PENSION BENEFIT REFORM AND THE SUBSTITUTION OF YOUNGER FOR OLDER WORKERS

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Abstract

The age structure of employment reflects the relative prices of retaining workers of different ages, and early pension benefits encourage workers to retire before normal pensionable age, yet little is known about the effects on employment of the young.. We use a recent reform to pension benefits in Denmark to analyze the relationship between the wages and employment of workers of different ages at the firm level. We find that the reform changed retirement ages of unskilled workers – the group with lowest wages and largest replacement rate changes due to the reform. We estimate the elasticity of substitution between young and old unskilled workers at the firm level to be unity – they are perfect substitutes.

INTRODUCTION

In a celebrated paper Katz and Murphy (1992) show that changes in demographic composition affect both the relative supply and, while interacting with the demand side, relative wages. This observation is at the core of the methodological study of the impact of migration on local labour markets developed further by Card (2001), Card and Lemieux (2001) and Borjas (2003). In principle, a a similar approach applies when studying the effect of an ageing population on the composition of the labour force, because the relative supply of older workers increases while the relative supply of younger workers decreases. In the European context, where youth unemployment has recently increased significatively, the composition of the work force is an important policy consideration. In many European countries, the policy options relating to the ageing population have had the intended objective of changing the age composition of the working population: for example the change in mandatory retirement age, the design of the pension payment age profile or the management of publicly funded early retirement schemes had the aim of altering the relative share of older (close to retirement age) and younger (close to their entry to the labour market) workers. We know little empirically however about the way labour markets operate to adapt to such changes. In this paper we consider the simple market mechanisms (demand and supply) and we focus on the elasticity of substitution between younger and older workers at the firm level.

The elasticity of substitution is likely to be an important determinant of the success of policies designed to decrease youth unemployment or to increase older worker’s participation at least in the short run (that is while technology remains unchanged). In the extreme if younger and older workers are complements in production, the effect of a policy attempting to increase the share of younger workers by, for example, subsidizing youth employment will only change the relative wage of older and younger workers without changing the composition of the labour force itself. The variation in employment is then determined by the effect of the subsidy on the aggregate price of labour (all else equal) relative to other inputs. Hence, if at the margin the subsidy leads to a decrease of the price of labour then overall employment will increase. Alternatively, if younger and older workers are perfect substitutes the same policy would affect the composition in the labour force in the same way as it affects the relative supply of labour. The equilibrium effect on prices and quantities in this case are less straightforward to investigate since much will depend on the elasticity of supply of each type of labour: ex ante and ex post the age differential will reflect differences in productivity such that at the margin both types of labour are equally profitable. It will be the difference in the labour supply wage elasticities which determine the workforce composition ex post.

These economic arguments are of course not the ones put forward as justification for such policy, instead the policy debate centers on various forms of the "lump of labour fallacy": the number of jobs in an economy is fixed, and the policy tool is well suited to affect the composition of work. This kind of argument (as reviewed by Kapteyn et al., 2004) was used to support work sharing based policies in France (see Crépon & Kramarz, 2002;) and elsewhere (see Kramarz et al., 2008 for an extensive discussion).

In the longer run, in response to a policy attempting to alter the workforce composition, firms may perceive the incentive to invest in physical capital or other production processes with the aim of reducing the impact of any policy affecting the age composition of the labour force. For example, firms could invest in capital which reduces the complementarity between types of labour. Empirically little is known about longer run technological effects of this type. We would however expect to observe differences in the processes which determine the renewal of jobs and firms before and after the introduction of the policy.

We approach these questions using the data from the population register of Danish firms observed between 1998 and 2006 which enables us to measure employment sizes and the wage bills for each age group within broad skill groups for each firm. Furthermore, we take advantage of a reform to public early and old age pension benefits which came in effect in 2004, but was announced in 1999. The reform modifies the labour supply of older workers to each firm differentially. Firms with no older workers will be unaffected by the reform within the sample period, while firms with an older workforce will observe a potential (and predictable) reduction in the incentives of their older workers to remain in work. We exploit this differential exposure between firms to measure the elasticity of substitution between young and old workers within skill groups at the firm level.

In a collection of works (Gruber and Wise, 2010) focusing on the evidence in support for the "lump of labour" hypothesis across many countries several studies (including the US, the UK and Denmark) found no evidence supporting the replacement of older retiring workers by younger labour market entrants. These studies however use incentive measures at an (economy-wide)aggregated level which is unlikely, to reveal the effect of differential eligibility between employers

By contrast we find that our empirical approach provides credible measurement for the skill group most affected by the reform (the unskilled) while we fail instrumental variables specification test all other skill groups. We produce extensive analysis of the IV estimates we produce for the unskilled group and for the other skill groups. We find that younger and older unskilled workers are perfect substitutes (at the firm level). This suggests that the differences in remuneration between age groups arise from differences in productivity and do not reflect technological interactions between the types of labour. We further compare the workforce composition in firms before the announcement of the policy with the composition in firms created after the enactment of the reform. We observe significant differences between older and younger firms. This suggests that while existing firms adjust their labour force composition to economic constraints, the effect of the policy may affect the creation and renewal of jobs and firms.

The paper is organized in the following way: the next section presents the specificity of the Danish context and the data source. Section 3 introduces a formal framework in which to discuss the issue of measurement. The fourth section presents in details the empirical approach and the estimation results. Finally we conclude.

Pension programs and wage setting

Prior to a reform that was announced in 1999, Old Age Pension (OAP) was available to all Danish residents from age 67, and early retirement benefits were available through the Post Employment Wage (PEW) program for some of those aged 60-66, subject to eligibility criteria. The reform brought the OAP age down to 65 and narrowed the PEW age range to 60-64. This age of eligibility change was implemented 2004-2006.

Eligibility to PEW was based on the history of voluntary individual contributions to unemployment insurance funds and level of benefits is a function of previous wages up to a low ceiling. Pre-reform, for those eligible to PEW, there was an incentive to delay first receipt of PEW until age 63 with 15% higher annual benefits. Post-reform, the incentive was to delay first receipt until age 62. PEW benefits received at 60-61 were means tested against private pension wealth. From 62 there was no means testing, basic benefits were 9% higher and a €1600 bonus was accumulated for every quarter not claiming benefits.

Disability Insurance benefits are available on medical and social grounds at any age. For those ineligible to Disability Insurance or PEW, the reform unambiguously increased retirement incentives at ages 65-66. Previously non-work income might come from unemployment insurance benefits, for those insured but without a long insurance history, or social assistance, which is less generous.

In summary, according to PEW eligibility, the reform changed incentives to retire at different ages. For those eligible to PEW, post-reform incentives differed by level of private pension wealth, but largely encouraged first benefit claim at age 62 rather than 63, we call this group PEW62. PEW ineligibles could first receive OAP benefits at age 65 rather than 67 pre-reform, we call this group OAP65.

In 1999, the reform announcement implied changes to individual retirement benefits and incentives effective latest 2006. Two groups can be distinguished where incentives to retire at different ages changed differentially according to pre-reform characteristics. In 1998, those currently aged 57-58 and not eligible to PEW, would be able to first receive OAP benefits aged 65 rather than 67. Also in 1998, those currently aged 52-56 and eligible to PEW, would be incentivized to retire at age 62 rather than 63.

Basic PEW benefit levels having a low ceiling means that they are most attractive to low wage workers with a high replacement rate. Similarly OAP benefits are demogrants with some means testing, which makes them most attractive to low wage workers. Hence we would expect benefit changes for both PEW eligible and ineligibles to have greatest incentive effects on retirement age for low wage workers.

Private sector wages in Denmark are determined at different levels. In 1998 there was a mixture of centralized bargaining (10%), firm-level bargaining (70%) and individual negotiations (10%). However, norms are established in centralized bargaining rounds taking place union-wise every two years. Unions are organized along occupational and industry lines and wage statistics at the occupation level form the baseline for negotiations about increases.

Four skill groups are distinguished according to ISCO classifications into to skill levels rather than skill specializations: unskilled, basic skills, intermediate skills, higher skills or management (ILO, 1990). Although skill levels can be obtained by a combination of formal education and work experience, for the sake of illustration we can compare skill levels to ISCED educational qualifications that would typically correspond. Unskilled occupations don't require any formal education and as such correspond to ISCED level 1, or compulsory schooling. Basic skills correspond to ISCED 2 and 3, or high school. Intermediate skills would be equivalent to ISCED 5, or some college. Higher skills correspond to ISCED 6 and 7. We bundle management together with higher skills. . In our empirical work we consider wage and employment changes within firm-occupation. Analysis is run in parallel for the five different occupations.

A SIMPLE MODEL

In this section we present a simple model which will justify the empirical methodology we pursue later on. Besides the different types of labour (young, *y*, middle aged, *m*, and older, *o*), the production function involves other inputs, which we will simply collect within an aggregate called capital, K. We assume further that the production function depends on young and old labour through a labour aggregate, L_{yo}.

We therefore assume that the production function takes the form:

$$Q = F\left(K, L_m, L_{yo}\right), \qquad (0)$$

where the young/old aggregate is defined implicitly as follows:

$$L_{yo} = \left[\theta L_y^{\rho} + (1-\theta) L_o^{\rho}\right]^{\frac{1}{\rho}}, \qquad (0)$$

for $-\infty \leq \rho \leq 1$. We set $\rho = 1 - \frac{1}{\sigma}$ where σ is the elasticity of substitution. The maximization of profit suggests a strict relationship between the relative wage and the relative employment size:

$$\begin{aligned} \ln \frac{w_o}{w_y} &= \ln\theta + (\rho - 1)\ln\frac{L_o}{L_y} \\ &= \ln\theta - \frac{1}{\sigma}\ln\frac{L_o}{L_y}. \end{aligned} \qquad (0)$$

The right hand side of equation (0) describes the (logarithm) of the marginal rate of substitution between the two kinds of labour. This specification is simple, it suggests that the within firm log wage young/old differential depends on the relative utilisation of the two inputs. This simple model is akin to the CES model which has been used in other context (but with similar objectives) by Katz and Murphy (1992), Card (2001) and Borjas (2003) among others in distinct contexts.

The parameter of the log ratio of employment identifies the substitution between young and old labour. This is the quantity of interest (given the assumption concerning the technology we make) since it determines the role that technological choices in response to an intervention designed to substitute between the labour of distinct generations of workers. The specification remains straightforward since it is (apparently) linear in the parameters of interest. The empirical difficulty is that the argument on the right hand side is likely to be determined endogenously. Hence before we consider the estimation methodology, we discuss the implicit assumptions we make concerning the supply side of young and old labour.

Specifically we assume that the labour supply for firm f at time t can be expressed as

$$L_{fty}^{S} = \mathcal{L}_{fty} l_{y}\left(\frac{w_{fty}}{w_{ty}^{*}}\right) \text{ for all } t, \tag{0}$$

and

$$L_{fto}^{S} = \mathcal{L}_{fto} PEW_{t}\left(\pi_{fto}\right) l_{o}\left(\frac{w_{fto}}{w_{to}^{*}}\right), \tag{0}$$

where w_{ty}^{*} and w_{to}^{*} denote the alternative (competitive) wages wage for young and old workers respectively. $l_{y}(\omega)$ and $l_{o}(\omega)$ are two increasing functions which describe the response of the type labour supply types to changes in the firm's wage (relative to the alternative wage on the market). $\mathcal{L}_{fty}$ and $\mathcal{L}_{fto}$ describe the maximum potential size of the young and old labour supply in the "local" labour market in which firm f operates. The evolution of the local labour market size is (at least given our time perspective) determined outside of the model. Furthermore we assume that PEW_t is a function of the proportion, π_{ft_0o} with $0 \leq \pi_{ft_0o} \leq 1$, of the older workforce's eligible to the early retirement programme after the introduction of the reform at time t_0. PEW_t is constant whenever $t < t_0$, i.e. $PEW_t\left(\pi_{ft_0o}\right) = 1$ for all , and thereafter it is strictly decreasing with $PEW_t(0) = 1$, $PEW_t'\left(\pi_{ft_0o}\right) < 0$ and $PEW_t \geq 0$ for all positive values of π_{ft_0o} whenever $t \geq t_0$. The function PEW_t indicates that the effect the eligibility to the early retirement programme announced at time t_0 will decrease the size of the potential labour supply which is directed to the firm after t_0. The important feature is that the reduction in the potential labour supply depends on the proportion of the workforce eligible to the programme. Since this proportion is predetermined and observable it acts like an exogenous variation of the labour supply to the firm in a fashion which can be controlled for by the researcher. We compare the within firm age wage differentials between firms with older workforces characterized by distinct intensities of eligibility to the programme , before and after the programme is introduced. It is this comparison which is informative about the value of the elasticity of substitution between labour types.

In equilibrium on the market for old and young labour for each firm, labour demand is equal to labour supply

$$L_{fty}^{D} = L_{fty}^{S} \Leftrightarrow L_{fty}^{D} = \mathcal{L}_{fty} l_{y}\left(\frac{w_{fty}}{w_{ty}^{*}}\right) \text{ for all } t, \qquad (0)$$

and

$$L_{fto}^{D} = L_{fto}^{S} \Leftrightarrow L_{fto}^{D} = \mathcal{L}_{fto} PEW_{t}\left(\pi_{fto}\right) l_{o}\left(\frac{w_{fto}}{w_{to}^{*}}\right). \qquad (0)$$

Assume that middle aged labour is fixed, the equilibrium conditions on the firm specific labour markets as well as the optimality condition for the determination of the optimal allocation of the young/old workforce lead to four expressions for the wages and the size of the labour force for each firm each period. In general we are not able to solve analytically these expressions.

Two cases however allow some direct analysis: the case of inelastic labour supply, and more interestingly the case where the labour supplies of each kind of labour are such that the wage elasticity is constant and such that they share the same wage elasticity. We will treat the former as a limit of the later.

EXAMPLE: COMMON WAGE ELASTICITY OF LABOUR SUPPLY.

Assume

$$L_{fty}^{S} = \mathcal{L}_{fty}\left[\frac{w_{fty}}{w_{ty}^{*}}\right]^{\varepsilon} \text{ for all } t, \tag{o}$$

and

$$L_{fto}^{S} = \mathcal{L}_{fto} PEW_{t}\left(\pi_{fto}\right)\left[\frac{w_{fto}}{w_{to}^{*}}\right]^{\varepsilon}, \tag{o}$$

After some manipulations we find:

$$\ln\frac{w_{fto}}{w_{fty}} = \frac{\sigma}{\sigma+\varepsilon}\ln\theta_{ft} - \frac{1}{\sigma+\varepsilon}\left(\ln\frac{\mathcal{L}_{fto}}{\mathcal{L}_{fty}} + \ln PEW_{t}\left(\pi_{fto}\right)\right) \tag{o}$$

$$\ln\frac{L_{fto}}{L_{fty}} = \frac{\varepsilon\sigma}{\sigma+\varepsilon}\ln\theta_{ft} + \frac{\sigma}{\sigma+\varepsilon}\left(\ln\frac{\mathcal{L}_{fto}}{\mathcal{L}_{fty}} + \ln PEW_{t}\left(\pi_{fto}\right)\right) \tag{o}$$

and we can derive simply the expression for the relative size of the payroll allocated to the young and old, we find:

$$\ln\frac{l_{fto}w_{fto}}{l_{fty}w_{fty}} = \sigma\frac{\varepsilon+1}{\sigma+\varepsilon}\ln\theta_{ft} + \frac{\sigma-1}{\sigma+\varepsilon}\left(\ln\frac{\mathcal{L}_{fto}}{\mathcal{L}_{fty}} + \ln PEW_{t}\left(\pi_{fto}\right)\right) \tag{o}$$

which again depends (log) linearly on the relative labour supply and on the effect of the eligibility to the early retirement programme. The firm specific wage differential response to a larger eligibility to the programme depends on the magnitude of $\left(\sigma+\varepsilon\right)^{-1}$: if the elasticity of substitution is small relative to the common elasticity of labour supply the wage differential will increase (the response to a larger eligibility is a smaller value of $PEW(\pi_{fto})$) mostly because of the supply response (to attract older workers the firm has to increase its wage differential). Alternatively if the substitution elasticity is large relative to the common elasticity of labour supply, the wage increase will be smaller thanks to the firm's ability to substitute away from the labour of older workers. Similarly, as a response to a relatively larger eligibility, the ratio of the old/young workforces will decrease more when the substitution possibility are large (large value of σ) than when they are small. The effect of a relatively larger eligibility on the ratio of the wage bills will depend on the magnitude of the substitution elasticity relative to 1. If $\sigma > 1$, the wage bill ratio will decrease with a relatively larger eligibility, and increase otherwise.

Equations (0), (0) and (0), can be estimated straightforwardly on any longitudinal data at the firm level if we ignore for the moment the issue of the likely endogeneity of the size of the middle age workforce and if we assume that $PEW_t\left(\pi_{ft3}\right)$ is known. They act like a set of reduced form equations. Estimating any two out of the three specification will be enough to identify the elasticity of substitution, σ_A, and (given our restrictions) the common labour supply elasticity, ε. For example estimating the first two equations allows for the estimation of σ by forming the ratio of the parameters of $PEW_t\left(\pi_{ft3}\right)$ in the two equations (and then deduce the size of the common labour supply elasticity).

In the limit, if labour supply functions for both types are inelastic, $\varepsilon = 0$, it is only the magnitude of the substitution elasticity which determines the effect of the differences in eligibility among firms. Clearly only equations (0) and (0) are informative about the substitution elasticity in this case: since the young or old labour supply do not respond to wage changes, it is as if the firm hires all the labour supplied and the wage differential adjusts according to the optimality condition.

In most other cases if each kind of labour supply is characterized by distinct elasticities (even in the isoelastic case), the analysis is not as straightforward and in particular we are not able to express analytically the reduced form for the firm wage differential or the relative size of the work force as a function of the eligibility to the programme and the size of the middle aged workforce only. The implicit relationship between either the firm wage differential or the relative workforce on the one hand and the eligibility to the programme will be non-linear. To estimate the substitution elasticity we can still use the optimality condition (0) as the estimating equation using an instrumental variable approach; because of the non-linearity between the endogenous variables and the programme eligibility the set of instrument variables will include non-linear transformations of the eligibility variable, π_{ft3} as well as interactions with other predetermined determinant of the endogenous variables.

The form of the CES technology we have adopted in the previous discussion is convenient, in particular it allow us to ignore any differences between firms of different sizes. Furthermore it treats the contribution of the young and the old in a somewhat symmetric fashion: only the ratio of the employment size for each group matters to determine the firm wage or payroll differential and the employment size.

A 2-FACTOR INTERPRETATION

The reduced form model described in equations (0) to (0) above can be restated once again as a bi-variate 2-factor model in the following way:

$$\ln\frac{l_{fto}}{l_{fty}} = \frac{\varepsilon\sigma}{\sigma+\varepsilon}F_{ft}^{T} + \frac{\sigma}{\sigma+\varepsilon}F_{ft}^{S}, \tag{0}$$

$$\ln\frac{l_{fto}w_{fto}}{l_{fty}w_{fty}} = \sigma\frac{\varepsilon+1}{\sigma+\varepsilon}F_{ft}^{T} + \frac{\sigma-1}{\sigma+\varepsilon}F_{ft}^{S}, \tag{0}$$

where the terms F_{ft}^{T} and F_{ft}^{S} capture the contribution from both sides of the market to the equilibrium determination of the labour size ratios and the wage bills ratios. F_{ft}^{T} captures the technological changes which drive the demand side of the market in which firm *f* operates at time *t*, while F_{ft}^{S} capture the labour supply side faced by *f* at time *t*.

In some extreme cases the estimation of the elasticity of substitution or of the labour supply elasticity can be obtained simply by the ratio of the observed variances of the LHS variables in equations (0) and (0). For example, if $\operatorname{Var}\left[F_{ft}^{T}\right]=0$ (or if the variance of the technological component across firms is small relative to the variance of the labour supply side) then

$$\frac{\operatorname{Var}\left[\ln\frac{l_{fto}w_{fto}}{l_{fty}w_{fty}}\right]}{\operatorname{Var}\left[\ln\frac{l_{fto}}{l_{fty}}\right]}=\left(\frac{\sigma-1}{\sigma}\right)^{2}=\rho^{2}, \tag{1}$$

(where the variance here is taken across firms) and the elasticity of substitution is directly identified. If instead it is the labour supply factor which varies relatively little, i.e. if $\operatorname{Var}\left[F_{ft}^{S}\right]=0$, then the same variance ratio equals to $\left(1+\varepsilon^{-1}\right)^{2}$ and this identifies ε, the labour supply elasticity.

OLS BIAS

In terms of the factors we have defined above, the relationship of interest is

$$\ln\frac{l_{fto}w_{fto}}{l_{fty}w_{fty}}=F_{ft}^{T}+\rho\ln\frac{l_{fto}}{l_{fty}}, \tag{2}$$

and the estimation difficulty concerns the estimation of the parameter ρ. The factor model formulation allows us to study the effect of direct estimation by OLS of ρ. More or less direct calculations lead to:

$$\begin{aligned}\rho_{OLS}&=\frac{\operatorname{Cov}\left[\ln\frac{l_{fto}w_{fto}}{l_{fty}w_{fty}},\ln\frac{l_{fto}}{l_{fty}}\right]}{\operatorname{Var}\left[\ln\frac{l_{fto}}{l_{fty}}\right]}=\\ &\rho+\frac{\sigma\varepsilon}{\sigma+\varepsilon}\operatorname{Var}\left[\ln\frac{l_{fto}}{l_{fty}}\right]^{-1}\operatorname{Var}\left[F_{jt}^{T}\right]+\frac{\sigma}{\sigma+\varepsilon}\operatorname{Var}\left[\ln\frac{l_{fto}}{l_{fty}}\right]^{-1}\operatorname{Cov}\left[F_{jt}^{T},F_{jt}^{S}\right].\end{aligned} \tag{3}$$

This suggests that the OLS estimator will be unbiased if $\operatorname{Var}\left[F_{jt}^{T}\right]=0$ (which in turn implies that $\operatorname{Cov}\left[F_{jt}^{T},F_{jt}^{S}\right]=0$) , i.e. if the technological factor does not contribute to the variation of the dependent variable on the RHS of the equation of interest. This is not surprising since the condition implies that the dependent variable on the RHS is not correlated with the demand side factor, i.e. as far as this equation is concerned if it is a "classical" regression covariate.

Alternatively, assume that the variance of the demand side factors dominates the variance of the supply side factors in the population of firms, i.e. $\frac{\mathrm{Var}\left[F_{ft}^{S}\right]}{\mathrm{Var}\left[F_{ft}^{T}\right]} = \kappa$, with κ small, then we can show that the OLS estimator is approximately

$$\hat{\rho}_{OLS} \approx \rho + \frac{\sigma+\varepsilon}{\sigma\varepsilon} = 1 + \varepsilon^{-1}, \qquad (4)$$

which in the limit, if $\kappa \to 0$, is independent of ρ.

THE LAW OF ONE PRICE AND IDENTIFICATION

The example makes the assumption that in effect each firm operates on its own labour market, or at least a differentiated labour market within which a distinct equilibrium wage rate is set. In this section we show that our empirical approach requires sufficient differences between the equilibrium firm specific wage rates to identify characteristics of the production function.

Consider a population of large firms, $f = 1,\ldots,F$, each employing n_f workers, i=1,…,n_f. Each worker supplies l_i^f units of labour and is payed w_i^f per unit of labour supplied. We assume that the individual wage rates can differ between individuals within the same firm, such that:

$$\ln w_i^f = \ln \overline{w}^f + u_i^f$$

where $\ln \overline{w}^f$ is the average log wage within firm f and u_i^f is a mean zero unobserved component which captures the individual differences from the mean log wage.

The logarithm of the wage bill for firm f is

$$\ln WB^f = \ln \sum_{i=1}^{n_f} w_i^f l_i^f$$
$$= \ln \overline{w}^f + \ln \sum_{i=1}^{n_f} \exp\left(u_i^f\right) l_i^f ,$$

and we can further factorize the total labour supplied

$$\ln WB^f = \ln \overline{w}^f + \ln \sum_{i=1}^{n_f} l_i^f + \ln \sum_{i=1}^{n_f} \exp\left(u_i^f\right) \alpha_i^f ,$$

where $\alpha_i^f = \frac{l_i^f}{\sum_{k=1}^{n_f} l_k^f}$ represents the share of individual i in firm's f total employment. The last term in this expression depends on the correlation between the unobserved individual differences in the wage rate and the individual labour supply. For large enough firms this quantity should approach (under some conditions which will assume satisfied)

$$\ln \frac{\mathrm{E}\left[\exp\left(U_i^f\right) L_i^f\right]}{\mathrm{E}\left[L_i^f\right]} .$$

If the individual labour supply and the individual wage are uncorrelated or even independent this constant will simply be $\ln \mathrm{E}\left[\exp\left(U_i^f\right)\right]$; if furthermore there are no differences between individual wages the term disappears entirely.

When the law of one price holds between firms, i.e. and as a consequence the same average wage rates holds for all firms, and there are no (or little) differences between individual wage rates a regression of the (log) wage bill on the log of the employment size will lead to a parameter estimate equal to or close to unity in the regression of the logarithm of the wage bill on the logarithm of the employment size.

In the more general case where we can expect a correlation between individual wage differences and individual labour supply, we expect this difference to increase or decrease depending on the correlation between the individual labour supply and wage however this will not depend on the technology. The unique average wage rate property will hold for all firms if it is the case that each firm shares the same marginal product of labour and it is equal to the unique average wage. Hence in this case the firm specific wage rate does not carry any information about any individual firm's production function. And the regression of the log of the wage bill on the log of employment does not carry any information about the technology.

PAB – INSTEAD OF WHAT? Instead, we assume that the average wage rate for each firm varies between firms according to a marginal condition setting the firm average wage against the value of the marginal product of labour in its particular labour market:

$$\bar{w}^f = p^f F_L\left(L^f\right),$$

where $F_L\left(L\right)$ stands for the marginal product of labour, *p* stand for the price of firm's *f* output. In the simplest possible case, where $F^f\left(L\right) = \frac{\theta^f}{\phi} L^{\phi}$ with $0 < \phi < 1$, this becomes

$$\bar{w}^f = p^f \theta^f \left(L^f\right)^{\phi-1},$$

which we substitute back into the wage bill equation to find

$$\ln WB^f = \ln\left(p^f \theta^f\right) + \left(\rho - 1\right)\ln\sum_{i=1}^{n_f} l_i^f + \ln\sum_{i=1}^{n_f} l_i^f + \ln\sum_{i=1}^{n_f}\exp\left(u_i^f\right)\alpha_i^f,$$

which simplifies to obtain

$$\ln WB^f = \ln\left(p^f \theta^f\right) + \rho\ln\sum_{i=1}^{n_f} l_i^f + \ln\sum_{i=1}^{n_f}\exp\left(u_i^f\right)\alpha_i^f.$$

This expression depends on the technology in an informative way, i.e. it depends on ρ (which does not have to be equal to unity).

Hence by analogy to our context where we consider differences between the logarithms of quantities defined for different age groups, we require some heterogeneity between the firms average wages as well as sufficient differences between the average wages for the young and the old (say). If for example, the ratio between average wages is constant between firms the information related to the technology is lost and the (log of the) ratio of wage bills will be simply related to the log of the relative employment sizes (with a parameter close to unity). For the wage bill regressions, or any regressions related to it, to be informative we require the firms to pay distinct average wage rates and for the pay differentials between age groups to be distributed across firms.

THE DANISH ADMINISTRATIVE DATA SOURCE

Our data originates from administrative population registers. Since 1968, all residents of Denmark have been issued with unique social security numbers which are used throughout public administration, thereby allowing in principle for register linkage at the individual level. Our sample is drawn from the Administrative Database for Labour Market Research (IDA) which is created by Statistics Denmark on the basis of information drawn from several registers. Three variables are of direct interest for our analysis: earnings, hours worked and occupation. Annual gross labour earnings are employer reports pay-as-you-earn to the tax authorities. Annual hours worked are derived from mandatory pension contributions made by employers on behalf of each employee as a step function of weekly hours (10-19, 20-29 and 30+). Occupations are obtained from an annual census of employers who are required to report for all employees in week 48.

The link between employers and employees is made on the basis of the annual week 48 census. IDA records the two most important attachments, in terms of those employments with the highest gross earnings during the year. Apart from collecting together variables which are relevant for labour market analysis, IDA validates continuity of workplace identity over time. While the census requires reporting of workplace address and firm identifier issued by the tax authorities, these identifiers may change for administrative reasons not reflecting a physical or legal reality. IDA runs an algorithm checking employer-employee continuity for spurious displacements and replacements and repairs identifiers accordingly. [Note: see Søren Leth Sørensen (1999) for more details of IDA].

Eligibility to PEW is not observed directly in IDA. Eligibility in 1998 required voluntary membership of an unemployment insurance fund for 20 out of the last 25 years. [Note: As part of the 1999 reform this requirement was increased to 25 of the last 30 years. However, for those then aged in their 50's, the old eligibility requirements were grandfathered]. [Note: The 1999 reform also unbundled new unemployment insurance contributions from PEW eligibility by requiring PEW-specific contributions. Our analysis uses 1998 eligibility status and is unaffected by this unbundling]. We derive eligibility from unemployment insurance fund membership history (which is only observed back to 1980) and mandatory pension contributions 1974-79. We assume that those who were members in 1980 were also members in previous years if they were working.

EMPIRICAL STRATEGY

We argue that the eligibility structure to the PEW before its reform affects the "labour demand of the firm" post reform. When the reform is introduced (1998), it is possible to count the number of workers who will be eligible to some aspect of the change in public pension arrangements after the reform is implemented few years later (2006). The number of eligible workers (or their proportion out of the total number of workers who will be at risk of eligibility after the reform) is predetermined: firms cannot change it and it will determine in theory the extent of the required firm's workforce (net) adjustment given the technology. This is the identifying assumption.

Hence a firm with a large proportion of eligible workers will change the composition of its young and old worker more than an alternative firm with a smaller proportion of eligible workers. Measures of the number of workers eligible to specific aspects of the reform provides in principle a set of satisfactory instruments. It remains to be shown that this set of instruments is empirically satisfactory in so far as it identifies the quantity of interest - the elasticity of substitution. This is the ultimate object of our empirical work.

We base our empirical approach on equation (o) expressed in differences between quantities measured before the announcement of the reform and the same quantities measured after the reform's implementation:

$$\underbrace{\ln\frac{w_{fa3}L_{fa3}}{w_{fa1}L_{fa1}}-\ln\frac{w_{fb3}L_{fb3}}{w_{fb1}L_{fb1}}}_{\text{growth of relative wage bill}}=\underbrace{\ln\theta_{fa}-\ln\theta_{fb}}_{\substack{\text{change in technological}\\ \text{charaterisitcs}}}+\rho\underbrace{\left(\ln\frac{L_{fa3}}{L_{fa1}}-\ln\frac{L_{fb3}}{L_{fb1}}\right)}_{\text{change in relative group size}}. \qquad (4)$$

The change in the relative group size and the growth of the relative wage bills are in principle determined simultaneously. We argue that the instruments allow us to solve the difficulty created by this simultaneity.

We show now that the instrument set is indeed well suited to this task. To that effect we describe first how the instruments correlate/explain the distribution and evolution of the firms pay structure and workforce composition. We can decompose the changes of the log ratios in terms of differences in changes within age group. For example in the case of the change of the relative wage bill around the reform we have:

$$\ln\frac{w_{fa3}L_{fa3}}{w_{fa1}L_{fa1}}-\ln\frac{w_{fb3}L_{fb3}}{w_{fb1}L_{fb1}}=$$
$$\underbrace{\left(\ln w_{fa3}L_{fa3}-\ln w_{fb3}L_{fb3}\right)}_{\text{change in wage bill of the "old"}}-\underbrace{\left(\ln w_{fa1}L_{fa1}-\ln w_{fb1}L_{fb1}\right)}_{\text{change in wage bill of the "young"}}.$$

RELATIVE WAGE BILL AND RELATIVE FTE, DESCRIPTIVES

Tables 1 and 2 describe first some characteristics of the various components of the change in the log ratios. Each table shows the mean, standard deviation and the number of observations by age and skill group of the different components. Moving from one table to another involves changes in the population of firms over which the statistics can be calculated, for example to calculate log ratios of the wage bills between age groups for a given skill requires that we observe both age groups in a given year in each firm, while calculating the growth in the payroll for a given age and skill group requires that we observe the particular age group before and after the reform (in 1998 and in 2006). Table 1 reports evidence on growth rates between 1998 and 2006 for the payroll or employment per firm by skill and age group. To contribute to this table firms have to exist in both time periods and experience enough employment for each (skill-age) group. This explains the different observation numbers relative to the previous table. We observe an evolution the previous discussion hinted at. The payroll of younger workers exhibits some weak growth (even negative for those with basic skills), while employment is in the main smaller in 2006 relative to 1998. For older workers the average payroll growth and employment growth are positive for all skill groups. Furthermore, the payroll growth of older workers is significantly larger than employment growth. The middle aged group experiences a similar evolution although not as systematically positive as the older age group. The middle aged workers with basic skills experience an even more contrasted evolution, their payroll increases on average (about 6%) while employment decreases by about 14%. For some particular (skill-age) group the number of firms which are observed to employ enough labour can be relatively small (see for example (high skill, young) with 541 firms contributing to the average growth measures).

Table 2 reports descriptive statistics on the quantities directly related to our empirical work, i.e. changes in the log ratios. The similarity between the changes in the log ratios of the payroll and employment is striking: on average the changes are very close to each other, consistently across skill groups. It suggests that firms behave as if they keep constant the relation between these log ratios.

The empirical question is whether this strict relationship we observe on average survives a more in depth statistical analysis using instrumental variables method.

WAGES AND EMPLOYMENT

Table 3 reports basic descriptive statistics for the log-wage differentials between old and young workers and between old and middle aged workers in 1998 and 2006. The number of firms which contribute to the table's entries is now significantly smaller, since we require a minimum number of young and old people within each firm to calculate the age group differentials. The distribution of the within firms age differentials are broadly comparable within skill groups (i.e. the mean and standard deviation are comparable in size). Overall we observe that older workers are paid significantly more than younger workers while the differentials between old and middle age workers are on average significantly smaller and less variable. This is clearly seen among workers with basic skills where the wage differentials between old and young workers is almost identical in 1998 and 2006 around 0.35 while the wage differential between old and middle aged workers is less than 0.02 in the two periods.

ELIGIBILITY DESCRIPTIVES

Table 4 reports average eligibility to various aspects of the reform in 1998 for the different skill groups. The first column reports the proportion of workers aged 52 to 56 among all workers aged 52 to 58 who are eligible to the PEW in 1998, i.e. workers who are part of the PEW62 group. The second column reports the proportion of workers aged 57 to 58 who are not eligible to the PEW in 1998, that is workers who belong to the OAP65 group. We argue above that these two characteristics, measured at the firm level, provide us with a credible instrument set. It is among the workers with basic skills that the proportion of workers aged 52 to 56 eligible to the PEW is the largest, see column PEW62, however it is among the high skilled workers that the proportion of workers aged 57 to 58 and not eligible to PEW is the largest, and about twice as large as the average, see column OAP65. We report the average value of the product of these two measures which we can interpret as a correlation between the two eligibility measures at the firm level, column PEW×OAP. On the face of it the correlation between the two instruments is small. Hence the two measures assess different aspects of the PEW reform.

REDUCED FORMS

The aim of the following discussion is to show that our proposed instruments have sufficient explanatory power to allow for an instrumental variables approach to the estimation of the elasticity of substitution. Our main interest at this stage is to show that the F-statistics for the reduced form equations are sufficiently large, to use the rule of thumb say greater than 10, for some of the skill groups. We proceed sequentially through the various components of the changes in the log ratios: Tables 5 and 6 report estimation results concerning the relationship between the growth rates, log ratios and changes in the log ratios with the instruments sets we consider. Each table reports the result of the same regression model of the dependent variable on two instrument sets, the first set only consider our two instruments, while the second set consider the two instruments, as well as their squares and their interaction. We report F-statistics for each regression, furthermore we report the marginal effect of each instrument on the variable of interest. Because of the design of the policy we are studying here, we expect a priori that the instruments will have a larger explanatory power when applied to the basic skill group and significantly less explanatory power for the other skill groups.

Table 5 summarizes the results for the logarithm of the ratio of the payroll of young or middle aged workers relative to the payroll of older workers in 1998 and 2006. Because of firm "death", the number of informative firms in 2006 is always smaller than the number of firms in 1998, indeed new firms cannot be added to the analysis since for them we would not observe the value of the instruments. Again in most cases the instruments have significant explanatory power, the medium skill is the notable exception for the ratio of the payroll of younger workers to older workers. A larger value of the instruments leads at the margin to a smaller ratio of the payroll between middle aged and older workers (i.e. firms devote less resources to paying middle aged workers relative to older workers when eligibility to the PEW reform in 2006 is larger). For the comparison between younger and older groups the results are not as clear cut. However in the case of the basic skilled workers, a larger eligibility to PEW in 1998 among 52 to 56 year old employed leads to a smaller payroll for younger workers in 1998 but a larger one in 2006. For this skill group we observe further that the F-statistics are large (greater than 15 for the most flexible specification). Medium and high skill groups exhibit clearly a different response, a larger eligibility to PEW in 1998 leads at the margin to larger ratios of the wage bill between young and older workers both in 1998 and 2006.

Table 6 repeats this analysis for the case of the logarithm of the ratio between the number of Full Time Equivalent workers in 1998 and separately in 2006. The results are similar to those found in Table 10: the same conclusions can be drawn. In the case of the unskilled group the explanatory power of the instruments for the ratio of the size of the young workers group relative to the size of the older workers group is clear, the F-statistics of overall significance are greater than 14 for the more flexible specification. For the other skill groups the same statistics are only half as large. For the unskilled group in particular, a larger eligibility to PEW in 1998 leads at the margin to a smaller log ratio in 1998 (i.e. the younger group is paid relatively less), but to a larger ratio in 2006.

Finally Table 7 presents the results of the analysis applied to the change in the log ratios between age groups for payroll and employment that is for the variables on each side of the equation of interest, equation (4). This time the analysis focuses only on the firms which allow for the measurements of the ratios in 1998 and 2006. Concentrating on the more flexible specification, the F-statistics for the null hypothesis of overall significance of the regressors are at least twice as large for the basic skill group whatever the comparisons between age groups relative to the other skill groups. This provides for prima facie evidence that this set of instruments has some explanatory power among the skill group which is affected by the reform: the basic skill group. In the discussion of the estimation results, we present formal tests which confirm this observation. Note that for a given skill (and for a given comparison of age group) the magnitudes of the estimated marginal effects are broadly comparable and that their precisions are similar. In particular, at the margin, the proportion of workers eligible to PEW aged between 52 and 56 in 1998 has a positive effect on the growth of the ratios, i.e. a larger eligibility to PEW in 1998 has a significant and positive effect on the growth between 1998 and 2006 of the relative payroll and relative employment (between old and young workers).

ESTIMATION RESULTS AND TESTS

Table 8 presents the OLS parameters estimates based on equation (4). We report estimates where we pool all skill groups together (first column) and add skill group dummies (the omitted category is skill 5), as well as group specific estimates. The estimates for the parameter of interest, ρ, take similar values all bunched around 0.95 and are well determined (see the robust standard errors below the estimated values). Our discussion of the relationship between the mean change in ratios suggested such a close relationship between the change in the log of the ratio of the wage bill and the log of the ratio of the number of full time equivalent employees between old and young. These estimates suggest that the relationship holds at the firm level, note that the fit is remarkably good for estimates based on individual firm data. We argued above that this may be explained by the endogeneity of the variable on the RHS of equation (4) and therefore an Instrumental Variables approach is required.

Table 9 presents IV estimates based on two sets of instrumental variables. The first set contains the two proposed instrumental variables while the second set contains these two variables, their squares and their interaction. We saw in our empirical description of the relationship between the change in the log ratios and the instruments set that the quality of the explanatory power of the instruments varies between skill groups. This is obviously important for the success of the IV approach. As is now well understood the IV approach requires the instruments to be uncorrelated with the unobserved component in the substantive equation of interest and furthermore the instruments must be able to explain enough of the variation of the endogenous variable on the RHS (and therefore explain enough of the variation of the endogenous variable on the LHS). In this sense the unskilled group appear to be the group where we would expect our IV approach to work well (see Table 12 and our discussion on the size of the F-statistics) and the results we obtain for other group should be less reliable. Table 8 present estimates separately for each skill group and for each set of instruments. Relative to the corresponding OLS estimates presented in Table 8, the IV point estimates are less precisely estimated (the standard errors are 4 to 10 times larger) and in some cases take distinctly different values, e.g. skill group 3 and 4. Most of the recent methodological development concerning the use of IV methods stresses the testing of several aspects of the quality of the instruments to qualify the trustworthiness of the IV point estimates. We follow the modern approach concerning the quality of IV estimates surveyed by Stock, Wright and Yogo (2002) and advocated for example by Angrist and Pischke (2009). Crucial to this approach is the explanatory power of the first stage (of the 2 stage least squares) as an indicator of the nature of the proposed instruments: if the F-statistics of the first stage is small (as a rule of thumb less than 10) the instruments may be weak and the potential bias on the TSLS estimator can be large.

Table 9 presents the value of test statistics which ascertain the quality of the instruments in different ways. The Anderson-Rubin Statistics tests the joint hypothesis that the parameter of the endogenous regressor on the RHS of the structural equation is equal to zero and that the over-identification exclusion restrictions are satisfied. We have commented on these statistics before in table 12 where they are the F-stats for the regression of the change in log ratios on the two alternative instrument sets, i.e. The F-statistics of the (IV) first stage. Hence we stress (again) that it is for the unskilled only that the F-statistics takes large values (i.e. >10), whereas for the other skill groups the value of the F-statistics is at best marginal.

The Id-stat report the Kleinberger & Paap LM test statistics of the null hypothesis of under-identification, i.e. the null hypothesis that the matrix of reduced form parameters has reduced rank.

The hypothesis of under-identification is clearly rejected for the unskilled group and for the skill 0 group, while for the other skill groups it cannot be rejected. Finally the Weak-id stat reports the Kleinberger & Paap F statistics of the null hypothesis of weak identification. In our particular case of a single endogenous regressor, the Weak-Id statistics is identical to the F-statistics reported in Table 12 for the regressions of the change in log ratio of the full time equivalent number of employees for the young relative to the old on the alternative instruments sets. Again a possible rule of thumb is to require that these F-statistics are large (i.e. >10) enough. Here we are in effect treating the endogenous variable symmetrically, we require the instruments to explain the variability of the two endogenous variable to the same extent. The unskilled group stands out, with large enough values, while for the other groups the value of the test statistics are at best marginal (skill 0) or small. Finally Table 9 reports the J-statistics for the test of the null hypothesis of over-identification (since we have more instruments than endogenous variable on the RHS of the structural equation). Here we note that the null hypothesis is not rejected for any skill group and in particular in our case for the unskilled.[1]

Overall the evidence presented in Table 9 suggests that in the case of unskilled workers the empirical approach we suggested produces trustworthy estimates for the parameter ρ. Moreover, where our instrumental approach is unlikely or less likely to identify satisfactorily ρ the test statistics indicate clearly that the parameters should be treated with caution.

The LIML estimator provides another route for estimation which is less sensitive to the weak instrument issue in the over-identified case. We present the LIML estimators in Table 15. We observe

[1] LIML parameter estimates are very similar to the IV estimates. For the unskilled estimated standard errors are also comparable in magnitude. Estimates are available on request.

that the results obtained are almost identical to the IV results presented in Table 14. The literature suggests that trustworthy estimates obtain when the TSLS and the LIML estimator are "similar" (Angrist and Pischke, 2009). Furthermore, we report formal test statistics which independently test the null hypotheses that either the parameter of interest is not identified by the proposed set of intruments, or the instrument set only weakly identifies the parameter of interest, or all the components of the instrument set can be excluded from the "structural" equation.

The discussion of the reduced form suggests that the IV estimates for the unskilled are trustworthy since the F-statistics for the relevant first stage (reduced form estimation) are large enough for this group alone. This has been the accepted practice among much of the recent empirical work using IV techniques.

The robust confidence intervals suggest that for most skill groups we cannot reject the hypothesis that the parameter ρ is close or equal to unity which suggests that young and old workers are essentially perfect substitutes, i.e. $\sigma \rightarrow +\infty$. The evidence arises from the firms which existed in 1998 and survived until 2006. This should perhaps not surprise us, all these firms are faced with the prospect of replacing regularly older worker who retire (early or not) with other workers (young or, in the classification of our empirical work, middle aged). Hence it is plausible that the technological choices (surviving) firms make ensure that, once the marginal products per efficient unit of labour are accounted for, workers of different kind are good substitutes to one another.

To discuss the overall effect of the PEW reform in Denmark requires more information on the supply side. The tractable model we describe in equations (0) to (0) to study the effect of the PEW on firms age wage differentials and work force composition is clearly not adapted to the facts we discussed in tables 1-3. $\sigma \rightarrow +\infty$ in this context implies that the effect of the PEW will leave the wage differential constant but change the relative size of employment of the older workers relative to younger workers. Our (reduced form) observation is at odds with this observation in particular for unskilled workers (skill group 2). Hence the model does not explain the facts despite our empirically credible estimates of the elasticity of substitution. The model relies in particular on the assumption that the labour supply elasticities are the identical for older and younger workers. Failing this assumption the analytical results we provide earlier on do not hold and a more involved model would be required (as well as estimates of the labour supply elasticities). This is not an aspect we pursue here any further.

Instead we wish to consider however an alternative channel to explain the potential effect of the PEW reforms on the composition of the workforce which focuses on the process of birth and death of firms.

BIRTH AND DEATH OF FIRMS

In Table 10 we study the effect of survival to 2006 on the log ratios measured in 1998. To that effect we regress the log ratios (wage bill or number of full time equivalent workers) of all firms we observe in 1998 on a set of dummy variables indicating whether the firm will have a particular work force composition in 2006. We distinguish between firms which will not have enough young and older workers ("00", i.e. as far as young and older workers are concerned the firms disappeared), firms which will have younger workers only ("10") and firms which will have older workers only ("01"). The omitted category contains the firms which have young and old workers in both periods. The dummies are jointly significant. Relative to the firms that maintain a work force in both age groups over time, the other firms have a larger ratio for the number of younger worker to the number of older workers and a larger ratio for the size of the wage bill for younger workers to the size of the wage of older workers. Hence firms which disappear from the sample we based our IV estimates on are systematically different from the surviving firms.

Table 11 repeats this analysis on the log ratios for all the firms present in 2006 and this time we attempt to capture the difference between firms which were born between 1998 and 2006 ("00") and firms which only had younger workers in 1998 ("10") or firms which employed older workers only in 1998 ("01"). Once more the group of firms which employ both age groups in 1998 and 2006 is the omitted category. The dummy variables are jointly significant for all skill groups and all ratios. However the effect of “birth” (in the sense of employing both old and young workers in 2006 but not in 1998) on labour composition and the relative wage bill is not homogenous, for instance among skill group 3 and 4 new firms in 2006 (00->11) exhibit a smaller wage bill and a smaller number of FTE worker for older workers relative to younger workers, while for the other groups we observe the opposite effect. Similarly firms without younger workers in 1998 but with both younger and older workers in 2006 (01->11) use more older workers and pay more for their services in 2006 relative to younger workers for the first three skill groups (skill groups 0,1 and 2), while this does not seem to matter significantly for skill groups 3 and 4. Finally firms without older workers in 1998 employ and pay relatively more to younger workers in 2006 independently of the skill group. This suggests that the process of birth of firms matters for the determination of the log-ratios we consider here. Comparing the numbers of observations in each table (they are broadly similar) it suggests that the effect of birth and death of firms on labour composition is substantial and could potentially dominate the effect of the pension reform on surviving firms only (these amount overall to about a third to a half of the total population of firms in 2006).

CONCLUSION

An ageing population and early pension benefits both contribute to the growing share of the population being retired from the labour market in many countries. Changes in demographics and non-work benefits affect the supply of workers. Firms adjust wages reflecting their demand for different demographic groups in the face of non-work benefits. The extent to which different groups are substitutes in production can be estimated provided exogenous variation in group supply by making functional form assumptions and observing wage and employment responses by group. In this paper we consider population data spanning a pension benefit reform, assume a CES production function and observe wage and employment changes within firm and skill group according to worker age – young, middle aged and old.

Other studies have observed long run changes in the supply of different skills or exploited changes in regional migration to provide exogenous supply variation. Observation units were rather aggregated, respectively for many skills at the national level, or state-wise. Our study is at the level of firm-skill group. We measure changes between periods nine years apart, from before announcement until full implementation of a pension benefit reform. Over this relatively short period we abstract from changes in the supply of skills and focus exclusively on age structure within skill group within firm.

Assuming a CES production function, pension benefit reform provides valid instruments only for the basic skilled – those with lowest wages and largest relative replacement rate changes. We find an elasticity of substitution between old and young of unity. For other skill groups the reform does not provide sufficient exogenous variation in order to identify retirement age responses and thereby substitution elasticities.

Our finding that young and old unskilled workers are perfect substitutes is different to Card, who estimates an elasticity of 3 and much less substitutability. While Card's analysis was at a more aggregate level than ours, using states rather than firms, to operationalize our estimator we need to observe workers in a skill group in both age groups pre- and post-reform for calculating our ratios of interest. Countervailing responses cannot a priori be ruled out, whereby for example firms lose all of their older unskilled workers. A robustness analysis shows such selective firm skill group "exit" to be modest.

Our finding that unskilled older workers retiring on early pensions were easily replaced by unskilled young workers without large wage responses is reassuring for ease of the demographic transition of the growing proportion of the elderly unskilled into retirement. However, youth employment prospects will worsen to the extent that early pension benefits are rolled back in order to discourage early retirement.

Future work could use a similar framework to ours in the context of exogenous variation in the supply to the firm of older skilled and white collar workers in order to identify the elasticity of substitution between old and young workers across the skills distribution.

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Table 1: Growth Rates 2006-1998, by age and skill groups.

		Young		Middle Aged		Old	
Skills	Growth	Payroll	Employment	Payroll	Employment	Payroll	Employment
Basic	mean	-0.009	-0.208	0.061	-0.142	0.660	0.452
	sd	1.264	1.239	1.048	1.027	1.250	1.276
	N	12,558	12,558	31,109	31,109	2,715	2,715
Medium	mean	0.028	-0.146	0.292	0.096	0.572	0.386
	sd	1.294	1.318	1.112	1.079	1.174	1.144
	N	1,202	1,202	11,602	11,602	943	943
High	mean	0.123	-0.073	0.148	-0.019	0.389	0.263
	sd	1.317	1.400	1.044	1.000	1.379	1.292
	N	541	541	11,421	11,421	1,530	1,530

Table 2: Change in log Ratios, 2006-1998, by age and skill group.

		Old vs Young		Old vs Middle Aged	
Skill		Payroll	Employment	Payroll	Employment
Basic	mean	0.995	0.990	0.631	0.639
	sd	1.655	1.631	1.325	1.347
	N				
Medium	mean	0.903	0.895	0.368	0.391
	sd	1.494	1.555	1.254	1.225
	N				
High	mean	0.583	0.606	0.316	0.364
	sd	1.833	1.804	1.568	1.459
	N				

Table 3: Log Wages differentials, Firms spanning 1998-2006.

		Old vs Young		Old vs Middle Aged	
Skills	stats	1998	2006	1998	2006
Basic	mean	0.343	0.349	0.020	0.012
	sd	0.373	0.373	0.286	0.248
	N	1,741	1,741	2,590	2,590
Medium	mean	0.451	0.459	0.016	-0.008
	sd	0.417	0.421	0.286	0.253
	N	272	272	849	849
High	mean	0.590	0.567	0.030	-0.018
	sd	0.531	0.465	0.401	0.369
	N	183	183	1,296	1,296

Table 4: Mean Eligibility in 1998, by skill group

Skill		PEW62	OAP65
Basic	mean	0.552	0.042
	N	1741	1741
Medium	mean	.530	0.044
	N	272	272
High	mean	0.410	0.097
	N	183	183

Table 5: Log Ratios, Payroll

Skill		PEW62	OAP65	*N*	F (k=2)	F (k=5)	F_2	F_2, p value
Basic	1998, Young vs Old	-0.214	-1.102	6,291	6.570	23.501	33.960	0.000
		0.059	*0.362*					
	2006, Young vs Old	0.319	-0.006	4,688	25.221	15.345	10.390	0.000
		0.065	*0.419*					
	1998, Mid-Age vs Old	-1.780	-2.069	9,835	471.935	590.266	598.255	0.000
		0.044	*0.258*					
	2006, Mid-Age vs Old	-0.064	-0.783	7,190	3.147	59.603	96.182	0.000
		0.044	*0.291*					
Medium	1998, Young vs Old	0.082	1.308	1,056	0.594	0.967	1.173	0.319
		0.149	*0.729*					
	2006, Young vs Old	0.676	1.737	955	15.638	9.591	7.780	0.000
		0.136	*0.808*					
	1998, Mid-Age vs Old	-2.185	-2.705	3,290	147.035	225.049	247.941	0.000
		0.088	*0.392*					
	2006, Mid-Age vs Old	-0.550	-1.727	2,987	3.615	33.782	54.614	0.000
		0.081	*0.431*					
High	1998, Young vs Old	0.763	0.788	757	5.128	8.353	10.082	0.000
		0.227	*0.723*					
	2006, Young vs Old	0.941	1.309	636	9.107	7.429	5.545	0.001
		0.235	*0.802*					
	1998, Mid-Age vs Old	-2.558	-2.861	4,831	94.866	217.427	274.259	0.000
		0.104	*0.282*					
	2006, Mid-Age vs Old	-0.757	-1.505	3,533	2.117	38.133	61.368	0.000
		0.096	*0.320*					

Notes: For any skill level and for any broad age group, the table reports the marginal effects of the instruments on the firms' log Payroll ratios in a regression model including each instrument, their squares and their interaction (column 1 & 2), the robust standard errors are given in italic below the estimated values. Column 3 reports the number of observed firms; Column 4 reports the F-statistic for the regression of the log Payroll ratios on the instruments without higher orders; Column 5 reports the same information for the more general regression model. Finally Column 6 & 7, report the F-statistic and the p-value for the test of the null hypothesis that the squares of the instruments and the interaction between instruments have no explanatory power.

Table 6: Log Ratios, Employment

Skill		PEW62	OAP65	*N*	F (k=2)	F (k=5)	F_2	F_2, p value
	1998, Young vs Old	-0.142	-0.941	6,291	2.419	14.105	21.192	0.000
		0.060	*0.362*					
	2006, Young vs Old	0.286	0.141	4,688	21.287	15.033	13.004	0.000
Basic		*0.065*	*0.416*					
	1998, Mid-Age vs Old	-1.719	-1.940	9,835	426.671	534.520	551.371	0.000
		0.045	*0.258*					
	2006, Mid-Age vs Old	-0.052	-0.670	7,190	3.359	59.907	96.682	0.000
		0.045	*0.293*					
	1998, Young vs Old	-0.015	0.781	1,056	0.315	0.625	0.894	0.444
		0.146	*0.722*					
	2006, Young vs Old	0.534	1.472	955	10.857	6.533	4.739	0.003
		0.145	*0.896*					
Medium	1998, Mid-Age vs Old	-2.186	-2.770	3,290	150.325	236.418	259.112	0.000
		0.086	*0.385*					
	2006, Mid-Age vs Old	-0.568	-1.639	2,987	4.980	35.740	56.056	0.000
		0.078	*0.414*					
	1998, Young vs Old	0.493	0.656	757	2.284	4.691	6.447	0.000
		0.224	*0.714*					
	2006, Young vs Old	0.828	1.472	636	7.874	7.312	6.425	0.000
		0.233	*0.814*					
High	1998, Mid-Age vs Old	-2.597	-2.836	4,831	114.756	253.547	314.738	0.000
		0.098	*0.267*					
	2006, Mid-Age vs Old	-0.810	-1.461	3,533	4.545	41.301	65.652	0.000
		0.094	*0.314*					

Notes: For any skill level and for any broad age group, the table reports the marginal effects of the instruments on the firms' log Employment ratios in a regression model including each instrument, their squares and their interaction (column 1 & 2), the robust standard errors are given in italic below the estimated values. Column 3 reports the number of observed firms; Column 4 reports the F-statistic for the regression of log Employment ratios on the instruments without higher orders; Column 5 reports the same information for the more general regression model. Finally Column 6 & 7, report the F-statistic and the p-value for the test of the null hypothesis that the squares of the instruments and the interaction between instruments have no explanatory power.

Table 7: Change in Log Ratios (Growth of Ratios), 1998-2006

Skill		PEW62	OAP65	*N*	F (k=2)	F (k=5)	F_2	F_2, p value
Basic	Young vs Old, Payroll	0.161	-0.007	1,741	15.536	15.719	14.464	0.000
		0.168	*0.766*					
	Young vs Old, Employment	0.142	-0.382	1,741	15.326	14.644	13.738	0.000
		0.163	*0.741*					
	Mid-Age vs Old, Payroll	0.327	-0.022	2,590	32.719	24.682	19.605	0.000
		0.099	*0.474*					
	Mid-Age vs Old, Employment	0.316	-0.146	2,590	28.869	20.972	15.940	0.000
		0.102	*0.490*					
Medium	Young vs Old, Payroll	0.512	0.809	272	1.647	0.702	0.181	0.910
		0.403	*2.204*					
	Young vs Old, Employment	0.762	0.425	272	2.954	1.269	0.318	0.813
		0.401	*2.189*					
	Mid-Age vs Old, Payroll	0.336	-0.325	849	6.888	7.674	8.701	0.000
		0.160	*0.690*					
	Mid-Age vs Old, Employment	0.418	0.039	849	9.310	9.105	9.349	0.000
		0.151	*0.636*					
High	Young vs Old, Payroll	0.359	2.353	183	0.547	0.427	0.649	0.585
		0.582	*1.815*					
	Young vs Old, Employment	0.533	2.653	183	0.722	0.916	1.338	0.263
		0.541	*1.710*					
	Mid-Age vs Old, Payroll	0.916	0.948	1,296	12.650	10.466	10.101	0.000
		0.154	*0.460*					
	Mid-Age vs Old, Employment	0.877	0.690	1,296	14.051	10.933	10.203	0.000
		0.142	*0.420*					

Notes: For any skill level and for any broad age group, the table reports the marginal effects of the instruments on the change in the log ratios in a regression model including each instrument, their squares and their interaction (column 1 & 2), the robust standard errors are given in italic below the estimated values. Column 3 reports the number of observed firms; Column 4 reports the F-statistic for the regression of the change in the log ratios on the instruments without higher orders; Column 5 reports the same information for the more general regression model. Finally Column 6 & 7, report the F-statistic and the p-value for the test of the null hypothesis that the squares of the instruments and the interaction between instruments have no explanatory power.

Table 8: Ordinary Least Squares Estimation Results

	Skill		
Δlog ratio Payroll	Basic	Medium	High
Δlog ratio Employment	0.974	0.913	0.956
	(0.008)**	(0.023)**	(0.029)**
Constant	0.032	0.086	0.003
	(0.014)*	(0.034)*	(0.050)
N	1,741	272	183
K	1	1	1
R^2	0.921	0.903	0.886
F	13,317.564	1,581.256	1,072.254

Note: the estimates presented in this table are produced using the stata command reg. The estimates are OLS estimates and the standard errors are robust to the presence of heteroscedasticity. For each skill group, each firm contributes a single observation to the estimates.

Table 9: Instrumental Variables Estimation Results

	Skill					
	Basic		Medium		High	
Δlog ratio Payroll	#iv=2	#iv=5	#iv=2	#iv=5	#iv=2	#iv=5
Δlog ratio Employment	1.007	1.014	0.697	0.682	0.837	0.708
	(0.056)**	(0.038)**	(0.179)**	(0.167)**	(0.275)**	(0.215)**
Conditional LR CI, ρ=1	[0.91,1.12]	[0.95,1.10]	[-∞,+∞]	[-∞,+∞]	[-∞,+∞]	[-∞,+∞]
p-value CLR test H0:ρ=1	0.879	0.568	0.038	0.083	0.476	0.129
Constant	-0.002	-0.008	0.279	0.293	0.076	0.154
	(0.058)	(0.041)	(0.170)	(0.158)	(0.181)	(0.149)
N	1,741	1,741	272	272	183	183
K	1	1	1	1	1	1
R^2	0.920	0.919	0.852	0.845	0.872	0.826
F	322.714	714.030	14.989	16.540	9.182	10.762
Weak-id stat.	15.326	14.644	2.954	1.269	0.722	0.916
J stat.	0.277	8.933	0.946	1.379	1.526	2.876
J stat. p-value	0.598	0.063	0.331	0.848	0.217	0.579
J stat. degrees of freedom	1	4	1	4	1	4
Id-stat.	28.703	64.582	5.483	5.887	1.580	3.655
Id-stat. p-value	0.000	0.000	0.064	0.317	0.454	0.600
Id-stat. degrees of freedom	2	5	2	5	2	5
A-R F-stat.	15.536	15.719	1.647	0.702	0.547	0.427
A-R F-stat. P-value	0.000	0.000	0.195	0.622	0.580	0.829
A-R F-stat. degrees of freedom, d_1	2	5	2	5	2	5
A-R F-stat. degrees of freedom, d_2	1,738	1,735	269	266	180	177

Note: the estimates presented in this table are produced using the stata command ivreg2 (Baum, Schaffer and Stillman, 2007). The estimates are IV estimates and the standard errors are robust to the presence of heteroscedasticity. For each skill group, each firm contributes a single observation to the estimates.
Using the command condivreg (Moreira and Poi, 2003, and Mikusheva and Poi, 2006), we calculate for each IV slope estimate the 95% confidence interval around ρ=1 based on the inversion of the conditional likelihood ratio test statistic of the null hypothesis H0:ρ=1 (see Moreira 2003) and we provide the corresponding p-value. When the instruments are weak and the data is not informative about the parameter of interest, the confidence interval can be of infinite size.
F is the F statistics of significance of all the regressors, its critical value depends on the number of regressors excluding the constant (*k=1* here) and the number of observations (*N-k*) . R^2 reports the centered R-squared. Weak-id stat. reports the Kleibergen-Paap rk F statistics for the test of the null hypothesis of weak identification. The J statistics is the Hansen J statistics of over-identification, the following rows report its p-value and the relevant degrees of freedom. A-R F-stat. reports the Anderson-Rubin F-statistics for the test of the joint null hypothesis that the endogenous regressor on the RHS of the structural equation is equal to zero and that the over-identification exclusion restrictions are satisfied. Id-stat. reports the Kleibergen-Paap rk LM test statistics for the null hypothesis that the matrix of reduced form parameters has reduced rank, i.e. it tests the null hypothesis of under-identification. The following rows report the p-value for the statistics under the null and the relevant degree of freedom.

Table 10: Log Ratios Given Future Work Force Composition, 1998

Skill	Basic Payroll	Basic Employment	Medium Payroll	Medium Employment	High Payroll	High Employment
11->00	0.432	0.410	0.161	0.114	-0.225	-0.176
	0.040	*0.037*	*0.098*	*0.095*	*0.145*	*0.133*
11->01	0.775	0.778	0.158	0.169	0.021	-0.012
	0.062	*0.058*	*0.122*	*0.114*	*0.165*	*0.150*
11->10	0.275	0.217	-0.154	-0.093	-0.243	-0.094
	0.054	*0.050*	*0.179*	*0.165*	*0.243*	*0.211*
Const.	-0.856	-1.187	0.311	-0.175	1.330	0.660
	0.032	*0.030*	*0.081*	*0.081*	*0.122*	*0.112*
N	4,922	4,922	889	889	526	526
K	3	3	3	3	3	3
R^2	0.036	0.041	0.006	0.005	0.008	0.005
F-stat	65.888	74.013	1.907	1.358	1.552	0.899
p value	0.000	0.000	0.127	0.254	0.200	0.441

Notes: For each skill level and separately for the 1998 log ratios of Payrolls and number of Employment workers, the table reports the estimates of the dummy variables which indicate whether the age groups exist in 2006. The omitted category is the group of firms which employ both age groups in 1998 and 2006. Firms in 1998 must exhibit both age groups in 1998.The robust standard errors for the estimated parameters are reported in italic below each estimate.

Table 11: Log Ratios Given Past Work Force Composition, 2006

Skill	Basic Payroll	Basic Employment	Medium Payroll	Medium Employment	High Payroll	High Employment
00->11	0.297	0.287	-0.485	-0.463	-0.632	-0.533
	0.058	*0.052*	*0.102*	*0.095*	*0.152*	*0.140*
01->11	0.483	0.507	-0.031	-0.052	0.006	-0.003
	0.112	*0.107*	*0.137*	*0.131*	*0.172*	*0.160*
10->11	-0.289	-0.323	-0.661	-0.673	-0.602	-0.631
	0.041	*0.039*	*0.114*	*0.107*	*0.179*	*0.175*
Const.	0.024	-0.325	1.191	0.685	1.755	1.112
	0.032	*0.031*	*0.080*	*0.077*	*0.115*	*0.113*
N	4,018	4,018	818	818	445	445
K	3	3	3	3	3	3
R^2	0.037	0.046	0.057	0.064	0.059	0.059
F-stat	53.908	72.516	15.552	17.076	9.463	9.281
p value	0.000	0.000	0.000	0.000	0.000	0.000

Notes: For each skill level and separately for the 2006 log ratios of Payrolls and number of Employment workers, the table reports the estimates of the dummy variables which indicate whether the age groups exist in 1998. The omitted category is the group of firms which employ both age groups in 1998 and 2006. Firms in 2006 must exhibit both age groups in 2006.The robust standard errors for the estimated parameters are reported in italic below each estimate.

Table 12: Log Ratio given Future Work Force Composition and Instruments, Young vs Old, 1998

Skill	Basic Payroll	Basic Employment	Medium Payroll	Medium Employment	High Payroll	High Employment
11->00	0.260	0.264	0.170	0.117	-0.062	-0.046
	0.041	*0.039*	*0.101*	*0.099*	*0.154*	*0.142*
11->01	0.696	0.711	0.165	0.173	0.104	0.062
	0.062	*0.058*	*0.122*	*0.114*	*0.163*	*0.150*
11->10	-0.001	-0.018	-0.138	-0.092	-0.086	0.051
	0.057	*0.052*	*0.180*	*0.169*	*0.243*	*0.220*
PEW62	-2.394	-2.034	-0.249	-0.208	1.987	1.719
	0.167	*0.157*	*0.387*	*0.356*	*0.564*	*0.490*
PEW62 SQUARED	2.176	1.837	0.228	0.156	-1.634	-1.545
	0.172	*0.162*	*0.384*	*0.356*	*0.605*	*0.508*
OAP65	-2.579	-2.134	0.593	-0.083	2.547	1.562
	0.569	*0.512*	*1.190*	*1.068*	*1.049*	*0.980*
OAP65 SQUARED	2.425	1.952	-1.096	-0.328	-2.762	-1.858
	0.611	*0.559*	*1.275*	*1.132*	*1.147*	*1.085*
PEW62×OAP65	2.585	2.255	1.757	1.828	-3.211	-2.336
	0.860	*0.776*	*1.761*	*1.629*	*1.926*	*1.713*
Constant	-0.358	-0.760	0.311	-0.149	0.820	0.282
	0.045	*0.042*	*0.117*	*0.109*	*0.164*	*0.152*
N	4,922	4,922	889	889	526	526
k	8	8	8	8	8	8
R^2	0.089	0.084	0.013	0.008	0.047	0.034
F	64.270	61.315	1.403	0.984	4.256	3.053
F, p-value	0.000	0.000	0.191	0.447	0.000	0.002
Fi	51.757	63.720	1.947	1.410	0.545	0.294
Fi, p-value	0.000	0.000	0.120	0.238	0.651	0.830
Fc	56.439	46.999	1.047	0.743	4.785	3.541
Fc, p-value	0.000	0.000	0.389	0.592	0.000	0.004

Notes: For each skill level and separately for the 1998 log ratios of Payrolls and number of Employment workers, the table reports the regression estimates of the dummy variables for the future work force composition and the estimates of the effects of the instruments, their squares and their interaction. The omitted category is the group of firms which employ both age groups in 1998 and 2006. Firms in 1998 must exhibit both age groups in 1998. The robust standard errors for the estimated parameters are reported in italic below each estimate. We report F statistics and p-values for the null hypotheses that i) the regressors have no explanatory power (F and F, p-value), ii) the dummies describing the composition of the future work force have no explanatory power (Fi and Fi, p-value), iii) that the instruments squared and their interaction have no explanatory power (Fc and Fc, p-value).