

WORK START TIME AND WORKER COMPENSATION: IMPLICATIONS FOR STAGGERED-WORK-HOURS POLICIES

Eva Gutiérrez-i-Puigarnau

VU University, De Boelelaan 1105, 1081 HV Amsterdam, The Netherlands
egutierrez@feweb.vu.nl

Jos van Ommeren

VU University, De Boelelaan 1105, 1081 HV Amsterdam, The Netherlands
jommeren@feweb.vu.nl

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Abstract

Staggered-work-hours policies that affect workers' working schedules to mitigate peak congestion have received a lot of attention, but little is known about the welfare effects. We examine this by estimating the effect of changes in workers' start times on their preferences and productivity that are both captured by wages using panel data for Germany. Our results suggest that staggered-hours policies, even if introduced on a small scale, may not be welfare enhancing, because the additional costs (due to changes in inconvenient scheduling costs, commuting time and productivity) exceed the reduction in external commuting costs. Policies that induce firms to move work starting times from peak towards before-peak times are probably more promising than policies that move start times towards after-peak times.

Keywords: work start time, wage, productivity, staggered work hours, congestion

JEL codes: J2, J3, R41

1. Introduction

Traditionally, most of the labour supply has been structured following a set working time pattern under which all workers start and end working at the same time (Henderson, 1981).¹ This situation causes a large volume of traffic around the work start and end times and consequent heavy morning and evening peak congestion.² During the last three decades, traffic congestion has become a major worry not only for policymakers, but also for employers as it increases the travel costs of workers to arrive at work. One way to mitigate the lengthening of the commute time, due to traffic congestion during the morning and evening peaks, has been by diversifying work schedules. The current paper focuses on start times.³

Commute time induced by traffic congestion is directly related to the workers' distribution of start times (Vickrey, 1969; Henderson, 1974; Chu, 1995; Fosgerau, 2008). When workers' arrival and departure times are spread out, peak congestion is flattened. The present paper focuses on morning work start times⁴ and on the workers' compensation related to spread in work start times, allowing us to get more insight about the welfare effects of mandatory staggered-work-hours programs, which induces firms and therefore workers to vary the time they arrive and leave the workplace (see e.g. Hamermesh, 1999).⁵ The number of firms adopting staggered work hours has been increasing in recent years (Mun and Yonekawa, 2006). In Germany, which will be the focus of our empirical analysis, staggered work hours are a matter of great interest and have become very widespread, utilised by one out of three firms (Bauer et al., 2007). Several studies, for example

¹ For example, Henderson (1981) reports that, in 1979, 75% of workers arrive within a time interval of 15 minutes.

² In the economic literature, we find two main approaches to model peak-period congestion. One approach was developed by Vickrey (1969) and elaborated in Arnott et al. (1993). The other approach was developed by Henderson (1974).

³ Other ways to diversify work schedules include a compressed work week, where a worker works her usual number of hours over a fewer number of workdays, or flextime, where a worker has some choice in establishing her work schedule.

⁴ In the current study, we will ignore work end times. End times are more spread out than start times, and evening schedule delays may be less critical in work departure decisions.

⁵ The literature distinguishes between internal (within a company) and external (among different firms in a town or area) programs, and mainly focuses on dominant employers, such as the government, which are more likely to consider a mandatory staggered-work-hours program, so the external costs of commuting are internalized.

Arnott (2007), has argued that this is key to understand the effect of mandatory staggered-work-hours programs to reduce external costs of peak congestion.⁶

Benefits and costs of different starting times may accrue to workers, employers and the society at large as the external costs of congestion are lowered. These benefits and costs can, in principle, be examined using workers' wages. The large empirical literature focusing on the effect of job attributes on wages, *hedonic wage theory*, does not quantify the costs or benefits associated with start time, the only exception being Wilson (1988), but his methodologies and results have been controversial (Arnott, 2007), as it will be explained later on in detail.⁷

The relationship between wages and start times is the result of the effect of start time on workers' utility/*preferences* due to inconvenient schedule costs and longer commuting times, as well as the effect of start time on productivity. So, with preferences we refer to the worker's utility derived from the starting time which may involve (i) inconvenient scheduling costs of leisure activities (e.g. family responsibilities and socializing) and (ii) commute time costs, as there is a strong relationship between starting time and the time length of the commute due to congestion (see Chu, 1995).

To explain the relationship between wages and starting times, it is convenient to suppose that workers have identical preferences. Given identical preferences, all workers prefer to start work at the same time. Consistent with the celebrated paper by Hotelling (1929), one may argue that workers prefer to enjoy leisure activities at the same time with other workers and hence wish to start work at the same time, which is, by construction, the peak time. Synchronization of leisure activities may arise because of social and family interactions, but also because of child care (Bernheim, 1994).

⁶ Staggered-work-hours programs may involve some implementation barriers. If worker unions are very powerful, the employer may lack the flexibility to lower the wage of workers who prefer and enjoy of staggered work hours or may even lack the flexibility to implement a staggered-work-hours program. Some employers may resist implementing staggered-work-hours programs believing that if workers start and end work at different times, it reduces the opportunities for scheduling meetings, inhibits responsiveness to clients and/or other firms, or reduces workers interaction (Weiss, 1996). Team work and interaction with clients and/or other firms, however, might be important only at some period during the work day and, generally, workers under staggered hours must be present certain 'core hours' during the day.

⁷ See, for example, Cahuc and Zylberberg (2004) for an exposition of hedonic wages theory.

Further, the work start time has been traditionally set by external factors such as daylight and temperature (Weiss, 1996).⁸

Workers' productivity may depend on the start time (Golembiewski et al., 1974; Shepard et al., 1996), but the relationship between productivity and start time may be firm specific. For example, workers' productivity has been argued to depend on the number of other workers that are active at a certain time (Henderson, 1981; Arnott, 2007).⁹ However, for firms where worker's productivity does not depend on start time (e.g. firms with diminishing marginal returns of labour but with fixed capital costs), start times will be spread out over the 24-hours day (Lucas, XX).¹⁰ Henderson (1981) argues then that, in a competitive labour market, a variety of start times may be offered to workers at different wages reflecting preferences and productivity of workers varying by work start time.

More generally, in a competitive labour market that accounts for workers' productivity and scheduling costs, a staggered-work-hours equilibrium locus of wages and start times exists (see Henderson, 1981). This locus can be estimated directly from the observed relation between start time and wages. In equilibrium, workers maximize then their utility, which depends on costs related to commute time and inconvenient scheduling costs. Further, the wage is then equal to workers' marginal productivity, which varies with work start time.¹¹ This equilibrium leads to an efficient

⁸ Workers starting before the peak may find that family or socializing activities occur too late. Workers starting after the peak may enjoy of fewer daylight hours or may miss some family or socializing activities that they would otherwise enjoy. Thus, inconvenient scheduling costs are larger if the worker stops working after the peak than before it, holding the length of workdays constant. One may conclude that starting at a peak time is the most desired time, implying the lowest value for inconvenient scheduling costs. Note that congestion in commuting may favour staggering of work start times. However, since congestion in commuting is typically external to leisure activities, it has little effect on the desired start time.

⁹ This implies the existence of external economies of scale to the firm in production (Mills, 1967; Brainard, 1997).

¹⁰ Productivity may depend on starting time for jobs in which the nature of the job requires that workers interact with other workers/clients. Examples of such jobs are assembly-line manufacturing, classroom teaching, police and fire services and emergency-medical services. In contrast, productivity may not depend on starting time for jobs in which work can be conducted efficiently regardless of other-workers' start and end times. Examples of such jobs are executives, administration, management, manufacturing and on-line sales functions.

¹¹ Typically, workers face a trade-off between start time and congestion while maximizing their utility that makes it not worth incurring scheduling costs, and they are therefore willing to pay in the form of increased commuting congestion to have a start time that facilitates the scheduling of leisure activities. Of course, as Wilson (1989) remarks, some workers may willingly choose to start work at an off-peak time rather than the peak starting time. Those workers who choose off-peak start times still incur scheduling costs, but they have just found some trade-off that makes it worth incurring these costs.

matching of workers with employers, in the absence of external costs (congestion) and benefits (agglomeration).

To simplify the terminology, it is useful to distinguish only between peak start time (when many workers are at work) and an off-peak time.¹² To explain the relationship between wages, worker preferences and productivity, it is useful to distinguish between two possible equilibria that may arise.¹³ In the first equilibrium, wages are a U-shaped function of start time, so the wages are the lowest at the peak time. In this case, it must be true that, *ceteris paribus*, workers prefer to work at peak time, and are compensated through a wage increase for inconvenience schedule costs at non-peak times that exceed the savings from reduced commuting time. Furthermore, workers must be more productive at non-peak times (as otherwise firms are not willing to pay a higher wage). In the second equilibrium, wages are an *inverse* U-shaped function of start time, so the wages are the highest at peak time. In this opposite case, it must be true that, *ceteris paribus*, workers prefer to work at non-peak times (because savings in commuting time exceeds inconvenience scheduling costs), and are compensated for longer commuting times at peak times. In addition, workers must be more productive at peak times.

The present paper attempts to increase our understanding of the two effects of work start time on worker productivity and preferences.¹⁴ We do so by studying how variations in work start time are related to variations in wages.

Wilson (1988) finds that the relationship between wages and start time is *strongly* inverse U-shaped. So, workers starting at a peak time are paid much more than those starting later or earlier, supporting the seminal study by Henderson (1981). However, as stated above, this interpretation is controversial. Arnott (2007) has recently criticized the interpretation by Wilson (1988), because the study does not control sufficiently for worker characteristics, as it relies on cross-section data. We

¹² Note that, given constant-length workdays, workers' scheduling behaviour is fully described by the work start time (see also Wilson, 1989).

¹³ Of course, these are just stereotype examples. Different equilibria may arise.

¹⁴ The distinction between employees and self-employed is not essential. If the worker is self-employed, she selects an optimal work start time based on her own preferences and her own productivity.

cannot state it more clear than Arnott (2007, p.190): “Wilson found that ... the daily average wage is on average twice as high for workers with a peak work start-time ... than for those with an off-peak work start-time. Intuition suggests that this difference is too large to be explained by intra-day productivity effects alone, and that sorting of workers across start times, on the basis of ability attributes observable to employers but not to the empirical researcher, must play an important role too. No empirical work has been done that attempts to distinguish between the two effects”. An important contribution of the present paper is that we control for (unobserved) worker characteristics including the ability attributed by using panel data.

Our results suggest that the empirical conclusion by Wilson (1988) is unfounded. Another contribution is that we examine the net effect of policy-induced changes in start time on social welfare, as mandatory staggered-work-hours policies encourage off-peak start times in order to mitigate traffic congestion (see e.g. Giuliano and Golob, 1990; Arnott et al., 2005).

The outline of the paper is as follows. In Section 2 we provide information on the data employed, introduce the econometric model of wages and present the empirical results. In Section 3, we discuss welfare implications of potentially interesting mandatory staggered-hours policies. Section 4 concludes.

2. The Worker Compensation Analysis for Start Time

2.1. The data

Our study is based on information from the German Socio-Economic Panel (GSOEP) for the years 2004 and 2006. For these years, we have information on work start time as well as on hourly wages. This implies that we have the possibility to examine workers’ changes over time in start times and wages.

2.2. Descriptive statistics

The analyses are based on a dataset of 13,231 annual observations for 9,210 workers, where 4,021 workers are observed both in 2004 and 2006. The data includes information on age, gender, education, type of worker, firm location, industry, firm size, length of time with firm, self-employed, commuting distance, household monthly earnings, presence of partner in the dwelling and children. Hourly wage, our main dependent variable, is calculated by dividing net monthly earnings by monthly (contractual) hours.

In our data, we have also information about whether the work schedule is flexible or fixed (so it does not change from day to day). When it is fixed, we also know the exact work start time. This applies to the large majority of workers (72% of all workers). Since we are interested in effects related to the morning peak congestion, we measure starting time only for workers with work start times between five and twelve o'clock in the morning (96% of all workers with a fixed start time start in this interval).¹⁵

Figure 1 shows the frequency distribution of morning start times. Although start time is, in principle, a continuous variable, workers report mainly full and half hour starting times. For example, 23% report to start exactly at 8:00 a.m.¹⁶ Start times occur mainly within a short time interval: 65% of all workers start between 6:59 and 8:01 a.m., which we will call *peak start time*. The number of workers that start before peak times is roughly the same as the number of workers that start after peak times. 16% of workers start before the peak, whereas 19% start after the peak. The mean and median starting times occur at 7:35 and 7:30 a.m. respectively, so in the middle of the peak interval.

In the econometric analysis we will also analyse worker's differences in starting times. (changes between 2004 and 2006). Figure 2 shows the distribution of differences in start times. Usually, there is no change in start times observed. However, it appears that 7.2% of workers change their starting time by more than one hour between 2004 and 2006. Net hourly wages range from €5 to

¹⁵ Start times outside this interval include, for example, night work.

¹⁶ This is also relevant when specifying start time by means of dummy variables.

€62, with a mean of €10.8.

2.3. *Econometric model*

The approach we use to estimate the effect of start time on wages is standard in the hedonic wage literature (see e.g. Duncan and Holmlund, 1983). We estimate the logarithmic wage as a function of start time, individual and job characteristics. We therefore specify wage W as follows:¹⁷

$$\log W_{it} = X_{it}\beta + \varepsilon_i + v_{it},$$

where X_{it} is a row-vector of variables including work start time and other control factors which, according to the literature, may affect the worker's i wage level at time t ,¹⁸ β is a column-vector of parameters to be estimated, ε_i is the individual specific error term and v_{it} is the individual and time specific error term.¹⁹

When controlling for observed differences among workers (based on X_{it}), wage variation could still be consequence of sorting of workers across start times, on the basis of a match between unobserved worker characteristics (e.g. ability) and firm technology (see Arnott, 2007). For example, workers who are more productive for reasons that are not observed in the data (e.g. unobserved innate ability and motivation) may sort themselves into a preferred schedule. To control for sorting, we have included a worker fixed effect ε_i which controls for unobserved time-invariant worker characteristics. When taking first differences, only differences, only differences in variables is employed in the estimation procedure.²⁰ So, $\log(W_{it}) - \log(W_{it-1}) = (X_{it} - X_{it-1})\beta + v_{it} - v_{it-1}$.

¹⁷ Note that Wilson (1988) uses the same approach, so our cross-section results are in principle comparable to those of that study. Note however that in the cross-section, we use more control variables and our dataset is 40 times larger allowing us to generate more precise estimates.

¹⁸ We control for observable worker characteristics, the size and location of the firm, and industry, which reflect wage variation due to productivity. We further control for other variables, such as presence of a child, which may be correlated with omitted variables (e.g. childcare start time) that are correlated with our variable of interest, work start time.

¹⁹ Note that according to the hedonic wage literature, conditional on ε_i , the variables X_{it} can be assumed to be exogenous in the estimation procedure, because employers implicitly set wages as a function of work start time.

²⁰ In a first-differences model, time-invariant controls for worker characteristics (e.g. gender) and unobserved time-invariant worker heterogeneity are treated as fixed parameters.

2.4. Empirical results

2.4.1. First-differences model

As emphasized above, the dependent variable in the model is the difference in the logarithm of net hourly wage. We focus on the results of the main independent variable of interest: the difference in the morning work start time for the interval of interest (5–12 a.m.). Start time is measured in *hours*. We control for work schedules that start outside this interval by including three work schedule *dummies*: flexible schedules, night work and evening work.

As emphasized above, it is plausible that the effect of work start time on wage is U-shaped or inverse U-shaped, which excludes the use of linear specifications of start time. The effect of start time is therefore examined using a range of non-linear specifications. First, we use a quadratic specification of start time (see similarly Wilson, 1988); see Table 1, column 1. Our results suggest that the relationship between wages and start time is U-shaped (the effect of start time on wage is negative and the square of start time is positive). However, the overall effect of the start time and start time squared is statistically insignificant (at the 5% level) using a standard F-test, see bottom of Table 1.²¹

The use of a quadratic specification may not be appropriate though, because it allows for an (inverse) U-shaped function, it does *not* allow for any other functional non-linear form. So, we have also estimated the model specifying work start time using three dummies for the morning time interval: work starting at the peak time (6:59–8:01 a.m.), before the peak (5:00–6:59 a.m.) or after the peak (8:01–12 a.m.), see column 2. Our results indicate that wages before the peak do not differ from the peak time wages (the point estimate is -0.018 with a s.e. of 0.012), but, after the peak, wages are higher and this difference is statistically significant at 5% level (about 0.027 with s.e. 0.012). Our results imply therefore that, for workers whose start time moves from the peak to after the peak, workers must be compensated by an increase their wage of about 3% due to an increase in workers'

²¹ Controlling for other variables does not appear to be essential, because the estimated effect of start time on wage not controlling for any other variable generates similar results.

inconvenience scheduling costs that exceed the savings in commute time costs. Hence, the overall finding is that savings in commute time are not sufficient to compensate workers for late start times, but are sufficient to compensate workers with early start times. We have also measured start time by means of six dummies, see column 3. The results are qualitatively similar, but clearly indicate that after the peak, wages must be higher the later the start time is.

The disadvantage of the dummy specifications is that it is assumed that the effect *within* the time interval specified by the dummy is absent. This seems restrictive, as the difference between 9:01 and 9:59 a.m. may be quite large. So, we have also estimated a piecewise linear regression where the function is continuous, but between predefined knots (see e.g. McGee and Carleton, 1970). We have set four knots: 5:00, 6:59, 8:01 a.m. and 12:00 a.m., so one estimates three different slopes. As can be seen from Table 1 column 4, the marginal effect of work start time on wage is negative but statistically insignificant if work start moves from 7 to 5 a.m. (-0.026 with s.e. 0.022), whereas it is positive and statistically significant if it moves from 8 to 10 a.m. (0.006 with s.e. 0.003).²² Hence, again we find that workers' wage appears to be constant up to a certain start time (eight o'clock) and then increases when starting time increases.

Importantly, the conclusion of Wilson (1988) that the relationship between wages and start time is inverse U-shaped is strongly rejected by our analysis, as our results indicate that workers starting after peak time receive a wage premium. This finding is consistent with studies that examine willingness to pay to reduce travel time (see ref, XX). A possible explanation for the wage premium associated with after-peak starting times but not found for before-peak starting times relates to the nature of scheduling costs, because workers on early schedules may be inconvenienced by having to wait for a period of time after finishing work before engaging in many leisure activities, but workers on a later schedule, may be excluded altogether from social, family and child care activities, particularly if they work finish time is late enough. Hence, one would expect higher costs associated

²² We have also examined other knots, but the marginal effect is still statistically negligible before the peak and statically positive after the peak.

with later starting times (see Wilson, 1989).²³ Our findings imply that, at least for some jobs, workers are more productive at an after-peak time, as no employer seems to be willing to pay for an inconvenient scheduling unless the worker is more productive. Our results also imply that, at least for some jobs, workers are equally productive at peak times and before-peak times.

2.4.2. Pooled regression model

We will also shortly discuss estimates of an ordinary linear regression without a worker fixed effect (pooled regression) which allow us to compare the results with the empirical literature that does not rely on a worker fixed effect (Wilson, 1988). As emphasized above, sorting of workers based on unobserved variables that are correlated with start time is not control for, and therefore we consider pooled regression estimates as spurious. Given all specifications (see Table A1), results spuriously suggest that the relationship between wages and start time is strongly inverse U-shaped.

2.5. Sensitivity analysis

We also investigate whether it is useful to distinguish between workers *with* and *without* young children, because the inconvenience of work schedules may be different for these two groups. For example, workers with young children may have a higher level of family responsibility to meet child-care. In our data, 33% of all workers have at least one child aged below 14 years.²⁴ We have therefore re-estimated the above models distinguishing between workers with or without children (aged below 14 years old) in the household, which results are provided in Table A2.

Given a quadratic specification of start time (columns 1–2), our results suggest that the relationship between wages and start time is U-shaped for workers with a child, but not for workers without a child. Our results indicate therefore that workers with a child have to be compensated by

²³ This is particularly true if the number of hours work per day is the same for all workers (Wilson, 1989). This appears to be true for the large majority of workers (see, Hamermesh, XX).

²⁴ Another motivation to distinguish between workers with (or without) children is that in separate analyses where we examine the effect of worker and job characteristics on start time, we find that the presence of *children in the household* is the main determinant of start times.

higher wages if they start work at an off-peak time. Given a piecewise linear function (columns 5–6), we find no effect for workers without children, or may be the effect is too small to be identified. We find that the wage of workers with a child appears to be a constant up to eight o'clock and then increases when start time increases. Results specifying start time using three dummies (before, during and after the peak) present a positive and statistically significant effect of start time on wage for worker without children starting after the peak. Hence, our results for the groups of workers with and without a child are consistent with the results for all workers. No evidence is found to support the idea that wages are an inverse U-shaped relationship of start time.²⁵

Finally, since we are primarily interested in the effect of variation in start time on wage related to morning peak congestion, one may wonder whether or not the use of a smaller interval of start times to estimate this effect affects our results. We have used a measure of starting time only for observations with work start times between six and ten o'clock (90% of all workers with a fixed start time). No evidence is found to reject the previous results. We have also re-estimated all models controlling for commuting distance²⁶, controlling for job tenure and also taking interactions of start time with self-employed²⁷, but the results remain the same.

3. Implications for Staggered-Work-Hours Policies

The welfare effects of a program that requires firms to stagger work hours (e.g. the government may tax start times or regulate the distribution of a firm's work start times) are a priori unclear: they may be positive or negative (see Arnott et al., 2005). So, Arnott et al. (2005) concludes that it is better that governments do nothing. First, workers who are forced to adjust their work start time away from the

²⁵ We find that the relationship between wages and start time is statistically significant and inverse U-shaped for workers without children when estimating a pooled regression model, whereas for workers with children the effect is statistically insignificant.

²⁶ Note that we are not able to control for commuting time as it is unobserved in our dataset. In our main analyses, we do not control for commuting distance because commuting distance, in search theory literature, can be argued to be endogenous (see Manning, 2003). For example, heterogeneous workers commuting longer distances tend to be compensated by higher wages.

²⁷ The sample of self-employed is very small, merely 10% of workers are self-employed.

peak may be made worse off by greater inconvenient scheduling costs. Second, workers whose start time is altered may be made better off but only if they save enough travel time to compensate for increased inconvenient costs (if any). This will most probably be true for workers who are moved from a peak time to a start time before the peak, but not for those workers who are moved to a start time after the peak. Finally, firms may not improve in production, but only worsen. Workers seem to be equally (or less) productive if worker's productivity does not depend (does depend) on work start time, such as capital intensive firms (labour intensive firms).

In order to evaluate the welfare effects of a staggered-work-hours policy, (at least) two pieces of information are necessary. First, one must know how to calculate the gains or losses of the worker's utility of scheduling preferences (net of savings in the length of commute time costs) associated with changes in the worker's start time. Second, calculate whether worker's productivity is larger than worker's utility. Our results above do not quantify the worker's productivity nor the worker's utility associated with work start time. However, under the assumption that workers have the same preferences (preference to start at a peak time) but firms differ in their technology, we can obtain interpretable results. Note that if worker's productivity does not depend on start time (e.g. capital-intensive firms), the effect of start time on worker's productivity is then be constant ($\partial \log W / \partial \text{Start time} = 0$).²⁸ We can then quantify the welfare effect of a change in work start time for each worker based on the amount of wage a worker must be given to compensate her loss (gain) in utility of scheduling preferences plus the additional welfare gains (losses) from external savings in commute time costs. Changes in worker's utility U can then be calculated as the effect of start time on wage, because $\partial \log W / \partial \text{Start time} = -\partial U / \partial \text{Start time}$. If, however, worker's productivity depends on start time (e.g. labour intensive firms), the welfare loss is slightly more complex to calculate, as changes in worker's productivity and worker's preferences may be of the same or opposite sign, and not necessarily of equal magnitude. If worker's productivity varies when start time moves from peak

²⁸ For example, firms where solo activities play a role and not interactive activities (e.g. maintenance).

to off-peak times, the welfare loss is underestimated (overestimated) when some workers are more (less) productive. As we used first differences in our estimates, this is identified on workers that change their start times, whereas it is not identified on workers that are efficiently matched with firms.

Based on estimates of Table 1, we can calculate the welfare effect of a policy that staggers work hours in Germany. For ease of calculation, we first presume that worker's productivity does not depend on start time, but we later on relax this assumption. The *external* savings in commute time costs from moving away from the peak are estimated to be about €2.31 per worker per day.²⁹ A workers whose start time moves away from the peak towards a later start time, by moving from seven to nine o'clock, her disutility from scheduling behaviour increases by about €6.05 per worker per day (based on a mean *daily* wage in hour data of €86.4 and a mean effect of work start time of 0.03, see Table 1 column 2). Hence, such a policy generates a welfare loss of about €3.74 per worker per day in Germany. If we, however, relax the previous assumption, given the large magnitude of inconvenient scheduling costs, it is less than obvious that worker's productivity is increased enough to compensate for increased inconvenience of work schedules.

There are ad hoc reasons to believe that the welfare loss resulting from a staggered-work-hours policy may be mainly driven by some groups of workers, such as workers with children, because these workers have a larger disutility of inconvenience of work schedules than the average worker. A government that worries about the price paid for the policy by certain groups of the population, such as workers with children, should stagger work hours to a smaller extent to this particular group (which may be an acceptable policy based on e.g. family-friendly policies). Furthermore, our results indicate that it may be welfare-enhancing to stagger work hours from a peak towards an earlier starting time but only targeting workers without children. However, workers without children should

²⁹ The latter estimate has been based on the external congestion cost of a commuting trip of 0.068€/km (see Small and Verhoef, 2007, p. 99) and at a mean one-way commuting distance of 17 km. This estimate is likely a maximum as it is based on the assumption that the commute at an off-peak travel time can be accomplished without any congestion if staggering of work hours were implemented.

voluntarily stagger work hours as firms are not always allowed to treat differently workers with and without children.

4. Conclusion

Transport economists have been interested in workers' work starting time for many years, as starting time is closely related to morning peak congestion. Work-staggered-hours policies by governments to mitigate congestion affect worker's preferences and worker's productivity, but little is known about the effect of workers' *morning* start times on wages (Arnott, 2007). In this paper, we examined the effect of workers' start time on wages using the socio-economic panel data for Germany for 2004 and 2006, while controlling for factors such as age, gender, children, education, industry and firms size, which may also affect wages. As far as we are aware, there is only one previous study by Wilson (1988) that looked at this issue. Wilson finds that wages are an inverse U-shaped relationship of start time, and therefore concludes that workers at peak start times are *much* more productive than those with off-peak start times, supporting the seminal paper by Henderson (1981). This finding is consistent with the idea that workers prefer to start work at an off-peak start time because savings in the commute time costs are larger than the reduction in scheduling costs. However, as emphasized by Arnott (2007), the estimation procedure by Wilson (1988) presents several drawbacks. The main drawbacks are cross-section data are used and there are few controls, so that sorting of workers based on unobserved variables that are correlated with start time is not controlled for. These drawbacks strongly suggest that Wilson's results are very likely biased.

We improve on Wilson (1988) by using a first-differences model, more controls and more data. By using first differences, we control for worker sorting bases on unobserved variables (e.g. controlling for workers' ability and preference differences). Our results indicate that the relationship between wages and start time is U-shaped (and not inverse U-shaped, as reported by Wilson). However, the exact effect of start time is too small to be precisely identified if start time is before the

peak start time (the peak start time interval is defined from seven to eight o'clock). On average, after morning peak time wages are three percent *higher* than at peak time. Our finding implies that workers prefer to start work at a peak time rather than after the peak, so that the after-peak-time inconvenient scheduling costs outweigh any savings in commute time costs. This finding may explain to some extent the persistence of concentrated starting times during the morning peak.

The main implication of our results is that staggering of work hours by governments in order to mitigate congestion may enhance or reduce social welfare (see Arnott, 2005). A policy that moves starting times away from the peak will increase workers' inconvenient scheduling costs and reduce (or keep constant) workers' productivity. However, at the same time, workers and firms will be better off because of *external* savings in commute time. Hence, the net welfare effect of such a policy is a priori unclear. Our estimations of a policy that moves start times from peak times to after-peak times generates a welfare loss of about €3.74 per worker per day in Germany.

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Table 1. *Estimates of Net Hourly Wage in Log (in Euros) (GSOEP 2004, 2006): First-Differences Approach*

	[1]	[2]	[3]	[4]
	Quadratic function	3 start time dummies	6 start time dummies	Piecewise linear function
<i>Start time between 5:00–12:00</i>				
Start time (hours)	–0.069 (0.060)			
Start time squared (hours)	0.049 (0.003)*			
Start time 5:00–6:59 (before-peak start time)		–0.018 (0.012)		
Start time 8:01–12:00 (after-peak start time)		0.028 (0.012)**		
Start time (hours) (Before-peak start time)				–0.013 (0.022)
Start time (hours) (Peak start time)				0.004 (0.003)
Start time (hours) (After-peak start time)				0.003 (0.001)**
Start time 5:00–5:59			–0.022 (0.016)	
Start time 6:00–6:59			–0.012 (0.109)	
Start time 8:01–8:59			0.027 (0.012)**	
Start time 9:00–09:59			0.063 (0.029)**	
Start time 10:00–12:00			0.090 (0.051)*	
Flexible schedule	0.013 (0.009)	0.009 (0.009)	0.007 (0.027)	–0.511 (0.139)
Night work	0.080 (0.057)	0.078 (0.057)	0.077 (0.040)	0.018 (0.148)
Evening work	0.008 (0.027)	0.001 (0.027)	0.005 (0.028)	–0.059 (0.142)
<i>Productivity variables</i>				
Self-employed	–0.005 (0.018)	–0.004 (0.018)	–0.005 (0.018)	–0.004 (0.018)
White collar worker	0.005 (0.015)	0.006 (0.015)	0.006 (0.015)	0.006 (0.015)
Civil servant	0.035 (0.029)	0.036 (0.029)	0.036 (0.029)	0.036 (0.029)
Firm size < 20 workers	0.021 (0.010)**	0.020 (0.010)**	0.021 (0.010)**	0.020 (0.010)**
Firm size from >=20 – <200 workers	0.019 (0.009)**	0.018 (0.009)**	0.019 (0.009)**	0.019 (0.009)**
Firm size from >=200 – <2000 workers	0.009 (0.009)	0.010 (0.009)	0.009 (0.009)	0.009 (0.009)
Firm size unknown	0.032 (0.017)*	0.032 (0.017)*	0.031 (0.017)*	0.032 (0.017)*
Industry controls	Included	Included	Included	Included
Firm location controls	Included	Included	Included	Included
<i>Other control variables</i>				
Other household income in log (in euros)	–0.035 (0.004)**	–0.036 (0.005)**	–0.035 (0.005)**	–0.036 (0.005)**
Other household income unknown or zero	0.093 (0.011)**	0.092 (0.011)**	0.093 (0.011)**	0.093 (0.011)**
Partner in dwelling	0.040 (0.014)**	0.040 (0.014)**	0.039 (0.014)**	0.040 (0.014)**
Child in dwelling	0.043 (0.013)**	0.044 (0.013)**	0.044 (0.013)**	0.044 (0.013)**
Female × child	–0.003 (0.022)	0.000 (0.002)	0.000 (0.002)	0.000 (0.022)
Year controls	Included	Included	Included	Included
Adjusted R ²	0.871	0.870	0.871	0.871
No. observations	13,231	13,231	13,231	13,231
F-test (start time)	1.882	F-test	F-test	F-test
Minimum wage (start time)	5.794 (5.700)			

Notes: Monthly net income of other household members. The reference categories for start time, type of worker, and firm employment size are ‘dummy start time between 7:00 and 8:00’, ‘industrial worker or unknown type of worker’ and ‘firm size > 2000 workers’. **, * – indicate that estimates are significantly different from zero at 0.05 and 0.10 level. Standard errors are in parentheses.

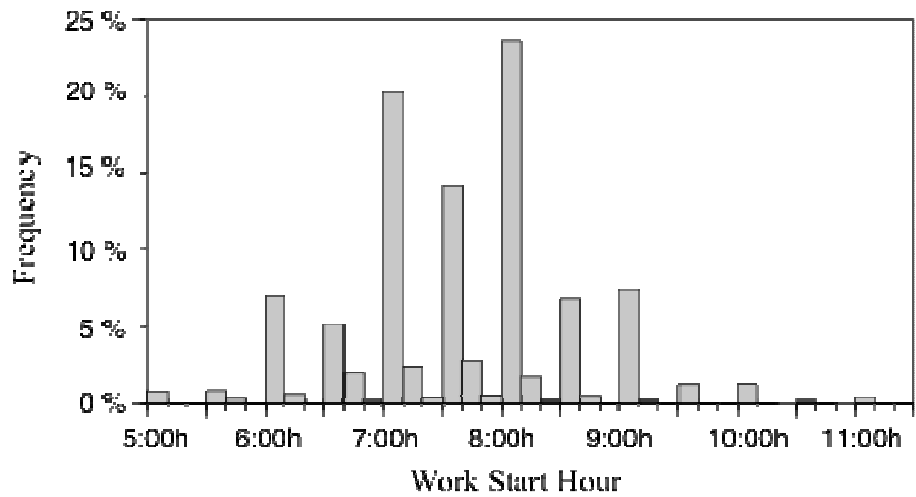


Figure 1. *Frequency Distribution of Work Start Hour (GSOEP 2004, 2006)*

-FIGURE 2 HERE-

Figure 2. *Frequency Distribution of Changes in Work Start Hour (GSOEP 2004, 2006)*

Appendix A: Tables

Table A1. *Estimates of Net Hourly Wage in Log (in Euros) (GSOEP 2004, 2006): Pooled Regression Approach*

	[1]	[2]	[3]	[4]	[5]	[6]
	Quadratic function			6 start time dummies		
<i>Start time between 5:00–12:00</i>						
Start time (hours)	0.539 (0.045)**	0.048 (0.010)**	0.196 (0.035)**			
Start time squared (hours)	-0.031 (0.003)**	-0.042 (0.011)**	-0.010 (0.002)**			
Start time 5:00–5:59				-0.179 (0.015)**	-0.076 (0.013)**	-0.086 (0.012)**
Start time 6:00–6:59				-0.119 (0.009)**	-0.058 (0.008)**	-0.006 (0.001)**
Start time 8:01–8:59				0.046 (0.012)**	0.048 (0.009)**	0.045 (0.009)**
Start time 9:00–09:59				-0.084 (0.027)**	0.007 (0.021)	0.016 (0.020)
Start time 10:00–12:00				-0.263 (0.047)**	-0.062 (0.037)*	-0.070 (0.036)*
Flexible schedule	-0.057 (0.008)**	0.021 (0.007)**	0.016 (0.006)**	0.170 (0.022)**	0.049 (0.017)**	0.046 (0.017)**
Night work	-0.283 (0.042)**	-0.143 (0.033)**	-0.145 (0.032)**	-0.291 (0.032)**	-0.145 (0.026)**	-0.156 (0.025)**
Evening work	-0.229 (0.020)**	-0.031 (0.016)*	-0.033 (0.016)**	-0.246 (0.021)**	-0.036 (0.017)**	-0.039 (0.017)**
<i>Productivity variables</i>						
Self-employed		0.194 (0.011)**	0.190 (0.010)**		0.194 (0.011)**	0.189 (0.010)**
White collar worker		0.116 (0.007)**	0.116 (0.007)**		0.115 (0.007)**	0.114 (0.007)**
Civil servant		0.322 (0.014)**	0.320 (0.014)**		0.323 (0.014)**	0.321 (0.014)**
Firm size < 20 workers		-0.128 (0.010)**	-0.123 (0.010)**		-0.129 (0.010)**	-0.123 (0.010)**
Firm size from >=20 – <200 workers		-0.091 (0.010)**	-0.087 (0.009)**		-0.092 (0.010)**	-0.087 (0.009)**
Firm size from >=200 – <2000 workers		-0.038 (0.010)**	-0.039 (0.010)**		-0.038 (0.010)**	-0.040 (0.010)**
Firm size unknown		-0.036 (0.017)**	-0.027 (0.016)*		-0.037 (0.017)**	-0.028 (0.016)*
Industry controls		Included	Included		Included	Included
Firm location controls		Included	Included		Included	Included
Primary and lower education		-0.304 (0.011)**	-0.294 (0.010)**		-0.230 (0.011)**	-0.290 (0.010)**
(Upper) secondary education		-0.270 (0.007)**	-0.260 (0.007)**		-0.267 (0.007)**	-0.257 (0.007)**
Post-secondary non tertiary education		-0.217 (0.011)**	-0.210 (0.011)**		-0.214 (0.011)**	-0.207 (0.011)**
First stage of tertiary education		-0.198 (0.010)**	-0.200 (0.010)**		-0.195 (0.010)**	-0.196 (0.010)**
Education unknown		-0.256 (0.023)**	-0.232 (0.023)**		-0.252 (0.023)**	-0.229 (0.023)**
Age/10		0.082 (0.003)**	0.083 (0.003)**		0.082 (0.003)**	0.083 (0.003)**
Female		-0.231 (0.006)**	-0.178 (0.007)**		-0.232 (0.006)**	-0.180 (0.007)**
<i>Other control variables</i>						
Other household income in log (in euros)			-0.023 (0.003)**			-0.023 (0.003)**
Other household income unknown or zero			0.115 (0.008)**			0.115 (0.008)**
Partner in dwelling			0.070 (0.007)**			0.070 (0.007)**
Child in dwelling			0.142 (0.008)**			0.141 (0.008)**
Female × child			-0.079 (0.011)**			-0.008 (0.001)**
Constant	0.027 (0.173)	1.454 (0.140)**	1.385 (0.137)**	2.334 (0.006)**	2.261 (0.017)**	2.285 (0.029)**
Year controls	Included	Included	Included	Included	Included	Included
Adjusted R ²	0.032	0.414	0.448	0.036	0.415	0.449

	[1]	[2]	[3]	[4]	[5]	[6]
No. observations	13,231	13,231	13,231	13,231	13,231	13,231
F-test (start time)	143.7	23.67	31.95	F-test	F-test	F-test
Maximum wage (start time)	8.569 (0.113)**	9.667 (0.559)**	9.493 (0.436)**			

Notes: Monthly net income of other household members. The reference categories for start time, type of worker, firm employment size and education are ‘dummy start time between 7:00 and 8:00 a.m.’, ‘industrial worker or unknown type of worker’, ‘firm size > 2000 workers’ and ‘second stage of tertiary education’. **, * – indicate that estimates are significantly different from zero at 0.05 and 0.10 level. Standard errors are in parentheses.

Table A2. *Estimates of Net Hourly Wage in Log (in Euros) By Workers With and Without Children (GSOEP 2004, 2006): First-Differences Approach*

	[1]	[2]	[3]	[4]	[5]	[6]
	No child Quadratic function	Child	No child 3 start time dummies	Child	No child Piecewise linear function	Child
<i>Start time between 5:00–12:00</i>						
Start time (hours)	0.097 (0.063)	-0.228 (0.100)**				
Start time squared (hours)	-0.0001 (0.0001)	0.0003 (0.0001)**				
Start time 5:00–6:59 (before-peak start time)			-0.037 (0.014)**	0.018 (0.030)		
Start time 8:01–12:00 (after-peak start time)			0.023 (0.014)	0.009 (0.023)		
Start time (hours) (Before-peak start time)					0.013 (0.026)	-0.056 (0.048)
Start time (hours) (Peak start time)					0.004 (0.003)	0.002 (0.05)
Start time (hours) (After-peak start time)					0.002 (0.002)	0.003 (0.003)
Flexible schedule	-0.009 (0.011)	0.042 (0.017)**	-0.003 (0.011)	0.003 (0.016)*	0.114 (0.161)	-0.329 (0.294)
Night work	0.044 (0.062)	0.099 (0.159)	0.056 (0.062)	0.084 (0.159)	0.170 (0.168)	-0.275 (0.334)
Evening work	-0.121 (0.038)**	0.091 (0.049)*	-0.114 (0.038)**	0.083 (0.049)*	0.003 (0.165)	-0.278 (0.299)
<i>Productivity variables</i>						
Self-employed	-0.035 (0.022)	0.403 (0.346)	-0.033 (0.022)	0.041 (0.035)	-0.033 (0.022)	0.040 (0.035)
White collar worker	-0.015 (0.018)	0.023 (0.030)	-0.013 (0.018)	0.024 (0.030)	-0.014 (0.018)	0.022 (0.030)
Civil servant	-0.013 (0.035)	0.095 (0.053)*	-0.011 (0.035)	0.098 (0.053)*	-0.011 (0.035)	0.096 (0.053)*
Firm size < 20 workers	0.039 (0.012)**	0.008 (0.020)	0.039 (0.012)**	0.007 (0.020)	0.039 (0.012)**	0.006 (0.020)
Firm size from >=20 – <200 workers	0.024 (0.011)**	0.020 (0.018)	0.024 (0.011)**	0.019 (0.018)	0.024 (0.011)**	0.018 (0.018)
Firm size from >=200 – <2000 workers	0.014 (0.011)	0.018 (0.018)	0.014 (0.011)	0.019 (0.018)	0.014 (0.011)	0.017 (0.018)
Firm size unknown	0.050 (0.021)**	0.069 (0.037)*	0.050 (0.021)**	0.072 (0.037)*	0.050 (0.021)**	0.070 (0.037)*
Industry controls	Included	Included	Included	Included	Included	Included
Firm location controls	Included	Included	Included	Included	Included	Included
<i>Other control variables</i>						
Other household income in log (in euros)	-0.039 (0.005)**	-0.021 (0.009)**	-0.039 (0.005)**	-0.021 (0.009)**	-0.039 (0.005)**	-0.021 (0.009)**
Other household income unknown or zero	0.111 (0.013)**	0.065 (0.021)**	0.111 (0.013)**	0.062 (0.021)**	0.111 (0.013)**	0.064 (0.021)**
Partner in dwelling	-0.052 (0.016)**	-0.086 (0.045)*	0.052 (0.016)**	-0.083 (0.045)*	0.052 (0.016)**	-0.085 (0.045)*
Year controls	Included	Included	Included	Included	Included	Included
Adjusted R ²	0.876	0.863	0.876	0.863	0.876	0.863
No. observations	8,830	4,401	8,830	4,401	8,830	4,401
F-test (start time)	2.409	5.187	F-test	F-test	F-test	F-test
Minimum wage (start time)	9.573 (1.748)**	7.189 (0.386)**				

Notes: Monthly net income of other household members. The reference categories for start time, type of worker, and firm employment size are ‘dummy start time between 7:00 and 8:00 a.m.’, ‘industrial worker or unknown type of worker’ and ‘firm size > 2000 workers’. **, * – indicate that estimates are significantly different from zero at 0.05 and 0.10 level. Standard errors are in parentheses.