RIGID WAGES AND FLEXIBLE EMPLOYMENT?
CONTRASTING RESPONSES TO FIRM-LEVEL AND
SECTOR-LEVEL PRODUCTIVITY DEVELOPMENTS*

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ABSTRACT:
We evaluate the elasticity of firms’ employment and real average labour compensation to total factor productivity (TFP) using firm-level data for Belgium over the period 1997-2005. Our results show that the short-run elasticity of average labour compensation and that of labour to firm-level TFP are positive but relatively low. However, the long-run elasticity of labour is much higher than that of average labour compensation, consistent with real wage rigidity. Further, while the elasticity of average labour compensation to firm-level TFP is close to zero, the elasticity with respect to sector-level TFP is substantially higher. Lastly, our results indicate that adjustment to sector-level TFP occurs through coordinated wage decisions embodied in sector-level collective agreements.

JEL: J30, J50, J60.

Keywords: real labour compensation, employment, Total Factor Productivity, firm-level panel data.

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Introduction

This paper examines the response of firms' real average labour compensation and firms' employment to Total Factor Productivity (TFP) at the microeconomic level. We distinguish between idiosyncratic (firm-level) TFP and aggregate (sector-level) TFP and between short-run and long-run effects. While comparing the elasticity of average labour compensation and labour to firm-specific TFP and to sector-level TFP, we also discuss the role of centralised wage bargaining.

First, we compare the elasticity of average labour compensation and labour to firm-specific TFP. This can be related to the existence of real wage rigidity and employment adjustment costs. There are several reasons for wage rigidity and it can manifest itself in various ways, as documented in recent microeconomic research. One particular feature of the Belgian labour market is full automatic indexation of base wages. This has been pointed out as a source of real wage rigidity. It motivates our focus on adjustment of real, as opposed to nominal, labour compensation. Theoretical models incorporating real wage rigidity typically find that wages have a smaller and more sluggish response to economic shocks while employment exhibits larger variability in response to productivity shocks, as compared to the flexible wage scenario (see, for example, Boldrin and Horvath, 1995; Hall, 2005). In addition to wage rigidities, other frictions alter the functioning of labour markets. Hiring and firing costs together with training expenses may generate employment adjustment costs that impede labour adjustment. The impact of such adjustment frictions on employment goes against the effect of wage rigidity.

Second, we compare the elasticity of average labour compensation to firm-specific TFP and to sector-level TFP. These elasticities may be affected by economic structures and institutional features of the labour market. In particular, stronger competition on the labour market may reduce the sensitivity of wages to firm-level TFP. Isolated wage cuts may not be desirable if firms compete for workers on the labour market, due to efficiency wage considerations and efforts to minimise the

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1 Multi-period contracts, implicit contracts, efficiency wages etc. may imply that wages do not respond to contemporaneous shocks. The resistance to wage cuts may imply reduced sensitivity to adverse shocks. This so-called downward wage rigidity may even reduce the sensitivity of wages to favourable shocks (Elsby, 2006). A sluggish response of wages may also be the outcome of wage bargaining between risk-averse workers and risk-neutral firms, leading to "wage insurance" (Azariadis, 1975).

2 Guiso et al. (2005), Cardoso and Portela (2005) and Katay (2009) provide microeconomic evidence that firms do insure workers against temporary firm-specific shocks to productivity. Evidence on downward wage rigidity in Belgium can be found in Dickens et al. (2006, 2007), Du Caju et al. (2007), Holden and Wulfsberg (2008), Knoppik and Beissinger (2005), and Messina et al. (2010).

3 In an economy with positive inflation and no automatic indexation, real wages can be reduced by maintaining nominal wages constant. This is impossible when wages are automatically and fully indexed to price developments, as discussed in de Walque et al. (2010). Babecký et al. (2010) report that estimates of downwards real wage rigidity obtained by Messina et al. (2010) for a set of countries and sectors are positively correlated with the percentage of firms that declare that nominal wages are a function of inflation.

4 To the best of our knowledge, only Carlsson et al. (2011) estimate the effect of firm-level and sector-level productivity on workers' wages. In contrast to this paper, Carlsson et al. (2011) focus on job stayers.
risk of on-the-job shirking or job quits. By contrast, the elasticity of wages to sector-level TFP may be high because coordinated wage actions in response to common TFP variations make it possible to internalise the externalities of wage changes and alleviate the above-mentioned impact of competition. Coordination, in turn, is facilitated in economies with centralised collective wage bargaining, as is the case in Belgium where sector-level collective wage agreements play a major role in wage-setting.

With respect to the above discussion, we note that Belgian labour market features make it a suitable country to analyse the role of wage rigidity, centralised wage bargaining and low employment protection. Belgium is typically characterised as a country with real wage rigidity and important role of sector-level collective bargaining in wage-setting. According to the OECD Employment Protection Legislation indicator, employment protection for permanent workers in Belgium is below the average, and although it is higher for temporary employment, this only concerns a small fraction of the workforce compared to other European countries.

In order to obtain the elasticities discussed above, we estimate dynamic models for average labour compensation and employment. Our approach is purely empirical but the specification resembles those derived by Arellano and Bond (1991), Nickell and Nicolitsas (1999), Funke et al. (1999) or Hernando and Martínez-Carrascal (2008) and others. The main variables are obtained from companies' annual accounts and social balance sheets recorded in Belgium over the period 1997-2005. TFP is measured using the methodology of Ackerberg et al. (2006). Note that we use firm-level information on average labour compensation rather than individual earnings data. The advantage of using individual earnings data is that changes in wages cannot be confused with changes in the workforce composition. The main drawback is that wage changes can only be constructed for job stayers, while our approach also takes into account newly hired workers and workers that leave the firm together with job stayers when measuring average labour compensation changes. Our empirical analysis evaluates how average labour compensation varies following a TFP shock. In order to take into account changes in the composition of the labour force that might have an impact on firm's productivity, we include a set of control variables for labour force composition in our labour compensation models, as in Carneiro and Portugal (2008). More precisely, we control for the fraction of part-time workers, the percentage of women, the fraction of blue-collar workers, together with proxies for short superior education and for university education.

Our results may be summarised as follows. First, we examine the relative sensitivity of average labour compensation and labour to firm-specific TFP changes. Our estimates indicate that the short-run (or within the year) elasticity of average labour compensation to TFP and the elasticity of labour are both fairly low. In the long run, as the effect cumulates over the years, the response of labour to firm-specific TFP is much larger than the response of labour compensation, in line with the

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5 This argument can be traced back to Bruno and Sachs (1985) who find that countries with more centralised wage bargaining find it easier to adjust real wages to adverse macroeconomic shocks.
existence of real wage rigidity. Second, we contribute to the literature by comparing
the elasticity of average labour compensation to firm-specific TFP and sector-level
TFP. We find that the elasticity of average labour compensation to sector-level TFP
is much higher than that to firm-level TFP. Third, we relate this finding to the fact
that wage dynamics in Belgium is mostly driven by sector-level collective
agreements.

This paper is organised as follows. Section 1 provides a brief overview of Belgian
labour market institutions, introduces the data and describes the methodology.
Section 2 presents our main results and the conclusion.

1. INSTITUTIONS, DATA AND METHODOLOGY

Institutional features of the Belgian labour market

In this section, we briefly introduce the main features of the Belgian labour market
that are relevant for the interpretation of our results. Notable characteristics of the
wage formation process in Belgium include the minimum wage, automatic
indexation of the base wage, a cap on average wage increases, and sectoral
collective wage bargaining.

Wage setting in Belgium may be described as the outcome of three mechanisms.
First, a prominent feature is the full automatic indexation of nominal gross wages to
the so-called health index, which is the consumer price index excluding alcoholic
beverages, tobacco and motor fuels. This impedes real wage reductions for job
stayers through the pace of inflation. Second, the so-called wage norm, set at the
national level, is a recommended maximum nominal hourly labour compensation
increase. It is set by an interprofessional agreement for two years and takes into
account, among others, the predicted indexation and evolution of labour costs of
Belgium's main trading partners (namely Germany, France and the Netherlands).
Third, sector-level collective wage bargaining between trade unions and employers’
representatives plays a major role in the wage formation process and covers vast
majority of firms. According to the survey conducted by Druant et al. (2008),
bargaining at sectoral level concerns 98% of Belgian firms. These agreements are
typically organised separately for white-collar workers and blue-collar workers
every two years. They determine various aspects of compensation, such as pay
scales and real wage increases, which often consist of an absolute raise in the
minimum pay scale, as well as other aspects, such as training or mobility. Pay
scales set a minimum wage by sector and occupation and vary with age or tenure
for white-collar workers and some blue-collar workers. On top of this, a minority of
companies engage in firm-level wage bargaining. In the manufacturing, energy,
construction and business service sectors approximately 16% of companies
concluded firm-level wage agreements covering slightly over 20% of overall
employment between 1999 and 2005 (larger firms being more likely to engage in
firm-level bargaining).\footnote{Data on coverage of firm level agreements come from the Structure of Earnings Survey for the years 1999 to 2005.} Several papers have shown that firm-level bargaining is
associated with higher wages (e.g. Plasman et al., 2007 or Rycx, 2003, for Belgium). These papers are, however, silent as to whether this induces more wage flexibility in response to productivity changes. Finally, note that for companies with 50 or more employees union representation, works councils7 and worker involvement within the firm are compulsory. Trade union participation is stronger and better structured in firms employing 100 or more people.8 These features explain why Belgium has substantial real wage rigidity. However, it should be noted that labour compensation involves extra-wage components such as bonuses and premiums, which make total compensation more flexible than the base wage.

Employment developments over the last decade have been characterised by changes in the labour force composition. Trends include a smaller proportion of blue-collar workers in private sector employment (from 54% in 1990 to 49% in 1997 and 46% in 2005 according to social security statistics), an increasing fraction of part-time workers (accounting for 13.5% of employment in 1990, 16.3% in 1997 and 18.1% in 2005; OECD, 2002; 2004; 2006), and a slightly higher number of employees with fixed-term contracts. Fixed-term contracts represent only a small proportion of wage earners in Belgium, 6.3% in 1997 and 8.8% in 2005, in comparison with EU average of 12% in 1997 and 14% in 2005 (Eurostat’s New Cronos database).

Among OECD member states, Belgium has a slightly higher than average degree of employment protection legislation. This is a result of a below average protection of regular employment and an above average protection of temporary jobs and specific requirements for collective dismissals (see OECD, 2004). On the other hand, flexibility of the labour market is enhanced by early retirement procedures. For firms in distress or in the process of restructuring, early retirement is possible under specific conditions for workers aged 50 and older.

Data and variables definition

The main variables of interest related to labour compensation are taken from firms’ annual accounts. Almost all firms in Belgium have to file their annual accounts with the Central Balance Sheet Office. In this paper we focus on the manufacturing, construction and market services sectors. We perform a range of consistency checks to identify possible data issues and exclude extreme observations as outliers. We consider only firms with at least 50 employees.9 In our analysis, we estimate dynamic equations of employment and labour compensation by System GMM. To make sure that sufficient history is available to build lagged instruments, we

7 The works council is jointly composed of employee representatives and management staff. Its aim is to provide a forum for consultation and negotiation between employers’ and employees’ representatives.
8 In firms with a workforce of more than 100, employees’ representatives in the works council have to be elected every four years; in smaller firms, the representatives’ mandate is simply renewed.
9 We prefer to disregard smaller firms because their employment dynamics may be specific, among others due to labour indivisibility issues. Our preliminary estimates, not reported here, indicate that the elasticity of labour to TFP is higher for larger firms. This is also supported by the results of a recent survey for Belgium (Druant et al., 2008).
consider only trajectories with at least 6 consecutive observations per firm.\textsuperscript{10} Last, we exclude sectors with either too few observations to estimate the production function ("electricity, gas and water", "coke, refined petroleum and nuclear fuel", and "leather and footwear"), or those that are too heterogeneous to deliver reliable estimates of production function coefficients ("other non metallic products" and "transport, storage and communication"), and two sectors for which the estimated production function coefficients where unrealistic. This concerns "chemicals" and "post and telecommunication" for which the estimated labour production coefficients were above 1.\textsuperscript{10} Altogether, the dataset contains 10,675 firm-year observations on 1,518 firms with more than 50 employees over the period 1997-2005.\textsuperscript{12} The real wage bill of firm $i$ at time $t$ is denoted as $W_{Bi}$ and includes total remuneration and direct social benefits deflated by sector-specific value added prices with deflators defined at the level of 31 branches. Employment, abbreviated as $L_{it}$, is measured as the average number of employees in full-time equivalent positions over the year. Average labour compensation per firm ($W_{i}$) is calculated as the ratio of the total real wage bill to the average number of employees over the year in full-time equivalents. Value added of sector $s$ at time $t$, $VA_{st}$, was obtained from national accounts statistics. Variables related to workforce composition, like the percentage of blue-collar workers ($\%$BLUE$_{it}$), the percentage of women ($\%$WOMEN$_{it}$) and the proportion of workers with fixed-term contracts ($\%$TEMP$_{it}$) are provided in the so-called social balance sheet, which forms part of firms' annual accounts. We also consider a proxy for the share of skilled workers, for two levels of skills. Due to the lack of data on the stock of workers by skill type, we compute the turnover of workers with a short superior education ($\%$SUP$_{it}$) and those with university degree ($\%$UNIV$_{it}$) as proxies for the proportion of workers with high education.\textsuperscript{13} All in all, we control for four educational groups: blue-collar-workers, workers with short superior degree, workers with university degree, and lastly, white-collar workers with at least secondary education but no superior degree, which are used as reference group. The construction of the capital stock ($K_{it}$) is based on the perpetual inventory method. It relies on the firm-specific depreciation expenditures on capital over the years in which the firm is in business, and on the initial capital stock as reported from the earliest available annual account for the firm going back up to 1985,\textsuperscript{14} and deflated

\textsuperscript{10} The Appendix describes these steps in more detail.

\textsuperscript{11} All in all, the following sectors are excluded from our analysis:(i) agriculture, hunting, forestry and fishing; (ii) mining and quarrying; (iii) community, social and personal services; (iv) electricity, gas and water supply; (v) leather, leather products and footwear; (vi) coke, refined petroleum and nuclear fuel; (vii), other non metallic products; (viii) transport, storage and communication; (ix) chemicals, and (x) community, social and personal services.

\textsuperscript{12} Descriptive statistics on the variables used in the paper are reported in Table A1 in the Appendix.

\textsuperscript{13} The turnover of workers with particular level of education is defined as the sum of the number of entrant workers with the particular level of education and that of exiting workers with the same level of occupation over the sum of all newly hired workers and all workers that leave the company.

\textsuperscript{14} We restrict our estimation period to 1997-2005 because data on employment and employment flows by worker type were not reported in earlier years.
by sector-level deflator on gross capital formation, where again deflators are defined at the 31 branches level.

Our measure of average labour compensation per firm (as total labour compensation divided by the number of employees in full-time equivalent positions) corresponds to Carneiro and Portugal (2008). However, this contrasts with empirical research based on individual wages such as Cardoso and Portela (2005) or Guiso et al. (2005). These studies focus on job stayers. Such analyses may underestimate the sensitivity of wages if wages of job stayers are less flexible than those of newly recruited workers, for example because they are (partly) set by multi-period contracts. Evidence that wages of new hires or movers are more flexible than those of job stayers is provided by Carneiro et al. (2012), Fehr and Goette (2005) and Haefke et al. (2008). One advantage of our measure is that it also includes employees whose wages might be more easily adjusted than those of permanent job stayers, such as newly hired workers or workers on fixed-term contracts. To get an idea of the importance of these phenomena, note that on average in our sample employment turnover (defined as half of the sum of entrants and exiters over the number of workers at the beginning of the period) amounts to 0.40 and the percentage of workers under fixed-term contract is 0.04. A potential disadvantage of our measure of average labour compensation is that it may vary with changes in the composition of the labour force. We account for this by including control variables related to workforce composition in our equations, namely the percentage of blue-collar workers, women, and workers under fixed-term contracts, and proxies for the fraction of workers with high education. We do not control for the percentage of newly hired workers in our main equations because it does not reflect workforce composition, but report robustness results with respect to the inclusion of this variable in Appendix. Note also that our measure of average labour compensation, i.e. the firm’s average labour compensation per employee, may be more flexible than the base wage because it includes extra-wage components such as bonuses and premiums. Survey evidence, reported in Bertola et al. (2008) for European countries and Druant et al. (2008) for Belgium, indeed shows that this is the main adjustment margin of labour compensation.

Last, we attempt to capture the impact of sector-level collective bargaining agreements on each firm's average labour compensation. This is motivated by the considerable importance of sector-level collective agreements in the wage-setting process in Belgium and our estimates confirm their relevance for firms’ average labour compensation. The variables are constructed as follows. The nominal index of collectively agreed nominal wage increases at the sector level for blue-collar workers and white-collar workers is published by the Federal Ministry of Labour. We deflate these by the corresponding sector-level value added deflator to obtain the real measure. We use the indices of collectively agreed wage increases for blue-collar workers and white-collar workers, \(I_B^u\) and \(I_W^u\) and multiply them by the percentage of blue-collar workers and white-collar workers, respectively, in each firm. The sum of the two components serves as a proxy for collectively agreed wage changes relevant for each firm and we denote it ICWAit (ICWAit = \(\%BLUE_i \cdot I_B^u + \%WHITE_i \cdot I_W^u\)). The measure is not perfect because collectively
agreed wage increases are set on a more detailed scale (in terms of sectors, occupation and age or tenure). Discrepancies with respect to the average labour compensation may capture the firm-specific pay policy but also reflect the fact that collective agreements do not apply to more flexible components of labour compensation, such as bonuses and premiums.

In order to measure our TFP variable, we adopt the Ackerberg et al. (2006) procedure. Estimates of production function coefficients are reported in Table A2 in Appendix, together with a brief description of the Ackerberg et al. (2006) methodology. In this paper, we decompose TFP into a firm-specific or idiosyncratic TFP component, $\text{TFP}_{it}$, and a sector-level or aggregate TFP component, $\text{TFP}_{st}$. In short, we regress the Ackerberg et al. (2006) measure of TFP on a full set of interactive sector and year dummies ($\delta_{st}$). The firm-level TFP, $\text{TFP}_{it}$, is obtained as the residual of this equation, and sector-level TFP, $\text{TFP}_{st}$, as the estimated coefficients of the sector-specific time dummies. Formally,

$$ y_{it} - \hat{\beta}_L L_{it} - \hat{\beta}_K K_{it} = \sum_{s=1}^{S} \sum_{t=1}^{T} \text{tfp}_{st} \delta_{st} + \text{tfp}_{it} $$

where $\hat{\beta}_L$ and $\hat{\beta}_K$ are estimated according to Ackerberg et al. (2006).

**Empirical model specification**

We adopt a dynamic specification for labour and real labour compensation. Even though we do not present a theoretical model, our specifications resemble those commonly used in the literature. A dynamic specification is standard in employment equations due to, for instance, adjustment costs (see Arellano and Bond, 1991; Nickell and Nicolitsas, 1999; Nickell and Wadhwani, 1991). In the case of labour compensation equations, the inclusion of lags in the endogenous variable may be motivated by multi-period contracts, wage smoothing, wage rigidity or the existence of reference norms for example. In addition, from an empirical point of view, omitting lags in endogenous variables leads to serially correlated residuals.

In the labour compensation equation, we control for the composition of the labour force by including the percentage of workers with fixed-term contracts, $\text{TEMP}_{it}$, the percentage of women, $\text{WOMEN}_{it}$, the percentage of blue-collar workers, $\text{BLUE}_{it}$, and proxies for the fraction of workers with short superior education, $\text{%SUP}_{it}$, and with university degree, $\text{%UNIV}_{it}$. In order to take into account the impact of firm size in our regressions, we include a dummy that is equal to one for firms with more

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Note that collectively agreed nominal wage increases in Belgium are the result of two mechanisms: indexation and collective agreements concerning real wage increases. We do not attempt to estimate the latter, i.e. we do not try to discriminate between indexation and real wage increases negotiated under sectoral collective agreements. Rather, we evaluate the impact on the firm's labour compensation of wage increases triggered by the sector-level collective agreement that is decided outside the firm. From the point of view of the company, these costs have to be compared to the firm's real output prices. Therefore, we deflate the collectively agreed nominal wage increases by the value added deflator.
than 100 employees, \((L>100)\). This threshold is motivated by the fact that union participation may be considered as more structured in firms with 100 employees or more (see section 2) and it is close to the median firm size in our sample.\(^{16}\) Our labour equations follow standard labour demand specifications, including installed capital and average labour compensation per firm, and are augmented by TFP.\(^{17}\)

Equation (2a) and (2b) show the baseline model that we estimate in Section 2 for labour compensation and labour respectively:

\[
\begin{align*}
\text{wit} &= \rho_1 \text{wit-1} + \rho_2 \text{wit-2} + \beta_1 \text{tfp}_t + \beta_2 \%\text{TEMP}_t + \beta_3 \%\text{WOMEN}_t \\
&+ \delta^1_t + \epsilon^1_{it} \quad \text{(2a)} \\
\text{lit} &= \rho_1 \text{lit-1} + \rho_2 \text{lit-2} + \beta_1 \text{tfp}_t + \beta_2 \text{kit} + \beta_3 \text{wit} + \delta^2_t + \delta^3_s + \epsilon^2_{it} \quad \text{(2b)}
\end{align*}
\]

Variables in lower case are expressed in logs and \(\rho\)’s and \(\beta\)’s are the coefficients to be estimated. Firm-fixed effects, \(\delta_t\), capture unobserved firm characteristics; while sector-level conditions, such as aggregate demand or prices, are taken into account by interactive year and sector dummies, denoted as \(\delta_{st}\). In our alternative specification, the role of sector-specific variables is examined by replacing the sector-specific time dummies, \(\delta_{st}\), by a set of year dummies, \(\delta_t\), sector dummies, \(\delta_s\), and sector-level variables. These include sector-level TFP, and sector-specific value added in the labour compensation equations,\(^{18}\) or the log change of sectoral value added in the labour equations (as in Nickell and Wadhwni, 1991).

\[
\begin{align*}
\text{wit} &= \rho_1 \text{wit-1} + \rho_2 \text{wit-2} + \beta_1 \text{tfp}_t + \beta_2 \text{tfp}_{st} + \beta_3 \text{va}_{st} + \beta_4 \%\text{TEMP}_t \\
&+ \delta^3_s + \delta^3_t + \delta^3_s + \epsilon^3_{it} \quad \text{(3a)} \\
\text{lit} &= \rho_1 \text{lit-1} + \rho_2 \text{lit-2} + \beta_1 \text{tfp}_t + \beta_2 \text{tfp}_{st} + \beta_3 \Delta\text{va}_{st} + \beta_4 \text{kit} + \beta_5 \text{w}_{it} \\
&+ \delta^4_s + \delta^4_t + \epsilon^4_{it} \quad \text{(3b)}
\end{align*}
\]

\(^{16}\) In Section 2, we report robustness test with respect to the use of employment as a measure of firm size, and to hours per worker.

\(^{17}\) As reported in the robustness section 3, we also consider a specification that involves changes in labour compensation and lags of labour compensation to take into account efficiency wage mechanisms (Nickell and Wadhwni, 1991). However, these terms are insignificant. What is missing with respect to wage bargaining models is the outside wage option. To the extent that unemployment benefits are proportional to wage payments, this term will be taken into account by lagged labour compensation.

\(^{18}\) Unemployment is often used as a determinant of wages. Because unemployment rates are not available at the sector level, we use a proxy for sector-level business conditions.
Lastly, to investigate the role of sector-level collective wage bargaining, we also estimate labour compensation equations that include the log of the index of wage increases determined by sector-level collective wage agreements (icwa_it) relevant for each firm given its composition of blue-collar and white-collar workers:

\[ w_{it} = \rho_{w1}^t w_{it-1} + \rho_{w2}^t w_{it-2} + \beta_{1}^t \text{tfp}_{it} + \beta_{2}^t \text{icwa}_{it} + \beta_{3}^t \text{va}_{it} + \beta_{4}^t \%\text{TEMP}_{it} + \beta_{5}^t \%\text{WOMEN}_{it} + \beta_{6}^t \%\text{BLUE}_{it} + \beta_{7}^t \%\text{SUP}_{it} + \beta_{8}^t \%\text{UNIV}_{it} + \beta_{9}^t (L>100)_{it} + \delta_{it} + \delta_{it}^s + \delta_{it}^t + \epsilon_{it} \] (4)

Equations (2) to (4) include firm-specific fixed effects, as it is common in the literature. This implies that instrumental variables should be used to take into account endogeneity of the lagged dependent variable. The dynamic panel equations are estimated by the System GMM procedure proposed by Arellano and Bover (1995) and Blundell and Bond (1998). We report the two-step estimates with the small sample correction for standard errors proposed by Windmeijer (2004). We assume that TFP, the firm-size dummy, labour force composition, sector-specific value added, and the impact of sector-level collective agreements on firms’ wages are exogenous. Lags of the remaining variables are used as instruments. In the Appendix, we report robustness tests with respect to some of these assumptions. We chose two lags of the dependent variable on the right-hand side of our models in order to take into account the dynamic properties of the series and following autocorrelation specification tests.

2. RESULTS

Estimating the elasticity of average labour compensation and labour to firm-specific TFP

In this section, we compare the elasticity of labour compensation with respect to firm-specific TFP to that of labour, as described in equations (2a) and (2b). The results are reported in Table 1. The coefficients on control variables have the expected sign. Firms with a higher percentage of blue-collar workers or workers with fixed-term contract have significantly lower average labour compensation, all else equal. Companies with a higher fraction of educated workers or males tend to experience higher average compensation, although the coefficients are not significant.19 The capital stock has a significant positive coefficient in the employment equation while labour compensation appears insignificant in the same model.20

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19 This contrasts with estimates of individual wage equations in which these variables are in general significant. One reason may be that our wage equation captures differences across firms within a sector (for which these variables may not fluctuate much) rather than differences across workers within a firm as is the case in typical individual wage equations.

20 Robustness estimates of labour equations, not reported for the sake of brevity, indicate that neither current nor lagged labour compensation is significant.
Our estimates indicate that the contemporaneous elasticity of average labour compensation and that of labour to TFP is small, but significantly larger than zero in both cases. Comparing the two, the elasticity of the average labour compensation with respect to TFP (0.025) is more than two times lower than the elasticity of employment (0.068). More strikingly, the long-run impact of firm-level TFP on employment (1.58) is almost ten times larger than the impact on labour compensation (0.16).\footnote{The long-run impact is computed as } \frac{\beta_1}{(1-\rho_1)(1-\rho_2)}, \text{ where } \beta_1 \text{ is the TFP coefficient, } \rho_1 \text{ and } \rho_2 \text{ are the coefficients on lagged dependent variables, see equations (2a) and (2b).}

These results are consistent with previous analyses for Belgium. The survey evidence in Druant et al. (2008) indicates that when reducing costs following an adverse economic shock, 60% of Belgian firms declared that they cut employment, 14% of the companies said they adjust pay (and only do so through the variable components). The results of the wage bill decomposition in Fuss (2009) also reveal that employment is the driving component of wage bill adjustment.

The higher elasticity of employment relative to that of average labour compensation, both in the short run (within one year) and the long run (as the effect cumulates over time), supports the hypothesis of real wage rigidity that shifts the burden of adjustment towards employment. Indeed, models with wage rigidity typically find greater variability of employment in response to productivity shocks, as compared to the flexible wage scenario (see, for example, Hall, 2005; Blanchard and Galí, 2007, 2008) so that labour productivity can match the real wage. However, our estimates do not provide a test or a measure of real wage rigidity because there is no theoretical reference value for the average labour compensation elasticity and labour elasticity under the flexible wage case. In the model of Blanchard and Galí (2008) without labour market frictions, there is no response of labour under perfect wage and price flexibility. But this results from the fact that income and substitution effects cancel out in their model.

The finding of a low response of wages to productivity developments is in line with other studies. For the US, Haefke et al. (2008) find an elasticity of wages aggregated over all workers to labour productivity in the range from 0.17 to 0.37. Biscourp et al. (2005) estimate the current elasticity of job stayers’ wages to labour productivity at 0.026 in France. A series of papers distinguish between permanent and transitory shocks to investigate the question of wage insurance.\footnote{This hypothesis implies that firms insure workers against wage fluctuations due to transitory shocks but not against permanent ones.} They find a low response of wages to transitory shocks (not significant in Italy and Portugal and equal to 0.05 in Hungary)\footnote{According to OECD (2004), Hungary is among the countries with the most flexible labour market, which may explain why wages react even to transitory shocks.}, and a response to permanent shocks ranging from 0.07 in Italy to 0.11 in Hungary (see Cardoso and Portela, 2009; Guiso et al., 2005, and Katay, 2009). Last, using a detailed dataset for Sweden, Carlsson et al. (2011) find that the reaction of job stayers’ wages to firm-level labour productivity is around 0.15 and that to sector-level TFP is around 0.05. The elasticity of labour to
productivity may be compared to the results of Marchetti and Nucci (2007) for manufacturing firms in Italy and Carlsson and Smeedsaas (2011) for Sweden. They analyse the response of hours to productivity shocks and find a cumulated effect of TFP shocks on hours of around 0.15.

Our results point to a larger response of labour than of labour compensation to TFP developments. Admittedly, our finding of a positive impact of TFP on labour may be due to the fact that TFP measures may capture demand shocks or variations in factor prices together with technological changes because nominal variables are deflated using sector-level price indices rather than firm-level output prices (Foster et al., 2008; Katayama et al., 2003; Klette and Griliches, 1996). Demand shocks will tend to induce a positive correlation with labour and a smaller correlation with wages (except to the extent that demand shocks raise profits and wages through rent-sharing mechanisms).

<table>
<thead>
<tr>
<th>TABLE 1. SGMM ESTIMATES OF EQUATIONS (2A) AND (2B)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Equation (2a) for real labour compensation</strong></td>
</tr>
<tr>
<td>coefficient</td>
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</tr>
<tr>
<td>ln-2</td>
</tr>
<tr>
<td>tfp</td>
</tr>
<tr>
<td>%TEMPit</td>
</tr>
<tr>
<td>%WOMENit</td>
</tr>
<tr>
<td>%BLUEit</td>
</tr>
<tr>
<td>%SUPit</td>
</tr>
<tr>
<td>%UNIVit</td>
</tr>
<tr>
<td>L&gt;100it</td>
</tr>
<tr>
<td><strong>Equation (2b) for labour compensation</strong></td>
</tr>
<tr>
<td>coefficient</td>
</tr>
<tr>
<td>wt</td>
</tr>
<tr>
<td>ln</td>
</tr>
<tr>
<td>fa</td>
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</table>

Note: Firms with at least 50 employees and 6 consecutive annual accounts. 1,503 firms and 9,172 observations. Variables are defined as follows: wt: log of real wage bill per average number of employees in euro; ln: log of average number of employees per year; tfp: log of firm-specific TFP; %TEMP: percentage of employees under fixed-term contract; %WOMEN: percentage of women; %BLUE: percentage of blue-collar workers; %SUP: turnover of workers with short superior education; %UNIV: turnover of workers with university degree; L>100: dummy equals to one when the firm employs 100 workers or more.

Two-step System GMM estimates are reported with standard errors in parentheses following the correction proposed by Windmeijer (2004). All equations include a constant, interactive sector and year dummies but their coefficients are not reported. Instruments in the difference equation for wt include lags 4 and 5 of the endogenous variable. Instruments in the level equation for wt include lag 3 of the endogenous variable. Instruments in the difference equation for ln include lags 4 and 5 of the endogenous variable, and wage; lags 3 and 4 of predetermined capital stock. Instruments in the level equation for ln include lag 3 of the endogenous variable, and wt; lag 2 of predetermined capital stock. The remaining
regressors are treated as exogenous. AR displays the test for serial correlation in the first-differenced residuals. Lower-case variables are in log. The remaining variables are defined in the text. * indicates significance at the 10% level, ** at the 5% level, *** at the 1% level.

Nevertheless, one possible explanation for the small estimated elasticity of labour compensation to firm-specific TFP is the importance of sector-level collective agreements for firms’ pay policies. As noted above, most companies follow the sector-level collective wage agreement. Indeed, the survey evidence in Druant et al. (2008) indicates that firms hire workers at a pay scale based on their existing internal pay scale (50 percent of the firms) or defined within a sector-level collective wage agreement (another 36 percent of the cases). This leaves little room for adjustment of labour compensation at the firm level, except for those that operate through changes in the level of bonuses and premiums.

In addition to institutional factors that may be responsible for wage rigidity, the low response of firms' wages to firm-specific shocks may be explained by labour market competition and efficiency wage considerations. In a tight labour market, it may not be desirable for a company to reduce wages following a negative productivity shock because this would have a negative impact on workers morale and effort and makes other companies more attractive for its best workers. The survey evidence presented by Druant et al. (2008) indeed shows that these reasons were pointed out by more than 80 percent of companies as an explanation why they would not reduce wages in adverse times. Further, this may generate adverse selection problems. In what follows, we examine in more detail whether the findings hold also for sector-level TFP and investigate the role of collective wage agreements in shaping the response of average labour compensation.

*Differences in the elasticity to firm-specific TFP and sector-level TFP*

In this section we compare the response of labour compensation and labour to firm-specific TFP and to sector-level TFP. A new secret recipe or a patented innovation can serve as examples of idiosyncratic productivity development. The innovating firm will then have a productivity advantage over its competitors. The introduction of new software by Microsoft would be a common productivity change, for instance. In principle, all firms have access to this technological improvement. Clearly, an individual firm might have different incentives and varying ability to change its wages and prices when it is the only one facing the shock than if the shock is common to all firms. As discussed above, a firm may refrain from individual wage contractions to avoid shirking, quits, and adverse selection effects. However, the argument does not hold when all firms undertake wage contractions at the same time, as opposed to a single company doing so unilaterally.

Estimates of equations (3a) and (3b), including firm-level as well as sector-level TFP are reported in Table 2. The estimates allow for additive year and sector dummies, instead of sector-specific year effects. To account for other fluctuations at the sector level, we also include value added per sector in the labour compensation equations and the log change in value added per sector in the labour equations.

The most striking result is that the elasticity of average labour compensation to sector-level TFP is very high (0.424) compared to that with respect to firm-specific
TFP (0.032). For the sake of comparison, Carlsson et al. (2011) found that the reaction of job stayers wages to sector-level labour productivity is around 0.05 in Sweden. It was already mentioned that Haefke et al. (2008) estimated the elasticity of wages aggregated over all workers to labour productivity for the US in the range from 0.17 to 0.37.

While we find a higher response of wages to sector-level TFP than to firm-level TFP, our estimates show that the elasticity of employment to sector-level TFP (0.055) is of the same order of magnitude as that with respect to firm-specific TFP (0.060), but it is not significantly different from zero. The long-run impact of sector-level TFP on labour compensation (1.97) is more than 35 percent larger than the impact on employment (1.45). On the contrary, the long-run impact of firm-specific TFP on employment (1.58) is more than ten times larger than that on wages (0.15).

The picture that emerges from these results is one of sluggish response of employment and average labour compensation to idiosyncratic TFP, but much more responsive average labour compensation to aggregate TFP fluctuations. Robustness tests reported in the Appendix show that these qualitative conclusions remain robust to alternative specifications of the labour compensation and labour equations and endogeneity assumptions.

Our results suggest that firms have little room for adjusting their average labour compensation to firm-specific developments but respond to sector-level TFP. One interpretation of these results is that firms in Belgium are bound by sector-level collective wage agreements, that play a dominant role in the real wage-setting as explained in Section II, and tend not to deviate too much from them for workers already employed by the firm, i.e. job stayers. Further, there is limited scope for adjustment of labour compensation to extra wage payments. Bonuses and premiums generally do not account for a substantial proportion of earnings in Belgium. Indeed, data from the Belgian Structure of Earnings Survey (SES) indicate that bonuses form on average 8.4 percent of earnings. The proportion varies from 2.4 percent in hotels and restaurants to 13.3 percent in financial services.

Second, one might argue that firms could adjust their average wage bill by applying a different pay scheme to new entrants and workers under fixed-term contracts. However, the percentage of workers under fixed-term contracts in Belgium is below the average for Europe (see Section 1). In addition, minimum pay scales set at the activity, occupation and tenure level, within sector-level collective agreements, provide a lower bound for new entrants' wages. The survey results in Druant et al. (2008) reveal that firms set newly recruited employees' wages mostly according to collective wage agreements or their own internal pay scale.
RIGID WAGES AND FLEXIBLE EMPLOYMENT? CONTRASTING RESPONSES TO FIRM-LEVEL AND SECTOR-LEVEL PRODUCTIVITY DEVELOPMENTS

### TABLE 2. SGMM ESTIMATES OF EQUATIONS (3A) AND (3B)

<table>
<thead>
<tr>
<th></th>
<th>Equation (3a) for real labour compensation</th>
<th>Equation (3b) for labour compensation</th>
</tr>
</thead>
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<tr>
<td></td>
<td>coefficient</td>
<td>std. error</td>
</tr>
<tr>
<td>$w_{it-1}$</td>
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<td>(0.196)</td>
</tr>
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<td>$w_{it-2}$</td>
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<td>(0.151)</td>
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<td>(0.011)</td>
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<td>$tftp_{it}$</td>
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<td>(0.033)</td>
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<td>$%UNIV_{it}$</td>
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<td>(0.003)</td>
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<td>1.56</td>
<td>0.119</td>
<td>0.04</td>
<td>0.971</td>
</tr>
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</table>

Note: Firms with at least 50 employees and 6 consecutive annual accounts. 1,503 firms and 9,172 observations. Variables are defined as follows: $w_{it}$: log of real wage bill per average number of employees in euro; $l_{it}$: log of average number of employees over the year; $tftp_{it}$: log of firm-specific TFP, $tftp_{it}$: log of sector-level TFP, $v_{it}$: log of sector-level value added; $\%TEMP_{it}$: percentage of employees under fixed-term contract; $\%WOMEN_{it}$: percentage of women; $\%BLUE_{it}$: percentage of blue-collar workers; $\%SUP_{it}$: turnover of workers with short superior education; $\%UNIV_{it}$: turnover of workers with university degree; $L>100_{it}$: dummy equals to one when the firm employs 100 workers or more.

Two-step System GMM estimates are reported with standard errors in parentheses following the correction proposed by Windmeijer (2004). All equations include a constant, interactive sector and year dummies but their coefficients are not reported. Instruments in the difference equation for $w_{it}$ include lags 4 and 5 of the endogenous variable. Instruments in the level equation for $w_{it}$ include lag 3 of the endogenous variable, and $w_{it}$ and lags 3 and 4 of predetermined capital stock. Instruments in the level equation for $l_{it}$ include lag 3 of the endogenous variable, and wages; lag 2 of predetermined capital stock. The remaining regressors are treated as exogenous. AR displays the test for serial correlation in the first-differenced residuals. Lower-case variables are in log. The remaining variables are defined in the text.

* indicates significance at the 10% level, ** at the 5% level, *** at the 1% level.

In addition, in a competitive labour market, idiosyncratic wage changes may not be optimal. For instance, when firms compete for workers on the labour market, firm-specific wage cuts may be harmful due to efficiency wage, adverse selection and shirking considerations. On the contrary, coordinated wage decisions may alleviate the problem incurred with isolated wage actions. In turn, coordination of wage decisions may be eased by the existence of sector-level collective wage bargaining structures. This hypothesis is examined in the next section.
The role of sector-level collective wage bargaining

In order to illustrate the role of sector-level collective bargaining in shaping the response of average labour compensation to TFP, Table 3 below reports two sets of estimates for average labour compensation. The first two columns are directly taken from Table 2. The last two columns (equation (4)) include the impact of sector-level collective wage agreements on firms' average labour compensation but omits sector-level TFP (we do not include the two together for colinearity reasons explained below).

Sector-level collective agreements are set every two years. The agreed wage increases are, in general, spread over the two years. Our estimates show that the impact of sector-level collectively agreed wage increases at the firm level is positive and significant. More importantly, the long-run elasticity of average labour compensation to collectively agreed wage is near unity (0.91). Note that, using comprehensive individual wage data López-Novella and Sissoko (2009) also obtain a close to unity elasticity of wages to the index of wage increases agreed in sector-level collective wage agreement in Belgium.

We then perform a simple OLS regression of changes in the log of the indices of sector-level collectively agreed wage increases (deflated by value-added prices) on changes in sector-level TFP per sector, including separate time and sector effects. This reveals that there is a highly significant and positive relationship between TFP and collective wage increases at the sector level. The coefficient of TFP is equal to 0.45 (with a standard error of 0.16). This confirms the conjecture that productivity developments are taken into account in sector-level collective wage agreements in Belgium. Importantly, this also suggests that the impact of TFP on average labour compensation is not zero. Rather labour compensation adjusts, among others through collectively agreed wage increases, which take into account sector-level common productivity evolutions rather than idiosyncratic or firm-specific changes.
### Table 3. SGMM Estimates of Equations (3a) and (4) for Average Real Labour Compensation

<table>
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<th>Equation (3a) for real labour compensation</th>
<th>Equation (4) for real labour compensation</th>
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<tr>
<td>coefficient</td>
<td>std. error</td>
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<tr>
<td>( w_{it-1} )</td>
<td>0.953***</td>
</tr>
<tr>
<td>( w_{it-2} )</td>
<td>-0.168</td>
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<tr>
<td>( tfp_{it} )</td>
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<tr>
<td>( tfp_{it} )</td>
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<td>( icwa_{it} )</td>
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<tr>
<td>( va_{it} )</td>
<td>-0.074***</td>
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<tr>
<td>( %TEMP_{it} )</td>
<td>-0.074***</td>
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<tr>
<td>( %WOMEN_{it} )</td>
<td>-0.081**</td>
</tr>
<tr>
<td>( %BLUE_{it} )</td>
<td>-0.132***</td>
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<tr>
<td>( %SUP_{it} )</td>
<td>0.021*</td>
</tr>
<tr>
<td>( %UNIV_{it} )</td>
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<td>( L&gt;100_{it} )</td>
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**Note:** Firms with at least 50 employees and 6 consecutive annual accounts. 1,503 firms and 9,172 observations.

Variables are defined as follows: \( w_i \): log of real wage bill per average number of employees in euro; \( l_i \): log of average number of employees over the year; \( tfp_i \): log of firm-specific TFP, \( tfp_{it} \): log of sector-level TFP; \( icwa_{it} \): log of the firm's impact of collectively agreed real wage change; \( va_{it} \): log of sector-level value added; \( %TEMP_{it} \): percentage of employees under fixed-term contract; \( %WOMEN_{it} \): percentage of women; \( %BLUE_{it} \): percentage of blue-collar workers; \( %SUP_{it} \): turnover of workers with short superior education; \( %UNIV_{it} \): turnover of workers with university degree; \( L>100_{it} \): dummy equals to one when the firm employs 100 workers or more.

Two-step System GMM estimates are reported with standard errors in parentheses following the correction proposed by Windmeijer (2004). Instruments in the difference equation for \( w_i \) include lags 4 and 5 lags of the endogenous variable. Instruments in the level equation for \( w_i \) include lag 2 of the endogenous variable. The remaining regressors are treated as exogenous. All equations include a constant, additive sector and year dummies but their coefficients are not reported. AR displays the test for serial correlation in the first-differenced residuals. Lower-case variables are in log. The remaining variables are defined in the text.

* indicates significance at the 10% level, ** at the 5% level, *** at the 1% level.
CONCLUSION

In this paper, we have estimated the sensitivity of average labour compensation and employment to Total Factor Productivity. The contributions are twofold. First, we compare the elasticity of labour compensation and that of employment. The sign and size of these elasticities may be affected by the presence of wage rigidity as well as employment adjustment costs. On the one hand, real wage rigidity reduces the sensitivity of wages to shocks and shifts the burden of adjustment towards labour (Boldrin and Horvath, 1995; Hall, 2005). On the other hand, hiring and firing costs may restrict adjustment through employment.

The second contribution of the paper is to compare the response of average labour compensation and labour to firm-level TFP with the response to sector-level TFP. Our argument is that when firms compete for workers on the labour market, they may refrain from isolated wage adjustments. Common wage actions make it possible to alleviate these constraints. Given the prominent role of sector-level wage bargaining, collective wage agreements offer an opportunity to coordinate decisions and ease wage adjustment. These arguments suggest a higher elasticity of average labour compensation with respect to sector-level TFP than with respect to firm-specific TFP.

Our results are based on a dataset obtained from firms' annual accounts and social balance sheets in Belgium over the period 1997-2005. Belgium is usually singled out as a country with substantial real wage rigidity, due in part to its system of full automatic indexation of base wages. In addition, wage developments are largely driven by sector-level collective wage agreements. This makes Belgium a relevant case to study the role of real wage rigidity on alternative adjustment margins, and the role of centralised collective agreements in wage dynamics.

Our results can be summarised as follows. First, focusing on the response to firm-level TFP, our estimates of the elasticity of average labour compensation and employment to TFP are significant and positive but relatively low. However, the long-run elasticity of labour is substantially larger than that of labour compensation. Although our analysis does not provide a test or evaluation of the extent of real wage rigidity, these findings are consistent with the hypothesis of real wage rigidity in response to idiosyncratic productivity developments.

Second, in contrast to the response to idiosyncratic TFP, the elasticity of average labour compensation to aggregate TFP is high. This is consistent with the labour market competition and product market competition issues discussed above.

Third, our results support the view that the high importance of centralised wage bargaining at the sector level in Belgium may ease coordination of wage adjustment to aggregate changes. Indeed, the response of average labour compensation to sector-level TFP is relatively large. Additional estimates suggest that real wage increases agreed within sector-level collective agreements do respond to sector-level TFP developments and have a significant impact on firms' labour compensation.
REFERENCES


APPENDIX

Data appendix

The dataset was constructed as follows. We start with all firms that report their annual accounts in Belgium which corresponds to 2.4 million observations in nearly 394,000 firms between 1997 and 2005. We focus on the manufacturing, construction and market services sectors, i.e. firms classified in nace Rev1.1 classes 15 to 74 (loosing about 13% of observations). Additional data trimming concerns the legal situation of the firm. Foreign and public companies, as well as non-profit associations, are excluded from the sample (-2% of observations). Only annual accounts covering the period from January to December are considered in order to ensure consistency between firms (-24% of observations). We consider only firms with at least 50 employees (-98% of observations, but only -35% to -39% of value added and employment). Outliers are removed by excluding observations below the 1st percentile or above the 99th percentile (defined year by year) of the following variables: employment growth (defined with respect to the number of employees and full-time equivalents), level and growth of the average wage per worker and average wage per hour, growth in firm-specific nominal value added, hours per worker, and the investment-capital ratio. We also exclude observations for which TFP could not be estimated, i.e. due to missing data on intermediate inputs (which is only compulsory for firms filling out the full annual accounts form). These restrictions further lower the number of observations by 34%. Last, we consider only spells with at least 6 consecutive observations to make sure that sufficient history is available to build lagged instruments in the GMM procedure. This last step diminishes the number of observations by 30% to 10,675.
## Table A1. Descriptive Statistics

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<td>0.02</td>
<td>0.08</td>
<td>-0.10</td>
<td>0.01</td>
<td>0.14</td>
</tr>
<tr>
<td>$\Delta L_{it}$</td>
<td>10675</td>
<td>0.01</td>
<td>0.11</td>
<td>-0.13</td>
<td>0.01</td>
<td>0.18</td>
</tr>
<tr>
<td>$\Delta (h-l)_{it}$</td>
<td>10675</td>
<td>-0.01</td>
<td>0.06</td>
<td>-0.09</td>
<td>0.02</td>
<td>0.15</td>
</tr>
<tr>
<td>$\Delta (wb-h)_{it}$</td>
<td>10675</td>
<td>0.02</td>
<td>0.08</td>
<td>0.09</td>
<td>0.02</td>
<td>0.15</td>
</tr>
<tr>
<td>$\Delta v_{it}$</td>
<td>112</td>
<td>9.92</td>
<td>4.97</td>
<td>0.00</td>
<td>9.98</td>
<td>20.42</td>
</tr>
<tr>
<td>$\Delta v_{it}$</td>
<td>112</td>
<td>0.02</td>
<td>0.05</td>
<td>-0.07</td>
<td>0.02</td>
<td>0.10</td>
</tr>
</tbody>
</table>

Notes: Descriptive statistics for firms with more than 50 employees and 6 consecutive annual accounts over the years 1999-2005. P5 and P95 refer to the 5th and 95th percentile. Lower-case variables are in log. $\Delta$ stands for the difference operator.

$W_{it}$: Real wage bill per average number of employees in euro

$L_{it}$: Average number of employees over the year

$\Delta L_{it}$: Growth rate of hours per worker

$I_{it}/K_{it}$: Investment-capital ratio.

$\%\text{TEMP}_{it}$: Percentage of employees under fixed-term contract

$\%\text{WOMEN}_{it}$: Percentage of women

$\%\text{BLUE}_{it}$: Percentage of blue-collar workers

$\%\text{SUP}_{it}$: Turnover of workers with short superior education

$\%\text{UNIV}_{it}$: Turnover of workers with universitary degree

$\%L_{it}>100$: Dummy equals to one when the firm employs 100 workers or more

$\Delta (h-l)_{it}$: Growth rate of hours per worker

$\Delta (wb-h)_{it}$: Growth rate of real wage bill per hour worked

$\Delta v_{it}$: Growth rate of real value added at sector-level
**TFP estimation**

Several estimates of TFP have been proposed in the literature. The accounting revenue-based Solow residual defines productivity growth as the difference between output (or value added) growth and inputs growth weighted by their revenue share.\(^{24}\) Approximating production function coefficients by the revenue shares holds under the assumptions of constant returns to scale, perfect competition on product and factor markets and perfect factor mobility. The model has been extended to imperfect competition on the product market. Hall (1988) and Roegers (1995) propose methods to estimate jointly TFP and markups, under the assumption of constant returns to scale. These methods are based on the cost shares of production factors.

Alternatively, methods have been proposed that allow deviating from the constant returns to scale assumption based on estimates of production function coefficients, rather than assuming that they are equal to the revenue shares or cost shares of production factors. In this paper, we use the Ackerberg et al. (2006) methodology. To clarify the exposition, consider the following production function estimation:

\[
y_{it} = \beta_{1}l_{it} + \beta_{k}k_{it} + z_{it} + \eta_{it}
\]

where \(y_{it}\) denotes value added, \(l_{it}\), labour and \(k_{it}\) the capital stock available at the beginning of the period. The residual, \(z_{it} + \eta_{it}\), is decomposed into one component observable to the firm when making its input decision, \(z_{it}\), the productivity shock, and another one not observed by the firm when making its input decision, \(\eta_{it}\), which can be associated to unexpected productivity changes as well as measurement error. Ordinary Least Squares turn infeasible because factor demand is likely to be correlated with current productivity shocks.

Olley and Pakes (1996) and Levinsohn and Petrin (2003) propose alternative ways to deal with this simultaneity bias. In short, in order to solve the simultaneity problem they augment the equation with a proxy for unobserved productivity. Olley and Pakes (1996) show that this can be expressed as a non parametric function, \(\phi\), of investment, capital and possibly age, for active and positively investing firms.

\[
y_{it} = \beta_{1}l_{it} + \beta_{k}k_{it} + \phi(i_{it},a_{it},k_{it}) + \eta_{it}
\]

However, because \(k_{it}\) also appears in the equation through \(\phi\), \((i_{it},a_{it},k_{it})\), the parameter \(\beta_{k}\) is not identified. In order to estimate the capital coefficient, express productivity, \(z_{it}\), as the sum of expected productivity \(E[z_{it}/Z_{it-1}]\) and productivity innovations, \(\phi\). The capital stock available at the beginning of the period is

\(^{24}\) Carlsson et al. (2011) show that TFP measures derived from value added series are strictly speaking valid only under perfect competition and constant returns. In the case of decreasing returns to scale, a TFP measure based on value added would be negatively correlated with the growth rate of primary inputs. In this case, a positive demand shock would likely lead to higher production and the use of labour and due to decreasing returns measures of TFP based on value added will decline.
independent of productivity innovations, $a_{it}$, that occur during period $t$. This allows identifying $\beta_k$ in the following regression.

$$y_{it} = \beta_1 l_{it} + \gamma_t (\dot{a}_{it} - \beta_0 a_{it-1} + \beta_k k_{it-1}) + \eta_{it} + \xi_{it}$$  \hspace{1cm} (a.3)

where $\gamma_t$ can be approximated by a polynomial function of higher order than $\phi_t$.

The method of Levinsohn and Petrin (2003) proposed to use intermediate inputs instead of investment to invert the productivity shock. This overcomes two drawbacks of the Olley and Pakes (1996) methodology but it can only be applied to observations with positive investment. Further, investment may be characterised by substantial lumpiness, contrary to intermediate inputs.

Recently, Ackerberg et al. (2006) highlight a collinearity issue in Olley and Pakes and Levinsohn (2003) procedures that invalidates the estimation of the labour coefficient. The labour production coefficient cannot be identified in the first step if labour and intermediate input or investment decisions are taken simultaneously. Ackerberg et al. (2006) then propose an alternative estimation procedure in which all production function parameters are estimated in the second stage. Identification of the capital parameter rests on the assumption that the capital stock available at the beginning of the period is independent of current productivity shocks, as in the Olley-Pakes and Levinsohn-Petrin procedures. Identification of the labour parameter is achieved under the assumption that lagged labour does not respond to current productivity shocks.

In practice, for each sector, for given values of $\beta_k$ and $\beta_l$ we first estimate the non-linear equation (a.2) taking a polynomial function to proxy $\phi_t$. From these estimates, we compute $\xi_{it}$. Then we regress $\xi_{it}$ on a polynomial function of $\xi_{it-1}$, and compute $\xi_{it}$. Lastly, we evaluate the sample analogue to the moment conditions used to identify the production function parameters, i.e.

$$\frac{1}{N} \sum_t \sum_i \xi_{it} \left( \frac{k_{it}}{l_{it-1}} \right)$$

The procedure is repeated for different values of the parameters, using a grid search procedure.
TABLE A2. ESTIMATED PRODUCTION FUNCTION COEFFICIENTS AND INCOME SHARES

<table>
<thead>
<tr>
<th>NACE</th>
<th>capital</th>
<th>labour</th>
</tr>
</thead>
<tbody>
<tr>
<td>food</td>
<td>DA</td>
<td>0.24</td>
</tr>
<tr>
<td>textiles</td>
<td>DB</td>
<td>0.12</td>
</tr>
<tr>
<td>wood</td>
<td>DD</td>
<td>0.15</td>
</tr>
<tr>
<td>paper</td>
<td>DE</td>
<td>0.11</td>
</tr>
<tr>
<td>rubber</td>
<td>DH</td>
<td>0.17</td>
</tr>
<tr>
<td>metals</td>
<td>DJ</td>
<td>0.28</td>
</tr>
<tr>
<td>machinery &amp; equipment</td>
<td>DK</td>
<td>0.19</td>
</tr>
<tr>
<td>electrical equipment</td>
<td>DL</td>
<td>0.14</td>
</tr>
<tr>
<td>other manufacturing</td>
<td>DN</td>
<td>0.36</td>
</tr>
<tr>
<td>construction</td>
<td>FF</td>
<td>0.17</td>
</tr>
<tr>
<td>trade</td>
<td>GG</td>
<td>0.13</td>
</tr>
<tr>
<td>hotels and restaurants</td>
<td>HH</td>
<td>0.09</td>
</tr>
<tr>
<td>financial services</td>
<td>JJ</td>
<td>0.11</td>
</tr>
<tr>
<td>real estate</td>
<td>KK</td>
<td>0.26</td>
</tr>
<tr>
<td>mean</td>
<td></td>
<td>0.18</td>
</tr>
</tbody>
</table>

Robustness tests

In this Appendix, we evaluate the robustness of our results with respect to alternative specifications and exogeneity assumptions. For the sake of brevity, we only report the estimates of the coefficient on firm-specific and sector-level TFP of equations (3a) and (3b). In Table A3, we first report the results from Table 2.

Firstly, we investigate whether changes in the specification of the labour compensation equation and labour equations alter the estimates of the TFP coefficients. In the labour equation, we replace the size dummy L>100, by a continuous size variable, measured as the number of employees. The variable is instrumented by its own lags. In the labour equations, we introduce additional lags of average labour compensation. More specifically, following Nickell and Wadhwani (1991), we introduce the log change in average labour compensation and one lag of labour compensation; this aims to capture efficiency wage effects. So, the second set of results reported in Table A.3 refers to the estimates of the following equations for labour compensation and labour, respectively:

\[
\begin{align*}
W_{it} = & \rho_1 W_{it-1} + \rho_2 W_{it-2} + \beta_1 \text{tfp}_{it} + \beta_2 \text{tp}_{it} + \beta_3 \text{va}_{it} + \beta_4 \% \text{TEMP}_{it} \\
& + \beta_5 \% \text{WOMEN}_{it} + \beta_6 \% \text{BLUE}_{it} + \beta_7 \% \text{SUP}_{it} + \beta_8 \% \text{UNIV}_{it} \\
& + \beta_9 \text{size}_{it} + \delta_i + \delta_s + \delta_t + \varepsilon_{it} \tag{a.4}
\end{align*}
\]

\[
\begin{align*}
L_{it} = & \rho_1 L_{it-1} + \rho_2 L_{it-2} + \beta_1 \text{tfp}_{it} + \beta_2 \text{tp}_{it} + \beta_3 k_{it} + \beta_4 \Delta W_{it} + \beta_5 a_{it-1} + \beta_6 \Delta W_{it} \\
& + \beta_7 \Delta a_{it} + \beta_8 \Delta \text{va}_{it} + \delta_i + \delta_s + \delta_t + \varepsilon_{it} \tag{a.5}
\end{align*}
\]
Estimates of TFP coefficients in the labour equations remain essentially unchanged, while the coefficient in the labour compensation equation slightly increases. Our main finding of strong differences between the elasticity of wages to idiosyncratic TFP compared to that with respect to sector-level TFP is unaffected.

Secondly, we augment both the labour compensation and labour equations with hours per worker. Indeed, in firms where hours worked are lower, average wages may be smaller and the number of required workers higher, all else being equal. We allow hours per worker to be endogenous, and instrument it by its own lags. The estimates indicate a small but positive coefficient on hours per workers, but there is virtually no impact on the coefficient of TFP and TFP.

Thirdly, as discussed in above, one advantage of considering the firm average wage bill is that it accounts for wage flexibility from new hires. However, as most papers focus on job stayers wages, we also present results controlling for the percentage of newly hired workers. This variable does not signficant affect the average wage and our main result is essentially unchanged.

Fourthly, we evaluate the robustness of our results when considering firm-specific TFP as endogenous, and instrument TFP by its own lags. This does not change the main conclusions of our paper, but tends to reduce the significance level of firm-specific TFP, due to the difficulty of finding appropriate instruments.

Last, we estimate the real labour compensation equation (2a) assuming that the variables that capture composition effects are endogenous. We instrument these variables by their own lags. Results reported in the last lines of Table A.3 show that our conclusions are unaffected.

All in all, our main qualitative conclusions remain robust to these alternative specifications and assumptions. The elasticity of labour compensation and labour to firm-specific TFP are positive but close to zero. The elasticity of labour is higher, consistent with real wage rigidity. By contrast, the elasticity or labour compensation to sector-level TFP is very high, while that of labour is low and not significantly different from zero.

25 Note that, in labour compensation equations, neither the size dummy in Table 2, nor the size variable is significant at 10% level. In the labour equation, neither average labour compensation, nor the log change in average labour compensation is significant.
### TABLE A3. SGMM ESTIMATES - ROBUSTNESS TESTS

<table>
<thead>
<tr>
<th>Equation (3.a) for real labour compensation</th>
<th>Equation (4) for real labour compensation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>coefficient</td>
</tr>
<tr>
<td>(1) Results of equation (3a) as in Table 2</td>
<td></td>
</tr>
<tr>
<td>tftp₁</td>
<td>0.032**</td>
</tr>
<tr>
<td>tftp₂</td>
<td>0.424***</td>
</tr>
<tr>
<td>(2) alternative specifications (a.4)</td>
<td></td>
</tr>
<tr>
<td>tftp₁</td>
<td>0.057**</td>
</tr>
<tr>
<td>tftp₂</td>
<td>0.442***</td>
</tr>
<tr>
<td>(3) Equation (3a) augmented with hours per worker</td>
<td></td>
</tr>
<tr>
<td>tftp₁</td>
<td>0.033***</td>
</tr>
<tr>
<td>tftp₂</td>
<td>0.434***</td>
</tr>
<tr>
<td>(4) Equation (3a) augmented with the percentage of new hires</td>
<td></td>
</tr>
<tr>
<td>tftp₁</td>
<td>0.033***</td>
</tr>
<tr>
<td>tftp₂</td>
<td>0.425***</td>
</tr>
<tr>
<td>(5) TFPₜ assumed endogenous</td>
<td></td>
</tr>
<tr>
<td>tftp₁</td>
<td>0.011</td>
</tr>
<tr>
<td>tftp₂</td>
<td>0.460***</td>
</tr>
<tr>
<td>(6) composition effects assumed endogenous</td>
<td></td>
</tr>
<tr>
<td>tftp₁</td>
<td>0.056***</td>
</tr>
<tr>
<td>tftp₂</td>
<td>0.469***</td>
</tr>
</tbody>
</table>

**Notes:** The Table presents only results for TFPₜ and TFPₑ. In addition, each equation includes the same control variables as in Table 2. For details on GMM estimation, see note under Table 2. Standard errors in parentheses.

* indicates significance at the 10% level, ** at the 5% level, *** at the 1% level.