantial, and such mismeasurement is likely to lead to under-estimation of productivity trends.

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Appendix

Firm level results: OLS and 2SLS comparison.

Starting from models estimated without considering the endogeneity issues that may bias the results (column 1 in Table A1), we find that higher LP at the firm level is associated with higher (average) wages of their workers. This result is robust to controlling for the industry and TTWA mean LP, with these latter controls being insignificant, however. The effect is economically small, with an estimated elasticity of approximately 0.05, i.e., on average, an increase in firm's LP by 10% translates into a 0.5% increase in individual wages.

The productivity-wages relationship is not found to differ in London (col. 2), relative to the rest of GB. The interaction with the London dummy variable is insignificant, and so is the non-interacted dummy for London. This suggests that the relationship between firm productivity and wages does not differ substantially between London and the rest of the UK. That is, also in London, on average, an increase in firm's LP by 10% translates into a 0.5% increase in individual wages. In S&H, we find a larger effect of LP on wages than in the rest of the UK, although this result is not confirmed in the 2SLS estimates presented in Table 1.

Table A1: Impact of firm-level productivity on workers' wages, aggregate sample

	(1)	(2)	(3)	(4)
Dep. Var.	Ln(hourly wage)			
Estimator	OLS	OLS	OLS	OLS
Sample	**All**			
Ln(LP)	0.00501**	0.00467**	0.00430**	0.00377**
	(0.00205)	(0.00200)	(0.00180)	(0.00161)
Ln(LP_SIC)	-0.000673	-0.000651	-0.00112	-0.00110
	(0.00383)	(0.00383)	(0.00342)	(0.00341)
Ln(LP_TTWA)	-0.00443#	-0.00441#	-0.00432#	-0.00431#
	(0.00279)	(0.00278)	(0.00273)	(0.00273)
London		0.0107		0.00518
		(0.0130)		(0.0124)
Ln(LP)*London		0.00181		0.00289
		(0.00333)		(0.00321)
Heath. & Slough			-0.0823*	-0.0797*
			(0.0419)	(0.0428)
Ln(LP)*Heath. & Slough			0.0170*	0.0174**
			(0.00858)	(0.00863)
Worker-Firm FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
N	283588	283588	283588	283588

Note: all estimated models include controls for the workers' tenure, age, and full-time status. Standard errors clustered at the 2-digit SIC 2007 industry level in parentheses: # p<0.15, * p<0.10, ** p<0.05, *** p<0.01.

In Table A2 we estimate the econometric model separately on the subsamples of firms located in London and those located in the rest of the UK. Without instrumenting LP, the positive association of labour productivity and wages found in Table A1 is confirmed only for the rest of the GB subsample, with no effect found for London, and a positive effect found in S&H. The 2SLS results, however, reassure us about the existence of a positive and causal effect of productivity on wages on the London and overall GB samples, but not in the S&H subsample.

Table A2: Impact of firm-level productivity on workers' wages, Rest of GB and London subsamples

	(1)	(2)	(3)
Dep var.	Ln(hourly wage)	Ln(hourly wage)	Ln(hourly wage)
Sample	Rest of GB	London	Heathrow & Slough
Estimator	OLS	OLS	OLS
Ln(LP)	0.00314*	0.00555	0.0141*
	(0.00159)	(0.00411)	(0.00724)
Ln(LP_SIC)	-0.00277	-0.00602	0.0138*
	(0.00284)	(0.00530)	(0.00819)
Ln(LP_TTWA)	-0.00317	-0.00737	-0.00560
	(0.00232)	(0.00507)	(0.00646)
Worker-Firm FE	Y	Y	Y
Year FE	Y	Y	Y
N	230702	38085	10831

Note: all estimated models include controls for the workers' tenure, age, and full-time status. Standard errors clustered at the 2-digit SIC 2007 industry level in parentheses: # p<0.15, * p<0.10, ** p<0.05, *** p<0.01.

Table A3 presents the results obtained from estimating the same relationship presented in Table A1 separately on 10 macro-sectoral groups.[25]

We find that results differ substantially across sectors for the entire country, London, and for the difference between the two. We provide here a summary of those results.

First, in most sectors we do not observe a positive impact of labour productivity on firm wages.

Second, we find a positive association (as we are inspecting OLS estimates) between LP and wages only in the manufacturing and transport sectors, with similar magnitude to those of the aggregate sample. Notice that the manufacturing sector is also the one for which the computation of productivity is most reliable, from an accounting perspective.

The London interaction coefficient is found to be negative in manufacturing and in wholesale and retail trade. In manufacturing, in London, an increase in productivity results in lower increases in wages, although on average all wages in London manufacturing are higher than

[25] Manufacturing, SIC-2007 codes: 10 to 33; Construction, SIC-2007 codes: 41, 42, 43; Wholesale and retail trade, SIC-2007 codes: 45, 46, 47; Transport, SIC-2007 codes: 49, 50, 51, 52, 53; Hotel and restaurants, SIC 2007 codes: 55, 56; Information and communication, SIC 2007 codes: 58, 59, 60, 61, 62, 63; Financial services, SIC 2007 codes: 64, 65, 66; Professional activities, SIC 2007 codes: 68, 69, 70, 71, 72, 73, 74; Business services, SIC 2007 codes: 77, 78, 79, 80, 81, 82; Other services, SIC 2007 codes: 90, 91, 92, 93, 94, 95, 96.

the rest of the UK. In wholesale and retail, also wages are significantly higher than in the rest of the country, but, again, productivity increases are rewarded with lower increases in wages, on average.

We find an opposite relationship for the transport and financial services sectors: in GB there seem to be no relationship between productivity and wage, but in London there is: as productivity rises, wages increase by more than in the rest of the UK.

When we correct for potential endogeneity issues, instrumenting the LP with the TFP and estimating 2SLS coefficients, the positive relationship between productivity and wages vanishes for all sectors, except for the professional services activities sector, across the UK, but not for London. The London interaction is again found to be negative in manufacturing and positive in financial services, indicating a lower and higher impact on wages relative to the rest of the UK, respectively.

Results by sector:

Table A3: Impact of firm-level productivity on workers' wages, by macro-sectors

	(1)	(2)	(3)	(4)	(5)	(6)
Estimator	OLS	OLS	OLS	OLS	OLS	OLS
Sample	Manufacturing		Construction		Wholesale and retail trade	
Ln(LP)	**0.00338***	0.00545*	0.00196	0.000597	-0.00140	-0.00198
	(0.00188)	(0.00288)	(0.00233)	(0.00116)	(0.00458)	(0.00531)
Ln(LP_SIC)	-0.00288	-0.00283	0.00350	0.00373	-0.00634	-0.00635
	(0.00657)	(0.00638)	(0.00523)	(0.00464)	(0.00398)	(0.00407)
Ln(LP_TTWA)	-0.000908	-0.000567	0.00296	0.00296	-0.00237	-0.00230
	(0.00279)	(0.00240)	(0.00684)	(0.00612)	(0.00191)	(0.00193)
London		0.203*		0.00370		0.0215*
		(0.106)		(0.0368)		(0.00533)
Ln(LP)*London		-0.0411**		0.00345		-0.00239#
		(0.0176)		(0.0105)		(0.000852)
Heath. & Slough		0.118		-0.238*		-0.0527
		(0.152)		(0.0707)		(0.0660)
Ln(LP)*Heath. & Slough		-0.0313		0.0389		0.0193
		(0.0286)		(0.0207)		(0.0223)
Worker-Firm FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
N	46805	46805	9548	9548	93248	93248

Note: all estimated models include controls for the workers' tenure, age, and full-time status. Standard errors clustered at the 2-digit SIC 2007 industry level in parentheses: # p<0.15, * p<0.10, ** p<0.05, *** p<0.01.

Table A3, continued.

	(7)	(8)	(9)	(10)	(11)	(12)
Estimator	OLS	OLS	OLS	OLS	OLS	OLS
Sample	Transport		Hotels and restaurants		Information and communication	
Ln(LP)	**0.00999****	0.00684	0.00140	0.00177	0.000155	0.00213
	(0.00274)	(0.00547)	(0.00523)	(0.00523)	(0.00463)	(0.00469)
Ln(LP_SIC)	0.0336*	0.0274	-0.00463	-0.00462	0.0101	0.00987
	(0.0138)	(0.0170)	(0.00243)	(0.00260)	(0.00894)	(0.00900)
Ln(LP_TTWA)	-0.00627	-0.00576	0.00785	0.00810	-0.00854***	-0.00851***
	(0.0102)	(0.00995)	(0.00198)	(0.00260)	(0.00200)	(0.00199)
London		0.0292*		-0.0210		0.0595
		(0.0111)		(0.0371)		(0.0449)
Ln(LP)*London		0.000444		0.00395		-0.0111
		(0.00340)		(0.0122)		(0.00917)
Heath. & Slough		-0.124		0.0679		-0.0422
		(0.0819)		(0.0829)		(0.127)
Ln(LP)* Heath. & Slough		0.0216		-0.0207		0.00542
		(0.0172)		(0.0300)		(0.0267)
Worker-Firm FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
N	38042	38042	12407	12407	25352	25352

Note: all estimated models include controls for the workers' tenure, age, and full-time status. Standard errors clustered at the 2-digit SIC 2007 industry level in parentheses: # p<0.15, * p<0.10, ** p<0.05, *** p<0.01.

Table A3, continued

	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Estimator	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
Sample	Financial services		Professional activities		Business services		Other services	
Ln(LP)	0.00105	0.000494	0.00677	0.00545	-0.00452	-0.00582	0.00427	0.00671
	(0.00261)	(0.00278)	(0.00460)	(0.00461)	(0.0108)	(0.00830)	(0.00553)	(0.00798)
Ln(LP_SIC)	0.00782	0.00732	-0.00911	-0.00953	-0.000505	-0.000663	-0.00246	-0.00247
	(0.00650)	(0.00540)	(0.00647)	(0.00649)	(0.00334)	(0.00314)	(0.00571)	(0.00563)
Ln(LP_TTWA)	-0.00716	-0.00808	0.00400	0.00370	-0.00763	-0.00741	-0.00116	-0.00112
	(0.00725)	(0.00729)	(0.00363)	(0.00382)	(0.00634)	(0.00624)	(0.00379)	(0.00384)
London		-0.00548		0.0199		-0.0169		0.00357
		(0.0104)		(0.0194)		(0.0649)		(0.0459)

Ln(LP)*London		0.00356**		0.00539		0.00449		-0.00711
		(0.000512)		(0.00465)		(0.0190)		(0.0126)
Heath. & Slough		0.0768*		-0.00703		-0.0534*		0.0511
		(0.0236)		(0.0728)		(0.0254)		(0.0646)
Ln(LP)* Heath. & Slough		0.00214		0.00345		0.0135*		-0.0155
		(0.00236)		(0.0203)		(0.00625)		(0.0151)
Worker-Firm FE	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y
N	3362	3362	27367	27367	15740	15740	8906	8906

Note: all estimated models include controls for the workers' tenure, age, and full-time status. Standard errors clustered at the 2-digit SIC 2007 industry level in parentheses: # p<0.15, * p<0.10, ** p<0.05, *** p<0.

TTWA level results: OLS and 2SLS comparison

The tables below compare the results from estimating the effect of productivity changes on wage changes at the TTWA level, by exploiting OLS and 2SLS models.

Table A4 presents the estimation results for 10-year changes. Starting from the non-instrumented models on averages in columns 1-4, it appears that a larger increase in productivity at the TTWA level is associated with a larger increase in the mean wage at the TTWA level, with this result being statistically significant. The magnitude of the effect is rather small however, with a £1 larger increase in LP over the 10-year period resulting in an £0.075 larger increase in wages. The relationship is stronger in London relative to the rest of GB (about twice as large), as the positive and statistically significant interaction term suggests.[26]

Results are very similar, albeit smaller in magnitude, when we consider the relationship with the median wage (cols 5-8). This result seems to suggest that top wages (above median) grow more in areas with higher productivity than the wages of the typical (median) worker.

Table A4: The effect of productivity on wages at the TTWA area level, 10-year changes

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Mean wage				**Median Wage**			
Dep var.	Δ10 Hourly wage				Δ10 Hourly wage			
Estimator	**OLS**	**OLS**	**OLS**	**OLS**	**OLS**	**OLS**	**OLS**	**OLS**
Δ10 LP	0.0753*	0.0714*	0.0782*	0.0743*	0.0511##	0.0501##	0.0520*	0.0511##
	(0.0399)	(0.0404)	(0.0400)	(0.0405)	(0.0312)	(0.0318)	(0.0314)	(0.0320)
Δ10 LP * London		0.110***		0.109***		0.0276**		0.0270**
		(0.0155)		(0.0155)		(0.0131)		(0.0132)
Δ10			-	-0.167***			-	-

[26] Results on the London differential relationship should be taken very cautiously when using the 10-year change, because they are based on one single observation (TTWA).

LP*Heath.&Slough			0.169***				0.0553***	0.0549***
			(0.0123)	(0.0125)			(0.0105)	(0.0107)
N	217	217	217	217	217	217	217	217

Note: Labour productivity is measured as nominal GVA per hours worked, excluding rental income. Robust standard errors clustered at the TTWA level in parentheses. # p<0.20, ## p<0.15, * p<0.10, ** p<0.05, *** p<0.01

When we instrument LP with the shift-share instrument and estimate a 2SLS model to reduce the problem of endogeneity (e.g., higher wages or living costs pushing productivity), the coefficient on LP increases noticeably in size (Table 4 above), but results are only weakly statistically significant. This means that the endogeneity is biasing downwards the non-instrumented estimates, possibly due to unobserved factors positively related to productivity and negatively to wages, for instance increasing labour supply and productivity (e.g., improved mobility infrastructures). Results are less statistically significant, but suggest a positive impact of LP on wages at the TTWA level, of a causal nature.

Table A5 presents the results from exploiting stacked changes over two 5-year periods.

Table A5: the effect of productivity on wages at the TTWA area level, 5-year changes

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Mean wage				**Median Wage**			
Dep var.	Δ5 Hourly wage				Δ5 Hourly Wage			
	OLS	**OLS**	**OLS**	**OLS**	**OLS**	**OLS**	**OLS**	**OLS**
Δ5 (LP)	0.0497##	0.0444#	0.0509##	0.0457#	0.0294	0.0254	0.0297	0.0258
	(0.0325)	(0.0326)	(0.0326)	(0.0327)	(0.0231)	(0.0232)	(0.0232)	(0.0233)
London		-0.801***		-0.802***		-1.261***		-1.262***
		(0.0973)		(0.0980)		(0.0807)		(0.0813)
Δ5 (LP) * London		0.310***		0.310***		0.337***		0.337***
		(0.0279)		(0.0281)		(0.0234)		(0.0236)
Heath. & Slough			-1.135***	-1.150***			-0.515***	-0.531***
			(0.173)	(0.174)			(0.142)	(0.142)
Δ5 LP*Heath. & Slough			0.153***	0.159***			0.0928**	0.0983**
			(0.0468)	(0.0469)			(0.0399)	(0.0400)
Period FE	Y	Y	Y	Y	Y	Y	Y	Y
N	434	434	434	434	434	434	434	434

Standard errors in parentheses
# p<0.20, ## p<0.15, * p<0.10, ** p<0.05, *** p<0.01

In the non-instrumented models, for both the mean and the median wage, we again find a positive association of productivity with wages, and again the effect is larger in London relative to the rest of GB. Note, however, that the introduction of the period FE absorbs much of the significance of the labour productivity coefficients, leaving only the interaction with London

to be statistically significant. That is, in the shorter 5-year period, TTWAs with higher productivity do not experience a statistically significant higher (average or median) wage. But London does! The magnitude of the effects for London is larger when exploiting 5-year changes, relative to using 10-year changes. For a £1 increase in LP, workers in London, in both periods, also experienced a £0.3 higher (average and median) wage.

With 5-year changes, we can estimate the (non-interacted) London dummy, whose negative coefficient suggests a lower change in wages in London relative to the rest of the UK.

In all the 2SLS models of Table 5 (above) the LP coefficients are a great deal larger than in the OLS models, but instrumenting labour productivity with the shift-share IV variable produces effects that differ slightly between models exploiting the mean and the median wage as dependent variables.