AGEPROD – Ageing workforces and the productivity of Belgian firms

Final Report

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- June 09 Ageing Workforce, Productivity and Labour costs of Belgian Firms, BELGIAN DAY FOR LABOUR ECONOMISTS, A PAI-IUAP Workshop, Brussels, ULB, Tuesday June 16

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- Oct 11, Are firms willing to employ more older men and women?, Workshop “Productivity & Ageing” , St. Gallen, Switzerland, 4-5 October

- April 2011: Microeconomics applied to firm-level micro data. The case of ageing workforces, Centro de Estudos sobre Desigualdade e Desenvolvimento – CEDE, Programa de Pós-Graduação em Economia – PPGEn Universidade Federal Fluminense – UF, Brazil

-Nov 11, Industrial restructuring and the challenge of an ageing workforce, 19th Congrès de Economistes Belges de Langue Française, Nov. 17th, Namur.

- Oct 11, Are firms willing to employ older men and women?, CREPP seminar, Université de Liège, October 28

- April 11, Boosting the employment rate of older men and women. An empirical assessment using Belgian firm-level data on productivity and labour costs, UFF, Universidade Federal Fluminense, seminar of the Economics Department, April 7

- June 10, Ageing Workforce, Productivity and Labour costs of Belgian Firms, ZEW seminar, Mannheim, June 15, 2010

1. The theoretical background

1.1. Production functions

Economists began conceiving and measuring the relationship between output to inputs in the early 1800's. A large literature on production functions has followed. There is also that economic theory yields testable predictions. Chambers (1997) provides a brief history of production function estimation. Recent years have also seen a dramatic increase in research on productivity that use longitudinal micro-level (i.e., mainly firm-level) data sets, which follow large number of firms over time. The popularity of this emerging research area can be ascribed, to a large extent, to availability of micro-level data similar to those we have exploited throughout this research. Displeasure with the outcome of exercises estimating more aggregate (ie. macroeconomic) production functions also plays a role. For a recent review of this micro and longitudinal stream of work and its determiants see Bartelsman & Doms (2000).

1.2. Theories and predictions regarding ageing workforces and productivity

Regarding production function estimation, with a particular focus on the age of workers, the literature is less abundant. From purely theoretical point of view, at least two different hypotheses are relevant concerning ageing workforces. The first one is based on productivity measurement on the individual level. Here, many studies reviewed by Skirbekk (2004, 2008) 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-aged 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, 2008). Between 1920 and 1950 this plant experienced strong productivity gains of 2.5 percent, 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. 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.

1.3. The need for empirical studies using micro data

The existence of two competing, but not exclusive, hypotheses on the effect of workforce ageing on productivity highlights the need for more studies. Economic theory provides no clear-cut conclusion as to where ageing should lead us in terms of productivity and employability. The existence of two opposite hypotheses on the effect of workforce ageing supports the need for more thorough empirical studies using micro data.

Many existing studies look at the consequence of *ageing population* in terms of higher dependency rates and rising social security costs (Gruber and Wise, 2004, 2008). Another strain of the literature on ageing examines the retirement behaviour of older individuals (Mitchell & Fields, 1984) and its determinants; for example how the generosity of early-pension and other welfare regimes entices people to withdraw from the labour force (Saint Paul, 2009).

In the Belgian case, there is strong evidence that easy access and high replacement rates (Blondäl & Scarpetta, 1999; Jousten et al., 2010) have played a significant role in the drop in the employment rate among older individuals since the mid 1970s. Other papers with a supply-side focus examine how bad health status precipitates retirement (Kalwij & Vermeulen, 2008) or the importance of non-economic factors (i.e. family considerations) in the decision of older women to retire (Pozzebon & Mitchell, 1989 ; Weaver, 1994)

However, the consequences of *an ageing workforce*, from the point of view of firms, forming the *demand side* of the labour market, have, so far, largely been overlooked. EU-SILC data show a negative relationship between older individuals' employment rate and how much they cost to employ, suggesting the labour cost can be a barrier to old employment. There is also abundant evidence suggesting that firms "shed" older workers. Dorn and Sousa-Poza (2010)[1] show for instance that *involuntary* early retirement is the rule rather than the exception in several continental European countries. In Germany, Portugal, and Hungary, more than half of all early retirements are, reportedly, not by choice. These elements give to understand that one cannot take for granted that older individuals who are willing to work do get employed.

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[1] Their survey data allows them to identify individuals who i) were early retirees and who ii) assessed their own status as being involuntary using the item "I retired early - by choice" or "I retired early - not by choice" for the questionnaire.

1.4. Assessing the productivity handicap

Some economists have started examining the relationship between age and productivity at the level where this matters most: firms. They have estimated production functions expanded by the specification of a labour-quality index à la Hellerstein & Neumark (1995) (HN henceforth).[2] According to Malmberg et al. (2008), an accumulation of high shares of older adults in Swedish manufacturing plants does not negatively impact plant-level productivity. By contrast, Grund & Westergård-Nielsen (2008) find that both mean age and age dispersion in Danish firms are inversely U-shaped in relation to firms' productivity. But these authors use cross-sectional approaches. More recent analysis of German data, by Göbel & Zwick (2009), using panel to control for the endogeneity of age structure, produces little evidence of an age-related productivity decline. By contrast, Lallemand & Ryck (2009), who use Belgian firm-level panel data[3], conclude that older workers (>49) are significantly less productive than prime-age workers, particularly in ICT firms.

Using panel data and coping with the endogeneity of the age structure of the workforce has become key in this literature (more on this in Section 3).

1.5. Assessing the productivity and the employability handicap of older workers

Another key distinction in terms of methodology is between studies which only examine productivity and those that simultaneously consider pay or labour costs. Economists with a focus on labour demand – and we would include ourselves into that group - assess **employability** by examining the ratio of (or the gap between) individuals' productivity to (and) their cost to employers.

What is essential is that evidence of a negative impact of older workers on that ratio can be interpreted as harmful to their employability, either because firms facing downturns have a strong incentive to concentrate layoffs on the less profitable segments of their workforce, or because firms refuse, when recruiting an unemployed old person, to match the wage levels paid by the previous employer. On the contrary, the absence of such evidence conveys the message that firms face no disincentive to employing a rising number of old individuals who are present on the labour market. Also, *ceteris paribus*, job transitions for older workers should not be more problematic than for young or prime-age workers.

One of the first papers that combined the productivity and labour cost dimensions was that of Hellerstein et al. (1999). In a recent replication of that seminal analysis using data covering the US manufacturing sector, the authors (Hellerstein & Neumark, 2007) estimate relative productivity of

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[2] The key idea of HN is to estimate a production function (or a labour-cost function), with heterogeneous labour input, where different types (e.g. men/women, young/old) diverge in terms of marginal product.

[3] The Structure of Earnings Survey and the Structure of Business Survey conducted by Statistics Belgium.

workers aged 55+ is only 0.87 (ref. group <35 =1), whereas relative wages is 1.12. Most papers based on cross-sectional data conclude that firm productivity has an inverted U-shaped relationship with age, while labour costs are either rising with age or flat beyond a certain threshold with a negative impact on the productivity-labour cost ratio after 55 (Skirbekk, 2004, 2008).

Turning to authors using (*a priori* more trustworthy) panel data, the evidence is mixed. For Belgium, Cataldi, Kampelmann & Rycx (2011)[4] find evidence of a negative effect of older workers on the productivity-labour cost gap. Aubert & Crépon (2003, 2007), observe that the productivity of French workers rises with age until around the age of 40, before stabilizing, a path which is very similar to that of wages. But a negative effect on the productivity-labour cost gap is observed with rising shares of workers aged 55+. On the contrary, the absence of such evidence seems to hold for manufacturing in the Netherlands, as explained by van Ours & Stoeldraijer (2011), and in Portugal for the whole economy, as shown by Cardoso, Guimaraes & Varejao (2011).

2. The overall objectives

One of the challenges faced by ageing Western societies is that of maintaining a workforce large enough to supply the goods and services needed by the entire population. In the coming decades, these societies will experience a fall in the share of the working-age population due to one of the most salient demographic trends of recent decades. In many European countries, including Belgium, the number of people aged 60-64, many of whom are about to retire, already exceeds the number of people aged 15-19, who will soon enter the labour market. Ageing on the anticipated scale will put welfare systems under unprecedented pressure. It will also affect economic growth. According to the OECD, on the basis of unchanged participation patterns and productivity growth, the growth of GDP per capita in the OECD area would decline to around 1.7 % per year over the next three decades, as compared with about 2.4% per year between 1970 and 2000. These negative consequences of ageing could possibly be offset by increased immigration, higher fertility or faster productivity growth (although the positive economic effects of higher fertility would take decades to show).

While these developments would help to counterbalance the negative effects of ageing populations, most labour economists, including us, think they need to go hand-in-hand with attempts to better mobilize available labour. And one of the most significant sources of additional labour supply is older people aged 50+ who are currently inactive. In the coming years, in order to compensate the fall in the share of the working-age population and to alleviate the rising cost of

4 Extending the analysis *of Structure of Earnings Survey* and the *Structure of Business Survey* to examine age-wage-productivity nexus.

publicly funded old-age pension schemes, public authorities will keep trying to expand the (currently sometimes very low) employment rate, particularly among individuals aged 55-64.[5]

2.1. Assessing demand-side barrier to employment for older individuals

The key policy question we raise in this research is weather firms and labour market will be able/willing to absorb more of the older workers. As explained above, the existing economic literature primarily covers the supply side of the old-age labour market, whereas the demand-side barriers to old employment have been underscored. The main objective of this research was to fill that void. Our aim is to investigate the causes of the weakness of the old-age labour markets in the European context, in particular the relative unwillingness of firms to re/employ older individuals.

And this implies analysing firm-level panel empirical evidence on the age-productivity-labour cost nexus. More precisedly, it implies analysing the sensitivity of the productivity-labour cost ratio to the workforce structure of firms (see Section 3 for the algebra). We do using Belgian data that have been aggregated at the firm level (see Section 4). Our key assumption is that statistically significant evidence of a negative impact of larger shares or older workers on that ratio is conducive to weak labour demand of these older workers, and detrimental to their overall employability.

2.2. More specific issues

Another important issue examined in this study is that of the existence of a gender employability gap in that economy. Does ageing affect more significantly the productivity and employability of older women. We know that expanding the range of employment opportunities available to older workers will become increasingly important in most EU countries as demographics (ageing populations[6] and public policy will combine to increase the share of older individuals in the labour force. It is less known, that across the EU, with the exception of some Nordic countries, older women are clearly less present in employment than older men.[7] But this should change. Two elements combine indeed in support of this prediction. The first one is the lagged effect[8] of the rising overall female participation in the labour force (Peracchi & Welch, 1994).[9] The second factor is labour policy. Policymakers will concentrate on promoting older women's employment because -

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[5] In many EU 15 countries (Belgium, France, Luxemburg, Austria, Spain, Italy and Greece), in 2010, their employment rate was still well below the 50 percent threshold (Eurostat: http://epp.eurostat.ec.europa.eu. 2010)

[6] In Belgium, between 1999 and 2009 the share of individuals aged 50-65 in the total population aged 15-65 rose from 25.2% to 28.8% (http://statbel.fgov.be).

[7] See the European Labour Force Survey (EU-LFS) 2010 (Eurostat, 2010).

[8] Also referred to as a cohort effect.

[9] Driven, *inter alia*, by a higher educational attainment of women and a lower fertility of the younger generations.

conditional on a certain young- or prime-age participation record - women still leave the labour market earlier than men[10] (Fitzenberger *et al.*, 2004).

The next issue is that of the distinction between blue- and white-collar workers, known to recoup important differences in terms of labour laws and wage settlement mechanisms, in particular seniority rules. To our knowledge, collective agreements applying to blue-collar general define wage level mainly to the category to which the worker, that refers to the nature of his/her task and the amount of training necessary for proper execution. There is no reference to age. By contrast, among white collars; age and seniority play an important and explicit role (BNB, 2010). The point is that the distinction blue- vs. while-collar may hold institutional asymmetry in the degree of alignment of labor costs on productivity. In case of age-related productivity decline, we could expect less of wedge between productivity and pay for blue-collar workers.

Further, we consider the potential role of job training, in particular the question of whether firms that consistently spend money to train their workers have a particular configuration (more favourable) of the productivity by age profile. Some observers would argue that increased training effort could compensate the problem of age-related declining productivity. On the other hand, international evidence rather supports the view that older employees get relatively less training (or less effective training) than younger employees (D´Addio, Keese & Whitehouse, 2010). *Ceteris paribus*, this should rather increase older workers' employability handicap. Our empirical strategy to examine this question is to use information about company-based (and -financed) training gathered in the Social Report (available in Bel-first). Our dataset does not unfortunately inform about how training is distributed across age groups inside firms. We are only able to isolate those of the firms that constantly – ie. over most of the years forming our panel – report positive spending on training.

In a final development, we focus on young workers (18-29 years) in comparison with older workers (50-64 years). This exercise brings up the question of the existence of implicit contracts, that decouple productivity and labour costs over the overall duration of employment contracts.

3. The methodology used

3.1. Overall presentation

In this report, productivity is examined at the level where it matters most: that of firms. A study of the relationship between age, productivity and pay requires data at the level of the firm, because productivity is in essence a firm-level phenomenon. Individual workers' productivity is hardly ever

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[10] In other words, life-cycle participation/employment profiles vary by gender. And the female profiles have not changed markedly across cohorts.

observed. By contrast, many datasets contain good-quality information about what firms are able to produce (e.g. firm sales, value added). Similarly, the alignment of productivity and pay at the individual level is hard to assess. By contrast, it can be evaluated with firm-level aggregates and used to assess the attractiveness of older workers to employers. Workers' characteristics (e.g. their age, gender, labour contract type, skill category) can be aggregated at the firm level and introduced into firm-level equations in order to explore how they influence productivity and pay.

Works exposed here are based on employee-employer matched firm-level panel data sets. We estimate production (and pay) functions with heterogeneous labour input à la Hellerstein & Neumark (1995,1999), where different types (e.g. young/prime-age/old, male/female, white- blue-collar workers) diverge in terms of productivity and pay.

This said, establishing how age itself affects labour productivity (and to a lesser extent pay) remains a challenge. First, productivity is sector- or firm-specific. Firms' productivity may be driven by the degree of maturity of the market they are predominantly active in, or the vintage of capital in use, and these might be correlated with the age structure of the firm's workforce, biasing ordinary least square (OLS) results Second, (short-term) productivity changes can also be spuriously correlated with the age structure of firms. An anticipated downturn could translate into a recruitment freeze, or, alternatively, into a multiplication of "involuntary" (early) retirements.[11] A recruitment freeze affects youth predominantly, and translates into rising share of older workers during negative spells, creating a negative correlation between older workers' share and productivity, thereby leading to underestimated estimates of their productivity (when resorting to Ordinary Least Squares(OLS)). By contrast, if firms primarily promote early retirements when confronted with adverse demand shocks, we would expect the correlation to be positive, leading to an overestimation of older workers' productivity with OLS.

Most works presented here assume that the identification of the causal link between productivity/pay and the age composition of the workforce requires dealing with *i)* time-invariant, firm-specific characteristics that are unobservable, but that simultaneously drive the firm's average productivity and age**,** and *ii)* the short-term simultaneity or endogeneity bias (i.e. the aforementioned spurious correlation between productivity shocks[12] and share of older workers). The panel structure of their data permits the use of fixed-effects methods (mean-centring or first differences) to cope with non-randomly distributed time-invariant unobservables. To account for the presence of an endogeneity bias, we have resorted to IV-GMM methods. This is a strategy regularly used in the production function literature with labour heterogeneity (Aubert & Crépon,

[11] Dorn & Sousa-Poza (2010) report that, in many Continental European countries, the proportion of involuntary retirement is significantly higher in years with increasing unemployment rates. One explanation for this finding is that firms promote early retirement when they are confronted with adverse demand shocks in an economic recession.

[12] Anticipated by firms, but unobserved by the econometrician.

2003, 2007). The key idea is to instrument potentially endogenous first-differenced age shares by lagged values of these shares.

An alternative to IV-GMM, used by Dostie (2011), is to adopt the more structural approach initiated by Olley & Pakes (1996) and further developed by Levinsohn & Petrin (2003). The essence of the Levinsohn & Petrin strategy is to use some function of a firm's demand for intermediate inputs (raw materials, electricity,...) in order to infer a value for the short-term productivity shocks causing the endogeneity bias. Firms can swiftly (and also at a relatively low cost) respond to productivity developments by adapting the volume of the intermediate inputs they buy on the market. Whenever information on intermediate inputs is available in a data set, these can be used to proxy short-term productivity deviations.

3.2. Algebraic presentation

In order to estimate age-productivity profiles, following most authors in this area, we consider a Cobb-Douglas production function (Hellerstein *et al.*, 1999; Aubert & Crépon, 2003, 2007; Dostie, 2011; van Ours & Stoeldraijer, 2011, Vandenberghe, 2011b,c):

$$ln\,(Y_{it}/L_{it}) = lnA + \alpha\, ln\, QL_{it} + ß\, lnK_{it} - lnL_{it} \qquad (1)$$

where: Y_{it}/L_{it} is the average value added per worker (average productivity hereafter) in firm *i* at time *t*, QL_{it} is an aggregation of different types of workers, and K_{it} is the stock of capital.

The variable that reflects the heterogeneity of the workforce is *the quality of labour index* QL_{it}. Let L_{ikt} be the number of workers of type *k* (*e.g.* young, prime-age, old/men, women) in firm *i* at time *t*, and μ_{ik} be their productivity. We assume that workers of various types are perfectly substitutable[13] with different marginal products. As each type of worker *k* is assumed to be an input in quality of labour aggregate, the latter can be specified as:

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

where: $L_{it} \equiv \sum_k L_{ikt}$ is the total number of workers in the firm, μ_{i0} the marginal productivity of the reference category of workers (*e.g.* prime-age men) and μ_{ik} that of the other types of workers.

If we further assume that a worker has the same marginal product across firms, we can drop subscript *i* from the marginal productivity coefficients. After taking logarithms and doing some rearrangements equation (2) becomes:

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[13] We will see, in Section 2, how this assumption can be relaxed, when we present the econometric models used to identify the key coefficients of this production function.

$$ln\ QL_{it} = ln\ \mu_0 + lnL_{it} + ln\ (1+ \textstyle\sum_{k>0} (\lambda_k\ - 1)\ P_{ikt}) \qquad (3)$$

where $\lambda_k \equiv \mu_k/\mu_0$ is the relative productivity of type k worker and $P_{ikt} \equiv L_{ikt}/L_{it}$ the proportion/share of type k workers over the total number of workers in firm i .

Using the approximation that $ln(1+x) \approx x$, (3) can be simplified as:

$$ln\ QL_{it} = ln\ \mu_0 + ln\ L_{it} + \textstyle\sum_{k>0} (\lambda_k\ - 1)\ P_{ikt} \qquad (4)$$

And the production function becomes:

$$ln(Y_{it}\ /L_{it}) = lnA + \alpha\ [ln\mu_0 + ln\ L_{it} + \textstyle\sum_{k>0} (\lambda_k -1)\ P_{ikt}] + ß\ lnK_{it} - lnL_{ik} \qquad (5)$$

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

$$ln\ (Y_{it}\ /L_{it}) = B + (\alpha-1)l_{it} + \eta_1\ P_{i1t} + \ldots\ \eta_N\ P_{iNt} + ß\ k_{it} \qquad (6)$$

where:

$B=lnA+\alpha\ ln\ \mu_0$

$\lambda_k=\mu_k/\mu_0 \qquad k=1\ldots N$

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

….

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

$l_{it}=lnL_{it}$

$k_{it}=lnK_{it}$

Note first that (6), being loglinear in P, has coefficients that can be directly interpreted as the percentage change in the firm's average labour productivity of a 1 unit (here 100 percentage points) 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 k worker's relative marginal productivity, (*i.e.* λ_k), coefficients η_k have to be divided by α, and 1 needs to be added to the result.[14]

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[14] Does all this matter in practice? Our experience with firm-level data suggests values for α ranging from 0.6 to 0.8 (these values are in line with what most authors estimates for the share of labour in firms' output/added value). This means that λ_k are larger (in absolute value) than η_k.. If anything, estimates reported in the first column of Tables 3 and 4 underestimate the true marginal productivity difference vis-à-vis prime-age workers.

A similar approach can be applied to a firm's average labour cost. If we assume that firms operating in the same labour market pay the same wages to the same category of workers, we can drop subscript *i* from the remuneration coefficient π.[15] Let π_k stand for the remuneration of type *k* workers (*k=0* being reference type). Then the average labour cost per worker becomes:

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

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

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

where the Greek letter $\Phi_k \equiv \pi_k / \pi_0$ denotes the relative remuneration of type *k* workers (*k>0*) with respect to the (*k=0*) reference group, and $P_{ikt} = L_{ikt} / L_{it}$ is again the proportion/share of type *k* workers over the total number of workers in firm *i* .

The logarithm of the average labour cost finally becomes:

$$ln\ (W_{it} / L_{it}) = B^w + \eta^w_1 P_{i1t} + \dots \eta^w_N P_{iNt} \qquad (9)$$

where:

$B^w = ln\ \pi_0$

$\eta^w_1 = (\Phi_1 - 1)$

….

$\eta^w_N = (\Phi_N - 1)$

Like in the average productivity equation (6) coefficients η^w_k capture the sensitivity to changes of the age/gender structure (P_{ikt}).

The key hypothesis test of this paper can now be easily formulated. Assuming spot labour markets and cost-minimizing firms, the null hypothesis of no impact on the productivity-labour cost gap for type *k* worker implies $\eta_k = \eta^w_k$. Any negative (or positive) difference between these two coefficients can be interpreted as a quantitative measure of the disincentive (incentive) to employ the category of workers considered. This is a test that can be easily implemented, if we adopt strictly equivalent econometric specifications for the average productivity and average labour cost; in particular if we introduce firm size (*l*) and capital stock (*k*) in the labour cost equation (9). Considering three age groups (1=[20-29], 2=[30-49]; 3=[50-64[) and with prime-age (30-49) workers forming the reference group, we get:

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[15] We will see, how, in practice via the inclusion of dummies, this assumption can be relaxed to account for sector/industry wage effects, that must be important given Belgium's tradition of binding sector-level wage bargaining.

$$ln(Y_{it}/L_{it})=B+(\alpha-1)l_{it}+\eta_1 P_{it}^{18\text{-}29}+\eta_3 P_{it}^{50\text{-}64}+ß\, k_{it}+\gamma F_{it}+\varepsilon_{it} \quad (10)$$

$$ln\,(W_{it}/L_{it})=B^{w}+(\alpha^{W}-1)l_{it}+\eta_1^{W} P_{it}^{18\text{-}29}+\eta^{W}_3 P_{it}^{50\text{-}64}+ß\, k_{it}+\gamma^{W} F_{it}+\varepsilon^{w}_{it} \quad (11)$$

What is more, if we take the *difference* between the logarithms of average productivity (10) and labour costs[16] (11) we get a direct expression of the productivity-labour cost gap[17] as a linear function of its workforce determinants.

$$Gap_{it}\equiv ln(Y_{it}/L_{it})-ln(W_{it}/L_{it})=B^{G}+(\alpha^{G}-1)l_{it}+\eta^{G}_1 P_{it}^{18\text{-}29}+\eta^{G}_3 P_{it}^{50\_64}+ß^{G}\, k_{it}+\gamma^{G} F_{it}+\varepsilon^{G}_{it} \quad (12)$$

where: $B^{G}=B-B^{w}$; $\alpha^{G}=\alpha-\alpha^{W}$, $\eta^{G}_1=\eta_1-\eta^{w}_1$; $\eta^{G}_3=\eta_3-\eta^{w}_3$; $\gamma^{G}=\gamma-\gamma^{w}$ and $\varepsilon^{G}_{it}=\varepsilon_{it}-\varepsilon^{w}_{it}$.

It is immediate to see that coefficients η^{G} of equation (12) provide a direct estimate of how the productivity-labour cost gap is affected by changes in terms of percentages/shares of employed workers.

Note also the inclusion in (12) of the vector of controls F_{it}. In all the estimations presented hereafter it contains region[18], year *X* sector[19] dummies. This 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 or trends, labour quality and intensity of efficiency wages differentials across sectors and other sources of systematic productivity differentials (Hellerstein et al., 1999). More importantly, since the dataset we use does not contain sector price deflators, the introduction of these dummies can control for asymmetric year-to-year variation in the price of firms' outputs at the sector level. An extension along the same dimensions is made with respect to the labour cost equation. Of course, the assumption of segmented labour markets, implemented by adding linearly to the labour cost equation the set of year/sector dummies, is valid as long as there is proportional variation in wages by age group along those dimensions.

It is also worth stressing the inclusion in F_{it} of firm-level information on the (log of) average number of hours worked annually per employee; obtained by dividing the total number of hours reportedly worked annually by the number of employees (full-time or part-time ones indistinctively). The resulting variable is strongly correlated with the intensity of part-time work. Although there is little evidence that older workers more systematically resort to part-time work in Belgium, it seems reasonably to control for this likely source of bias when studying the causal relationship between

[16] Labour costs used in this paper, which were measured independently of value added, include the value of all monetary compensations paid to the total labour force (both full- and part-time, permanent and temporary), including social security contributions paid by the employers, throughout the year. The summary statistics of the variables in the data set are presented in Table 1.

[17] Measured in %. This is because logarithms, used in conjunction with differencing, convert absolute differences into relative (i.e., percentage) differences: i.e. (*Y-W)/W.*

[18] NUTS1 Belgian regions : Wallonia, Flanders and Brussels.

[19] NACE2 level.

age-gender and productivity, labour costs or the gap between these two.

But, as to a proper identification of the causal links, the main challenge consists of dealing with the various constituents of the residual ε_{it} of equation (10).[20] We assume that the latter has a structure that comprises three elements:

$$\varepsilon_{it} = \omega_{it} + \theta_i + \sigma_{it} \qquad (13)$$

where: $cov(\theta_i, P_{ik,t}) \neq 0, cov(\omega_{it}, P_{ik,t}) \neq 0, E(\sigma_{it})=0$

In words, the OLS sample-error term potentially consists of *i)* an unobservable firm fixed effect θ_i; *ii)* a short-term shock ω_{it} (whose evolution may correspond to a first-order Markov chain), and is observed by the firm (but not by the econometrician) and (partially) anticipated by the firm, and, *iii)* a purely random shock σ_{it}.

Parameter θ_i in (13) represents firm-specific characteristics that are unobservable but driving average productivity. For example, the maturity of the market they are predominantly active in, the vintage of capital in use, or the overall stock of human capital[21], firm-specific managerial skills, location-driven comparative advantages....[22] And these might be correlated with the age structure of the firm's workforce, biasing OLS results. Older workers for instance might be overrepresented among plants built a long time ago, that use older technology. However, the panel structure of our data allows for the estimation of FD models that eliminate fixed effects. The results from FD can be interpreted as follows: a group (e.g. young, prime-age or old) is estimated to be more (less) productive than another group if, within firms, a increase of that group's share in the overall workforce translates into productivity gains (loss).

This said, the greatest econometric challenge is to go around the simultaneity/endogeneity bias (Griliches & Mairesse, 1995). The economics underlying that concern is intuitive. In the short run, firms could be confronted to productivity deviations, ω_{it}; say, a lower turnover, itself the consequence of a missed sales opportunity. Contrary to the econometrician, firms may know about ω_{it} (and similarly about it short-term dynamics). An anticipated downturn could translate into a recruitment freeze, or, alternatively, into a multiplication of "involuntary" (early) retirements.[23] A recruitment freeze affects youth predominantly, and translates into rising share of older workers during negative spells, creating a negative correlation between older workers' share and

[20] And its equivalent in equation (12).
[21] At least the part of that stock that is not affected by short-term recruitments and separations.
[22] Motorway/airport in the vicinity of logistic firms for instance.
[23] Dorn & Sousa-Poza (2010) report that, in many Continental European countries, the proportion of involuntary retirement is significantly higher in years with increasing unemployment rates. One explanation for this finding is that firms promote early retirement when they are confronted with adverse demand shocks in an economic recession.

productivity, thereby leading to underestimated estimates of their productivity (when resorting to OLS or even FD estimates). By contrast, if firms primarily promote early retirements when confronted with adverse demand shocks, we would expect the correlation to be positive, leading to an overestimation of older workers' productivity with OLS or FD.

To account for the presence of this endogeneity bias we first estimate the relevant parameters of our model using only "internal" instruments. The essence of this strategy is to use lagged values of endogenous labour inputs as instruments for the endogenous (first-differenced) labour inputs (Aubert & Crépon, 2003, 2007; van Ours & Stoeldraijer, 2011; Cataldi, Kampelmann & Rycx, 2011).[24] First differences are good at purging fixed effects and thus at coping with unobserved heterogeneity terms θ_i. But (lagged) variables in level, although they might be orthogonal to the short-term shock ω_{it}, tend to prove poor predictors of first differences (i.e. they are weak instruments). Blundell and Bond (1998) then proposed an improved estimator called system-GMM (S-GMM) that uses extra moment conditions. S-GMM consists of a system of two equations estimated simultaneously. One corresponds to the above-mentioned first-difference equation, where the instruments are the (lagged) labour inputs in level. The second equation consists of using regressors in level, with (lagged) first-differenced of the endogenous variables as instruments. S-GMM estimator has become the estimator of choice in many applied panel data settings. We use it here to cope with simultaneity/endogeneity of the labour inputs (i.e. both the overall level of labour and the share by age).

An alternative to S-GMM that seems promising and relevant is to adopt the structural approach initiated by Olley & Pakes (1998) (OP hereafter) and further developed by Levinsohn & Petrin (2003) (LP hereafter), and more recently by Ackerberg, Caves & Frazer (2006) (ACF, hereby). The essence of the OP approach is to use some function of a firm's investment to control for (proxy) time-varying unobserved productivity, ω_{it}. The drawback of this method is that only observations with positive investment levels can be used in the estimation. Many firms indeed report no investment in short panels. LP overcome this problem by using material inputs (raw materials, electricity,...) instead of investment in the estimation of unobserved productivity. They argue that firms can swiftly (and also at a relatively low cost) respond to productivity developments, ω_{it}, by adapting the volume of the intermediate inputs they buy on the market. ACF argue that there is some solid and intuitive identification idea in the LP paper, but they claim that their two-stage estimation procedure delivers poor estimates of the labour coefficients and propose an improved version of it.

[24] The other key feature of these methods is that they are based on the Generalized Method of Moments (GMM), known for being more robust than 2SLS to the presence of heteroskedasticity (see appendix in Arellano, 2003).

Simplifying our notations to make them alike those used by ACF, average productivity equation becomes:

$$ln\ (Y_{it}\ /L_{it})= B+ \varphi\ ql_{it} + ß\ k_{it} + \gamma F_{it} +\varepsilon_{it} \qquad (14a)$$

with the labour quality index (or vector of labour inputs) equal to:

$$\varphi\ ql_{it} \equiv(\alpha-1)l_{it} +\eta_1 P_{it}^{18-29}+\eta_3 P_{it}^{50-64} \qquad (14b)$$

and the ACF error term:

$$\varepsilon_{it} = \omega_{it} +\sigma_{it} \qquad (14c)$$

Note that the latter does not contain a proper fixed effect θ_i, as we have assumed above, and as is traditionally assumed by the authors using S-GMM.

Like ACF, we assume that firms' (observable) demand for intermediate inputs (int_{it}) is a function of the time-varying unobserved term ω_{it} as well as (log of) capital, and the quality of labour index ql_{it} and its components:

$$int_{it} =f_t(\omega_{it}\ ,\ k_{it},\ ql_{it}) \qquad (15)$$

By contrast, LP unrealistically assume that the demand of intermediate goods is not influenced by that of labour inputs.[25]

ACF further assume that this function f_t is monotonic in ω_{it} and its other determinants, meaning that it can be inverted to deliver an expression of ω_{it} as a function of int_{it} , k_{it}, ql_{it}, and introduced into the production function:

$$ln\ (Y_{it}\ /L_{it})= B+ \varphi\ ql_{it} + ß\ k_{it} + \gamma F_{it} +f_t^{-1}(int_{it},\ k_{it},\ ql_{it}) + \sigma_{it} \qquad (16a)$$

We use this strategy here. However - unlike ACF - we do this in combination with first differences (FD) to properly account for firm fixed effects θ_i,meaning that our production function writes

$$ln\ (Y_{it}\ /L_{it})= B+ \varphi\ ql_{it} + ß\ k_{it} + \gamma F_{it}+ f_t^{-1}(int_{it},\ k_{it},\ ql_{it}) +\boldsymbol{\theta_i} + \sigma_{it} \qquad (16b)$$

In a sense, we stick to what has traditionally been done in the dynamic-panel literature underpinning the S-GMM strategy discussed above. We also believe that explicitly accounting for firm fixed effects increases the chance of verifying the key monotonicity assumption required by the ACF approach in order be able to invert out ω_{it} , and completely remove the endogeneity problem. In the ACF framework (similar in that respect to the LP or OP ones), the firm fixed effects

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[25] Consider the situation where ql_{it} is chosen at $t-b$ ($0<b<1$) and int_{it} is chosen at t. Since ql_{it} is chosen before in_{it}, a profit-maximizing (or cost-minimizing) optimal choice of int_{it} will generally directly depend on ql_{it} (Ackerberg, Caves & Frazer, 2006).

are *de facto* part of ω_{it}. Allowing for a time-varying firm effect is *a priori* appealing. For instance, it preserves more identifying variation.[26] On the other hand, the evidence with firm panel data is that fixed effects capture a large proportion (>50%) of the total productivity variation.[27] This tentatively means that, in the ACF intermediate goods function $int_{it}= f_t(\omega_{it}, k_{it}, ql_{it})$, the term ω_{it} can vary a lot when switching from one firm to another and, most importantly, in a way that is not related to the consumption of intermediate goods. In other words, firms with similar values of int_{it} (and k_{it} or ql_{it}) are characterized by very different values of ω_{it}. This is something that invalidates the ACF assumption of a one-to-one (monotonic) relationship, and the claim that the inclusion of intermediate goods in the regression adequately controls for endogeneity/simultaneity. This said, we still believe that intermediate goods can greatly contribute to identification, but conditional on properly accounting for firm fixed effects. In practice, how can this be achieved? The ACF algorithm consists of two stages. We argue that only stage one needs to be adapted.

In stage one, like ACF, we regress average productivity on a composite term Φ_t that comprises a constant, a 3^{rd} order polynomial expansion in $int_{it}, k_{it}, ql_{it}$, and our vector of controls added linearly. This leads to

$$ln\,(Y_{it}/L_{it}) = \Phi_t(int_{it}, k_{it}, ql_{it}, F_{it}) + \boldsymbol{\theta_i} + \sigma_{it} \qquad (17)$$

Note that Φ_t encompasses $\omega_{it} = f_t^{-1}(.)$ displayed in (16b) and that φ, $ß$ and γ are clearly not identified yet.[28] The point made by ACF is that this first-stage regression delivers an unbiased estimate of the composite term Φ_{it}^{hat}; i.e productivity net of the purely random term σ_{it}. We argue that this is valid only if there is no firm fixed effect θ_i or if the latter can be subsumed into $\omega_{it} = f_t^{-1}(.)$ - something we believe unrealistic and problematic for the reasons exposed above. Hence, we prefer assuming that fixed effects exist and explicitly account for them; which can easily be done by resorting to first differencing (FD) to estimate equation (17). The FD-estimated coefficients - provided they are applied to variables in levels - will deliver an unbiased prediction of Φ_{it}^{hat}. Specifically, Φ_{it}^{hat}, net of the noise term and firm-fixed effects, is calculated as $\Phi_{it}^{hat} = (\upsilon_{a1})^{FD}\, int_{it} + (\upsilon_{a2})^{FD}\, int^2_{it} + \ldots + (\upsilon_{b1})^{FD}\, k_{it} + \ldots + (\upsilon_{c1})^{FD} ql_{it} + \ldots + (\upsilon_{d1})^{FD}\, int_{it}k_{it} \ldots$, where $(\upsilon_{a1})^{FD}$, $(\upsilon_{a2})^{FD}\ldots$ represent the first-differenced coefficient estimates on the polynomial terms.

As an aside, note the presence in Φ_t of a 3^{rd} order polynomial expansion in (inter alia) $ql_{it.}$ and its components, namely l_{it}, $P_{it}^{18\text{-}29}$, $P_{it}^{50\text{-}64}$. To this point, the production function (a Cobb-Douglas) has been specified so that workers of different types have different marginal products but are perfectly

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26 Fixed effect estimators only exploit the within part of the total variation.

27 Another illustration of the same idea is that published studies have documented, virtually without exception, enormous and persistent measured (but unexplained) productivity differences across firms, even within narrowly defined industries (Syverson, 2011).

28 Note in particular that the non identification of vector φ (ie. labour input coefficients) in the first stage is one of the main differences between ACF and LP.

substitutable. Because this specification may be too restrictive, we should also consider evidence from estimates of a production function in which workers are imperfect rather than perfect substitutes. Resorting to a translog specification is what Hellerstein & al. (1999) did in their seminal paper. But the first stage equation above (17) consists of regressing the log of productivity on a 3rd order polynomial that contains interaction terms between the various labour input variables. We have thus gone part-way toward doing what Hellerstein & al. (1999) do when estimating translog production function to allow for imperfect substitutability across age groups. We will mobilise this feature when presenting our results in Section 4.

Returning to the ACF procedure, we basically argue that their second stage is unaffected by the modifications discussed above. Key is the idea that one can generate implied values for $\boldsymbol{\omega}_{it}$ using first-stage estimates Φ_{it}^{hat} and candidate[29] values for the coefficients φ , $ß$, γ:

$$\omega_{it}= \Phi_{it}^{hat} - ql_{it}\,\varphi - ß\, k_{it} - \gamma F_{it} \quad (18)$$

ACF assume further that the evolution of ω_{it} follows a first-order Markov process

$$\omega_{it}= E[\omega_{it} \mid \omega_{it-1}]- \xi_{it} \quad (19)$$

That assumption simply amounts to saying that the realization of ω_{it} depends on some function g(.) (known by the firm) of *t-1* realisation and an (unknown) innovation term ξ_{it}.

$$\omega_{it}= g(\omega_{it-1}) +\xi_{it} \quad (20)$$

By regressing non-parametrically (implied) ω_{it} on (implied) ω_{it-1}, ω_{it-2}, one gets residuals that correspond to the (implied) ξ_{it} that can form a sample analogue to the orthogonality (or moment) conditions identifying φ,$ß$ and γ. We would argue that residuals ξ_{it} are orthogonal to our controls F_{it}

$$E[\xi_{it} \mid F_{it}]=0 \quad (21a)$$

Analogous to ACF, we would also argue that capital in period *t* was determined at period *t-1* (or earlier). The economics behind this is that it may take a full period for new capital to be ordered and put to use. Since k_{it} is actually decided upon *t-1*, *t-2*…, it must be uncorrelated with the implied innovation terms ξ_{it}:

$$E[\xi_{it} \mid k_{it}]=0 \quad (21b)$$

[29] OLS estimates for example.

Labour inputs observed in t are probably also chosen sometime before, although after capital – say in $t\text{-}b$, with $0<b<1$. As a consequence, ql_{it} will be correlated with at least part of the productivity innovation ξ_{it}. On the other hand, assuming *lagged* labour inputs were chosen at time $t\text{-}b\text{-}1$ (or earlier), ql_{it-1}, ql_{it-2}… should be uncorrelated with the innovation terms ξ_{it}. This gives us the third (vector) of moment conditions needed for identification of φ:

$$E[\xi_{it|}\ ql_{it-1}, ql_{it-2}\ldots]=0 \quad (22a)$$

or more explicitly, given the composite nature of ql_{it}, we have:

$$E[\xi_{it|}\ l_{it-1}, l_{it-2}\ldots]=0 \quad (22b)$$

$$E[\xi_{it|}\ P^{18\text{-}29}_{it-1}, P^{18\text{-}29}_{it-2}\ldots]=0 \quad (22c)$$

$$E[\xi_{it|}\ P^{50\text{-}54}_{it-1}, P^{50\text{-}64}_{it-2}\ldots]=0 \quad (22d)$$

4. Results

4.1. Data

Most of the results exposed here come from a panel of around 9,000 firms with more than 20 employees, largely documented in terms of sector/industry (see appendix), location, size, capital used, labour cost levels, productivity. These observations come from the Bel-first database (firm-level data on firms based in Belgium). Via the so-called Carrefour data warehouse (i.e. social security records of workers), 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.

Descriptive statistics are reported in Tables 1 and 2. Table 2 in particular suggests that firms based in Belgium have been largely affected by ageing over the period considered. It shows that between 1998 and 2006, the average age of workers active in private firms located in Belgium rose by almost 3 years: from 36.15 to 39.10. This is very similar what has occurred Europe-wide. For instance Göbel and Zwick (2009) show that between 1997 and 2007 the average age of the workforce in the EU25 has risen from 36.2 to 38.9. In the Belgian private economy (Table 2), 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%.

Intermediate inputs play a key role in our analysis, as they are central to one of our strategies to overcome the simultaneity/ endogeneity bias (see Section 3). 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.

A weakness of our dataset is that it does not contain the workers' educational attainment. The point is that younger cohorts are better-educated and, for that reason, potentially more productive than older ones. As we do not control for educational attainment, how large is the risk that our estimates confound age and cohort/education, and consequently exaggerate the age-related productivity handicap?

Not so much, we think, for three reasons. First, although we do not observe education, our vector of controls F_{it} comprises good firm-level proxies for education (i.e. the share or blue-collar workers and the share of managers). Second, in this paper the identification of the effect of age on productivity is driven by younger (and presumably better-educated) cohorts entering the 50-64 age bracket. With FD, identification comes from the confrontation of production changes recorded between *t* and *t-1* and the simultaneous change (presumably rise) of the share of older workers. But in a panel, cohort/year-of-birth and time of observation are monotonically related: individuals belonging to the 50-64 age band in *t* are likely to belong to younger (and better-educated) cohorts than those observed in *t-1* in the same age band. In short, with FD identification of the consequence of ageing workforces is driven by better-educated individuals. Skeptics will rightly argue that with FD identification rather comes from the comparison between *i)* productivity gains achieved by firms with rising shares of old (50-64) workers *ii)* and those obtained by firms[30] with no (or less of) such rises. How do the two types of firms compare in terms of cohort (and thus educational) changes between *t* and *t-1*? The workers' average year of birth has probably risen more in the second type of firms, due to a more pronounced propensity to replace older workers by younger (better-educated) ones. This leads us to our third argument. Unobserved asymmetries across firms in terms of cohort (and education) dynamics are unlikely to bias results obtained in an HN framework. This is because with HN productivity is measured in *relative* terms. The estimated coefficient for the share of 50-64 workers corresponds to the relative productivity of that group vis-à-vis the reference group (i.e. prime-age workers). If, within each firm, the pace at which younger/better-educated cohorts enter the prime-age and the old age brackets does not vary significantly, firm-specific cohort biases will just cancel out.

[30] The same reasoning applies to different periods of observation.

Table 1: Bel-first-Carrefour panel. Main variables. Descriptive statistic.

Variable	Mean	Std. Dev.
Productivity (ie.value added) per worker (th. €) (log)	4.08	0.56
Labour cost per worker (th. €) (log)	3.71	0.38
Capital (th. €) (th. €) (log)	6.85	1.75
Number of workers (th. €) (log)	3.94	1.00
-------------	------------	-------------
Share of 18-29	0.423	0.18
Share of 30-49	0.424	0.13
Share of 50-65	0.153	0.11
-------------	------------	-------------
Use of intermediate inputs (th. €) (log)	8.97	1.56
Share of blue collar workers in total workforce	0.55	0.35
Share of Manager in total workforce	0.01	0.04
Number of hours worked annually per employee (log)	7.37	0.22
-------------	------------	-------------
Share of firm from the manufacturing sector (spells)	0.31	0.46
Share of firms with a consistent[a] training record (spells)	0.71	0.45
Share of firms in 10-90th perc. size[b] bracket (spells)	0.88	0.32
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Number of spells	8.73	0.94

a: That spend on training during the whole duration of the panel

b: Size is defined as the firms' overall labour force

Source: Bel-first-Carrefour

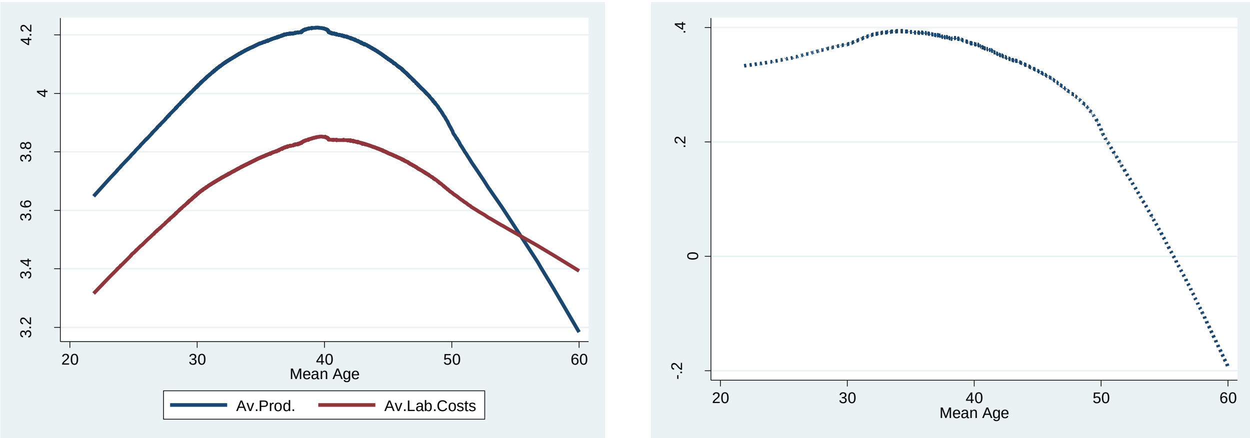
Table 2: Bel-first-Carrefour panel. Basic descriptive statistics. Evolution of shares of workers between 1998 and 2006

Year	Mean age (year)	Share of 18-29 (%)	Share of 30-49 (%)	Share of 50-65 (%)
1998	36.15	48.58%	39.35%	12.08%
1999	36.43	46.98%	40.37%	12.67%
2000	36.64	45.84%	40.90%	13.26%
2001	37.00	44.24%	41.77%	14.00%
2002	37.37	42.61%	42.76%	14.64%
2003	37.96	40.64%	43.12%	16.24%
2004	38.33	39.17%	43.77%	17.06%
2005	38.72	37.66%	44.43%	17.91%
2006	39.10	36.33%	44.66%	19.00%

Source: Bel-first-Carrefour

Figure 1 (left panel) displays how the (log of) average productivity and the (log of) average labour costs evolve with mean age, for the year 2006 subsample. The right panel of Figure 1 corresponds to the difference between these two curves which is equal to the productivity-labour cost gap expressed in percent.[31] These stylised facts suggests that, in the Belgian private economy, the productivity-labour cost gap in percent rises up to the (mean) age of 35-38 where it reaches 40%, but then declines steadily. It falls below the 10% threshold when mean age exceeds 55.

Figure 1: (Left panel) Average productivity and average labour costs. (Right panel) Productivity-labour cost gap (%) according to mean age. Year 2006

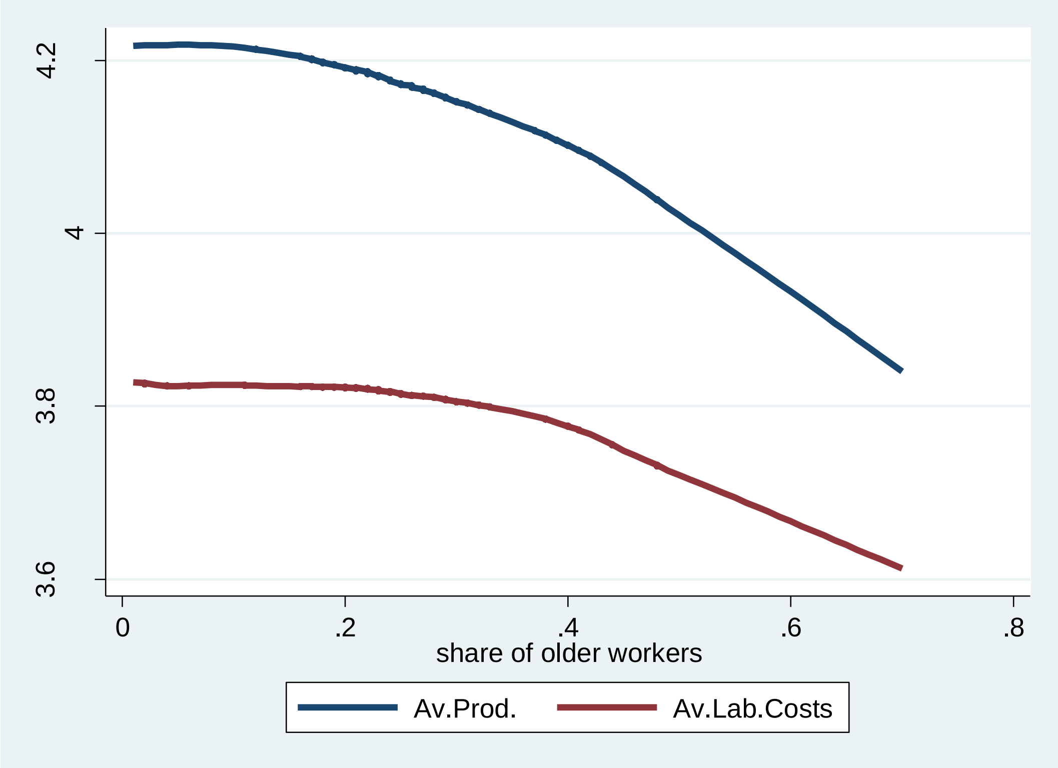


Curves on display correspond to locally weighted regression of *y* (i.e. log of average productivity, log of average labour cost [left panel] and productivity-labour cost gap in % [right panel]) on *x* (i.e. mean age). OLS estimates of *y* are fitted for each subsets of *x*. This method does not require specifying a global function of any form to fit a model to the data, only to fit segments of the data. It is thus semi-parametric.

Figure 2 is probably more directly echoing the main issue raised in this research. It depicts the relationship between the share of older (50-64) workers and the average productivity and the average labour costs. It also suggests that firms employing larger shares of older workers in excess of the 10% threshold have a significantly smaller productivity-labour cost gap.

[31] For small values, the log-first-difference transformation delivers *a* good approximation of the relative difference in percent : ie. log*(Y)-log(LC)* ≈*(Y-LC)/LC*.

Figure 2: Average productivity and average labour cost (in log) according to share of old (50-64) workers. Year 2006



Curves on display correspond to locally weighted regression of *y* (i.e. log of average productivity, log of average labour cost on *x* (i.e. share of workers age 50-64). OLS estimates of *y* are fitted for each subsets of *x*. This method does not require specifying a global function of any form to fit a model to the data, only to fit segments of the data. It is thus semi-parametric.

4.2. Main results

i) Key estimates

Table 3 presents the parameter estimates of the average productivity (ie; value added per worker) (see equation 10, Section 2), labour costs (equation 11) and productivity-labour cost gap equations (12), under five alternative econometric specifications. Note that, equation (12) being the difference between equation (10) and equation (11), it is logical to verify that η-$\eta^{W}\approx\eta^{G}$ for each age category. Standard errors on display have been computed in a way that accounts for firm-level clustering of observations. To get the results on display in Table 3 we use all available observations forming our (unbalanced) panel.

The first set of parameter estimates comes from OLS, using total variation [1]. The next strategy [2] consists of using intermediate inputs à-la-ACF. Then comes first differences (FD), where parameters are estimated using only within-firm variation [3]. Model [4] implements the Blundell-

Bond strategy relying on a system of equations using internal lagged[32] labour inputs as instruments (S-GMM). The last model [5] combines FD and the ACF intermediate-goods proxy idea (FD-ACF).[33]

In Table 3, parameter estimates (η) for the average productivity equation support the evidence that older workers (50-65) are less productive than prime-age (30-49) workers (our reference category). Sizeable (and statistically significant) negative coefficients are found across the range of models estimated. OLS results [1] suggest that an increase of 10%-points in the share of old workers depresses productivity by 2.7%. But this is compensated by a sizeable and statistically significant reduction of the average labour cost. A 10%-points rise in the share of old workers depresses labour costs by 1.9%. In all this translate into a .9% reduction of the productivity-labour cost gap, synonymous with lower employability.

But OLS results suffer from unobserved heterogeneity bias. Even the inclusion of controls in F_{it}, mostly a large set of dummies[34], is probably insufficient to account for firm-level singularities that may affect simultaneously firms' productivity and age structure. First-differencing as done in [2] is still the most powerful way out of this problem. Results from this model point at a much lower productivity handicap for older workers: an increase of 10%-points of their share in the workforce depresses productivity by 1.12%. Similarly, the labour cost coefficient appears smaller (in absolute value): a 10%-points increment in the share of older workers leads to a .52% reduction of the average cost for employers. Both results are supportive of the idea that older workers are overrepresented (within NACE2 industries) in firms that are intrinsically less productive and remunerative. But the first effect still dominates the second, with the implication that a 10%-points surge of the share of older workers translates into a .59% reduction of the productivity-labour cost gap.

OLS also potentially suffers from endogeneity bias. This justifies considering ACF i.e using intermediates goods to proxy for a plant's unobservable productivity shocks. ACF has the advantage over the more typical FD panel data approach of allowing for time-varying plant effects and allowing for more identifying variation in the other inputs. It is not, however, a complete panacea. We have explained above that it is difficult to believe in the existence of a one-to-one relationship between a firm's consumption of intermediates goods and a term ω_{it} that would systematically comprise all the firms' unobservables. Results [3] in Table 3 somehow comfort us in

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[32] By default, our Stata xtabond2 command uses, for each time period, all available lags of the specified variables in levels dated *t-1* or earlier as instruments for the FD equation and uses the contemporaneous first-differences as instruments in the levels equation.

[33] As suggested in Section 2 (equ. 21, 22 a-d), identification is provided by a set of moment conditions imposing orthogonality between implied innovation terms ξ_{it} and k_{it} ; ξ_{it} and lags 1 to 3 of the labour inputs.

[34] All our models, including OLS, use data in deviations from region (Wallonia, Flanders, Brussels) plus year interacted with NACE2 industry means. See appendix for a detailed presentation of the NACE2 classification.

our *a priori* scepticism. ACF fail to take us significantly away from OLS, as point estimates are essentially identical. A 10%-points rise in the share of older workers depressed productivity by 2.8% (2.7% with OLS), reduces labour costs by 1.4% (1.9% with OLS); that eventually translates into a depreciation of the productivity-labour cost gap of .99% (.94% with OLS).

Remember also that ACF – due to the inclusion of interaction terms between the various age share variables - is a way to allow for imperfect substitutability across labour age groups (Hellerstein & al., 1999). We interpret the great similarity between our ACF results [3] and those of the OLS-estimated Cobb-Douglas production function [1] as an indication that the assumption of perfect substitutability across age groups may not be abusive or a major source of distortion of our key estimates.

We now turn to our preferred models. If FD [2] probably dominates ACF [3], FD alone is not sufficient. The endogeneity in labour input[35] choice is a well-documented problem in the production function estimation literature (*e.g*. Griliches & Mairesse, 1995). In short, heterogeneity and endogeneity deserved to be simultaneously treated. And this is precisely what we attempt to do in [4] by estimating S-GMM, and in [5] by combining FD with ACF (see Section 2 for the algebra). Estimations [4] and [5] in Table 3 are *a priori* the best insofar as the parameters of interest are identified from within-firm variation to control for firm unobserved heterogeneity, and that they control for short-term endogeneity biases either via the use of ACF's intermediate input proxy, or internal instruments.

Model [4], based on S-GMM, shows that a 10%-points rise in the share of older workers depresses productivity by 2% (vs. 1.1% with FD), reduces labour costs by .94% (.52% with FD); which eventually turns into a depreciation of the productivity-labour cost gap of 1.24% (.59% with FD).[36] Those from the FD-ACF model [5] are very similar: a 10%-points rise in the share of older workers causes a drop of productivity of 2.2%, of labour costs of .9% and productivity-labour cost gap of 1.27%. Both series of estimates are significant at the 1 ‰ threshold.

As to the labour demand for older workers, the most important parameters are those of the productivity-labour cost gap equation (η^G_3). Negative signs basically tell us that older workers (50-64) display lower productivities ($\eta_3<0$) that are not fully compensated by lower labour costs; implying that they could be less employable than the reference category.

It is also worth stressing that our preferred models [4] and [5] deliver estimates of older workers

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[35] Remember that one specificity of our analysis is to assume endogeneity for both *i)* the choice of the overall level of labour and *ii)* the age structure of the workforce.

[36] In all our S-GMM estimates, reported in Tables 3 & 4, our instruments pass the standard test statistics provided by xtreg2, namely Arellano-Bond test for AR(1) in first differences, Arellano-Bond test for AR(2) in first differences, Sargan test of overid. restrictions and difference-in-Sargan tests of exogeneity of instrument subsets.

productivity that are *lower* than those obtained with FD [2]. This is supportive of the idea that private firms based in Belgium primarily resort to early retirements - rather than recruitment freezes - to cope with negative demand shocks. Remember that, in that case, we have predicted in Section 2 that models that do not control for endogeneity (OLS or FD) overestimate older workers' productivity.

Table 3: Parameter estimates (standard errors). Older (50-64) workers productivity (η_3), average labour costs($\eta^w{}_3$) and productivity-labour cost gap ($\eta^G{}_3$).– Overall, unbalanced panel sample.

	[1]-OLS	**[2]-First Differences**	**[3]-intermediate inputs ACF[$]**	**[4]- System GMM**	**[5]- First Differences + intermediate inputs ACF[$]**
Productivity (η_3)	-0.277***	-0.112***	-0.284***	-0.204***	-0.220***
std error	*(0.021)*	*(0.025)*	*(0.052)*	*(0.029)*	*(0.054)*
Labour Costs ($\eta^w{}_3$)	-0.191***	-0.052***	-0.141***	-0.094***	-0.090***
std error	*(0.012)*	*(0.013)*	*(0.010)*	*(0.015)*	*(0.007)*
Prod.-Lab. Costs gap ($\eta^G{}_3$)	-0.094***	-0.059**	-0.099**	-0.124***	-0.127***
std error	*(0.018)*	*(0.023)*	*(0.045)*	*(0.027)*	*(0.021)*
#obs	79,187	68,991	38,944	79,206	38,944
Controls	All data are deviations from region+ year interacted with NACE2 industry means. See appendix for NACE2 classification of industries				
	capital, number of employees, hours worked per employee[a], share of blue-collar workers, share of managers	capital, number of employees, hours worked per employee[a], share of blue-collar workers, share of managers + **firm fixed effects**	capital, number of employees, hours worked per employee[a], share of blue-collar workers, share of managers	capital, number of employees, hours worked per employee[a], share of blue-collar workers, share of managers + **firm fixed effects[a]**	capital, number of employees, hours worked per employee[a], share of blue-collar workers, share of managers + **firm fixed effects**
Orthogonality conditions/instruments used to identify endog. labour shares			Innovation in ω_{it} ⊥ lag$_{1-3}$ labour shares	All available lags of labour shares, & first-differenced labour shares	Innovation in ω_{it} ⊥ lag$_{1-3}$ labour shares

a: Average number of hours worked by employee on an annual basis, which is strongly correlated to the incidence of part-time work.

*p < 0.05, **p < 0.01, *** p < 0.001

[$] Ackerberg, Caves & Frazer.

ii) Robustness checks

We have undertaken three further steps in our analysis to assess the robustness of results reported in Table 4. For each of these extensions, the focus will be on the results of our preferred models [4] and [5].

First, we test whether we reach similar conclusions, with regards to those coming from the unbalanced panel used so far, when we restrict the analysis to the (only slightly smaller) *balanced* panel[37] sample. The rationale for doing is at least twofold. First, data quality is likely to be lower with the unbalanced panel. Poor respondents are likely to be overrepresented among short-lived firms forming the unbalanced part of the panel. Second, and more importantly, entering and exiting firms probably have a-typical, not so meaningful, productivity-age profiles. Entering firms (that tend also to be those exiting the sample due to a high mortality rate among entrants) are usually less productive and employ a younger workforce than incumbents. More to the point, the short-term dynamic of their productivity performance (which matters a lot in an analysis that rests heavily on FD estimates) is much less predictable and inadequately captured by the identification strategies mobilised in this paper. Bartelmans & Doms (2000) reviewing the US evidence, explain that a few years after entry a disproportionate number of entrants have moved both to the highest and the lowest percentiles of the productivity distribution.

Parameter estimates are exposed on the right-hand side of Table 4, alongside those of Table 3 (preferred models [4],[5] only) for comparison purposes. If anything, the old workers' employability handicap(η^G_3) highlighted with the unbalanced panel now appears stronger. In terms of average productivity, S-GMM [4] shows that a 10%-points expansion of older workers' share in the firm's workforce causes a 2.6% reduction (vs. 2% with the unbalanced panel), whereas FD-ACF model [5] points at 3.7% fall (2.2% with the unbalanced data). In terms of productivity-labour cost gap (i.e. employability), S-GMM suggests that a 10%-points expansion causes a 1.52%-points decline (vs. 1.24% with unbalanced panel), while FD-ACF points at a 1.46% contraction of the gap (1.27% with unbalanced data).

Second. We examine whether we reach substantially different conclusions when we exclude observations from the financial/insurance industry, real estate, utilities and a few other activities that can be associated with the non-profit sector.[38] We do this because many argue that the productivity and capital of firms in these industries are hard to measure. Results, in the third

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[37] The sample of firms that are observed *every* year between 1998 and 2006. By and large, descriptive statistics are quite similar to those of the unbalanced set (Table 2), be it in terms of average value-added, labour cost or firm size...

[38] Electricity, gas, steam and air-conditioning supply, water supply, sewerage, waste management and remediation financial and insurance activities; activities of households as employers; undifferentiated goods activities of extra-territorial organisations and bodies real estate activities. See appendix, Table 5 for more details

column of Table 5, also show a slightly higher productivity handicap (η_3) for older workers, compared with the unbalanced panel. But it is mainly in terms of employability (i.e. productivity-labour cost gap) that their handicap appears larger. S-GMM suggests that a 10%-points expansion of their share causes a 2.29% decline (vs. 1.24% with unbalanced panel), whereas FD-ACF points at a 1.64% contraction of the gap (1.27% with unbalanced data).

Three, we check whether firm size (i.e. overall number of workers) matters. We exclude the firms that systematically (i.e. during the 9 years of the panel) stay below the 10th percentile[39] and above the 90th percentile of the overall (annual) sample distribution. The main reason for doing this is to somehow reconnect with that important stream of the empirical literature that has assumed (and convincingly shown) that worker outcomes are primarily associated with (or caused by) firm characteristics, notably their size.[40] So far in this paper, we have assumed that firms' outcomes are caused by the characteristics of their employees, in particular their age. But contrary to some authors in this stream of research (Hellerstein & al. 1999), we have not included firm size class dummies in our vector of control F_{it} . Results (Table 4, last column) regarding productivity performances are mixed. S-GMM suggests a small handicap for older individuals than when using the overall sample of firm, but FD-ACG point a significantly larger handicap. Estimates of the employability handicap obtained with the "trimmed" data are almost equal to those obtained with the overall sample of firms. Although this analysis is very limited in scope, it is supportive of the idea that the relationship between age, productivity and labour costs that we have highlighted in this paper is orthogonal to the one relating firm size to the last two dimensions.

39 Remember that our overall sample already excludes firms with less than 20 employees.

40 The relationship between firm size and labour productivity is well documented. Van Ark & Monnikhof (1996) document this relationship for France, Germany, Japan, the United Kingdom and the United States,
For example, they show that in 1987, the gross output per employee in U.S. manufacturing plants with 0-9 employees was 62 per cent of that of all manufacturing plants, while the gross output per employee in plants with 500 or more employees was 126 per cent of that of all manufacturing plants

Table 4: *Parameter estimates (*standard errors*). Older (50-64) workers productivity (η_3), average labour costs($\eta^w{}_3$) and productivity-labour cost gap ($\eta^G{}_3$).–* ***Robustness Analysis***

	Overall, unbalanced panel (ref.)	Balanced panel	Excluding financial, real estate, utilities and non-profit activities[a]	Firms with a persistant training record[b]	Firms in 10-90th perc. size[c] bracket
[4]- System GMM					
Productivity (η_3)	-0.204***	-0.269***	-0.207***	-0.192***	-0.125***
std error	*(0.029)*	*(0.024)*	(0.029)	*(0.036)*	*(0.032)*
Prod.-Lab. Costs gap ($\eta^G{}_3$)	-0.124***	-0.152***	-0.229***	-0.152**	-0.121**
std error	*(0.027)*	*(0.022)*	*(0.027)*	*(0.034)*	*(0.029)*
#obs	79,206	75,582	75,485	56,188	62,977
Controls	- All data are deviations from region+ year interacted with NACE2 industry means. See appendix for NACE2 classification of industries - Capital, number of employees, hours worked per employee[d], share of blue-collar workers, share of managers + firm fixed effect				
Instr. indentifying endog. labour shares	All available lags of labour shares, & first-differenced labour shares				
[5]- First Differences + intermediate inputs ACF[$]					
Productivity (η_3)	-0.220***	-0.376***	-0.285***	-0.432***	-0.351***
std error	*(0.054)*	*(0.000)*	*(0.053)*	*(0.056)*	*(0.045)*
Prod.-Lab. Costs gap ($\eta^G{}_3$)	-0.127***	-0.146***	-0.164***	-0.163**	-0.132**
std error	*(0.021)*	*(0.023)*	*(0.023)*	*(0.042)*	*(0.031)*
#obs	38,944	37,968	37,251	28,459	31,445
Controls	- All data are deviations from region+ year interacted with NACE2 industry means. See appendix for NACE2 classification of industries - Capital, number of employees, hours worked per employee[d], share of blue-collar workers, share of managers + firm fixed effects				
Orthog. conditions identifying endog. labour shares	Innovation in ω_{it}⫫ $\text{lag}_{1\text{-}3}$ labour shares				

*p < 0.05, **p < 0.01, *** p < 0.001
$: Ackerberg, Caves & Frazer.
a: Electricity, gas, steam and air-conditioning supply,water supply, sewerage, waste management and remediation financial and insurance activities; activities of households as employers; undifferentiated goods activities of extra-territorial organisations and bodies real estate activities
b: That spend on training during the whole duration of the panel
c: Size is defined as the firms' overall labour force
d: Average number of hours worked by employee on an annual basis, which is strongly correlated to the incidence of part-time work

iii) Final comments

Our research investigates the consequences of an ageing workforce for the demand for older workers. We ask in particular whether firms based in Belgium are *a priori* willing to employ more older workers. The answer is no, as we find robust evidence of a negative impact of older workers on the productivity-labour cost gap: an increment of 10%-points of their share in the firms' workforce causes a 1.2-1.6% contraction. The reason for this is that lower productivity of older workers is not compensated by lower labour costs. We posit that is likely to depress the labour demand for older workers, in particular to compromise their chances of re-employment in case of job loss.

This key result is reproduced, and even reinforced, when we turn to several variants of our main analysis (i.e. elimination of firms that are not observed during the 9 consecutive years forming our panel, of those belonging to sectors where productivity is difficult to measure, focus on firms who systematically spend on training, elimination of very small and very large firms).

We finish by briefly mentioning some limits and considerations that should be held in mind when interpreting our results. First, only "average firm profiles" are calculated, which may imply that we overlook the (in)capacity or some firms to neutralize the effect of ageing on productivity (by implementing or not *ad hoc* actions that compensate for the age-related loss of performance). Second, and most importantly, the workers' sample that we use in this paper might not be representative of the entire population of older individuals aged 50-65. Belgium, alongside a few other EU countries, is known for its very low employment rate among individuals aged 50 or more (37% in 2010 according to Eurostat). This means that there is a risk of a *selection bias*, in particular if this low employment rate corresponds to early ejection from the workforce of individuals that are intrinsically less productive or less motivated. To the extent that this selection bias is an issue, we could view our estimated coefficients for older workers' relative productivity as lower-bounds (in absolute value).

Third, the econometric strategies underpinning this literature are still developing. This could soon deliver improvements and eliminate some of the divergence in terms of the impact of ageing observed between Belgium (Vandenberghe, 2011b, Cataldi, Kampelmann &Rycx, 2011) and a few others (van Ours & Stoeldraijer, 2011 for the Netherlands ; Cardoso, Guimaraes & Varejao, 2011 for Portugal). An open question is whether "natural experiments" (now commonly used in empirical labour economics in order to identify causal relationships) could help assess the impact of ageing on firm-level productivity. To our knowledge, such a strategy has never been used to disentangle the age-productivity-pay nexus.

Four. We focus here on the ratio between labour productivity and labour costs which is, without doubt, an important metric for employers. However, many observers would rightly argue that ultimately employers will care about financial survival and profits. Can it be the case that firms can employ older workers, singularly older women, and still make a profit or simply survive? First of all, remember that what is at stake here is not the financial survival of firms. All that we show in that paper is that firms employing older women (and to a lesser extent older men) have to live with a lower (but still positive) markup between *i)* what they manage to produce per worker and *ii)* how much they spend to remunerate them. Beyond, how does this ultimately translate in terms of profits (i.e. return on capital)? The answer depends on the amount of capital in use per capita in firms with larger shares of older female workers. If it is the same as in other firms employing a younger or more masculine workforce, then returns will be lower, and this will further entice firms to reduce their demand of older female workers. Alternatively, these firms could operate with a lower capital base, in order to maintain returns. That could somehow preserve labour demand, but implies than an older and more feminized workforce will lead to the expansion of activities than are intrinsically less capital-intensive. This raises important issues (e.g. the degree of complementarity between young/old labour and capital) that go beyond the scope of this paper, but certainly call for more research by economists with an interest in ageing.

Finally, the important cross-country differences (Belgium vs. Portugal or the Netherlands) with regard to how age, productivity and labour costs are related could be due to data specificities or to econometric issues. But one cannot reject the hypothesis that they point to country effects. It could be, for instance, that the way age affects productivity is partially dependant on the set of labour-market institutions present in one country. Some of these institutions may be conducive to greater investment (from both employers and employees), combating or compensating age-related productivity declines, whereas others may have the opposite effect. The issue remains open for discussion and calls for more research.

4.3. Gender

i) Context

As stated above, in most EU countries, demographics (ageing populations[41]) and public policy[42] (reforms aimed at raising the employment rate of older individuals) will combine to increase the share of older workers in the labour force. Across the EU, there is also the fact that older women

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[41] For instance Göbel and Zwick (2009) show that between 1987 and 2007 the average age of the workforce in the EU25 has risen from 36.2 to 38.9. In Belgium, between 1999 and 2009 the share of individuals aged 50-65 in the total population aged 15-65 rose from 25.2% to 28.8% (http://statbel.fgov.be).

[42] The Lisbon Agenda suggested raising employment of individuals aged 55-64 to at least 50% by 2010.

are clearly less present in employment than older men.[43] But this should change. The point we raise here is that a greying workforce will also feminize.

Two elements combine in support of this prediction. The first one is the lagged effect[44] of the rising overall female participation in the labour force (Peracchi & Welch, 1994).[45] The second factor is labour policy. Policymakers will concentrate on promoting older women's employment because - conditional on a certain young- or prime-age participation record - women still leave the labour market earlier than men[46] (Fitzenberger *et al.*, 2004).

The demand side of the labour market for older individuals has started to receive some attention from economists (see above). Several authors have examined the relationship between age and productivity at the level where this matters most: firms. The point we raise here is that none of the existing papers has adequately considered the *gender* dimension of ageing, in a context where women are likely to form a growing part of the older labour force. We try to fill that void.

ii) Methodology

Like in the previous section, the point is to assess the current willingness of employers to (re)employ older male and female workers. And, again we posit that the answer to this question largely depends on how larger shares of older (male or female) workers affect private firms' productivity-labour cost ratio. And we keep assuming that a sizeable negative impact of older men/women on that ratio can adversely affect their respective chances of being employed.

We keep employing the framework pioneered by HN, which consists of estimating production and/or labour cost functions that explicitly account for labour heterogeneity. Applied to firm-level data, this methodology presents two main advantages. First, it delivers productivity differences across age/gender groups that can immediately be compared to a measure of labour costs differences, thereby identifying the net contribution of an age/gender group to the productivity-labour cost ratio (which can be directly interpreted as conducive to weak or strong employability). Second, it measures and tests for the presence of market-wide impact on the productivity-labour cost ratio that can affect the overall labour demand for the category of workers considered.

Algebraically, the notations are very similar to those used so far. The key equations underpinning the analysis are the following. We consider three age groups (1=[20-29], 2=[30-49]; 3=[50-64[) and

[43] See the European Labour Force Survey (EU-LFS) 2010 (Eurostat, 2010).
[44] Also referred to as a cohort effect.
[45] Driven, *inter alia*, by a higher educational attainment of women and a lower fertility of the younger generations.
[46] In other words, life-cycle participation/employment profiles vary by gender. And the female profiles have not changed markedly across cohorts.

prime-age (30-49) male workers as the reference group. We thus get a productivity equation of the form

$$\ln(Y_{it}/L_{it})=B+(\alpha-1)l_{it}+$$

$$\eta_{1m}P_{it}^{m18-29}+\eta_{3m}P_{it}^{m50-64}+\eta_{1f}P_{it}^{f18-29}+\eta_{2f}P_{it}^{f30-49}+\eta_{3f}P_{it}^{f50-64}+ß\, k_{it}+\gamma F_{it}+\varepsilon_{it} \quad (1)$$

The (per capital) labour cost write

$$\ln(W_{it}/L_{it})=B^{w}+(\alpha^{W}-1)l_{it}+$$

$$\eta^{W}_{1m}P_{it}^{m18-29}+\eta^{W}_{3m}P_{it}^{m50-64}+\eta^{W}_{1f}P_{it}^{f18-29}+\eta^{W}_{2f}P_{it}^{f30-49}+\eta^{W}_{3f}P_{it}^{f50-64}+ß^{w}k_{it}+\gamma^{W}F_{it}+\varepsilon^{w}_{it} \quad (2)$$

And - if we take the *difference* between the logarithms of average productivity (1) and labour costs[47] (2) we get a direct expression of the productivity-labour cost ratio[48] as a linear function of its workforce determinants.

$$Ratio_{it}\equiv\ln(Y_{it}/L_{it})-\ln(W_{it}/L_{it})=B^{R}+(\alpha^{R}-1)l_{it}+$$

$$\eta^{R}_{1m}P_{it}^{m18-29}+\eta^{R}_{3m}P_{it}^{m50\_64}+\eta^{R}_{1f}P_{it}^{f18-29}+\eta^{R}_{2f}P_{it}^{f30-49}+\eta^{R}_{3f}P_{it}^{f50-64}+ß^{R}k_{it}+\gamma^{R}F_{it}+\varepsilon^{R}_{it} \quad (3)$$

where: $B^R=B-B^w$; $\alpha^R=\alpha-\alpha^W$, $\eta^R_{1m}=\eta_{1m}-\eta^w_{1m}$; $\eta^R_{3m}=\eta_{3m}-\eta^w_{3m}$; $\eta^R_{1f}=\eta_{1f}-\eta^w_{1f}$; $\eta^R_{2f}=\eta_{2f}-\eta^w_{2f}$; $\eta^R_{3f}=\eta_{3f}-\eta^w_{3f}$; $\gamma^R=\gamma-\gamma^w$ and $\varepsilon^R_{it}=\varepsilon_{it}-\varepsilon^w_{it}$.

It is immediate to see that coefficients η^R of equation (13) provide a direct estimate of how the productivity-labour cost ratio is affected by changes in terms of percentages/shares of male/female employed workers.

iii) Data and results

Descriptive statistics are reported in Tables 1-4. Tables 2 and 3 suggest that firms based in Belgium have been largely affected by ageing over the period considered. Table 2 confirm that between 1998 and 2006, the mean age of workers active in private firms located in Belgium rose by almost 3 years: from 36.2 to 39.1.

Table 3 also shows that, in the Belgian private economy, between 1998 and 2006, the percentage

[47] Labour costs used in this paper, which were measured independently of value added, include the value of all monetary compensations paid to the total labour force (both full- and part-time, permanent and temporary), including social security contributions paid by the employers, throughout the year. The summary statistics of the variables in the data set are presented in Table 1.

[48] Measured in %. This is because the logarithms, used in conjunction with differencing, convert absolute differences into relative (i.e., percentage) differences: i.e. *(Y-W)/W.*

of old male workers (50-65) has risen steadily from 10% to almost 15%. And the proportion of older women has risen even more dramatically, from 2% to 4.1%. While starting from a low level in 1998 (2.13%), the rise of the share of older women has been of more than 96% in cumulative terms. The corresponding figure for older men is only 48 %.

What may explain this gender asymmetry? We would formulate two (non-mutually exclusive) explanations. The first one, already mentioned above, is the "lagged effect" of surge of female participation in the labour market, itself explained by the lowering of the birth rate and a surge in the number of women accessing tertiary education. The second hypothesis is that of the impact of the pension reform that took place in Belgium in 1997. Before 1997, the legal age of retirement was 60 for women, but 65 for men. The European court of Justice considered this as a form of gender discrimination.

The exact timing of gender alignment decided in 1997 is exposed in Table 4. The point is the coincidence between the calendar of the 1997 reform (first step towards alignment in 1997, full alignment in 2007) and that of our panel (1998-2006). Of course, there is no certainty that the increase in the share of older women in our data is primarily due to the reform. But one cannot exclude this hypothesis. What is more, it has some methodological interest as to the econometric identification of the consequences of ageing workforces.

If we assume that at least part of the increase in the share of elderly women can be ascribed to the 1997 reform, then we could argue that we are dealing with a “natural experiment”. And the latter could help assess the impact of ageing on firm-level productivity. We will argue hereafter that there a chance that our estimates for older female workers are intrinsically less biased due to selectivity than those obtained for older men. We will elaborate on this in the final section of the paper.

Table 1: Bel-first-Carrefour panel. Main variables. Descriptive statistic.

Variable	Mean	Std. Dev.
Productivity (ie.value added) per worker (th. €) (log)	4.076	0.565
Labour cost per worker (th. €) (log)	3.706	0.381
Productivity-Labour cost ratio/markup	0.372	0.404
Capital (th. €) (th. €) (log)	6.835	1.752
Number of workers (th. €) (log)	3.937	0.994
Share of 18-29 (Male)	0.287	0.163
Share of 30-49 (Male)	0.309	0.152
Share of 50-65 (Male)	0.122	0.103
Share of 18-29 (Female)	0.137	0.153
Share of 30-49 (Female)	0.115	0.117
Share of 50-65 (Female)	0.031	0.050
Use of intermediate inputs (th. €) (log)	8.939	1.575
Share of blue collar workers in total workforce	0.544	0.351
Share of Manager in total workforce	0.010	0.042
Number of hours worked annually per employee (log)	7.377	0.163
Number of spells	8.730	0.944

Source: Bel-first-Carrefour

Table 2: Bel-first-Carrefour panel. Basic descriptive statistics. Evolution of shares of workers between 1998 and 2006

Year	Mean age (year)	Share of 18-29 (%)	Share of 30-49 (%)	Share of 50-65 (%)
1998	36.15	48.58%	39.35%	12.08%
1999	36.43	46.98%	40.37%	12.67%
2000	36.64	45.84%	40.90%	13.26%
2001	37.00	44.24%	41.77%	14.00%
2002	37.37	42.61%	42.76%	14.64%
2003	37.96	40.64%	43.12%	16.24%
2004	38.33	39.17%	43.77%	17.06%
2005	38.72	37.66%	44.43%	17.91%
2006	39.10	36.33%	44.66%	19.00%

Source: Bel-first-Carrefour

Table 3. Shares of male vs female old workers (50-64). Private sector economy. Belgium. 1998-2006

	Share of old men	Share of old women	Evolution share of old men (1998=100)	Evolution share of old women (1998=100)
1998	9.92%	2.13%	100.00	100.00
1999	10.33%	2.30%	104.08	107.62
2000	10.73%	2.48%	108.13	116.25
2001	11.22%	2.72%	113.06	127.53
2002	11.69%	2.92%	117.76	136.82
2003	12.90%	3.31%	130.02	155.06
2004	13.47%	3.56%	135.75	166.73
2005	14.04%	3.83%	141.43	179.29
2006	14.72%	4.20%	148.31	196.86

Source : Bel-first, Carrefour

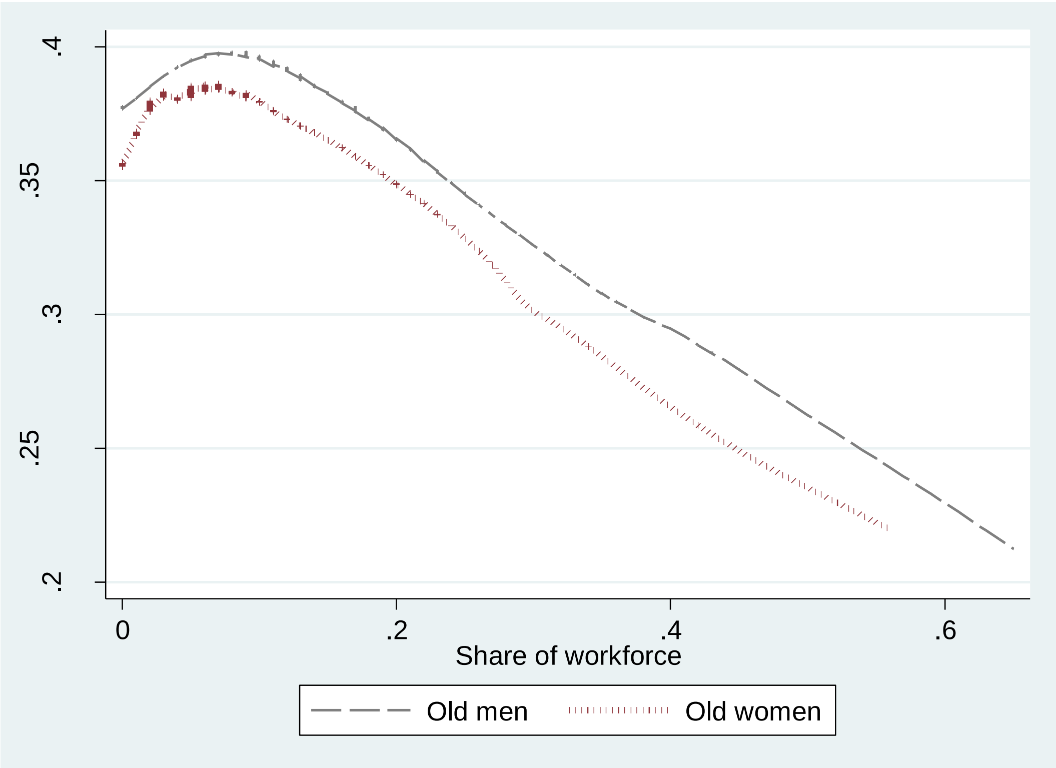
Table 4. Pension reform of 1997. Calendar of the alignment of legal age of retirement for women on that of men.

	1996	**1997**	2000	2003	2006	**2009**
Male	65	65	65	65	65	65
Female	60	61	62	63	64	65

Source : www.socialsecurity.be

Figure 1 depicts the relationship between the share or older (50-64) men or women and the productivity-labour cost ratio. It suggests that firms employing shares of older men and women in excess of the 7-8% threshold have a significantly smaller productivity-labour cost ratio. It is also shows that firms employing a given share of older women systematically achieve a lower ratio than firms employing the same share of older men.

Figure 1: Productivity-Labour cost ratio (in %) according to share of older men or women



Curves on display correspond to locally weighted regression of *y (productivity-labour cost ratio)* on *x (shares).* It does this by fitting an OLS estimate of *y* for each subsets of *x*. This method does not required to specify a global function of any form to fit a model to the data, only to fit segments of the data. It is thus semi-parametric.

Table 5 presents the parameter estimates of the average productivity (see equation 1), labour costs (equation 2) and productivity-labour cost ratio equations (3), under four alternative econometric specifications. Note that, with equation (3) being the difference between equation (1) and equation (2), it is logical to verify that $\eta\text{-}\eta^{W}\approx\eta^{R.}$ for each age/gender category. Standard errors on display have been computed in a way that accounts for firm-level clustering of observations. To get the results on display in Table 5 we use all available observations forming of our (unbalanced) panel.

The first set of parameter estimates comes from OLS, using total variation [1]. Then comes first differences (FD), where parameters are estimated using only within-firm variation [2]. Model [3] combines FD and the IV-GMM approach using internal lagged labour inputs as instruments (FD-IV-GMM). The last model [4] combines FD and the ACF intermediate-goods proxy idea (FD-ACF).[49]

Estimations [3] [4] in Table 5 are a priori the best insofar as *i)* the parameters of interest are identified from within-firm variation to control for firm unobserved heterogeneity, and *ii)* that they control for short-term endogeneity biases either via the use of ACF's intermediate input proxy, or internal instruments.

OLS results suffer from unobserved heterogeneity bias. Even the inclusion of controls in F_{it}, mostly a large set of dummies[50], is probably insufficient to account for firm-level singularities that may affect simultaneously firms' productivity and age structure. First-differencing as done in [2] is still the most powerful way out of this problem. 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 (namely year, sector) in F_{it} can account for part of this heterogeneity bias, first-differencing as done in [2], [3] or [4] is still the most powerful way out. But first differences alone [2] are not sufficient. The endogeneity in labour input choices is well documented problem in the production function estimation literature (*e.g*. Griliches & Mairesse, 1995) and also deserved to be properly and simultaneously treated. And this is precisely what we have attempted to do in [3] and [4] by combining first differences with techniques like IV-GMM or ACF.

To assess the credibility of our FD-IV-GMM approach [3] we performed a range of diagnostic tests. First, an Anderson correlation relevance test. If the correlation between the instrumental variables and the endogenous variable is poor (*i.e.* if we have "weak" instruments) our parameter estimate may be biased. The null hypothesis is that the instruments are weak (correlation in nil). Rejection of the null hypothesis (low p-values) implies that the instruments pass the weak instruments test, i.e. they are highly correlated with the endogenous variables. In all our FD-IV-GMM estimates reported in Table 6 our instruments pass the Anderson correlation relevance test. Second, to further assess the validity of our instrument we use the Hansen-Sargan test. – also called Hansen's J test – of overidentifying restrictions. The null hypothesis is that the instruments are valid instruments (i.e., uncorrelated with the error term), and that the instruments are correctly "excluded" from the estimated equation. Under the null, the test statistic is distributed as chi-square in the number of overidentifying restrictions. A failure to reject the null hypothesis (high p-values) implies that the instruments are exogenous. In all our FD-IV-GMM estimates we cannot reject the null hypothesis that these restrictions are valid.

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[49] As suggested in Section 2 (equ. 21, 22 a-d), identification is provided by a set of moment conditions imposing orthogonality between implied innovation terms ξ_{it} and k_{it} ; ξ_{it} and lags 1 to 3 of the labour inputs.

[50] All our models, including OLS, use data in deviations from year interacted with NACE2 industry means. See Appendix 2 for a detailed presentation of the NACE2 classification.

In Table 5, parameter estimates (η) for the average productivity equation support the evidence that older worker (50-65) - both men and women - are less productive than prime-age (30-49) male workers (our reference category). Sizeable (and statistically significant) negative coefficients are found across the range of models estimated. Those from the FD-ACF model [4] suggest that an increase of 10%-points in the share of old male workers depresses productivity by 1.54%-points. Model [3], based on FD-IV-GMM, points at a smaller (not statistically significant) drop by only 0.37%t.

As to old women both FD-IV-GMM [3] and the FD-ACF model [4] deliver large negative estimates of the impact of larger shares of old women on productivity. An increase of 10%-points in the share of older female workers reduces productivity by 2.32% [3] to 3.81% [4].

Turning to the average labour cost coefficients (η^W), we find some evidence of lower labour cost for older men and women. Estimates for model [3] show that a 10%-points rise of the share of older male (female) workers reduces average labour cost by 0.31%-point (0.49%-point respectively). Evidence from model [4] is supportive of wage declines of 0.67% for men, and 2.96 %-points for women. The slightly lower labour costs for older women could reflect the fact that they have accumulated lower tenure in firms; something that, ceteris paribus, may reduce their cost to employ in a country where seniority plays an important role in wage formation (BNB, 2010).

However, regarding the labour demand for older men and women, the most important parameters are those of the productivity-labour cost ratio equation (η^R). Their sign informs as to whether a lower productivity is fully compensated by lower labour costs. Remember that we posit that a negative (and statistically significant) coefficient is a indication that the category of workers is less employable than the reference category. Results for old men are mixed. Model [3] delivers a coefficient that is not statistically different from O. Model [4] suggests that a 10%-points rise of their share causes a modest 0.88% reduction of the productivity-labour cost ratio.

The situation is quite different for old women. Model [3] suggests that a 10%-points expansion of their share in the total workforce causes a 1.8% reduction of the productivity-labour cost ratio. And model [4] points to a 2.11% drop of that ratio.

Table 5- Parameter estimates (*standard errors*[£]). Older (50-64) male/female and prime-age (30-49) female workers productivity (η), average labour costs(η^{w}) and productivity-labour cost ratio (η^{R}). Overall, unbalanced panel sample.

	[1]-OLS	**[2]-First Differences (FD)**	**[3]- FD-IV-GMM**	**[4]- FD + intermediate inputs ACF[$]**
		Share of 50-64 (Men)		
Productivity (η_{3m})	-0.218***	-0.071**	-0.037	-0.154***
std error	*(0.024)*	*(0.028)*	*(0.027)*	*(0.034)*
Labour Costs (η^{w}_{3m})	-0.170***	-0.017	-0.031**	-0.067***
std error	*(0.013)*	*(0.012)*	*(0.015)*	*(0.021)*
Prod.-Lab. Costs ratio (η^{R}_{3m})	-0.054***	-0.054**	-0.002	-0.088***
std error	*(0.020)*	*(0.027)*	*(0.037)*	*(0.024)*
		Share of 30-49 (Women)		
Productivity (η_{2f})	-0.281***	-0.031	-0.119***	-0.050
std error	*(0.021)*	*(0.032)*	*(0.045)*	*(0.055)*
Labour Costs (η^{w}_{2f})	-0.347***	-0.043***	-0.037**	-0.081**
std error	*(0.012)*	*(0.014)*	*(0.019)*	*(0.031)*
Prod.-Lab. Costs ratio ($\eta^{R}_{2}f$)	0.019	0.012	-0.076*	0.003
std error	*(0.017)*	*(0.031)*	*(0.044)*	*(0.044)*
		Share of 50-64 (Women)		
Productivity (η_{3f})	-0.638***	-0.210***	-0.232***	-0.381***
std error	*(0.038)*	*(0.053)*	*(0.070)*	*(0.080)*
Labour Costs (η^{w}_{3f})	-0.665***	-0.056**	-0.049*	-0.296***
std error	*(0.021)*	*(0.023)*	*(0.029)*	*(0.049)*
Prod.-Lab. Costs ratio (η^{R}_{3f})	-0.017	-0.153***	-0.180***	-0.211**
std error	*(0.031)*	*(0.051)*	*(0.068)*	*(0.070)*
#Obs.	77,847	67,678	50,176	38,296
Controls	All data are deviations from region+ year interacted with NACE2 industry means. See appendix for NACE2 classification of industries			
	capital, number of employees, hours worked per employee[a], share of blue-collar workers, share of managers	capital, number of employees, hours worked per employee[a], share of blue-collar workers, share of managers + fixed effects: **firm**	capital, number of employees, hours worked per employee[a], share of blue-collar workers, share of managers + fixed effects: **firm**	capital, number of employees, hours worked per employee[a], share of blue-collar workers, share of managers + fixed effects: **firm**
Orthogonality conditions/instruments used to identify endog. labour shares			Second differences and lagged second differences	Innovation in ω_{it} ⫫ *lag1-3* labour shares Innovation in ωit⫫ lag1-3 labour shares
Identification tests			**<u>IV relevance</u>**: Anderson canon. corr. LR statistic√ **<u>Overidentifying restriction</u>**: Hansen J statistic √	

a: Average number of hours worked by employee on an annual basis, which is strongly correlated to the incidence of part-time work.
£:Standard errors estimates are robust to firm-level clustering
*p < 0.05, **p < 0.01, *** p < 0.001
[$] Ackerberg, Caves & Frazer

Table 6 contains a series of important results that can be derived from a further analysis of those displayed in Table 5. The first column simply reproduces the estimates for the average productivity and productivity-labour cost ratio equations, using our preferred estimation strategies [3] [4]. The following columns contain the results of three *hypothesis tests* aimed at answering key questions about age and gender. First, are old women (50-64) less productive [and less employable, due to a lower productivity-labour cost ratio] than old men? The question amounts to verifying that $\eta_{3m} > \eta_{3f}$ [$\eta^R_{3m} > \eta^R_{3f}$] in absolute value and testing H0: $\eta_{3m} = \eta_{3f}$ for productivity [H0: $\eta^R_{3m} = \eta^R_{3f}$ for employability]. Results, for FD-IV-GMM model [3], point to a 1.95% productivity handicap for old women relative to old men, and an employability handicap of 1.78%. Both estimates are highly statistically significant. They mean that a 10% rise of the share of older women is causing an additional 1.95% [1.78%] reduction of labour productivity [productivity-labour cost ratio], compared with a similar increase of the share of older men.

The second question that can be addressed is whether old women's productivity[employability] handicap relative to old men is driven by more pronounced effects of age on women than on men's productivity[employability].

We can first examine, for each gender separately, how age affects productivity[employability] using the prime-age category as a reference .As already stated above, the evidence for old vis-à-vis prime-age male workers (ie. estimated η_{3m} [η^R_{3m}]) is mixed. Results for the FD-IV-GMM model [3] suggest an absence of significant deterioration of productivity[employability], whereas FD-ACF model [4] is supportive of a small deterioration. A 10%-points rise of the share of old men causes a 1.54% [0.88] decline of productivity[employability].

Assessing the situation of older women relative to prime-age women is less immediate and requires hypothesis testing (ie. rejecting H0: $\eta_{2f} = \eta_{3f}$ [H0: $\eta^R_{2f} = \eta^R_{3f}$]). Results, for FD-IV-GMM model [3], point to a 1.1% productivity handicap (not statistically significant at the level of 5 percent) for old women relative to prime-age women. In terms of employability, the handicap is of 1.04% (also not statistically significant). Results with FD-ACF model [4] are larger in magnitude and statistically significant, namely a productivity handicap of 3.31%-, and an employability handicap of 2.14%.

Furthermore, we can test whether age affects more women's than men's productivity[employability] by testing H0: $\eta^R_{3f} - \eta^R_{2f} = \eta^R_{3m}$ [H0: $\eta_{3f} - \eta_{2f} = \eta_{3m}$]. Results point to a 0.7% to 1.77% productivity handicap of women vis-à-vis men in terms of age-related productivity decline, and a 1.02% to 1.26% handicap in terms of employability decline. But none of these estimates are statistically significant at the level of 5 percent.

Table 6 – Parameter estimates (*standard errors*[£]) and hypothesis testing. Older (50-64) male/female and prime-age (30-49) female workers productivity (η), average labour costs(η^{w}) and productivity-labour cost ratio (η^{R}). Overall, unbalanced panel sample.

		Hyp Test $\eta_{3f}=\eta_{3m}$ (old women vs old men)			**Hyp Test** $\eta_{3f}=\eta_{2f}$ (old women vs prime-age women)			**Hyp Test** $\eta_{3f}-\eta_{2f}=\eta_{3m}$ (within gender ageing differences)		
	Coefficient	$\eta_{3f}-\eta_{3m}$	**F**	**Prob >F**	$\eta_{3f}-\eta_{2f}$	**F**	**Prob >F**	$(\eta_{3f}-\eta_{2f})-\eta_{3m}$	**F**	**Prob >F**
[3] - FD- IV-GMM										
Productivity										
Men 50-64 (η_{3m})	-0.037									
	(0.027)									
Women 30-49 (η_{2f})	-0.119***	-0.195**	6.67	0.0098	-0.112	2.57	0.1089	-0.075	0.89	0.3452
	(0.045)									
Women 50-64 (η_{3f})	-0.232***									
	(0.070)									
Prod.-Lab. Costs ratio										
Men 50-64 (η^{R}_{3m})	-0.002									
	(0.037)									
Women 30-49 (η^{R}_{2f})	-0.076**	-0.178*	5.91	0.015	-0.104	2.35	0.1257	-0.102	1.72	0.1891
	(0.044)									
Women 50-64 (η^{R}_{3f})	-0.180***									
	(0.068)									
#obs	50,176									
[4]- FD + ACF intermediate inputs LP[$]										
Productivity										
Men 50-64 (η_{3m})	-0.154***									
	(0.034)									
Women 30-49 (η_{2f})	-0.050	-0.227**	6.88	0.0087	-0.331***	11.61	0.0007	-0.177	2.67	0.1022
	(0.055)									
Women 50-64 (η_{3f})	-0.381***									
	(0.080)									
Prod.-Lab. Costs ratio										
Men 50-64 (η^{G}_{3m})	-0.088***									
	(0.024)									
Women 30-49 (η^{G}_{2f})	0.003	-0.123	2.55	0.1106	-0.214*	5.52	0.019	-0.126	1.60	0.2056
	(0.044)									
Women 50-64 (η^{G}_{3f})	-0.211**									
	(0.070)									
#obs	38,296									

Controls: capital, number of employees, hours worked per employee, share of blue-collar workers, share of managers + firm fixed effects. **FD-IV-GMM**: Instruments=second differences and lagged second differences. Tests: IV relevance: Anderson canon. corr. LR statistic √ Overidentifying restriction: Hansen J statistic √. **FD-ACF**: Innovation in $\omega_{it\perp}$ *lag1-3* labour share, innovation in $\omega_{it\perp}$ *lag1-3* labour shares. **£**:Standard errors estimates are robust to firm-level clustering; ***p < 0.1, **p < 0.05, *** p < 0.01**
$$: Ackerberg, Caves & Frazer.

We have undertaken two further steps in our analysis. First, like in the previous section, we test whether we reach similar conclusions, with regards to those coming from the unbalanced panel used so far, when we restrict the analysis to the (smaller) *balanced* panel[51] sample. Second, and more importantly, we examine whether we reach substantially different conclusions, as to the productivity-labour cost ratio gender asymmetry, when we further restrict the sample to the ***services industry***. We do this because observers *a priori* posit that age and gender should matter less for productivity in a services-based economy than in one where agriculture or industry dominates.

Our main analysis so far has been based on unbalanced panel data that comprise all firms available in our sample. By way of sensitivity analysis we now present the parameter estimates (for models [3][4] and only for the productivity and productivity-labour cost ratio equations[52]) based on balanced panel data, consisting only of firms surveyed in each of the 9 years between 1998 and 2006. This subset comprises 7,933 firms (vs. approx. 9,000 in the unbalanced sample). On average (see Appendix 1 for the details) they are quite similar to those of the unbalanced set, be it in terms of average value-added, labour cost or size...

If anything, the old worker gender asymmetry highlighted with the unbalanced panel now appears stronger. Parameter estimates are exposed on the right-hand side of Table 7, alongside those of Table 6 for comparison purposes. For old men, productivity-labour cost parameter estimates (η^R) delivered by model [3] are consistently not statistically different from zero, whereas FD-ACF [4] suggests a small negative impact of -0.6% (vs. -0.88% with the unbalanced panel. By contrast, for older women, both models deliver coefficients that are larger in magnitude than with the unbalanced panel. FD-IV-GMM [3] shows that a 10%-points expansion of their share in the firm's workforce causes a 2.19% reduction (vs. 1.8% with the unbalanced panel), while FD-ACF model [4] points at 3 % fall (vs. 2.11% with the unbalanced panel).

Table 7 also contains the results of three cross-gender tests of equality. In short, these tend to reinforce the conclusions obtained with the unbalanced panel. First, old women (50-64) appear significantly less productive and less employable than old men. Results, for FD-IV-GMM [3],point to a 2.44% productivity handicap (vs. 1.95% with the unbalanced panel) of old women relative to old men. In terms of employability the old women's handicap is of 2.4%- (vs. 1.78% in Table 6). And both estimates are statistically significant at the level of 5 percent. Similar rises of the productivity handicap are observed when using FD-ACF[4].

The other results on display in Table 7, using prime-age women as a reference, confirm that age

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51 The sample of firms that are observed observed *every* year between 1998 and 2006.

52 Those from the labour cost equation (η^W) can be easily inferred from the relationship $\eta + \eta^W \approx \eta^R$

negatively affects the productivity [employability] of women. Results for FD-IV-GMM [3] point to a, now statistically significant, 1.71% (vs. 1.11 %-points with unbal. data) productivity handicap.. In terms of employability, the handicap rises from 1.04% (unbal.) to 1.64% with the balanced panel, and also becomes statistically significant.. Similar results are obtained with FD-ACF model [4], namely a (highly statistically significance) productivity handicap rising from 3.31% (unbal.) to 4.58%; and an employability handicap going from 2.14% (unbal.) to 3.83%. There is also stronger evidence, based of the "within gender" comparison of coefficients, that age affects more women's than men's productivity[employability]. Results, in the last column of Table 7 show female productivity[employability] handicaps that are systematically above 1.5%. And most of them are now statistically significant at the level of 5 percent.

Table 7 – Parameter estimates (*standard errors*£) and hypothesis testing. Older (50-64) male/female and prime-age (30-49) female workers productivity (η), average labour costs(η^w) and productivity-labour cost ratio (η^R). Balanced panel sample.

	Coefficient	Coef. (bal.)	Hyp Test $\eta_{3f}=\eta_{3m}$ (old women vs old men)			Hyp Test $\eta_{3f}=\eta_{2f}$ (old women vs prime-age women)			Hyp Test $\eta_{3f}-\eta_{2f}=\eta_{3m}$ (within gender ageing		
			$\eta_{3f}-\eta_{3m}$	F	Prob >F	$\eta_{3f}-\eta_{2f}$	F	Prob >F	$(\eta_{3f}-\eta_{2f})-\eta_{3m}$	F	Prob >F
[3] FD- IV-GMM											
Productivity											
Men 50-64 (η_{3m})	-0.037	-0.025									
	(0.027)	*(0.038)*									
Women 30-49 (η_{2f})	-0.119***	-0.098**	-0.244**	9.96	0.0016	-0.171*	5.72	0.0168	-0.146	3.21	0.0734
	(0.045)	*(0.046)*									
Women 50-64 (η_{3f})	-0.232***	-0.269***									
	(0.070)	*(0.072)*									
Prod.-Lab. Costs ratio											
Men 50-64 (η^R_{3m})	-0.002	0.022									
	(0.037)	*(0.037)*									
Women 30-49 (η^R_{2f})	-0.076**	-0.055	-0.241**	10.26	0.0014	-0.164*	5.58	0.0182	-0.186*	5.52	0.0189
	(0.044)	*(0.045)*									
Women 50-64 (η^R_{3f})	-0.180***	-0.219***									
	(0.068)	*(0.070)*									
#obs	50,176	46,882									
[4]- FD + ACF intermediate inputs LP$											
Productivity											
Men 50-64 (η_{3m})	-0.154***	-0.110**									
	(0.034)	*(0.042)*									
Women 30-49 (η_{2f})	-0.050	0.049	-0.299**	8.29	0.004	-0.458***	12.93	0.0003	-0.348*	5.49	0.0191
	(0.055)	*(0.071)*									
Women 50-64 (η_{3f})	-0.381***	-0.409***									
	(0.080)	*(0.092)*									
Prod.-Lab. Costs ratio											
Men 50-64 (η^R_{3m})	-0.088***	-0.060*									
	(0.024)	*(0.029)*									
Women 30-49 (η^R_{2f})	0.003	0.083	-0.240**	7.10	0.0077	-0.383***	12.78	0.0004	-0.323**	7.03	0.0080
	(0.044)	*(0.055)*									
Women 50-64 (η^R_{3f})	-0.211**	-0.300***									
	(0.070)	*(0.078)*									
#obs	38,296	35,776									

Controls: capital, number of employees, hours worked per employee, share of blue-collar workers, share of managers + firm fixed effects. **FD-IV-GMM**: Instruments=second differences and lagged second differences. Tests: IV relevance: Anderson canon. corr. LR statistic √ Overidentifying restriction: Hansen J statistic √. **FD-ACF**: Innovation in $\omega_{it\perp}$ *lag1-3* labour share, innovation in $\omega_{it\perp}$ *lag1-3* labour shares. **£**:Standard errors estimates are robust to firm-level clustering; ***p < 0.1, **p < 0.05, *** p < 0.01**
$$: Ackerberg, Caves & Frazer.

Secondly, we have re-estimated the average productivity and productivity-labour cost ratio equations (using the balanced panel data), but now isolating the services industry.[53] Remember that we do so because many observers posit that age and gender differences probably matter less for productivity in a service-based economy than in one where industry dominates. Another good reason for focusing on services is that women are overrepresented in that industry, in comparison with construction or manufacturing.

Parameter estimates from models [3] [4] are reported on the right-hand side of Table 8, alongside those presented in Table 6 and Table 7; again to facilitate comparison. The key result is that the important gender asymmetry emerging from the analysis of the panel pooling all sectors is reinforced when using services-only data. For older women, both model [3] and model [4] deliver productivity (η) and employability coefficients (η^R) that are of larger magnitude than those displayed in Tables 6 or 7 (all sectors pooled). FD-IV-GMM [3] shows that a 10%-points expansion of their share in the firm's workforce causes a 3.57% reduction of labour productivity (vs. 2.69% with the bal. & all sectors polled data), whereas FD-ACF model [4] points at a 6.43% reduction (vs. 4.09% with the bal. & all sectors polled data).

Table 8 also contains the results of the three important cross-gender tests of equality. And once again, the previous conclusions get reinforced. First, old women (50-64) appear less productive and less employable than old men. Results, for FD-IV-GMM [3], show a 3.05% productivity handicap (vs. 2.44% with the bal. & all sectors polled data of Table 7) for old women, with respect to their male counterpart. As to employability, the old women's handicap reaches 3.71% (vs. 2.41% in Table 7). The other results displayed in Table 8 also strengthen the idea that age is particularly harmful to women's productivity[employability]. Results for FD-IV-GMM [3] point to a 2.28% (vs. 1.71% when with the bal. & all sectors polled data) statistically-significant productivity handicap for old women relative to prime-age ones. In terms of employability, the handicap rises from 1.64% to 2.45%. Similar results are obtained with ACF model [4]. There is also evidence - though more limited due to less accurate estimates - that age is more of an issue for women's than men's productivity[employability] in the services industry than in the overall private economy.

The tentative conclusion is that the (now dominant and highly feminized) services industry does not seem to offers working conditions to older women, mitigating their productivity or employability disadvantage vis-à-vis other categories of workers.

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[53] A detailed in terms of NACE 2 categories is to be found in Appendix 2. Manufacturing and construction are excluded. We also exclude observations from the financial/insurance industry, real estate, utilities and a few other activities that can be associated with the non-profit sector. We do this because the productivity and capital of firms in these service industries are, arguably, hard to measure.

Table 8 - Parameter estimates (*standard errors*£) and hypothesis testing. Older (50-64) male/female and prime-age (30-49) female workers productivity (η), average labour costs(η^W) and productivity-labour cost ratio (η^R). Balanced panel sample, services industry.

	Coefficient	Coef. (bal.)	Coefficient (bal. SERVICES)	Hyp Test $\eta_{3f}= \eta_{3m}$			Hyp Test $\eta_{3f}= \eta_{2f}$			Hyp Test $\eta_{3f}-\eta_{2f}=\eta_{3m}$		
				$\eta_{3f}- \eta_{3m}$	F	Prob >F	$\eta_{3f}- \eta_{2f}$	F	Prob >F	$(\eta_{3f}-\eta_{2f})-\eta_{3m}$	F	Prob >F
[3] FD- IV-GMM												
Productivity												
Men 50-64 (η_{3m})	-0.037	-0.025	-0.052									
	(0.027)	*(0.038)*	*(0.054)*									
Women 30-49 (η_{2f})	-0.119***	-0.098**	-0.129**	-0.305**	9.13	0.0025	-0.228*	5.93	0.0148	-0.175	2.61	0.1059
	(0.045)	*(0.046)*	*(0.060)*									
Women 50-64 (η_{3f})	-0.232***	-0.269***	-0.357***									
	(0.070)	*(0.072)*	*(0.092)*									
Prod.-Lab. Costs ratio												
Men 50-64 (η^R_{3m})	-0.002	0.022	0.037									
	(0.037)	*(0.037)*	*(0.052)*									
Women 30-49 (η^R_{2f})	-0.076**	-0.055	-0.089	-0.371***	14.56	0.0001	-0.245**	7.39	0.0066	-0.282**	7.25	0.0071
	(0.044)	*(0.045)*	*(0.058)*									
Women 50-64 (η^R_{3f})	-0.180***	-0.219***	-0.334***									
	(0.068)	*(0.070)*	*(0.089)*									
#obs	50,176	46,882	23,574									
[4]- FD + ACF intermediate inputs LP$												
Productivity												
Men 50-64 (η_{3m})	-0.154***	-0.110**	-0.224**									
	(0.034)	*(0.042)*	*(0.082)*									
Women 30-49 (η_{2f})	-0.050	0.049	-0.173	-0.418*	4.65	0.031	-0.470*	4.21	0.0403	-0.246	0.84	0.3597
	(0.055)	*(0.071)*	*(0.120)*									
Women 50-64 (η_{3f})	-0.381***	-0.409***	-0.643***									
	(0.080)	*(0.092)*	*(0.169)*									
Prod.-Lab. Costs ratio												
Men 50-64 (η^R_{3m})	-0.088***	-0.060*	0.011									
	(0.024)	*(0.029)*	*(0.073)*									
Women 30-49 (η^R_{2f})	0.003	0.083	-0.237*	-0.387*	4.02	0.0451	-0.139	0.27	0.603	-0.150	0.27	0.6007
	(0.044)	*(0.055)*	*(0.116)*									
Women 50-64 (η^R_{3f})	-0.211**	-0.300***	-0.377**									
	(0.070)	*(0.078)*	*(0.171)*									
#obs	38,296	35,776	18,265									

Controls: capital, number of employees, hours worked per employee, share of blue-collar workers, share of managers + firm fixed effects. **FD-IV-GMM**: Instruments=second differences and lagged second differences. Tests: IV relevance: Anderson canon. corr. LR statistic √ Overidentifying restriction: Hansen J statistic √. **FD-ACF**: Innovation in $\omega_{it\perp}$ *lag1-3* labour share, innovation in $\omega_{it\perp}$ *lag1-3* labour shares. **£**:Standard errors estimates are robust to firm-level clustering; ***p < 0.1, **p < 0.05, *** p < 0.01**

$$: Ackerberg, Caves & Frazer.

iv) Final comments about gender

A greying European workforce should also become more female. There is indeed robust evidence that older women are still under-represented in employment in comparison with older men. But this should change due to the combined effect of two elements. First, participation rates in the 50-60 age range will partially align with those currently observed in some Nordic countries (Sweden, Iceland), because successive cohorts of women with an increasing history of youth and prime-age participation are reaching older ages. Second, labour policy will try to close the gender participation gap that persists beyond 50, independently of the above-mentioned trend.

Optimists may believe that an ageing and feminized workforce will have only a minimal impact on firms' performance and on labour markets. This section presents evidence, based on the analysis of private-economy firm-level panel data, suggesting the opposite. We show that the age/gender structure of firms located in Belgium is a key determinant of their productivity-labour cost ratio. Employing a larger share of female workers aged 50-64 could translate *ceteris paribus* a lower markup between productivity (ie value added) and labour cost.

Our results show that, using prime-age men as a reference, an increase of 10%-points in the share of older female workers (50-64) depresses firms' productivity-labour cost ratio by 1.8 to 2.1%, depending on the estimation method and the sample chosen. The equivalent results for old men a moderate reduction in the productivity-labour cost ratio ranging from 0 to 0.88%. A closer look at the results reveals three important things.

First, the handicap of old female workers vis-à-vis old male workers is driven by a lower productivity that is not compensated for by lower average labour costs.

Second, older women are, collectively, less productive and employable than prime-age women.

Third, some of our results – obtained when focussing on balanced panel data and the service industry data - also support the idea that age affects women's productivity[employability] more than men's. In short, older women's employability handicap vis-à-vis older men stems from a productivity handicap caused by a more pronounced effect of age, which is not compensated by lower labour costs.

There is no doubt that welfare institutions played a role in lowering the country' supply of old labour, and have contributed to its low employment rate, singularly amongst women. According to Eurostat, in the first quarter of 2010, only 36% of individuals aged 55-64 were employed; which is 11.1%-points lower than the European average (EU 15). What is more, old women's employment rate (barely 30%) lags behind that of men (44%). In Belgium, qualifying for early retirement benefits was, until very recently, indeed relatively easy by international standards. While the age of 58 was *a priori* the minimum access age, a lower age of 55, 56 or 57 was possible in some sectors (steel, glass, textile, etc.). Even more pronounced reductions in the minimum age were possible for companies in need of thorough overhaul,, under which circumstance the age could be brought down to 52 years, or even 50.

These social welfare determinants of the supply of old labour have traditionally been emphasized by economists to explain the country's particularly low employment rate among individuals aged 50 and over. Our main point here is that the latter could also be demand-driven. Firms based in Belgium face financial disincentives to employing older workers - particularly older women.

To conclude, we would like to elaborate on some of the reasons that could explain the old female (relative) handicap highlighted in this paper, particularly the factors driving their apparent productivity handicap.

Selectivity bias could be less pronounced for older women. Remember that the worker sample that used in this paper might not be representative of the entire population of older individuals aged 50-64. This means that there is a risk of a *selection bias*, in particular due to early ejection from the workforce of less productive/motivated older (male or female) workers., meaning that we a priori *underestimate* the productivity (and possibly also the employability) handicap of older workers. This said, our data show that in Belgium, between 1996 and 2006, there has been a more pronounced rise of employment among older women than older men. If only a fraction of that extra rise can be ascribed to the 1997 pension reform - lifting the legal age of retirement of women to align it on the one applicable to men - then part of the female productivity handicap, as identified it in this paper, could be the consequence of a exogeneous "natural experiment". Consequently, the tendency of our coefficients to *underestimate* the productivity handicap of older individuals could be less pronounced for older women than older men. Simply said, our estimates of the firm-level performance of older female workers could better reflect the actual productivity performance of older individuals than the estimates we get from the observation of older male workers.

Gender health gap could also be an issue (van Oyen *et al.*, 2010; Case & Paxson, 2004). Women in Belgium – as in the US and many other advanced economies - have worse self-rated health, visit GPs more often, and have more hospitalization episodes than men, from early adolescence to late middle age[54]. This said, the existing evidence suggests that this health gender gap tends to shrink when individuals turn 50 and more.

Lastly, in Belgium, like throughout much of the OECD, more and more people aged 50-64 need to provide *informal care to their old parents* aged 70+[55] while, perhaps, they are still intensively supporting their children who, for example, need baby-sit help. The point is that informal carers are predominantly female aged 50-64 (OECD, 2011). Caring responsibilities may cause burnout and stress, and lead to a lower attachment to the labour force, that is not properly captured by our data. All this could ultimately translate in to lower firm-level productivity.

4.4. Blue- vs white-collar labour contracts

Here we look at another very important distinction the Belgian context: that between workers (or blue collars) and employees (or white collars). This distinction cuts across two major categories of employment contracts: the blue-collar contracts (applicable mostly to manual functions) and employees (primarily intellectual functions). We consider that distinction in the light of age-related productivity-labour cost issues.

The correspondence blue-collar contract = manual work performed by individuals with little education vs. white-collar contracts = intellectual work performed by individuals more educated suffers more and more exceptions. However, we propose to use it to test the hypothesis of a differentiated effect of age on employability.

Our key motivation is that of an institutionally-based difference in the way seniority (presumably strongly correlated to age) affects labour costs. Many industrial/sectoral wage agreements only apply to blue- or white-collar contract. An seniority wage rules are predominantly defined in these agreements in Belgium.

As far as we now, sector agreements applicable to blue-collar contracts consists of wage ladders organizing wage progressing by reference to the category of task (importance, complexity) executed by the worker. The point is that there is no explicit reference to seniority. And this is in sharp contrast with the regime applicable to those employed under a white-collar labour contract. For the latter, seniority-wage progression is explicit and mechanical (BNB, 2010). And we conclude that this heteterogeneity in terms of labour contracts applicable to different segments of the labour force could translate into statistically significant differences as to the degree of alignment of productivity and labour costs.

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54 But they are less likely to die at each age.

55 Which is, incidentally, another striking manifestation of ageing.

The methodology of analysis remains similar to the one used so far. We only report here some stylized facts and the key econometric results. Table 1 informs about the level and the evolution of the respective shares of white- vs blue-collars contracts in our Bel-first/Carrefour data basis. The overall ageing trend is to be found in both categories of workers, almost identically.

Table 1. Share of blue- vs white-collar contracts according to the age group. Belgian private economy(1998-2006)

Year	Blue-collar contracts			White-collar contracts		
	18-29 year	30-49 year	50-64 year	18-29 year	30-49 year	50-64 year
1998	26.84%	23.35%	6.62%	21.79%	16.01%	5.43%
1999	25.61%	23.81%	6.98%	21.41%	16.55%	5.66%
2000	24.62%	23.84%	7.27%	21.27%	17.05%	5.95%
2001	23.19%	23.96%	7.67%	21.10%	17.82%	6.29%
2002	21.96%	24.09%	8.05%	20.72%	18.65%	6.55%
2003	20.57%	23.98%	9.17%	20.13%	19.13%	7.03%
2004	19.74%	24.07%	9.68%	19.48%	19.68%	7.35%
2005	18.85%	24.09%	10.17%	18.88%	20.33%	7.71%
2006	17.84%	23.60%	10.76%	18.56%	21.05%	8.20%

Source : Bel-first/Carrefour

The econometric results are reported in Table 2. The most reliable ones from an econometric point of vue are to the right. They correspond to the implementation of the S-GMM and DP-ACF methods discussed in the previous sections, which control for both heterogeneity (i.e. firm fixed-effects) and simultaneity.

The main observation is that both methods conclude to a lesser alignment of labour cost on productivity for white-collar workers. Indeed, whereas a 10%-point rise of the share of blue-collar workers leads to a limited fall of the productivity-labour cost ratio (from -0.02% to -0.67%), a similar increment of the share of white-collar workers translates into a more significant reduction of that ration (from -1.07% to 2.42%). The tentative conclusion is that seniority wages, as currently implemented for white-collar workers in Belgium, are detrimental to their employability beyond the age of 50.

These results must be considered carefully. However; it they are worth considering in the ongoing debate on how to abolish the distinction between white- and blue-collar employment contracts. The current state of affairs is that blue-collar contracts seem to be better at preserving employability among ageing workforces.

Table 2: Estimated coefficients (standard-errors[£]). Share of older workers(50-64) ***blue- vs. white-collar contracts*** *and productivity-labour cost ratio (η^{G}_{3})*

	[1]-OLS	[2]-First Differences	[3]-S-GMM	[4]- First Differences + intermediate inputs ACF[$]
Blue collars (η^{G}_{3O})	-0.079***	-0.035	-0.002	-0.067**
std error	*(0.025)*	*(0.030)*	*(0.037)*	*(0.023)*
While collars (η^{G}_{3E})	-0.148***	-0.239***	-0.107***	-0.242***
std error	*(0.022)*	*(0.037)*	*(0.070)*	*(0.037)*
#obs	79,210	69,031	79,229	38,943
Controls	All data are deviations from region+ year interacted with NACE2 industry means. See appendix for NACE2 classification of industries			
	capital, number of employees, hours worked per employee[a], share of blue-collar workers, share of managers + fixed effects: **firm**	capital, number of employees, hours worked per employee[a], share of blue-collar workers, share of managers + fixed effects: **firm**	capital, number of employees, hours worked per employee[a], share of blue-collar workers, share of managers + fixed effects: **firm**	capital, number of employees, hours worked per employee[a], share of blue-collar workers, share of managers + fixed effects: **firm**
Orthogonality conditions/instruments used to identify endog. labour shares			Second differences and lagged second differences	Innovation in ω_{it}⫫ *lag1-3* labour shares Innovation in ωit⫫ lag1-3 labour shares

a: Average number of hours worked by employee on an annual basis, which is strongly correlated to the incidence of part-time work.

£:Standard errors estimates are robust to firm-level clustering

*p < 0.05, **p < 0.01, *** p < 0.001

[$] Ackerberg, Caves & Frazer

4.5. Company-paid training

We try to analyze the role of training. At this stage we have established that the aging and feminizing workforce means lower productivity performance for firms, that is not compensated by lower labour costs. And this may adversely affect the demand for older individuals. A policy to support old labour demand – aimed at preserving or increasing the employment rate of senior individuals could require either *i)* to reform the Belgian wage formation mechanism, in particular seniority-based wage rules *ii)* introduce labor cost subsidies targeted at senior workers (more on this in Section 7).

However, an increased company-based training effort could also combat – at the source - the problem of age-related declining productivity. There is evidence, in Belgium of a causal relationship between the intensity of firm-based training and labour productivity. Konings & Vanormelingen (2011), using Belgian firm-level data find evidence of a positive causal effect of company-based training on the labour productivity of large firms.

On the other hand, international evidence rather supports the view that older employees get relatively less training (or less effective training) than younger employees (D´Addio, Keese & Whitehouse, 2010). *Ceteris paribus*, this should rather increase older workers employability handicap.

Our empirical strategy to examine this question is to use information about company-based (and -financed) training gathered in the Social Report (available in Bel-first). But this can now be done using matched employer-employee data and the adequate methodology. Since 2008, the level of education of workers is available in the Bel-first data. Bel-first also contains, as a supplement to firms' annual income statement, information on various elements of training, such as the proportion of workers that received training, the number of hours they were trained and the cost of training to the employers. These items can be used to assess the effect of on-the-job or company-based training of productivity.

But unfortunately Bel-first does not inform about how training is distributed across age groups inside firms. What is more, many firms do not report their training effort. We therefore need to restrict the analysis to those of the firms in Bel-first that constantly – ie. over the 9 years forming our panel – report positive spending on training. We then isolate those who declare spending more that 1% of the overall payroll cost.

Key results are reported in Table 1. The first column reproduces the results of Section 3, based on the unrestricted data set. The ones obtained with the sub-sample of firms that consistently report training spending in Bel-first are reported in the two columns to the right. As announced, we distinguish those that report reliable training data (A) and those, less numerous, that report training expenses at least equal to 1% of the overall labour costs (B).

The main result is that our two preferred econometric methods point at a larger productivity handicap of older workers inside firms that spend more on training (B). Estimates delivered by the S-GMM[4] strategy show that a 10%-points rise of the share of older workers causes a fall of firm's overall labour productivity per head of 2.46% among training-intensive firms [B] (vs. 1.92% in the reference group [B]). S-GMM estimates also point at a slightly large employability handicap (i.e. impact of age on the productivity-labour cost ratio) among training-intensive firms (B). The DP-ACF method [5] also highlights a significantly larger productivity handicap inside these firms (B): a 10%-point rise of the share of older workers goes along with a 5.33% fall of labour productivity (vs. 4.32% for the reference group [A]).

Table 1 : Parameter estimates (*standard errors*[£]). Older (50-64) workers productivity (η), and productivity-labour cost ratio (η^R). – *Firms systematically reporting training spending vs . those systematically reporting company-based training equal or above 1% of the overall annual payroll cost*

	Overall unbalance panel (for information)	Firms systematically reporting training spending **(ref.) (A)**	Firms systematically reporting company-based training equal or above 1% of the overall annual payroll cost **(B)**
[4]- System GMM			
Productivity per head. (η_3)	-0.204***	-0.192***	-0.246***
Standard-error	*-0.029*	*-0.036*	*0.045*
Productivity-labour cost ratio ($\eta^G{}_3$)	-0.124***	-0.152**	-0.214***
Standard-error	*-0.027*	*-0.034*	*0.042*
#obs	79,206	56,188	40,413
[5]- First differences + intermediate goods ACF[$]			
Productivity per head. (η_3)	-0.220***	-0.432***	-0.533***
Standard-error	*-0.054*	*-0.056*	*0.078*
Productivity-labour cost ratio ($\eta^G{}_3$)	-0.127***	-0.163**	-0.268***
Standard-error	*-0.021*	*-0.042*	*0.040*
#obs	38,944	28,459	18,674

*p < 0.05, **p < 0.01, *** p < 0.001

$: Ackerberg, Caves & Frazer.

a: Positive spending during at least 8 (out of 9) years forming the panel.

4.6. Evidence of deferred payment?

A last aspect of ageing that we would like to consider is deferred compensation. So far we have produced robust evidence of a (negative) wedge between labour cost and productivity for workers aged more than 50. But we have overlooked the results for young workers.(18-29 ans). Remember that the productivity equation writes:

$$ln(Y_{it}/L_{it})=B+(\alpha-1)l_{it}+\boldsymbol{\eta_1 P_{it}^{18\text{-}29}}+\eta_3 P_{it}^{50\text{-}64}+{}_{+}\beta\, k_{it}+\gamma F_{it}+\varepsilon_{it} \qquad (1)$$

where $P_{it}^{18\text{-}29}$ refers to the share of 18-29 year-olds, and where coefficient $\boldsymbol{\eta_1}$ captures the effect of variations of that share on the firm's overall labour productivity per head. Similarly for the productivity-labour cost equation, we have

$$Ratio_{it}=B^G+(\alpha^G-1)l_{it}+\boldsymbol{\eta^G{}_1 P_{it}^{18\text{-}29}}+\eta^G{}_3 P_{it}^{50\_64}+\beta^G\, k_{it}+\gamma^G F_{it}+\varepsilon^G{}_{it} \qquad (2)$$

with $\eta^G{}_1$ capturing the effect of varying share of young worker on that ratio.

Table 1 contains the estimates of these $\eta^G{}_1$ alongside those for older workers $\eta^G{}_3$. We first comment first those obtained with the overall sample of firms (left part of Table 1). S-GMM results show that a 10% rise of the share of young workers causes a modest by statistically significant rise of the productivity-labour cost ratio of 0.94%. The corresponding effect for older workers is a decline of 1.24%.

This may be interpreted as evidence of the presence of deferred compensation in the Belgian private economy (situations where, wage structures are designed, not to compensate productivity in the short run, but rather to magnify incentives to effort, (Lazear, 1979) and where spells of overpayment at the end of the carriers have been somehow prefinanced during the early moments of the carriers, synonymous with underpayments).

Several restrictions apply however (Vandenberghe, 2011a). First, our DP-ACF do not confirm these results. DP-ACF suggests a 0.85 % rise of the ratio consecutive to a 10%-point rise of the share of young workers, but it is not statistically significant.

Second. We fail to find stronger evidence of deferred compensation mechanisms where we expect them the most: in manufacturing. In the second part of Table 1 (columns to the right) we present the coefficients estimated when using the data from the manufacturing sector exclusively (see appendix for the exact definition).

*Table 1 : Estimated coefficients (standard errors [£]). Older workers (50-64) and **young workers (28-29)**. Productivity-labour cost ratio ($\eta^G{}_3$) and indications of deferred compensation in the Belgian private economy – Overall, unbalanced panel*

	Overall sample of firms		**Manufacturing sector**	
	Young workers (18-29)	**Older workers (50-64)**	**Young workers (18-29)**	**Older workers (50-64)**
[4]- Système GMM				
Prod.-Lab. Costs ratio ($\eta^G{}_3$)	0.094***	-0.124***	0.094***	-0.346***
std error	*(0.019)*	*(0.027)*	*(0.029)*	*(0.040)*
#obs	79.206		24.321	
[5]- First differences and intermediate consumption ACF[$]				
Prod.-Lab. Costs ratio ($\eta^G{}_3$)	0.085	-0.127***	0.064***	-0.132***
std error	*(0.059)*	*(0.021)*	*(0.011)*	*(0.038)*
#obs	38.944		12.728	

$: Ackerberg, Caves & Frazer.

Third. Singularly FD-ACD suggest a productivity handicap for older workers that is much large in magnitude than the productivity advantage applicable to young workers. Remember that the theoretical literature on deferred compensation would still support the idea that, on average over the duration of the employment contract, labour costs should remain in line with productivity. This condition is not met here.

Four. None of the results displayed in Table 1 represent a direct evaluation of the deferred compensation idea. Data requirements to do this sort of evaluation, exceed, by far those of the works done so far. They ideally imply to be able to reconstruct the productivity and pay record of the individuals age 50-64 than we observe here somewhere between the end of the 1990s and the mid-2000s.

Finally. One cannot exclude the more straightforward interpretation of the coefficients of Table 1, which is that they are supportive of an employability advantage of young workers over prime-age one. Along this, rather orthodox line of reasoning, one possible conclusion would then be that older workers suffer from and employability handicap vis-à-vis young workers than is even larger than the one they have vis-à-vis prime-age workers.

5. Conclusions

This research is innovative in several respects. First, it develops a stream of the economics of ageing that has been largely overlooked by economists so far: the importance and the determinants of demand-side barriers to employment among the older segments of the labour force. The bulk of the existing works in economics focus on the challenged posted by ageing in terms of the financial sustainability of the welfare state. Macroeconomists are concerned with its impact on the overall rate of growth of advanced economies. Another well developed strain of the economic literature on ageing examines the retirement behaviour of older individuals and its institutional determinants. The focus there is clear on the supply side of the old labour market. The key assumption is that the low employment rate beyond the age of 50 that has emerged in many advanced economies over the past decades can be explained by things like a high implicit taxation rate on continuing work; itself driven by the generosity of (early)pension or assimilated regimes. However, the consequences of *an ageing workforce* from the point of view of firms, forming the *demand side* of the labour market, have received much less attention, singularly in Belgium. There is comparatively few works in Economics that have looked at evidence of demand-side barriers to employment of individuals aged more than 50.

Second. None of the (few) existing papers has adequately considered the *gender* dimension of ageing, in a context where women are likely to form a growing part of the older labour force. Using, our HN framework we assess the existence of demand-side barriers separately for old men and women.

Third. Training. Many economists have studied either the propensity of firms to invest in training (in a context where human capital is a priori mobile and easy to poach) or the overall effects of training on labour productivity. In this research, we produce preliminary evidence as to the relationship between company-based training and ageing.

Four. Labour contracts. We also produce evidence that labour market institutions play a role in determining the intensity of older workers' employability handicap. Belgium is known for having two rather distinct forms of labour contracts. The first one (historically applicable to white-collar workers) contains an explicit reference to seniority (and thus age) that governs the level of pay. But this is much less the case with the other type of contract (typically used for manual/blue-collar positions), where wages are primarily driven by the content and the complexity of the task. The point is that our estimates on the employability handicap of older workers recoup this institutional distinction..

Five. Methodology. In this research we use the most recent applications of the HN methodology that we apply to panel data that have been first differenced (FD), in order to account for time-invariant unobserved heterogeneity. We also apply two strategies that are aimed at coping with endogeneity/simultaneity. Following many authors in this area (Aubert & Crépon, 2003, 2007; van Ours & Stoeldraijer, 2011; Cataldi, Kampelmann & Rycx, 2011), we first estimate the relevant parameters of our model using "internal" instruments (i.e lagged values of endogenous labour inputs) using so-called System GMM (S-GMM here after). Second, we also implement the more structural approach initiated by Olley & Pakes (1998), further developed by Levinsohn & Petrin (2003) and more recently by Ackerberg, Caves & Frazer (2006) (ACF), which primarily consists of using intermediate inputs to control for short-term simultaneity bias.

We strongly believe that the problem of endogeneity of labour inputs can be addressed using the most recent developments of the proxy-variable approach by ACF. However - unlike ACF and their predecessors - we propose doing this in combination with first differences (FD) to properly account for time-constant unobserved heterogeneity (firm fixed effects). This increases the chance of verifying the key monotonicity assumption required by the ACF approach to invert out the unobserved short-term productivity term, and completely remove the simultaneity bias. Using our Belgian data we show that ACF alone delivers estimates that barely differ from OLS ones, whereas FD-ACF generates results that are similar to those delivered when, after differencing, lagged inputs are used as instruments for changes in the inputs.

The main results of the research are the following

First, the research highlights the importance of properly considering the existence of firm-level demand-side constraints to employing (more) older workers. In the Belgian case, the dominant view among labour economist is that easy access and high replacement rates (Blondäl & Scarpetta, 1999; Jousten et al., 2010) are the key determinant in the drop in the employment rate among older individuals since the mid 1970. We produce robust evidence that demand barriers also exist. We first show that the age structure of firms located in Belgium is a key determinant of their productivity. We also ask whether firms based in Belgium are *a priori* willing to employ more older workers. The answer is no, as we find robust evidence of a negative impact of older workers on the productivity-labour cost ratio: an increment of 10%-points of their share in the firms' workforce causes a 1.2-1.6% contraction. The reason for this is that lower productivity of older workers is not compensated by lower labour costs. We posit that is likely to depress the labour demand for older workers, in particular to compromise their chances of re-employment in case of job loss.

Second. Our results suggest small negative impacts of larger shares of older men on firm's productivity-labour cost ratio. However, there is strong evidence that large shares of older women significantly deteriorate that ratio. This is not good news for older women's employability. Another interesting result is that the vast and highly feminized services industry does not seem to offer working conditions that mitigate older women's productivity and employability disadvantage, on the contrary.

Third. We produce evidence suggesting that current forms of training, inside Belgian firms, do not mechanically compensate for age-related productivity handicaps, on the contrary.

Four. We show that white-collar contracts are correlated with a larger employability handicap that the blue-collar contracts. This support the idea that labour market arrangements play a importing role in supporting (or not) the employability of older workers.

Five. Methodology also matters. In this research we argue that the problem of endogeneity of labour inputs can be addressed using the most recent developments of the proxy-variable approach by Ackerberg, Caves & Frazer (2006). However - unlike ACF and their predecessors - we propose doing this in combination with first differences (FD) to properly account for time-constant unobserved heterogeneity (firm fixed effects). Our key result is that those from the FD-ACF model are very similar to those delivered by FD-IV-GMM but also completely different that those from ACF alone without first differencing.

6. How does this translates into policy-relevant considerations and recommendations?

Most economists believe that the main obstacle to raising the employment rate among individuals aged 50+ is supply-side driven. There is indeed no doubt that welfare institutions played a role in lowering the country' supply of old labour, and have contributed to its low employment rate, singularly amongst women. According to Eurostat, in the first quarter of 2010, only 36% of individuals aged 55-64 were employed; which is 11.1%-points lower than the European average (EU 15). What is more, old women's employment rate (barely 30%) lags behind that of men (44%). In Belgium, qualifying for early retirement benefits was, at least until early 2012, relatively easy by international standards. The age of 58 was *a priori* the minimum access age, but a lower age of 55, 56 or 57 was possible in some sectors (steel, glass, textile, etc.). Even more pronounced reductions in the minimum age were applicable when the company was recognized as being in financial trouble, under which circumstance the age could be brought down to 52 years, or even 50.

These social welfare determinants of the supply of old labour have traditionally been emphasized by economists to explain the country's particularly low employment rate among individuals aged 50 and over. We argue that our research delivers robust evidence that the latter could also be demand-driven.

Firms based in Belgium face financial disincentives to employing older workers - particularly older women. We show that the age structure of firms located in Belgium is a key determinant of their productivity. Rising shares of workers aged 50-65 will, ceteris paribus, translate into lower productivity gains *ceteris paribus*. An increase of 10%-points in the share of older workers (50-65) depresses value-added per worker by 2-2.4%, depending on the estimation method chosen. This corresponds to annual labour productivity gains per year, as recorded during the 2000s.

Another key results - that matters a lot to gauge the capacity of the private sector to absorb a rising number of older individuals in the labour force - is the one on the negative effect of larger shares of older workers on the productivity-labour cost ratio: an increment of 10%-points of their share in the firms' workforce causes a 1.2-1.6% contraction of that ratio. This is conducive of low employability of old workers, and may explain why firms tend to shun them when then turn 50 or recruit very few new recruits belonging to that age bracket.

Our results also show that there is a gender employability gap beyond the age of 50. An increase of 10%-points in the share of older female workers (50-64) depresses firms' productivity-labour cost ratio by 1.8 to 2.1%, depending on the estimation method and the sample chosen. The equivalent results for old men a more moderate reduction in the productivity-labour cost ratio ranging from 0 to 0.88%.

These results, in a context of rising supply of older individuals on the labour marked due to the combined effect of demography and (early)pension reforms, call for policy initiatives aimed at boosting the employability of older workers. Otherwise, there is a big risk of rising unemployment, or a more systematic use of disability benefits schemes, or even poverty for those aged 50+.

We show that the employability of older workers is currently low, due primarily by to a negative effect of age on productivity that is not compensated by lower labour cost. Boosting older individuals' employability can thus be achieved by *i)* raising the numerator (productivity), or *ii)* reducing the denominator (labour cost) or *iii)* a combination of both.

Raising productivity - or more purposely given the evidence accumulated in this report, combating age-related productivity declines - probably calls for a large range of far-reaching initiatives. These include more training targeted at individuals aged 40+. The existing evidence about Belgium suggests that the bulk of training opportunities and resources are concentrated on young and prime-age workers. Efforts are needed to persuade workers and their employers of the need to keep (re)training beyond 50. This probably requires mentality changes as well as a marked reallocation of existing resources. Note that the extension of the career horizon, imposed by the gradual postponement of the end of the carrier, provided it is adequately factored in, should help the stakeholders make the necessary steps into that direction.

Better ergonomics could also play a key role. There is evidence (although somewhat too anecdotal for an economist to be thoroughly convincing) that small changes to the work environment can make a difference. In a recent experiment, BMW decided to staff one of its production lines with workers of and an age likely to be typical at the firm in 2030. At first "the pensioners' assembly line" was less productive. But the firm brought it up to the level of the rest of the factory by introducing 70 relatively small changes, such as new chairs, comfier shoes, magnifying lenses and adjustable tables (The Economist, 2010).

Lower labour costs for older individuals can be achieved in several ways. One is to revised seniority-based wage systems/ladders. These systems are rather common across sectors and industries in Belgium, and probably need to be revisited given the perspective of longer carriers, and also in the light of the econometric results on display here. There is some evidence that seniority-based wage setting is indeed on the wane internationally. In Sweden, for example, seniority clauses pay arrangements have been replaced by merit- or performance-based clauses in the early 1990s. Similarly in Japan (one of the OECD countries most affected by ageing) there is increasing emphasis in the private sector on performance-related pay.

Another option is to lower taxes and social security contributions on older categories of workers. It should ideally be combined with significant productivity-enhancing efforts and a commitment to revised wage ladders by social partners. This is to limit the risk of them free riding the Treasury in order to boost old labour demand. Another point worth considering is that the tax wedge is particularly important in Belgium. It could be probably be reduce to stimulate the demand of older workers. The direct foregone taxes and contributions entailed by these subsidies could be compensated by much lower (early)pensions payments and longer periods of activity and contributions (albeit at la lower rate during workers' final years of activity). A number of countries, including Belgium to a moderate extent (Vandenberghe, 2011a), have taken direct action to reduce the cost of employing older workers through wage subsidies or a reduction in social security contributions. Some of these schemes are simply targeted on age alone, while others also take account of additional characteristics of older workers (low educational attainment, gender...).

Finally, there is a need to develop job-placement services capable of matching the supply and demand sides of the old labour market. The current system of relatively widespread job-search exemptions for unemployed people older than 50 or 55, *de facto*, amounts to an absence of intervention/support by public employment services, and a lack of activation for many unemployed older individuals. But the return to work past 50 is intrinsically more difficult and requires substantial effort and support. There is thus an urgent need to better activate older unemployed people and to support them with adequate job-placement and follow-up services.

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Appendix :

Table 5- Sectors/Industries and NACE2 codes/definitions

NACE2 code		**Industry**
10 to 12	Manufacturing	Manufacture of food products, beverages and tobacco products
13 to 15	Manufacturing	Manufacture of textiles, apparel, leather and related products
16 to 18	Manufacturing	Manufacture of wood and paper products, and printing
19	Manufacturing	Manufacture of coke, and refined petroleum products
20	Manufacturing	Manufacture of chemicals and chemical products
21	Manufacturing	Manufacture of pharmaceuticals, medicinal chemical and botanical pro
22 + 23	Manufacturing	Manufacture of rubber and plastics products, and other non-metallic
24 + 25	Manufacturing	Manufacture of basic metals and fabricated metal products
26	Manufacturing	Manufacture of computer, electronic and optical products
27	Manufacturing	Manufacture of electrical equipment
28	Manufacturing	Manufacture of machinery and equipment n.e.c.
29 + 30	Manufacturing	Manufacture of transport equipment
31 to 33	Manufacturing	Other manufacturing, and repair and installation of machinery and e
35	Utilities	Electricity, gas, steam and air-conditioning supply
36 to 39	Utilities	Water supply, sewerage, waste management and remediation
41 to 43	Construction	Construction
45 to 47	Services	Wholesale and retail trade, repair of motor vehicles and motorcycles
49 to 53	Services	Transportation and storage
55 + 56	Services	Accommodation and food service activities
58 to 60	Services	Publishing, audiovisual and broadcasting activities
61	Services	Telecommunications
62 +63	Services	IT and other information services
64 to 66	Finance/insurance	Financial and insurance activities
68	Services	Real estate activities
69 to 71	Services	Legal, accounting, management, architecture, engineering, technical
72	Services	Scientific research and development
73 to 75	Services	Other professional, scientific and technical activities
77 to 82	Services	Administrative and support service activities
90 to 93	Services	Arts, entertainment and recreation
94 to 96	Services	Other services
97 to 98	Non-profit	Activities of households as employers; undifferentiated goods

99	Non-profit	Activities of extra-territorial organisations and bodies