Aging and Productivity - Evidence from Piece-Rates

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Abstract

We evaluate the effects of aging on productivity using data from piece-rates. Our data contains the population of Finnish blue collar metal industry workers from years 1996-2000. A unique feature of the data is that we can observe the exact hours worked on piece-rates and time rates as well as earnings from both performance schemes. Moreover, a subset of workers receive both piece-rates and time rates within the same quarter. For these workers, we can directly compare the age profile of hourly wages under piece-rate and time rate pay systems. The results show that productivity increases with age through most of the career. Productivity increase is initially faster than wage increase but after age 30 productivity increases at a slower rate than wages.

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1 Introduction

Population aging has been a focus of intensive debate in the industrialized countries in recent years. Economists have traditionally concentrated on the consequences of this phenomenon on the sustainability of public finances. More recently also the productivity implications of population aging have caught the attention of economists. This is an important question since demographic changes may have sizable implications for economic growth. For example, Feyrer (2002) as well as Tang and MacLeod (2006) have studied the effects of population aging on aggregate productivity growth in the United States and Canada, respectively.

While aggregate labor productivity may be reasonably measured by relating the quantity of output to the quantity of its inputs, measuring individual output or individual productivity is substantially more difficult. Yet, to fully understand the productivity implications of population aging, it is crucial to study the effect of aging on the worker productivity at the micro level. A priori, it is not clear how the productivity of an individual changes with age. The medical and psychological literature indicates that individual's physical strength as well as cognitive abilities and learning capacities deteriorate with age. However, the economic theory suggests than learning on the job may mitigate some of the negative effects of aging on skills. How important all of these factors are depends crucially on the characteritics of the job. Hence, the net effect of aging on productivity is an open question and the answer will potentially depend on characteristics of the tasks.

Earlier studies on the effect of aging on productivity have followed several different strategies. In some specific occupations, direct measures on individual's output are available and age-productivity profiles can easily be calculated. Examples of these professions are academics, artists, and sports professionals.[1] For more representative categories of workers the traditional solution has been to use individual wages as a proxy for productivity. Alternatively, many authors have used supervisors' performance evaluations as proxies for productivity. Influential studies by Medoff and Abraham (1980, 1981) showed that worker's job tenure is either unrelated or negatively associated with performance

[1] Oster and Hamermesh (1998) as well as Weinberg and Galenson (2000) focus on academics; Galenson and Jensen (2001) study the careers of a number of great painters; Fair (1994) is a study on the age-productivity profiles of track and field athleles.

evaluations. This result was later replicated in a very different institutional setting by Flabbi and Ichino (2001). More recently, the use of linked employer-employee datasets has become more common in the field. Authors such as Hellerstein et al (1999), Crépon et al (2003), Ilmakunnas and Maliranta (2005) as well as Dostie (2006) use firm-level information to estimate the effect of workforce composition on the firm productivity. Also these studies, with an important exception of Hellersein et al (1999), tend to find that productivity of the older workers is lower than that of prime age workers.

While these approaches have yielded important information about the relationship of productivity and age, they also suffer from some major limitations. Direct information on individual output is available for so few professions that the results from these studies are hard to generalise. Individual wages, on the other hand, also increase with age independently of changes in productivity due to incentive mechanisims built into individual contracts. While supervisors' performance evaluations can serve as sufficient statistics for worker's productivity in ideal circumstances, it is far from clear whether supervisor's want to evaluate the worker's current productivity in reality. Supervisor's may just as well want to reward the worker for past achievements or to grade some fixed component of their individual productivity. Finally, studies that estimate the effect of workforce characteristics on firm productivity usually have to rely on strong assumptions regarding for example the shape of the production function. Most disturbingly it is usually necessary to assume that workers of different age are perfect substitutes with each other and that the allocation of workers across firms is essentially a random process.

In this paper we use piece rates as a proxy for productivity. We use data from a population of male blue-collar workers in Finnish manufacturing industries from the years 1996 to 2000. Data contains information on workers employed in a wide variety of tasks and are therefore more representative than studies based on specific narrow occupations or single firms. Our data have a unique feature that they contain information on the exact earnings and hours worked under both time-rate and piece-rate compensation schemes. We use panel data that allows us to follow workers over time and examine the changes in hourly compensation when the workers get older and when they change from a piece-rate to a time-rate compensation scheme or vice versa. A subset of workers also receives both piece-rate and time-rate pay during the same quarter. For these workers we can directly observe the differences in the time-rate and the piece-rate earnings from the same point in time.

Piece-rates are a good proxy for worker productivity since, unlike fixed time rates, they are directly determined by worker's individual output. The idea of using age–earnings profile when working on piece-rates as a proxy for the age-productivity profile is similar to the use of age-earnings profiles of the self-employed workers as in Lazear and Moore (1984) or Mendes de Oliviera et al (1989). However, there are two major problems common to these approaches. First, the payment schemes are not randomly allocated across workers. Typically, the most productive workers have more to gain from output-based pay system and will be more likely to choose to be self-employed or to work on piece-rate contracts. Thus, it is likely that also the age-earnings profile on time-rates for the workers that chose to work on piece rates would look very different from the average age-earnings profile. Second, the piece rate contracts create an incentive to exert more effort. If this incentive effect is different for workers of different ages, the age-profile of the piece-rate earnings may reflect differences in effort levels instead of differences in productivity.

We deal with these problems in the following way. To eliminate selectivity problems we use data on the workers that receive both time-rate and piece rate compensation during the same quarter. In order to assess the nature of selectivity in more typical data sets, we also compare this group of workers to those who are paid under a pure piece-rate or pure time rate compensation scheme. In order to distinguish between the effects of piece-rates on effort from the underlying differences in productivity we use sickness absenses as a proxy for effort and test whether the effect of incentives created by piece-rate contracts on absenteeism varies with age.

Our main results show that worker productivity, measured in piece rates, increases with age through most of the worker's career. Productivity increase is initally faster than the wage increas, measured in fixed hourly wages, but after the age 30 productivity increases at a slower rate than wages. We also explore the age profiles of productivity in jobs of varying complexity. The results suggest that productivity growth peaks at later ages in more complex jobs. It is also clear that if one fails to account for the selection into the piece-rate jobs, one ends with large overestimates of wage productivity gap. Indeed, for the older workers the productivity wage gap between old piece rate and fixed rate workers is four times higher than the within individual productivity wage gap.

We begin by explaining the methodology of using piece rate wages as proxy for productivity. The third section describes the data and the results are presented in the fourth section. The fifth section concludes.

2 Methodology

The theoretical literature on payment methods tends to stress that none of the conventionally used payment schemes is completely invariant to output. Even fixed hourly rates are usually coupled with some minimum output requirements. The relevant distinction is between payment schemes where wages vary continuously with output (piece rates) and schemes where this variation is discrete so that wages are paid only if the output exceeds a certain threshold (fixed rates). The use of piece rates as a proxy for worker's individual productivity is usually motivated by the fact that under piece rates the relationship between output and compensation is contemporaneous and continuous. The agency problems, apart from the well-known ratchet effect, should be absent under piece rates and only determinant of the wage should be current output.

However, the use of piece rates as a productivity proxy is made more complicated by the selection of workers into the compensation scheme. Lazear's (1986) model is the benchmark for the selection of payment schemes, with subsequent reformulations by Brown (1990), Booth and Frank (1999), and Lazear (2000). Lazear's two-period model is largely concerned with the sorting of workers between piece rate firms and fixed rates firms. Fixed rate workers are paid a salary, S, that is independent of productivity while piece rate workers are paid based on output (q), but must be monitored which incurs a cost, M, resulting in a piece rate wage of q - M. Workers know their own q's and choose the payment method that yields the highest earnings. Thus, workers will choose the piece rate firm iff q - M > S while others choose the salary firm. This of course implies that only more productive workers will work for the piece rate firm.

Booth and Frank extend Lazear's model to a richer case where worker output is a function of both effort and ability where effort cannot be monitored. Lazear (2000) makes a similar extension. Both of these theories yield the same conclusion that earnings for piece rate workers will be higher than fixed rate workers, but unlike Lazear (1986), part of this earnings effect it due to selection on ability and part is due to an incentive to work harder. Thus, the piece contracts can have a direct effect on productivity through the incentive effect.

We claim that we can overcome the problem of selection into piece rate jobs because for a subset of workers in our data we can observe piece rate and fixed rate wages contemporaneously. Thus, we regress productivity V_i, that is piece rate wages, on age dummies A_{ik} and a set of conventional conventional controls X_i:

$$\ln V_i = \alpha_1 + \beta_{1k} \sum_{k=1}^{4} A_k + X_i \gamma_1 + e_{1i} \tag{1}$$

for the same workers, we also regress their fixed rate wage, W_i, on the same variables:

$$\ln W_i = \alpha_2 + \beta_{2k} \sum_{k=1}^{4} A_k + X_i \gamma_2 + e_{2i} \tag{2}$$

and compare the age-profiles β_1 and β_2.

Usually the problem with this approach would be that V and W would not be observed for the same workers. Indeed, the theory implies that only very high productivity workers would work on piece rates. However, as will become clear below, in our case we can observe the V's and W's of the same workers.

The incentive effect of the piece rate contracts creates an additional problem for the analysis of the age profiles. If the effect of piece rate contracts on worker effort varies with age, the age-profile of piece rate wages may reflect differences in effort and not in underlying productivity. This is certainly a difficult problem to solve. Our strategy is to use a proxy for worker effort, sickness absenteeism, and see if the effect of piece rate contracts on absenteeism varies with age.

3 Data

The data that we use come from the wage records of the Confederation of Finnish Industry and Employers. They contain all payroll records including earnings and hours worked for all workers who are employed in firm affiliated with the Confederation. In the case of manufacturing in Finland, this covers virtually all the firms. We have access to yearly information on the male blue-collar population from 1996 to 2002. Each observation in our data contains the accumulated hours worked and earnings within the last quarter of each calendar year. After eliminating some observations due to missing information, we have a panel of 1,009,939 employee-year observations representing 269,477 workers from 56 industries and 2,517 firms.

3.1 Payment schemes in the Finnish manufacturing

The Finnish manufacturing industries are unionized with the general guidelines on wage determination set out in the collective agreement of the industry. The collective agreement allows the firms to choose from three different contracts: fixed rates, piece rates and reward rates. The spirit of the collective agreement is that the payment method should be determined by the characteristics of the tasks performed by the worker.

On fixed rates, workers are paid by the hour; however, fixed rate contracts have provisions for discretionary bonuses. For example in the metal industry, which employs the largest number of workers, this bonus can amount to 2%-17% of the job-specific minimum wage. Furthermore, the final level of the fixed rate is set at the local level so that there is considerable variation across workers and firms in fixed rate wages even within detailed occupations.

On piece rates, workers are paid purely based on individual output. The collective agreement indicates that piece rates should be used on clearly specified task assignments, and that payment should be based on output measures such as units, kilograms or meters produced. Piece rates are the least common payment scheme in the industry at only 10% of total hours worked.

The final compensation contract in the Finnish manufacturing industries is reward rates, which are a mix of piece rates and fixed rates, and could also include a team-based bonus. Thus, a part of the wage is a fixed hourly amount, while a part is determined purely on individual-based output, and another part could be based on team output. Unfortunately, the payroll records from the Confederation do not separate the part of reward rate pay that was earned from output versus the part that was fixed. The exact share of output-determined (either individual or team) earnings may vary across firms and across tasks.

3.2 The use of performance pay

A unique feature in these data is that we can observe the exact number of hours that the individual has worked under each payment scheme in each year. This information reveals that 205,558 (76 %) workers in our data never worked on piece rates and only 8,474 (3%) worked exclusively on piece rate contracts and 1,987 (1%) only on piece and reward rate contracts. Thus, for 80% of the workers the productivity-wage gap cannot be calculated

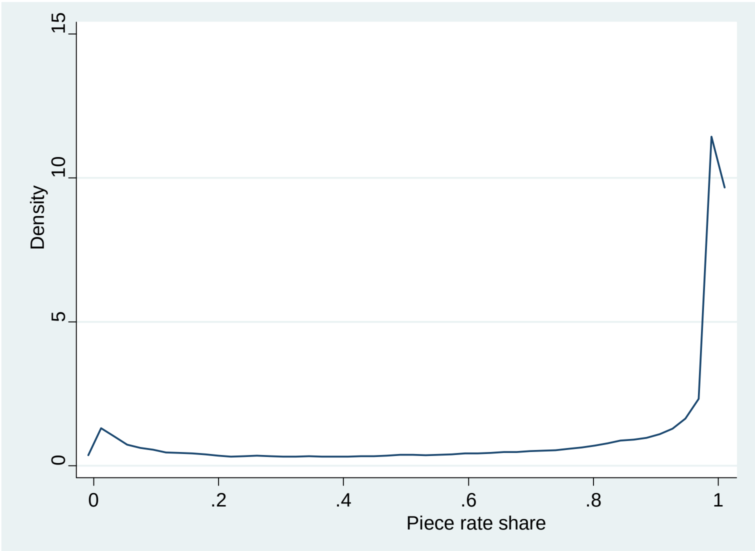


Figure 1: Kernel estimate of the distruibution of the piece rate share of hours among workers who work positive number of piece rate hours

because the counterfactual is never observed. This leaves us with 53 458 (20%) workers who we observe on both piece rate and either fixed or reward rate contracts. What is interesting is that 47.930 of these 53,458 workers tend to share their working hours between different payment schemes. That is, they switch between payment schemes within the same year. Changing from working only on piece rates to working only on another type of contracts is extremely rare in these industries. Figure 1 plots the kernel estimate of the density of positive piece rate shares. Although there is clear peak close to 1 in figure 1, the density is still positive over the whole support.

As figure 1 makes clear, there are workers who change between payment schemes even within one year. We will concentrate our analysis on these workers, since for them we can observe counterfactual fixed rate wages and productivity proxied by the piece rate wage. We call these workers "switchers" and the rest of the sample "non-switchers". Table 1 provides the summary statistics for both of these groups. As one can see from table 1, switchers tend to have higher fixed and piece rate wages than non-switchers. Also, they tend to come from smaller firms.

The share of hours worked on piece rates also varies with age, although these differences tend to be rather small. The pattern of piece rate work by age is depicted in figure 2. The share of piece rate hours increases until the age of 32 after which it starts to

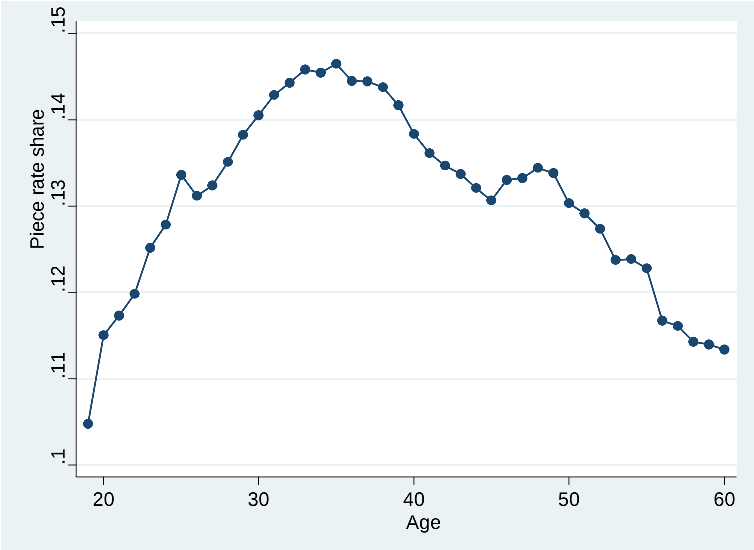


Figure 2: The average share of piece rate hours by age

decline. Figure 2 clearly illustrates that piece rate work is done by workers of all ages in these industries and is not limited to entry level jobs.

4 Results

Figure 3 plots the age profiles of both fixed and piece rate wages in the manufacturing worker population during 1996-2002. Fixed rate wages follow the familiar concave pattern that is typical for wage schedules. However, the profile of piece rate wage is than that of fixed rate wages. Figure 4, which plots the growth rates of fixed and piece rate wages, reveals that piece rate wages do grow slower than fixed rate wages although these differences are not big.

However, as was discussed in the outset, figures 3 and 4 do not take into account the selection of workers into piece rate work. The theory of compensation schemes implies that only high productivity workers select themselves to piece rate work. Thus, one would expect their fixed rate wages to be higher than the average fixed rate wages. It is possible that the fixed rate wage profiles of those workers who choose to work on piece rate wages are also flatter than the average fixed rate age profile.

To examine the differences in the age profiles of wages and productivity, we ran regressions of wages and productivity on agegroup dummies and observables in both

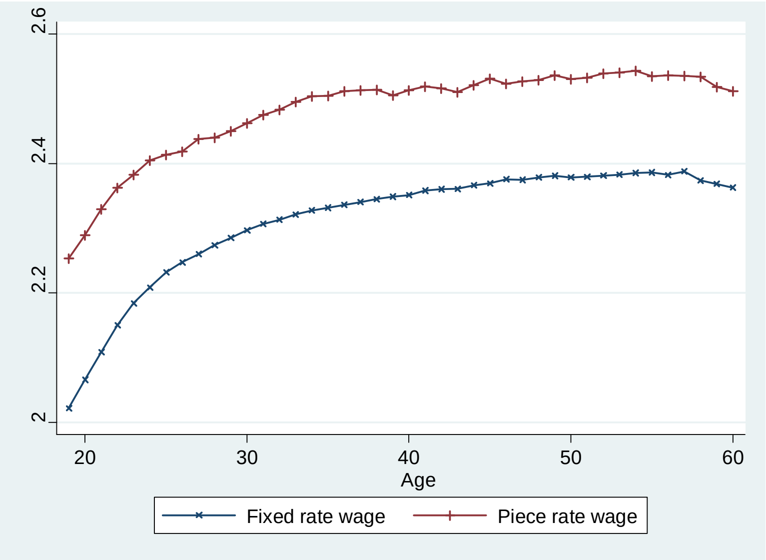


Figure 3: Piece rate and fixed rate age profiles in the whole population

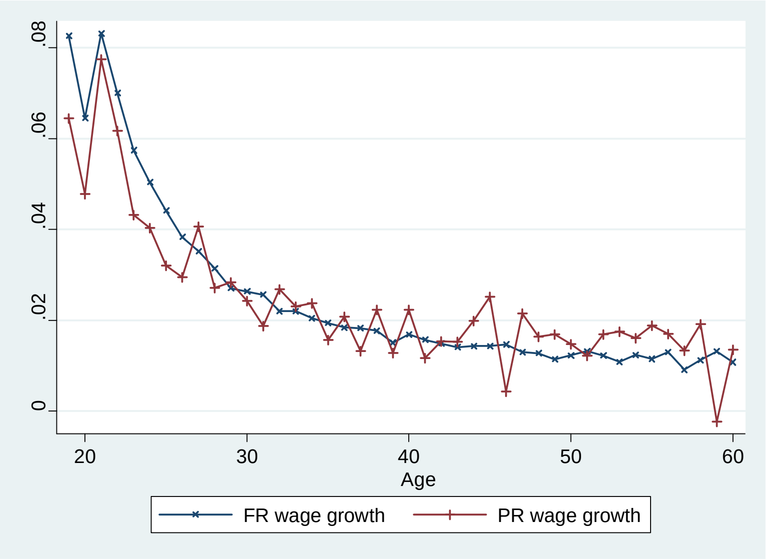


Figure 4: Age profiles of piece and fixed rate wage growth in the population

non-switcher and switcher populations. The results are reported in table 2. We follow Hellerstein et al (1999) and Crépon et al (2003) and divide the workers into 4 subgroups according to their age. Workers below 25 years old are classified as "entry" level workers, workers older than 24 but younger than 35 are "young" workers, workers older than 34 but younger than 35 are "prime age" workers and the rest of the workers are "old". As controls we include a dummy for skilled workers that takes value one if the worker has 12 or more years of education, a part-time dummy, the number of employees in the firm and dummies for double and triple shift work. All regressions also control for a full set of 153 occupational dummies.

As was to be expected, the fixed rate wages increase more rapidly with the worker's age than productivity in both non-switcher and switcher populations. In the switcher population, the wages of older workers are .16 log points higher than the wages of entry level workers, while their productivity is only .09 points higher. The initial productivity-wage gap of the entry workers of .16 log points has decreased to .09. Running the same analysis among non-switcher, exaggerates the wage-productivity gaps considerably. There the initial gap is .41 log points and it is only reduced to .37 among the older workers.

The analysis in table 2 clearly illustrates how failure to observe the actual counterfactuals can lead to seriously biased estimates of the productivity-wage gap. Switchers have higher fixed rate wages than non-switchers and they also earn lower piece-rate wages than non-switchers. Because we observe the counterfactuals for each switcher, we can calculate the exact productivity-wage gap for each switcher observation. This is simply the log difference of piece rate and fixed rate wages for worker i at age k:

$$markdown_{ik} = \log V_{ik} - \log W_{ik}$$

In the column (5) of table 2, we regress these markdowns on age dummies and the same set of observables as in columns (1)-(4). Not surprisingly, the results in column (5) correspond almost exactly to the difference between column (4) and column (3). The initial markdown is .16 log points and it is decreased by .07 log points as the workers reach the older worker category.

In figure 5, we plot the average markdown by age along with its 5% confidence intervals. This figure shows dramatically the fall in the productivity-wage gap as the workers grow older. During the first ten or so years of the worker's career the gap is reduced from well over 0.20 to just 0.10. After this the gap stays stable for the rest of

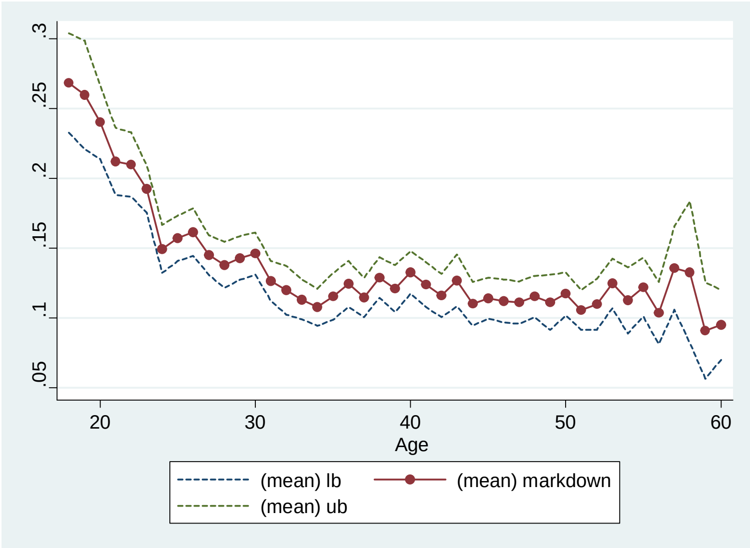


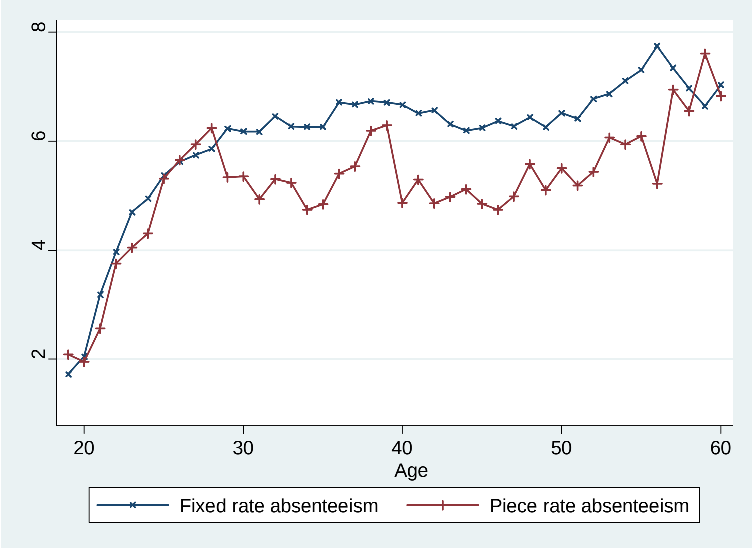
Figure 5: Markdown as a function of age

the worker's career.

The results in table 2 and in figure 5 clearly indicate than younger workers on fixed rates wages are paid considerably lower wages than their piece rate productivity would imply. Wages then increase more rapidly than productivity as the worker ages but they never reach the same level. Whether the remaining productivity wage gap reflects the true gap or is driven by the incentives to exert more effort on piece rate contracts is difficult to disentangle with these data. We lack a direct measure of effort. Nevertheless, the data do contain information on sickness absenteeism. Using the wages paid during sickness one can easily calculate the days of sickness absenteeism for each worker. Over a third of these workers (21 126) is never absent during 1996-2000 while the average number of days absent per quarter in the whole population is 6 days.

Figure 6 plots the average absence days by age for workers who work zero and positive piece rate hours. What is interesting in figure 6 is that among young workers, for whom the estimated productivity wage gap is the highest, there is no virtually no difference in the absenteeism of piece rate and fixed rate workers. These differences only emerge later. From 30 years onwards peace rate workers are absent less often than fixed rate workers.

This pattern is confirmed, when we regress absenteeism in hours on agegroup dummies, piece rate share and their interactions. The results are reported in table 3. The



regression controls for the same set of variables as the wage and productivity regressions in table 2. Piece rate share has a negative and significant effect on absenteeism only among prime-age and older workers. Otherwise, piece rate and fixed rate workers do not differ in their absenteeism.

We interpret these results as indicating that piece rate contracts do not have significant effort effects among young workers. Only as workers grow older, working on piece rate contracts also induce them to exert more effort. This pattern may imply that the true productivity wage among older workers may infact be closer to zero or even negative. However, the most important conclusion from table 2 - that younger workers are paid fixed rate wage below their productivity - clearly survives these effort effects.

5 Conclusions

This paper introduces a new way of examining the age profiles of wages and productivity. Unlike the previous literature that used either supervisors' performance evaluations of value added per worker type as a proxy for productivity, we use the age profile of piece rate wages as a proxy for the worker's productivity profile and contrast this to the age profile of fixed rate wages. We have access to unique data where one can observe the exact share of hour s worked on and earnings from each compensation scheme. Furthermore, the data contain a subset of workers who switch between compensation schemes within the same years. For the these workers, we can observe the age specific counterfactual fixed and piece rate wages.

Our results imply that younger workers are paid wages that are clearly below their productivity as measured by their piece rate wages. However, wages increase much more rapidly with age than productivity so that this gap is considerably narrowed when workers reach prime age category. Simply comparing piece rate and fixed rate workers can lead to large overestimates of the productivity gap. When we observe the exact counterfactual piece and fixed rate wages, the level of productivity-wage gap is lower and it also decreases more rapidly with age.

Varying incentive effects on effort cannot explain away the differences in the estimated productivity-wage gap by age categories. On the contrary, it seems that among younger workers, where the estimated gap is the largest, piece rate contracts do not seem to have any effect on effort as measured by sickness absenteeism. However, among older and prime age workers piece rate contracts do have a significant negative effect on absenteeism. This may imply that the true productivity-wage gap among these workers is actually even lower than we estimate with piece and fixed rate wages.

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Table 1 Summary statistics on non-switchers and switchers

	Non-switchers		Switchers	
	Mean	St. Dev	Mean	St. Dev
Average hourly wage	10.84	7.87	11.74	3.15
Fixed rate wage	9.81	36.41	10.60	2.92
Reward rate wage	13.85	79.82	11.67	3.61
Piece rate wage	11.39	12.56	13.42	16.65
Age	39.47	11.00	38.78	10.57
Tenure	10.89	10.97	8.56	9.44
Piece rate share	0.07	0.25	0.64	0.33
Reward rate share	0.32	0.46	0.03	0.14
Single shift	0.08	0.28	0.14	0.35
Double shift	0.49	0.50	0.61	0.49
Triple shift	0.18	0.38	0.14	0.35
Firm size	1764.98	3552.31	643.72	780.70
Part-time	0.08	0.27	0.02	0.13

Wage in Euros. Piece rate and reward rate share are as fractions of total hours. Firm size refers to the number of employees.

Table 2 Regression results

	(1) Non-switcher wages	(2) Non-switcher productivity	(3) Switcher wages	(4) Switcher productivity	(5) Switcher markdown
Young	0.133	0.092	0.110	0.090	-0.020
	(0.001)**	(0.003)**	(0.002)**	(0.003)**	(0.003)**
Prime-age	0.189	0.122	0.146	0.117	-0.028
	(0.001)**	(0.003)**	(0.002)**	(0.003)**	(0.003)**
Older	0.212	0.140	0.162	0.121	-0.041
	(0.001)**	(0.003)**	(0.002)**	(0.003)**	(0.003)**
Double shift	0.000	0.001	0.001	0.001	0.001
	(0.000)**	(0.000)**	(0.000)**	(0.000)**	(0.000)**
Triple shift	-0.004	0.008	0.019	-0.000	-0.019
	(0.002)**	(0.007)	(0.004)**	(0.007)	(0.007)**
Firm size/100	0.011	0.008	0.013	0.010	-0.003
	(0.001)**	(0.002)**	(0.001)**	(0.002)**	(0.002)
Part-time dummy	-0.022	-0.014	-0.003	-0.000	0.002
	(0.001)**	(0.004)**	(0.002)	(0.004)	(0.004)
Skilled	-0.011	-0.026	-0.024	-0.034	-0.010
	(0.001)**	(0.003)**	(0.002)**	(0.004)**	(0.004)**
Constant	2.147	2.340	2.213	2.423	0.210
	(0.001)**	(0.003)**	(0.002)**	(0.003)**	(0.003)**
Observations	584395	67972	122100	122100	122100
R-squared	0.43	0.36	0.39	0.31	0.18

In columns (1) and (3) the dependent variable is the log of real fixed rate hourly wage and in columns (2) and (4) the log of real piece rate hourly wage. In column (5), the dependent variable is the difference between log real piece rate and fixed rate wages. Young refers to workers aged 25-34, prime-age to workers aged 35-54, and older to workers older than 55. The omitted category are the workers yonger than 25. Skilled refers to workers who 12 or more years of education.

Table 3 Absenteeism regression

Variable	Coefficient
Young	15.591
	(0.689)**
Prime-age	16.837
	(0.678)**
Older	17.158
	(0.776)**
Piece rate share	4.288
	(2.523)
Piece rate share * Young	-3.498
	(2.913)
Piece rate share * Prime-age	-7.920
	(2.756)**
Piece rate share * Older	-7.446
	(3.032)*
Double shift	6.767
	(0.496)**
Triple shift	-0.245
	(0.611)
Firm size / 100	1.166
	(0.017)**
Part-time dummy	4.687
	(1.597)**
Skilled	-5.353
	(0.458)**
Constant	37.385
	(0.709)**
Observations	230103
R-squared	0.05

Standard errors in parentheses
* significant at 5%; ** significant at 1%

The dependent variable is sickness absenteeism in hours. Young refers to workers aged 25-34, prime-age to workers aged 35-54, and older to workers older than 55. The omitted category is the workers younger than 25. Skilled refers to workers who 12 or more years of education.