EUROPEAN CENTRAL BANK

EUROSYSTEM

WAGE DYNAMICS NETWORK

WORKING PAPER SERIES
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EVIDENCE FROM MONTHLY MICRO WAGE DATA

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In 2009 all ECB publications feature a motif taken from the €200 banknote.

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Wage Dynamics Network

This paper contains research conducted within the Wage Dynamics Network (WDN). The WDN is a research network consisting of economists from the European Central Bank (ECB) and the national central banks (NCBs) of the EU countries. The WDN aims at studying in depth the features and sources of wage and labour cost dynamics and their implications for monetary policy. The specific objectives of the network are: i) identifying the sources and features of wage and labour cost dynamics that are most relevant for monetary policy and ii) clarifying the relationship between wages, labour costs and prices both at the firm and macro-economic level.

The WDN is chaired by Frank Smets (ECB). Giuseppe Bertola (Università di Torino) and Julian Messina (Universitat de Girona) act as external consultants and Ana Lamo (ECB) as Secretary.

The refereeing process of this paper has been co-ordinated by a team composed of Gabriel Fagan (ECB, chairperson), Philip Vermeulen (ECB), Giuseppe Bertola, Julian Messina, Jan Babecký (CNB), Hervé Le Bihan (Banque de France) and Thomas Mathä (Banque centrale du Luxembourg).

The paper is released in order to make the results of WDN research generally available, in preliminary form, to encourage comments and suggestions prior to final publication. The views expressed in the paper are the author's own and do not necessarily reflect those of the ESCB.

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Abstract

This paper assesses the degree of wage flexibility in Luxembourg using an administrative data set on individual base wages covering the entire economy over the period 2001-2006 with monthly frequency. We find that the wage flexibility at the discretion of the firm is rather low once we limit measurement error and remove wage changes due to institutional factors (indexation, changes in statutory minimum wage, age and marital status). The so adjusted frequency of wage change lies between 5% and 7%. On average, wages change less often than consumer prices. Less than one percent of (nominal) wages are cut both from month to month and from year to year. Due to automatic wage indexation, wages appear to be subject to substantial downward real wage rigidity. Finally, wage changes tend to be highly synchronised as they are concentrated around the events of wage indexation and the month of January.

Keywords: wage flexibility, wage rigidity.

JEL Classification: J31

Non-technical summary

Nominal rigidities are a mainstay of the New Keynesian literature. Whether wages or prices are flexible or rigid bears important implications for monetary policy as *"temporary nominal rigidities provide key friction that gives rise to nonneutral effects of monetary policy."* (Clarida et al. (1999)). Measures of wage rigidity appear to have important implications for the degree of inflation persistence and the optimal monetary policy. While many recent macroeconomic models incorporate wage and price rigidities and rely on some measure of price and wage stickiness in their calibration, such as the frequency of price and wage change or the duration of nominal contracts, until recently, little was known about the strength of these rigidities in European countries. Over the recent past a comprehensive literature has emerged assessing the stickiness of prices based on individual quotes of consumer and producer prices. So far, empirical evidence on the rigidity of wages remains scarce, although wage rigidities might be a source of price stickiness and are often considered the main reason for higher structural unemployment in Europe compared to the US. Moreover, wage rigidity restricts adjustment to shocks within a currency union and interferes with efficient allocation of resources.

The aim of this paper is to assess the degree of wage flexibility in Luxembourg using a unique administrative dataset with information on individual earnings. The administrative dataset has monthly frequency and covers all firms and employees in Luxembourg between January 2001 and December 2006. We focus on the flexibility of base wages referring to individual occupations (i.e. unique employer-employee relationships). Throughout the analysis, the degree of wage flexibility is measured as the frequency of wage change. In order to assess more specifically the degree of downward wage flexibility we distinguish between wage increases and wage cuts. In contrast to the vast majority of the existing research, the very wide coverage and the high frequency of the database provide a representative measure of wage flexibility covering nearly all sectors of the economy, all firm-size classes and all types of employees over a period as long as six years. In addition, the paper illustrates how measurement error (e.g. due to lack of explicit information on overtime hours and compensation) can lead to implausibly frequent wage adjustment. We provide estimates of the frequency of wage change based on two alternative approaches to limit measurement error. One of the approaches defines a set of judgmental rules to eliminate supposedly implausible patterns of wage adjustment. The other approach is based on the assumption that measurement error free wage trajectory is a step function and identifies true wage changes as structural breaks in the individual base wage series. Finally, we provide estimates of wage flexibility at the discretion of a firm by adjusting the frequency of wage change by a set of institutionally determined wage changes (such as changes due to statutory wage indexation).

Our main findings can be summarized as follows. First, measurement error in the reported number of hours worked can substantially bias the estimated frequency of wage change upwards. In the raw dataset we obtain an average monthly frequency of wage change of approximately 57%. However, after limiting measurement error, the remaining frequency of wage change is between 9% and 14%. The resulting wage change frequency is thus lower than the consumer price change frequency in Luxembourg (17%) and the average frequency of producer price change in six euro area countries other than Luxembourg (21%).

Second, we find a substantial degree of heterogeneity across firms of different size, between public and private firms, across sectors of the economy, occupational groups and between different periods. Blue-collar workers reveal the lowest frequency of wage change, while civil servants exhibit the highest frequency. While wages of civil servants change more often, they change by the smallest amount at the same time. The same reasoning explains why public sector enterprises have higher frequency of wage change than private enterprises. Our results also suggest that larger firms tend to change wages more often.

Third, we find that wage changes tend to be highly synchronised as they are concentrated around months of wage indexation and the month of January. In a typical year, approximately 50% of all wage changes occur in the event of indexation and another one quarter of wage changes is observed in the month of January, reflecting the predominant share of collective wage agreements entering into effect in this month. Nearly all wages change during indexation events. Our results suggest that the overall frequency of wage change is substantially driven by institutional factors which are not at the discretion of the firm. If we adjust for institutionally determined wage changes (i.e. wage changes due to indexation, changes in statutory minimum wage or changes in age and marital status), the remaining monthly wage change frequency is between 5% and 7%. This suggests that the measured frequency of wage adjustment may overstate the extent of wage flexibility at the discretion of the firm.

Finally, the evidence presented in the paper suggests that wages in Luxembourg are subject to substantial downward wage rigidity, both in nominal terms and in real terms. We find that less than one percent of (nominal) wages are cut both from month to month and from year to year. Moreover, only few wages are cut in real terms, i.e. either the nominal wage decreases or it grows by less than the inflation rate stipulated by the automatic wage indexation mechanism (i.e. 2.5%). The vast majority of wages in Luxembourg increase by this rate in the event of indexation.

1 Introduction

In this paper, we assess the degree of wage flexibility in Luxembourg using monthly data on base wages referring to individual occupations (i.e. unique employer-employee relationships) over the period 2001 to 2006. Whether wages are flexible or rigid remains a controversial question that enters many theoretical and policy discussions. From the theoretical point of view, the assumption of rigid nominal adjustment is a distinctive feature of the New Keynesian literature. As Clarida et al. (1999) state, *"the approach [..] is based on the idea that temporary nominal rigidities provide key friction that gives rise to nonneutral effects of monetary policy."* Many recent macroeconomic models incorporate wage and price rigidities and rely on some measure of price and wage stickiness in their calibration, such as the frequency of price and wage change or the duration of nominal contracts. Measures of wage rigidity appear to have important implications for the degree of inflation persistence and the optimal monetary policy (e.g. Blanchard and Galí (2007)).

The Eurosystem Inflation Persistence research Network (IPN) concluded that wage rigidity can be a cause of price stickiness observed in the euro area. Numerous papers document that prices change less frequently for products with a larger labour share, like services (Altissimo et al. (2006); Alvarez et al. (2005); Dhyne et al. (2005); Vermeulen et al. (2007)). It was suggested that this may be due to sluggish marginal costs, in particular rigid wages.

This paper is also related to the policy debate concerning wage rigidity. Wage rigidity is often considered a primary cause of higher unemployment rates in Europe, as compared to the US (Jackman et al. (1999)). The argument suggests that labour market rigidities, such as minimum wages, collective agreements etc., prevent companies from cutting wages. Furthermore, wage rigidity restricts adjustment to shocks within a currency union and interferes with efficient allocation of resources.

We assess the degree of wage stickiness using a set of broad-based measures based on a unique microeconomic high-frequency administrative dataset. This study extends the empirical literature in several ways. First, most of the microeconomic evidence on wage adjustment is based on an analysis of annual earnings (e.g. Fehr and Goette (2005)) or quarterly wage data (e.g. Heckel et al. (2008)), while we study wage adjustment at monthly frequency. Second, we consider actual wage adjustments at the employer-employee level, rather than analysing data on collective wage agreements (see, for example, Cecchetti (1987)) or referring to a small number of representative employees (e.g. Heckel et al. (2008), Birscoup et al. (2005)). Third, in contrast to studies of specific labour markets (Akerlof et al. (1996)) or individual firms (Altonji and Devreux (2000)), we provide a representative measure of wage flexibility covering nearly all sectors of the economy, all firm-size classes and all types of employees over a period as long as six years. Fourth, we provide estimates of the frequency of wage change based on two alternative approaches to limit measurement error and illustrate how measurement errors can lead to implausibly frequent wage adjustment. Fifth, by adjusting the total frequency of wage change by a set of institutional wage changes (such as due to statutory wage indexation), we provide estimates of wage flexibility at the discretion of the firm.

Our main findings can be summarized as follows. Measurement error in the reported hours worked can substantially bias the estimated frequency of wage

change upwards. In the raw dataset we obtain an average monthly frequency of wage change of approximately 57 percent. However, after limiting measurement error, the remaining frequency of wage change is between 9% and 14%. The resulting wage change frequency is thus lower than the consumer price change frequency in Luxembourg (17% reported by Lünnemann and Mathä (2005)) and the average frequency of producer price change in six euro area countries excluding Luxembourg (21% reported by Vermeulen et al. (2007)).

In addition, we find a substantial degree of heterogeneity across firms of different size, between public and private firms, across sectors of the economy, occupational groups and different periods. Blue-collar workers reveal the lowest frequency of wage change, while civil servants exhibit the highest frequency. The same reasoning explains why public sector enterprises have higher frequency of wage change than private enterprises. While wages of civil servants change more often, they change by the smallest amount at the same time. Our results also suggest that larger firms tend to change wages more often. Moreover, wage changes tend to be highly synchronised as they are concentrated around months of wage indexation and the month of January. In a typical year, approximately 50% of all wage changes occur in the event of indexation and another one quarter of wage changes is observed in January, reflecting the predominant share of collective wage agreements entering into effect in this month. Nearly all wages change during indexation events. Our results suggest that the overall frequency of wage change is substantially driven by institutional wage changes which are not at the discretion of the firm. If we remove the effects of institutional wage changes (i.e. wage changes due to indexation, to changes in statutory minimum wage and to changes in age and marital status), the remaining monthly wage change frequency is at most 7 percent. This suggests that the measured frequency of wage adjustment may overstate the extent of wage flexibility that is really at the discretion of the firm.

Put together, the evidence presented in the paper suggest that wages in Luxembourg are subject to substantial downward real wage rigidity (DRWR). DRWR implies that only few wages are cut in real terms, i.e. either the nominal wage decreases or it grows by less than the inflation rate stipulated by the automatic wage indexation mechanism (i.e. 2.5%). The vast majority of wages in Luxembourg increase by this rate in the event of indexation. We documented that less than one percent of (nominal) wages are cut both from month to month and from year to year.

The paper is organised in four sections. Section 2 provides a brief overview of the macroeconomic situation in Luxembourg over the 6-year sample period and reviews the wage bargaining process and labour market institutions. Section 3 describes the dataset and the way we adjust for measurement error in reported hours worked. It also formalizes our approach to the measurement of wage stickiness. Section 4 present the results, while Section 5 concludes and provides an outlook for further research.

2 Key elements of the labour market in Luxembourg

To put our results on the frequency of wage adjustment into perspective, one has to consider the specific aspects of the labour market in Luxembourg. Trade union density in Luxembourg is relatively high compared to other western European countries according to Du Caju et al. (2008). The wage bargaining is decentralized with wage bargaining typically undertaken at the firm-level. Coordination of wage bargaining is achieved mainly through automatic state-imposed indexation of wages and minimum wage regulation. The coordination mechanism has important implications for the monthly frequency of wage adjustment and hence we describe it in detail in the following subsections, while other aspects of the labour market in Luxembourg are discussed in Appendix A.

2.1 The wage indexation mechanism

Explicit wage indexation schemes are imposed in a number of European countries (e.g. Belgium, Cyprus, the Czech Republic and Slovenia, see Du Caju et al. (2008)). However, only in a few countries (among which Luxembourg) is wage indexation the dominant coordination mechanism. While in most countries wage indexation applies only to a sub-set of the entire workforce (e.g. for the public sector, as in the Czech Republic), in Luxembourg, all wages (and pensions) are completely indexed.[1] Wage indexation in Luxembourg as well as in Belgium and Cyprus is entirely automatic.

The state-imposed wage indexation mechanism is entirely backward-looking, with wages being indexed to past developments in the Luxembourg national index of consumer prices ($NICP$ hereafter).[2] For most of the period under study (namely from 2001 to mid-2006), the legislation required automatic wage indexation to kick in whenever the 6-month moving average of the $NICP$ increased by 2.5% relative to its level at the time of the preceding wage indexation event. In the event of a new round of indexation, wages were increased by 2.5% at the beginning of the month following the breach of the 2.5% threshold. Importantly, the wage indexation mechanism made no distinction with regard to the sources of inflation. Regardless of the sources underlying, increases in the general price level were fully passed through to wages in the event of wage indexation. In 2006, the Luxembourg Government chose to deviate from this purely mechanical implementation[3] and introduced an amendment (*modulation* hereafter) governing the implementation of automatic wage indexation over the period 2006-2009. This was justified by competitiveness concerns following the rapid increase in oil prices and lead to a lower number of wage indexation events during 2006-2009. For 2006, the *modulation* excluded any further wage indexation prior to December 2006 regardless of the actual developments in the price level. In December 2006, wages were indexed by 2.5%, i.e. a rate inferior to the

[1] Prior to the law of 27 May 1975, and since 1921, indexation was applied only to civil servants and railway staff (Adam and da Costa (2002)).

[2] Minor exceptions apply. A very small number of price changes are not taken into account within the framework of the wage indexation mechanism.

[3] Similar deviations occured in the past, e.g. in the wake of the devaluation of the Belgian and the Luxembourg Franc in 1982 (Fontagné (2004)).

increase in the general price level observed since the preceding event of wage indexation (i.e. October 2005).[4]

Automatic wage adjustments due to indexation are exogenous to the individual firm. However, firms can anticipate the timing and the size of wage adjustments due to indexation.[5] First, the level of the $NICP$ (and, implicitly, the accumulated increase in the general price level since the last indexation) is regularly published by the national statistical institute (*Statec*). Second, both *Statec* and the *Banque centrale du Luxembourg* provide inflation forecasts twice a year which are available to the public at large. Third, the wage indexation mechanism is often considered a cornerstone of the *Luxembourg model*, both in politics and by the general public. Its desirability as well as the prospects for an upcoming round of wage indexation are widely discussed within the national press. Over the period under study, wage indexation kicked in six times.[6] As reported in Du Caju et al. (2008), in Luxembourg, wage indexation is the dominant form of coordination in the economy as a whole. Whereas its impact on wages is obvious, Lünnemann and Mathä (2006) report that firms in the services sector consider wage indexation to be the second most important reason for price increases.

2.2 The statutory minimum wage

In addition to the imposed mechanism of wage indexation, wage formation in Luxembourg is subject to a legal minimum wage. This extends to all sectors of the Luxembourg economy and the minimum wage level imposed is identical for all sectors of the Luxembourg economy. As in other countries with a minimum wage, a 20% (25%) reduction is applied to the wages of young workers in the age of 17 (age of 15 and 16). For qualified workers, a 20% premium is applied. However, in general, there is no distinction according to tenure. As reported in Du Caju et al. (2008), the minimum wage level in Luxembourg is fairly high and so is the proportion of workers covered by the minimum wage regime (between 10 and 20%).The minimum wage is defined as an hourly rate and as a monthly wage (the latter being derived on the basis of 173 hours worked per month). At the end of the sample period the monthly minimum wage was EUR 1.503 (EUR 1.804) for unskilled workers (skilled workers) aged 18 or more. In the event of an automatic wage indexation, the minimum wage is adjusted accordingly. Importantly, changes to the minimum wage can result for reasons other than wage indexation. Adjustments in the minimum wage unrelated to indexation are first negotiated within the framework of the *tripartite*. The Government considers changes to the minimum wage at biannual frequency. Ultimately, any such changes are implemented by Government on the grounds of an assessment

[4]The postponement of the indexation to no earlier than December 2006, as stipulated by the led to a 14-month period of no-indexation, similar to almost all other years under study. While the modulation has not affected the rate by which wages are changed in the case of indexation, given the fairly high inflation rates observed in 2006, it might have had an impact on wage negotiations and wage setting behaviour in more general. However, the amendment has been introduced in mid-2006 only, probably after standard collective wage agreements had been concluded. Moreover, with an average length of collective wage agreements in Luxembourg of roughly 2 years, only a subset of collective agreements was settled in 2006.

[5]This applies in particular to the period of *modulation* when actual inflation considerably exceeded the 2.5% threshold.

[6]Wage indexations occured in April 2001, June 2002, August 2003, October 2004, October 2005 and December 2006.

of the developments in real salaries over the past two years. During the sample period, ex-indexation adjustments to the minimum wage took effect in January 2003 and in January 2005.

2.3 Other coordination mechanisms

Additional forms of coordination, other than wage-indexation and minimum wages also apply, though they are not dominant. The most important of these secondary coordination mechanisms is "intra-associational coordination".[7] Unlike some countries, inter-associational coordination [8] and pattern bargaining do not apply in Luxembourg. As already indicated, the patterns of wage adjustment (in particular their frequency) may also depend on the duration of collective wage agreements. Du Caju et al. (2008) report an average duration of collective agreements in Luxembourg of roughly two years. As in many other countries, we observe a strong seasonal pattern in the timing of such collective wage agreements. Wage negotiations typically start around the turn of the year and agreements are typically reached within the first quarter of the following year (as in Belgium and France). However, different seasonal patterns may apply to selected sectors. Moreover, in *Industry*, *Market services* and *Non-market services* sectors, the actual timing may lag behind the above seasonal pattern due to persistent difficulties in finding an agreement. Substantial delays typically lead to agreements that are applied retrospectively and/or lead to one-off payments. Pre-expiry renegotiations are common in the *Industry*, *Market services* and *Non-market services* sectors, in particular during periods of slower growth and rising concerns about competitiveness.

3 Data, methods and variables

Hereafter, the analysis makes reference to four main samples (*raw*, *baseline*, *cleaned* and *adjusted* dataset). The *raw dataset* is only used to provide aggregate figures for the entire Luxembourg economy and, later on, to assess the impact of measures aimed at limiting measurement error and the impact of cleaning on size of the subsample relative to the entire population. The *raw dataset* reflects the total Luxembourg labour market. However, it encompasses, among others, occupations/observations with partly missing information (e.g. Nace code, firm ID, etc.), which is needed to derive estimates of frequencies of wage change or disaggregated results (e.g. sectoral results). The *baseline dataset* includes all observations that can be used to compute measures of frequency of wage change without addressing measurement error. This *baseline dataset* is therefore the broadest one for which meaningful frequencies can be obtained. Measures of the frequency of wage change based on this dataset are thus not affected by any of the methods used later on to limit measurement error or to adjust for institutional wage changes.[9] The *cleaned dataset* is obtained by adjusting the *baseline dataset* for (supposedly) implausible observations or wage

[7] Intra-associational coordination refers to wage bargaining undertaken at the level of umbrella organisations of either employers or trade unions. Du Caju et al. (2008) cite intra-associational coordination dominant for the majority of the countries studied.

[8] Inter-associational coordination is meant to characterize wage bargaining determined at the national level or by means of cross-sectoral agreements, see Du Caju et al. (2008).

[9] The baseline dataset had to be slightly modified in order to derive estimates of wage flexibility based on the multiple break point test (see Section 3.1 and C.2).

trajectories based on judgemental rules. Finally, the *adjusted dataset* attempts to approximate the true degree of wage flexibility at the discretion of a firm. For this reason we adjust the *cleaned dataset* for the effects of wage indexation, changes of statutory minimum wage, age and marital status.

3.1 Baseline dataset

The analysis is based on micro data from the Luxembourg social security authority (*Inspection Générale de la Sécurité Sociale*, IGSS hereafter). The data is that reported by employers to the social security institutions on behalf of all their affiliated employees. The data is organised at monthly frequency and covers the period from January 2001–December 2006.[10] The *raw dataset* includes more than 21 million observations reporting individual wage data for almost 475 000 employees affiliated with more than 45 000 employers covering more than 830 000 occupations. In 2006, the aggregate volume of salaries covered by the dataset (i.e. more than 12.5 bn EUR) corresponded to an amount equivalent to approximately 37% of nominal GDP.

For any given unique relationship between an employee i and an employer j in month t, the data base provides the following type of information:

1. Information related to the employee, such as date of birth, gender, marital status, nationality, country and place of residence, date of first affiliation with the Luxembourg social security system;

2. Information related to the employer, such as the location and sector (according to two-digit *NACE rev. 1.1*) and

3. Information related to the occupation itself, such as the base salary, bonuses granted, contributions to social security (paid by employer and employee), start date, occupational group[11], the number of hours worked, etc. Our key indicator of interest in the analysis of wage flexibility is the base salary[12]

In addition, there is complementary information implicit in the database related to the employee (the number of occupations maintained) or to the employer (the total number of staff, public institution versus private enterprise).

Due to missing or inappropriate information, estimates of the frequencies of wage change cannot be obtained at the level of the *raw dataset*. For analytical purposes, we remove observations that either cannot be used (e.g. due to missing information) or are of limited use for the analysis which focuses on representative types of employment. Most importantly, we remove observations with extremely high/low number of hours worked, occupations lasting less than 6 consecutive months and firms that existed for less than 36 months, the household sector, the

[10] Strictly speaking, the database includes retired persons, pre-retired, jobless, freelancers, etc. However, the following analysis is restricted to regularly employed people only. On the other hand, the data does not provide information on officials affiliated with the local EU institutions, such as the European Court of Justice, the European Court of Auditors, the European Commission, the European Investment Bank.

[11] Throughout the analysis, and based on the information available from the database, we distinguish between three types of occupational groups, namely blue-collar workers, white-collar employees and civil servants

[12] On the issue of measurement error see also Section 3.2 below.

last month of each occupation and some other peculiar observations. Specific details on the reasons for removing such observation and their impact on the size and representativeness of the dataset are discussed in Appendix B.1.

After applying these restrictions, the dataset (*baseline dataset* hereafter) contains more than 17.3 million wage observations, representing more than 437 000 occupations maintained between more than 16 000 firms and more than 350 000 employees. The data cleaning thus yields a substantial reduction in the number of firms (roughly -65%), employees (-26%) and observations (-20%). The sharp reduction in the number of firms considered is largely due to the exclusion of NACE sector P *Activities of households*, the household sector being the largest sector of the Luxembourg economy in terms of number of "firms". The impact on the total volume of base wage bill earned is less sizeable (-9.4%). The *baseline dataset* includes only observations that can be used to compute measures of frequency of wage change, without any further measures to limit measurement error. The *baseline dataset* is therefore the broadest one for which frequencies can be derived. Measures of the frequency of wage change based on the *baseline dataset* are thus not affected by any of the methods used later on to limit measurement error or to adjust for institutional wage adjustments.[13]

3.2 Cleaned dataset

There may be several reasons why the measured frequency of wage change is a poor indicator of true wage flexibility. First, this may result from misreported data, i.e. wages earned and/or hours worked. Indeed, studies of individual firms are less prone to measurement error and typically find much fewer cases of nominal wage cuts than studies based on survey data (see Altonji and Devreux (2000)). Second, an upward bias in the measured frequency of wage change may result from incomplete information available to the researcher. For example, our database lacks explicit information on overtime hours and overtime remuneration. Variation in the number of overtime hours may lead not only to changes in the monthly salary for hourly workers, but also to a different average hourly wage rate when such overtime hours are remunerated at rates other than those applied to normal work hours (e.g. Sundays, night work).[14]

Below we list the rules that we implemented in order to filter out such observations (in case of blue-collar workers) or trajectories (in case of white-collar workers) from the baseline dataset.[15] Further details on the rules are provided

[13]The baseline dataset had to be slightly modified in order to derive estimates of wage flexibility based on the multiple break point test (rather than based on explicit judgemental rules). The reasons are twofold. First, the multiple break point test appears to be sensitive to very large wage changes that are most likely outliers and hence we removed 2.5 percent of the largest wage changes. Second, given the limited number of potential break points for which critical values are reported by Bai and Perron (1998), we decided to adjust the baseline dataset by known wage changes (institutional reasons, in particular due to wage indexation and adjustments to the minimum wage.

[14]Similarly, changes in the monthly salary and the average hourly wage rate may result if the total base wage consists of a fixed and a variable component.

[15]We apply distinct rules to blue-collar workers on the one hand and white-collar employees and civil servants on the other hand. Assuming that white-collar employees and civil servants are typically remunerated according to a monthly salary with relatively infrequent changes in the number of hours worked, the presence of overtime hours/compensation leads to the exclusion of the entire wage trajectory. Applying an identical rule to blue-collar workers, who

in Appendix B.2 and their impact on the sample size is listed in Table 17.

1. We remove trajectories (in case of white-collar workers and civil servants) or observations (in case of blue-collar workers) which do not fulfil the requirements used to identify well-behaved trajectories of hours worked (on the definition of well-behaved trajectories of hours worked see item 1 of Appendix B.2.)

2. We remove trajectories (in case of white-collar workers and civil servants) or observations (in case of blue-collar workers) consisting of four consecutive wage changes. Given the substantial obstacles with regard to frequent wage changes typically reported in firm surveys (see, for example, Druant et al. (2008)), we consider four consecutive wage changes an indication of (unreported) changes in the number of hours worked and/or shift assignments.

3. We require, for each round of indexation, the minimum wage reported after indexation to be higher than the minimum wage reported before the indexation. Wage trajectories not obeying this requirement are removed.[16]

4. We disregard wage changes which lead to a monthly salary or hourly rate equivalent to former wage levels within a period shorter than six months. Such wage change reversals can reflect a series of offsetting changes or, alternatively, two wage changes of same magnitude but different sign.

5. The frequency of wage change should not depend on the size of wage changes, but from an economic point of view, the role of wage changes may well depend on their size. Tiny wage changes in terms of few euro cents are probably not evidence of underlying wage flexibility. By contrast, huge wage changes (say doubling the base wage) tend to be fairly exceptional and/or suggest poor data quality, in particular when reverted shortly afterwards. Whenever the hourly wage rate (in absolute terms) changes by less than 0.25% and/or less than 0.075 EUR, we consider this a *no-change*. Observations implying a reduction of/ an increase in the base wage by more than 25% are also omitted.

6. In addition to disconsidering selected observations (huge wage changes) and replacing selected others (tiny wage changes or reverting wage changes), we eliminate wage trajectories characterised by frequent tiny and/or huge wage changes and by numerous replacements (e.g. due to reversion to former wage level). This is to avoid an estimate of wage change frequency primarily based on adjustments/replacements. In order for the entire wage trajectory to be removed (rather than a single observation from this trajectory), we require the number of adjustments/replacements to represent more than one half of all observations in the trajectory.

7. In the case of employees and civil servants, we remove observations that report a decrease in base wage in December together with a bonus. In

are typically remunerated according to an hourly wage rate and characterised by relatively frequent changes in the number of hours worked, would inevitably lead to an extreme loss of observations. In the case of blue-collar workers, thus, we decide to eliminate but observations affected by overtime hours/compensation.

[16] Note that we do not impose downward nominal rigidity in a strict sense.

these cases, the base wage in January either continues at its November level or is increased. In such cases, we omit the December observation (i.e. split the trajectory).

8. Sometimes wage changes are entirely reversed by the following wage change. These exact wage reversions are probably associated with misreported overtime hours, misreported one-off payments, etc. For this reason, in the case of white-collar employees and civil servants, we drop all wage trajectories revealing at least one exact wage reversion (regardless of the duration after which a wage change is reverted).

9. We remove wage trajectories with less than 12 potential wage changes (i.e. minimum length of 13 months per trajectory).

10. Observations related to occupations between employers and workers within NACE sector N *Health and social work* and observations maintained with Governmentoperated postal services. Both the monthly salary and the hourly wage tend to be very volatile. The high degree of volatility is likely to result from changes in the composition of the hours worked (e.g. hours worked on Sundays are remunerated at a premium) rather than a result of underlying wage flexibility.

In total, the remaining dataset (*cleaned dataset* hereafter) retains over 4.1 million wages reported covering more than 88 000 employees affiliated with more than 10 000 employers. Overall, the above measures lead therefore to a substantial reduction in the number of firms (-32%), of employees (-75%) and of observations (-76%) relative to the baseline dataset. The *cleaned dataset* covers approximately 27% of the *raw dataset* in terms of the volume of base wages.[17] The *cleaned dataset* provides estimates of the frequency of wage change based on judgemental rules.[18]

3.3 Adjusted dataset

If we abstract from measurement error, the remaining genuine wage changes do not necessarily reflect true wage flexibility. Instead, wage changes may be entirely due to institutional factors, such as automatic wage indexation. From the perspective of a single firm, such purely institutional/administered wage changes might even be considered an obstacle to wage flexibility. More specifically, we adjust the *cleaned dataset* for the effects of wage indexation, changes of statutory minimum wage, age and marital status. Of course, wages may change for reasons including other institutional elements (at the level of a single firm at least) which we cannot identify based on the information in the dataset (such as collective wage agreements). The resulting adjusted frequency of wage change, therefore, is still an upper bound on the flexibility at the discretion of the firm.

As already mentioned in Section 2.1, firms in Luxembourg are legally obliged to increase base salaries by 2.5% whenever the wage mechanism is triggered. The

[17] On the distribution of occupations, firms and total wages across NACE sectors, see Section B.3 in the Appendix. Our attempts to limit measurement error have a disproportionately larger impact on the number of blue-collar workers.

[18] It is not used when deriving estimates of the frequency of wage change based on the multiple break test. Rather, the multiple break point test – which serves as an alternative to the judgemental rules – is applied to the *baseline dataset*.

sample period under study is characterised by six wage indexation events which may substantially add to the measured frequency of wage change.[19] Given that wage changes due to wage indexation are a poor proxy for the degree of wage flexibility at the discretion of the firm, we adjust the measured frequency of wage change by removing wage changes due to indexation. In order to allow for wage changes coinciding with wage indexation but for reasons other than indexation, we lower the observed size of wage change by the standard 2.5%.[20]

Changes in the minimum wage are another institutional factor leading to wage changes. Adjustments in the minimum wage mainly result from two factors, namely wage indexation and adjustments in line with the general rise in wages (other than the statutory minimum wage). Overall, the impact of adjustments in the minimum wage for reasons other than wage indexation is expected to be much smaller than in the case of indexation because changes in the minimum wage for reasons other than wage indexation apply directly only to a subset of employees and appear only twice during the sample period. The size and the timing of these adjustments in the minimum wage and apply to all occupations remunerated at the minimum wage. We allow for other simultaneous wage adjustments (beyond those due to minimum wage adjustments) by lowering the observed wage change by the stipulated increase in the minimum wage in January 2003 (3.5%) and January 2005 (2.1%).

Depending on the institutional arrangements governing the level and the dynamics of wages across sectors and occupational groups, wage changes may result from changes in age and/or marital status.[21] Unlike automatic wage indexation, the impact of a change in the age and/or the marital status on the wage level is not unique, but varies depending on the sector of the company and/or the occupational group. Moreover, the size of the wage change due to a change in age and/or marital status cannot be determined from the information available. Therefore, we decide not to adjust the size of wage adjustment but rather to eliminate all wage changes reported in the event of a change in age and/or marital status of employees (i.e. the trajectory is split).

3.4 Methods and variables

3.4.1 Defining wage

Even though the database does include information about the status of the employee (blue-collar/white-collar worker/civil servant), it remains unclear whether the person is a salaried employee or an hourly worker. By default we assume that white-collar workers and civil servants are salaried and blue-collar workers are compensated per hour. We distinguish the two situations by testing whether the hourly wage or monthly salary appear to be indexed (i.e. are increased precisely by 2.5% in the indexation periods). We did not find any white-collar worker or civil servant whose hourly wage appeared to be indexed (without having their salary indexed at the same time). On the other hand, several blue-collar workers

[19] With no wage changes other than indexation, wage indexation would imply a frequency of more than eight percent for a person observed during the entire sample period.

[20] Depending on the degree to which wages are indexed, this adjustment can lead to lower or higher frequency of wage change.

[21] For similar, institutional reasons, salary increases may result in the event of birth of a child. However, as we have no information on the number of children, we cannot adjust for such changes.

had their monthly salaries indexed, while their hourly earnings did not appear to be indexed. In such situations we calculate the frequency of changes in the monthly salary excluding bonuses divided by normal working hours, rather than analysing the hourly base wage.

We base our calculation of the frequency of wage change on the following measure of base wage. For hourly workers (most of the blue-collar workers, as defined above) we divide the monthly base wage by the reported number of hours. For salaried workers (white-collar workers, civil servants and some blue-collar workers), we divide the monthly base wage by the constant normal hours worked corresponding to the particular part-time/full-time profile (e.g. 173 hours for all full-time workers).

3.4.2 Frequency of wage adjustment

In analogy to the recent literature studying micro price stickiness,[22] we study the degree of wage rigidity based on the analysis of trajectories of base wages (referred to as wages hereafter) reported for individual occupations. A wage trajectory is defined below as a sequence of wage records characterising a single occupation over time. A wage trajectory can be divided into one or more wage spells, i.e. periods of constant wages for any given employee-employer relationship. As in the micro price studies (see, for example, Alvarez et al. (2005) and Aucremanne and Dhyne (2004)), we present evidence on the frequency of wage changes and the size of such wage changes. Given the importance of downward wage rigidity, throughout the analysis we distinguish between wage reductions and wage increases. Let w_t^{ij} denote the wage paid to employee i affiliated with firm j in period t. The frequency of wage change is the number of actual wage changes divided by the number of potential wage changes. All observations are potential wage changes except for those with missing information on the wage level in period $t-1$ for the same employee i and employer j. Formally, we define the frequency of wage change $F_{ij}^{\pm}$ as

$$F_{ij}^{\pm} = \frac{\sum_{t=2}^{T} d_{t,t-1}^{+} + d_{t,t-1}^{-}}{\sum_{t=2}^{T} d_{t,t-1}^{+} + d_{t,t-1}^{-} + d_{t,t-1}^{=}}, \tag{1}$$

where T denotes the length of the wage trajectory and

$$d_{t,t-1}^{+} = \begin{cases} 1 & \text{if } w_t^{ij} > w_{t-1}^{ij} \\ 0 & \text{else} \end{cases}$$

$$d_{t,t-1}^{-} = \begin{cases} 1 & \text{if } w_t^{ij} < w_{t-1}^{ij} \\ 0 & \text{else} \end{cases}$$

$$d_{t,t-1}^{=} = \begin{cases} 1 & \text{if } w_t^{ij} = w_{t-1}^{ij} \\ 0 & \text{else} \end{cases} .$$

In analogy we define the frequency of wage increases and decreases. The formulas are included in Appendix C.1 together with the definitions of the average

[22] The following analysis owes much to the methods used to study price stickiness using micro consumer and producer price data, see e.g. Dhyne et al. (2005).

size of wage changes/increases/decreases. When applying the formulas to the baseline or cleaned dataset, we refer to the results as *direct* measures of wage adjustment.

3.4.3 Measure of wage frequency based on structural break test

In Section 3.2 we proposed to limit the measurement error in the dataset by focusing on well-behaved wage trajectories and eliminating implausible patterns of wage adjustment. Admittedly, the procedure can provide but a judgemental assessment of the underlying degree of wage flexibility. As a means of cross-checking, in this section, we describe a complementary method for handling measurement error in wage datasets as proposed by Gottschalk (2005). The method is based on the test procedure for identifying multiple endogenous structural breaks in time series developed by Bai and Perron (1998) and is based on the assumption that an error-free wage trajectory is a step function. By contrast, wage changes other than those suggesting a break in the wage trajectory are considered reflecting measurement error. The aim of the multiple break point test proposed by Bai and Perron (1998) is to model a given series (i.e. a wage trajectory of length T)

$$\left\{w_t^{ij}\right\}_{t=1}^{T} = \left\{w_1^{ij}, w_2^{ij}, w_3^{ij}, ..., w_{T-2}^{ij}, w_{T-1}^{ij}, w_T^{ij}\right\}$$

through a set of $M+1$ series such that

$$\{w_t\}_{t=1}^{T} = \begin{cases} \bar{w}_1 + \mathrm{e}_t & \text{if } t = 1, ..., T_1 \\ \bar{w}_2 + \mathrm{e}_t & \text{if } t = T_1 + 1, ..., T_2 \\ \bar{w}_3 + \mathrm{e}_t & \text{if } t = T_2 + 1, ..., T_3 \\ ... & ... \\ \bar{w}_{M-1} + \mathrm{e}_t & \text{if } t = T_{M-2} + 1, ..., T_{M-1} \\ \bar{w}_M + \mathrm{e}_t & \text{if } t = T_{M-1} + 1, ..., T_M \\ \bar{w}_{M+1} + \mathrm{e}_t & \text{if } t = T_M + 1, ..., T \end{cases} \quad (2)$$

where equation (2) omits the ij superscript and hence $w_t^{ij}(w_t)$ denote the wage observed for an occupation between worker i and firm j in period t, T_m denotes the m^{th} break date (where $m \in \{1, ..., M\}$) and e_t denotes the residual. $\bar{w}_1$ to $\bar{w}_{M+1}$ stand for the $M+1$ wage levels prevailing between any two (out of a total M) subsequent break dates.

The multiple break point test proposed by Bai and Perron (1998) provides a least squares estimator of the number of break points (M) and their timing (T_1 to T_M) as well as the corresponding wage levels ($\bar{w}_1$ to $\bar{w}_{M+1}$) based on a recursive algorithm. Intuitively, the procedure identifies the first structural break as the one leading to the lowest sum of squared residuals over the two subsamples. Next, we test the null hypothesis of no break versus the alternative of a single break. If one break is identified, the sample is broken at that break point and the test is applied again to split the samples. In this second round the null hypothesis is that there is only one break and the alternative is that there are two breaks. In practice the regression model is the same at each stage but the critical values for finding additional breaks become stricter with each successive test. Details on the procedure and its implementation are provided in Appendix C.2.

The working assumption of this test when applied to micro wage data is that break points will be identified whenever the change in the mean wage between two subsequent segments is sufficiently large relative to the variation of the wage around the mean within the segment. The rejection of the null hypothesis of no structural change is meant to characterise a *genuine* wage change. By contrast, wage changes not leading to a sufficiently large variation are considered reflecting measurement error. Bai and Perron (1998) show that the asymptotic properties of their multiple break point test hold for a very general form of measurement error.[23]

We apply the break test to the baseline dataset after removing outliers in the wage change distribution and after requiring a minimum length of 36 months for each wage trajectory. The choice of maximum number of breaks is determined by the trajectory length and asymptotical critical values reported by Bai and Perron (1998). For a wage trajectory consisting of 72 observations this implies nine breaks. Taken into account that six rounds of wage indexation occured in the period under study, this upper limit might be too restrictive. For this reason we removed from the baseline dataset wage changes that are due to institutional factors, namely wage changes due to indexation, changes in the statutory minimum wage, age and marital status. The results of the multiple breakpoint test indicate that the upper bound is not too restrictive (see Section 4.2). After obtaining estimates of the trajectory consisting of $\bar{w}_1$ to $\bar{w}_{M+1}$ (see equation (2)), we can apply the formula in equation (1) to this trajectory to obtain a measure of frequency of wage change implied by the break point test. To allow for comparison with the direct measures of wage change frequency that include institutional wage changes, we define the *augmented* frequency of wage change by adding the number of institutional wage changes that were removed from the baseline dataset to the number of structural breaks identified by the multiple break point test. This is clearly an upper bound on the true frequency as some of the institutional wage changes might not have been considered as structural breaks if the procedure allowed for higher maximum number of structural breaks.

4 Results

In this section we provide results on the frequency and size of base wage changes in Luxembourg. First, we discuss direct measures of wage adjustment based on the baseline, cleaned and adjusted dataset. To compare our results with the literature, we also report the year on year frequency of wage change. We supplement the evidence on direct measures with results obtained from the break test and finally we explore the differences in the frequency and the magnitude of wage changes across firms of different size, public and private institutions, sectors of the economy, months etc.

[23] The critical values provided by Bai and Perron (1998) can be safely used in the case where some data are trending.

4.1 Direct measures of wage change frequency and size

4.1.1 Unadjusted frequency and size of wage change

Based on the baseline dataset, the overall frequency of a base wage change is 57% (see Table 1). The frequency of wage increases (wage cuts) is 34% (24%).[24] Thus, the relative share of wage increases/wage cuts in total wage changes is roughly 60%:40%. We observe substantial heterogeneity across occupational groups. The highest frequency of wage change appears for blue-collar workers (77%), while the lowest frequency of wage change applies to civil servants (29%). For white-collar employees, the frequency of wage change is 42%. The frequency of wage cuts ranges from 5% in the case of civil servants to 35% in the case of blue-collar workers. The proportion of wage cuts in all wage changes, therefore, ranges from 18% in the case of civil servants to 45% blue-collar workers.

Section 3.2 discussed the potential measurement error stemming from the fact that overtime hours and compensation are not explicitly reported in the dataset. In the clean dataset we limit the scope of measurement error and this has a substantial impact on the observed frequency of wage change. Overall, the frequency of wage change declines from 57% to 14%, see Table 2.[25] The impact of measurement error differs substantially across occupational groups. In the case of blue-collar workers, the frequency of wage change falls to 13% (i.e. a drop of more than 60 percentage points when compared to the baseline dataset). By contrast, the above adjustments have a fairly limited impact on the frequency of wage change in the case of civil servants (21%, down from 29%) implying that their recorded wages are relatively less affected by measurement error or that there is less scope for paid overtime work. After adjusting for measurement error, the highest frequency of wage change is observed for civil servants.[26] Their high frequency of wage change, however, results from a high frequency of wage increases (above 20%), while at the same time they exhibit a relatively small frequency of wage cuts). Moreover, limiting the measurement error has an important implication for the relative importance of wage cuts. Their share in total wage changes diminishes to 4% (from more than 40% in the baseline dataset).[27] The strongest degree of asymmetry between wage increases and wage cuts is observed for civil servants with wage cuts representing less than 2% of all wage changes. Finally, limiting measurement error not only leads to a lower frequency of wage change but also to smaller wage changes on average (3.3% compared to an unadjusted 6.6%).[28]

4.1.2 Accounting for institutionally determined wage changes

In this section we discuss the importance of wage changes that are due to institutional factors as these wage changes do not necessarily reflect the true degree of wage flexibility from the point of view of the firm. More specifically, we adjust

[24] Differences due to rounding.

[25] This would correspond to an increase in the implied average duration of wage spells from 1.2 months to 6.5 months.

[26] The implied average duration of wage spells ranges from 4.3 months to 7.3 months.

[27] Again, the more than proportional decline in the number of wage cuts suggests that the measures in Section 3.2 succeed in eliminating wage changes around the general trend.

[28] This might primarily reflect the fact that we removed huge (and tiny) wage changes in the cleaning procedure in Section 3.2.

for the effects of wage indexation, changes in the statutory minimum wage, age and marital status.

Overall, after adjusting for wage changes due to indexation, the frequency of wage change drops from 14.3% to 7.4% (see Table 3, section I). Overall, thus, wage indexation accounts for almost one half of all wage changes observed in the cleaned dataset. For all three occupational groups, adjusting for wage indexation leads to substantially lower estimates of the frequency of wage change. The share of wage changes due to indexation in total wage changes ranges from 37% (civil servants) to 56% (blue-collar workers).[29] Interestingly, adjusting for wage indexation not only leads to a substantially lower frequency of wage increases but it also increases the measured frequency of wage cuts (from 0.6% to 1.4%). This suggests that although firms are legally required to index base wages by 2.5% in the event of wage indexation, for a subset of workers the wage increase reported right in the month of wage indexation is lower than the standard 2.5%. This does not necessarily suggest that the salaries of these employees are not increasing by a full 2.5% around the time wage indexation kicks in.[30] The increase in the frequency of wage cuts after adjusting for wage indexation is lowest for civil servants (0.4%), whose employers might be expected to follow the legal provisions most strictly.

As in the case of wage indexation, adjusting for changes in the minimum wage implies a reduction in the overall frequency of wage change, see Table 3 Section II. As expected, the impact of this adjustment is substantially smaller than in the case of adjustments for wage indexation, lowering the overall frequency of wage change by slightly more than 0.2 percentage points. Adjusting for changes in the minimum wage, too, has an asymmetric impact on the frequencies of upward and downward wage changes. On the one hand, the overall frequency of wage increases declines (from 13.7% to 13.5%). On the other hand, adjusting for changes in the statutory minimum wage has virtually no impact the frequency of wage cuts (0.6%). As illustrated in Table 3, the observed reduction in the frequency of wage increases does not apply to civil servants. By contrast, the largest reduction is observed for white-collar workers (from 12.8% to 12.5%).[31] As adjusting for minimum wage changes has no impact on the frequency of wage cuts, there is no evidence of an incomplete adjustment of salaries in the event of changes in the statutory minimum wage.

[29] This difference in the relative share of wage changes due to wage indexation is by and large due to differences in the overall frequency of wage change between the three stati. By contrast, omitting wage changes due to wage indexation leads to a fairly similar reduction in the frequency of wage change in absolute terms (between 6.5 percentage points in the case of white-collar employees and 7.7 percentage points in the case of civil servants.

[30] For instance, numerically, wage increases of 2.5% could be achieved via a set of smaller wage increases around the time of wage indexation. Alternatively, firms could anticipate the wage indexation or postpone the 2.5% wage increase (and compensate for the foregone wage increases at a later stage). Strictly speaking, however, firms are required to apply the 2.5% increase to the wage prevailing in the month prior to indexation, regardless of whether they already implemented a wage increase shortly before indexation or not. Similarly, firms are not allowed to delay the implementation of wage indexation, even when compensating for the foregone increase later on.

[31] The differences with regard to the impact of adjusting for changes in the minimum wage across stati are likely linked to differences in the proportion of employees/workers/civil servants subject to the statutory minimum wage.

Removing wage changes related to changes in age and marital status reduces the overall frequency of wage change to 14.0% (down from an unadjusted 14.3%, see Table 3 Section III. A lower frequency of wage change is observed for all occupational groups, the largest reduction appearing for civil servants (19.3%, down from an unadjusted 20.7%). For blue-collar workers and white-collar employees, the reduction in the frequency of wage change is marginal (less than 0.25 percentage points). The differences between stati are likely to reflect a different degree to which changes in age and/or marital status give rise to changes in salaries according to their collective wage agreement. As such clauses are most common in the public service sector, the differences between occupational groups might reflect the different proportions of employees in the public and private sector. Similar to adjustments for changes in the minimum wage, adjusting for wage changes due to age and/or marital status has virtually no impact on the measured frequency of wage cuts.

The combined impact of all adjustments on the frequency of wage adjustment is sizeable (see Table 4). Overall, the adjusted frequency of wage change is 7.0% (down from 14.3% in the cleaned dataset). More than one half of all wage changes in the cleaned dataset are institutional. Overall, after all adjustments, the relative share of wage cuts in wage changes rises to almost 20%, after approximately 4% in the cleaned dataset.[32] Combining all three types of adjustments yields a reduction in the measured frequency of wage change by −6.7 percentage points (white-collar employees) to −8.6 percentage points (civil servants). Moreover, the adjustments have a more than proportional impact on the frequency of wage cuts. Adjusting for institutional wage changes has no impact on the ordering of the frequency of wage change by occupational group. As in the cleaned dataset, the highest frequency of wage change is observed for civil servants (12.0%).[33] The frequencies for blue-collar workers and white-collar employees are 5.1% and 8.2%, respectively. Again, the high frequency of wage change for civil servants reflects a relatively high frequency of wage increases (11.6% compared to 6.1% and 4.3% in the case of white-collar employees and blue-collar workers). At the same time, civil servants reveal the lowest frequency of wage cuts (less than 0.5%). For workers and employees, the frequency of wage cuts is higher (0.8% and 2.1%, respectively). Consequently, the share of wage cuts in total wage changes is extremely low for civil servants (less than 4% compared to an overall 20%). By contrast, adjusting for institutional wage changes in general has a limited impact on the average size of wage changes (3.8% after combining all adjustments compared to 3.3% in the cleaned dataset).[34]

4.1.3 Year on year frequency of wage change

The extent to which wages respond to negative shocks (such as decline in demand) is examined in a growing literature on downward wage rigidities. Papers

[32] According to our a priori beliefs, purely institutional wage changes almost always lead to wage increases. Note that this applies also to wage changes resulting from wage indexation. The measured increase in the frequency of wage cuts, however, suggests that in some cases wages increase by less than the full 2.5%.

[33] Again, civil servants' wages may rise more frequently but they increase by less on average.

[34] The one exception being that adjusting for wage indexation substantially reduces the average size of wage cuts. This is related to the number of cases in which wages rise by less than 2.5% in the case wage indexation.

using the Panel Study of Income Dynamics (PSID) data, a large representative survey dataset for the US, typically find that 7%–10% of respondents working for the same employer in two interviews one year apart report the same nominal wage in both interviews. At the same time 15%–20% of respondents experience a cut in nominal wage between the interviews. Depending on the point of view, these results were interpreted both as an evidence downward nominal wage rigidity and wage flexibility.[35] On the other hand, studies based on wage records from individual firms (Altonji and Devreux (2000)) or specific labour markets (Akerlof et al. (1996)) find that only two to three percent of employees experience nominal wage cut during one year and that the prevalence of constant wages is higher than that found in the PSID. More specifically, Altonji and Devreux (2000) report that only half percent of salaried workers and 2.5 percent of hourly workers in a large U.S. financial corporation experienced nominal wage cuts in a one-year period. In contrast to the findings from the PSID studies, this implies substantial downward nominal wage rigidity. Gottschalk (2005) reconciles these findings by concluding that larger part of the nominal wage cuts for hourly workers in the PSID are a result of mesurement error in the survey data. After applying a structural break test to the PSID data to remove measurement error in the wage series, he finds that only 4%–5% of respondents working for the same employer in two interviews one year apart received a nominal wage cut. At the same time, constant wages were much more common than in the unadjusted data comprising of 49%–54% of observations.

For the sake of comparison with the numbers reported in the literature, Table 10 provides the *annual* direct frequency of wage decreases and constant wage in the three different datasets considered in this paper—the raw, baseline and cleaned datasets. It is derived the same way as the monthly frequency discussed in Section 3.4.2 except that all references to $t-1$ are replaced by references to $t-12$. In the raw and baseline datasets, approximately 12.5% of occupations (for which a wage quote for the same month in the previous year exists) are characterised by a decrease in base wage, while about 3% occupations are reporting the same wage. The picture is substantially different in the cleaned dat set that limits the degree of measurement error. Here, the probability of yearly decline in the base wage is less than 1 percent and the probability of constant wage for a period of one year is more than 4 percent. Compared to the results of Gottschalk (2005), we find less wage cuts that would be sustained for a one-year period and also substantially fewer constant wages. This suggests that Luxembourg cannot be characterized by substantial downward nominal wage rigidity (DNWR).[36] Compared to the results of Altonji and Devreux (2000), the probabilities of yearly decline in the base wage are of the same order of magnitude. However, we find less wage cuts for blue-collar workers and more wage cuts for white-collar workers than Altonji and Devreux (2000).

[35]Card and Hyslop (1996) and Kahn (1997) stress the presence of a spike at zero in the nominal wage change distribution which they interpret as a strong evidence of downward nominal wage rigidity. On the other hand, McLaughlin (1994) compares the cumulative density below zero with the correponding density in the upper tail of the wage change distribution and concludes that due to the symmetry of the whole distribution, nominal wages are not rigid.

[36]DNWR implies that in a histogram of wage changes, one observes a spike at zero (constant wages) and a low density in the area left from zero (few wage cuts). DRWR also implies few wage cuts, however, the spike in the wage change histogram appears at the (expected) inflation or more specifically at the wage bargaining focal point.

Put together, the pieces of evidence presented so far strongly suggest that wages in Luxembourg are subject to high degree of donward real wage rigidity (DRWR). DRWR implies that only few wages are cut in real terms, i.e. either the nominal wage decreases or it grows by less than the (expected) inflation rate. Because wages in Luxembourg are automatically and fully indexed to CPI inflation, wages would not be downward rigid in real terms only if the effect of indexation was reversed by nominal wage cuts in other months. However, we have already documented that less than one percent of (nominal) wages are cut both from month to month or from year to year. This suggests that undercutting the wage indexation growth is not common in Luxembourg.

4.2 Results based on the multiple break test

As a means of cross-checking, we present estimates of the frequency of wage change based on the multiple break test proposed by Bai and Perron (1998). According to Table 11, the overall frequency of wage change is approximately 4.8%.[37] The formal break point test, therefore, yields an even lower frequency of wage change than the direct measures of wage flexibility based on the adjusted dataset as discussed in Section 4.1.2 (reporting the overall frequency of wage change of 7%). As already indicated in Section 3.4.3, given the length of wage trajectories in the dataset, the overall low frequency of wage change obtained by the breakpoint test might be due to the restriction on the maximum number of breakpoints. The maximum number of breaks allowed is binding for 8.3% of wage trajectories.[38] This might imply understating the true frequency of wage change in the case of frequent wage adjustments.

The frequency of wage cuts in the breakpoint test (0.8%) is also lower than the corresponding direct measure based on the adjusted dataset and so is the proportion of wage cuts in overall wage changes (16.9% in the break test and 19.5% in the adjusted dataset). Again, this share is in the same order of magnitude as the share of price cuts in total price changes for consumer services.[39] The results from the break point test procedure therefore confirm that wage changes and especially wage cuts are fairly infrequent.

Moreover, in spite of the slightly different overall level of the frequency estimates, we obtain identical rankings according to occupational status. Both the simple measures and the breakpoint test suggest that the highest frequency of wage change is found among civil servants, whereas the lowest frequency is obtained for blue-collar workers. This finding might suggest that the adjusted wage trajectories still entail elements of institutional wage changes. In particular, one reason for a lower frequency of wage change of blue collar workers could be a longer average duration of collective wage agreements.

[37] Again, the overall frequency is weighted by the proportion of observations per occupational group in the raw data.

[38] For wage trajectories prevailing throughout the entire dataset, the maximum number of breaks allowed is nine and hence the frequency of wage change is implicitely truncated at 12.7%

[39] Although the relative shares of wage increases/cuts in total wage changes is fairly similar at the aggregate level, we do obtain a slightly different proportion of wage cuts at the level of two occupational groups, i.e. for white-collar employees and blue-collar workers.

4.3 Results for different categories

4.3.1 Firm characteristics

Evidence from micro price studies suggests that prices subject to regulation display more price rigidity than freely determined prices. Dhyne et al. (2005) study a selection of 50 products and report that administered prices exhibit roughly 10% lower probability of price change than freely determined prices. Dexter et al. (2004) report that significant inertia in aggregate price adjustments is due to the presence of price regulation. Against this background, we distinguish between private and public employers.[40] Table 7 reports the direct measure of frequency of wage changes and the size of such changes for privately-owned firms and public institutions in the adjusted dataset. To allow for differences in the staff composition in the public and the private sector, we present disaggregated results by occupational group. Our estimates suggest a substantially higher frequency of wage change for public institutions. This applies to both white-collar workers (12.6% in public sector versus 7.7% in private sector) and blue-collar employees (12.5% in public sector versus 3.9% in private sector), i.e. the two occupational groups featuring in both the private and the public sector. We find very small differences in the frequency of wage change only between the three occupational groups within the public sector (all between 12.0% and 12.7%). The high frequency of wage changes observed in the public enterprises explains the high frequency of wage changes observed for civil servants in previous sections given that by definition they are employed only by public enterprises. The difference in the frequency of wage change between the public and the private sector may be almost as large as nine percentage points (in the case of blue-collar workers). The higher frequency of wage change in the public sector is almost entirely due to more frequent wage increases, while at the same time the frequency of wage cuts tends to be lower in the public sector. As wage increases tend to be more frequent in the public sector, they also tend to be smaller (e.g. 2.1% in the public sector versus 4.4% in the private sector in the case of blue-collar workers, see Table 7).[41] A similar general picture emerges from the results based on the break test, see Table 14.

Firms of different size have in general different compensation policies. Large firms typically have a more complex compensation policy with more variable extra-wage components (like bonuses). Even though we take into account only the base wage, the overall compensation policy can have an impact on the frequency of base wage adjustment. Heckel et al. (2008) find in their dataset for France an increasing frequency of base wage change with the exception of the 0-20 employees category. Our results based both on the direct measure of frequency using the adjusted dataset in Table 6 and on the break test procedure in Table 13 are in line with this finding and suggest that larger firms are

[40] The database does not provide information on the public/private nature of the firm. As the second-best proxy, we classify a firm in the public sector if and only if there is at least one staff member with civil servant status. We cannot exclude that there are public institutions only employing blue-collar and white-collar workers. This might lead to an underestimation of the spread between public and private firms.

[41] Given the substantial degree of heterogeneity in the frequency of wage change by sector, we cannot exclude that the comparison between the public and the private sector is affected by a different composition of their activities. Unfortunately, there are very few *hybrid* sectors in which both private and public sector firms operate.

characterised by more frequent base wage adjustment. The frequency of wage change reported in Table 6 varies from 4.2% for small companies (i.e. less than 15 employees) to 10.2% for large companies (i.e. 150 or more employees). For medium-sized companies, the frequency of wage change is 6.4%. The differences across size categories can be primarily related to the differences in the frequency of wage increases as the frequency of wage cuts varies only between 1.1% and 1.7% in the adjusted dataset and between 0.7 and 0.8% in the break test procedure.[42]

4.3.2 Sectors of the economy

The frequency of wage change by NACE sectors is reported in Table 5 for the adjusted and clean dataset and in Table 12 for the break test procedure. We find substantial heterogeneity across sectors in both cases. The frequency of wage change is always higher in the adjusted dataset than in the break test procedure. Nevertheless, both approaches paint a similar picture. The four sectors with the highest probability of a wage change are the same: *Public administration* (L), *Electricity, gas and water supply* (E), *Financial intermediation* (J) and *Education* (M). One can infer that the high frequency is related to the disproportionaly large representation of public enterprises in the above mentioned sectors with the exception of *Financial intermediation*. At the same time those four sectors are characterised by the highest average monthly earnings among the NACE sectors considered in the raw dataset (see Table 18). On the other hand, among the four sectors with the lowest probabilities of a wage change we find in both cases *Hotels and restaurants* (H), *Construction* (F) and *Mining and quarrying* (C), i.e. sectors with a disproportionally large number of blue-collar workers employed in private enterprises who appear to have exceptionally low frequency of wage change (see Table 14). *Hotels and restaurants* and *Construction* are also characterised by low average monthly earnings.

The heterogeneity across sectors relates to both the frequency of wage increases (varying between 2.3% in *Hotels and restaurants (H)* and 11.5% in *Public administration* (L)) and wage cuts (varying from 0.4% in *Public administration* (L) to 3.2% in *Financial intermediation* (J)), numbers refer to the direct measure of wage change frequency based on the adjusted dataset as reported in Table 5. For all sectors (save *Financial intermediation*), the frequency of wage cuts is less than 2%. The median and the average shares of wage cuts in total wage changes are approximately 21%.[43]

How does the frequency of wage change compare with the evidence on price adjustment? The overall (weighted average) frequency of wage change in the cleaned dataset (14%) and the augmented wage change frequency obtained from the break test (9%) are both lower than the average consumer price change frequency in Luxembourg (17% reported by Lünnemann and Mathä (2005)) and the average frequency of producer price change in 6 euro area countries excluding Luxembourg (21% reported by Vermeulen et al. (2007)). However, the frequency of wage change are still higher than estimates of the frequency of

[42] As a result, larger companies reveal a higher proportion of wage increases in total wage changes (86-88% versus 74-78% in small and in medium-sized companies).

[43] This is similar to the 80:20 split for changes in services prices typically reported in the analysis of micro price data Dhyne et al. (2005).

consumer prices changes in the Luxembourg service sector (i.e 7% according to Lünnemann and Mathä (2005)).

4.3.3 Months

Evidence from various euro area countries suggests that the frequency of price change may exhibit strong seasonal patterns, in particular that the frequency of price change is typically highest in January. The special role of this month for price dynamics applies in particular to services prices. Based on their analysis of consumer prices in Luxembourg, Lünnemann and Mathä (2005) find that almost 15% of services' prices change in January. Moreover, approximately one in six changes in service prices occurs in January. Figure 1 shows the frequency of wage change by month based on the adjusted dataset and break test.

The average frequency of wage change is 7% in the adjusted dataset and 4.8% in the break test procedure.[44] Despite the difference in the average frequency, the pattern observed across months is very similar. We observe distinct spikes in the months of January and there are also apparent spikes in the event of wage indexation in the adjusted dataset. The break point test is capable of disregarding wage changes in the adjusted dataset that are part of partial/early or delayed indexation and hence the spikes are less prominent as one could expect if the adjustment for indexation was perfect. In ordinary months the frequency of wage change is a mere 3.8% in the adjusted dataset and 3.3% in the break test procedure, see Table 9 and Table 15. By contrast, in the month of January and in the event of wage indexation the frequency rises to almost 37% and 15% in the adjusted dataset and to 21% and 6% in the break procedure.[45] The predominance of wage changes occuring in the month of January or in the event of wage indexation suggests that the overall measured frequency of wage change tends to overstate the flexibility at the discretion of the firms. Moreover, the high concentration of wage changes around two distinct types of periods (i.e. months with wage indexation and the month of January) suggests that wage changes tend to be synchronised.

In the adjusted dataset, for all occupational groups the month of January is clearly marked by the highest frequency of wage change (24.1%, 38.4% and 98.6% for workers, employees and civil servants, respectively). The histogram of wage changes in the months of January in Figure 2 highlights the concetration of wage increases between 0.5% to 1% and at 1.5%. This is likely to reflect wage changes due to (new) collective wage agreements. In Luxembourg, most of such collective agreements (and changes to existing agreements) enter into effect beginning January. This is particularly evident from the very high fre-

[44] The first and last two observations were disregarded because they are not considered a potential break date in the break test. For the direct measures, by definition, only the first observation is not considered a potential break date.

[45] This is the frequency of wage change after adjusting for changes due to wage indexation, changes in the statutory minimum wage and changes in age/marital status. As illustrated in Table 8, the distinctive spikes in the frequency of wage change are even more prominent in the cleaned dataset. Without adjusting for institutional wage changes, the frequency of wage change reaches 4.2% in ordinary months, but rises to 52.9% in the month of January and to 98.3% in the months in which wage indexation kicks in. Overall, in unadjusted terms, approximately 25% of all observed wage changes take place in the month January and one out of two wage changes occur in months in which wage indexation kicks in.

quency of wage change in the month of January for the case of civil servants.[46] For services, Lünnemann and Mathä (2005) not only report an exceptionally high frequency of price change, but also an exceptionally high share of price increases in the month of January in Luxembourg (i.e. approximately 80% of all price changes). For wages, in the month of January, the share of increases in total changes is even higher (between 96% and 97% in both the adjusted and cleaned dataset and in the break test procedure), also in comparison with ordinary calendar months (86% and 87% in the adjusted and cleaned dataset, respectively and 81% in the break test procedure).

In the month of January the high adjusted frequency of wage change is due to very frequent wage increases but in the case of months with wage indexation, the rise in the adjusted frequency is mostly due to a larger number of (adjusted) wage cuts relative to the other two periods, see Table 9 and Table 15.[47] This can be a result of incomplete/deferred/early indexation or might reflect misclassification of hourly and salaried workers. While an extraordinarily high frequency of wage change in monthss of indexation could also be achieved in the case of full-indexation of wages coinciding with a wage cut for reasons other than indexation, the overall low frequency of genuine wage cuts makes a scenario of two simultaneous wage changes rather unlikely.

The overall frequency of wage increases (cuts) in these periods is 4.9% (9.6%) in the adjusted dataset and 3.1% (3%) in the break test procedure. Contrary to blue-collar workers and white-collar employees, wage reductions remain fairly infrequent in the event of wage indexation in the case of civil servants (and much less frequent than wage increases). In the case of civil servants, thus, there is no evidence of an incomplete application of wage indexation. In general, firms operating in countries with automatic wage indexation might face serious real downward wage rigidity to the extent that they cannot implement wage changes smaller than those stipulated by wage indexation. In Luxembourg, the vast majority of wages are increased exactly by 2.5% in the event of indexation (see the spike at zero in the adjusted dataset in Figure 2) and only a small proportion of wages are increased by less than the 2.5% threshold in an indexation event (i.e. the adjusted wage change is below zero). Figure 2 also demonstrates that wages change relatively infrequently from one month to another (spikes at zero). After adjusting for indexation, slightly more than 50% of all wage cuts take place in months with wage indexation.

4.3.4 Heterogeneity across firms

Figure 3 below illustrates the distribution of the frequency of wage change across companies. We obtain a substantial degree of heterogeneity across the 10 874 firms in the adjusted dataset. Overall, the frequency of wage change varies from 0% to 41.7%. As expected, the distribution of the frequency of wage change by firm reveals a high degree of skewness. Approximately 22% of all firms in the adjusted dataset never changed wages. The average (median) frequency of wage

[46] Civil servants tend to be remunerated acoording to a unique collective wage agreement typically entering into force in the month of January.

[47] A wage decrease in the indexation period in the adjusted dataset has to be interpreted as a wage change lower than 2.5% in unadjusted terms.

change per firm is 4.8% (3.6%). For less than one out of 7 firms, the frequency of wage change is higher than 10%. Moreover, for approximately 3/4 of all firms the frequency of wage change is lower or equal to the reported frequency of service price change. Finally, more than one half of all firms did not cut wages during the sample period. The average (median) frequency of wage cut across firms is 1.5% (0%).

5 Conclusion

The paper provides a unique insight into the wage adjustment process at the microeconomic level using an administrative monthly data set covering all firms and employees in Luxembourg between January 2001 and December 2006. The frequency of wage adjustment has important implications for the optimal monetary policy, price adjustment and labour market outcomes, such as unemployment rates.

The dataset does not provide explicit information on overtime work and compensation and hence we employ two different procedures to limit the impact of variation in overtime worktime and compensation on the frequency of base wage. First, we defined well-behaved trajectories of hours and removed implausible patterns of wage adjustment. As such approach can be considered judgemental, we apply in addition a structural break test to the individual wage trajectories. This approach is based on the assumption that the true wage trajectory follows a step function. Without limiting the impact of measurement error due to overtime work, the overall monthly frequency of wage change reaches 57%. After cleaning the dataset, the frequency drops to 14% and the augmented frequency from the break test provides an upper bound of the wage change frequency at 9%. The resulting average wage change frequency is lower than the consumer price change frequency in Luxembourg (17% reported by Lünnemann and Mathä (2005)), but higher than their estimate of the frequency of price change for consumer services (7%).

Even genuine wage changes that do not reflect measurement error are not necessarily a sound indicator of true wage flexibility as some of them might be determined by institutional factors. For this reason, we adjust for wage changes due to indexation, changes in the statutory minimum wage, age and marital status. As a result, the the direct measure of frequency of wage change is lowered to 7%, while the break test leads to a frequency of 5%. This suggests that wage flexibility at the discretion of the firm is rather low.

In addition, we find a substantial degree of heterogeneity across firms of different size, between public and private firms, across sectors of the economy, occupational groups and different periods. Blue-collar workers reveal the lowest frequency of wage change, while civil servants exhibit the highest frequency. The same reasoning explains why public sector enterprises have higher frequency of wage change than private enterprises. While wages of civil servants change more often, they change by the smallest amount at the same time. Our results also suggest that larger firms tend to change wages more often. Moreover, we find that wage changes tend to be highly synchronised as they are concentrated around months of wage indexation and the month of January. In a typical year, approximately 50% of all wage changes occur in the event of indexation and another one quarter of wage changes is observed in January, reflecting the pre-

dominant share of collective wage agreements entering into effect in this month. Nearly all wages change in the event of wage indexation. The concentration of wage changes around two types of periods implies a high degree of synchronisation of wage changes.

The picture that emerges from the pieces of evidence presented in this paper is a situation of substantial DRWR in Luxembourg. DRWR implies that only few wages are cut in real terms, i.e. either the nominal wage decreases or it grows by less than the (expected) inflation rate. Vast majority of wages in Luxembourg increase by 2.5% in the event of indexation. We documented that less than one percent of (nominal) wages are cut both from month to month and from year to year. Quantifying the degree of DRWR in Luxembourg and comparing it to other countries remains a task for future research.

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Appendix

A Additional details on Luxembourg and its labour market

A.1 Key macroeconomic indicators of Luxembourg

On average, the sample period is characterized by moderately strong economic growth and moderate to high inflation rates. Overall, the average annual growth in GDP between 2000 and 2006 stood at 4.1%. Over the sample period, the growth dynamics changed quite substantially. In 2003 the Luxembourg economy grew only 2.1%, but by 2006 the growth rate almost tripled (6.1%). Moreover, the growth dynamics reveal a high degree of heterogeneity across economic sectors. In selected sectors, gross value added increased by more than 5% per annum over the sample period. This applies to *Financial intermediation* (NACE J, 7.4%), *Health and social work* (NACE N, 6.3%), *Transport, storage and communication* (NACE I, 5.7%) and *Construction* (NACE F, 5.4%). By contrast, gross value added actually fell in *Activities of households* (NACE P, -8.4%), *Agriculture, hunting and forestry and fishing* (NACE AB, -4.7%) and *Hotels and restaurants (NACE H, -2.2%).* Throughout the sample period, the annual increase in the price level according to the HICP was approximately 2.8% on average. Again, the inflation rate varied quite substantially throughout the years 2001 - 2006. During the period 2001 − 2003, the increase in the general price level remained around (2.1% − 2.5%). In 2004 and 2005, HICP inflation substantially increased to 3.2% in 2004 and 3.8% in 2005. In 2006, average annual inflation moderated to 3.0%, a rate still fairly high compared to the increases in the price level observed in the euro area.

A.2 Aggregate labour market figures

During the sample period, on average, more than 300 000 occupations[48] per month were recorded in Luxembourg. In 2001, the average number of occupations was roughly 277 000. In 2006, the average number of occupations was almost 330 000. (average annual growth in the number of occupations: 3.5%). The largest sectors (in terms of average number of occupations per month) are *Real estate, renting and business activities* (NACE K, 16.9%), *Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods* (NACE G, 12.4%) and *Financial intermediation* (NACE J, 11.6%). Occupations are fairly asymmetrically distributed across economic sectors. During the sample period the six largest sectors account for almost 3/4 of all occupations, while the nine smallest sectors accounted for 17% of all occupations.

The average number of firms per month is higher than 25 000. In 2001, the average number of firms per month was roughly 23 000, in 2006 the average

[48]Hereafter, the term occupation characterises a unique employer-employee relationship in the absence of obvious "qualitative changes" in this relationship, such as a change from full-time to part-time affiliation. Each occupation is characterised by a single wage trajectory. As a consequence, an occupation is the lowest level of aggregation for which a frequency of wage change can be derived. This applies to both the judgemental rules and the breakpoint test. To the extent that a given position with a specific firm is held by different employees (due to replacement), a single position is affiliated with several wage trajectories.

number of firms was more than 28 000. The average annual increase in the number of firms over the sample period was 4.2%. The three largest sectors (in terms of average number of firms per month) are *Activities of households* (NACE P, 32.4%), *Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods* (NACE G, 16.1%) and *Real estate, renting and business activities* (NACE K, 13.2%).

The strong employment growth observed over the sample period is also reflected in a strong increase in the total wage bill. Starting off with some EUR 9.2 bn in 2001, the total amount of wages (i.e. base wage and bonuses) increased to EUR 12.6 bn in 2006 (i.e. an average annual growth rate of 6.4%). The share of the volume of bonuses paid in the total wage bill was approximately 8.5% (9.1% in 2006). The largest sectros in terms of wage bill (excluding bonuses) are *Financial intermediation* (NACE J, 17.8%), *Public administration and defence; compulsory social security* (NACE L, 15.8%)and *Real estate, renting and business activities* (NACE K, 13.3%).

Not only do we observe substantial heterogeneity with regard to the size of the sectors within the Luxembourg economy, but also the growth pattern varies substantially across sectors. This applies to the number of employers registered, the number of occupations and the total amount of salaries and bonuses. From 2001 to 2006, on average, the number of occupations increased by an annual 3.5%. Whereas the number of occupations, on average, increased by more than 7% per annum in some sectors (e.g. NACE N *Health and social work*, NACE M *Education* and NACE P *Activities of households*), their number diminished in NACE D *Manufacturing*). The amount of base wages increased by 6.2% on average. Again, the rise in total wages has been particularly strong in NACE M *Education* (+ 12.9% per annum) and NACE N *Health and social work* (11.4%). By contrast, the annual growth in the base wagebill was 2.1% in NACE D *Manufacturing*.

A.3 The wage bargaining process

The institutional aspects of the wage bargaining process constitute an important background to the patterns of wage adjustment. The role of trade unions, the degree of centralisation and coordination as well as the role of Government intervention, may clearly influence wage setting. Not only can they may affect the level of wages (including their degree of dispersion and asymmetry; e.g. through minimum wage schemes, see 2.2), but also the patterns of wage adjustment (both with regard to the timing and the size of such adjustments; e.g. through wage indexation (see 2.1)). In particular, the frequency of wage adjustments, their size and the degree to which wage adjustments are synchronised bear important implications for monetary policy. For example, collective wage bargaining might lead to a strong resistance to nominal wage cuts on various grounds (such as fairness considerations). During recessions, the scope for market clearing through downward real wage adjustments may be fairly limited, with adjustment mainly achieved through inflation. Other institutional elements of the wage bargaining process may lead to stronger real wage rigidities (see, for example, Dickens et al. (2008) on the role of unionisation). With perfect wage indexation, for example, downward real wage adjustment cannot be achieved through inflation. Again other institutional settings of the wage bargaining process may clearly affect the scope for wage adjustment through changes in the number of hours worked.

The regulations specified within a given wage agreement can create obstacles to wage adjustment, but also the duration of such agreements can create an additional element of rigidity (see Taylor (1983)). In their cross-country comparison covering 22 EU countries, the US and Japan, Du Caju et al. (2008) report significant differences with respect to the institutional features of wage bargaining.[49] In the following, key elements of the wage setting procedure in Luxembourg are described.

Collectivisation is an important characteristic of the institutional settings of the wage bargaining process. The degree of *collectivisation* is often measured by the proportion of workers that are trade union members (*trade union density*) and/or covered by a collective wage agreement (*collective bargaining coverage*). Collectivisation may affect the behaviour of wages in various ways. In particular, collectivisation may lead to a more uniform pattern of wage adjustment. Ceteris paribus, this applies to both the timing and the size of such adjustments. For Luxembourg, overall, Du Caju et al. (2008) report a "moderate" degree of trade union density (i.e. between 51% and 75% of all workers belonging to a trade union). This overall "moderate" degree of trade density is still relatively high by European standards and compared to the US/Japan, which in general feature trade union densities of less than or equal to 50% and less than or equal to 25%, respectively. In Luxembourg, the degree of collectivisation varies substantially across sectors. In 2000 the proportion of workers belonging to a trade union was less than or equal to 25% in agriculture, but trade union density was 76% or higher in *Industry*, *Market services* and *Non-market services*.[50] As in many other developed countries, trade union coverage also varies according to firm size. In addition, as in most European countries, *extension procedures* apply in Luxembourg, extending the scope of collective agreements to all employees and employers within their usual field of application (well beyond the contracting employers and trade unions). The application of *extension procedures* may lead to a degree of collectivisation much higher than suggested by trade union density. However, in Luxembourg, *extension procedures* do not kick in automatically. Rather, their implementation is subject to political debate within the framework of public commissions.

The degree of *centralisation* in wage bargaining may also affect the wage level and wage adjustments. For example, a high degree of *centralisation* may lead to a more homogeneous pattern of wage adjustment, in particular across firms and/or regions. Empirical results obtained with micro data seem to confirm a narrowing of wage dispersion with highly centralized wage bargaining (see Card and de la Rica (2006) and Cardoso and Portugal (2005)). Compared to its neighbouring countries, wage bargaining in Luxembourg is rather decentralised as wage bargaining usually occurs at the company level. Wage bargaining at the sectoral level and at the occupational level also applies, but much less frequently.

The degree of *coordination* relates to the extent to which wage negotiations are coordinated among the various wage bargaining levels/actors within an econ-

[49] Unless otherwise stated, the figures referred to in the remainder of this section are taken from Du Caju et al. (2008).

[50] Note that for most countries the figures reported by Du Caju et al. (2008) refer to 1995, while the figures for Luxembourg usually refer to 2000.

omy (Du Caju et al. (2008)). Coordination of wage bargaining can be horizontal (i.e. synchronisation within a given level of bargaining parties) and vertical (synchronisation across levels of bargaining). It can be implemented through different mechanisms, some of which are based on Government intervention (such as state-imposed minimum wages) and others not (such as intra-associational coordination). In Luxembourg, the dominant coordination mechanisms are based on state-imposed minimum wages and state-imposed wage indexation.

B Data

B.1 Towards the baseline dataset

In this section we provide additional details on the restrictions applied to the original dataset and their impact on the size and representativeness of the data. Below we list the set of restrictions applied to the raw dataset. The impact of each step separately on the number of observations in the raw dataset is reported in Table 16.

1. Multiple occupations between any given employer-employee pair for any given period t. As we cannot reliably distinguish between such multiple occupations, the frequency and the size of wage adjustments cannot be measured in any meaningful way. Overall, this reduces the number of occupations by approximately 868 000 (i.e. 4% of the raw dataset), 92% of which relating to blue-collar workers.[51]

2. Observations with missing information about the employer, the branch, the number of hours worked, the salary earned, etc. This leads to a small reduction in the number of observations (approximately 25 500, i.e. 0.1%), 87% of which relating to the blue-collar workers.

3. The last observation of every occupation. This is to avoid an upward bias in the measured frequency of wage change due to one-off payments (e.g. severance pay). The number of observations omitted is approximately 630 000 (i.e. 2.9% of all observations), roughly 2/3 of which relating to the blue-collar workers.

4. Occupations characterised by less than six consecutive observations. This is to insure a minimum degree of representativeness and to avoid to strong an impact of a single wage change event. The number of observations omitted is roughly 790 000 (i.e. 3.6% of all observations), more than 2/3 of which relating to blue-collar workers.

5. Observations revealing a very low/high number of hours worked. Occupations characterised by less than 40 hours worked per month often reveal extremely low salaries, both in absolute terms and relative to the number of hours worked. It is likely that their remuneration is predominantly driven by (administered) changes in the statutory minimum wage rather than genuine changes in wage agreements between market participants. By contrast, observations suggesting a monthly work load of 300 hours and more are difficult to interpret, most likely reflecting periods of overtime at above-normal remuneration. This rule leads to the largest reduction in the number of observations (7.2%). More than 85% of the observations omitted relate to blue-collar workers.

6. Individuals above the retirement age and younger than 18 years. Observations related to such situations form less than 0.5% of the raw dataset.

[51] Note that the share of blue-collar workers in the initial sample is approximately 47% in terms of observations. Approximately 45% (8%) of all observations relate to white-collar employees (civil servants).

7. Observations reflecting changes to the employment status during a given month t. "Mid-month" changes in the employment status (e. g. employee leaving for (pre-)retirement, parental leave, change of employer) lead to an upward bias in the measured degree of wage flexibility. This rule leads to the third largest reduction in the umber of observations (almost 1.2 million, or 5.4% of all observations), almost 83% relating to blue-collar workers.

8. Observations implying an hourly wage rate below the statutory minimum wage wage.[52] This leads to a reduction in the number of observations by roughly 575 000 (i.e. 2.6%).

9. Observations in *Activities of households* (NACE P). The number of observations omitted is roughly 620 000 (i.e. 2.9% of all observations), 99% of which relating to blue-collar workers.

10. Observations referring to firms that existed for less than 36 months. This is to avoid any bias due to wage setting practices which might/did turn out to be unsustainable over a sufficiently long period of time. It leads to a reduction in the number of observations by roughly 1.1 million (4.9%), 55% of which relating to blue-collar workers.

11. Observations related to occupations between employers and workers in *Health and social work* (NACE N). Both the monthly salary and the hourly wage tend to be very volatile. The high degree of volatility is likely to result from changes in the composition of the hours worked (e.g. hours worked on Sundays are remunerated at a premium) rather than a result of underlying wage flexibility. This leads to the second largest reduction in terms of observations (more than 1.3 million, i.e. 6.2%), roughly 70% of which relating to white-collar employees.

12. Observations maintained with Government-operated postal services. As with hospital service workers, these occupations are characterised by very frequent and relatively small wage changes often reverted afterwards (not necessarily offsetting each other). The high degree of volatility applies to both the monthly salary and the hourly wage rate. This leads to a relatively small reduction in the number of observations (216 000 observations, i.e. less than 1.0% of all observations). Contrary to all other rules, the majority of observations omitted relate to civil servants (more than 57%).

B.2 Towards the cleaned dataset

Below we list details on the rules that we apply in the baseline dataset in order to filter out observations (in case of blue-collar workers) or trajectories (in case of white-collar workers) that might be contaminated by reporting issues related to the fact that we do not have information on overtime compensation. Table 17 reports the impact of each step (applied on its own in the baseline dataset) on the number of observations.

[52] According to *IGSS* representatives, lower than hourly minimum wage declarations tend to result from an implausibly high number of hours worked reported by the employer.

1. We remove trajectories (in case of white-collar workers and civil servants) or observations (in case of blue-collar workers) which do not fulfil the requirements used to identify well-behaved trajectories of hours worked. In some cases the number of hours worked reported corresponds to the actual number of hours remunerated, in other cases the number reported corresponds to the normal number of hours worked in a specific month (based on the assumption of eight hours per work day in a given month or, alternatively, per average work day in the year). In the first case, the number of hours worked may be time-varying, in the two latter cases firms report either a constant number of hours worked per month (i.e. 173 for full-time employees) or a series with all observations taking one of the following values: 160 (in months with 20 work days), 168 (21 work days), 176 (22 work days) or 184 (23 work days). Depending on the way in which firms report the number of hours worked, variation in the number of hours reported may therefore reflect both a change in the number of normal hours (which should have no impact on the monthly salary or hourly wage) or the number of overtime hours (possibly affecting the monthly salary and the hourly wage) or both. For salaried employees (white-collar workers and civil servants), we allow for the two types of trajectories of hours reported described above (constant number of hours or a series featuring the normal hours worked) for both full-time workers and the most important categories of part-time workers, who work 40%, 50%, 60%, 75%, 80% or 90% of the number of full-time hours.

   This measure yields a very substantial reduction in the size of the dataset. As a result the number of potential and actual wage changes decreases relative to the baseline dataset by 53% and 66%, respectively.[53] Table 17 highlights that the impact on different occupational groups is highly asymetrical. The lowest relative reduction in the number of potential and actual wage changes is recorded for civil servants (11% and 12%, respectively) and the highest reduction for blue-collar workers (73% and 83%, respectively). It reflects the fact that public sector companies have the highest reporting standards and civil servants are the least likely to work "non-standard" number of hours.

2. We remove trajectories (in case of white-collar workers and civil servants) or observations (in case of blue-collar workers) consisting of four consecutive wage changes. Given the substantial obstacles with regard to frequent wage changes typically reported in firm surveys (see, for example, Druant et al. (2008)), we consider four consecutive wage changes an indication of (unreported) changes in the number of hours worked and/or shift assignments. Taken in isolation, this measure would again lead to a substantial reduction in the number of potential and actual wage changes relative to the baseline dataset. This applies in particular to the case of blue-collar workers (−84% of potential wage changes). The corresponding reductions

[53] The potential number of wage changes (abbreviated as "obs. pot." in the tables) characterises whether a wage trajectory is continued (i.e. a potential wage change) or interrupted (i.e. no potential wage change). If and only if the wage trajectory is continued (i.e. a potential wage change) a distinction is made between an actual wage change or, alternatively, an unchanged wage. The frequency of wage change is computed as the proportion of actual wage changes over potential wage changes (see equation (1)).

for white-collar employees and civil servants are −40% and −14%, respectively, hence the same assymetry as in the previous step is revealed.

3. We require, for each round of indexation, the minimum wage reported after indexation to be higher than the minimum wage reported before the indexation. Wage trajectories not obeying this requirement are removed.[54] Admittedly, under the assumption that all wages are integrally indexed, this might lead to a situation in which wage cuts of more than 2.5% are dropped. However, we consider the information lost to be outweighed by the otherwise lower noise in the dataset. On its own, this step would remove 15% of potential wage changes and 20% of actual wage changs. The reduction is the largest for white-collar workers and the smallest for civil servants, hence the same assymetry as in the previous two steps holds.

4. We disregard wage changes which lead to a monthly salary or hourly rate equivalent to former wage levels within a period shorter than six months. Such wage change reversals can reflect a series of offsetting changes or, alternatively, two wage changes of same magnitude but different sign. Wage changes preceded and followed by observations with the same wage are considered *no-changes*.[55] In isolation, this measure would reduce the number of actual wage changes is by 20% relative to the baseline dataset. The largest reduction is obtained white-collar employees (-24%). In the case of blue-collar workers and civil servants, the reduction in the number of potential wage changes is -16% and -11%, respectively.

5. The frequency of wage change should not depend on the size of wage changes, but from an economic point of view, the role of wage changes may well depend on their size. Tiny wage changes (less than 1 EUR say in terms of monthly salary or, alternatively, less than 0.1 percent in terms of the hourly wage) are probably not evidence of underlying wage flexibility. By contrast, huge wage changes (say doubling the base wage) tend to be fairly exceptional and/or suggest poor data quality, in particular when reverted shortly afterwards. Overall, roughly 26% of all base wage changes (both upward and downward) are smaller than 1% in absolute terms. Moreover, we observe a substantial share of fairly sizeable wage changes. More than 3.6% (4.7%) of all wage increases (of all wage cuts) are larger than 25%. Interestingly, the share of both tiny and huge wage changes is larger for wage cuts than for wage increases. There is no obvious threshold for wage changes to be considered "tiny". Figure 5 illustrates the frequency of wage change as a function of the (lower boundary of the) size of wage change. As indicated in 4.1.1, for white-collar employees and civil servants the overall frequency of wage increases is approximately 40% when considering all wage changes (i.e. with a minimum threshold of 0%). The frequency of wage increase falls to approximately 20% when ignoring wage increases of less than 2.5% in relative terms. The upper panel of Figure 5 also illustrates the overriding role of the automatic wage indexation for wage adjustments. The frequency of wage increases (but not wage cuts) clearly reveals a kinked pattern around a wage change of 2.5%, illustrating the

[54] Note that we do not impose downward nominal rigidity in a strict sense.

[55] Note that by considering reverting changes a *no-change*, we reduce the number of observed wage changes, while leaving the number of potential wage changes unchanged.

large number of wage changes due to automatic wage indexation. Tiny wage changes are probably a poor indication of wage flexibility, probably reflecting marginal regulatory changes, so we decide to consider them a *no-change*. Whenever the hourly wage rate (in absolute terms) changes by less than 0.25% and/or less than 0.075 EUR we consider this a *no-change*. Observations implying a reduction of / an increase in the base wage by more than 25% (in absolute terms) are also omitted in the following.[56] The effect of this measure on the number of actual wage changes in the baseline dataset ranges from a reduction of 21% for blue-collar workers to 5% for civil servants.

6. In addition to disconsidering selected observations (huge wage changes) and replacing selected others (tiny wage changes or reverting wage changes), we eliminate wage trajectories characterised by frequent tiny and/or huge wage changes and by numerous replacements (e.g. due to reversion to former wage level). This is to avoid an estimate of wage change frequency primarily based on adjustments/replacements. In order for the entire wage trajectory to be removed (rather than a single observation from this trajectory), we require the number of adjustments/replacements to represent more than one half of all observations in the trajectory. The baseline dataset would be reduced by 32% of actual wage changes and 3% of potential wage changes if only this measure was applied. The impact on the number of wage changes ranges from −38% for blue-collar workers to −14% for civil servants.

7. In the case of employees and civil servants, we remove observations that report a decrease in base wage in December together with a bonus. In these cases, the base wage in January either continues at its November level or is increased. In such cases, we omit the December observation (i.e. split the trajectory). This measure has only a minor impact on the number of potential and acutal wage changes, reducing their number by approximately 1% and 2%, respectively, for both white-collar workers and civil servants.

8. Sometimes wage changes are entirely reversed by the following wage change. These exact wage reversions are probably associated with misreported overtime hours, misreported one-off payments, etc. For this reason, in the case of white-collar employees and civil servants, we drop all wage trajectories revealing at least one exact wage reversion (regardless of the duration after which a wage change is reverted). This measure has significant impact on the number of potential and actual wage changes as compared to the baseline dataset. The percentage of potential wage changes removed in this step relative to the baseline dataset is 44% and 30% for white-collar workers and civil servants, respectively.

9. We remove wage trajectories with less than 12 potential wage changes (i.e. minimum length of 13 months per trajectory). This measure has

[56] Note that adjusting for tiny wage changes has an impact on the number of observed wage changes, but not on the number of potential changes. By contrast, the omission of observations related to huge wage changes affects both the number of observed and of potential wage changes.

only limited impact on the number of potential and actual wage changes, reducing their number by 4% in both cases.

10. Observations related to occupations between employers and workers within NACE sector N *Health and social work* and occupations maintained with government-operated postal services. Both the monthly salary and the hourly wage tend to be very volatile. The high degree of volatility is likely to result from changes in the composition of the hours worked (e.g. hours worked on Sundays are remunerated at a premium) rather than a result of underlying wage flexibility. This leads to a reduction in the number of potential observations and actual wage changes by 8% and 10%, respectively. The impact of this step is the largest for white-collar workers and civil servants.

B.3 Structure of the dataset

Table 18 outlines the impact of our cleaning procedures on the structure of the dataset. The number of observations (occupations) fall from 21.7 million in the raw data to 17.3 million in the baseline dataset and 4.21 million in the cleaned dataset after adjustment for measurement error. In the process of cleaning we loose 92.4 % of observations for blue-collar workers, 76.7 % for white-collar workers and 33.3 % for civil servants. As a result, the proportion of civil servants increases from 7.8 % in the raw dat to 27.1 % in the adjusted dataset. Similarly, the proportion of public enterprises more than doubles. To maintain representativeness of our results, we provide weighted results for the whole economy, using the proportion of each occupational group in the raw data as weights. At the same time, small firms are overrepresented in the adjusted dataset, as compared to the raw data reflecting the situation in Luxembourg.

C Defintions and notation

C.1 Frequency and size of wage change

The dataset consists of sequences of monthly base wage observations w_t^{ij} denoting the wage paid to employee i affiliated with firm j in period t.

Equation (1) in Section 3.4.2 defines the frequency of wage change $F_{ij}^{\pm}$. In analogy, we define the frequency of wage increases and wage reductions as

$$F_{ij}^{+} = \frac{\sum_{t=2}^{T} d_{t,t-1}^{+}}{\sum_{t=2}^{T} d_{t,t-1}^{+} + d_{t,t-1}^{-} + d_{t,t-1}^{=}}$$

and

$$F_{ij}^{-} = \frac{\sum_{t=2}^{T} d_{t,t-1}^{-}}{\sum_{t=2}^{T} d_{t,t-1}^{+} + d_{t,t-1}^{-} + d_{t,t-1}^{=}},$$

where $d_{t,t-1}^{=}$, $d_{t,t-1}^{+}$ and $d_{t,t-1}^{-}$ are defined in the main text below equation (1) as the number of wage observations that remained constant, increased or decreased between period $t-1$ and t.

The average size of a wage increase S_{ij}^{+} and the average size of a wage reduction S_{ij}^{-} are determined by

$$S_{ij}^{+} = \frac{\sum_{t=2}^{T} d_{t,t-1}^{+} * s_{t,t-1}}{\sum_{t=2}^{T} d_{t,t-1}^{+}},$$

$$S_{ij}^{-} = \frac{\sum_{t=2}^{T} d_{t,t-1}^{-} * s_{t,t-1}}{\sum_{t=2}^{T} d_{t,t-1}^{-}}.$$

The average size of a wage change $S_{ij}^{\pm}$ is obtained as

$$S_{ij}^{\pm} = \frac{\sum_{t=2}^{T} d_{t,t-1}^{+} - \sum_{t=2}^{T} d_{t,t-1}^{-} * s_{t,t-1}}{\sum_{t=2}^{T} d_{t,t-1}^{+} + \sum_{t=2}^{T} d_{t,t-1}^{-}},$$

where

$$s_{t,t-1} = 100 \left[\ln\left(w_t^{ij}\right) - \ln\left(w_{t-1}^{ij}\right) \right].$$

Admittedly, log differences may be less intuitive than simple percentage differences. In addition, using log differences may yield a considerable underestimation of wage changes (relative to percentage differences) in the case of very sizeable wage changes. However, unlike percentage differences, log differences yield identical wage increases and decreases when wage changes are reversed reversed. Finally, log differences are used in order to preserve comparability with analyses of price behaviour based on micro data.[57]

To gain an idea about the duration of wage spells, we calculate the average duration implied by the wage change frequency (*implied average duration*). As highlighted by Baudry et al. (2004), by assuming stationarity of and homogeneity of the data generating process, in a large sample, the inverse of the

[57] The use of log differences is pretty much standard in the analysis of price changes based on micro data, see for example Dhyne et al. (2005). On the importance of price change reversals in the total frequency of price changes see, for example, Lünnemann and Mathä (2005).

frequency of wage change converges asymptotically to the average duration of a wage spell. In continuous time representation, and assuming a constant probability of wage change throughout the month, the implied average duration D^{avg} and the implied median duration D^{med} can be written as:

$$D^{avg} = -\frac{1}{\ln(1-F)} \quad \text{and} \quad D^{med} = \frac{\ln(0.5)}{\ln(1-F)} \tag{3}$$

C.2 Implementation of the break point test

The multiple break point test proposed by Bai and Perron (1998) provides a least squares estimator of the number of break points (M) and their timing (T_1 to T_M) as well as the corresponding wage levels ($\bar{w}_1$ to $\bar{w}_{M+1}$) based on a recursive algorithm. The test being applied to every single wage trajectory, its main idea consists in determining each *m-partition* (i.e. a vector of break dates $T_1, ..., T_m$) by minimising the sum of squared residuals $SSR(T_1, ..., T_m)$

$$(\hat{T}_1, ..., \hat{T}_m) = argmin_{T_1,...,T_m} SSR(T_1, ..., T_m),$$

where

$$SSR(T_1, ..., T_m) = \sum_{k=1}^{m+1} \sum_{t=T_{k-1}+1}^{T_i} [w_t - \bar{w}_k]^2$$

The break-point estimators, thus, are global minimisers of the objective function and the regression parameters (in our case the constant wage level between two subsequent break points) are simple least squares estimates applying the estimated *m-partition*. While, in principle, the break points can only take a finite number of (discrete) values, the computational burden rapidly increases for more than two break points. Bai and Perron (1998) propose an efficient algorithm to obtain the global minimisers of the sum of squared residuals using a dynamic programming algorithm. An important mainstay of this algorithm is that the global sum of squared residuals for any *m-partition* $(T_1, ..., T_m)$ and for any number of breaks is a particular combination of the sum of squared residuals associated with each of the potential regimes. The aim of this algorithm is to "compare possible combinations of these sums of squared residuals (corresponding to different m-partitions) to achieve a minimum global sum of squared residuals" Bai and Perron (2003), i.e. the *m-partition* $(\hat{T}_1, ..., \hat{T}_m)$ with the estimated break dates.

In the first step, the hypothesis of no break in the wage trajectory (i.e. m=0) is tested against the alternative of one or more breaks on the basis of double maximum tests (multiple breakpoint test).[58] In the second step, and provided the multiple breakpoint test suggests the presence of one or more breaks, the $supF_T(l+1|l)$ test proposed by Bai and Perron (1998) is used. A model with $l+1$ breaks is rejected if the overall minimum value of the sum of sqaured residuals across all segments is suffiently smaller than the sum of squared residuals from the model with l breaks. Initially, the entire trajectory of length T is divided

[58] Contrary to the procedure proposed by Bai and Perron (2003), we use an equal weighted *supF* test ($UDmax$). This is because the weighted *supF* test ($WDmax$) frequently led to econometric issues, in particular in the event of step-like wage trajectories.

into two segments. Using an F-test of the sum of squared residuals (with and without the break), one can test for the presence of a structural break. If the null of no structural break is rejected, the two segments are retained and a similar test is applied to each of the resulting two segments. This procedure is continued (i.e. increasing l) until the test $supF_T(\text{l+1}|\text{l})$ fails to reject the null hypothesis of no additional structural change. The final number of breaks is therefore equal to the number of rejections obtained on the basis of the parameter constancy tests.[59]

The setup of the breakpoint test in this paper is as follows. We specify $\epsilon = 0.05$ as the value of the trimming (in percentage) for the critical values used in the $UDmax$, the $supF(l+1|l)$ test and the sequential procedure.[60] Contrary to the direct measures of wage frequency based on the clean and adjusted dataset, when applying the multiple break point test we require a minimum length of 36 months for each trajectory (to avoid dealing with discontinuous wage trajectories) and we remove outliers defined as the upper 2.5 percentile of the wage change distribution in percent and lower 2.5 percentile of the wage change distribution in absolute value (effectively removing wage changes smaller than approximately 0.1 cent). The maximum number of breaks allowed is specified such that it does not exceed the number of breaks for which asymptotical critical values are reported by Bai and Perron (1998). In the case of a wage trajectory prevailing over the entire sample period, the maximum number is breaks allowed is nine. This upper limit might clearly be too restrictive, in particular as (genuine) wage changes do also occur for purely institutional reasons.[61] In order to reserve the limited number of breakpoints to genuine wage changes (rather than wasting them on the identification of wage indexation and other obvious institutional wage changes), the breakpoint test is not applied to the original wage trajectories in the baseline dataset. Rather, the tests are applied only after adjusting the wage trajectories for changes due to indexation, the statutory minimum wage and changes in age and marital status the same way as it is described in Section 3.3 except that in this case the adjustment procedure is applied directly to the baseline dataset.

[59] This is as we start with l=0.

[60] This leads to a minimum length of wage spell of 3 months in the case of a trajectory prevailing over the entire sample period, i.e. 72 months.

[61] In particular, the period under study spans six rounds of wage indexations.

D Tables

Table 1: Size and frequency of wage changes in the baseline dataset

	Frequency of wage			Average size of wage			
Occup. group	change	incr.	decr.	change	incr.	decr.	Obs. pot.
Blue-collars	76.89	42.35	34.53	5.76	5.69	5.86	6 828 003
White-collars	41.83	26.36	15.47	7.83	7.03	9.21	8 276 087
Civil servants	29.37	23.99	5.38	4.69	3.81	8.60	1 651 225
All	57.31	33.68	23.63	6.62	6.15	7.59	16 755 315

Note: "Obs. pot." refers to potential wage changes, i.e. the denominator of equation (1). Results for "All" are weighted by the proportion of observations per occupational group in the raw data, see Table 18.

Table 2: Frequency and size of wage changes in the cleaned dataset

	Frequency of wage			Average size of wage			
Occup. group	change	incr.	decr.	change	incr.	decr.	Obs. pot.
Blue-collars	12.80	12.44	0.35	3.04	2.93	7.02	678 042
White-collars	14.82	13.87	0.95	3.61	3.47	5.63	2 211 758
Civil servants	20.65	20.25	0.40	2.54	2.47	6.16	1 107 264
All	14.33	13.70	0.63	3.26	3.14	6.32	3 997 064

Note: See Table 1.

Table 3: The effect of indexation, minimum wage, age and marital status on the frequency and size of wage changes

	Frequency of wage			Average size of wage			
Occup. group	change	incr.	decr.	change	incr.	decr.	Obs. pot.
I. Indexation							
Blue-collars	5.69	4.86	0.83	3.51	3.49	3.69	678 042
White-collars	8.31	6.22	2.09	4.16	4.58	2.91	2 211 758
Civil servants	13.00	12.55	0.44	2.46	2.34	5.84	1 107 264
All	7.45	6.08	1.37	3.72	3.89	3.50	3 997 064
II. Minimum wage							
Blue-collars	12.36	12.00	0.35	3.04	2.92	7.02	678 042
White-collars	14.80	13.85	0.95	3.61	3.47	5.63	2 211 758
Civil servants	20.65	20.25	0.40	2.54	2.47	6.16	1 107 264
All	14.11	13.48	0.63	3.26	3.14	6.32	3 997 064
III. Age and marital status							
Blue-collars	12.56	12.21	0.36	3.05	2.93	7.02	676 215
White-collars	14.64	13.68	0.95	3.61	3.47	5.63	2 206 949
Civil servants	19.29	18.89	0.40	2.49	2.41	6.16	1 088 616
All	14.03	13.40	0.63	3.26	3.14	6.32	3 971 780

Note: The numbers are relative to the sample adjusted for measurement error. "Obs. pot." refers to potential wage changes, i.e. the denominator of equation (1). Results for "All" are weighted by the proportion of observations per occupational group in the raw data, see Table 18.

Table 4: The impact of all adjustments on the frequency and size of wage changes

	Frequency of wage			Average size of wage			
Occup. group	change	incr.	decr.	change	incr.	decr.	Obs. pot.
Blue-collars	5.10	4.26	0.83	3.58	3.56	3.69	676 927
White-collars	8.16	6.07	2.09	4.17	4.60	2.91	2 208 637
Civil servants	12.04	11.59	0.448	2.39	2.26	5.84	1 095 228
All	7.02	5.65	1.37	3.752	3.93	3.50	3 980 792

Notes: "Obs. pot." refers to potential wage changes, i.e. the denominator of equation (1). Results for "All" are weighted by the proportion of observations per occupational group in the raw data, see Table 18.

Table 5: The branches of the economy and the frequency and size of wage changes

	Frequency of wage			Average size of wage			
Branch	change	incr.	decr.	change	incr.	decr.	Obs. pot.
I. Adjusted dataset							
A+B	3.90	2.87	1.03	4.59	4.86	3.82	17 084
C	3.99	3.43	0.56	4.16	4.40	3.02	2 408
D	4.85	3.67	1.18	4.04	4.31	3.23	235 967
E	10.53	9.21	1.32	3.04	2.42	5.02	14 468
F	4.43	3.51	0.91	4.53	4.45	5.12	252 597
G	5.02	3.66	1.36	4.42	5.09	2.80	459 620
H	3.61	2.28	1.34	4.86	6.57	2.07	143 235
I	6.61	5.43	1.18	3.95	4.23	3.13	354 476
J	10.55	7.35	3.20	3.87	4.15	3.27	555 828
K	5.46	3.99	1.47	4.44	5.03	2.94	619 766
L	11.90	11.46	0.4	2.40	2.25	6.43	1 182 601
M	8.26	6.60	1.66	5.05	4.72	6.32	21 419
O	5.82	4.80	1.02	4.41	4.54	3.74	121 323
II. Cleaned dataset							
A+B	10.46	10.20	0.27	3.40	3.27	8.81	17 087
C	12.11	11.65	0.47	3.11	3.09	3.86	2 408
D	12.12	11.56	0.56	3.20	3.09	5.88	236 006
E	18.05	16.90	1.16	2.88	2.55	5.20	14 498
F	11.73	11.26	0.48	3.39	3.19	8.07	252 624
G	11.97	11.48	0.49	3.49	3.39	5.99	459 663
H	10.97	10.63	0.34	3.51	3.41	6.98	143 245
I	13.73	13.25	0.48	3.23	3.14	5.49	356 625
J	17.26	15.52	1.74	3.52	3.29	5.61	557 471
K	12.53	11.96	0.57	3.57	3.48	5.78	619 892
L	20.48	20.10	0.38	2.55	2.46	6.94	1 194 738
M	15.70	14.50	1.19	3.92	3.57	8.16	21 436
O	13.19	12.65	0.54	3.40	3.31	5.79	121 371

Note: Results are weighted by occupational group (using the proportion of observations per occupational group in each branch in the raw data). Branches are defined as A: Agriculture, hunting and forestry; B: Fishing; C: Mining and quarrying; D: Manufacturing; E: Electricity, gas and water supply; F: Construction; G: Wholesale and retail trade; H: Hotels and restaurants; I: Transport, storage and communication; J: Financial intermediation; K: Real estate, renting and business activities; L: Public administration and defence; compulsory social security; M: Education; O: Other community, social and personal service activities.

Table 6: The size of enterprises and the frequency and size of wage changes

	Frequency of wage			Average size of wage			
Size category	change	incr.	decr.	change	incr.	decr.	Obs. pot.
$0-14$ empl.	4.25	3.12	1.12	4.92	5.65	2.95	898 538
$15-149$ empl.	6.37	4.68	1.7	4.19	4.55	3.36	1 077 492
≥ 150 empl.	10.2	8.92	1.30	2.90	2.86	4.02	2 004 762

Note: Size refers to the average number of employees over the sample period. Results are based on the adjusted dataset and are weighted by occupational group (using the proportion of observations per occupational group in each size category in the raw data).

Table 7: Public and private enterprises

	Frequency of wage			Average size of wage			
Occup. group	change	incr.	decr.	change	incr.	decr.	Obs. pot.
(1) Private enterprises							
Blue-collars	3.86	2.97	0.88	4.36	4.64	3.42	579 922
White-collars	7.69	5.46	2.23	4.40	5.06	2.76	2 001 276
(2) Public enterprises							
Blue-collars	12.52	11.99	0.53	2.14	1.95	6.30	97 005
White-collars	12.62	11.90	0.72	2.82	2.54	7.38	207 361
Civil servants	12.04	11.59	0.45	2.39	2.26	5.84	1 095 228

Note: Results are based on the adjusted dataset.

Table 8: Composition of observations per period (cleaned dataset)

	Changes in a typical			Frequency of wage		
	year		month			
Period	Number	Pct.	Number	increase	constant	decrease
Indexation	54 542	48.6	54 542	98.23	1.19	0.58
January	30 656	27.3	30 656	52.53	45.89	1.59
Other	27 121	24.1	2 712	4.18	95.19	0.63

Note: Results are not weighted. The dataset is adjusted for measurement error but not for indexation, minimum wage etc. Wages are considered to be constant if its log change lies between -0.1 and 0.1.

Table 9: Frequency and size of wage changes by period, adjusted dataset

	Frequency of wage			Average size of wage			
Period	change	incr.	decr.	change	incr.	decr.	Obs. pot.
(1) Blue-collar							
Indexation	10.78	4.43	6.35	2.16	2.97	1.59	55 144
January	24.14	23.33	0.81	2.50	2.32	7.56	47 154
Other	2.99	2.68	0.30	4.79	4.53	7.04	574 629
(2) White-collar							
Indexation	19.75	5.21	14.54	2.07	5.20	0.95	182 676
January	38.40	35.99	2.41	3.23	3.15	4.38	156 740
Other	4.49	3.64	0.85	5.74	5.72	5.85	1 869 221
(3) Civil servants							
Indexation	7.15	6.38	0.78	4.65	4.70	4.26	91 700
January	98.58	98.17	0.41	1.53	1.52	3.45	78 837
Other	5.15	4.73	0.42	3.50	3.24	6.34	924 691
(4) Total							
Indexation	14.5	4.93	9.61	2.31	4.11	1.51	329 520
January	36.63	35.11	1.52	2.75	2.64	5.77	282 731
Other	3.84	3.28	0.56	5.12	4.97	6.45	3 368 541

Note: Results for "Total" are weighted by occupational groups (the proportion of observations in each occupational group and period in the raw dataset). The results are based on the adjusted dataset, hence a wage decrease in the indexation period has to be interpreted as a wage change lower than 2.5% in unadjusted terms.

Table 10: Percentage of year-on-year observations

	Raw data		Baseline data		Cleaned data	
Category	Decreased	Constant	Decreased	Constant	Decreased	Constant
Blue-collars	16.00	3.63	16.96	2.36	0.57	7.56
White-collars	11.56	3.65	11.00	3.55	1.10	5.70
Civil servants	3.60	0.17	3.54	0.17	0.52	0.08
Total	12.66	3.29	12.48	2.70	0.84	4.26

Note: Results for "Total" are not weighted.

Table 11: The frequency of wage change based on the break test

	Frequency of wage				
Occup. group	change	increase	decrease	change augm.	Obs. pot.
Blue-collars	3.51	2.68	0.83	6.00	4 372 688
White-collars	5.42	4.54	0.88	10.79	4 714 499
Civil servants	8.70	8.45	0.25	17.35	1 402 423
All	4.78	3.97	0.81	9.05	10 489 610

Note: The break test procedure of Bai and Perron (1998) is run on the baseline dataset. "Obs. pot." refers to potential wage changes, i.e. the denominator of equation (1). The augmented frequency of wage change includes wage changes due to indexation, minimum wage changes, changes in age and marital status. Results for "All" are weighted by the proportion of observations per occupational group in the raw data, see Table 18.

Table 12: The frequency of wage change based on the break test for NACE1 branches

	Frequency of wage				
Branch	change	increase	decrease	change augm.	Obs. pot.
A+B	3.74	2.35	1.39	7.60	37 116
C	3.19	2.59	0.61	5.83	15 539
D	3.68	2.98	0.70	5.70	1 542 650
E	6.03	5.59	0.44	10.70	47 497
F	3.52	2.49	1.04	6.40	1 214 075
G	3.85	3.01	0.83	7.61	1 194 241
H	3.29	2.53	0.76	7.42	276 815
I	4.96	4.32	0.64	9.91	1 040 356
J	5.95	4.93	1.02	11.94	1 405 753
K	4.49	3.51	0.98	9.60	1 062 506
L	7.92	7.41	0.51	15.94	1 686 936
M	6.55	5.63	0.92	12.74	45 670
N	4.85	4.30	0.55	8.67	674 624
O	4.24	3.64	0.60	9.00	245 832

Note: Results are based on the break test procedure of Bai and Perron (1998) and are weighted by occupational group (using the proportion of observations per occupational group in each branch in the raw data). Branches follow NACE1 definitions, see note under Table 5. "Obs. pot." refers to potential wage changes, i.e. the denominator of equation (1). The augmented frequency of wage change includes wage changes due to indexation, minimum wage changes, changes in age and marital status. Results for "All" are weighted by the proportion of observations per occupational group in the raw data, see Table 18.

Table 13: The size of enterprises, results based on the break test

	Frequency of wage			
Size category	change	increase	decrease	Obs. pot.
$0-14$ empl.	3.78	2.92	0.86	1 451 363
$15-149$ empl.	4.41	3.51	0.90	3 321 422
≥ 150 empl.	5.39	4.67	0.72	5 716 825

Note: Size refers to the average number of employees over the sample period. Results are based on the break test procedure of Bai and Perron (1998) and are weighted by occupational group (using the proportion of observations per occupational group in each size category in the raw data).

Table 14: Public and private enterprises, results based on the break test

	Frequency of wage			
Occup. group	change	increase	decrease	Obs. pot.
(1) Private enterprises				
Blue-collars	3.28	2.48	0.80	3 913 619
White-collars	5.20	4.29	0.91	4 318 743
(2) Public enterprises				
Blue-collars	5.43	4.40	1.03	459 069
White-collars	7.87	7.27	0.60	395 756
Civil servants	8.70	8.45	0.25	1 402 423

Note: Results are based on the break test procedure of Bai and Perron (1998).

Table 15: Frequency of wage changes by period, results based on the break test

	Frequency of wage			
Period	change	increase	decrease	Obs. pot.
Indexation	6.12	3.14	2.98	764 530
January	20.66	19.83	0.83	796 982
Other	3.27	2.65	0.62	8 928 098

Note: Results for "Total" are weighted by occupational groups (the proportion of observations in each occupational group and period in the original dataset).

Table 16: From raw to the baseline dataset, lost observations

	Blue-collar		White-collar		Civil servants	
Step	Obs.	Pct.	Obs.	Pct.	Obs.	Pct.
Total	10 185 734		9 811 394		1 699 546	
1	- 800 251	−7.86	- 67 676	−0.69	- 326	−0.02
2	- 22 095	−0.22	- 3 168	−0.03	- 216	−0.01
3	- 410 685	−4.03	- 215 275	−2.19	- 5 037	−0.30
4	- 539 147	−5.29	- 245 968	−2.51	- 3 687	−0.22
5	-1 340 576	−13.16	- 230 519	−2.35	- 1 894	−0.11
6	- 62 779	−0.62	- 34 349	−0.35	- 4 190	−0.25
7	- 961 987	−9.44	- 200 786	−2.05	- 3 220	−0.19
8	- 407 288	−4.00	- 166 301	−1.69	- 1 027	−0.06
9	- 613 146	−6.02	- 6 050	−0.06		0.00
10	- 580 405	−5.70	- 469 434	−4.78	- 262	−0.02
11	- 389 561	−3.82	- 941 751	−9.60	- 10 913	−0.64
12	- 54 084	−0.53	- 34 294	−0.35	- 117 299	−6.90

Note: All lost observations are relative to the initial number of observations ('Total') in the raw dataset. The steps are described in detail in Appendix B.1.

Table 17: Lost observations in the cleaning procedure

	Blue-collar		White-collar		Civil servants	
Step	Obs. pot.	Wage chg.	Obs. pot.	Wage chg.	Obs. pot.	Wage chg.
Baseline	6 828 003	5 249 780	8 276 087	3 461 814	1 651 225	485 041
1	-62.2%	-72.0%	-53.7%	-63.3%	-10.7%	-11.6%
2	-83.3%	-94.2%	-39.6%	-70.2%	-14.0%	-32.1%
3	-20.4%	-22.5%	-13.0%	-17.8%	-4.8%	-7.6%
4	0.0%	-23.8%	0.0%	-15.9%	0.0%	-10.8%
5	-2.3%	-20.8%	-1.7%	-12.8%	-0.7%	-5.2%
6	-4.8%	-37.5%	-2.8%	-27.2%	-0.7%	-13.7%
7	n/a	n/a	-0.7%	-1.6%	-0.5%	-1.7%
8	n/a	n/a	-43.5%	-48.9%	-30.1%	-41.7%
9	-5.0%	-4.5%	-3.9%	-3.8%	-0.5%	-0.3%
10	-5.0%	-4.7%	-10.3%	-16.3%	-7.6%	-15.6%

Note: All lost observations (wage changes) are relative to the number of observations (wage changes) in the baseline dataset. The steps are described in detail in Appendix B.2. "Obs. pot." refers to potential wage changes, i.e. the denominator of equation (1). "Wage chg." is the number of wage changes, i.e. the numerator of equation (1).

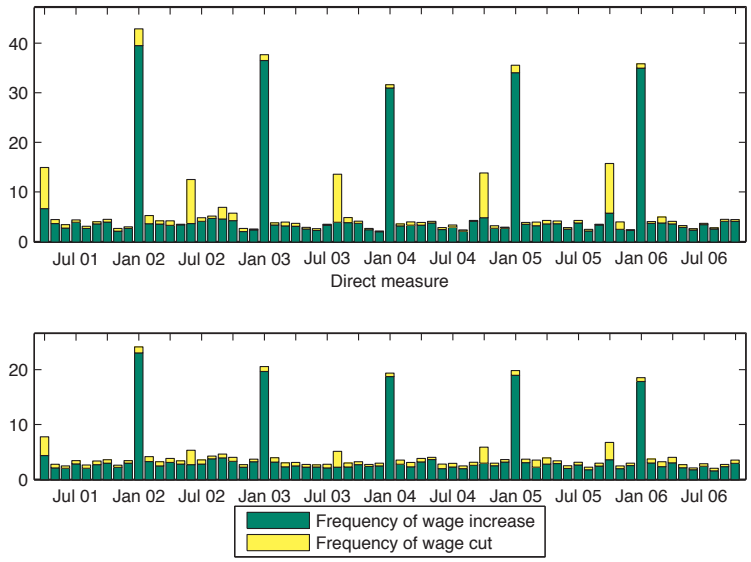
Table 18: Structure of the dataset

	Raw data			Baseline data			Cleaned data		
Category	Obs.	Pct.	Av. salary	Obs.	Pct.	Av. salary	Obs.	Pct.	Av. salary
Blue-collars	10 185 734	46.9		7 094 383	41.0		770 749	18.4	
White-collars	9 811 394	45.2		8 517 323	49.3		2 284 783	54.5	
Civil servants	1 699 546	7.8		1 680 730	9.7		1 134 363	27.1	
Indexation	1 824 682	8.4		1 423 794	8.2		342 506	8.2	
January	1 485 792	6.8		1 211 445	7.0		298 141	7.1	
Other period	18 386 200	84.7		14 657 197	84.8		3 549 248	84.7	
Private	18 656 890	86.0		14 387 219	83.2		2 736 432	65.3	
Public	3 037 418	14.0		2 905 217	16.8		1 453 463	34.7	
0-14 empl.	4 558 777	21.0	1 955	3 125 751	18.1	2 423	1 594 776	38.1	3 016
15-149 empl.	6 865 405	31.6	2 667	5 911 116	34.2	2 833	1 042 206	24.9	4 081
$\geq$ 150 empl.	10 272 492	47.3	3 101	8 255 569	47.7	3 535	1 552 913	37.1	4 587
A+B	100 372	0.5	1 774	70 127	0.4	1 994	19 006	0.5	2 130
C	23 316	0.1	2 715	20 484	0.1	2 771	2 484	0.1	3 874
D	2 491 268	11.5	2 858	2 257 231	13.1	2 953	248 701	5.9	3 780
E	73 100	0.3	4 234	68 784	0.4	4 243	14 858	0.4	5 203
F	2 228 618	10.3	2 266	1 915 391	11.1	2 365	276 353	6.6	2 724
G	2 682 401	12.4	2 168	2 235 711	12.9	2 304	488 542	11.7	2 758
H	899 802	4.1	1 671	644 304	3.7	1 828	162 313	3.9	1 904
I	1 836 412	8.5	3 011	1 619 448	9.4	3 169	370 181	8.8	3 599
J	2 525 654	11.6	4 159	2 315 347	13.4	4 248	574 545	13.7	5 025
K	3 655 494	16.8	2 147	2 173 338	12.6	2 962	644 428	15.4	3 662
L	2 507 676	11.6	3 730	2 270 045	13.1	4 000	1 237 097	29.5	4 574
M	116 570	0.5	3 260	94 480	0.5	3 524	22 569	0.5	3 653
N	1 342 225	6.2	2 812	1 167 121	6.7	3 010			
O	564 245	2.6	2 278	440 625	2.5	2 629	128 818	3.1	3 021
Total	21 696 674	100		17 292 436	100		4 189 895	100	

Note: "A+B" to "O" refer to NACE1 sectors. For definition, see note below Table 5. "Av. salary" refers to the average montly base earnings across all workers (whether part- or full-time, regardless of tenure, etc.) in Euro (i.e. excluding bonuses).

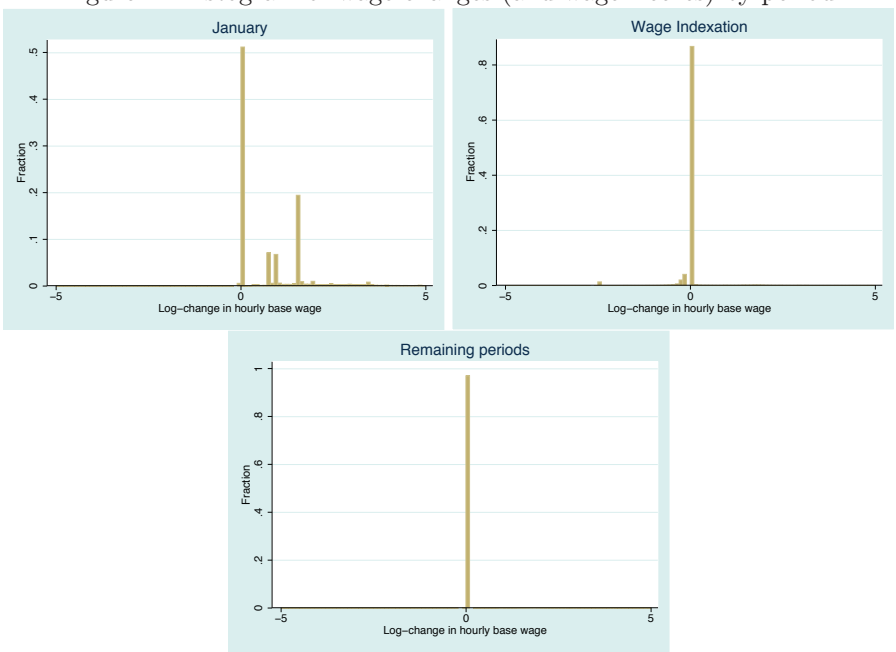
E Figures

Figure 1: Frequency of wage change by month



Note: The first and last two months are omitted because they are not considered a potential break date in the break test. Spikes correspond to the months of January and to months coinciding with wage indexation.

Figure 2: Histogram of wage changes (and wage freezes) by period



Note: Graphs are based on the adjusted dataset. Hence, the spike at zero in the "Wage indexation" panel would appear as an identical spike at 2.5% in the unadjusted dataset.

Figure 3: Frequency of wage change by firm (2001-2006)

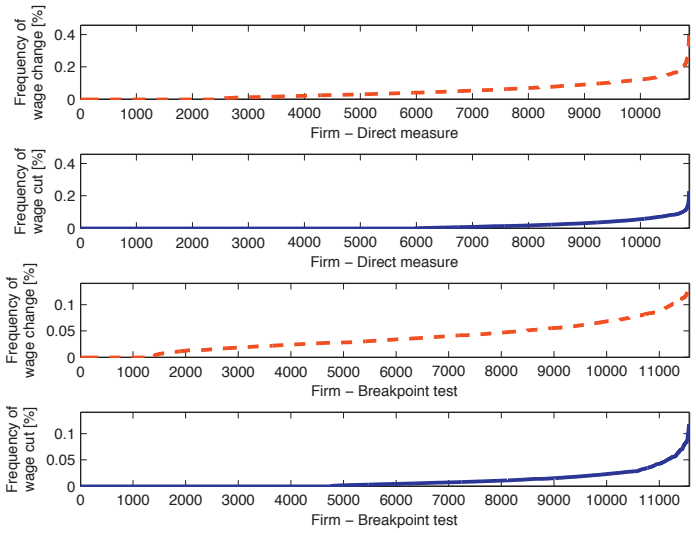
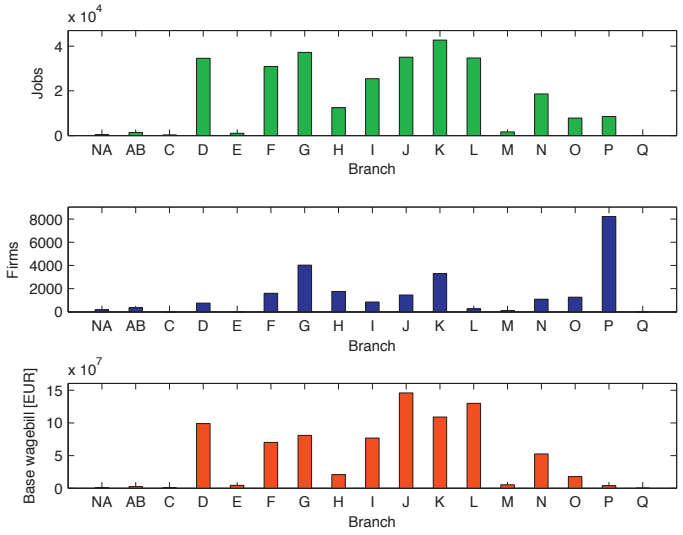


Figure 4: Number of firms and employees and wage bill by sector



Note: "AB" to "Q" refer to NACE1 sectors. For definition, see the note below Table 5.

Figure 5: Frequency of base wage changes as a function of their size (2001-2006)

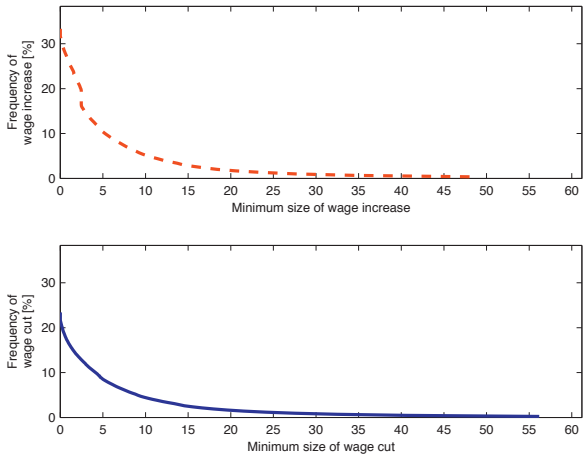
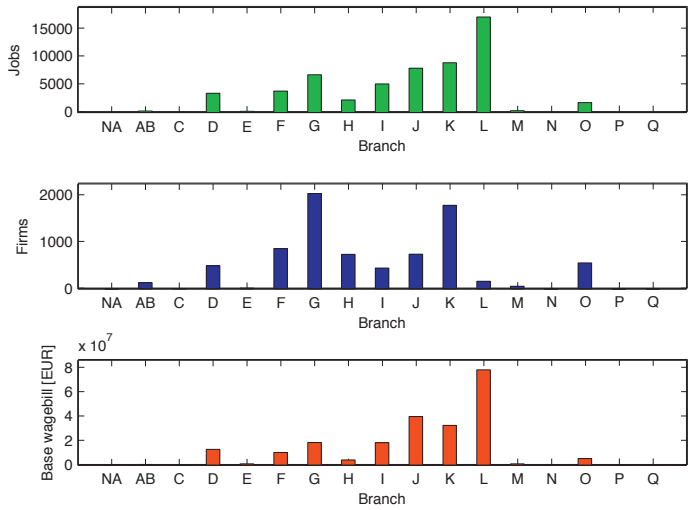


Figure 6: Number of firms and employees and wage bill by sector in the cleaned dataset



Note: "AB" to "Q" refer to NACE1 sectors. For definition, see the note below Table 5.

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