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Ageing workforce, productivity and labour costs of Belgian firms *

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ABSTRACT

The Belgian population is ageing due to demographic changes, so does the workforce of firms active in the country. Between 1998 and 2006, the average age of workers rose by almost 3 years. Such a trend is likely to remain for the foreseeable future. And it will be reinforced by the willingness of public authorities to expand employment among individuals aged 50 or more. But are employers *a priori* willing to employ (more) the older workers? The answer depends to a large extent on the ratio between older worker's productivity and their cost to employers. To address this question we tap into a unique employer-employee panel data set to produce robust evidence on the causal effect of ageing on productivity and labour costs. Unobserved firm fixed-effects and short-term endogeneity of workforce age pose serious estimation challenges, which we try to cope with. Our results indicate a negative productivity differential for older workers ranging from 20 to 40% when compared with prime-age workers. What is more, these productivity differentials are not compensated by lower relative labour costs. Furthermore, the (now dominant) service sector does not seem to offer working conditions that mitigate the negative age/productivity relationship. Another important result is that older workers in smaller firms (<100 workers) display a larger productivity differential and a productivity that is less aligned on labour costs.

JEL Classification: J24, C52, D24
Keywords: Ageing, Labour Productivity, Panel Data Analysis, Belgium.

RESUMO
Em razão de evoluções demográficas, está envelhecendo a população belga, bem como a força de trabalho das firmas que operam no país. Entre 1998 e 2006, a idade média dos trabalhos cresceu em quase 3 anos. É provável que esta tendência se mantenha no futuro próximo, e que seja reforçada pela intenção das autoridades públicas de expandir a participação no mercado de trabalho de indivíduos acima dos 50 anos. Mas será que os empregadores têm interesse em empregar trabalhdores idosos? Em grande medida, a resposta depende da relação entre as produtividades dos trabalhadores idosos e seus custos para os empregadores. Para estudar esta questão, este artigo recorre a um painel de dados sobre empregadores e empregados, a fim de tentar fornecer evidências, tão robustas quanto possível, sobre o efeito causal do envelhecimento sobre a produtividade e os custos laborais. Características não observáveis das firmas, bem como a endogeneidade da idade da fora de trabalho no curto prazo impõem sérios desafios econométricos, com os quais tentamos lidar. Nossos resultados indicam um hiato de produtividade negativo para os trabalhadores idosos com relação aos adultos, oscilando entre 20 e 40%. Além disso, tais hiatos são apenas parcialmente compensados por custos laborais relativamente mais baixos. Por fim, o (agora dominante) setor de serviços não parece oferecer condições de trabalho capazes de moderar a relação negativa entre idade e produtividade. Outro resultado é importante indica que trabalhadores idosos sem firmas pequenas (<100 trabalhadores) apresentam hiato de produtividade antes maior, e que sua produtuvidade é ainda menos alinhada com custos laborais.

Classificação JEL: J24, C52, D24
Palavras-chaves: Envelhecimento populacional, produtividade do trabalho, dados em painel, Bélgica.

1. Introduction

The Belgian population is ageing due to demographic changes, so does the workforce of firms active in the country. Between 1998 and 2006, the average age of workers rose by almost 3 years: from 36.2 to 39.1. Such a trend is likely to remain for the foreseeable future. For many reasons, including the fact that one of the goals of the European Union's so-called Lisbon Strategy – that of raising employment of individuals aged 55-64 to at least 50% by 2010 – will not be attained by Belgium[1], public authorities will certainly try to expand employment among individuals beyond 50 years-old, reinforcing the demographic trends. Ageing and policies aimed at maintaining older individuals in employment raise crucial issues. One of them is the effect on the productivity performance of firms, and, by extension, of the whole economy. Another one is simply whether employers are willing to employ older workers, given the relationship between their productivity and what they cost to employ.

At least two different hypotheses are relevant about ageing workforces and productivity. The first one is based on productivity measurement on the individual level. Here, many studies indicate that labour productivity peaks somewhere between 30 and 50 years of age, possibly due to (relative) physical decay or human capital depreciation or obsolescence. This suggests that a relatively prime-age workforce would be more productive than an old-aged one.

The second hypothesis is based on the learning-by-doing assumption formulated by Becker or Arrow. On-the-job experience can enhance workers' human capital. This assumption is supported by numerous Mincerian wage equations in which the coefficient of the experience term is positive. It is also by anecdotal evidence, like that of the Horndal steel-plant in central Sweden (Malmberg, Lindh & Halvarsson, 2005). Between 1920 and 1950 this plant experienced strong productivity gains of 2.5 percent per year, in spite of a very aged workforce and the fact that no major investments were undertaken. In 1930, more than a third of the workers were older than 50 years-old; in 1950 these represented more that half of the total. The Horndal experience thus suggests that an ageing workforce could be compatible with rapid increases in labour productivity through a learning-by-doing effect.

Economic theory provides no clear-cut conclusion as to where ageing should lead us in terms of productivity. The existence of two competing hypotheses on the effect of workforce ageing on productivity highlights the need for more thorough empirical studies using micro data.

1 See Annex2 for 2008 statistics about the employment rate of older workers in Belgium and in the EU.

As to ageing and the evolution of labour costs (or wages), the standard theory is that under perfect competition, the latter should simply reflect productivity.

Quite surprisingly, the empirical evidence on the economic consequences of ageing, investigated at the level of the firm remains limited. Except for a few studies on American (Hellerstein *et al.*, 1999), French (Aubert & Crépon, 2003), Danish (Grund &Westergård-Nielsen, 2005) and Canadian firms (Dostie, 2006), it seems that the topic has so far received little attention. Among the few existing studies, some (Malmberg, Lindh & Halvarsson, 2005) exclusively examine the situation of the industry (manufacturing, mining or construction sectors).

One great advantage of our Belgian data is that they contain information on firms from the (now dominant) service sector, where administrative and intellectual work is predominant. Another advantage is that our measure of firms' productivity (i.e.; the valued added) enhances comparability of data across industries, which vary in their degree of vertical integration (Hellerstein *et al.*, 1999). We have information on firms' capital stock, which is not the case in some of the previous contributions in the literature. We know how much firms spend on their employees (gross wages plus social security contributions and other related costs). This allows for a direct comparison of relative labour cost and relative productivity of different categories of workers (older, prime-age and younger), and the relative labour demand of firms towards these types of workers. Finally, it is worth stressing that our panel is long, covering a period running from 1998 to 2006.

The microeconometric study of data combining information about firms and workers, focusing on the issue of age, productivity and labour cost, is a novelty for Belgium. But the interest of the project goes well beyond the Belgian borders. Ageing workforces is a phenomenon affecting most OECD countries, possibly also China and other emerging countries. And its analysis via micro and firm-based data has not been done extensively so far.

The main objective of this paper is to properly identify and quantify the causal effect of ageing on firms' productivity, while also considering the parallel relationship between age and labour costs in order to test for the presence of a productivity- vs. labour cost gap. Attaining these objectives is essential in order to achieve what should rather be seen as a *goal*: enhancing the quality of policy-making in Belgium and neighbouring countries. Better policy-making at the micro or sectoral level presupposes we get solid knowledge on how internal and external labour markets will be affected by the growing presence of older workers. What consequences ageing will have on the formation of wages, given the pivotal role of productivity gains at that level? At a more macro level, we need to better understand how ageing is likely to affect productivity growth. This is crucial to properly evaluate the rate at which tax and social security contributions will rise in the future.

In this paper we measure, and test for, the presence of productivity- vs. labour cost gap for older workers (50-65)[2] in the Belgian labour market by employing a methodological approach, pioneered by Hellerstein and Neumark (hereafter HN) (1995), to a large data set that matches firm-level data, retrieved from Belfirst, with data from Belgian's Social Security register containing detailed information about the characteristics of the employees in those firms. This methodological approach uses firm-level data to identify and measure the *gap* between a measure of older workers' compensation relative to prime-age ones (the labour cost differential)[3] and a measure of older workers' productivity relative to prime age workers (the productivity differential).

Its main advantages are two. First, it *provides a direct measure of productivity differences* that can be immediately compared to a measure of labour cost differences, thereby identifying productivity- vs. labour cost gaps. Second, it measures, and tests for the presence of, a concept of *market-wide* productivity- vs. labour cost gaps than can impact on the overall labour demand for the category of workers considered. HN's methodology has also been used to test other wage formation theories, most notably those investigating the relationship between wages and productivity along gender and/or race profiles, *e.g.* HN (1995), Borowczyk Martins & Vandenberghe (2010). Extensions of the basic methodology include enlarging the scope of workers characteristics, such as age, race and marital status, e.g. Hellerstein *et al.*(1999), and the consideration of richer data sets regarding employee information, *e.g.* Crépon, Deniau, and Pérez-Duarte (2002). In this paper, we will focus on age.

From the econometric standpoint, recent developments of HN's methodology have tried to improve the estimation of the production function by the adoption of alternative strategies to deal with potential heterogeneity bias (unobserved time-invariant determinants of firms' productivity) and simultaneity bias (endogeneity in input choice in the short run that include the gender mix of the firm). Aubert and Crépon (2006) control for the heterogeneity bias using a «within» transformation, thereby identifying gender wage discrimination from within-firm variation, and deal with the simultaneity bias by estimating Arellano and Bond's (1991) GMM (Generalized Method of Moments) estimator. Dostie (2006) alternatively controls for the endogeneity in input choice by applying Levinsohn and Petrin's (2003) structural production function estimator and takes into account both firm and workplace heterogeneity in the model of wage determination.

We follow the most recent applications of HN's methodology and explore within-firm variation provided by panel data to identify gender wage discrimination. Next, we deal with potential endogeneity in input choice by implementing Levinsohn and Petrin's (henceforth LP) (2003) intermediate good proxy approach.

Our results suggest that an increase of 10 percentage points in the share of older workers (>50) in a firm depresses its added value by 2 to 4%, depending on the estimation method chosen, with an intermediate results of about 3.2% in our preferred model. Our results indicate a negative (and large) productivity *differential* for older workers of up to 45% when compared with prime-age workers. What is more, these

[2] We also examine the situation of young adults (18-29). The reference category is formed by the prime-age workers (30-49).

[3] Our measure exploits labour cost data (that include gross wage and social security contributions) which are very good proxy of what employees get paid.

productivity differentials are not compensated by lower relative labour costs for employers creating a productivity- vs. labour cost *gap*.

As to the terminology used in the paper, the reader should bear in mind that the term “differential” designates the productivity (or labour cost) differences between the considered age group and the reference (i.e. prime-age workers); whereas the term “gap” refers to the difference between the productivity and the labour-cost differentials characterizing an age-group.

The paper is organized as follows. In the next section, we briefly go through the main theoretical predictions and empirical findings of the literature related to our topic. In Section 3, our methodological choices are unfolded, regarding the estimation of both the production function and the labour cost equation. Section 4 is devoted to an exposition of the dataset. Section 5 and 6 contain the results and the conclusions, respectively.

2. Related literature

Of course, at some point in a person’s life his potential productivity should tend to go down because of increasingly severe health problems, until reaching the limiting case of no productivity at all. Having said that, it is relevant to understand from what moment in the lifecycle the productivity actually goes down and how fast it progresses. In particular, do we know whether the biological decline usually affects people during their working life?[4] Beyond obvious health-related issues, are there other economic explanations to expect productivity to go down with age? Or are there, instead, reasons to expect it to go up or to be kept stable? To what extent are those hypotheses empirically verified? Because of its importance, both for firms and policymakers, a related question concerns the interplay between productivity and wages along the lifecycle: do they follow a similar path or do they depart from each other at a given point in a worker’s career?

A natural starting point to address the issues at stake here is human capital theory.[5] Within that approach, there are conflicting predictions regarding the evolution of productivity with age. On the one hand, one would expect productivity to go down with age, due to: *i)* a natural or biological decline in physical and mental capacities, *ii)* depreciation or obsolescence of the human capital stock, *iii)* the non-optimality of investments in on-the-job training after a given worker’s age, due to the short spell for returns to come about. On the other hand, one would predict a productivity decrease or stabilization with age, due to: *i)* benefits accruing from a worker’s experience; *ii)* learning-by-doing effects; *iii)* the possibility that workers devise mitigating strategies when they observe signs of their own physical or mental decline (Volkoff *et al.,* 2000).

Regarding the link between labour costs and productivity, while human capital theory would expect wages to generally follow the trend in the productivity curve, alternative approaches do not endorse such prediction, assuming that wage structures are designed, not to compensate productivity in the short run, but rather to magnify incentives to effort, such as in efficiency-wage models (Shapiro & Stiglitz, 1984) or in deferred-compensation-schemes arguments (Lazear, 1979), or to permit economies of job-

4 As an international convention, the working life is generally defined as up to 65 years-old.
5 For a comprehensive review made by one of its main contributors see Mincer (1994).

searching costs (Mirrlees, 1997). Although relying on different channels or mechanisms, all these strands of the literature would consider it likely to observe a decoupling of a worker's productivity and his wage along the lifecycle.

Empirical evidence does not seem to be sufficient to provide indisputable conclusions. In a survey, Lumsdaine & Mitchell (1999), mention, on the one hand, that "there is a psychological literature examining the link between performance on certain clinical tests and age, and it shows that in many manual dexterity areas older people are less able"; on the other hand, the same authors report that other studies claim that "in several other regards older people have superior skills than do their younger peers". While some studies point to an absence of a strong age effect on productivity, e.g., in academic performance (Smith, 1991), others state that fatal accidents are more frequent among older workers (Mitchell, 1988). Studying US athletics records by age for men over 35 years-old, Fair (1994) tried to estimate how fast their performance worsens with age, concluding that remarkable performances can be attained at very advanced ages through appropriate training.[6] Costa (1995) finds that male's labour force participation is much less responsive to body mass index today than it was in the beginning of the 20th century, suggesting that in the long run, health – and thus ageing – becomes less relevant in determining retirement decisions; it might also have become less relevant in determining productivity. Based on the SHARE database, Kalwij & Vermeulen (2008) find that bad health status is correlated with early retirement in most European countries, and particularly so in Belgium. What is not clear, however, is whether the early retirement event is mainly driven by labour supply decisions or by demand side behaviour.

Quite surprisingly, the empirical evidence on the economic consequences of ageing, investigated at the level of the firm – the focus of this paper –, remains limited. Labour supply has been more often studied, be it in Belgium[7] or elsewhere: "Employer-side models of *demand* for older workers, however, have lagged behind the supply-side developments and are not well developed to date" (Lumsdaine & Mitchell, 1999).

It seems that the demand side of the topic, with proper consideration to the relationship between age, productivity, and labour costs, has so far received little attention, except for a few studies. According to Malmberg, Lindh, & Halvarsson (2006), an accumulation of high shares of older adults in Swedish manufacturing plants does not seem to have a negative effect on plant level productivity. But that article does not examine the relationship between age and labour costs (or wages). Gründ & Westergård-Nielsen (2008) also focus exclusively on productivity. They find that both mean age (and age dispersion) in Danish firms are inversely u-shaped related to firm productivity.

The first contribution to focus on productivity and wages simultaneously was the seminal paper of Hellerstein et al. (1999). They estimated productivity and wages of different types of workers in American firms – including age groups – finding that both wages and productivity tend to grow with age. Aubert & Crépont (2003), in turn,

[6] It is of course questionable whether such results would apply to an average worker, who does not need to be constantly performing at maximal levels, and whether they would extend to primarily intellectual tasks.

[7] See Sneessens & Van der Linden (2005) or de la Croix & Pestieau (2007) for recent examples (written to non-economic readers, though).

observed that the productivity of French workers rise with age until around the age of 40, before stabilizing, a path which is very similar to those of wages. A wage-productivity gap is observed only for workers aged more than 55. Using data for Canadian plants, Dostie (2006) obtained concave age-productivity profiles. Significant wage-productivity gap occurs only with one particular type of worker, namely, males aged 55 and more, which have at least an undergraduate degree.

Summing up, we could say that on the one hand the decreasing relation between productivity and age during working life, and on the other hand a rising relation between age and wages, are by and large assumptions, which are taken for granted in different conceptual approaches in the economic literature. Nonetheless, empirical counterparts do not yet offer clear-cut conclusions. Current knowledge does not allow a clear *a priori* expectation regarding the effect of age on the demand for labour we would encounter in Belgium.

3. Methodology

In order to estimate gender-productivity (and similarly gender-wage profiles), first consider (the econometric version of) a Cobb-Douglas production function

$$log\ Y_{it} = \alpha\ log\ L_{it}^{A} + ß\ logK_{it} \qquad (1)$$

where: Y is the value added by firm i at time t, L^A is an aggregation of different types of workers, K is the capital stock, and μ is the error term.

The key variable in this production function is *the quality of labour aggregate* L^A. Let L_{ikt} be the number of workers of type k (young, prime-age, old) in firm i at time t, and μ be their productivity. We assume that workers of various types are substitutable with different marginal product. And each type of worker k is assumed to be an input in the production function. The aggregate can be specified as:

$$L_{it}^{A} = \sum_k \mu_{ik}\, L_{ikt} = \mu_{i0}\, L_{it} + \sum_{k>0} (\mu_{ik} - \mu_{i0})\, L_{ikt} \qquad (2)$$

where: L_{it} is the total number of workers in the firm, μ_0 the productivity of the reference category of workers (*e.g.* men). It should be noted that, while Hellerstein *et al*. (1999) originally developed a more general setting in terms of workers' types (race, gender, age…), here those types refer exclusively to different age groups.

If we further assume that a worker has the same marginal product across firms, we can drop subscript i and rewrite equation (2) as:

$$Ln\ L_{it}^{A} = ln\ \mu_0 + ln\ L_{it} + ln\ (1+ \sum_{k>0} (\lambda_k\ - 1)\ P_{ikt}) \qquad (3)$$

where $\lambda_k \equiv \mu_k/\mu_0$ the relative productivity of type k worker and $P_{ik}= L_{ik}/L_{i0}$ is the proportion/share of type k workers (*e.g.* share of young adults or older workers) over the total number of workers in firm i .

Since $log(1+x) \approx x$, we can approximate (3) by:

$$Log\ L_{it}^{A} = log\ \mu_0 + log\ L_{it} + \sum_{k>0} (\lambda_k - 1)\ P_{ikt} \quad (4)$$

And the production function becomes:

$$log\ Y_{it} = \alpha\ [log\ \mu_0 + log\ L_{it} + \sum_{k>0} (\lambda_k - 1)\ P_{ikt}] + ß\ logK_{it} \quad (5)$$

Or, equivalently, if $k=0,1,....N$ with $k=0$ being the reference group (*e.g.* prime-age workers)

$$y_{it} = A + \alpha\ l_{it} + \eta_1\ P_{i1t} + \ ...\ \eta_N\ P_{iNt} + ß\ k_{it} \quad (6)$$

where:

$A = \alpha\ log\ \lambda_0$

$\lambda_k = \mu_k/\mu_0 \quad k-=1...N$

$\eta_1 = \alpha\ (\lambda_1 - 1)$

….

$\eta_N = \alpha\ (\lambda_N - 1)$

$y_{it} = logY_{it}$

$l_{it} = logL_{it}$

$k_{it} = logK_{it}$

Note first that (6) being loglinear in P the coefficients can be directly interpreted as the percentage change in productivity of a 1 unit (here 100%) change of the considered type of workers' share among the employees of the firm. Note also that, strictly speaking, in order to obtain a type's relative productivity, (*i.e.* λ_k), coefficients η_k have to be divided by α, and 1 needs to be added to the result.

In order to test the null hypothesis of no gender wage discrimination we still need to define a labour costs/wage equation to obtain an estimate of the older workers' labour cost differential. Under the identifying assumptions of spot labour markets and cost-minimizing firms, young, prime-age or older workers should be paid according to their marginal product. Let the total labour costs of a firm (*LC*) be decomposed in two components: labour costs with prime-age workers (k=0) and labour costs with young/older workers($k>0$). By assumption, firms operate in the same labour market. So they pay the same wages to the same category of workers (we can thus drop subscript i), which in our framework is the only feature that differentiates workers. Let π_k stand for the remuneration of type k workers. Then:

$$LC_{it} = \sum_k \pi_k\ L_{ikt} = \pi_0\ L_{it} + \sum_{k>0} (\pi_k - \pi_0)\ L_{ikt} \quad (7)$$

Taking the log and using again $log(1+x) \approx x$, we can approximate this by:

$$ln\ LC_{it} = ln\ \pi_0 + ln\ L_{it} + \sum_{k>0} (\Phi_k - 1)\ P_{ikt} \quad (8)$$

where the Greek letter $\Phi_k \equiv \pi_k/\ \pi_0$ denotes the yearly labour costs differential between old/young ($k>0$) and prime-age ($k=0$), hereafter referred to as the labour cost differential, and $P_{ik}= L_{ik}/L_{i0}$ is the proportion/share of type k workers over the total number of workers in firm i .

The labour costs/wage model finally becomes:

$$w_{it} = B + \rho_1 P_{i1t} + \ldots \rho_N P_{iNt} \tag{9}$$

where:

$B = ln\ \pi_0$

$\Phi_k \equiv = \pi_k / \pi_0 \qquad k=1,\ldots N$

$\rho_1 = \Phi_1 - 1$

….

$\rho_N = \Phi_N - 1$

$w_{it} = ln\ LC_{it} - ln\ L_{it}$

Note in particular that the dependent variable corresponds to the average labour costs per worker. By estimating equation (9) we can directly obtain an estimate of the labour cost differential by adding 1 to estimated ρ_k:

The productivity- vs labour cost gap hypothesis test est can now be easily formulated. Assuming spot labour markets and cost-minimizing firms the null hypothesis of no gap for type k worker implies $\lambda_k=\Phi_k$. Moreover, the gap between the productivity differential and the wage differential provides a quantitative measure of the disincentive to employ the category of workers considered.[8] As it will be made clear in Section 5, this is a test we can easily implement in our econometric specifications of the production function and the labour costs equation.

We now consider the econometric version of our linearised Cobb-Douglas model (10). Note first that we have added a matrix F_{it}, wherein we concentrate wherein we concentrate region (#3), year (#8), sector[9] (#10) and interaction of year and sector dummies. The extension of the production function by introducing year, sector and region dummies allows for systematic and proportional productivity variation among firms along these dimensions. This assumption can be seen to expand the model by controlling for year- and sector- specific productivity shocks, labour quality and intensity of efficiency wages differentials across sectors and other sources of systematic productivity differentials (HN, 1995). More importantly, since the data set we used did not contain sector price deflators, the introduction of these sets of dummies can control for asymmetric variation in the price of firms' outputs at sector. An extension along the same dimensions is made with respect to the labour costs equation.

We recall that the labour costs equation is definitional: under the assumption of cost-minimizing firms that operate in the same competitive labour market, all workers in the same demographic categories earn the same wage. By introducing year, region and sector controls we consider the possibility that firms operate in year-, region- and sector-specific labour markets[10] and, therefore, allow for wage variation along these

[8] We assume for presentational simplicity that older workers are less productive than prime-age one, so that the productivity differential is below 1.

[9] NACE 1 level.

[10] Its probably the sector dimension that is the most relevant in the case of Belgium.

dimensions. Of course, the assumption of segmented labour markets, implemented by adding linearly to the labour costs equation the set of dummies, is valid as long there is proportional variation in wages by gender along those dimensions (HN, 1995).

But from an econometric point of view, the main challenge consists of dealing with the various constituents of the residual ε_{it} of the production function. First, the *unobservable* (time-invariant) *heterogeneity* across firms, θ_i (equ. 10).

$$y_{it} = A + \alpha\, l_{it} + \eta_1\, P_{i1t} + \ldots\, \eta_N\, P_{iNt} + ß\, k_{it} + \gamma F_{it} + \varepsilon_{it} \qquad (10)$$

where $\varepsilon_{it} = \theta_i + \omega_{it} + \sigma_{it}$

where: $cov(\theta_i, P_{i1,t}) \neq 0$ and/or $cov(\theta_i, P_{i2,t}) \neq 0$, $cov(\omega_{it}, P_{i1,t}) \neq 0$ and/or $cov(\omega_{it}, P_{i2,t}) \neq 0$, $E(\sigma_{it})=0$

The latter corresponds to specific characteristics of the firm, which are unobservable but driving the productivity. For example the age of the plan, the vintage of capital used, firm-specific managerial skills, location-driven comparative advantage[11]…. What is more these might be correlated with the age-structure of its workforce. Older worker for instance might be overrepresented among plants built a long time ago using older technology. The panel structure of our data allows us to use fixed-effects or within methods, attenuating that problem in many of the specifications.

The greatest econometric challenge, however, is to go around *simultaneity or endogeneity bias* (Griliches & Mairesse, 1995). The economics underlying that concern is intuitive. In the short run firms could be confronted to productivity shocks, ω_{it} (equ. 10); say, a positive shock due to a turnover, itself the consequence of a missed sales opportunity). Contrary to the econometrician, firms may know about this and respond by expanding recruitment of temporary- or part-time staff. Since the latter is predominantly female, we should expect that the share of female employment should increase in periods of positive productivity shocks and decrease in periods of negative shocks. This would generate positive correlation between the share of female labour force and the productivity of firms, thereby leading to overestimated OLS estimates of the gender productivity differential.

Instrumenting the age by lagged values is a strategy regularly used in the production function literature (Arellano & Bond, 1991) to cope with this short-term simultaneity bias. Nevertheless, it has some limits, among which concerns about the quality of lagged values as instruments, and the large standard errors usually found, which make it difficult to draw solid conclusions.[12] A development of that procedure, which has been proposed by Blundell & Bond (2000), is a system-GMM, in which the endogenous variables are instrumented with variables considered to be uncorrelated with the fixed effects and estimated by GMM. Still in this case, there are at least two types of problems: *i)* the estimated results are typically extremely sensitive to a great number of methodological choices (e.g., the number of lags for each variable), and, *ii)* instruments are often weakly identified, casting doubts on the quality of the estimations.

11 Motorway/airport in the vicinity of logistic firms for instance.

12 These limits have been acknowledged by Aubert & Crépon (2003), who applied such strategy to French data, and are also mentioned by Dostie (2006) or Roodman (2007).

An alternative that seems to be particularly promising and relevant given the content of our data it to adopt the approach suggested by Levinsohn & Petrin (2003) and used, for example, by Dostie (2006). Their idea is that firms primarily respond to productivity shocks ω_{it} by adapting the volume of their *intermediate inputs*. Whenever such kind of information is available in a data set — which happens to be the case with ours — they can be used to proxy productivity shocks. An advantage with respect to the system-GMM method mentioned above is that this method based on intermediate inputs does not carry the burden of relying on instruments that lack a clear-cut economic meaning and which are, as mentioned above, typically weak.[13] Moreover, by using the LP method, the number of discretionary methodological choices that have to be made by the researchers is reduced, contributing to providing results which are easier to understand and to compare with others in the literature.[14]

Formally, the demand for intermediate inputs would be a function of productivity shocks as well as the level of capital:

$$int_{it} = I(\omega_{it}, k_{it}) \qquad (11)$$

Assuming this function is monotonic in ω and k, it can be inverted to deliver an expression of ω_{it} as a function of *int* and *k*. Expression (10) thus becomes:

$$y_{it} = A + \alpha\, l_{it} + \eta_1 P_{i1t} + \ldots \eta_N P_{iNt} + ß\, k_{it} + \gamma F_{it} + \theta_i + \omega_{it}(int_{it}) + \varepsilon_{it} \qquad (12)$$

with: $\omega_{it}(int_{it})$ that can be approximated by a polynomial expansion in *int*.

While the latter technique is our preferred one, we have decided to report results of different econometric techniques, because of the well-known challenges and controversies involved in the estimation of any production function (Griliches & Mairesse, 1995).

4. Data

We are in possession of a panel of around 9,000 firms with more than 20 employees, largely documented in terms of sector, location, size, capital used, wage levels, productivity and profits. These observations come from the Belfirst database. Via the so-called Carrefour data warehouse, using firm identifiers, we have been able to inject information on the age of (all) workers employed by these firms, and this for a period running from 1998 to 2006, which is a long panel as compared to what is usually found in the literature.

One great advantage of our Belgian data is that they contain information on firms from the (now dominant) service sector, where administrative and intellectual work is predominant. Just as in Aubert & Crépon (2003) and Dostie (2006), we have a measure

[13] That is instruments are only weakly correlated with the included endogenous variables.

[14] For example, employing the Arellano-Bond method, Aubert & Crépon (2003) have used a different number of lags for labour (2 lags) and other variables (all lags). Although they chose to reduce the number of lags for labour in order not to inflate too much the orthogonality conditions, it is not clear what procedure has been used to set those lags on the specific values they have chosen. We do not know whether their main results would be robust to different lag choices.

of firms' productivity (the net valued added), which is measured independently from firms' labour cost. Moreover, since our two databases are linked through firm identifiers, we do not need to assign workers to firms using statistical matching methods like in Hellerstein *et al.* (1999). Finally, contrary to Dostie (2006), we do have a measure of firms' capital stock, such that no imputation method is required. The intermediate inputs to which we assign a great role in this paper correspond to the value of "services and other goods" that firms declare buying on the market to ensure production.

Descriptive statistics are reported in Tables 1 and 2. They suggest that firms based in Belgium have been largely affected by ageing over the period considered. Between 1998 and 2006, the percentage of old workers (50-65) has risen steadily from 12% to 19%. But the proportion of prime-age workers has also risen from 39% to almost 45%. The first consequence of ageing is to increase the proportion of what basic human capital theory would consider as the most productive group: the prime-age workers (30-49).

*Table 1: Belfirst-Carrefour panel. Basic descriptive statistics. Mean (*Standard deviation in italics*).*

Year	Nobs	Net value-add (th.€)	Labour costs (th.€)	Number of employees[a]	Capital (th.€)	Mean age	Share of 18-29	Share of 30-49	Share of 50-65	Intermediate input (th. €)
1998	8265	7822	4796	103.09	6402	36.16	0.49	0.39	0.12	27991
		48627	*31591*	*443.06*	*95642*	*4.29*	*0.19*	*0.15*	*0.10*	*158639*
1999	8432	8231	5008	110.31	6561	36.44	0.47	0.40	0.13	28466
		52816	*31289*	*555.40*	*99479*	*4.24*	*0.19*	*0.14*	*0.10*	*162346*
2000	8625	8835	5286	109.99	6842	36.65	0.46	0.41	0.13	34447
		53436	*31382*	*463.24*	*107771*	*4.21*	*0.18*	*0.13*	*0.10*	*222657*
2001	8825	9034	5607	112.46	7424	37.01	0.44	0.42	0.14	35869
		52081	*31782*	*455.26*	*114725*	*4.19*	*0.18*	*0.13*	*0.10*	*256231*
2002	8967	9620	6136	118.23	7960	37.39	0.43	0.43	0.15	37472
		57884	*37765*	*677.41*	*125480*	*4.16*	*0.18*	*0.13*	*0.11*	*271372*
2003	9053	10126	6324	119.40	8388	37.99	0.41	0.43	0.16	38148
		56938	36648	665.52	133159	4.26	0.18	0.12	0.11	254523
2004	9061	10935	6610	122.21	8725	38.35	0.39	0.44	0.17	42160
		61691	*36344*	*622.20*	*141718*	*4.28*	*0.17*	*0.12*	*0.12*	*296394*
2005	9038	11363	6831	122.05	7975	38.73	0.38	0.44	0.18	47585
		62527	*36381*	*589.10*	*60530*	*4.24*	*0.17*	*0.12*	*0.12*	*416106*
2006	8954	12234	7214	126.62	8158	39.10	0.36	0.45	0.19	52744
		66647	*38292*	*618.50*	*59775*	*4.25*	*0.17*	*0.12*	*0.12*	*509653*

Table 2: Belfirst-Carrefour panel. Basic descriptive statistics

Firm size	**Nobs**
1-49	44354
50-99	14664
100+	13928
Sector	
Commerce	20199
Industry	36248
Service	22773
Region	
Brussels	10722
Vlaanderen	46008
Wallonia	16216

Figure 1 shows an expected pattern: a positive relation between firms' net value added and their labour costs, with an overwhelming majority of firms reporting lower labour costs than their net value added.[15]

Figure 1: Firms' labour costs versus *firms' net value added*

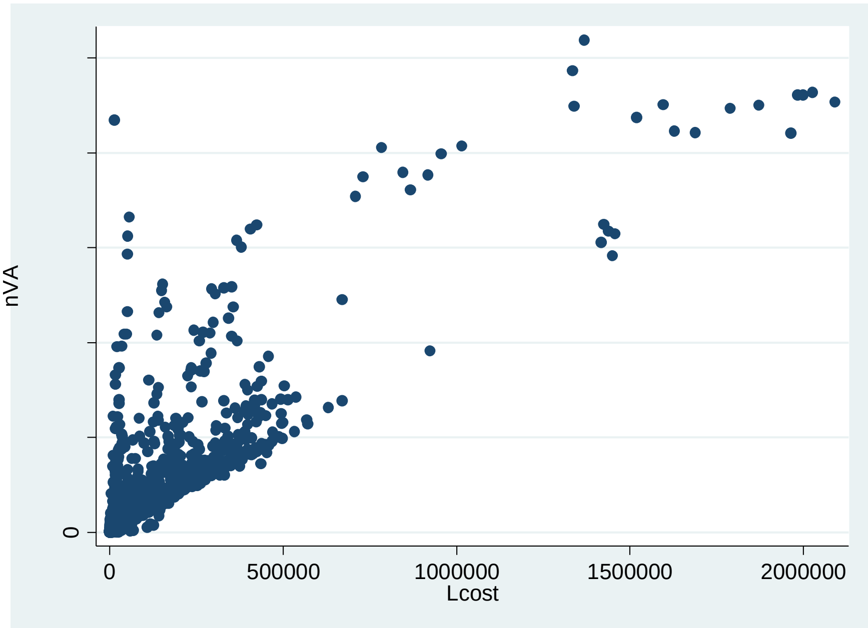


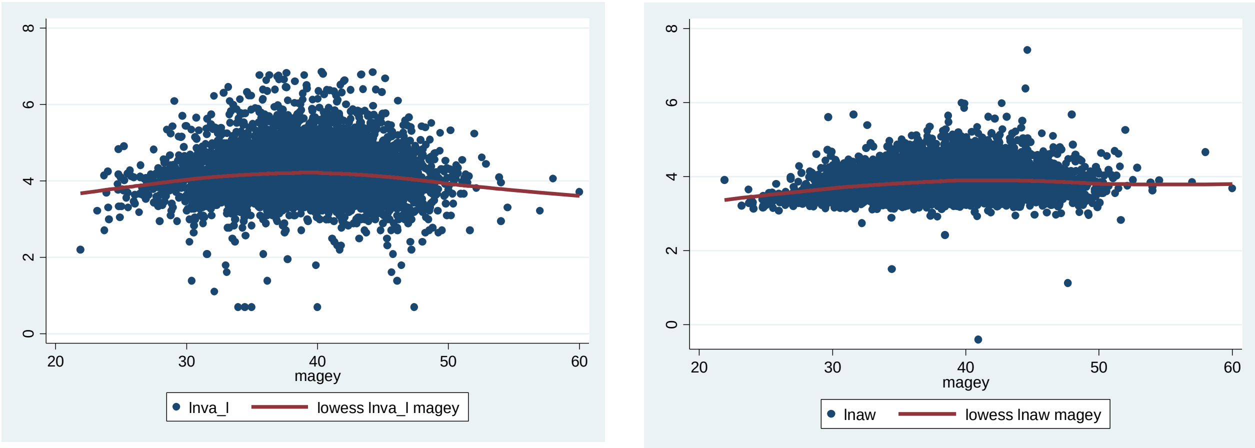
Figure 2 reveals that firms presenting higher net value added per employee tend to have an intermediately aged workforce, whilst firms with either relatively younger or relatively older workforces have lower product per capita. It should be mentioned that this graph is extremely similar to the analogous one reported by Grund & Westergård-Nielsen (2005) for Danish firms.

15 One we regress one variable against the other, we find that *net value added* = 1.43 *labour cost*.

Finally, intermediate inputs pay a key role in our analysis, as they are central to our strategy to overcome the simultaneity or endogeneity bias. It is calculated here as the differences between the firm's turnover (in nominal terms) and its net value-added. It reflects the value of goods and services consumed or used up as inputs in production by enterprises, including raw materials, services and various other operating expenses (see last column of Table 1 for descriptive statistics).

Figure 2: Average age of workers (*on the horizontal axis*) versus *firms' i) log of net value added per employee ii) log of labour costs per employee. Year 2006. Scatter plot and non-parametric regression*

Log value-added per employee   Log labour costs per employee



Source: Carrefour, Belfirst

5. Econometric results

In Table 3 we present results of the independent estimation of production and the labour costs equations under six alternative econometric specifications: standard OLS, using total- [1], between- [2] and within-firm variation, centring on firm-average [3]) or via first-differencing [4] , and the HP estimation procedure using total- [5] and within-firm [6] variation. Further ahead, in Table 4, we will focus on the *simultaneous* estimation of these two functions (using our preferred specification [6] and the statistical significance of the gap between gender productivity vs. labour costs differentials.

Specification [6] is a priori the best insofar as the coefficients of interest are identified from within-firm variation and that it controls for potential heterogeneity and simultaneity biases using HP's intermediate input proxy strategy. Heterogeneity bias might be present since our sample covers all sectors of the Belgian private economy and the list of controls included in our models is limited. Even if the introduction of the set of dummies can account for most of this bias, the «within firm» transformation is still the most powerful way to account of inter-firm unobserved heterogeneity.

On the other hand, the endogeneity in input choice is a largely well documented problem in the production function estimation literature (*e.g.* Griliches and Mairesse, 1995) and also deserved to be properly treated. Moreover, given that our data do not distinguish between part- and full-time and temporary and permanent workers and that there is evidence from the Belgian labour market indicating that women tend to be overrepresented in part-time and temporary employment, the presence of simultaneity bias may underestimate the OLS estimates of the gender productivity differential.

Results on display in Table 3 unambiguously suggest that older worker (50-65) are less productive than prime-age (30-49) ones. While the negative sign of the estimated coefficient is to be found across the range of models estimated, the magnitude varies considerably, highlighting the importance of using a wide range of techniques. These results suggest that an increase of 10 percentage points (say, from 40% to 50%) in the share of older workers in a firm on average depresses its added value by 2 to 4%, depending on the estimation method chosen. Our preferred model [6] proxies short-term endogenous productivity shock with intermediate inputs, and uses firm fixed effects. Its results are that an increase of 10 percentage points in the share of older workers in a firm would depress its added value on average by around 3.2%, a value which incidentally is very close to the average of all estimated coefficients.

Remember that, strictly speaking, the coefficients reported in the upper parts of Table 3 for age group k is equal to $\alpha(\mu_k/\mu_0-1)$. In order to properly reflect their relative productivity in percent the coefficients have to be divided by the estimated coefficient of labour variable α. The results of these minor transformations are reported in the lower part of Table 3. These are supportive of the existence of large (negative) productivity gaps for older workers ranging from 29 to 45%.

Table 3 also reveals that younger workers (18-29) are less productive than prime-age worker, but such result is less robust, since the estimated coefficients are not always statistically different form zero. In model [6] the coefficient associated with the share of younger workers is slightly positive, but not stable enough to be statistically different from zero.

Table 3: Separate estimation of Production Function and Labour Costs Equations

Method:	[1]-OLS	[2]-Between	[3]-Within (firm fixed effects)	[4]-First Differences	[5]-Intermediate inputs (LP$)	[6]-Within (firm fixed effects+ intermediate inputs LP$)
			Productivity equation			
Share of 18-29 workers	-0.324***	-0.460***	0.009	0.081***	-0.334***	0.022
p-value	*0.0000*	*0.0000*	*0.5134*	0.000	*0.0000*	*0.2043*
Share of 50-65 workers	-0.253***	-0.396***	-0.293***	-0.178***	-0.295***	-0.321***
p-value	*0.0000*	*0.0000*	*0.0000*	0.000	*0.0000*	*0.0000*
Controls	capital, number of employees + fixed effects: year, NACE1, region	capital, number of employees + fixed effects: year, NACE1, region	capital, number of employees + fixed effects: firm	capital, number of employees	capital, number of employees + fixed effects: firm, year	capital, number of employees + fixed effects: firm, year
Nobs.	76,512	76,512	76,512	66,615	61,975	61,975
			Labour cost equation			
Share of 18-29 workers	-0.450***	-0.615***	-0.122***	-0.084***	-0.491***	-0.118***
p-value	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*
Share of 50-65 workers	-0.191***	-0.381***	-0.012	0.015	-0.202***	*-0.0085*
p-value	*0.0000*	*0.0000*	*0.3559*	*0.4576*	*0.0000*	*0.5999*
Controls	fixed effects: year, NACE1, region	fixed effects: year, NACE1, region	fixed effects: firm, year	capital, number of employees	fixed effects: year, NACE1, region	fixed effects: firm, year
Nobs.	77,696	77,696	77,696	67,854	61,973	61,973
			Productivity vs labour cost differentials			
productivity (λ) 18-29	0.63***	0.50***	1.01	1.17***	0.62***	1.03
Labour cost (Φ) 18-29	0.55***	0.38***	0.88***	0.92***	0.51***	0.88***
Gap (λ-Φ) 18-29	**0.08**	**0.11**	**0.14**	**0.25**	**0.11**	**0.15**
productivity (λ) 50-65	0.71***	0.56***	0.57***	0.63***	0.66***	0.55***
Labour cost (Φ) 50-65	0.81***	0.62***	0.99	1.01	0.80***	1.01
Gap (λ-Φ) 50-65	**-0.10**	**-0.05**	**-0.41**	**-0.38**	**-0.14**	**-0.47**

*p < 0.05, **p < 0.01, *** p < 0.001 ; $ Levinsohn and Petrin's

The labour cost estimations are reported in the central part of Table 3. For young workers the magnitude of the coefficients is smaller that those observed for the production equation, implying a positive productivity vs. labour cost gap (lower par of Table 3). In other words, young adult workers are paid *below* their productivity that we estimate to be in the range of 15 percentage points with model [6]. The situation is completely different for the older workers. The focus on within firm variances (models [3], [5] and [6] suggest that, unlike productivity, labour costs do not decline with age. Model [6] in particular points at 1 percentage point (non significant) increment of the labour cost. When related to the 45 percentage points productivity differentials mentioned above, this leads to a 47 percentage point productivity- vs. labour cost gap. Simply said, older workers in Belgium seem to be paid well above their productivity.

We have undertaken three further steps in our analysis: *i)* a test of whether, for each age group (bar the reference group), labour cost gaps are significantly different than productivity gaps, and *ii)* whether we reach substantially different results, with regards to those coming from the pooled sample results displayed so far, when we partition the sample across three sectors largely defined; *iii)* whether our results change much when we partition the sample in terms of firm size. For each of these three extensions, the focus will be on the results of the model with intermediate inputs *à-la*-Levinsohn-Petrin with firm fixed effects, for the older workers aged 50 and more.

So firstly, employing only preferred model [6], we test the hypothesis of equality of labour cost and productivity gaps for older workers (and younger ones also). We now make a final a justification for our preferred joint estimations of production and labour cost equations (Table 4). We recall that the focus of our analysis is the implementation of the gender wage discrimination test, which involves testing the equality of estimates of productivity (λ) and labour costs (Φ) differentials, obtained from estimations of the production function and the labour costs equation. Options here are essentially twofold.

5.1. Testing the significance of the productivity- vs. labour cost gap

We first embark in a series of joint estimation of the two equations. We recall that the arguments for joint estimation — what corresponds to *system FGLS* estimation in Wooldridge (2002)'s terminology[16] — are essentially two. One is that joint estimation provides a direct way to implement a Wald test of the equality of a non-linear combination of coefficients across equations. If there are unobservables in both equations that bias the estimates of λ and Φ, as long as they affect the two equations equally, which should occur under the null, their effect on the Wald equality test is neutralized. Another is that joint estimation makes use of cross-equation correlations in the errors, thereby increasing the efficiency (i.e. generate smaller standard errors) of the coefficient estimates.

Alternatively, one can perform so-called *system OLS* estimation. This consists of estimating the two equations separately, but to use those estimates to construct a cluster-adjusted[17] robust sandwich variance-covariance matrix, which can be used to perform a Wald test of equality of the two coefficients.[18]

The choice between system OLS and system FGLS can be viewed as a trade-off between robustness and efficiency. On the one hand, system OLS is more robust (i.e. generate coefficient that are less likely to be biased). It is consistent under the milder assumption of contemporaneous exogeneity, while the consistency of system FGLS is conditional on strict exogeneity of the regressors. Moreover, the Wald test computed from system OLS estimation can be made robust to arbitrary heteroskedasticity and serial correlation in the error term, while system FGLS does so under the assumption of system homoskedasticity. In principle, we could construct a cluster-adjusted robust sandwich variance-covariance matrix from the FGLS estimates. However, the Stata command that implements FGLS, *SUREG*, does not permit its computation from standard commands. On the other hand, system FGLS takes advantage of increased efficiency from cross-equation correlations in the errors.

We decided to implement *system OLS* in addition to the more common *system FGLS* (used for instance by HN (1999) and HNT (1999) for four reasons. First, because we are using panel data, so that the error term should normally be serially correlated for the same firm, the ability to control for arbitrary heteroskedasticity and serial correlation across time is a strong advantage. Second, the advantage of controlling for potential unobservables is substantially smaller in our case: while HN (1999) and HNT (1999) used cross section data and implemented standard OLS and IV estimators, instead, we use panel data and implement estimation procedures specifically designed to deal with potential biases due to unobservables. Third, the importance of cross-equation correlation in the errors needs to be assessed vis-à-vis the efficiency of the estimates obtained from independent estimations. In our case, the precision of coefficient estimates using system OLS is fairly satisfactory. Fourth and last, the assumption of strict exogeneity is very strong for production function estimation. That said, the efficiency gains associated with system FGLS seem to be high for our data set: the

[16] See chapter 7 of Wooldridge (2002) for a derivation of the properties of system OLS and system FGLS estimators.

[17] Here, a cluster is a firm.

[18] See Weesie (2000) for a description of the Stata procedure that constructs a cluster-adjusted robust sandwich estimator from two or more sets of independent estimates.

cross-equation correlation of the residuals is high both for the raw and the transformed data, respectively 69%, for total-firm variation, and 56% for within-firm variation, and 60%, for total-firm variation, and 40% for within-firm variation.

The results of joint estimations largely accord with those visible in Table 3. System FGLS points at a positive gap for young workers of 8 percentage points (*i.e.* young adults are paid below their productivity), whereas it confirms the existence of a sizeable (23 percentage points) negative gap for old workers which are clearly paid above their productivity. Results for system OLS are similar, although they suggest gaps of larger magnitude : + 12 and -42 percentage points for young and old workers respectively.

More importantly, we exploit here one of the features of Stata, namely the possibility to test the equality of estimated coefficients across two equations. We use in particular the possibility for these tests to be non-linear.[19] The rational for non-linear testing derives from the fact the estimated coefficients for the production function (equ. 6) correspond to $\alpha(\mu_k/\mu_0 - 1)$ and that we are primarily interested in the labour productivity component $(\mu_k/\mu_0 - 1)$. Hence, the cross-equations equality test has to be carried out on $\alpha(\mu_k/\mu_0 - 1)$ divided by the estimated total labour coefficient α.

Estimated χ^2 (and corresponding *p-values*) are reported in the far-right column of Table 4 and they suggest that the equality assumption ($\lambda = \Phi$) can be rejected confidently for both system FGLS and system OLS, meaning in particular that the older workers productivity gap is very unlikely to be compensated by an equivalent labour-cost gap.

Table 4: Joint estimates of productivity and labour costs differentials. Within (firm fixed effects) + intermediate inputs (Levinsohn-Petrin). Cluster-robust estimation of standard-errors.

	Production diff. (λ): ref=30-49	**Labour-cost diff (Φ): ref=30-49**	**Gap (λ-Φ)**	**Wald Hyp. Test (λ=Φ)** χ^2	**Prob>χ^2**
System FGLS					
18-29	0.93	0.86	**0.08**	19.71	*0.0000*
50-65	0.78	1.01	**-0.23**	81.73	*0.0000*
System OLS					
18-<30	0.98	0.86	**0.12**	9.76	*0.0018*
50-<65	0.59	1.01	**-0.42**	46.43	*0.0000*

[19] Non-linear testing (NLTEST) is a postestimation option of the STATA estimation procedure used here.

5.2. Sectors

Secondly, we have re-estimated both the production function and the labour-cost one, employing only our preferred-model again, but now partitioning the sample across three sectors, largely defined, namely: manufacturing, services, and trade.[20]

The results from simultaneous estimation of the equations are reported in Table 5. For older workers in particular, they do not differ in qualitative terms from those obtained using the pooled sample. Productivity- vs. labour cost gaps in Industry range from -15 (system FGLS) to -35 (system OLS) percentage points.

There is a point worth stressing however concerning the productivity of older workers. The service sector does not seem to translate into a lower gap, on the contrary. For that sector our estimates suggest a gap ranging from -28 to -44 percentage points (lower part of Table 5). This result is at odds with the prediction that ageing would be less of a problem for productivity in a de-industrialized world where the share of the service industry is large and still expanding.

[20] A detailed definition of these three sectors in terms of NACE 2 categories is to be found in Annex 2.

Table 5: Joint estimates of productivity and labour costs differentials. Within (firm fixed effects) + intermediate inputs (Levinsohn-Petrin). Cluster-robust estimation of standard-errors. Partition by sector.

	Production diff. (λ): ref=30-<50	**Labour-cost diff (Φ): ref=30->50**	**Gap (λ-Φ)**	**Wald Hyp. Test (λ=Φ)** χ^2	**Prob>χ^2**
		Industry			
System FGLS					
18-29	1.05	1.04	**0.01**	35.20	*0.0000*
50-65	0.88	1.03	**-0.15**	17.91	*0.0000*
System OLS					
18-29	1.15	0.90	**0.24**	17.19	*0.0000*
50-65	0.68	1.03	**-0.35**	14.01	*0.0002*
		Commerce			
System FGLS					
18-29	0.96	0.87	**0.09**	5.22	*0.0224*
50-65	0.70	0.99	**-0.29**	24.38	*0.0000*
System OLS					
18-29	1.00	0.87	**0.12**	2.23	*0.1354*
50-65	0.53	0.99	**-0.46**	12.15	*0.0005*
		Service			
System FGLS					
18-29	0.77	0.78	**-0.01**	0.08	*0.7798*
50-65	0.74	1.02	**-0.28**	30.67	*0.0000*
System OLS					
18-29	0.78	0.78	**0.00**	0.00	*0.9476*
50-65	0.58	1.02	**-0.44**	16.61	*0.0000*

5.3. Firm size

Thirdly, we have re-estimated our equations simultaneously using model [6], but partitioning the sample according to firm size[21] (<50, 50-99 , 100+). Results are reported in Table 6.

Once again, for older workers the results follow closely the pattern we have described so far; with large productivity- vs. labour costs gaps ranging from -16 to -55 percentage points. It is noteworthy that the productivity gap characterising older workers is less important inside larger firms that employ more than 100 workers. Our system OLS estimates suggest a -32 percentage points gap for these firms, whereas is it of -55 percentage points for medium-size ones and -40 percentage points in the case of small firms (Table 6).

[21] Defined as the number of employees.

Table 6: Joint estimates of productivity and labour costs differentials. Within (firm fixed effects) + intermediate inputs (Levinsohn-Petrin). Cluster-robust estimation of standard-errors. Partition by firm size.

	Production diff. (λ): ref=30-49	Labour-cost diff (Φ): ref=30-49	Gap (λ-Φ)	Wald Hyp. Test (λ=Φ) χ^2	Prob>χ^2
Small firms (<50)					
System FGLS					
18-29	0.90	0.91	**-0.01**	0.76	*0.3841*
50-65	0.76	1.01	**-0.24**	57.22	*0.0000*
System OLS					
18-29	0.91	0.88	**0.03**	0.57	*0.4490*
50-65	0.61	1.01	**-0.40**	34.03	*0.0000*
Medium-size firms (50-99)					
System FGLS					
18-29	1.07	0.84	**0.23**	28.79	*0.0000*
50-65	0.82	1.08	**-0.26**	16.75	*0.0000*
System OLS					
18-29	1.22	0.87	**0.34**	16.74	*0.0000*
50-65	0.53	1.08	**-0.55**	12.38	*0.0004*
Big firms (100 +)					
System FGLS					
18-29	0.99	0.76	**0.23**	25.06	*0.0000*
50-65	0.78	0.94	**-0.16**	5.41	*0.0201*
System OLS					
18-29	1.08	0.78	**0.30**	10.88	*0.0000*
50-65	0.62	0.94	**-0.32**	3.71	*0.0541*

6. Conclusions

Due to demographic changes, both the Belgian population and the workforce of firms active in the country are ageing. And such trend is likely to remain in the future. Ageing and policies aimed at maintaining older individuals in employment raise crucial issues. One of them is the effect on the productivity performance of firms, and, by extension, of the whole economy. Another one is simply whether employers are willing to employ older workers, given the relationship between their productivity and what they cost to employ.

In this paper, we try to properly identify and quantify the causal effect of ageing on firms' productivity, while also considering the parallel relationship between age and labour costs. We tap into a unique employer-employee panel data set to produce robust evidence on the causal effect of ageing on productivity and labour costs. Unobserved firm fixed-effects and endogeneity of workforce age pose serious estimation challenges, which we try to cope with.

Our results suggest that an increase of 10 percentage points in the share of older workers (50-65) in a firm depresses its added value by 2 to 4%, depending on the estimation method chosen, with an intermediate result of 3.2 % in our preferred model. The same results indicate large productivity- vs. labour cost gap[22] for older workers ranging for -22 to -42 percentage points. The underlying data show that this is because the lower productivity of older workers is not compensated by lower labour costs. A gap of this magnitude could negatively affect the labour demand for older workers.

Finally, in qualitative terms, the effects observed for the pooled sample are reproduced when we turn to a sector-by-sector analysis, or to one that separate firms according to their size. One important observation however is that the (now dominant) service sector does not seem to offer working conditions that mitigate the negative relationship between age and productivity, on the contrary. Another important result is that older workers in smaller firms display a larger productivity differential and their productivity is less aligned onto labour costs, which suggests that small firms are less inclined to employ/recruit them.

We finish by briefly mentioning some limits that should be held in mind when interpreting our results. First of all, we lack further information about the composition of workforce (education skills, previous training etc.). Secondly, only "average firm profiles" are calculated. Thirdly, the worker's sample might not be representative of the population and there is a risk of a *selection bias*, in particular due to early ejection from workforce of older workers due to their lower (and financially uncompensated) productivity. To the extent that this selection bias is an issue, we could view our estimated coefficients for older workers' productivity differentials as upper-bounds.[23] Fourthly, the current sample of workers might not be representative of all generations – in particular, of future cohorts.

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[22] Remember that the term "differential" designates the productivity (or labour cost) differences between the considered age group and the reference (*i.e.* prime-age workers); whereas the term "gap" refers to the difference between the productivity and the labour-cost differentials characterizing an age-group.

[23] In other words, they could be even more negative is all older individuals were still working and part of our sample.

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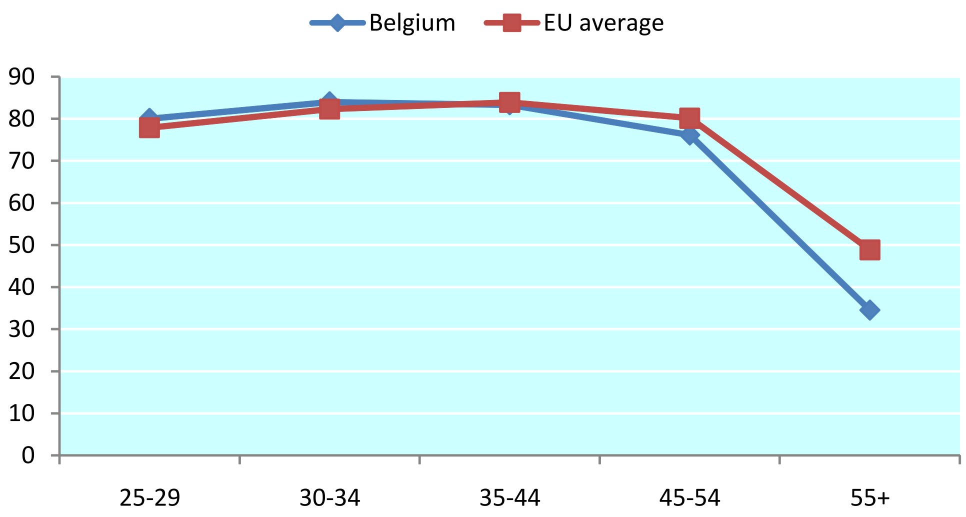
Annex 1 – Age and employment rate. Belgium vs. EU.. 2008



Source : EU Labour Force Survey

Annex 2: Sectors (Industry. Commerce and Service) and NACE2 codes/definitions

01="I_Culture et production animale. chasse et services annexes"
02="I_Sylviculture et exploitation forestière"
03="I_Pêche et aquaculture"
05="I_Extraction de houille et de lignite"
06="I_Extraction d'hydrocarbures"
07="I_Extraction de minerais métalliques"
08="I_Autres industries extractives"
09="I_Services de soutien aux industries extractives"
10="I_Industries alimentaires "
11="I_Fabrication de boissons"
12="I_Fabrication de produits à base de tabac"
13="I_Fabrication de textiles"
14="I_Industrie de l'habillement"
15="I_Industrie du cuir et de la chaussure"
16="I_Travail du bois et fabrication d'articles en bois et en liège. à l'exception des meubles; fabrication d'articles en vannerie et sparterie"
17="I_Industrie du papier et du carton"
18="I_Imprimerie et reproduction d'enregistrements"
19="I_Cokéfaction et raffinage"
20="I_Industrie chimique"
21="I_Industrie pharmaceutique"
22="I_Fabrication de produits en caoutchouc et en plastique"
23="I_Fabrication d'autres produits minéraux non métalliques"
24="I_Métallurgie"
25="I_Fabrication de produits métalliques. à l'exception des machines et des équipements"
26="I_Fabrication de produits informatiques. électroniques et optiques"
27="I_Fabrication d'équipements électriques"
28="I_Fabrication de machines et d'équipements n.c.a."
29="I_Construction et assemblage de véhicules automobiles. de remorques et de semi-remorques"
30="I_Fabrication d'autres matériels de transport"
31="I_Fabrication de meubles"
32="I_Autres industries manufacturières"
33="I_Réparation et installation de machines et d'équipements"
35="I_Production et distribution d'électricité. de gaz. de vapeur et d'air conditionné"
36="I_Captage. traitement et distribution d'eau"
37="I_Collecte et traitement des eaux usées"
38="I_Collecte. traitement et élimination des déchets; récupération"
39="I_Dépollution et autres services de gestion des déchets"
41="I_Construction de bâtiments; promotion immobilière"
42="I_Génie civil"
43="I_Travaux de construction spécialisés"

45="C_Commerce de gros et de détail et réparation véhicules automobiles et de motocycles"
46="C_Commerce de gros. à l'exception des véhicules automobiles et des motocycles"
47="C_Commerce de détail. à l'exception des véhicules automobiles et des motocycles"

49="S_Transports terrestres et transport par conduites"
50="S_Transports par eau"
51="S_Transports aériens"
52="S_Entreposage et services auxiliaires des transports"
53="S_Activités de poste et de courrier"
55="S_Hébergement"
56="S_Restauration"
58="S_Édition"
59="S_Production de films cinématographiques. de vidéo et de programmes de télévision; enregistrement sonore et édition musicale"
60="S_Programmation et diffusion de programmes de radio et de télévision"
61="S_Télécommunications"
62="S_Programmation. conseil et autres activités informatiques"
63="S_Services d'information"
64="S_Activités des services financiers. hors assurance et caisses de retraite"
65="S_Assurance. réassurance et caisses de retraite. à l'exclusion des assurances sociales obligatoires"
66="S_Activités auxiliaires de services financiers et d'assurance"
68="S_Activités immobilières"
69="S_Activités juridiques et comptables"
70="S_Activités des sièges sociaux; conseil de gestion"
71="S_Activités d'architecture et d'ingénierie; activités de contrôle et analyses techniques"
72="S_Recherche-développement scientifique"
73="S_Publicité et études de marché"
74="S_Autres activités spécialisées. scientifiques et techniques"
75="S_Activités vétérinaires"
77="S_Activités de location et location-bail"
78="S_Activités liées à l'emploi"
79="S_Activités des agences de voyage. voyagistes. services de réservation et activités connexes"
80="S_Enquêtes et sécurité"
81="S_Services relatifs aux bâtiments; aménagement paysager"
82="S_Services administratifs de bureau et autres activités de soutien aux entreprises"
84="S_Administration publique et défense; sécurité sociale obligatoire"
85="S_Enseignement"
86="S_Activités pour la santé humaine"
87="S_Activités médico-sociales et sociales avec hébergement"
88="S_Action sociale sans hébergement"
90="S_Activités créatives. artistiques et de spectacle"
91="S_Bibliothèques. archives. musées et autres activités culturelles"
92="S_Organisation de jeux de hasard et d'argent"
93="S_Activités sportives. récréatives et de loisirs"
94="S_Activités des organisations associatives"
95="S_Réparation d'ordinateurs et de biens personnels et domestiques"
96="S_Autres services personnels"
97="S_Activités des ménages en tant qu'employeurs de personnel domestique"
98="S_Activités indifférenciées des ménages en tant que producteurs de biens et services pour usage propre"
99="S_Activités des organisations et organismes extraterritoriaux"