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Abstract
Unpaid overtime in Britain has been excessive. The article measures the contribution of unpaid overtime in relation to UK industries economic output (Gross Value Added-GVA) for the period 2002-2012, using the Labour Force Survey (LFS) and the Office for National Statistics (ONS-Blue Book), capturing the different patterns before and after the 2007-8 crisis. Measuring unpaid overtime's contribution and the other parts of working day has important implication on labour's remuneration. The paper adopts an output-based approach evaluation of unpaid labour. A decomposed working day is therefore examined by employing statistical regression methods (Pooled OLS, LASSO and FGLS) to account for unpaid overtime's contribution to the UK industries' output (GVA). The results display a strong link between unpaid overtime and GVA, and particularly its post-crisis contribution to GVA is significant in contrast to the weak pre-crisis relationship.

JEL Classifications: E24, D24, J3, C01

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1 Introduction

During the last decades work-time deregulation has become the norm in developing countries, impacting also overtime hours' extension and its payment. According to worksmart.org (2018) -a platform used by the Trade Unions Congress (TUC) that employs a wage-based approach (assigning wage to unpaid activities)- 'over five million people at work in the UK regularly do unpaid overtime, giving their employers £31.2 billion of free work' for 2017. For the same year, according to ONS (2018) the seasonally adjusted GDP for 2017 was calculated to be around £492.7 billion in *chain volume measures* (CVM). This shows that unpaid overtime is equal to 6.33% of British GDP. These facts raise further questions on the wage system, on income distribution and the length of working day.

However, the term 'unpaid' is quite disputable among economists based on neoclassical methodology, confronting the term, and claiming that every time investment is somehow rewarded (eg. Pannenberg 2005). Whereas other schools of thought argue that any capitalistically organised labour of

dependent contract is partially unpaid (Mavroudeas and Ioannides 2011, Ioannides at al. 2014, Philp et al 2015, Ioannides and Mavroudeas 2018), acknowledging that unpaid overtime fits into the unpaid kinds of working day.

A parallel literature on forms of evaluating unpaid labour, including wage-based and output-based methods is also explored. This article critically evaluates wage-based approaches, and instead adopts an output-based approach of the decomposed working day. Within an industrial focus, unpaid overtime is located into a technical aggregate spectrum capturing also the pre- and post-crisis patterns.

2 British peculiarities, overtime and wage theories, and valuating unpaid labour

The increasing length of working-week during the past decades challenged scholars' perceptions that working-time could only be reduced after decades of declined patterns (Appendix 1 and 2). Together with the increasing length of working-day, its unpaid forms (overtime, 'volunteering' etc.) also appeared in an increasing pattern too. This raised questions on the factors behind that and the suitability of measuring unpaid activities. Individualised contracts add another complication disabling a uniform definition of overtime. Consequently in statistical records, overtime is barely represented. Even contracts that recognise overtime employees end up with varying hours[1]. The UK's exemption from the European Working Time Directive (EWTD-Council Directive 2003/88/EC) is further adding to the deregulation of the labour market (Philp et al., 2005, Philp et al., 2014), although the allowed 48-hour maximum working-week, is still higher than the working-week decades ago. Even when individuals choose the relative protection of the EWTD –usually during the job application/interview process- the 48 hours maximum working week still does not define universal 'normal' contractual hours for all employees. Moreover, in Britain, around 25% employees work part-time (Appendix 3) and 5-6% are temporarily employed (for 2002-2012). According to Conway and Sturges (2014), part-time workers in Britain are even more likely to engage in working unpaid overtime than full-time workers). Apart from these, records of unpaid overtime started being kept rather recently making a detailed historical approach more difficult (LFS starts from 1992).

2.1 Unpaid overtime and existing theories

Several scholars detected the existence of unpaid overtime, especially before crisis. Schor (1991, 1999) firstly observed that Americans work 158 hours more per year, equivalent to an extra month of work - from 1969-1989 (Schor 1999). Several researchers detected that pattern in other countries too, such as Germany, UK, Sweden, Switzerland, Netherlands and Australia (Golden

[1] Employees can work eg. for 7 hours per day (35 hours per week), allowing for 13 hours of legal overtime, while others work 48 'normal' hours per week, allowing for 0 overtime.

and Figart 2000, Bell et al. 2000, Campbell and Green 2002, Booth et al. 2003, Pannenberg 2005, Engellandt and Riphahn 2005, Meyer and Wallette 2005, Van Echtelt et al. 2007, Anger 2008, Drago et al. 2009, Swann and Stanford 2016). The phenomenon is still ongoing even after the 2007-8 crisis, as Sturges, (2013), Williams, et al. (2008) and Conway and Sturges (2014) present.

On the one hand, these developments engendered several theories justifying economically the phenomenon of unpaid overtime, while on the other, it generated more questions regarding the measurement of unpaid labour. Neoclassically-based explanations do not recognise the term 'unpaid'. For instance, the *deferred compensation theory* (Pannenberg 2005), *human capital accumulation* (Booth et al., 2003, based on Becker's, 2009 [1981], concept), unpaid overtime as a *Pareto improvement* (Bell et al., 2000), that are based on neoclassical assumptions, claim that employees are rewarded afterwards, or with alternative means, or to compensate for an existing high payment. Additionally, there are theories within the behavioural spectrum that regard unpaid overtime either as a *gift exchange* (Bell and Hart, 1999, based on Akerlof 1982), or as a *signalling device* (Ange 2008, based on Spence 1978) claiming that its existence does not necessarily contribute to economic returns. Nevertheless, according to Papagiannaki (2014) these theories predominantly focus on the individual, or disregard dimensions of power or class, or institutions, market deregulation are regarded as internal factors, or even imply that knowledge acquisition acts as form of payment, that employees can live off.

There are also approaches that take *historicity* and *structurality* into account, such as the *post-Fordist* labour processes (van Echtelt 2007), the *cyclicality* of economy (Hetrick 2000), the nature of *industry* (Golden and FIgart 2000), the level of *unionisation* in workplace, the kind of contract (Conway and Sturges 2014, Engellandt and Riphahn 2005), and other organisational factors (Zapf 2015, van der Meer and Wielers 2015, Tseng 2011). Within, the Marxist tradition, the rising unpaid overtime is attributed to the capitalists' pursuit of extracting more *surplus value* (Philp et al. 2005, Philp et al. 2014, Ioannides et al 2014, Ioannides and Mavroudeas 2018). Unpaid labour (including overtime) as a form of surplus value is therefore measured by economy's aggregate profits. In this article, we locate unpaid overtime in an aggregate scale, measuring the contribution-payment gap of the different component parts of the working day, demonstrating the wage and income distributions' implications.

This paper combines two pieces of literature: the one on method of measuring unpaid activities (e.g. volunteering, domestic labour) and the literature that focuses on productivity of labour and the UK productivity puzzle. On the one hand, we confront the use of wage-based approaches on valuing non-waged activities, and on the other hand we use popular measures of labour productivity in a decomposed working day: basic hours, paid and unpaid overtime.

2.2 Wage- or Output-Based Approaches in Measuring Unpaid Labour?

Measuring the precise extent and contribution of unpaid overtime has also policy-related issues. Domestic labour first, and volunteering later, triggered the debate of measuring labour that is unpaid. The United Nations General Assembly resolution (GA Res 56/38) called on governments to establish the economic value for volunteering, while the International Labour Organisation (ILO 2011)) proposed a methodology to guide countries in generating the data for volunteer work. National accounts also release measurement estimates on domestic and volunteering labour. The existing approaches of measuring unpaid labour time can be summarised in two basic categories: *i. wage-based approaches* attributing a relevant wage for the unpaid working hours and ii. *output-based approaches* that try to evaluate labour with respect to output per working-time. Wage-based approaches are more frequently used.

Two different kinds of wage-based approaches are identified too: a. the o*pportunity cost approach* and the b. r*eplacement cost* approach. The former evaluates activities according to the sacrifice of individuals who perform unpaid labour, as they give up other activities, 'along with all associated monetary and non-monetary benefits' (Hamdad 2003). This approach was originally used in measuring the value of domestic labour assuming that households give up working hours which would have been paid by the hourly income (Luxton 1997). The online calculator (worksmart.org 2017), used also by TUC, follows an opportunity cost approach for unpaid overtime, evaluating an extra overtime hour as equal to a basic hour.

Regarding the replacement cost approach, non-marketed unpaid labour is valued at the earnings level of other employees who (would) work in similar activities in the labour market (Wood 1997). According to Hamdad (2003) a way of calculating the value of domestic labour, is by the amount of money saved by households (for not occupying a third person).This method also originates in measuring domestic labour, and has been used by ONS (2020) proposing household members-workers' replacement by other employees. The UN and the ILO (2011) propose this approach to national governments for evaluating unpaid volunteering activities. Regarding unpaid overtime, its replacement cost is represented by the amount of money spent for hiring extra employees at a 'basic' wage, or by the amount of money spent on overtime premia for occupying existing employees.

Using wage-based approaches to measure labour's contribution can be challenged from various theoretical perspectives including a range from the Classical Political Economy to contemporary non-neoclassical approaches. These schools reject that wages reflect productivity -*contra* the neoclassical claim that wages are determined in the sphere of production (instead of distribution), and subsequently employees cannot receive less than their contribution. Dobb 1973, Cohen and Harcourt 2003 claimed that it is the a-priori distribution of wealth, income and property rights determining factor payments or prices instead of labour productivity.

According to Hamermesh (1986), the neoclassical school of thought assumes that, employees' wage represents their marginal product of labour,

under *perfect completion*, *full employment* and a *single sector economy*. Although there have been some several updates in the traditional neoclassical models labour models with imperfect competition, decentralised models, with uncertainty, or without full employment (Spence 1978, Becker 2009, Mortensen and Pissarides 1999, Rogerson et al. 2005) to explain deviations of wages from labour contribution, they still highly associate these two categories. Divergence of labour productivity from wages is allowed in models with imperfect competition. According to Fishback (1998), the gap between the marginal product of labour and wages due to *monopsony of labour* defines the degree of 'exploitation'[2]. ILO (2013) calculates this widening gap for the developed economies (Appendix 4). Additional research moves further into demonstrating not only a gap but a complete independence of wages from labour's product [Fine's proof (2016) focusing on two cases: i. developing (with labour surpluses) and ii. developed economies (with skilled labour)].

Apart from the above issues with wages, there are also approach-specific issues, when it comes to unpaid labour valuation. The opportunity cost approach infers that an extra unpaid overtime hour appears equal to a 'basic' hour, ignoring the wear and tear of labour that comes with overtime (Kivimäki et al 2015, Virtanen et al 2012, Shields, M., 1999). Instead, unpaid overtime's opportunity cost should logically be a 'paid' overtime hour. Additionally, the replacement cost approach faces similar criticisms. It is essential to decide with what we replace the cost of an overworked employee: with the overtime payment of their own contract, or with the basic payment of a newly-hired employee. Consequently the measurement method would strictly depend on the views of the analysist or policy-maker. Notwithstanding, wage-based approaches of measuring labour contribution conceal the divergence between labour's contribution and labour remuneration.

2.3 An output-based valuation of unpaid overtime?

Output measures of non-marketed/non-waged activities have not been as popular as waged-based ones though. However, national statistics frequently turn to the output-based approach when there is no marketable-equivalent, like in the case of domestic labour (eg. Fender 2012). The usefulness an output-based approach provides also the capacity of breaking down total working-hours into its component parts (basic, paid overtime and unpaid overtime). Goldschmidt-Clermont (1993), proposed a useful structure (mainly used for domestic labour), especially when some of these parts are not receiving any wage. According to him, the output-based approach can be applied when there is i. *physicality of units produced* ii. *valuation of products with market prices* iii. *output-related valuation of time* and iv. *valuation's relevance with economic purposes*. Therefore, Goldschmidt-Clermont's structured can also be applied to unpaid overtime too, with the third element (*output related valuation of time*), being actually the main purpose of the article, and therefore to be calculated.

Relating labour with its output is one measure of productivity. Most

[2] E=MPL-W > 0, (E is labour exploitation and W is the wage)

scholars adopt employees as a unit of assessment instead of working hours. Generally recent work on UK's productivity puzzle (e.g., Blundell et al., 2014; Broadbent, 2012; Barnett et al. 2014; Disney et al., 2013; Goodridge et al., 2013; McCafferty, 2014; Pessoa and Van Reenen, 2014; and Sargent, 2013) has used labour productivity (measured as gross value added per worker). Harris and Moffatt (2017) report a significant decline of productivity post-2008 that not recover (for the market-based economy) in the UK. The use of product per employee instead of working hours can conceal employees' changing working-day and the spread of productivity over the day. Therefore, our focal point is the working-day and its decomposition. More specifically, this paper examines the relation between labour and its output is through a Cobb-Douglas function, as an assessor of growth, rather than assessor of distributional outcomes (wages, profits).

2.4 An Aggregate versus an Individual Contribution

The output-based approach adopted in this article does not aim at measuring the performance of individual employees, by examining one against the other. Instead it aims at measuring the collective output. This article is not focusing on the individual firms either. Although this could provide very useful insights, the industry is comprised by numerous firms competing for the market share leading to one uniform market price and other industry spill-over effects. Therefore, with an industrial analysis, this extra layer of complexity is removed, and the whole process of price making/taking among the firms is internalised into the industry. There are also practical reasons for an industry analysis, as the ONS and the LFS datasets do not allow for a firm level analysis, but only individual, occupational (based on Standard Occupational Classification-SOC), or industrial (based on Standard Industrial Classification-SIC). For the UK there are 88 2-digit industry codes, but for practical reasons they have been merged to 60 in this study (Appendix 5 - For details see Papagiannaki (2019)).

Lastly, apart from the industry-level analysis (that captures economy's structure) of working-time, it requires also a longitudinal appraisal (that captures the 'historicity'). Capturing the patterns of working-time and unpaid overtime before and after the 2007-08 crisis is essential to inform the debate on economic recessions, and their aftermath. This research has implications on whether the UK overcomes crises through labour-saving technologies that increase productivity or by working day extension (Mavroudeas and Ioannides 2003, Liodakis, 2005).

3 Methodology and Model

Cobb-Douglas and Translog functions are employed to construct the aggregate production function. Alternative functions, such as CES and Leontief cannot perform without constant elasticity (Uzawa, 1962, McFadden, 1963) or without assuming only *supplementarity* among inputs (labour and capital) respectively. C-D does not come without issues either. It has been highly critiqued regarding its approximation with the National

Income Identity by giving misleading results regarding the income shares (Shaikh 1974). This article uses C-D as an input-output function, as a growth assessor without assuming marginal productivity of inputs determines factor payments. Also adopting the new ONS-output method (Blue Book 2015, *GDP(O)*) partly overcomes the association of factor contributions to their payments.

Additionally, the study also examines the use of the Translog for the aggregate production function. Although the Translog's coefficients are not reliable due to high multicollinearity, it is used as a complement to Cobb-Douglas. The translog model ensures that with a non-linear specification allows for a more flexible production function that can display local returns to scale, and the Cobb-Douglas gives more trustworthy decomposed working-time coefficients without the multicollinearity issues of the translog. Therefore, the models to be tested are:

$$lgva_{it} = a_0 + a_1 lnK_{it} + a_2 lnL_{it} + \frac{1}{2}\beta_1(lnK_{it})^2 + \frac{1}{2}\beta_2(lnL_{it})^2 + \frac{1}{2}\beta_3 lnK_{it} * lnL_{it}\ (+year) \quad (1)$$

$$lgva_{it} = a_0 + a_1 lnK_{it} + a_2 lnLb_{it} + a_3 lnLu_{it} + a_4 lnLp_{it} + \frac{1}{2}\beta_1(lnK_{it})^2 + \frac{1}{2}\beta_2(lnLb_{it})^2 + \frac{1}{2}\beta_3(lnLu_{it})^2 + \frac{1}{2}\beta_4(lnLp_{it})^2 + \frac{1}{2}\gamma_1 lnK_{it} * lnLb_{it} + \frac{1}{2}\gamma_2 lnK_{it} * lnLu_{it} + \frac{1}{2}\gamma_3 lnK_{it} * lnLp_{it} + \frac{1}{2}\gamma_4 lnLb_{it} * lnLu_{it} + \frac{1}{2}\gamma_5 lnLb_{it} * lnLp_{it} + \frac{1}{2}\gamma_6 lnLu_{it} * lnLp_{it}(+year) \quad (2)$$

$$lgva_{it} = a_0 + a_1 lK + blL_{it}\ (+year) \quad (3)$$

$$lgva_{it} = a_0 + a_1 lK + b_1 lLb_{it} + b_2 lLu_{it} + b_3 lLp_{it}\ (+year) \quad (4)$$

where a_0 is the constant, $lgva$ is the natural logarithm for Gross Value Added, lnK is the natural logarithm of Net Capital Stock, lnL is the natural logarithm of total working hours, $lnLb$ is the natural logarithm of basic working hours (excluding overtime), $lnLu$ is the natural logarithm of unpaid overtime, Lp is the natural logarithm of paid overtime, i is the industry based on the SIC codes, t is the year (t=2002, 2003,…2012) as a dummy variable. The year variable is interpreted as the estimate of technical change with 2002 as a base year.

4 Data and Empirical Findings

4.1 The Data

We use data from the ONS Blue Book (for capital and output) and the Labour Force Survey (LFS) (for labour variables) from 2002 until 2012. The LFS is comprised by approximately 40,000 responding UK households including 100,000 individuals per quarter. Respondents are interviewed for five successive waves at three-monthly intervals and 20% of the sample is replaced every quarter according to ukdataservice.ac.uk (2015). The LFS The extrapolation of labour variables to the population level took place after the *filtering*, *cleaning* and *conversion* of data for an 11 year period, from 2002 to 2012 is conducted (For more details see Papagiannaki 2019) [3]. However, it has

[3] LFS contains also data with odd values. For instance, there were cases where employees had negative weekly payment, eg values like -15, that are not within the range of acceptable responses. But LFS is still including these individuals as valid respondents. These odd

some limitations in detecting unpaid overtime, despite its detailed records. These limitations reflect the British market deregulation (individual contracts, 'flexible' working day, no overtime).

For the output, gross value added (*GVA*) from ONS's Blue Book is used at an industry-level in the form of *chained volume measures* (cvm) as the series have the effect of prices according to ONS (2016:*UK Sector Accounts*). GVA is defined usually as output minus inputs [proxied by the Index of Production (ONS,2017:*IoP*), is obtained by deducting intermediate consumption from gross output, and is equal to net output.

Net Capital Stock (NCS) 'reflects the market value of the stock of fixed assets' in the economy according to OECD (2018). NCS is calculated according to the Perpetual Inventory Method (geometric depreciation rate of investment (ONS 2016). Using *NCS* instead of *GCS* (Gross Capital Stock) means using the price at which the asset could be bought in its present situation, instead of the price at which the asset could be bought as if it was new. Gross Fixed Capital Formation (*GFCF*) or Capital Consumption (*CAPCONS*) are not used. The former is a flow measure showing the new 'value' of capital created (investment) or even destroyed (taking negative values), by industry, and it acts more as output, rather than input. Whereas *CAPCONS* is an 'assumed' indicator mainly representing depreciation (ONS 2016). Consequently, with this treatment of available data, we get measures of inputs and output as close to 'physical' as possible. This also gives us a more physical measurement of the contribution of working hours, including unpaid overtime.

4.2 Empirical Findings

In the growth period all indicators increased (Appendix 6). In the ratio analysis an interesting pattern is observed; basic hours consist of an increasing percentage of total working hours, while overtime a decreasing, with unpaid overtime consisting of the 5%-6% of total working hours (Appendix 7).

All Years

$$Total\ Working\ Hours_t = 92.38\%Lb_t + 5.7\%lLu_t + 1.82\%lLp_t \quad (5)$$

Before Crisis (2008)

$$Total\ Working\ Hours_t = 92.39\%Lb_t + 5.38\%lLu_t + 2.24\%lLp_t \quad (6)$$

After Crisis (2008)

$$Total\ Working\ Hours_t = 93.17\%Lb_t + 5.29\%lLu_t + 1.52\%lLp_t \quad (7)$$

responses can be attributed mainly to human error, and therefore, individuals like this were also excluded from the research of this thesis.

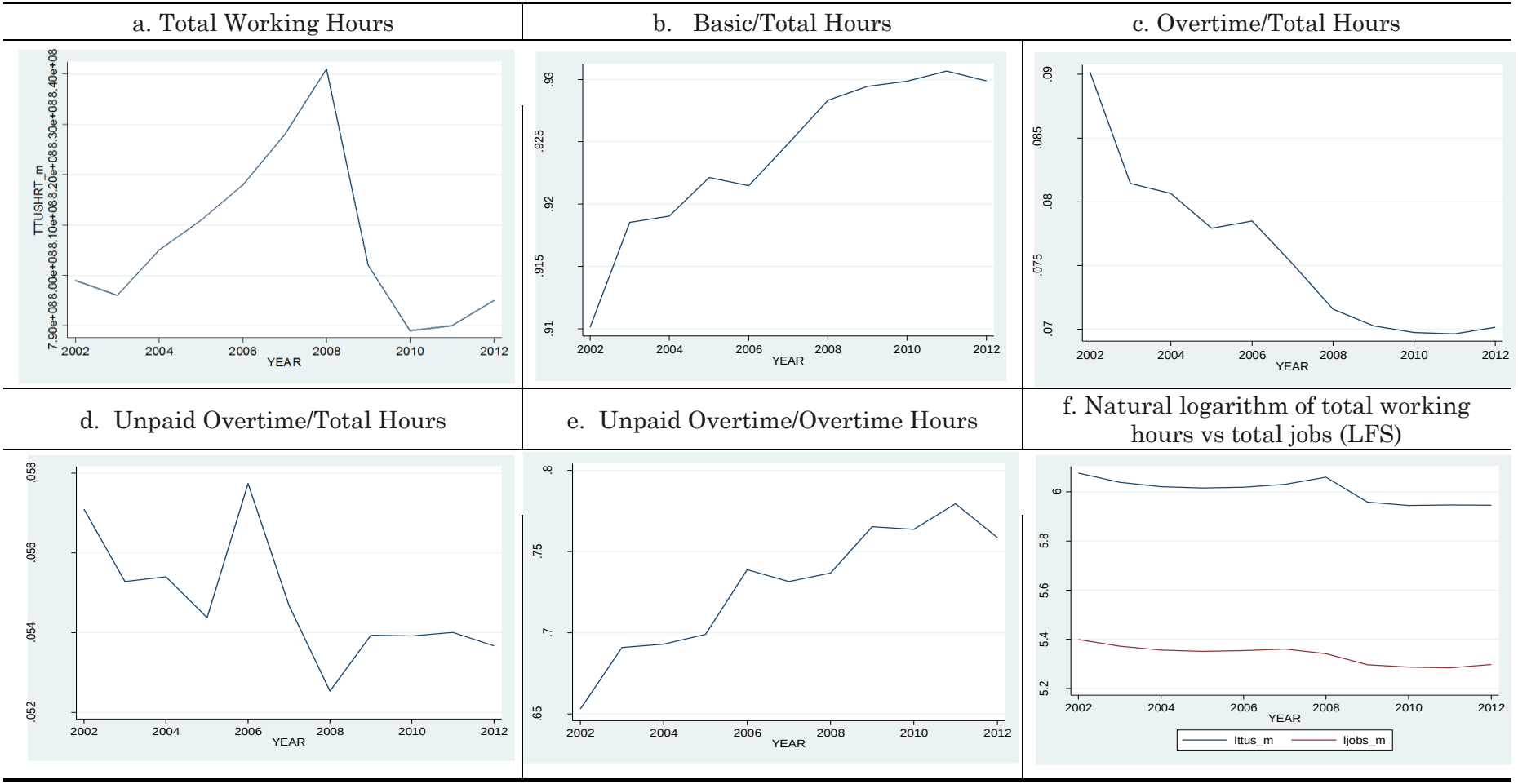

Figure 1 – Mean values of variables for all industries over the years - Before dropping outliers
Source: ONS and LFS

In the post-crisis UK total working hours have experienced a drop showing that employment until 2012 had not returned to its previous levels. Taking the increase in part-time jobs into account (Appendix 3), and the fact that it was working hours and not the number of jobs that fluctuated before and after crisis (Figure 1.f) there is some prevalent underemployment after the crisis, agreeing also with the existing literature. Another interesting finding is that the implied underemployment accompanied with relative reduction in aggregate overtime over the total hours, reinforcing the thesis that working hours –and not jobs– are associated with the cyclicality of the economy. Also the further post-crisis UK market deregulation can be also evidenced by the less overtime work reported. This, together with the increasing tendency of unpaid overtime over overtime hours act as further indicators of the labour-market deregulation.

These long-term patterns also challenge approaches that attribute the length of working day and unpaid overtime to individual choice, or that hypothesise deferred payment or rewards. Especially when GFCF is not recovering by 2012 (Appendix 6), the previously-invested working-hours does not seem to compensate for the long-hours performed.

Additionally, among the industries some act as outliers (Appendix 8) with industry 68 (Real Estate) being the 'ultimate' outlier with extreme values both in GVA and in its capital inputs, as it contains rental and purchase activities mainly reflecting demand-distorted market prices, and with 85 (Education) being the one with extreme records of unpaid overtime too. For details see Papagiannaki (2019). Although these outliers are dropped, they still are not altering the empirical results.

The empirical results have been derived using methods such as Pooled Ordinary Least Squares (Pooled OLS), LASSO (Least Absolute Shrinkage and Selection Operator) and Feasible Generalised Least Squares (FGLS) for Panel being applied to explore the contributions of labour in total and decomposed. Pooled OLS facilitates a combined analysis of cross-sectional and cross-time data simultaneously, enabling an inquiry into 'variables' not easily detected in simple cross-sectional or cross- time analysis, combining space and time relying upon higher variability of data. The results of the Pooled OLS translog regression analysis (Appendix 10) show that in the All-Industries and the Manufacturing industries-only, there is no evidence of misspecification. This implies that GVA is described better by a non-linear combination of variables than with the Cobb-Douglas model. However due to multicollinearity (as every translog model displays) the coefficients cannot be trusted. On the contrary, although the Pooled OLS Cobb-Douglas analysis shows omitted variables, it offers simpler results with fewer problems in coefficients (See Appendix 11, 12, 13).

After the OLS, we run LASSO (Least Absolute Shrinkage and Selection Operator) because one challenging issue in this analysis is that all labour variables are correlated with each other. The LASSO method enables the selection of variables to be picked for model construction. This is useful when there is multicollinearity in the model specification. Especially, in this case where unpaid overtime is not independent of the 'basic' hours with vif scores slightly above 10 for basic and unpaid overtime hours (See summarised vif

test in Appendices 11,12,13). The correlation makes sense as the higher the basic working hours, the higher the unpaid overtime, leading to a relationship between the two (Appendix 9)[4]. A stepwise regression is followed in order to eliminate the problem and select the best predictor variable to enter when other independent variables are present. The LASSO analysis is employed producing OLS results departing from their original weighing the more we try to reduce the number of independent variables. It also produces a graph showing the variable that should be removed first (Figure 2). Our analysis below shows that paid overtime is always the first variable to be removed, but unpaid is the last. Unpaid overtime appears to be strongly linked with variations in GVA compared to the others.

An issue with the Pooled OLS model is that according to Hicks (1994) there are several complications where errors tend to suffer from *autocorrelation* providing OLS estimators (still linear and unbiased) but without the minimum variance. In our data the Pooled OLS demonstrates correlated errors *across units,* causing heteroscedasticity. This is not surprising as we use industry data, and different sub sets of industries have differing variances across ranges. Therefore, to tackle these a time-dummy variable is introduced reducing heteroscedasticity and different subsets of industries are also analysed separately (manufacturing vs services). As expected, heteroscedasticity due to the in-group similarities among industries is reduced both when the time dummy variable is used, and when industries are analysed into industry groups or into year-groups.

The above facts indicate the presence of panel-specific heteroscedasticity and autocorrelation. Therefore FGLS –allowing for panel-specific heteroscedasticity and *autocorrelation*– are employed. If our assumptions for the structure of errors are correct, FGLS would provide consistent results. Although the Pooled OLS is used for testing the model's overall validity, for consistent coefficients, capturing unpaid overtime's contribution, we rely on the FGLS results.

[4] However, it is not only the labour variables that are correlated with each other, it is also that they are highly correlated (above 70%) with Gross Value Added, challenging the subsequent regression models, but also making theoretical sense, since any output needs labour to be produced.

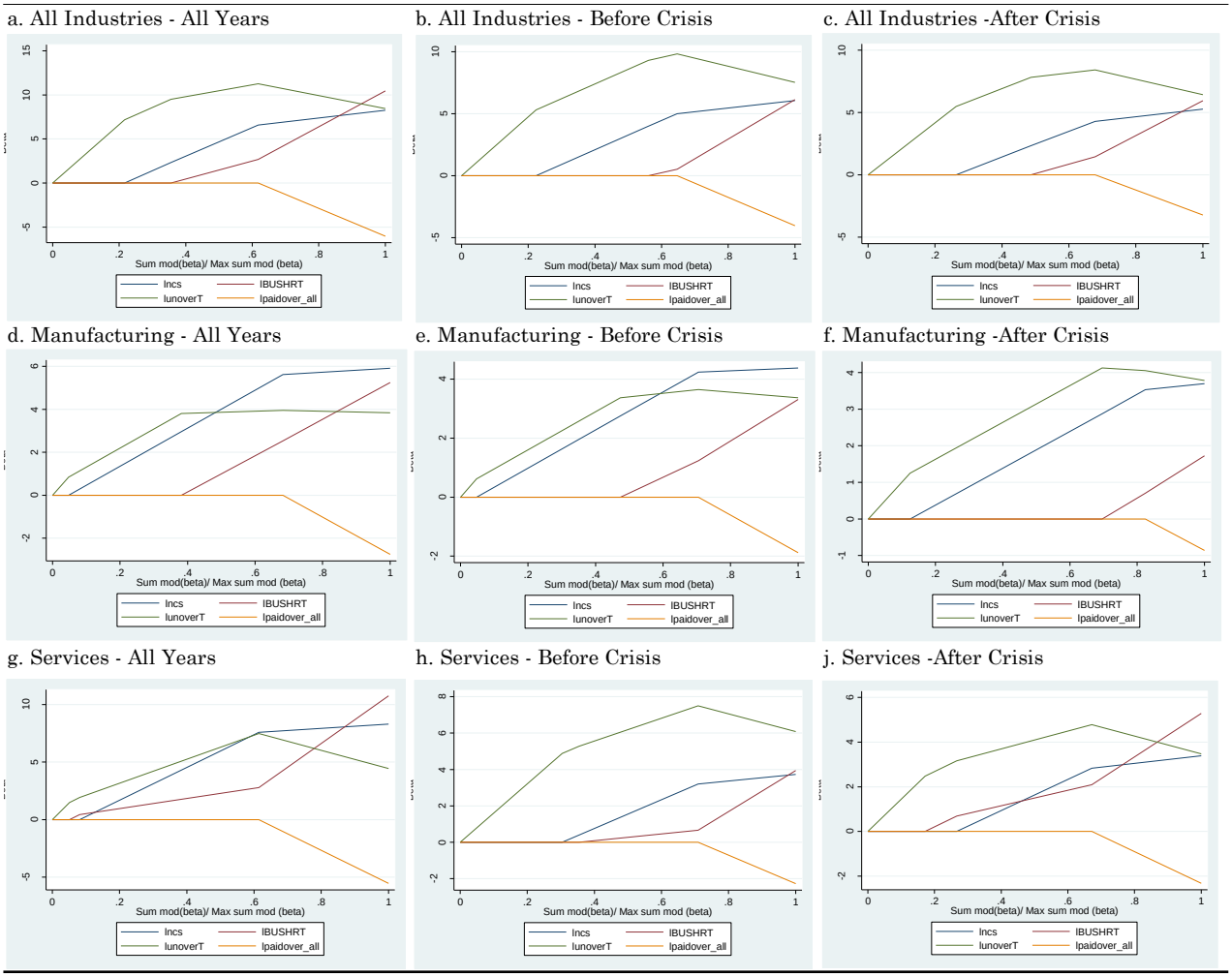

Figure 2 - Least Absolute Shrinkage and Selection Operator (LASSO)
Source: Quarterly Labour Force Survey and ONS Blue Book (2002-2012)

[5]

[5] The LASSO Table is read from the right to the left; the first variable whose curve 'touches' the 0 in the horizontal axis is the first to be dropped. Here it is paid overtime. And the last whose curve touches the horizontal 0 is the unpaid overtime. See Appendix 8

Table 1 - Effect on lgva Generalised Least Squares (Heterosk & Autocorrelation) for Panel - LFS and ONS Blue Book

	All industries				Manufacturing industries				Services industries			
Variable	Aggregate Labour		Decomposed Labour		Aggregate Labour		Decomposed Labour		Aggregate Labour		Decomposed Labour	
Obs	616		609		242		242		352		345	
constant	3.899***	4.139***	4.572***	4.46***	3.247***	2.302***	2.716***	2.399***	4.693***	4.561***	5.209***	4.513***
capital stock	0.254***	0.233***	0.196***	0.1896***	0.371***	0.425***	0.408***	0.374***	0.202***	0.182***	0.181***	0.207***
total hours	0.474***	0.467***			0.360***	0.430***			0.453***	0.485***		
basic hours			0.49***	0.4733***			0.404***	0.478***			0.418***	0.449***
paid overtime			-0.049***	-0.0222***			-0.025**	-0.006			-0.026***	-0.002
unpaid overtime			0.022	0.0353***			-0.0038	0.039*			0.005	0.020
YEAR												
2003		0.059***		0.054***		0.035***		0.036**		0.068***		0.066***
2004		0.081***		0.0795***		0.042**		0.045**		0.097***		0.097***
2005		0.125***		0.122***		0.093***		0.094***		0.138***		0.136***
2006		0.160**		0.16***		0.134***		0.139***		0.177***		0.176***
2007		0.196***		0.196***		0.169***		0.162***		0.214***		0.217***
2008		0.219***		0.218***		0.198***		0.215***		0.233***		0.233***
2009		0.208***		0.210***`		0.167***		0.168***		0.241***		0.243***
2010		0.252***		0.246***		0.219***		0.223***		0.277***		0.28***
2011		0.269***		0.254***		0.213***		0.243***		0.299***		0.298***
2012		0.293***		0.281***		0.258***		0.282***		0.326***		0.327***
		*p<.1		**p<.05	***p<.01							

Source: Quarterly Labour Force Survey and ONS Blue Book (2002-2012)

Table 2 - Effect on lgva Generalised Least Squares (Heterosk & Autocorrelation) for Panel BEFORE Crisis- LFS and ONS Blue Book

	All industries				Manufacturing industries				
Variable	Aggregate Labour		Decomposed Labour		Aggregate Labour		Decomposed Labour		Aggregate La
Obs	336		334		132		132		192
constant	3.7***	3.811***	4.17***	4.028***	2.599***	2.484***	2.27***	1.965***	4.217***
capital stock	0.225***	0.235***	0.23***	0.222***	0.344***	0.3***	0.44***	0.428***	0.197***
total hours	0.544***	0.516***			0.509***	0.607***			0.52***
basic hours			0.517***	0.533***			0.45***	0.484***	
paid overtime		-	0.116 ***	- 0.093 ***			- 0.063***	- 0.03*	
unpaid overtime			0.025	0.023			- 0.01027	0.038	
YEAR									
2003		0.066***		0.044***		0.051***		0.039***	
2004		0.096***		0.071***		0.075**		0.057**	
2005		0.137***		0.107***		0.123***		0.088***	
2006		0.18***		0.142***		0.174***		0.145***	
2007		0.22***		0.176***		0.196***		0.161***	
		*p<.1		**p<.05	***p<.01				

Source: Quarterly Labour Force Survey and ONS Blue Book (2002-2012)

Table 2 - Effect on lgva Generalised Least Squares (Heterosk & Autocorrelation) for Panel BEFORE Crisis- LFS and ONS Blue Book

	All industries				Manufacturing industries				Services industries			
Variable	Aggregate Labour		Decomposed Labour		Aggregate Labour		Decomposed Labour		Aggregate Labour		Decomposed Labour	
Obs	336		334		132		132		192		190	
constant	3.7***	3.811***	4.17***	4.028***	2.599***	2.484***	2.27***	1.965***	4.217***	4.124***	4.453***	3.614***
capital stock	0.225***	0.235***	0.23***	0.222***	0.344***	0.3***	0.44***	0.428***	0.197***	0.192***	0.222***	0.237***
total hours	0.544***	0.516***			0.509***	0.607***			0.52***	0.54***		
basic hours			0.517***	0.533***			0.45***	0.484***			0.49***	0.575***
paid overtime		-	0.116 ***	- 0.093 ***			- 0.063***	- 0.03*			- 0.085***	- 0.041***
unpaid overtime			0.025	0.023			- 0.01027	0.038			0.002	0.008
YEAR												
2003		0.066***		0.044***		0.051***		0.039***		0.081***		0.067***
2004		0.096***		0.071***		0.075**		0.057**		0.109***		0.094***
2005		0.137***		0.107***		0.123***		0.088***		0.16***		0.134***
2006		0.18***		0.142***		0.174***		0.145***		0.196***		0.172***
2007		0.22***		0.176***		0.196***		0.161***		0.241***		0.21***
		*p<.1		**p<.05	***p<.01							

Source: Quarterly Labour Force Survey and ONS Blue Book (2002-2012)

Table 3 - Effect on lgva Generalised Least Squares (Heterosk & Autocorrelation) for Panel AFTER Crisis- LFS and ONS Blue Book

	All industries				Manufacturing industries				Services industries			
Variable	Aggregate Labour		Decomposed Labour		Aggregate Labour		Decomposed Labour		Aggregate Labour		Decomposed Labour	
Obs	616		609		110		110		160		155	
constant	4.071***	4.004***	4.407***	4.209***	2.601***	2.493***	3.191***	2.975***	4.774***	4.506***	5.01***	4.239***
capital stock	0 .252***	0.251***	0.21***	0.219***	0.438***	0.435***	0.343***	0.373***	0.199***	0.193***	0.199***	0.246***
total hours	0.482***	0.482***			0.389***	0.413***			0.465***	0.515***		
basic hours			0.451***	0.456***			0.42***	0.404***			0.404***	0.442***
paid overtime			- 0.029***	- 0.019***			- 0.015	- 0.016			0.002	0.005
unpaid overtime			0.108***	0.118***			0.073**	0.088**			0.052**	0.084***
YEAR												
2009		- 0.0095		- 0.001		- 0.042***		- 0.062***		0.014**		0.02*
2010		0.033***		0.043***		0.018		- 0.007		0.043***		0.06***
2011		0.048***		0.052***		0.036**		0.025		0.067***		0.083***
2012		0.075***		0.082***		0.075***		0.06*		0.086***		0.111***
		*p<.1		**p<.05	***p<.01							

Source: Quarterly Labour Force Survey and ONS Blue Book (2002-2012)

Table 4 - Interpretation of GLS models (Years, Heterosk & Autocorrelation) for Panel

	Regression Cluster		% of Total Hours	Average lgva	GLS Coefficient - with year dummy	Significance	coeff. Towards lgva	Anti-logarithm [Exp(coeff twrds lgva)]	Hourly Contribution	Length of Working Day	10 hr working day product's contribution
ALL YEARS	All Industries	Total hours	1		0.467	***	4.369	78.998	£79.00	10hrs	£789.98
		Basic hours	0.923876		0.4733	***	4.428	83.794	*£90.70*	8hrs	*£725.59*
		Paid overtime	0.018222	9.3564	-0.022	***	-0.208	0.812	*£44.59*	2hrs	*£89.17*
		Unpaid overtime	0.057798		0.0353	***	0.330	1.391	*£24.07*	2hrs	*£48.15*
	Manufacturing	Total hours	1		0.43	***	3.847	46.837	*£46.84*	10hrs	*£468.37*
		Basic hours	0.920768		0.478	***	4.276	71.957	£78.15	8hrs	£625.19
		Paid overtime	0.027739	8.9458	-0.006		-0.053	0.949	£34.20	2hrs	£68.40
		Unpaid overtime	0.079166		0.039	*	0.349	1.417	£17.91	2hrs	£35.81
	Services	Total hours	1		0.485	***	4.678	107.545	£107.54	10hrs	£1,075.45
		Basic hours	0.929644	9.6452	0.449	***	4.331	75.996	£81.75	8hrs	£653.98
		Paid overtime	0.016293		0.0016		0.016	1.016	£62.36	2hrs	£124.71
		Unpaid overtime	0.053983		0.0205		0.197	1.218	£22.57	2hrs	£45.14
BEFORE CRISIS	All Industries	Total hours	1		0.516	***	4.802	121.795	£121.79	10hrs	£1,217.95
		Basic hours	0.923886		0.533	***	4.961	142.673	*£154.43*	8hrs	*£1,235.42*
		Paid overtime	0.022389	9.3069	-0.093	***	-0.866	0.421	*£18.80*	2hrs	*£37.59*
		Unpaid overtime	0.053805		0.023		0.214	1.239	*£23.02*	2hrs	*£46.04*
	Manufacturing	Total hours	1		0.607	***	5.417	225.226	*£225.23*	10hrs	*£2,252.26*
		Basic hours	0.915338		0.484	***	4.319	75.144	£82.09	8hrs	£656.75
		Paid overtime	0.032037	8.9244	-0.03	***	-0.268	0.765	£23.88	2hrs	£47.76
		Unpaid overtime	0.052704		0.038		0.339	1.404	£26.63	2hrs	£53.27
	Services	Total hours	1		0.54	***	5.052	156.403	£156.40	10hrs	£1,564.03
		Basic hours	0.923876	9.3564	0.575	***	5.380	217.002	£234.88	8hrs	£1,879.06
		Paid overtime	0.018222		-0.041	***	-0.384	0.681	£37.39	2hrs	£74.79
		Unpaid overtime	0.057798		0.008		0.075	1.078	£18.65	2hrs	£37.29
AFTER CRISIS	All Industries	Total hours	1		0.482	***	4.552	94.778	£94.78	10hrs	£947.78
		Basic hours	0.931652		0.456	***	4.306	74.144	*£79.58*	8hrs	*£636.67*
		Paid overtime	0.01517	9.443	-0.019	***	-0.179	0.836	*£55.09*	2hrs	*£110.19*
		Unpaid overtime	0.052921		0.118	***	1.114	3.047	*£57.58*	2hrs	*£115.17*
	Manufacturing	Total hours	1		0.413	***	3.705	40.657	*£40.66*	10hrs	*£406.57*
		Basic hours	0.928354		0.404	***	3.624	37.504	£40.40	8hrs	£323.18
		Paid overtime	0.021734	8.9714	-0.016		-0.144	0.866	£39.86	2hrs	£79.72
		Unpaid overtime	0.04964		0.088	**	0.789	2.202	£44.36	2hrs	£88.73
	Services	Total hours	1		0.515	***	5.023	151.807	£151.81	10hrs	£1,518.07
		Basic hours	0.932772	9.7526	0.442	***	4.311	74.490	£79.86	8hrs	£638.87
		Paid overtime	0.013129		0.005		0.053	1.054	£80.28	2hrs	£160.57
		Unpaid overtime	0.053845		0.084	***	0.819	2.269	£42.13	2hrs	£84.27

Looking at Table 4 (that summarises and interprets Table 1, 2 and 3) the first numerical column shows the percentage of each working-hour category over the total working hours. The 'Average *lgva*' shows the average natural logarithm of GVA produced by each cluster of industries/years. The 'FGLS coefficient – with year dummy' includes all the FGLS coefficients from the models that include a year dummy for each cluster, followed by the *level of significance* (* is for 10%, ** for 5% and *** for 1%). The 'coeff. Towards lgva' is the coefficient multiplied by the 'Average lgva' per cluster, followed up by its anti-logarithmic transformation. This brings the results back to the level-level scale, and the 'Hourly Contribution' is derived by dividing 'Antilogarithm' with the '% of Total Hours'. This gives the contribution of each

specific working-time category towards the production of GVA. Finally, the last two columns are showcasing an example of 10-hour working day's contribution if it is examined as a total or decomposed to its parts. In the last two columns, an employee can perform either paid or unpaid overtime, but not both.

Starting with the Aggregate Labour model, it is demonstrated that the average contribution of a working-hour in all UK industries is significantly higher than the average hourly wage, which is approximately £13 (See Appendix 14), leading to a surplus of approximately £65 per hour (£78.96–£13). Additionally, the Aggregate Labour models demonstrate differences between Manufacturing and Services with the former displaying a collapse in total labour contribution after crisis, while the latter manages to remain at the same standards.

Regarding the Decomposed Model, overall basic hours appear to have lower contribution compared to when working day is examined as a total. Despite that basic hour's contribution appears lower than total hours, they are still higher than the average hourly wage. With the lowest contribution of basic hours being £40.40 (Manufacturing after crisis) on average, and the average payment being around £13 per hour, this acts as further indication of the gap between employment and contribution.

Additionally, similar patterns to total labour are also observed in the decomposed labour. While the Manufacturing and Services Aggregate model show a large drop in total hours' contribution, the Decomposed model shows also something similar for the basic hours. The decomposed models per industry group also reveal that despite the collapse in basic hours' contribution, the overtime variables' contributions almost double after crisis. For the clustered models (manufacturing and services) paid overtime is statistically significant before crisis, while unpaid overtime is statistically significant after. This might justify the pre-crisis part of literature suggesting the non-productive role of unpaid overtime. This unpaid overtime's undeniable existence pre-crisis seemed to have continued post- crisis too. Nonetheless, this time its presence is permanent and productive both in Manufacturing and Services.

Regarding the specific effect of unpaid overtime, in most models appears statistically significant but mostly estimated to have a smaller contribution [not sure if this what you mean here] than basic paid hours. In most models, paid and unpaid overtime display lower returns as they possibly capture the wear and tear of labour (See Figures 3a,b and c). The gap between payment and contribution is slightly bigger with a basic hour offering a £77 surplus (£90.67–£13). With overtime being completely unpaid, £24.07 also added to the surplus. Although it is low, it remains higher than the average hourly payment. The only exemption where unpaid overtime appears to be accountable for more GVA than a basic hour is during post-crisis manufacturing.

Moreover, where paid overtime appears statistically significant, it is given a negative coefficient. This is not surprising if we take into account that all variables are in their logarithmic form, therefore a negative coefficient shows that a change of the independent variable will lead to a proportionally

smaller change. Interpreting the anti-logarithm by taking its exponent, gives an exact value of paid overtime's contribution with an average for all industries at £44.56 per hour. The contribution is still higher than its payment as in best cases paid overtime does not exceed the 1.5 of hourly basic payment.

An additional point regarding paid overtime is its significance as variable. Taking also into account the LASSO analysis, the variable reduction method shows that paid overtime is the variable that in every model is the first to be dropped as it carries the most correlated variation in the model.

Regarding the contribution of capital, the results display some differences between the aggregate and the decomposed labour. The decomposed models account for smaller capital contribution (except services and post-crisis manufacturing). There are also differences between models that include years and those that do not. One possible explanation could be that the year coefficient reflects productivity gains previously attributed to capital when the years were not included. The largest capital contributions and variations take place in Manufacturing industries and the smaller in Services. In All-industries and Manufacturing the total-labour model shows increased contribution after the outburst of crisis, while the decomposed a reduced one. In the services the changes in capital's contribution are similar before and after. Generally the decomposed labour model is more in accordance with existing literature of productivity. For instance, Harris and Moffat (2017) detected a reduced productivity of capital for Manufacturing, but a smaller one in Services, stressing that 'offsetting these effects, the capital stock increased slightly and there was a much smaller decline in employment compared to manufacturing, indicating that changes in factor inputs were less important in services'. Moreover, capital's lowered contribution to output is also explained by introducing year as a dummy variable. Year variable now captures part of the output growth originally attributable to capital. The constant coefficient becomes also higher now to counterbalance the change above.

Post-crisis results display a drop in coefficients, particularly for total labour hours (and basic hours in the decomposed model) and capital. This is in accordance to significant works on the UK puzzle. According to Harris and Moffat (2017), the so-called productivity puzzle was frequently discussed on the basis of labour productivity (measured as gross value added per worker), and not on the basis of Total Factor Productivity (TFP), which also explicitly captures the contributions of capital inputs. According to them, using firm-level UK panel data, average productivity levels under both single-factor, labour productivity and TFP declined significantly post-2008 and did not recover for the market-based economy. They also conclude that the loss in productivity is likely to be due to permanent rather than cyclical factors. Evidence of weak recovery in productivity in the UK is provided by other works too. Barnet et al. (2014) find that the proportion of firms with shrinking output and flat employment doubled from 11% in 2005-07 to 22% in 2011. Disney et al. (2013) also highlight that despite that post-recession, more people in employment but output remains below pre-recession levels. Or according to Patterson (2012) the 2008 post crisis productivity (output per

worker) is around 15% lower than in the early 1980s and 1990s, where productivity was more than 10% higher than at the start of the recession.

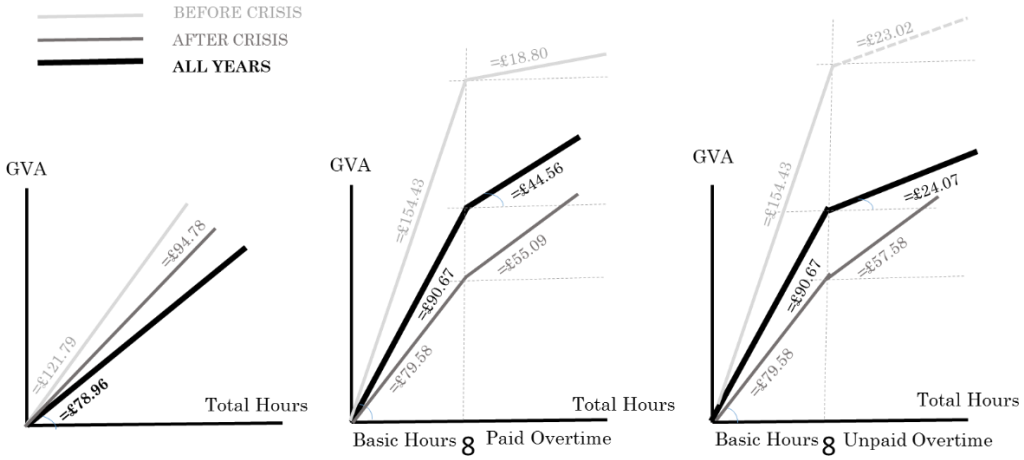

Figure 3 a– The Contribution of Working Hours towards GVA – Total and Decomposed (All Industries)

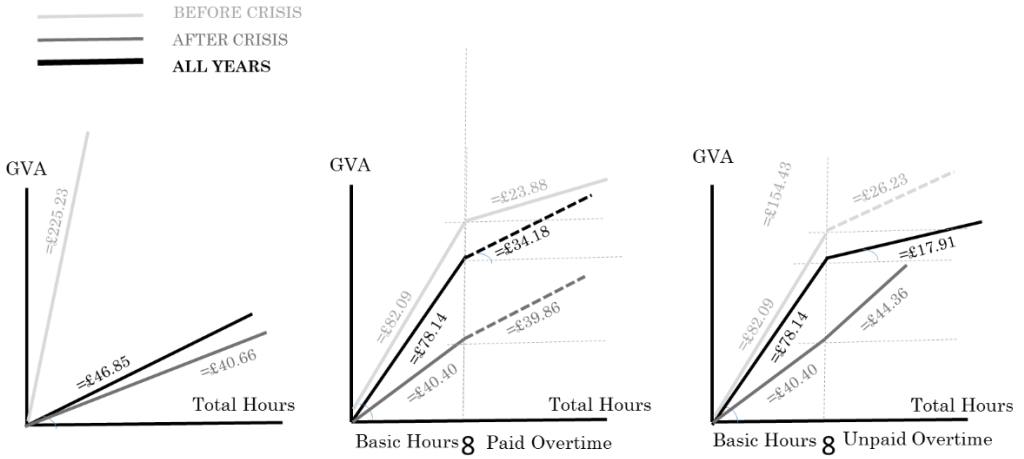

Figure 3 b– The Contribution of Working Hours towards GVA – Total and Decomposed (Manufacturing)

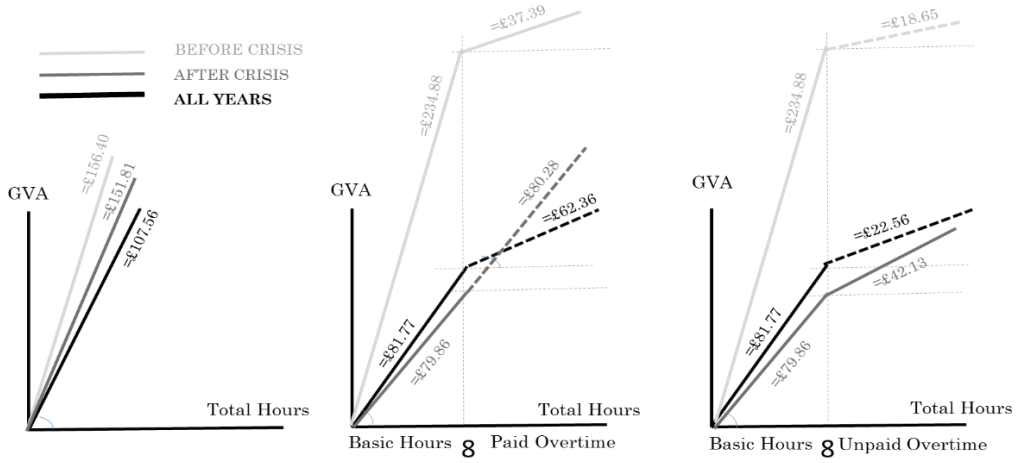

Figure 3 c– The Contribution of Working Hours towards GVA – Total and Decomposed (Services)

The above results demonstrate that, there are significant differences between labour contribution and its payment. In all cases total labour, basic hours, paid overtime and unpaid overtime's contributions to GVA are significantly higher relative to the average hourly wage in the UK. For the private sector this is particularly important, as it implies that the difference between contribution and wages either subsidises other factors of production or inflates private profits. For the publicly delivered services (e.g. health, reminding that education is exempted as outlier) this underpayment does not contribute to profits directly but could be interpreted as a measure of under-funding of public sector; instead of hiring more personnel to meet the public needs, these organisations rely on the extension of working day, particularly its unpaid part.

In this section we have detected a significant relationship between unpaid overtime and produced output in the UK industries. We have demonstrated that despite the connection, there is productivity loss attributable to the extension of working-time, particularly the unpaid one. In this sense, both claims for unpaid overtime's 'unproductive' use and employers' time-extension requests should be at least re-visited.

5 Discussion and Conclusion

The contributions of this paper are as follows: i) as unpaid overtime is detected still to be high (around 5% of total hours), ii) its post-crisis contribution to GVA is significant in contrast to the weak pre-crisis relationship, partially justifying theories that occasionally defended its 'unproductive' nature; iii) this contribution though productive, it is still less than the basic working hours, capturing the wear and tear of labour; iii) we finally show that only when we examine all industries together paid overtime's contribution to output is higher than when it is unpaid.

More specifically, taking into account the substantial gap between

average wages and working-time contributions over that period –and that between 2008 and 2018 real wages had frozen for Britons– the results are in agreement with the already detected patterns. These findings also concur with approaches claiming that technology and productivity growth do not necessarily reduce the length of the working day or increase employments' payment in a commensurate manner. Especially if we acknowledge that the production process is not a field of peaceful encountering between capital and labour. It is the existence of social relations within every industry, within every production unit, commanding that working hours determination are also the outcome of sociohistorical factors, bargaining, balance of forces in national and industrial level.

Moreover, our results raise questions on unpaid overtime's use by industries, when both kinds of overtime still do not reach the productivity of basic working hours, why do industries still relying on it? Two different responses can be provided here. First, extending working hours –instead of creating new jobs– is a more flexible strategy for companies to increase their production even with adverse effect on productivity. And this is a field for policy-makers to act. Second, relying on overtime –even when this does not provide the returns of basic hours– might accord well with approaches that have linked working day extension with employees' control.

This article also raises methodological questions on economists' use of wages as a proxy for labour productivity. As shown, wages substantially deviate from working-time contributions. The output-based measure of evaluating 'labour' is particularly useful as it incorporates output and working-time. Additionally, the use of working-time contributions emphasise that conventional measures of productivity 'per job', 'per employee' etc. may also mask or ignore other important factors, such as variations in the length of the working day. On this basis we propose this kind of 'labour valuation' as one that can be generated alongside existing conventional measures. This measure is of use to policymakers who truly prioritise restrictions in the length of working day. Undeniably, the reduction of working-week has obvious positive impact on employees' work-life balance. Even from an employer-orientated policy perspective, working-time restrictions are indeed demonstrated to be more productive. Consequently, as the above findings can offer a 'technical' basis that further contributes to the ongoing debate regarding the wage system, the length of working day, and labour productivity.

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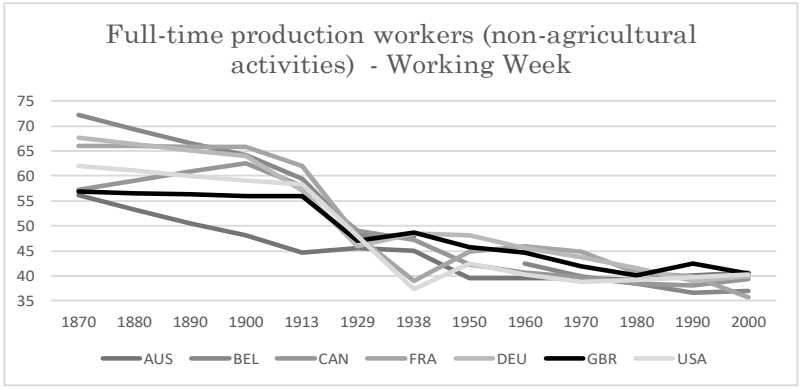
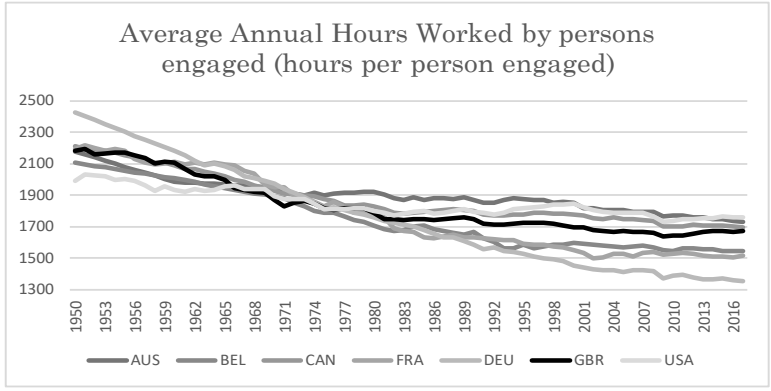
Appendices

Appendix 1 - Full-time production workers (non-agricultural activities) - Working Week



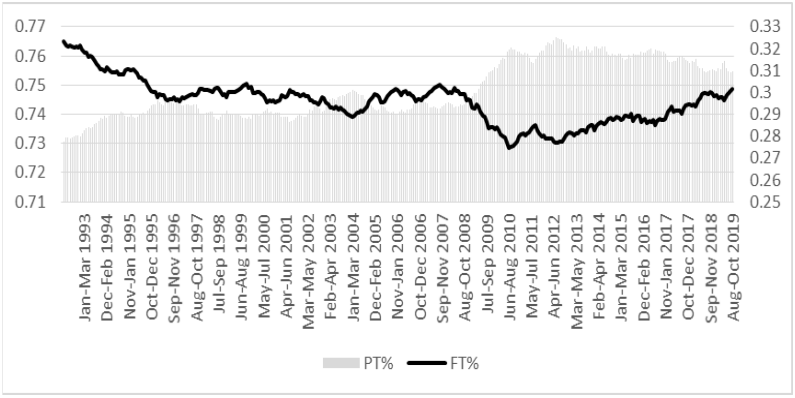
Source: Huberman and Minns (2007)

Appendix 2 – Annual Worldwide full time work hours – 1870-2000



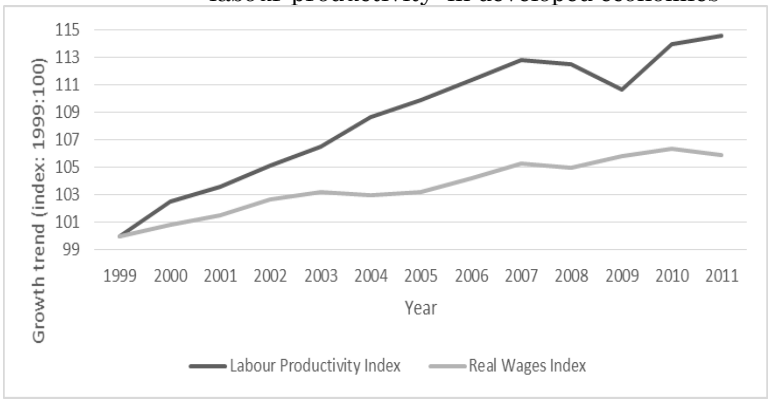
Source: Feenstra et al. 2015

Appendix 3– Weekly Part- time and Full-time hours in the UK



Source: Office for National Statistics, UK sector accounts, (2019)

Appendix 4 – Trends in growth in average wages and labour productivity in developed economies



Source: International Labour Organisation (2013)

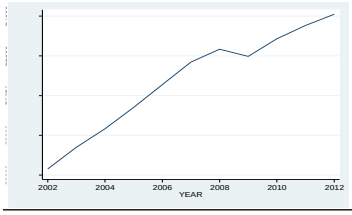
Appendix 5 - Standard Industrial Classification & Merged Industries

Article's industry code	SIC07	Description	Article's industry code	SIC07	Description
1	1	Crop and animal production, hunting and related ser	49	49	Land transport and transport via pipelines
2	2	Forestry and logging	50	50	Water transport
3	3	Fishing and aquaculture	51	51	Air transport
5	5	Mining of coal and lignite	52	52	Warehousing and support activities for transportation
	6	Extraction of crude petroleum and natural gas	53	53	Postal and courier activities
	7	Mining of metal ores	55	55	Accommodation
	8	Other mining and quarrying		56	Food and beverage service activities
	9	Mining support service activities	58	58	Publishing activities
10	10	Manufacture of food products	59	59	Motion picture, video and television programme
	11	Manufacture of beverages		60	Programming and broadcasting activities
	12	Manufacture of tobacco products	61	61	Telecommunications
13	13	Manufacture of textiles	62	62	Computer programming, consultancy & related activities
	14	Manufacture of wearing apparel		63	Information service activities
	15	Manufacture of leather and related products	64	64	Financial service activities, except insurance &pension funding
16	16	Manufacture of wood and of products of wood and cor	65	65	Insurance, reinsurance and pension funding, except compulsory socia
17	17	Manufacture of paper and paper products	66	66	Activities auxiliary to financial services and insurance activities
18	18	Printing and reproduction of recorded media	68	68	Real estate activities
19	19	Manufacture of coke and refined petroleum products	69	69	Legal and accounting activities
20	20	Manufacture of chemicals and chemical products		70	Activities of head offices; management consultancy activities
21	21	Manufacture of basic pharmaceutical products and p	71	71	Architectural & engineering activities; technical testing and analysis
22	22	Manufacture of rubber and plastic products	72	72	Scientific research and development
23	23	Manufacture of other non-metallic mineral products	73	73	Advertising and market research
24	24	Manufacture of basic metals	74	74	Other professional, scientific and technical activities
25	25	Ianufacture of fabricated metal products, except machiner		75	Veterinary activities
26	26	Manufacture of computer, electronic and optical proc	77	77	Rental and leasing activities
27	27	Manufacture of electrical equipment	78	78	Employment activities
28	28	Manufacture of machinery and equipment n.e.c.	79	79	Travel agency, tour operator & other reservation service &related
29	29	Manufacture of motor vehicles, trailers and semi-tra	80	80	Security and investigation activities
30	30	Manufacture of other transport equipment		81	Services to buildings and landscape activities
31	31	Manufacture of furniture		82	Office administrative, office support and other business
	32	Other manufacturing	84	84	Public administration and defence; compulsory social security
	33	Repair and installation of machinery and equipment	85	85	Education
35	35	Electricity, gas, steam and air conditioning supply	86	86	Human health activities
36	36	Water collection, treatment and supply	87	87	Residential care activities
37	37	Sewerage		88	Social work activities without accommodation
	38	Waste collection, treatment and disposal activities	90	90	Creative, arts and entertainment activities
	39	Remediation activities & other waste management		91	Libraries, archives, museums and other cultural activities
43	41	Construction of buildings		92	Gambling and betting activities
	42	Civil engineering	93	93	Sports activities and amusement and recreation activities
	43	Specialised construction activities	94	94	Activities of membership organisations
45	45	Wholesale &retail trade and repair of motor vehicles	95	95	Repair of computers and personal and household goods
46	46	Wholesale trade, except of motor vehicles and motor	96	96	Other personal service activities
47	47	Retail trade, except of motor vehicles			

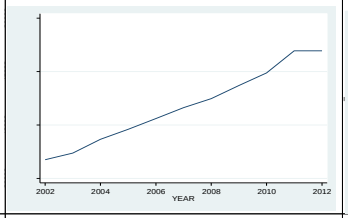
Source: ONS

Appendix 6 – Mean values of variables for all industries over the years

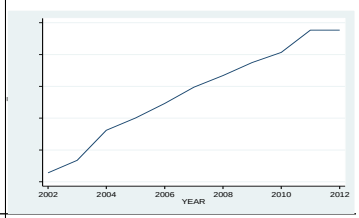
A. GVA - 10^6£ CVM



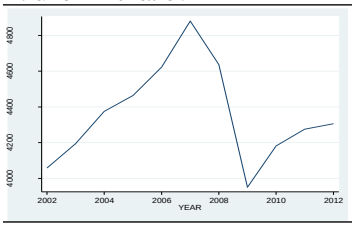
B. NCS – 10^6£ CVM



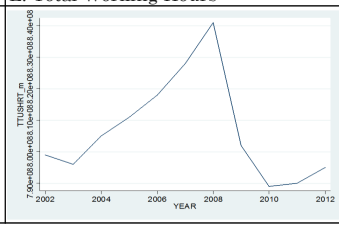
C. Capital consumption– 10^6£ CVM



D. GFCF – 10^6£ CVM



E. Total Working Hours



F. Basic Working Hours

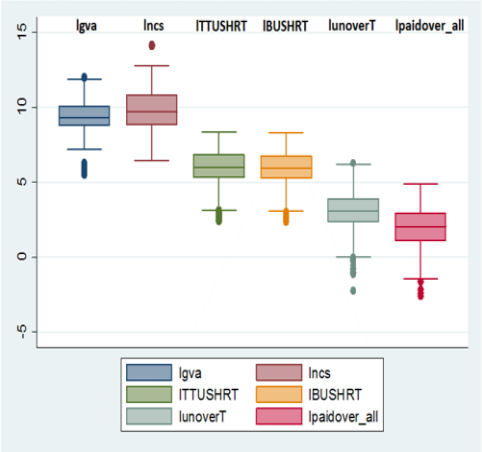
Source: ONS and LFS

Appendix 7 - Descriptive Statistics before dropping outliers - ONS and LFS

Variable		Obs	Mean	Std. Dev.	Min	Max
industry07	Standard Industrial Classification Code (SIC2007)	671			1	96
YEAR	Year	671			2002	2012
gfcf	Gross Fixed Capital Formation /1000000	671	4358.69	11500.4	-599	109000
gva	Gross Value Added /1000000	671	20770.6	24849.6	242	167000
gcs	Gross Capital Stock /1000000	671	103337	309992	1050	2590000
ncs	Net Capital Stock /1000000	671	61581.7	181504	624	1460000
capcons	Capital Consumption /1000000	671	41778.7	129109	305	1140000
ttuthrs	Total Usual Working Hours – Including Overtime /1000000	670	806.682	992.534	10.8	4300
bushrs	Basic Usual Working Hours – Excluding Overtime /1000000	670	745.274	915.067	10.2	4020
over	Overtime Hours /1000000	670	61.3156	83.5759	0.315	560
unover	Unpaid Overtime /1000000	670	46.6244	71.2709	0	531
paidover_all	All kinds of paid overtime//1000000	670	14.6992	19.5595	0	133.959
paidover1	Overtime hours paid equally to the basic hours/1000000	670	4.71053	8.9929	0	71.5
paidover2	Overtime hours paid more to the basic hours/1000000	670	9.31076	11.8343	0	96.9
paidover3	Overtime hours paid less to the basic hours/1000000	670	0.26741	0.73979	0	6.07019
paidover4	Overtime hours paid but in an unknown rate to the basic hours	670	0.41051	0.77256	0	6.28721
lgfcf	Natural Logarithm of gfcf	667	7.41933	1.32825	2.99573	11.5991
lgva	Natural Logarithm of gva	671	9.35636	1.15272	5.48894	12.0258
lgcs	Natural Logarithm of gcs	671	10.3804	1.42471	6.95655	14.7672
lncs	Natural Logarithm of ncs	671	9.83808	1.45775	6.43615	14.194
lcapcons	Natural Logarithm of capcons	671	9.46109	1.42604	5.72031	13.9465
lTTUSHRT	Natural Logarithm of ttuthrs	670	6.00535	1.25886	2.37955	8.36637
lBUSHRT	Natural Logarithm of bushrs	670	5.92608	1.25914	2.32239	8.29904
loverT	Natural Logarithm of over	670	3.38988	1.30515	-1.15518	6.32794
lunoverT	Natural Logarithm of unover	669	3.05293	1.34878	-2.2538	6.27476
lpaidover	Natural Logarithm of paidover_all	670	2.68779	2.97346		4.89753

Appendix 8 - Outlier industries over the years & Box-Plot - Outlier industries

Gross Value Added (GVA)	Net Capital Stock (NCS)	Total Working Hours (ttuthrs)	Basic Working Hours (bushrs)	Overtime Hours (over)	Unpaid Overtime (unover)
2(2012)	2(2006)	3(2004)	3(2004)	2(2011)	3(2011)
2(2011)	2(2002)	3(2005)	3(2009)	2(2007)	3(2005)
2(2002)	2(2003)	3(2009)	3(2005)	2(2004)	2(2011)
2(2003)	2(2005)	3(2003)	3(2012)	3(2004)	2(2004)
2(2004)	2(2004)	3(2011)	3(2011)	2(2012)	50(2010)
68(2009)	68(2008)	47(2003)	47(2005)	85(2004)	85(2004)
68(2008)	68(2009)	47(2005)	47(2006)	85(2005)	85(2007)
68(2010)	68(2010)	47(2004)	47(2007)	85(2003)	85(2003)
68(2011)	68(2011)	47(2007)	47(2004)	85(2007)	85(2007)
68(2012)	68(2012)	47(2008)	47(2008)	85(2002)	85(2002)



Appendix 9 - Correlation Analysis

	Gross Value Added	Capital Stock	Total Hours	Basic Hours	Overtime	Unpaid Overtime	Paid overtime 1	Paid overtime 2	Paid overtime 3	Paid overtime 4
Gross Value Added	1.000									
Capital Stock	0.633	1.000								
Total Hours	0.831	0.599	1.000							
Basic Hours	0.828	0.598	1.000	1.000						
Overtime	0.836	0.591	0.965	0.959	1.000					
Unpaid Overtime	0.850	0.523	0.951	0.947	0.977	1.000				
Paid overtime 1	0.502	0.487	0.795	0.792	0.793	0.713	1.000			
Paid overtime 2	0.590	0.627	0.661	0.654	0.737	0.592	0.590	1.000		
Paid overtime 3	0.370	0.209	0.525	0.522	0.540	0.476	0.641	0.422	1.000	
Paid overtime 4	0.526	0.485	0.582	0.578	0.620	0.560	0.501	0.575	0.402	1.000

Appendix 10 - Pooled OLS – Translog- LFS and ONS Blue Book

Variables\Model	All industries		Manufacturing		Services	
Obs	609		242		345	
constant	- 3.385**	- 3.124**	-2.787311	-2.927405	- 5.667***	- 5.275***
capital stock	1.109***	1.083***	1.87***	1.89***	1.954**	1.906***
basic hours	2.709***	2.61***	0.4417837	0.5200044	2.386***	2.199***
unpaid overtime	- 1.955***	- 1.867***	-0.9574563	-1.033676	- 2.186***	- 1.976***
paid overtime	- 0.441**	- 0.382*	-0.4089742	-0.3519953	- 0.547*	-0.438
capital stock^2	0.021414	0.021925	- 0.164***	- 0.162***	- 0.088***	- 0.088***
paid overtime^2	-0.029913	-0.0182	0.0492145	0.0873704	-0.031619	-0.02492
capital st.*basic hrs	- 0.564***	- 0.556***	-0.0648667	-0.110417	- 0.53***	- 0.495***
capital st.*unpaid ov.	0.410365	0.401***	0.2130236	0.26*	0.458***	0.418***
basic hrs *unpaid ov.	0.133**	0.132**	0.1025377	0.0851371	0.157**	0.147*
basic hrs *paid ov.	0.102788	0.083068	0.1576338	0.1549996	0.214	0.155556
unpaid ov.*paid ov.	0.012402	0.025148	-0.1779446	-0.1975335	-0.112891	-0.04889
2003		0.046264		0.066569		0.046212
2004	-	0.070241	-	0.0934264	-	0.089962
2005	-	0.114858	-	0.128247	-	0.16*
2006	-	0.136*	-	0.169*	-	0.174*
2007	-	0.171**	-	0.205**	-	0.219**
2008	-	0.1991**	-	0.275***	-	0.202**
2009	-	0.171**	-	0.233**	-	0.227**
2010	-	0.204**	-	0.273***	-	0.252**
2011	-	0.195**	-	0.269***	-	0.247**
2012	-	0.244***	-	0.289***	-	0.301***
crisis	-	-	-	-	-	-
adj.Rsquare	0.8063	0.8085	0.8418	0.8455	0.813	0.8166
Diagnostic Tests						
VIF	811.870	432.000	1133.480	615.230	801.490	429.710
hettest (p-value)	0.850	0.946	0.043	0.033	0.224	0.057
hettest, rhs(p-value)	0.000	0.000	0.000	0.000	0.000	0.000
estat imtest, white(p-v	0.000	0.068	0.000	0.008	0.000	0.293
ovtest(p-value)	0.325	0.516	0.073	0.153	0.000	0.001

*p<.1 **p<.05 ***p<.01

Appendix 11 - Pooled OLS - LFS and ONS Blue Book (All Years)

	All industries				Manufacturing industries				Services industries			
Variable	Aggregate Labour		Decomposed Labour		Aggregate Labour		Decomposed Labour		Aggregate Labour		Decomposed Labour	
Obs	616		609		242		242		352		345	
constant	3.791***	3.602***	3.872***	4.068***	2.835***	2.675***	3.066***	3.435***	4.352***	4.15***	4.420***	4.643***
capital stock	0.249***	0.244***	0.272***	0.261***	0.389***	0.383***	0.372***	0.359***	0.188***	0.183***	0.205***	0.195***
total hours	0.520***	0.527***			0.421***	0.433***			0.539***	0.544***		
basic hours			0.388***	0.309***			0.344***	0.224***			0.412***	0.318***
paid overtime			- 0.197 ***	- 0.159 ***			- 0.150**	- 0.089***			- 0.169***	- 0.124***
unpaid overtime			0.297***	0.348***			0.247***	0.323***			0.28***	0.334***
YEAR												
2003		0.069		0.056		0.039		0.047		0.085		0.069
2004		0.107		0.083		0.069		0.067		0.127		0.106
2005		0.149*		0.113		0.099		0.077		0.179		0.165
2006		0.195**		0.121		0.155		0.116		0.213*		0.242**
2007		0.231***		0.182**		0.179*		0.153		0.261**		0.234**
2008		0.263***		0.214***		0.207*		0.235**		0.285**		0.219**
2009		0.250***		0.162**		0.180*		0.167		0.296***		0.266**
2010		0.296***		0.202**		0.232**		0.198*		0.328***		0.237**
2011		0.315***		0.182**		0.240**		0.207*		0.358***		0.298***
2012		0.337***		0.259***		0.249**		0.264**		0.386***		0.323***
Adj R-sq	0.733	0.742	0.779	0.781	0.796	0.798	0.815	0.815	0.737	0.747	0.777	0.780
VIF	1.31	1.74	8.67	4.08	1.36	1.75	7.99	4.14	1.47	1.76	8.06	3.84
hettest	0.379	0.504	0.138	0.159	0.0005	0.0002	0.0001	0.0002	0.6113	0.2668	0.6616	0.9092
hettest, rhs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0031	0.3203	0.0695	0.5275
estat imtest	0.000	0.117	0.000	0.031	0.000	0.0001	0.000	0.002	0.045	0.997	0.0277	0.9843
ovtest	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0004	0.0077	0.0068	0.0125
		*p<.1		**p<.05	***p<.01							

Source: Quarterly Labour Force Survey and ONS Blue Book (2002-2012)

Appendix 12 - Pooled OLS - LFS and ONS Blue Book (Before Crisis)

	All industries				Manufacturing industries				Services industries			
Variable	Aggregate Labour		Decomposed Labour		Aggregate Labour		Decomposed Labour		Aggregate Labour		Decomposed Labour	
Obs	336		336		132		132		192		345	
constant	3.684***	3.602***	4.016***	4.096***	2.661***	2.574***	3.066***	3.062***	4.16***	4.033***	4.787***	4.953***
capital stock	0.245***	0.242***	0.27***	0.265***	0.394***	0.39***	0.388***	0.384***	0.176***	0.174***	0.196***	0.191***
total hours	0.533***	0.536***			0.432***	0.439***			0.575***	0.575***		
basic hours			0.314***	0.273***			0.296**	0.26*			0.279**	0.203
paid overtime			- 0.19***	- 0 .168***			- 0.146**	- 0.114***			- 0.138***	- 0.109***
unpaid overtime			0.378***	0.404***			0.312***	0.32**			0.406***	0.455***
YEAR												
2003		0.067		0.057		0.039		0.047		0.086		0.074
2004		0.107		0.082		0.069		0.065		0.127		0.111
2005		0.15*		0.113		0.1		0.07		0.179*		0.175*
2006		0.195**		0.121		0.156		0.107		0.213**		0.174*
2007		0.232***		0.182**		0.18*		0.146		0.26**		0.258***
Adj R-sq	0.7538	0.758	0.7941	0.7949	0.8297	0.8298	0.8415	0.8384	0.7648	0.7686	0.8037	0.8072
VIF	1.31	1.56	11.75	6.31	1.36	1.59	15.14	7.95	1.49	1.62	10.12	5.63
hettest	0.7884	0.8929	0.3079	0.3278	0.0194	0.0145	0.008	0.0108	0.7445	0.5962	0.3466	0.3832
hettest, rhs	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.1685	0.7114	0.0929	0.4017
estat imtest	0.003	0.3525	0.000	0.053	0.000	0.0017	0.000	0.000	0.1808	0.9715	0.0406	0.8065
ovtest	0.001	0.004	0.001	0.001	0.000	0.000	0.000	0.011	0.007	0.042	0.0055	0.0163
		*p<.1		**p<.05	***p<.01							

Source: Quarterly Labour Force Survey and ONS Blue Book (2002-2012)

Appendix 13 - Pooled OLS - LFS and ONS Blue Book (After Crisis)

	All industries				Manufacturing industries				Services industries			
Variable	Aggregate Labour		Decomposed Labour		Aggregate Labour		Decomposed Labour		Aggregate Labour		Decomposed Labour	
Obs	280		275		110		110		160		155	
constant	3.927***	3.899***	4.314***	4.356***	3.004***	2.987***	4.114***	4.185***	4.602***	4.559***	4.665***	4.697**
capital stock	0.247***	0.247***	0.258***	0.258***	0.376***	0.376***	0.331***	0.329***	0.192***	0.191***	0.202***	0.201***
total hours	0.516***	0.517***			0.426***	0.426***			0.51***	0.511***		
basic hours			0.321***	0.312***			0.173	0.16			0.399**	0.386***
paid overtime			-0.151***	-0.149***			-0.07	-0.07			-0.137***	-0.132***
unpaid overtime			0.317***	0.325***			0.347***	0.36***			0.241**	0.249**
YEAR												
2009		-0.0129		-0.05		-0.027		-0.067		0.010		-0.015
2010		0.033		-0.01		0.024		-0.036		0.042		0.023
2011		0.052		-0.028		0.032		-0.027		0.072		0.002
2012		0.07		0.046		0.041		0.035		0.100		0.082
Adj R-sq	0.723	0.720	0.763	0.761	0.769	0.761	0.793	0.787	0.720	0.714	0.743	0.738
VIF	1.320	1.510	7.990	4.880	1.380	1.530	6.900	4.350	1.450	1.550	7.310	4.560
hettest	0.343	0.336	0.158	0.192	0.005	0.004	0.007	0.006	0.412	0.357	0.943	0.809
hettest, rhs	0.000	0.001	0.000	0.002	0.000	0.000	0.000	0.000	0.024	0.270	0.364	0.801
estat imtest	0.001	0.228	0.016	0.451	0.000	0.010	0.002	0.083	0.333	0.990	0.724	0.993
ovtest	0.001	0.001	0.001	0.001	0.007	0.008	0.000	0.000	0.070	0.094	0.215	0.279
		*p<.1		**p<.05	***p<.01							

Source: Quarterly Labour Force Survey and ONS Blue Book (2002-2012)

Appendix 14 Average UK Hourly wage (assuming 37.5 hours week)

Source dataset: ONS, 2018, Time series: LMSB SA AWE total pay
WE Average Weekly Earnings time series dataset (EMP)