Barristers and Baristas: A Study of Working Hours and Occupations

Rachel Scarfe

University of Stirling *

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Abstract

This paper documents long-run structural changes in part-time work and develops a theoretical model that can explain them. I show that the quantity of part-time work has risen substantially, driven not only by a growing share of workers in part-time employment but also by a shift toward longer weekly hours among part-time workers. However, over the same period, the hourly wage gap between part- and full-time workers has narrowed, as the relative price of part-time work has increased.

To interpret these seemingly contradictory trends, I develop a model in which production consists of tasks that arrive stochastically and are costly to postpone to the next week. Applying results from queueing theory, I show that variation in task length and postponement costs endogenously generate convex earnings–hours relationships in some 'greedy' occupations. In equilibrium, workers with higher disutility of labour, particularly women with time constraints, sort into occupations where they can work fewer hours, but for lower hourly pay. The model provides a new micro-foundation for convex earnings–hours schedules and the effects of structural change on working hours.

*Economics Division, Stirling Business School, University of Stirling, UK (email: rachel.scarfe@stir.ac.uk).
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1 Introduction

The study of labour supply and working hours is as old as economics itself. As early as the seventeenth century, William Petty remarked that the labour supply curve could bend backwards at low incomes (Hatcher, 1998). With industrialisation, average weekly hours in the UK rose sharply, peaking at around 66 hours in 1830. By then, Adam Smith was already warning that working excessive hours reduced productivity: "the man who works so moderately as to be able to work constantly not only preserves his health the longest, but, in the course of the year, executes the greatest quantity of work" (Smith, 1776).

It was when women began to enter the labour force during the two World Wars that the formal idea of part-time work entered public discourse, as a way of enabling women with children to contribute to the war effort. After World War II, most women returned to home production, but by the 1960s labour shortages led governments to encourage part-time working again (Dale and Holdsworth, 1998). In the UK, for example, the percentage of women aged 20 to 64 with a job who were working part-time (the 'part-time share') increased from 16% in 1951 to 52% in 1991 (Bryson et al., 2021). This increase in women working part-time has attracted much academic attention (see Connolly and Gregory (2008), Hirsch (2005b), Manning and Petrongolo (2008) and Matteazzi et al. (2014)). Male part-time employment, by contrast, remains rare, although the male part-time share has increased slowly since the 1980s.[1]

The first contribution of this paper is to document structural changes in part-time work. Conditional on working part-time, weekly hours have increased: very short-hour arrangements (under 10 hours) have become less common, while a larger share of part-time workers now work between 21 and 30 hours per week. Turning to wages, I document a strong positive relationship between hourly pay and weekly hours. On average, part-time workers earn about 20–30% less per hour than full-time workers. However, this part-time pay penalty has fallen steadily since the 1990s, reversing the earlier increase in the penalty observed by Manning and Petrongolo (2008) and Harkness (1996). This decline persists after controlling for differences in worker and job characteristics. The penalty is roughly constant across the part-time hours range, so that workers doing 10 hours per week earn similar hourly wages to those working 25 hours, but there is a sharp discontinuity in hourly wages between 30 and 35 hours, marking the full-time threshold.

Together, these facts point to long-term structural change in both the quantity and the relative price of part-time work, beyond cyclical variation. However, observing equilibrium quantities and prices does not reveal whether these trends are driven by workers' preferences over working hours or by firms' production technologies. This distinction is central to understanding women's time use, as they are more sensitive to scheduling constraints created by production technology. Many labour-supply models assume earnings are linear in hours, implying constant hourly wages; such models cannot explain or predict the effects of policies such as childcare subsidies, parental-leave reforms, or limits on long hours when wages are nonlinear in hours.

From a policy perspective, knowing whether changes in part-time work are driven by technology or preferences has direct implications for gender equality and the allocation

[1] For example, between 1994 and 2010 the male part-time share nearly doubled, from 7% to 13%, with most of the increase concentrated among lower-wage workers (Belfield et al., 2017; Blundell et al., 2018).

of women's time across market and home production. The overall gender earnings gap is larger because women are more likely to work part-time and because part-time jobs pay lower hourly wages (Blau and Kahn, 2017). Policies that reduce the part-time pay penalty or expand the availability of high-quality part-time roles therefore have the potential to improve women's labour-market outcomes and facilitate their reallocation of time towards paid work.

Despite the importance of this question, there are few theoretical models explaining why earnings in some occupations are nonlinear in hours, and why part-time work is concentrated in some, lower-wage, occupations. Previous work has taken the nonlinearity as exogenous, assuming, for instance, lower productivity below a minimum hours threshold (Card, 1990) or imperfect substitutability between full- and part-time workers (Kang et al., 2020; Lariau, 2018). Other research assumes complementarities between workers (Battisti et al., 2020; Yurdagul, 2017; Rogerson, 2011; Cubas et al., 2023), which can generate bunching at full-time hours but cannot explain the observed coexistence of full- and part-time work alongside a declining part-time pay penalty.

The second contribution of this paper is to develop a model that fills this gap by applying methods from operations research and queueing theory to the study of occupations and working hours. The core idea is that production within an occupation consists of completing a stream of tasks, of stochastic length, that arrive during the working week. Occupations differ in two dimensions: (1) the variance in the length of time it takes to complete each tasks. This reflects whether tasks are homogeneous (as in routine service sector occupations) or highly variable (as in non-routine service sector occupations); and (2) the cost incurred when a task remains unfinished and must be postponed to the next week.

Applying results from queueing theory, I show that in this environment, the expected weekly output of a worker is a convex function of weekly hours whenever the length of tasks in an occupation is variable or when there is a loss in productivity if tasks are postponed. Intuitively, longer hours reduce the probability that a task is interrupted and thus raise effective productivity. When tasks are short and homogeneous, expected output is linear in hours. In equilibrium, this implies that earnings functions differ across occupations: in low-variance or low-cost occupations, earnings are linear in hours; while in high-variance or high-cost occupations, earnings are convex in weekly working hours. These high-variance occupations are the 'greedy jobs', defined by Goldin (2021), which reward longer hours and availability to firms.

Workers choose occupations given these earnings schedules. Those with a high disutility of labour, in particular women with caring responsibilities, sort into linear (low-skill service) occupations, while workers with a lower disutility of labour choose convex (high-skill or manufacturing) occupations. The equilibrium therefore reproduces four key empirical facts: (1) the coexistence of full- and part-time work within the same labour market; (2) higher hourly wages for full-time workers (the part-time pay penalty); (3) bunching of workers at full-time hours; and (4) the concentration of workers with high disutility of labour (particularly women) working part-time in low-skill service occupations. Technological change affects this equilibrium in two ways: reducing the relative productivity of manufacturing, which workers into low-hour service occupations and flattening task-length distributions or lowering postponement costs, which diminishes convexity and the part-time pay penalty. The framework thus provides a micro-foundation for the structural decline in the pay penalty and the rise in part-time work observed in the data.

The model is related to those in Goldin (2014), Bick et al. (2022), Erosa et al. (2016), and Jang and Yum, 2022, who consider the implications of nonlinear earnings–hours relationships for labour supply and occupational choice. This paper provides a micro-foundation for this non-linearity, derived from the task structure discussed above, rather than imposed exogenously. It is also related to the work of Coviello et al. (2014) and Coviello et al. (2015), who also model production as a stream of tasks, and show that it is optimal for workers to complete one task at a time.

I test the implications of the model using data from O*NET on the task composition of occupations. The model predicts that occupations characterised by more homogeneous, short-duration tasks will exhibit a higher part-time share and lower part-time pay penalty, while occupations involving complex or interdependent tasks exhibit a lower part-time share and higher part-time pay penalty.To test this hypothesis, I reduce the large number of types of task in the O*NET data into three latent factors: (1) Customer-service Tasks, which typically involve short interactions; (2) Information (i.e. analytical) Tasks, which often require extended, uninterrupted work and involve higher postponement costs; (3) Management Tasks, which depend on continuous oversight and decision-making across multiple projects or workers; and (4) Technical Tasks such as maintenance, repair, production monitoring, or technical installation, that often depend on specific equipment. These tasks often have high postponement costs, as incomplete work can delay production.

I find that occupations with a greater emphasis on customer-service tasks have significantly higher part-time employment shares. In contrast, occupations with higher requirements for information or management tasks (in which one worker cannot easily be substituted for another) have a higher part-time pay penalty and lower part-time shares. These relationships persist after controlling for worker characteristics and taking account of unobserved sorting of workers into occupations and working hours patterns. This evidence supports the model's mechanism: differences in the structure of tasks help explain why part-time work is concentrated in some occupations, and why the part-time pay penalty varies across occupations.

The rest of the paper proceeds as follows. Section 2 documents the empirical facts motivating the analysis. Section 3 sets out the theoretical model. Section 4 discusses the empirical analysis of occupations and tasks. Section 5 concludes.

2 Trends in working hours

In this section I describe the differences in part- and full-time workers and jobs, and how they have changed since the 1990s. I focus on two areas: the quantity of part-time work (both in the percentage of workers in part-time work and in their weekly hours of work) and the relative price (hourly wage) of part-time work compared to full-time work. Both the aggregate quantity and the average price of part-time work have changed substantially over this period. I also consider gender differences in part-time work, and show that the trends in part-time work have been very different for men and women.

There is no legal definition of part-time work in the UK, although the government states that someone who works less than 35 hours per week is usually considered part-time (UK Government, 2022). However, some benefits, such as the Working Tax Credit, define full-

time work to be above 30 hours. In my analysis I define part-time workers as those usually working 30 hours a week or fewer. There is a sharp increase in the share of respondents who describe themselves as part-time workers (from 47% of those usually working 30 hours a week to 85% of those working 29 hours a week) suggesting that 30 hours per week is a salient threshold in how workers classify their employment status.

I use data from the UK's Labour Force Survey (LFS), published by the Office for National Statistics (ONS). The LFS is a quarterly household survey, covering approximately 37,000 households, and covers the employment and personal characteristics of all individuals in a household. I provide more detail about the data in Appendix A.

I use data from the period 1994 to 2019, to avoid considering the effects of the Covid pandemic. In Appendix B I discuss UK Government policy regarding working hours over this time period. Policies have aimed to increase labour supply and flexibility, particularly through equal treatment for part-time workers and expanded rights to request flexible work. Meanwhile, in-work benefits like the Working Families Tax Credit have increased earnings for those working at least 16 and 30 hours a week, leading to bunching in hours at these thresholds (see Figure E.3 in Appendix E).

2.1 Changes in the quantity of part-time work

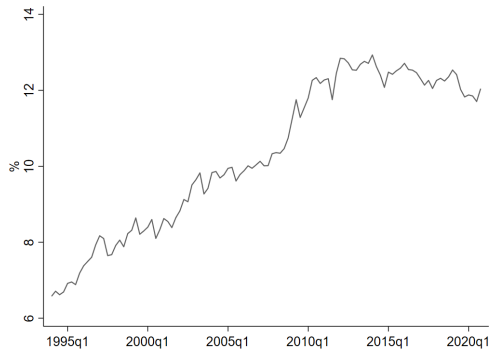
Historically, part-time work was a female phenomenon. However, there is evidence that this is changing. As Figure 1 shows, whilst the female part-time share decreased slightly between 1994 and 2009, the male part-time share increased from 11% to over 18%. The net result has been a slight increase in the overall part-time share, from 30% in 1994 to a peak of 34% in 2010. Over the same period, the percentage of the total male working-age population working full-time remained relatively stable (although it decreased during the financial crisis), suggesting that some of the long term increase in male part-time work may have come from men who previously would not have worked at all, rather than from those who would have previously worked full-time. The percentage of all working-age women working full-time increased slowly until the financial crisis, before falling from 2010 to 2012, and has increased sharply since then (see Figure E.4 in Appendix E).

As well as changes in the number of part-time workers, there have also been changes in their working hours, conditional on working part-time. Across Europe, the percentage working very long hours (generally defined as more than 48 hours per week, in line with the European Working Time Directive) has fallen since the mid 1990s (Messenger, 2010). However, conditional on working part-time, hours have actually *increased*. Figure 2 below shows the proportion of part-time workers doing 1-10, 11-20 and 21-30 hours. There has been a clear decline in the proportion working a very low number of hours per week, and a clear increase in the proportion working 21-30 hours per week. This pattern holds for both men and women, despite the different trends in male and female part-time work discussed above.[2]

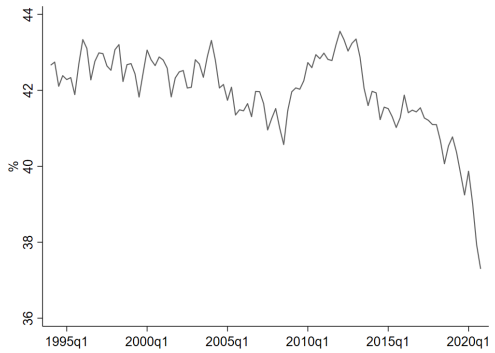
[2] To confirm that this increase was not driven by workers affected by the policy changes described above, in particular the introduction of working tax credits, I repeat this analysis using only the respondents in the upper quartile of the hourly wage distribution, who are unlikely to be eligible for such transfers. The pattern of changes is the same, suggesting that the observed increase is not solely due to the tax schedule. In addition, the increase in the percentage of part-time workers doing 21 to 30 hours shown in Figure 2c has happened steadily, rather than in the year or two following policy changes.

Figure 1: Part-time workers (as % of working population)

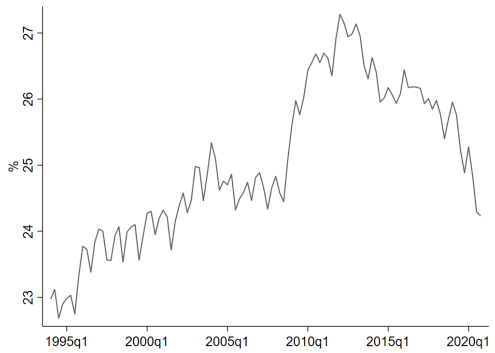
(a) Male



(b) Female



(c) All



Source: LFS

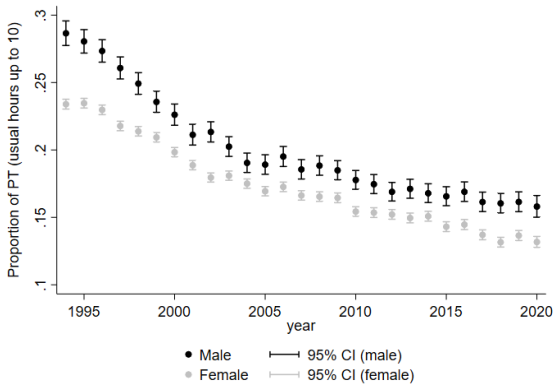
As a result of the decline in very long hours, and the increase in hours conditional on working part-time, the proportion of total hours done by part-time workers,the 'part-time share of all hours' has increased. In 1994 Q1, 16.7% of all working hours were done by part-time workers. By 2013 Q1 this figure had increased to a high of 21.9%, and remained at approximately at this level until 2019. Here the gender differences have become clear since the financial crisis; whilst the male part-time share of all hours for men has continued to grow, the opposite has happened for women. I show the 'part-time share of all hours' in Figure E.5.

One possibility is that these changes are due to structural changes in the distribution of occupations. Part-time work is heavily concentrated in certain occupations, particularly service occupations. It is also concentrated in occupations with lower skill requirements.

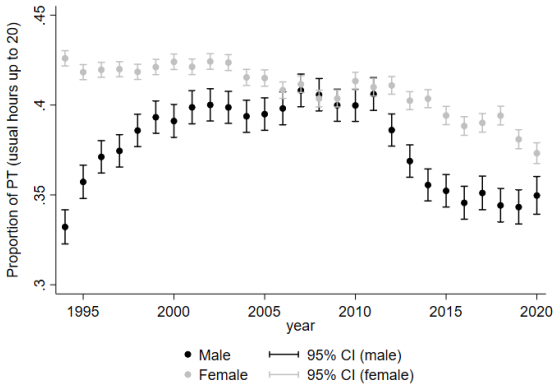
If it is the case that working hours within different occupations are constrained, then a change in the distribution of occupations may be the reason for the observed trends in part-time work. As Goos and Manning (2007), amongst others, explain, since the 1980s there has been an increase in low-wage service and unskilled jobs and in high-wage service and finance jobs. At the same time, there has been a decline in manafacturing jobs, which tend to be in the middle of the wage distribution. This phenomenon is known as job polarisation. If, for some reason, some of these growing jobs are more likely to be part-time, as suggested by the evidence above, then this may explain some of the increase in part-time work.

Figure 2: Trends in the distribution of part-time workers by usual weekly working hours

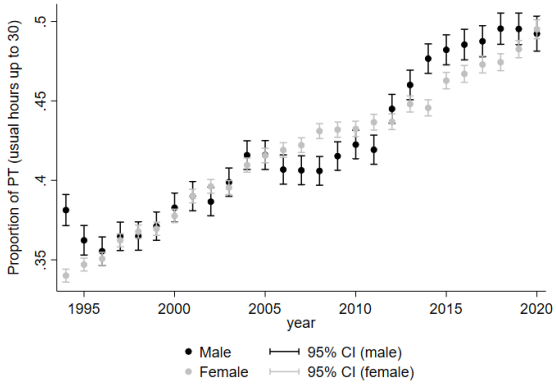
(a) Usual weekly hours 1-10



(b) Usual weekly hours 11-20



(c) Usual weekly hours 21-30



Source: LFS.

To test this hypothesis, I carry out a shift share analysis. This shows that approximately a third of the increase in the male part-time share has been due to an increase in employment in industries and occupations which have historically had a higher part-time share. The remaining two-thirds is due to more men working part-time within each industry and occupation. This contradicts to some extent the findings of Borowczyk-Martins and Lalé (2019) who find that changes in the composition of jobs by industry and occupation did not contribute to the increase in part-time work during the financial crisis. However, they compare the period before and after the financial crisis, rather than analysing the cumulative increase in part-time work over a period of time. For women, the pattern is less clear. Since 2000, there has been a decrease in female employment in jobs that have historically had a high part-time share. In other words, women moved away from service sector jobs and towards jobs with a lower part-time share. However, between 2000 and 2010, for women there was actually an increase in the part-time share within occupations. After the financial crisis the female part-time share within occupations fell. To summarise, while part-time work is strongly associated with certain occupations and their skill requirements, the changes in part-time work described above are not solely the result of changes in the distribution of workers across occupations.

2.2 Changes in the relative wages for part-time work

Alongside the increase in the part-time share of all hours, there has also been a steady decrease in the part-time pay penalty (PTPP). To estimate the average PTPP in year t I estimate the following model using OLS

$$\log w_{it} = X_{it}\gamma + \beta_t PT_{it} + \epsilon_{it}. \tag{1}$$

where w_{it} is the hourly wage, and X_{it} is a vector of controls, including a constant. PT_{it} is a dummy variable equal to one if an individual works part-time in year t. The coefficient of interest is β_t, which I allow to vary by year. β_t measures the difference in percentage points between average part- and full-time hourly wages, after any adjustments, so that $\hat{\beta}_t < 0$ indicates that part-time workers earn less. Figure 3 below shows the estimate of the PTPP over time. The top left panel (Figure 3a) shows the 'unadjusted' PTPP, including only controls for year and quarter (to capture the general and seasonal trend in wages). Figure 3b adds controls for 2-digit occupation and industry and other job characteristics.[3] Figure 3c includes worker-specific controls instead, and Figure 3d includes the full set of job- and worker-specific controls.[4]

The figures show that a large part of the PTPP is accounted for by occupational and industry segregation of part- and full-time work.[5] Controlling instead for worker specific characteristics also decreases the PTPP, although not as much. Across all model specifications, there is a steady decline in the PTPP over the time period. In other words, the hourly wage for part-time workers has increased, relative to full-time workers.[6]

The unadjusted PTPP (Figure 3a) is much larger for men, reflecting the fact that part-time work is concentrated at the bottom of the wage distribution, in occupations dominated by women. However, after controlling instead for worker characteristics the PTPP for both genders is approximately the same. This suggests that men may be more likely to sort into part-time work based on their individual characteristics than women. In Appendix C I discuss the sorting of workers into occupations, and show that the level and the trend in the PTPP are very similar are adjusting for potential selection bias.

As there has been a clear change in working hours conditional on working part-time, it is instructive to consider the full hours-wage profile, as well as the average pay penalty discussed above. Bick et al. (2022) show that, in the US, the relationship between hours and wages is non-monotonic; mean hourly wages increase up to 50 hours, and then decrease. Their analysis focuses on long working hours, and they do not consider anyone working less than 20 hours. I repeat their analysis, but as the focus of this paper is on part-time work, I include all workers with at least 5 hours. I also add controls for occupation and industry, job, and worker characteristics, as described above. To analyse the hours-wage

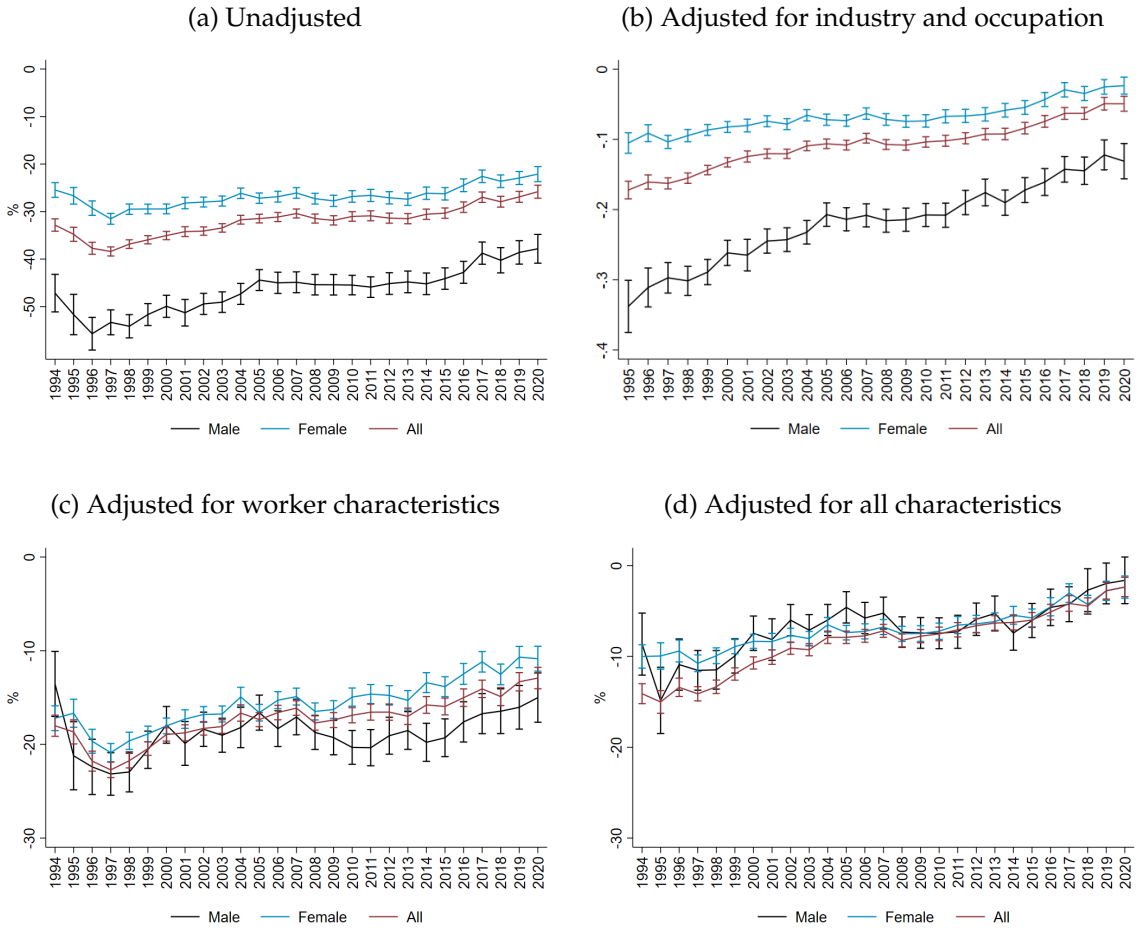
[3] Controls for job characteristics are for region; firm size; whether private or public sector; whether the worker is employed through an employment agency; and whether the job is temporary.

[4] Worker-specific controls are age; age squared; tenure; highest level of qualification; family type (single, single with children, living with a partner without children, living with a partner with children); whether currently studying; and whether the job is the worker's main job.

[5] This is consistent with previous research by Manning and Petrongolo (2008), Matteazzi et al. (2014).

[6] To confirm that this result is not due mechanically to the introduction and subsequent increases in the minimum wage since 1999, I repeat the estimation excluding anyone earning less than 5% above the minimum wage from the sample. The trend in the PTPP is the same, although the level is lower.

Figure 3: Trend in the part-time pay penalty



Source: LFS.

profile I estimate the following (cross-sectional) model using OLS

$$\log w_{it} = X_{it}\gamma + \sum_{h \in H} \beta_h d_{ih} + \epsilon_{it} \tag{2}$$

I partition weekly hours into groups of five indexed by $h \in H = \{5, 10, 15, ..., 80\}$ where h is the minimum hours for that group. For example, the group of workers with $h = 10$ includes all workers doing between 10 and 14 hours. d_{ih} equals one if worker i is in group h and zero otherwise. X_{it} is a vector of controls. I allow β_h to vary across the hours distribution to capture any non-linearity in the relationship. Figure 4 below shows the estimated coefficients $\hat{\beta}_h$. The 'base' group are those working 35-39 hours, so that $\hat{\beta}_h$ is an estimate of the pay penalty in percentage points relative to this group. The figure shows $\hat{\beta}_h$ estimated pooling all editions of the LFS, and for both genders. However, the results splitting the sample by year or gender are very similar.

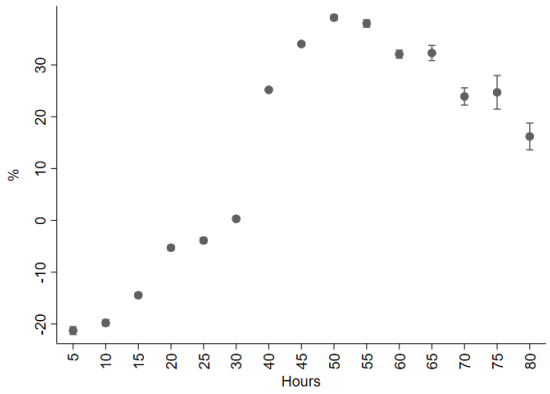
Across all specifications, hourly wages are higher for workers in higher hours groups. There is also a sharp increase in wages between 30 and 35 hours. As I explain above, this is approximately the threshold commonly considered to reflect 'full-time' work.[7] Including only controls for year and quarter, and for occupation and industry, hourly wages for part-time workers increase as hours increase from 5 to 30. However, when controls for worker

[7] Since Bick et al. (2022) only consider hours groups greater than equal to 20, it is not possible to see clearly from their analysis whether this jump occurs in the US as well as in the UK.

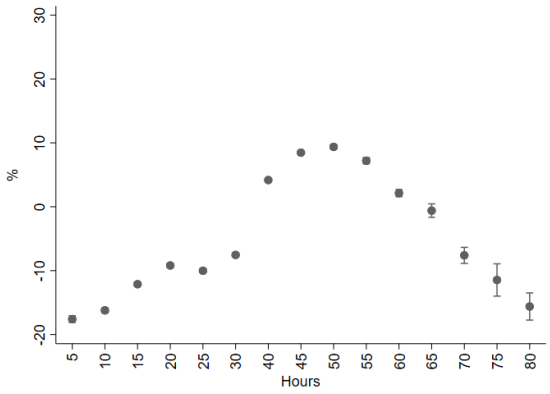
and job characteristics are included (Figures 4c and 4d), the increase is much smaller, and in fact, in Figure 4c, $\hat{\beta}_h$ is approximately constant from 5 to 30 hours. This would correspond to hourly wages that, conditional on worker characteristics, are constant between 5 and 30 hours.

Figure 4: Cross-sectional hours-wage profile, relative to a 35 hour working week

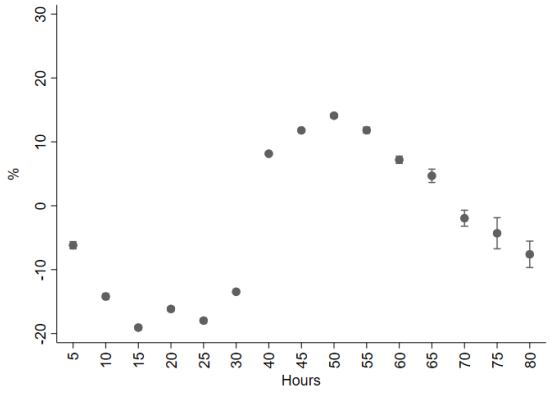
(a) Unadjusted



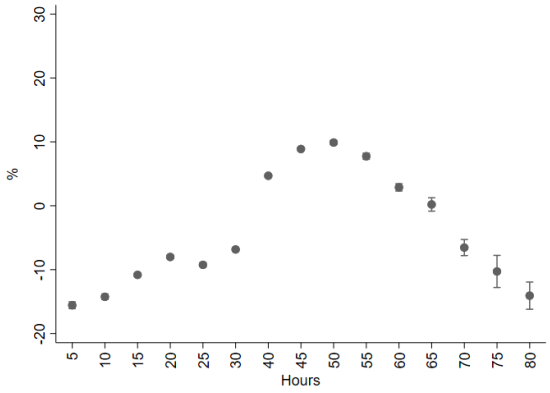
(b) Adjusted for industry and occupation



(c) Adjusted for worker characteristics



(d) Adjusted for job characteristics



To summarise, the stylised facts presented in this section suggest that there have been long-term, structural, changes in part-time work in the UK, in addition to the changes over the business cycle that are more widely studied. In aggregate, there has been an increase in both the quantity of part-time work, both through an increase in the part-time share and through an increase in hours conditional on working part-time. At the same time, there has been an increase in the price of part-time work relative to full-time work, which manifests in a fall in the part-time pay penalty. In the next section I present a model that can rationalise these facts.

3 Model

In the first part of this paper I show that there have been long-term, structural, changes in both the quantity and price of part-time work. In this section I set out a flexible neoclassical model of the labour market which can explain firms' and workers' preferences for part- and

full-time work. Given that part-time work is concentrated in some occupations, which are associated with different types of task, it is natural to begin with a production function that features occupations, consisting of different tasks, which have different characteristics. I show that modelling production as completion of a stream different of tasks can result in a mapping in which output is convex in working hours.

The equilibrium of the model features (1) the coexistence of part- and full-time work, (2) the concentration of part-time work at the lower end of the (hourly) wage distribution, (3) the bunching of workers at "full-time" hours, and (4) the concentration of workers with high disutility of labour (particularly women) working part-time in low-skill service occupations. Importantly, these outcomes are endogenous features of the equilibrium. Thus the model provides a micro-foundation for the convex hours-earnings relationship discussed in previous research (Goldin, 2014; Erosa et al., 2022).

The model is static, with a measure one of workers indexed by $i \in [0, 1]$, who are heterogenous in their disutility of labour. A representative firm produces a final good using output from occupations indexed by $j \in \{1, 2, ...J\}$. There is a single period with a length of one week, and workers supply weekly hours h in every week.

3.0.1 The firm

Total output in the period is a CES function of the output from $\{Y1, ..., Y_J\}$. The elasticity of substitution between occupations is given by $\sigma = \frac{1}{1-\rho}$, so that

$$Y = \left(\sum_{j=1}^{J} Y_j^{\rho} \right)^{\frac{1}{\rho}}.$$

The firm's problem is

$$\max_{\{Y_1,...,Y_J\}} \left(\sum_{j=1}^{J} A_j Y_j^{\rho} \right)^{\frac{1}{\rho}} - \sum_{j=1}^{J} w_j Y_j \tag{3}$$

where w_j is the price of a unit of output in occupation j, and A_j denotes the relative productivity of occupation j.

Output in occupation j is an aggregation across workers who each work h hours per week. Expected output in a period depends on weekly working hours of the individual workers, so that $E[y_j(h_i)]$ is the expected output for a worker with weekly hours $h_i \in (0, T]$.[8] T is the exogenous length of a full-time week. In the UK, this is usually considered to be between 35 and 40 hours. Thus total output from workers in occupation j is

$$Y_j = \int_{i \in m_j} E[y_j(h_i)] di.$$

where m_j is the set of workers working in occupation j. To abstract from indices of workers, rewrite the aggregation above as

$$Y_j = \int_0^T m_j(h) E[y_j(h)] dh$$

[8] In Section 3.4 I relax the assumption that $h \leq T$. Since my interest is in part-time work, I focus on the simpler model where $h \in (0, T]$

where $m_j(h)$ is the measure of workers with weekly hours h working in occupation j. I invoke a law of large numbers to assume that firms treat Y_j as deterministic in aggregate.

Workers

Workers must choose an occupation, and cannot combine occupations. They have utility that is linear in consumption and separable in consumption and hours. I assume that worker i has disutility of labour ϕ_i, distributed $\Psi(\phi)$ with support $[\phi_{min}, \phi_{max}]$. Their utility maximisation problem is

$$\max_{j=\{1,2,\ldots,J\}} \{U_j(h_{ij})\} \quad \text{s.t.} \quad U_j(h_{ij}) = \max_{h_j, c \geq 0} c - \frac{\phi_i h_{ij}^{1+\theta}}{1+\theta} \tag{4}$$
$$c = w_j E[y_j(h_{ij})]$$
$$h_{ij} \in (0, T].$$

For an individual worker, h_{ij} are decreasing in ϕ_i. Thus workers with a higher disutility of labour will, as is standard, work shorter hours.[9] I relax the assumption that $h \leq T$ in Section 3.4 below.

3.1 Expected output

In each occupation, workers are required to complete tasks of variable length. Tasks arrive at a Poisson rate λ_j, so that the expected number of tasks arriving in a working week of length h is $\lambda_j h$. Effective hours of labour of a worker working for h hours in occupation j is equal to the number of tasks arriving during the period, so that the worker may have some idle time, without a task to work on. Tasks arrive during the "usual" full-time week, which has length T.

Tasks that arrive when the worker is already busy completing another task join a queue, and are completed when they reach the front of the queue.[10] Modelling tasks in this way will allow the use of results from the operations research literature on queuing systems. To simplify the analysis, I assume that the system is in 'steady state', i.e. that is has reached an equilibrium between the arrival of tasks, and tasks being finished. Practically, this purely means that at the beginning of the period there is already some steady-state queue of tasks waiting to be completed, rather than an empty system.

Tasks differ across occupations along two dimensions:

1. A task takes τ hours to complete, which is drawn from the distribution $G_j(\tau)$, with $\tau > 0$. Some occupations involve tasks that take longer on average, and are more

[9] As written, the model does not incorporate the extensive margin. One could include a third choice for workers not to enter the labour force at all, which would give them some utility U_n, which would depend on ϕ.

[10] In their paper, Coviello et al. show that workers finish tasks more quickly when they work on one task at a time, and avoid 'task juggling', which carries a loss of productivity.

variable. In other occupations tasks are shorter, and there is less uncertainty about how long they will take to complete. I assume that the mean time to complete a task, $\bar{\tau} < \lambda$.[11] For simplicity, I assume that the distribution $G_j(\tau)$ is continuous and differentiable.

2. There is a cost, κ_j, that applies if a task is not completed within the week. This captures the loss of production caused by the disruption when a task is split over several weeks.

In queuing theory notation, production is modelled as an $M/G/1/\infty$ queue where the arrival process (M) is Possion, the distribution of task lengths is some general distribution (G), there is one 'server' (the worker, in this case), and there is no limit to the length of the queue of tasks.

Table 1 below lists some example occupations, and categorises them in terms of the cost to split tasks and the variability of task length. Most occupations attract some cost of postponing tasks to the next week. A possible exception are jobs where workers have flexibility to manage their own time. However, occupations differ greatly in the distribution of task lengths. For example, for a barista, making a cup of coffee is a discrete task with a fixed length. At the other end of the spectrum, a lawyer might spend an afternoon drawing up a simple contract, or several days for a more complex one.

Table 1: Example occupations

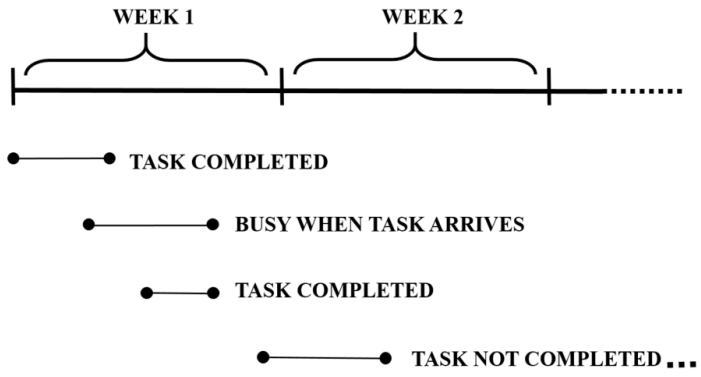
	Very little variability in τ	**Some variability in τ**	**High variability in τ**
Low cost to split tasks, κ_j	-	-	Artist
High cost to split tasks, κ_j	Retail or hospitality worker, Hairdresser	Healthcare worker, Factory worker	Lawyer, Agricultural worker, Engineer

I assume that tasks require human capital specific to the individual worker, which cannot be transferred between workers. For example, the client of a law firm might expect to be able to call their personal lawyer at any point during the working week. Thus one worker cannot be substituted for another in production.

Figure 5 below shows the process by which tasks arrive and are completed during two example weeks. The first task arrives at the beginning of the first week and is completed within the same week. The second task arrives when the worker is busy, and must wait to be completed. The third task arrives when the worker is not busy, and is completed within the week. The fourth task arrives when the worker is not busy, but is not completed within the week. It rolls over to the next week, incurring the time cost κ_j.

[11] Formally, this is required to ensure stability of the system, and convergence of the length of the queue of tasks waiting to be started and the time each task waits both converge to a steady state distribution (Adan and Resing, 2006). Informally, this assumptions ensures that tasks don't arrive faster than the worker can, on average, complete them.

Figure 5: Production by completing tasks



Proposition 3.1 *Expected weekly production in occupation j for an individual worker with weekly hours h is given by*

$$\begin{aligned} E[y_j(h)] &= E[\textit{tasks arriving} - \kappa \times \textit{tasks unfinished at time } h] \\ &= \lambda h - \lambda \kappa_j \int_0^h (1 - \Gamma_j(h-t))dt \end{aligned} \tag{5}$$

where the distribution $\Gamma_j(.)$ is the time between arrival and completion of a tasks, known as the 'sojourn time'

Proof: See Appendix D. The first term in this expression corresponds to the expected number of tasks that arrive with the worker, and the second term is the expected cost of leaving some of those tasks unfinished into the next week. The distribution $\Gamma_j(.)$ is known in the queuing literature as the distribution of the 'sojourn time'. This is the total length of time that the task takes to complete, including waiting for the worker to finish previous tasks, and completing the task itself.

If the distribution of task lengths is continuous, standard results of queuing theory show that the distribution of the sojourn time will also be continuous (Asmussen, 2003, Section 9a). In general, there is no closed form expression for Equation (5). However, there are a number of distributions where one can be found. For example, if the distribution of task lengths is exponential, so that $\tau \sim \text{Exp}(\mu)$, and the mean task length is $\bar{\tau} = 1/\mu$, then the sojourn time is distributed $\text{Exp}(\mu - \tau)$, and production is described as an $M/M/1/\infty$ queue (Adan and Resing, 2006). In this case, there is a closed form expression for Equation (5).

Proposition 3.2 (a) *Expected weekly production as a function of weekly working hours is convex for $h \in (0, T]$ when the following conditions hold:*

1. *The distribution of task lengths $G_j(x)$ is continuous and differentiable.*
2. *The cost of splitting a task between weeks is non-zero, i.e. $\kappa_j > 0$.*

(b) *If the distribution $G_j(\tau)$ is degenerate and if $\tau \to 0$, or if $\kappa_j = 0$ then expected annual production is linear in working hours.*

Proof: See Appendix D. The intuition for this result is that an increase in working hours has two effects. Firstly, it increases the expected number of tasks that will arrive during their working week. Second, it increases the probability that they will complete any given task during the week and avoid the cost of splitting tasks over weeks. This generates the nonlinearity in expected production.

As $h, T \to \infty$, i.e. when the working week is long, the number of unfinished tasks at the end of the week tends to the steady state queue length, which is equal to λ times the expected sojourn time (Adan and Resing, 2006). As $h \to 0$, no tasks are finished, and the number of unfinished tasks is equal to the number of tasks that arrive, giving

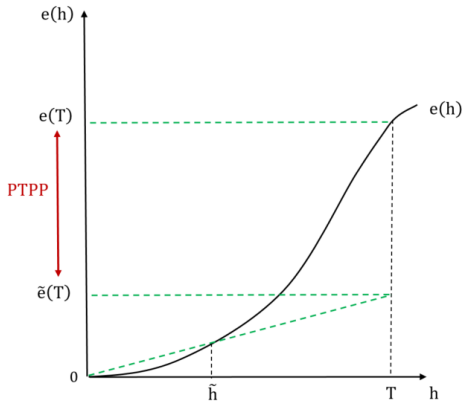
$$\begin{aligned} \lim_{h\to\infty} E[y_j(h)] &= \lambda(h - \kappa_j E[\Gamma]) \\ \lim_{h\to 0} E[y_j(h)] &= 0 \end{aligned} \tag{6}$$

The size of the part-time pay penalty within an occupation j depends on the extent of the convexity in the function $E[y_j(h)]$, and on weekly hours h. The ratio of hourly wages for a worker working h hours, and one working $h' < h$ hours is

$$\frac{\left(1 - \frac{\kappa_j}{h}\int_0^h (1 - \Gamma_j(h-t))dt\right)}{\left(1 - \frac{\kappa_j}{h'}\int_0^{h'} (1 - \Gamma_j(h'-t))dt\right)} > 1. \tag{7}$$

This ratio increases as h' decreases. Figure 6 illustrates this part-time pay penalty within an occupation.

Figure 6: Part-time pay penalty



Note: This sketch compares the earnings of a worker with weekly hours $\tilde{h}$ compared to a full-time worker with weekly hours T. $\tilde{e}(T)$ is the earnings the full-time worker would receive if they earned the same per hour as the worker with hours $\tilde{h} < T$. The diffference, $e(T) - \tilde{e}(T)$ is the part-time pay penalty.

I assume there is at least one occupation for which the distribution of x is degenerate. In other words, there is one occupation where all tasks are of the same length. I assume that $\tau \to 0$ so that tasks in this occupation are very short. I refer to this as the 'L', or linear, occupation, since expected production of workers in L occupations is linear in weekly hours. These occupations correspond to those in the bottom left and top right cells of Table 1,

and include the low-wage service sector occupations that have grown as a result of labour market polarisation.

To aid exposition, in the remainder of this paper I assume there is one other type of occupation, referred to as 'H' (or high-skilled service) occupations. I assume that H occupations are characterised by non-degenerate distributions of task length, $G_H(x)$ and non-zero costs of splitting a task, κ_H. These types of occupations can be found in the grey shaded cells in Table 1. Expected production of labour in H occupations is convex in weekly working hours. As an example, Figure 6 shows the expected production as a function of h for a worker in the H occupation. These occupations correspond to the 'nonlinear' occupations in Goldin (2014) and Erosa et al. (2022), and the 'greedy' occupations of Goldin (2021).

3.2 Equilibrium

From Equation (3), the equilibrium price of a unit of production in occupation j is given by

$$w_j = A_j^{\frac{1}{\rho}} Y_j^{\rho-1} \left(Y_H^{\rho} + Y_L^{\rho} \right)^{\frac{1-\rho}{\rho}}.$$

Equilibrium earnings in occupation j are given by $e_j(h) = w_j E[y_j(h)]$. Thus, since $E[y_H(h)]$ is convex in hours, earnings in the H occupations are also convex in hours. In equilibrium, since occupations are not perfectly substitutable in the production of the final good, we have the following result:

Proposition 3.3 *There exists $\hat{h}$ with $e_H(h) < e_L(h)$ when $h < \hat{h}$ and $e_H(h) > e_L(h)$ when $h > \hat{h}$.*

A full proof is given in Appendix D but the intuition is as follows: first, assume that the earnings for workers in L occupations are always greater than for H or M occupations, at any h. Then all workers would choose L occupations. The marginal product of labour for H occupations would be infinite so all workers would switch to H occupations. Hence, this cannot be an equilibrium. Thus, there must be some $\hat{h}$ where earnings in both types of tasks are equal.

Figure 7 shows the equilibrium weekly earnings in both occupations as a function of weekly working hours. It is clear that workers choosing their occupation (and working hours, conditional on occupation), will see the upper envelope of earnings as a function of weekly hours.

3.2.1 Sorting

A consequence of Proposition 3.3 is that, ceterus parabis, workers with a high disutility of labour, such as women with caring responsibilities, will choose to work in L occupations and those with a lower disutility of labour will choose to work longer hours in K occupations. Since earnings for workers in H occupations are convex in hours, these workers will earn more per hour than a worker who chooses to work in occupation L. Figure 8 shows an example of the hours choices of three workers. Worker 1 has a high disutility of labour and

Figure 7: Earnings as a function of weekly working hours

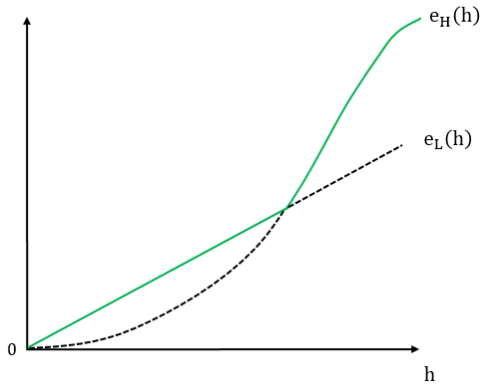
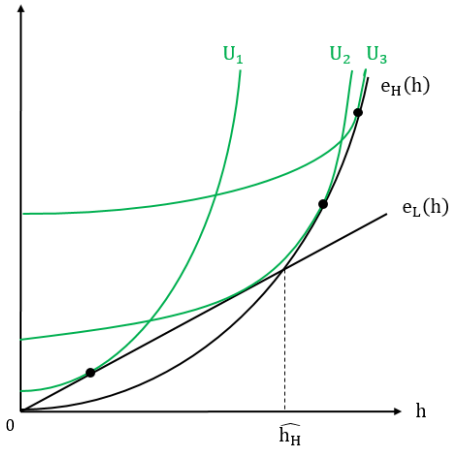


Figure 8: Example hours and occupation choices



Note: This sketch shows the hours and occupation choices of three workers, 1, 2 and 3 with decreasing disutility of labour.

hence chooses occupation L. Workers 2 and 3 have a lower ϕ and choose occupation H, for higher weekly hours.

If $\theta > 1$ and if the cumulative distribution of task lengths, $G(\tau)$ is concave, then the mapping from individual disutility of labour, ϕ_i, to the worker's optimal hours for both occupation, $h_H^*(\phi_i), h_L^*(\phi_i)$ is unique.[12] Thus, there is a marginal worker with disutility of labour $\hat{\phi} \in [\phi_{min}, \phi_{max}]$ that is indifferent between working in H or L occupations. The equilibrium part-time share is equal to $\Psi(\hat{\phi})$, and the full-time share is $1 - \Psi(\hat{\phi})$. Thus the model can replicate the sorting of workers into full- and part-time work, and occupations, based only on their disutility of labour. Workers with optimal working hours in H occupations $h_{iH}^* > T$ will bunch at full-time hours, T, provided that the maximum value of ϕ is sufficiently low.

The marginal worker with disutility of labour $\hat{\phi}$ is indifferent between working fewer hours in L occupations, or more hours in H occupations (this worker has utility indifference curve U_2 in Figure 8). The difference in hourly wages between these two choices corresponds to the discontinuity in hourly wages at approximately 35 hours per week shown in Figure 4.

[12] These assumptions are discussed in more detail in Appendix D.

It also explains why there are few workers with between 30 and 35 hours per week, as shown in Figure E.3.

The size of the discontinuity in hourly wages depends on the occupation and hours choice of workers in equilibrium. The ratio of hourly wages for a full-time worker in the H occupations, compared to a worker in the L occupations, is given by:

$$\left(\frac{A_H}{A_L}\right)^{1/\rho}\left(\frac{Y_H}{Y_L}\right)^{\rho-1}(T-\kappa_H\int_0^T(1-\Gamma_j(T-t))dt).$$

The expression above illustrates that the part-time pay penalty is shaped by three forces that can change over time: (1) the relative productivities of the occupations, A_H, A_L; (2) the cost of postponing tasks, κ_H and the distribution $\Gamma_j(\cdot)$ (and hence on the distribution of task lengths $G(\cdot)$); and (3) the distribution of disutility of labour, through Y_H, Y_L.

3.3 Technological change

Technological change enters the model in two ways. Firstly, it can manifest as decreases in the productivity of the H occupations A_H, and increases in A_L, pushing more workers into L occupations, where optimal working hours are lower. All else equal, this decreases the part-time pay penalty 'between' occupations. The rising productivity of L occupations also encourages workers in these occupations to work longer hours, aligning with the observed in hours in part-time workers.

Secondly, changes in the distribution of task length $G(\tau)$, and decreases in the cost of postponing tasks κ_H, 'flatten' the hours-earnings profile for H occupations, and make working long hours less attractive. This decrease in the convexity of weekly earnings in the H occupations decreases the part-time pay penalty 'within' these occupations, making H occupations more accessible to women who cannot work long hours.

Thus, the model can explain in two ways the long-term trends seen in the data. Both forces can explain how an increase in the part-time share, and in the working hours of part-time workers, can be accompanied by a decrease in the part-time pay penalty, as discussed in Section 2. A pure change in the disutility of labour would not be able to replicate this fact.

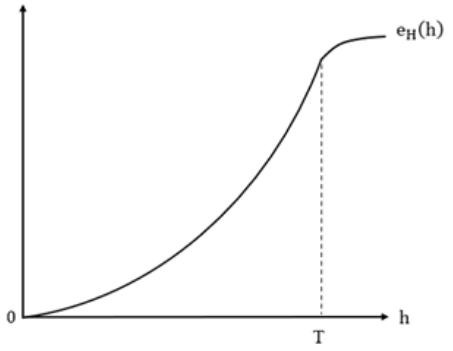
3.4 Long working hours

By relaxing the constraint that $h \leq T$, the model can also replicate the decrease in the hourly wage when weekly working hours are very long, as shown in Figure 4.

Proposition 3.4 *Assume that tasks stop arriving at the end of the full-time week. Then expected weekly production in H occupations as a function of weekly working hours is concave in the region $h > T$.*

See Appendix D for a proof. The condition requires that tasks stop arriving after the end of the full-time week. This means that workers with weekly hours greater than T can finish

Figure 9: Expected production when $h > T$



the back-log of tasks at the end of the week (reducing the cost of postponing tasks), so production continues to increase as h increases, but at a slower rate.

In this case, the lower marginal earnings from working another hour when $h > T$ will continue to create bunching at full time hours, but to a lesser extent than previously.

4 Part-time work and tasks

The model in the previous section suggests that there is a strong link between weekly working hours and the part-time pay penalty, and the types of task that make up an occupation. The model is capable of generating an equilibrium where workers sort into occupations and into full- or part-time work based on their disutility of labour, and where occupations characterised by more variable tasks have a lower part-time share and higher part-time pay penalty. In this section I investigate the link between an occupation's task profile and these two outcomes.

Goldin (2014) discusses the non-linearities in weekly earnings as a function of hours that appear in some occupations. Goldin analyses the characteristics of these "non-linear" occupations, and concludes that they are more likely to have a low level of schedule flexibility, and a high level of time pressure, compared to occupations where earnings are linear in hours. Hirsch (2005a) finds that part-time jobs are more prevalent in occupations that require lower verbal, mathematical, problem solving and technical skills, and Elsayed et al. (2017) finds that part-time workers are less likely to use computers compared to full-time workers in the same occupation, and that convergence in computer use and non-routine job tasks between part-time and full-time workers explains a large share of the decrease in the PTPP. In all of these analyses, the authors specify which skills are relevant.

I use the O*NET database to test the link between working hours and tasks. For every occupation in the US classification system, the database provides variables measuring the importance of a range of work activities ("tasks"), skills, and work context (defined by O*NET as physical and social factors that influence the nature of work) to effective performance in that occupation. I map these to the UK Standard Occupational Classification (UK SOC) using the procedure set out in Section A.2.

The aim of this analysis is to first reduce the large number of tasks into a smaller number of latent factors, capturing the correlation between different tasks. I begin by performing factor analysis on the work activity importance scores for each occupation.[13] This enables a reduction from 41 different tasks into four factors. These represent "Management Tasks" (with a higher factor loading for tasks such as training others, developing strategies, scheduling); "Information Tasks" (with higher factor loadings for analysing data, using computers, making decisions); "Technical Tasks" (operating machinery, monitoring processes, maintaining equipment); and "Customer Service Tasks" (assisting others, administration, performing general physical activites). The factor loadings are shown in Figure E.6.

In the second step of this analysis, I consider whether there are certain types of task that are associated with a higher part-time share and part-time pay penalty. I begin by estimating the following model:

$$Y_j = \beta X_j + \gamma \alpha_j + \epsilon_j \tag{8}$$

where Y_{jt} is (i) the part-time pay penalty (the calculation of this is discussed in Section A.2), and (ii) the part-time share in occupation j in the year 2019. α_j is a vector of O*NET task factors, and hence the coefficient of interest is γ. X_j is a vector of covariates for each occupation.[14] Columns (A) and (C) of Table 2 show the results of this estimation. A higher requirement for Technical and Customer Service tasks is strongly associated with a less severe part-time pay penalty, and a higher requirement for Information tasks is associated with a lower part-time share, even conditional on the characteristics of workers in an occupation. These are tasks in which it is particularly difficult to substitute one worker for another.

It is, of course, likely that there are unobserved factors that are correlated both with occupational choice and with the decision to work part-time. I therefore instrument the task factors described above with another O*NET measure: each occupation's skills requirements. The intuition is that these skills are required in order to carry out tasks, and are not directly linked to working hours. For example, a barrister will require good reading comprehension (a skill) in order to read and understand contracts (a task). This skill requirement should not affect working hours, other than through the task (in this case, a complicated contract might require a long, uninterrupted period to deal with).[15] The results, shown in Columns (B) and (D) of Table 2, are similar to the original estimation, although they provide some evidence that a higher requirement for Management tasks may increase the part-time pay penalty.

This analysis shows that there is a link between the types of task that make up an occupation, and the equilibrium quantity and price of part-time work, as predicted in the model described above. The task profile of an occupation affects these equilibrium outcomes even after accounting for the selection of workers into different occupations and into full- or part-time work based on observable or unobservable characteristics.

[13] In the O*NET data, each task is assigned an importance score of 1 to 5 for each occupation, which I then standardise.

[14] These are the share of women; the share of workers with children; the share who are married; the share of women with children; the average age and tenure; the proportion studying; the proportion who completed higher education; the proportion in the public sector; and the proportion with a temporary contract.

[15] Since there are 35 categories of skills, I use the Lasso selection method for many instruments developed by Belloni et al. (2012), implemented in Stata by Ahrens et al. (2018). The Lasso estimator selects 19 skill components as instruments.

Table 2: Regression of part-time share on task content of occupations

	Part-time Pay Penalty		Part-Time Share	
	(A)	(B)	(C)	(D)
Management Tasks	-0.01	-0.02*	-0.01	-0.01
	(0.010)	(0.012)	(0.007)	(0.008)
Information Tasks	0.00	0.01	-0.05***	-0.06***
	(0.008)	(0.012)	(0.007)	(0.013)
Technical Tasks	0.04***	0.03***	-0.01	-0.01
	(0.007)	(0.008)	(0.007)	(0.008)
Customer Service Tasks	0.03***	0.04***	0.01*	0.01
	(0.009)	(0.011)	(0.008)	(0.009)
Include instruments?	No	Yes	No	Yes
Observations	275	275	275	275
R^2	0.31	NA	0.342	NA

Robust standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

5 Conclusion

In this paper I examine long term trends in part-time work. I begin by documenting important aggregate changes in part-time work over the last 30 years. Firstly, the quantity of part-time work has increased. This increase has mostly occurred at the 'intensive' margin, as weekly hours, conditional on working part-time, have increased. Amongst men there has also been an increase at the 'extensive' margin, as the share of men employed who are working part-time has grown. Secondly, wages for part-time workers relative to full-time workers have increased for both genders, even after adjusting for differences in the characteristics of part- and full-time workers and jobs. I also show that there is a sharp discontinuity in hourly wages at approximately 35 hours per week.

Taken together, these trends suggest changes in both firm technology and worker preferences, and the aim of this paper is to develop a model that can incorporate both firm and worker preferences for part-time and full-time work. Changes in working hours could have effects on inequality, since part-time work is most often found at the bottom of the wage distribution, and it is therefore important to understand what is causing them. Using results from queuing theory, I develop a model which can explain both firm's and worker's preferences for part- versus full-time work. I use a task based approach, in which production is a CES aggregate of high-skilled and low-skilled occupations. The high-skilled occupations are associated with tasks that take an uncertain length of time, and that cannot easily be postponed, generating a convexity in the hours-earnings profile for these tasks. Low-skilled occupations are associated with tasks that always take the same amount of time, and thus weekly earnings in these occupations are linear in hours. As a result, in equilibrium, workers sort choose to work longer hours in the high-skilled sectors and shorter hours in the low-skilled service sector and hence earn less per hour. I show that the model can explain the observed increase in the part-time share, increase in part-time hours, and

simultaneous decrease in the part-time pay penalty.

Technological change flattens the earnings–hours relationship by reducing task variance and postponement costs, explaining both the rise of part-time work and the declining wage penalty since the 1990s. Empirical evidence from O*NET data supports this mechanism: occupations with more homogeneous task structures have higher part-time employment and smaller pay penalties.

Beyond these findings, the model offers a flexible framework for analysing how stochastic production processes affect the distribution of working hours. By invoking a law of large numbers across many identical workers, the model treats effective labour input as deterministic. However, one extension would be to allow workers to choose between firm employment and self-employment. Because self-employed workers accept the risks associated with unfinished tasks, the model naturally explains why occupations involving variable, long-duration, tasks with high postponement costs may be less conducive to self-employment, particularly when workers are risk-averse. Thus the framework developed in this model could be used to study new forms of work, such as the gig economy.

Another avenue for future research could be to explore how firms share or reallocate tasks among workers, as in Coviello et al. (2014). If improvements in communication and coordination technologies allow tasks to be more easily passed between employees, this would reduce postponement costs and thereby lower the part-time pay penalty. Such extensions could deepen our understanding of how technological and organisational change interact to shape the distribution of working hours and wages.

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Appendix A Data sample and definitions

A.1 Labour Force Survey data

In my sample I include all adults aged between 17 and 64. I use quarterly sampling weights provided by the ONS. The LFS records actual and usual hours worked. I use usual hours worked in an individual's main job as my measure of working hours (the variable TTUSHR). This measure of hours is self assessed, and may be subject to reporting error. Respondents are asked (1) how many hours per week they usually work, excluding meal breaks and overtime; (2) how many hours of paid overtime they usually work; and (3) how many hours of unpaid overtime they usually work. I include paid and unpaid overtime in order to reflect all the hours worked. For example, some workers may be paid high wages per contracted hour but also expected to work unpaid overtime, so that excluding overtime would overstate their hourly wage. I exclude anyone working more than 84 or less than 4 hours per week from the sample.

Respondents remain in the sample for five quarters, and are asked about their income in the first and fifth quarter that they are surveyed. The measure of wages I use is the variable GRSSWK which is the gross weekly pay calculated using the most recent pay period, and including overtime pay, divided by working hours. Respondents are also asked whether their most recent pay was the same as they usually receive. Where the answer is no, I replace actual gross pay with usual gross pay (the variable USUGPAY). I calculate real hourly wages using the CPI index published by the ONS.

One advantage of the LFS is that it samples all households. An alternative data source would be the Annual Survey of Hours and Earnings, which uses data reported by employers. However, this is likely to capture contracted, rather than actual, hours worked. In addition, firms with a turnover below the VAT threshold, or without employees earning more than the National Insurance Threshold do not have to register with the tax authorities and are not surveyed. Since part-time workers are more likely to be earning less, this suggests that the ASHE may not capture part-time workers as well as the LFS. Until 2004 the predecessor to the AHSE, the National Earnings Survey, did not make any adjustments or provide weights to correct for these issues (Bird, 2004).

A.2 Mapping O*NET to UK SOC

I begin by compiling task-based scores from version 24.0 of the ONET database, covering abilities, skills, work activities, and work context. For each component, I retain measures of importance. measuring the importance of the ability, skill, work activity or work context, which I then standardise.

Next, I link the O*NET-SOC 2010 codes to the International Standard Classification of Occupations (ISCO) using the crosswalks developed by Hardy et al. (2018), which provide mappings from US SOC occupation codes to both ISCO-88 and ISCO-08 classifications. These international frameworks serve as an intermediary, allowing me to connect the U.S.-based occupational data to the UK classification system.

I then map the ISCO codes to UK SOC 2010 occupations using correspondence tables published by the Office for National Statistics in the UK (Office for National Statistics, 2010). Because the ISCO–SOC mapping is not one-to-one, each SOC occupation can correspond to multiple ISCO occupations. In such cases, I take the mean of all available task scores across the linked ISCO codes. When no direct ISCO link exists at the four-digit SOC level, I impute missing values using the mean of all three-digit SOC codes within the same major occupational group.

This process yields a dataset that assigns a set of ONET-based task measures to each UK SOC 2010 occupation. Although the mapping inevitably introduces some measurement error due to differences between US and UK SOC codes and the imperfect nature of the crosswalks, it provides a framework for analysing the task content of UK jobs using internationally comparable ONET measures.

A.3 Estimation of PTPP for UK SOC occupations

For each occupation j with at least 20 part-time workers (working 30 hours per week or fewer), I estimate the part-time pay penalty by running separate wage regressions within occupations. I regress log hourly wages on an indicator for part-time status, controlling for year and quarter fixed effects as well as the additional covariates included in Equation (1). The estimated coefficient of the part-time indicator measures the within-occupation hourly wage differential between part-time and full-time workers for occupation j.

Appendix B Government policy regarding part-time work in the UK

It is clearly important to consider the role that working-time regulations, taxes and transfers may have had on the demand, supply and relative price of part-time labour in the UK. In general, these policies have been aimed at encouraging workers to supply more labour, whilst maintaining the birth rate by making work more flexible (United Nations Department of Economic and Social Affairs, Population Division, 2015).

Since 2000, the Part-time Workers (Prevention of Less Favourable Treatment) Regulations have required firms to treat part-time workers equally to comparable full-time workers so that, in theory, part-time workers should receive the same hourly pay as full-time workers with the same characteristics doing the same or similar job. Manning and Petrongolo (2008) note that since the part-time pay penalty after adjusting for selection in part-time work was already low, these regulations are unlikely to have had much effect on relative pay. However, they may have had an effect on other work amenities that are not captured by the LFS, and thus made part-time work more attractive to workers. On the other hand, these regulations may have made part-time work less attractive to firms, who must now pay part-time workers the same hourly wages and provide the same benefits.[16]

The other changes that may have affected the extent of part-time work in the UK are the successive increases in the categories of employees with the right to request flexible working (including part-time work). In 2000 this right was introduced for parents of young and disabled children. In 2003 and 2006 it was extended to carers and parents of older children and in 2014 to all employees (Pyper, 2018). The firm is able to deny such a request on a number of grounds, including if they believe it will negatively affect the employee's productivity. There is evidence that firms are doing so: surveys suggest that between 10% and 20% of requests were denied (Hegewisch, 2009), and in a 2015 survey, only 42% of fathers thought that they would be able to request flexible working, compared to 78% of mothers (Cook et al., 2021). However, these regulations may have made it easier for some employees to work part-time.

Unlike many other countries, in-work benefits in the UK depend on the number of hours worked. In 1999 the Working Families Tax Credit was introduced, which provided transfers to low paid workers with children. In order to be eligible, individuals had to work at least 16 hours a week, and there was an additional transfer for those working more than 30 hours. In 2003 this was extended to all adults aged over 25. As a result, the budget constraint of low-paid workers has kinks at 16 and 30 hours a week, which results in bunching (see Figure E.3 in Appendix E). Blundell et al. (2008) analyse the effect of these changes on womens' labour supply. They find that they led to higher working hours, but that most hours adjustments occurred when individuals changed jobs. They conclude that there is evidence that production technology leads to hours constraints in some jobs.

Appendix C Selection into part-time work

There are concerns that the PTPP may be a result of sorting into part- and full-time work on the basis of some unobserved variable (perhaps ability, or motivation) that also affects wages. To check whether this is the case I estimate the PTPP after adjusting wages for selection into part- and full-time work using a Heckman sample selection model. The assumption underlying the empirical model is that an individual's part-time status is determined by a latent variable

$$PT_i^* = \gamma Zi + \eta_i \tag{1}$$

[16] The legal database LexisNexis lists 237 cases involving the legislation between 2000 and February 2020. Many of these involved other benefits such as pensions or paid breaks.

where Z_i is a vector of characteristics that affect the propensity of individual i to work part-time. PT_i^* is not observed. Instead, the dummy variable PT_i is observed, with

$$PT_i = \begin{cases} 1 & \text{if} \quad PT_i^* > 0 \\ 0 & \text{if} \quad PT_i^* \leq 0 \end{cases} \tag{2}$$

Using a standard Heckman sample correction, I calculate a selection term for each individual, so that Equation (1) becomes

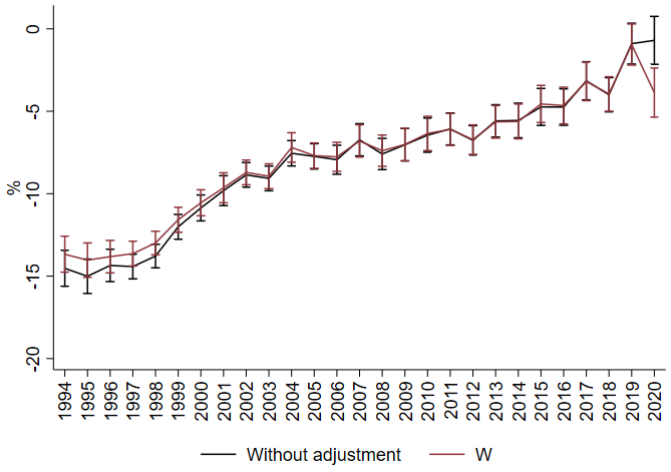
$$\log w_{it} = X_{it}\gamma + \beta_t PT_{it} + \delta\lambda(\gamma Zi) + \epsilon_{it} \tag{3}$$

where

$$\lambda(\gamma Zi) = \frac{\phi(\gamma Zi)}{\Phi(\gamma Zi)} \tag{4}$$

is the inverse Mill's ratio. The parameter γ is estimated by probit maximum likelihood. A disadvantage of this method is that, to avoid collinearity, there should be at least one characteristic in Z that affect the propensity to work part-time, but does not directly affect the wage. Following the literature, I include an individual's family status in Z_i and the number of children they have, but exclude both from X_i. Figure C.1 below shows the PTPP with the full set of firm and worker characteristics, with and without the Heckman sample selection adjustment.

Figure C.1: Trend in the part-time pay penalty, Heckman selection adjustment



Appendix D Proofs

D.1 Proof of Proposition 3.1

Consider an M/G/1/∞ system of tasks with tasks of mean length $\bar{\tau}$ and arrival rate λ. In each week, $E[y_j(h)]$ the expected number of tasks completed in a working week of length h, is derived as follows. I assume that the system has been running for many weeks, so the system is stationary. In other words, I assume that at the beginning of the week the worker

has a queue of tasks to finish, distributed according to the steady state queue length for an M/G/1/∞ process. Although this assumption is not necessary for convexity of $E[y(h)]$, it greatly simplifies the following proof, as it is not necessary to consider the transitionary dynamics of the system, which would be necessary if the queue was empty at the beginning of the week. This assumption requires $\bar{\tau} < \lambda$ (without this assumption, tasks would arrive faster than the worker can finish them and the queue of tasks would 'blow up'). In what follows I drop the j subscript for simplicity.

$$\begin{aligned} E[y(h)] &= E[\text{tasks arriving} - \kappa \times \text{tasks unfinished at time } h] \\ &= \lambda h - \kappa E[\text{tasks unfinished at time } h] \end{aligned} \tag{5}$$

The next step is to find the expected number of unfinished tasks. A task that arrives at time $t \in [0, h]$ is unfinished at the end of the week if the total time for it to get through the 'system' (the time waiting for other tasks to be finished plus the 'service' time to finish the task itself) is less than the remaining time $h - t$.

The number of unfinished tasks depends on the arrival times of the tasks during the week. If tasks arrive according to a Poisson process, then Campbell's theorem states gives the expectation of a function summed over a point process N with arrival rate λ

$$E[\sum_{x \in N} f(x)] = \lambda \int f(t)dx$$

Here a task that arrives at time t contributes a value of one to the sum if it is unfinished at time h. Thus

$$f(t) = \mathbb{1}\{\text{time through system} > h - t\}.$$

where f is defined on the interval $(0, h)$. In expectation,

$$E[f(t)] = Pr(\text{time through system} > h - t).$$

Applying Campbell's Theorem gives

$$\begin{aligned} E[\text{tasks unfinished at time } h] &= \lambda \int_0^h Pr(\text{time through system} > h - t)dt \\ &= \lambda \int_0^h 1 - Pr(\text{time through system} \leq h - t)dt. \end{aligned} \tag{6}$$

When the system is in steady state, the distribution of the time taken for a task to make its way through the system is known as the 'sojourn time'. The sojourn time is equal to the length of the task (known in the literature as the 'service time'), plus the time waiting for tasks already in system. For most task length distributions there is no closed form expression for the sojourn time, but if the distribution of task lengths is exponential, $\tau \sim \text{Exp}(\mu)$, so that the mean task length is $E[\tau] = 1/\mu$, then the sojourn time is distributed $\text{Exp}(\mu - \tau)$ (Adan and Resing, 2006). Denote the distribution of the sojourn time, $\Gamma(\dot{})$. Substituting into Equation (5) gives expected production as follows:

$$E[y(h)] = \lambda h - \lambda \kappa \int_0^h 1 - \Gamma(h - t)dt. \tag{7}$$

D.2 Proof of Proposition 3.2

Using Leibniz' integral rule, and denoting the probability density function of the sojourn time as $\gamma(\cdot)$,

$$\begin{aligned}\frac{\partial E[y(h)]}{\partial h} &= \lambda\Big(1-\kappa\big(1-\Gamma(h-h)+\int_0^h \gamma(h-t)dt\big)\Big)\\ &= \lambda\Big(1-\kappa\big(1-\Gamma(h)\big)\Big)\end{aligned}$$

Since $\kappa < 1$, this is positive for $h \in (0, T)$; working more hours increases expected weekly effective hours. Under the assumption that $G(\tau)$ is continuous and differentiable, then the sojourn time is also continuous and differentiable since it is the convocation of the waiting time and the task length Asmussen, 2003. Differentiating again,

$$\frac{\partial^2 E[y(h)]}{\partial h^2} = \lambda\kappa\gamma(h).$$

This is greater than zero, and so the expected weekly effective hours are convex as a function of weekly working hours. If all tasks are the same length (as is the case for low skilled service tasks), then $\gamma(h) = 0$ and expected production is linear. Equally, if there is no cost to split tasks, then expected production is also linear.

D.3 Proof of uniqueness of h^*_{ij}

The optimal choice of hours for worker i in occupation j solves (dropping i, j subscripts for simplicity)

$$\frac{h^\theta}{\phi} = w\lambda\big(1-\kappa(1-\Gamma(h))\big) \tag{8}$$

If $\theta > 1$ then the left-hand side of the equation above is convex. The second differential of the right-hand side is

$$w\lambda\kappa\gamma'(h).$$

If $\gamma(\cdot)$ is a decreasing function (e.g. the exponential distribution, or the Pareto distribution with a minimum at zero), then this is concave. At $h = 0$, the right hand side is equal to zero, and the left hand side is equal to $w\lambda(1-\kappa) > 0$ (since the distribution of the sojourn time is bounded below by zero). Thus, there can be at most one crossing point with $h \in (0, T]$. Thus, if $\theta > 1$ and if the distribution of the task time is a decreasing function, then the solution to Equation (8) is unique.

D.4 Proof of Proposition 3.3

Weekly earnings in occupation j as a function of weekly working hours h are given by $e_j(h) = w_j E[y_j(h)]$, where the price of a unit of effective labour in occupation j is given by

$$wj = A_j Y_j^{\rho-1}\Big(Y_H^\rho + Y_L^\rho\Big)^{\frac{1-\rho}{\rho}}. \tag{9}$$

w_H, w_L do not depend on h. From Section D.2 above, $e_L(h)$ is linear and $e_H(h)$ is convex for $h \in (0, T]$, and hence they can have at most two crossing points. Note that at $h = 0$, both $E[y_H(h)]$ and $E[y_L(h)]$ are equal to zero, so that $e_H(h), e_L(h)$ must have one crossing point at $h = 0$.

As $h \to 0$, both $E[y_H(h)], E[y_L(h)]$ tend to zero. The gradient of $e_L(h)$ is equal to $\lambda h w_L$. From Section D.2, when h is small (less that the expected task length τ), the gradient of $e_H(h)$ is equal to $\lambda h(1 - \kappa_H)w_H$.

First, assume that w_L, w_H are such that $\lambda h w_L < \lambda h(1 - \kappa_H)w_H$. In this case, $e_L(h) < e_H(h)$ for all h (since $e_H(h)$ is convex). In equilibrium, all workers would choose to work in H occupations, and Y_L would be zero. From Equation (9), the price of a unit of effective labour in L occupations would increase to infinity. This contradicts the assumption that $\lambda h w_L < \lambda h(1 - \kappa_H)w_H$. It must be the case that $e_L(h) > e_H(h)$ for small h.

Now assume that $e_L(h) > e_H(h)$ for all $h > 0$. Using similar arguments, this implies that all workers would choose to work in L occupations, and Y_H would be zero. From Equation (9), the price of a unit of effective labour in H occupations would increase to infinity, contradicting the assumption that $e_L(h) > e_H(h)$ for all h. Thus, there must be one crossing point, where $e_H(\hat{h}) = e_L(\hat{h})$, with $\hat{h} > 0$. If workers are constrained so that they must choose h in the interval $(0, T]$, then $\hat{h} \in (0, T]$.

D.5 Proof of Proposition 3.4

Beginning with Equation (6), the expected number of tasks unfinished at the end of the week is now

$$E[\text{tasks unfinished at time } h] = \lambda \int_0^T 1 - Pr(\text{time through system} \leq h - t)dt \tag{10}$$

where the limits of integration reflect the fact that tasks can only arrive up to time T. The queue of tasks at the beginning of each week will be smaller than when $h \leq T$, since some tasks are completed in the 'overtime' hours $h > T$. However, if T is sufficiently large relative to the average task length $\bar{\tau}$ then this will not affect the system by the end of the week. I assume this is the case. In this case, expected production is

$$E[y(h)] = \lambda h - \lambda \kappa \int_0^T 1 - \Gamma(h - t)dt. \tag{11}$$

Differentiating with respect to h,

$$\begin{aligned} \frac{\partial E[y(h)]}{\partial h} &= \lambda \left(1 - \kappa \int_0^T \gamma(h - t)dt\right) \\ &= \lambda \Big(1 - \kappa\big(\Gamma(h) - \Gamma(h - T)\big)\Big) \end{aligned}$$

Since $\kappa < 1$, this is positive for $h \in (0, T)$; working more hours increases expected weekly effective hours. Under the assumption that $G(\tau)$ is continuous and differentiable, and differentiating again,

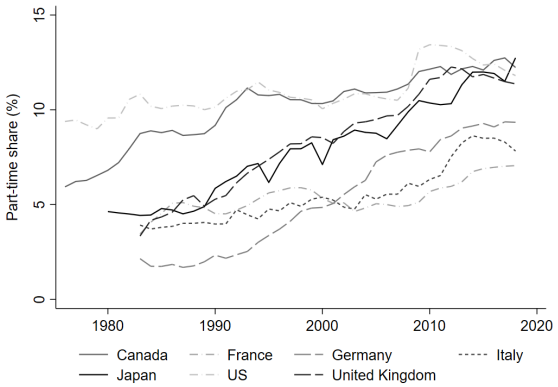
$$\frac{\partial^2 E[y(h)]}{\partial h^2} = -\lambda \kappa(\gamma(h) - \gamma(h - T)).$$

Provided that $\gamma(h) > \gamma(h-T)$, this is negative, and the function $E[y(h)]$ is concave for $h > T$.

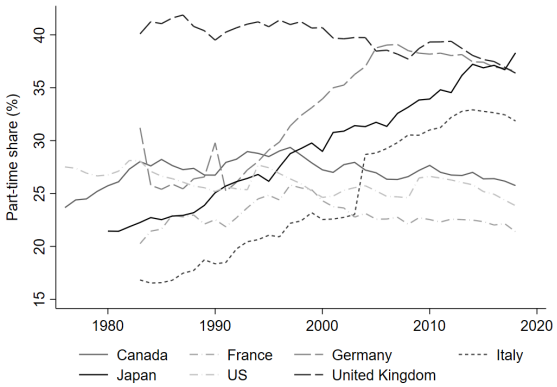
Appendix E Additional figures

Figure E.2: Part-time share across countries

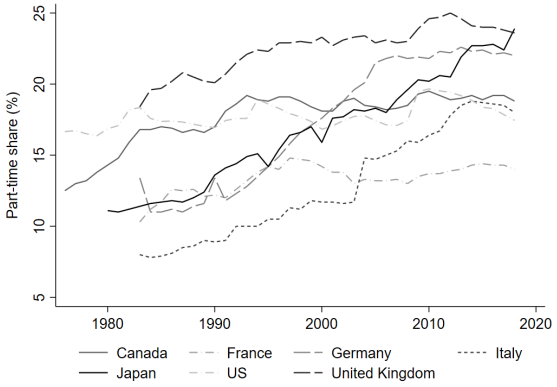
(a) Male



(b) Female

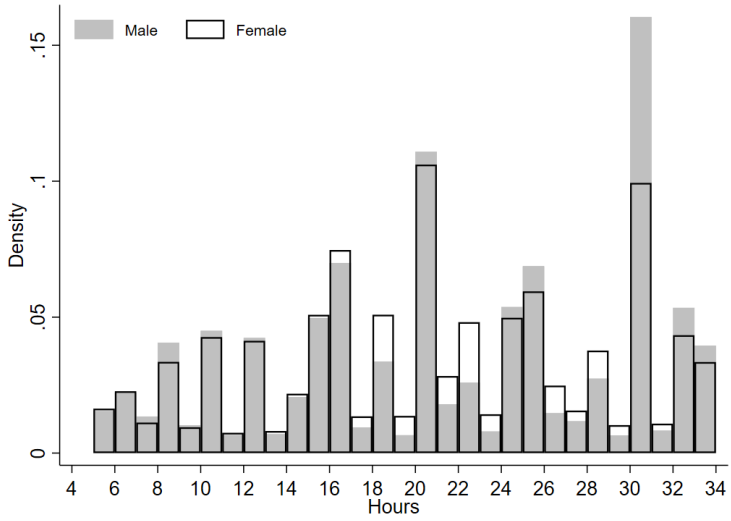


(c) All



Source: OECD (2019).

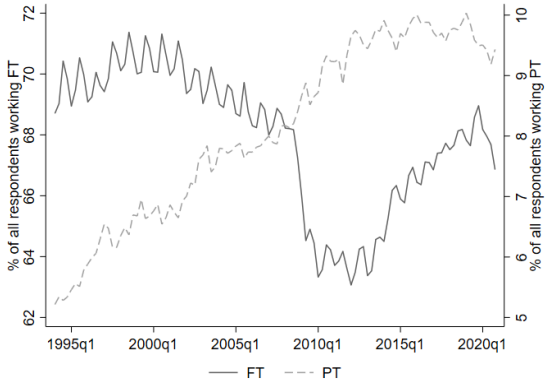
Figure E.3: Distribution of working hours for part-time workers, 1994-2020



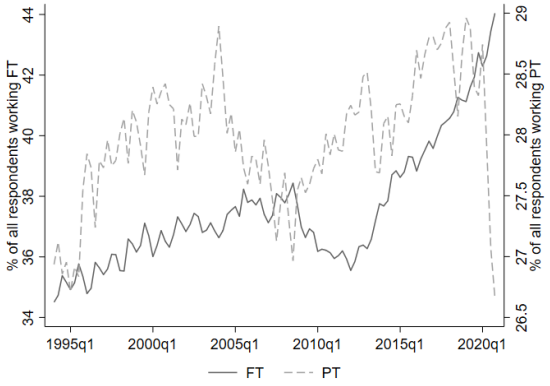
Source: LFS.

Figure E.4: Part-time and full-time workers (as % of whole population)

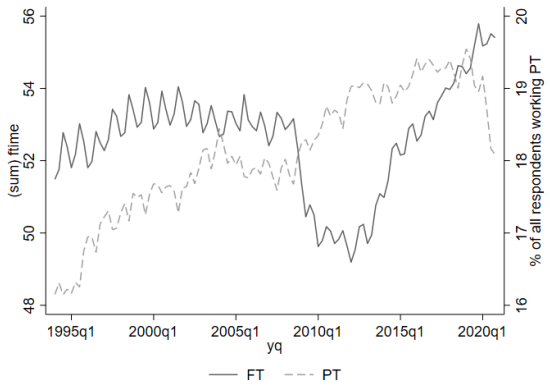
(a) Male



(b) Female



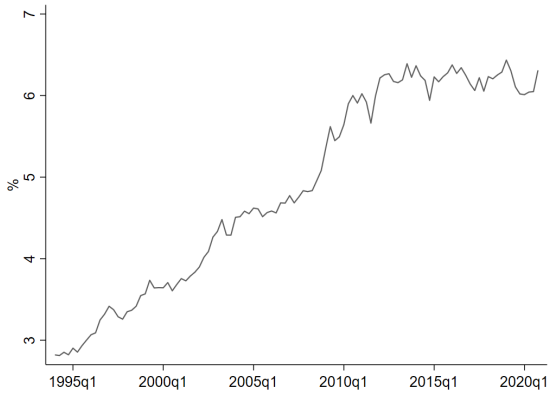
(c) All



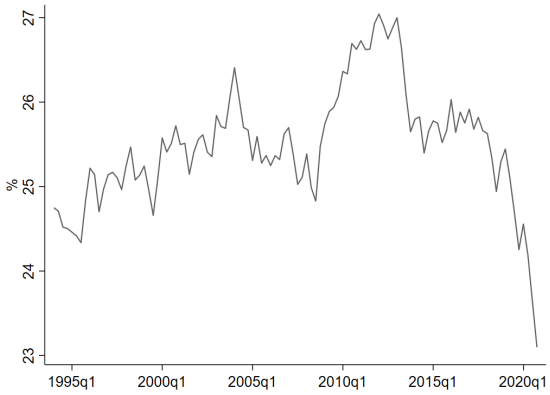
Source: LFS

Figure E.5: Percentage of all working hours done by part-time workers

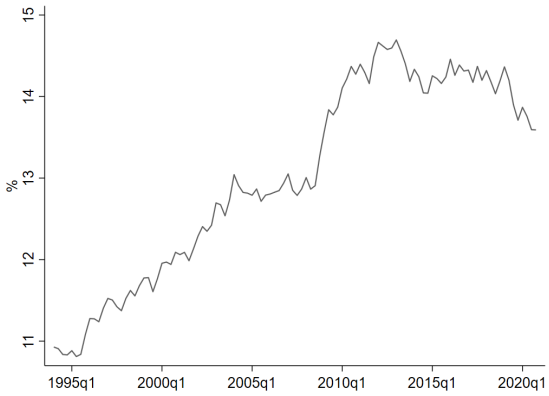
(a) Male



(b) Female



(c) All



Source: LFS.

Figure E.6: Task factor loadings

Variable	Factor1	Factor2	Factor3	Factor4
Coaching and Developing Others	0.99	-0.07	-0.10	-0.06
Guiding, Directing, and Motivating Subo	0.94	-0.05	0.06	0.07
Coordinating the Work and Activities of (	0.89	-0.01	0.06	0.11
Developing Objectives and Strategies	0.88	0.04	-0.09	0.05
Training and Teaching Others	0.88	0.03	0.06	-0.18
Staffing Organizational Units	0.77	0.00	-0.05	0.21
Developing and Building Teams	0.72	0.20	-0.18	-0.04
Monitoring and Controlling Resources	0.67	-0.01	0.16	0.25
Scheduling Work and Activities	0.61	0.21	0.01	0.21
Judging the Qualities of Things, Service	0.61	0.20	0.26	0.11
Provide Consultation and Advice to Oth	0.60	0.38	-0.14	-0.01
Thinking Creatively	0.50	0.12	-0.17	0.00
Establishing and Maintaining Interperson	0.35	0.28	-0.39	0.36
Estimating the Quantifiable Characterist	0.30	0.23	0.49	-0.10
Communicating with Supervisors, Peers	0.42	0.56	-0.08	-0.01
Organizing, Planning, and Prioritizing W	0.42	0.38	-0.20	0.17
Making Decisions and Solving Problems	0.39	0.63	0.11	0.02
Monitor Processes, Materials, or Surrour	0.28	0.52	0.59	-0.17
Interpreting the Meaning of Information f	0.26	0.70	-0.19	0.01
Processing Information	-0.05	0.87	-0.13	-0.02
Analyzing Data or Information	0.18	0.73	-0.17	-0.13
Evaluating Information to Determine Cor	0.17	0.76	0.15	-0.08
Identifying Objects, Actions, and Events	0.14	0.77	0.37	-0.01
Updating and Using Relevant Knowledg	0.10	0.79	-0.03	0.12
Getting Information	-0.09	0.87	-0.09	0.12
Documenting/Recording Information	-0.12	0.92	-0.04	0.13
Interacting With Computers	-0.08	0.67	-0.36	0.12
Performing for or Working Directly with th	0.07	-0.32	0.75	0.05
Inspecting Equipment, Structures, or Ma	0.05	0.04	0.94	-0.08
Drafting, Laying Out, and Specifying Te	0.02	0.10	0.59	-0.15
Operating Vehicles, Mechanized Device	0.00	-0.08	0.82	0.11
Repairing and Maintaining Mechanical E	-0.06	-0.08	0.89	-0.07
Handling and Moving Objects	-0.07	-0.31	0.78	0.02
Controlling Machines and Processes	-0.09	-0.11	0.83	-0.16
Repairing and Maintaining Electronic Eq	-0.21	0.22	0.82	-0.01
Performing General Physical Activities	-0.06	0.03	0.05	0.85
Performing Administrative Activities	0.09	0.45	-0.22	0.46
Communicating with Persons Outside O	0.07	0.38	-0.22	0.57
Resolving Conflicts and Negotiating with	0.47	0.10	-0.13	0.51
Selling or Influencing Others	0.37	-0.23	-0.09	0.60
Assisting and Caring for Others	0.22	0.12	0.12	0.31