# Firm Hierarchy and Wage Rigidity*

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December 30, 2023

**Abstract**

This paper presents new evidence on how the internal organization of firms shapes asymmetric wage risks over the business cycle, using matched employer-employee data in Germany from 1979 to 2010. We document three results. First, wage cyclicality is significantly more left-skewed for workers at lower hierarchical levels within firms. Second, there is substantial heterogeneity among low-ranking workers, depending on firm organizations. Third, the wage cyclicality for production workers becomes more left-skewed as the span of control for executives widens. Overall, the findings highlight the importance of firm organizations in driving the polarization of wage risks.

**Keywords**: firm organization, wage cyclicality

**JEL**: E24, E32, J31, L22, L23

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We thank Edouard Schaal, Katarína Borovičkovà, Mathieu Taschereau-Dumouchel, Andrea Caggese, Davide Debortoli, Jordi Galí, Ruben Enikolopov, Giacomo Ponzetto and seminar participants at CREI Macro Lunch and Internal Applied Lunch for helpful comments. We thank Anna Gumpert for kindly providing the occupation codes for hierarchy classification. Huang acknowledges financial support from the Spanish Ministry of Science and Innovation (FPI Grant PRE2020-092551). All errors are our own.

# 1 Introduction

Changes in worker wages are characterized by substantial heterogeneity and asymmetry. That is, as the aggregate economy fluctuates, wages of different workers respond in various ways; moreover, the booms and busts of the business cycle also affect workers to varying degrees (Carneiro et al., 2012; Card et al., 2013; Guvenen et al., 2014; Stüber, 2017; Guvenen et al., 2021; Busch et al., 2022). Understanding the *sources* of these heterogeneities and asymmetry is crucial not only for shedding light on the transmission mechanisms of aggregate shocks and hence macroeconomic modeling (Berger et al., 2023), but also for better public policy designs (Low et al., 2010).

Despite important progress in the past decades—see, for example the systematic evidence on heterogeneous wage changes across race (Bils, 1985), job status (Gertler et al., 2020), ages (Bayer and Kuhn, 2020), or skill levels (Grigsby, 2022)—an important perspective remains underexplored: Wages are increasingly negotiated and determined *within* the firm. In response to aggregate shocks, wage changes are determined by corporate policies that allocate surpluses or losses among workers, which in turn depends on the within-firm *interaction* among workers (Stole and Zwiebel, 1996). How do workers interact, and how does such interaction determine surplus-sharing rules within firms? Although theoretical insights have been developed for specific bargaining protocols (Cahuc et al., 2008; Brügemann et al., 2019), empirical evidence on how workers interact and the resulting implications for wages are still scarce.

This paper provides a first step towards answering this question through the lens of firm organization. Using the administrative matched employer-employee panel data in Germany for 1979-2010, we estimate heterogeneous wage cyclicalities through the lens of the internal organization of firms. Figure 1 illustrates our methodology. Specifically, we divide workers into different layers of management, ranging from production workers to executives (Caliendo and Rossi-Hansberg, 2012), and we further classify firms based on the number of layers. We then ask: how do wage cyclicalities differ across hierarchies? Most importantly, how do different hierarchies interact?

Overall, we show three main sets of empirical results.

First, wage changes over the business cycles are more negative for workers at lower hierarchical levels of the firms. Taking the example of a low-ranking worker with zero span of control and a manager supervising 50 workers. In response to a one percentage point increase in the GDP growth rate, the real wages of the manager (low-ranking worker) increase by 0.31% (0.18%) — suggesting that managers get more wage raise in booms compared to low-ranking workers. On the other hand, in response to a one percentage point decrease in the GDP growth rate, the wages of the manager even increase by 0.11%, while those for low-ranking worker decrease by 0.20%, meaning managers are well insulated from recessions. This result holds when we restrict the sample to workers in firms with top managing departments.

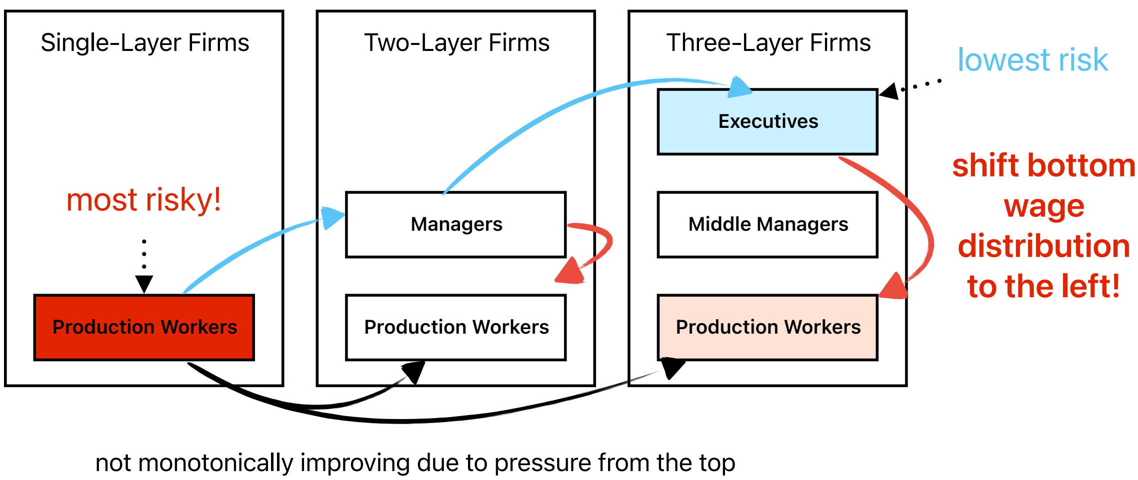


Figure 1: Main Findings

Note: This graph summarizes the main findings of this paper. Definition of worker hierarchies is given in Table 1. Firm organizations are given by number of unique worker hierarchies, provided that the hierarchies are continuous, as defined in Section 2.2.

Second, there is substantial heterogeneity between low-ranking workers, depending on the organizations of the firms. For workers in single-layer firms, wage cyclicality is strongly asymmetric and left-skewed, as illustrated in Figure 2. In contrast, for workers in multilayer firms, wages are responsive to both positive and negative shocks. For example, low-ranking workers in 3-layer firms experience 0.21% wage increase in response to a one percentage point increase in the GDP growth rate and a 0.29% wage decrease in response to a one percentage point decrease in the GDP growth rate.

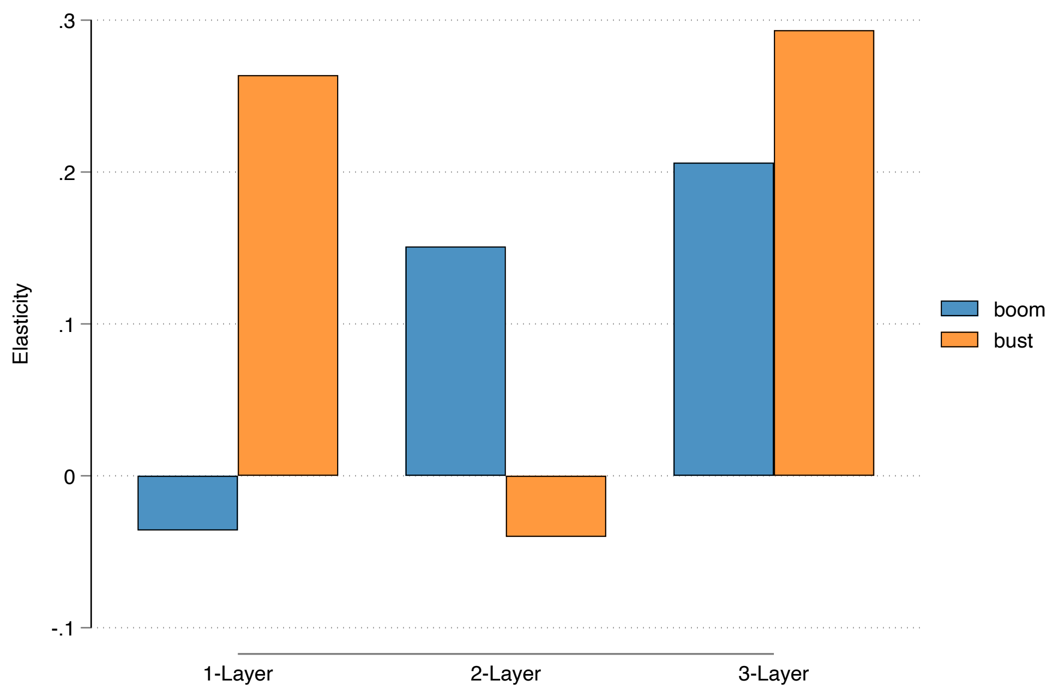


Figure 2: Wage Elasticity Across Firm Organizations

Note: This graph shows the wage elasticity of low-ranking workers to GDP growth rates by firm organizations. low-ranking workers refer to workers of layer 0; firm organizations refer to the number of distinct layers within firms. The definition of the hierarchical layer is given in Section 2.2.

Third, the reduction in wage risks is nonlinear, subject to the within-firm interactions among workers. In particular, focusing on multilayer firms, the wage cyclicality for production workers becomes more left-skewed as the span of control for executives widens. Compare production workers in firms with an executive span of control of 10 to those in firms with a span of control that is one standard deviation higher, namely 117. When the growth rate of GDP per capita increases by one percentage point, real wages of continuing production workers with a high executive span of control increase by 0.013%, which is smaller than the counterparts in firms with a low span of control. Conversely, as the growth rate of GDP per capita decreases by one percentage point, real wages for continuing production workers with a high executive span of control decrease by 0.026%, which is significantly higher than those associated with a low span of control. Since the span of control proxies the bargaining power of executives, the evidence suggests that stronger managerial power can increase the risks faced by production workers. Interestingly, it also indicates a potential trade-off between wage premiums and wage risks for these workers — although they enjoy higher wages through higher firm productivity or manager productivity, they also suffer from more wage risks from having top managers with power.

Overall, our results imply that workers at lower hierarchical levels of the firms have more left-skewed wage cyclicality. Furthermore, the larger the managerial power within a firm, the more left-skewed the wage cyclicality is for those low-ranking workers.

Over time, we observe a decrease in the executive span of control among multilayer firms, as well as an increase in the employment share of single-layer firms. These two trends suggest a polarization of wage risks. On the one hand, low-ranking workers in single-layer firms experience more left-skewed wage cyclicality. Their wages barely increase in booms and decrease in recessions. On the other hand, due to the reduction in managerial power, their wage cyclicality is more right-skewed. Their wages increase more in booms and decrease less in recessions. As firms optimize employment choices, policies aimed at enhancing the outside options of workers become imperative. Measures such as bolstering union rights, reducing barriers to job searches across occupations and locations, or implementing training programs to facilitate job ladder climbing within firms could mitigate the negative impact on the wage risks of these low-wage workers in single-layer firms. By doing so, these policies not only reduce wage risks but also contribute to enhancing the overall welfare of these workers, aligning with the evolving dynamics of the modern workplace.

**Related Literature**

This paper contributes to several strands of the literature.

First, this paper contributes to the extensive literature on the heterogeneous cyclicality of income across households. In an important paper, Guvenen et al. (2014) revisits the question of cyclical earnings risks using a large scale panel data from US Social Security Administration, and confirms the existence of substantial heterogeneity and skewness of earning risks. Various households and firm characteristics are proposed to explain the documented heterogeneity and asymmetry, including household debt (Mian and Sufi, 2016), skill level (Braxton et al., 2021), age (Catherine, 2022), and firm size (Bowlus et al., 2022). Our paper differs from this literature in two aspects. First, we focus on wages and abstract from other sources of income, which enables us to study the determinants of wage cyclicality the heterogeneous risks. Second, we focus on the role of firm hierarchy in shaping wage risks.

Second, our paper contributes to the recent literature on the implications of firm hierarchy and the aggregate economy. Prominent examples include Garicano and Rossi-Hansberg (2006), Caliendo and Rossi-Hansberg (2012) and Friedrich (2020). However, to the best of our knowledge, this paper is the first to study the role of firm hierarchy at business-cycle frequency.

**Layout.** The rest of the paper is organized as follows. Section 2 describes the data and introduces measures of firm hierarchy. Section 3 presents the empirical strategy as well as the main estimation results. All proofs as well as additional simulation and empirical results are relegated to the Supplemental Material.

# 2 Data

## 2.1 Data Source

The main source of data is the *Sample of Integrated Employer-Employee Data* (SIEED), which is a matched employer-employee dataset maintained by the Institute for Employment Research (IAB). The data set is a 1.5% sample of all establishments in Germany recorded as of June 30th from 1975 to 2018. For each sampled establishment, the IAB collects the entire employment history of all the employees subject to social security contributions, thereby excluding civil servants, self-employed persons and regular students[1]. Moreover, marginal part-time employment is not recorded until 1999. A detailed description of the dataset can be found in Vom Berge et al. (2019).

The main dependent variable is the real gross daily wage of workers. Specifically, the SIEED calculates the nominal gross daily wage *tentgelt* for each worker and employment spell from fixed period earnings.[2] Since the reported earnings are censored from both sides, we exclude all marginally employed workers whose earnings fall below the marginal part-time income threshold, and use a two-step Tobit regression to impute the top-coded wages following Dauth and Eppelsheimer (2020). Details of the wage imputation is provided in Appendix A.1. Nominal wages are deflated using the annual German CPI in 2015. To estimate wage elasticity to aggregate fluctuations, we merge the SIEED with GDP per capita for West Germany excluding West Berlin, constructed by Snell et al. (2018).[3]

Throughout, we focus on all full-time workers between 25 and 60 years of age in West Germany. For our main analysis, we restrict our sample from 1975 to 2010, since the occupation classification, based on which we construct the hierarchy measures, went through a significant change in 2010. For workers with multiple jobs within the same period, we choose the job with the longest duration as their primary jobs. Moreover, following Song et al.

[1] Whenever it causes no confusion, we use "firm" and "establishment" interchangeably in this paper.

[2] The earnings include performance-based bonuses.

[3] A popular alternative measure for aggregate cyclical variations is the unemployment rate. However, Snell et al. (2018) argues that the unemployment rate is not a good proxy for the business cycle in Germany.

(2019) we focus on establishments with more than 20 full-time employees who work more than 3 months within the establishments in a given year in our baseline analysis, and the results shown below hold under alternative selection criteria. In this paper, we abstract from the heterogeneity in wage cyclicality between job stayers and new hires, focusing specifically on job stayers.

## 2.2 Measures of hierarchy

Similar to Caliendo et al. (2015) and Gumpert et al. (2022), we define hierarchical layers based on the extent of managerial tasks of the jobs. In practice, the tasks are summarized by the German occupation classification (KldB1998). Table 1 reports our classification of the hierarchical layers, along with example occupations within each layer. Compared with Caliendo et al. (2015), our classification merges all intermediate layers between the non-managerial production workers and the executives, resulting in three hierarchical layers in total. Further comparisons between our classification and Caliendo et al. (2015) can be found in online Appendix A.

Table 1: Definition of Worker Hierarchy

| Level | Hierarchy | Occupations |
|---|---|---|
| 2 | Executives | CEOs, managing directors |
| 1 | Supervisors and managers | Supervisors, engineers, technicians, professionals |
| 0 | Production workers | Clerks, operators, production workers |

Note: This table defines the worker hierarchy, along with example occupations within each hierarchy. Further details can be found in online Appendix A.2.

Table A.2 summarizes worker characteristics across hierarchies. As we can see, managerial positions are held by a small fraction of workers, with supervisors, managers, CEOs and entrepreneurs accounting for 14.8%, 2.5% and 2.3% of the workers respectively. Moreover, managerial workers are in general older, more experienced (with longer tenure), more educated, performing more complicated tasks and receiving higher wages. Interestingly, we also find evidence of the glass ceiling —with only 16% female workers at the top hierarchy in contrast to 30% at the bottom. Overall, this suggests that our classification does capture the hierarchical feature of workers. More importantly, we also observe non-negligible variations in all characteristics within each layer, and thus hierarchy cannot be simply summarized by conventional worker characteristics such as tenure and skills.

Next, we measure the firm hierarchy structure by the number of distinct employee layers within the firm, and exclude all establishment observations whose hierarchies are not ordered consecutively from the bottom following Caliendo et al. (2015). For example, a firm is labeled as "2-layer firm" if it includes only production workers (layer 0) and supervisors (layer 1). Moreover, we exclude all establishments formed by only supervisors (layer 1) and managers (layer 2), because it lacks production workers (layer 0).

With the definition in hand, we construct two measures of internal organizations. The first one is the span of control, a continuous proxy measure of the power of a hierarchy defined as

$$Span_{eht} = \frac{\sum_{l=0}^{H} E_{elt}}{E_{eht}}, \quad Span_{e0t} = 0 \ . \tag{1}$$

Intuitively, the span of control is the number of workers "under control", and thus measures the managerial powers of a given hierarchy. To fix ideas, consider the example in Table 2. As we can see, although managers in firm 1 and firm 2 are in the same hierarchy (layer 1), the firm 1 manager —having much more production workers below— tends to enjoy greater power compared with the firm 2 counterpart. In fact, in this particular example the manager in firm 1 controls even more workers than the executive in firm 2. In this sense, the span of control provides a direct and accurate measure of the relative importance of a worker (hierarchy) within a firm.

The second measure is the dummy variable indicating the firm hierarchy, which ranges from 1 to 3. Among low-ranking workers, across firms, those in multilayer firms are also older and more experienced. They also earn higher wages. However, they do not differ from those in single-layer firms in gender ratio and education level. At the firm level, multilayer firms are larger and older. Table A.5 summarizes worker characteristics across firm hierarchies and Table A.7 summarizes characteristics of low-ranking workers across firm hierarchies.

# 3 Empirics

In this section, we explore the relationship between wage cyclicality (the tendency of wages to vary with the business cycles) and worker and firm hierarchies with the specification following Carneiro et al. (2012). We use the worker span of control to represent workers' power. The higher the span of control, the more individuals work under this worker, and thus, they have more power. Similarly, we use the span of control of the Executives to represent firm hierarchy power. The higher the span of control of the Executives, the more individuals work under them, and thus, they have less power.

## 3.1 Worker hierarchy

The first set of facts documents the correlation between the worker span of control and the wage cyclicality. Specifically, we estimate wage cyclicality by

$$\ln w_{ift} = y_t\beta + y_t \cdot S_{h_i,f,t-1}\theta + x'_{ift}\gamma + \lambda_{if} + \epsilon_{ift}$$

where $lnw_{ift}$ represents the log real daily wage of worker $i$ in firm $f$ in year $t$, $y_t$ is the GDP growth rate, which serves as a proxy for the German business cycle; $X_{ift}$ is a set of worker and firm level control variables, including age, age squared, tenure, education dummies, lagged wage, firm age, log firm size, and the share of workers with a university degree; $t$ and $t^2$ are linear and quadratic time trends; $\lambda_{ift}$ is a set of fixed effects, including both worker and firm fixed effects, and $\epsilon_{ift}$ is the zero mean error term.

The above econometric framework is standard in the empirical literature on wage cyclicality (e.g. Carneiro et al., 2012). Specifically, the parameter of interest is $\theta$, which measures the excess wage cyclicality associated with the span of control. For example, if $\theta > 0$, i.e. real wages decline more when the GDP growth rate is low and increase more when the GDP growth rate is high, as the workers have higher span of control – enjoying more power in the firm.

Results are presented in Table 3. The reported coefficients are re-scaled to reflect the percentage change in real wages per one percentage increase in the aggregate GDP growth rate. Three key observations stand out.

Even after controlling for worker time-varying characteristics and fixed effects, there remains a robust positive correlation between worker span of control and wage levels. The analysis indicates that higher span of control is consistently associated with higher real daily wages for workers. Specifically, with each additional subordinate to manage, a worker enjoys an extra 0.01% increase in their real daily wages.

Additionally, worker wages exhibit strong pro-cyclicality, aligning with findings in literature that utilize disaggregated wage data (Bils, 1985; Solon et al., 1994; Haefke et al., 2013; Gertler et al., 2020). For instance, a one percentage point increase in the growth rate of GDP per capita corresponds to a 0.19% increase in real wages for continuing workers. This finding is consistent with prior research, such as Gertler et al. (2020), who report responses of 0.147% for continuing workers and 1.789% for new hires.

Third, managerial wages are less procyclical but such difference is not significantly. The coefficient for the interaction term is negative but not significant, suggesting that wage cyclicality of managerial workers is not distinctly different from that of non-managerial counterparts.

To further explore the asymmetry in wage cyclicality of workers with different span of control, we estimate wage cyclicality by

$$\begin{aligned}\ln w_{ift} =& y_t^+ \beta^+ + y_t^+ \cdot S_{h_i,f,t-1}\theta^+ + y_t^- \beta^- + y_t^- \cdot S_{h_i,f,t-1}\theta^- \\ &+ x'_{ift}\gamma + \lambda_{if} + \epsilon_{ift}\end{aligned}$$

where $y_t^+$ is the growth rate of GDP or GDP per capita when it is positive and $y_t^-$ is the growth rate of GDP or GDP per capita when it is negative; a set of worker and firm level control variables, linear and quadratic time trends and a set of fixed effects are included; $\epsilon_{ift}$ is the zero mean error term.

The parameter of interest is $\theta^+$ and $\theta^-$, which measures the excess wage cyclicality associated with the span of control for boom and for recession, separately. For example, if $\theta^+ > 0$, i.e. real wages increase more when the GDP growth rate is positive and high , as the workers have higher span of control. On the other hand, if $\theta^- < 0$, i.e. real wages decrease more when the GDP growth rate is negative and low, as the workers have higher span of control.

The second and fourth columns in Table 3 reports the results. As before, the reported coefficients are re-scaled to represent the percentage change in real wages in response to one percentage increase in the aggregate GDP growth rate. We have three observations.

First, wage cyclicality is slightly asymmetric and left-skewed for production workers — their real wages are flexible in both booms and recessions. Both the coefficients $\beta^+$ and $\beta^-$ for GDP growth rates are positive, suggesting that real wages increase in boom and decrease in recession. $\beta^+$ is slightly smaller than $\beta^-$ but the difference is not significant. It indicates that there is slight asymmetry in wage cyclicality for workers with zero span of control.

Second, wage cyclicality is right-skewed for managers. The coefficient for the excess wage cyclicality in boom $\theta^+$ is significantly positive while the coefficient for the excess wage cyclicality in recession $\theta^-$ is significantly negative. Let us explain the results by comparing the wage changes for a production worker with zero span of control and a manager supervising 50 workers. [4] In response to a one percentage point increase in the GDP growth rate, the real wages of the manager increase more by 0.13% compared to the increase in real wages of the production worker, 0.18% — suggesting that managers, especially those at the top of the hierarchy, get more wage raise in booms compared to low-ranking workers. On the

[4] The average span of control for top managers is 48.5.

other hand, in response to a one percentage point decrease in the GDP growth rate, the wages of the manager decrease less by 0.305%, compared to the decline of real wages of the production workers, 0.20%, meaning managers may even experience a wage raise and are well insulated from recessions.

In summary, wage cyclicality is right-skewed for managers and slightly left-skewed for production workers. However, in this section, the production workers include all workers from both single-layer firms and multilayer firms. In the next section, we study how wage cyclicality differ across productions workers across firm hierarchies.

## 3.2 Firm hierarchy

We now discuss the second set of facts about the firm hierarchical structure. First, we study how wage cyclicality of production workers depend on the firm structure by

$$\ln w_{ift} = y_t\beta + \sum_{h=1}^{2} \mathbf{1}\{O_{f,t-1} = h\} \cdot [\rho_h + y_t \cdot \theta_h] + x'_{ift}\gamma + \lambda_{if} + \epsilon_{ift}$$

which is identical to (3.1) except that we replace the worker level hierarchy measure $S_{h_i,f,t-1}$ by firm level hierarchy dummies $\mathbf{1}\{O_{f,t-1} = h\}$. In this specification, $lnw_{ift}$ is the log real daily wage of worker $i$ in firm $f$ in year $t$, $y_t$ is the GDP growth rate which serves as a proxy for the German business cycle and $\mathbf{1}\{O_{f,t-1} = h\}$ equals to 1 if the worker belongs to a firm with the total number of layers as $h + 1$; following the previous specification, we include a set of worker and firm level control variables $X_{ift}$, linear and quadratic time trends $t$ and $t^2$ and a set of fixed effects $\lambda_{ift}$; $\epsilon_{ift}$ is the zero mean error term.

The parameter of interest is $\theta_h$, which measures the excess wage cyclicality associated with firm hierarchies. For example, if $\theta_1 > 0$, i.e. for production workers in 2-layer firms, real wages decline more when the GDP growth rate is low and increase more when the GDP growth rate is high.

Table 4 reports the results. For ease of interpretation, the reported coefficients are re-scaled to represent the percentage change in real wages in response to one percentage increase in the aggregate GDP growth rate.

First, wages are strongly procyclical for production workers, which is consistent with the results in the previous section. For example, the first column shows that as the growth rate of GDP per capita increases by one percentage point, real wages of continuing production workers in single-layer firms increase by 0.09%, compared to the 0.19% for all workers in Table 3.

Second, wages are more procyclical for production workers in 2-layer firms. For example, the first shows that as the growth rate of GDP per capita increases by one percentage point, real wages of continuing production workers in 3-layer firms increase more by 0.15%, compared to those in single-layer firms.

To further explore the asymmetry in wage cyclicality of workers across firm hierarchies, we again estimate wage cyclicality by

$$\begin{aligned}\ln w_{ift} = y_t^+ \beta^+ + \sum_{h=1}^{2} \mathbf{1}\{O_{f,t-1} = h\} \cdot [\rho_h + y_t^+ \cdot \theta_h^+] \\ + y_t^- \beta^- + \sum_{h=1}^{2} \mathbf{1}\{O_{f,t-1} = h\} \cdot [\rho_h + y_t^- \cdot \theta_h^-] + x_{ift}' \gamma + \lambda_{if} + \epsilon_{ift}\end{aligned}$$

where $y_t^+$ is the growth rate of GDP or GDP per capita when it is positive and $y_t^-$ is the growth rate of GDP or GDP per capita when it is negative; a set of worker and firm level control variables, linear and quadratic time trends and a set of fixed effects are included; $\epsilon_{ift}$ is the zero mean error term.

The second and fourth columns in Table 4 reports the results. For ease of interpretation, the reported coefficients are re-scaled to represent the percentage change in real wages in response to one percentage increase in the aggregate GDP growth rate.

First, wage cyclicality is strongly asymmetric and left-skewed for production workers in single-layer firms — their real wages barely increase in both booms and decrease a lot in recessions. The coefficients $\beta^+$, which represents the wage cyclicality in booms of production workers in 1-layer firms, is almost 0. And $\beta^{-}$, the wage cyclicality in recessions of these workers is positive and significant, suggesting that real wages decrease in recession by 0.26% for each one percentage point decrease in the GDP growth rate.

Interestingly, for workers in 2-layer firms, wage cyclicality is more right-skewed. For example, the first column shows that as the growth rate of GDP per capita increases by one percentage point, real wages of continuing production workers in 2- and 3-layer firms increase more by 0.19% and 0.24%, compared to those in single-layer firms. As the growth rate of GDP per capita decreases by one percentage point, real wages of continuing production workers in 2-layer firms decrease less by 0.30% and more by 0.03%, compared to those in single-layer firms.

In summary, real wages are procyclical for production workers. Furthermore, the wage cyclicality is more left-skewed for production workers in single-layer firms and more right-skewed for those in 2-layer firms. Notably, for production workers in 3-layer firms with top managing departments, their real wages increase during economic booms and decrease in recessions. The observed non-monotonicity suggests that while production workers in 3-layer firms enjoy a wage premium, they may also experience more wage risks compared to their counterparts in 2-layer firms. These results hint at the possibility that large firms may not fully insure their workers against economic downturns. In the next section, our focus shifts to production workers in 3-layer firms, where we examine the wage cyclicality across executive span of control.

## 3.3 Firms with CEOs: Executive span of control

We now discuss the third set of facts about the executive span of control within 3-layer firms — firms with top managing departments. First, we study how wage cyclicality of production workers depend on the executive span of control by

$$\ln w_{ift} = y_t\beta + y_t \cdot S_{2,f,t-1}\theta + x'_{ift}\gamma + \lambda_{if} + \epsilon_{ift}$$

which is identical to (3.1) except that we replace the worker level hierarchy measure $S_{h_i,f,t-1}$ by executive span of control of the firm $f$, $S_{2,f,t-1}$. Following the previous specification, we include a set of worker and firm level control variables $X_{ift}$, linear and quadratic time trends $t$ and $t^2$ and a set of fixed effects $\lambda_{ift}$; $\epsilon_{ift}$ is the zero mean error term.

The parameter of interest is $\theta$, which measures the excess wage cyclicality associated with executive span of control. For example, if $\theta > 0$, i.e. for production workers in firms with larger executive span of control, real wages decline more when the GDP growth rate is low and increase more when the GDP growth rate is high.

Table 5 reports the results. For ease of interpretation, the reported coefficients are rescaled to represent the percentage change in real wages in response to one percentage increase in the aggregate GDP growth rate. We have three observations.

First, wages are strongly procyclical for production workers in 3-layer firms. For example, the first shows that as the growth rate of GDP per capita increases by one percentage point, real wages of continuing production workers in firms with zero executive span of control (if there is a such firm) increase by 0.25%.

Second, even after controlling for a set of worker time-varying characteristics, firm size and a set of fixed effects, production workers in firms with higher executive span of control are still positively correlated with their real wage levels. The higher the executive span of control, the higher real daily wages a worker has. With one standard deviation of additional subordinates, that is 107 subordinates, the subordinate production worker enjoys an extra 0.16% higher in her real daily wages. This may suggest better management efficiency of these firms or higher productivity of the top managers.

Third, wage cyclicality may not change with executive span fo controls, as shown by the insignificance of $\theta$.

To further explore the asymmetry in wage cyclicality of workers across firm hierarchies, we again estimate wage cyclicality by

$$\begin{aligned}\ln w_{ift} =& y_t^+ \beta^+ + y_t^+ \cdot S_{2,f,t-1}\theta^+ + y_t^- \beta^- + y_t^- \cdot S_{2,f,t-1}\theta^- \\ &+ x'_{ift}\gamma + \lambda_{if} + \epsilon_{ift}\end{aligned}$$

where $y_t^+$ is the growth rate of GDP or GDP per capita when it is positive and $y_t^-$ is the growth rate of GDP or GDP per capita when it is negative; a set of worker and firm level control variables, linear and quadratic time trends and a set of fixed effects are included; $\epsilon_{ift}$ is the zero mean error term.

The second and fourth columns in Table 5 reports the results. For ease of interpretation, the reported coefficients are re-scaled to represent the percentage change in real wages in response to one percentage increase in the aggregate GDP growth rate.

First, wage cyclicality is strongly asymmetric and left-skewed for production workers — their real wages increase in booms and decrease more in recessions. The coefficients $\beta^+$, which represents the wage cyclicality in booms of production workers in firms with zero executive span of control, is positive and significant. For each one percentage point increase in the GDP growth rate, real wages increase by 0.17%. And $\beta^-$, the wage cyclicality in recessions of these workers is positive and significant, suggesting that real wages decrease in recession by 0.37% for each one percentage point decrease in the GDP growth rate.

Moreover, for workers in firms with higher executive span of control, wage cyclicality exhibits an even more pronounced left-skew. To illustrate, let's compare production workers in firms with 10 executive span of control to those in firms with a span of control one standard deviation higher, i.e., (10 plus 107) 117. When the growth rate of GDP per capita increases by one percentage point, real wages for continuing production workers in high executive span of control increase by a lesser extent, specifically, 0.013%, compared to their counterparts in low span of control firms. Conversely, as the growth rate of GDP per capita decreases by one percentage point, real wages for continuing production workers in high executive span of control decrease more significantly, by 0.026%, compared to those in low span of control firms. This suggests that, even after controlling for worker and firm characteristics, production workers in firms with high executive span of control are less insulated during recessions and experience lower wage increases in economic booms.

As a summary, real wages are procyclical for production workers in firms with top managers. Additionally, this wage cyclicality is left-skewed, with a more pronounced effect for production workers in firms with high executive span of control. These results suggest that firms with top managers overseeing larger worker spans may be less inclined to provide insurance to their production workers during recessions. Simultaneously, they appear to share less surplus with production workers in economic booms. This could explain the absence of a more right-skewed wage cyclicality for production workers in 3-layer firms compared to their counterparts in 2-layer firms.

In the next section, repeat the exercise as (3.1), we focus on all workers in 3-layer firms and study the wage cyclicality of production workers across worker span of control. We conduct this exercise to confirm that the results in the section 3.1 hold for 3-layer firms.

The first set of facts documents the correlation between the worker span of control and the wage cyclicality. Specifically, we estimate wage cyclicality by

$$\ln w_{ift} = y_t\beta + y_t \cdot S_{h_i,f,t-1}\theta + x'_{ift}\gamma + \lambda_{if} + \epsilon_{ift}$$

which is the same as (3.1) with a different subsample of workers — all workers in 3-layer firms.

Table 6 reports the results. For ease of interpretation, the reported coefficients are rescaled to represent the percentage change in real wages in response to one percentage increase in the aggregate GDP growth rate. Three observations are noteworthy.

First, similar to results in Table 3, after controlling for a set of worker time-varying characteristics and fixed effects, worker span of control are still positively correlated with workers' wage levels. With each additional subordinate to manage, a worker enjoys an extra

0.01% higher in her real daily wages.

Second, worker wages are more procyclical compared to the results with the whole sample. For example, the first shows that as the growth rate of GDP per capita increases by one percentage point, real wages of continuing workers increase by 0.25%, compared to 0.19% with the whole sample of workers.

Third, managerial wages are less procyclical but such difference is not significantly.

To further explore the asymmetry in wage cyclicality across workers with different span of control, we estimate wage cyclicality by

$$\begin{aligned} \ln w_{ift} =& y_t^+ \beta^+ + y_t^+ \cdot S_{h_i,f,t-1} \theta^+ + y_t^- \beta^- + y_t^- \cdot S_{h_i,f,t-1} \theta^- \\ & + x'_{ift} \gamma + \lambda_{if} + \epsilon_{ift} \end{aligned}$$

which is the same as (3.1) with a different subsample of workers — all workers in 3-layer firms.

The parameter of interest is $\theta^+$ and $\theta^-$, which measures the excess wage cyclicality associated with the span of control for boom and for recession, separately.

The second and fourth columns in Table 6 reports the results. The reported coefficients are re-scaled to represent the percentage change in real wages in response to one percentage increase in the aggregate GDP growth rate. We have three observations.

First, wage cyclicality is more asymmetric and left-skewed for production workers, compared to the results in the second and fourth columns in Table 3. The coefficients $\beta^+$, which represents the wage cyclicality in booms of production workers in firms with zero executive span of control, is positive and significant. For each one percentage point increase in the GDP growth rate, real wages increase by 0.16%. And $\beta^-$, the wage cyclicality in recessions of these workers is positive and significant, suggesting that real wages decrease in recession by 0.39% for each one percentage point decrease in the GDP growth rate. The results are similar to those in Table 5.

Second, wage cyclicality is right-skewed for managers. The excess wage cyclicality is similar to the results with the whole sample in Table 3. The coefficient for the excess wage cyclicality in boom $\theta^+$ is significantly positive while the coefficient for the excess wage cyclicality in recession $\theta^-$ is significantly negative. Let us again explain the results by comparing the wage changes for a production worker with (almost) zero span of control and a manager supervising 50 workers. in response to a one percentage point increase in the GDP growth rate, the real wages of the manager increase more by 0.105% compared to the increase in real wages of the production worker — suggesting that managers, especially those at the top of the hierarchy, get more wage raise in booms compared to low-ranking workers. On the other hand, in response to a one percentage point decrease in the GDP growth rate, the wages of the manager decrease less by 0.305%, compared to the decline of real wages of the production workers, meaning managers may even experience a wage raise and are well insulated from recessions.

In summary, in 3-layer firms, wage cyclicality is right-skewed for managers and left-skewed for production workers, similar to the wage cyclicality for the whole sample of workers.

# 4 Discussions

Overall, in the previous section, we show three main sets of empirical results. First, wage cyclicality is right-skewed for managers and left-skewed for production workers, for workers in all types of firms. Second, wage cyclicality is more left-skewed for those production workers in single-layer firms and less left-skewed for workers in 3-layer firms, and more right-skewed for those production workers in 2-layer firms. Third, among production workers in 3-layer firms, wage cyclicality is more left-skewed for those in firms with high executive span of control, which could be one of the reason why in the second set of findings, the wage cyclicality for production workers in 3-layer firms is not more right-skewed than those in 2-layer firms. These findings suggest a potential trade-off for production workers in 3-layer firms. While they enjoy higher wages attributed to increased firm or manager productivity, they also face heightened wage risks due to the influence of powerful top managers. The main empirical results are summarized in Figure 1. [5]

Several potential mechanisms could explain the observed wage cyclicality. We particularly focus on the interplay between surplus sharing rules and worker outside options. The relationship between these factors can shed light on the varying cyclicality patterns for different groups of workers.

Surplus sharing rules within firms can play a crucial role in determining wage cyclicality. In the context of intra-firm bargaining, where multiple workers negotiate with the firm in a specific order following Stole and Zwiebel (1996), those who negotiate first may extract more surplus from the firm-multi-worker relationship. In a model where worker outside options remain constant over the business cycle, this could result in more procyclical real wages for managers compared to production workers, instead of a more left-skewed wage cyclicality for production workers.

Our exploration extends beyond this static view. Drawing from existing literature and affirmed by our data, we recognize that low-paid and less-skilled jobs tend to be more vulnerable during economic downturns. This could result from their lower productivity and less bargaining power. The increased likelihood of unemployment for these workers during recessions further worsens their outside options, making them more amenable to wage cuts and reinforcing the left-skewed nature of their wage cyclicality in general equilibrium.

Looking ahead, our future work aims to develop a quantitative model to disentangle the effects of various potential mechanisms. By doing so, we aspire to provide a more nuanced understanding of the intricate dynamics that shape wage cyclicality across different worker and firm hierarchies.

Over time, the growing adoption of information and communication technology (ICT)

[5] In our empirical results, we compare wage cyclicality of workers across worker and firm hierarchies, taking both characteristics as given. In reality, firms adopt specific organization structures and employment and wage policies to minimize production costs — within-firm communication costs or labor costs — and to maximize productivity, such as managing efficiency. Workers also select into different firms and different hierarchical layers following their education levels and job search behavior. We abstract from the endogenous choices in this paper.

by firms has significantly enhanced managing efficiency. However, the effect of such technology change on firm span of control is ambiguous. On the one hand, higher communication efficiency between mangers and production workers allows the former to manage more subordinates. On the other hand, robotization enables firms to save labor costs by replacing less-productive, low-ranking workers, leading to a lower executive span of control.

From the data, we observe a decrease in the executive span of control among multilayer firms, as well as an increase in the employment share of single-layer firms. These two trends suggest a polarization of wage risks. On the one hand, low-ranking workers in single-layer firms experience more left-skewed wage cyclicality. Their wages barely increase in booms and decrease in recessions. On the other hand, workers are less-likely to be employed by multilayer firms. Once they do, due to the reduction in managerial power, their wage cyclicality is more right-skewed. Their wages increase more in booms and decrease less in recessions. As firms optimize employment choices, policies aimed at enhancing the outside options of workers become imperative. Measures such as bolstering union rights, reducing barriers to job searches across occupations and locations, or implementing training programs to facilitate job ladder climbing within firms could mitigate the negative impact on the wage risks of these low-wage workers in single-layer firms. By doing so, these policies not only reduce wage risks but also contribute to enhancing the overall welfare of these workers, aligning with the evolving dynamics of the modern workplace.

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## Tables and figures

| | Firm 1 | Firm 2 |
|---|---|---|
| Executives | 0 | 1 |
| Manager | 1 | 2 |
| Production Worker | 10 | 5 |
| $Span_2$ | / | 7 |
| $Span_1$ | 10 | 2.5 |
| $Span_0$ | 0 | 0 |

Table 2: Example: Span of Control

Table 3: Wage Cyclicality and Span of Control (>20 employees)

| | ΔGDPpp | | ΔGDP | |
|---|---|---|---|---|
| $y_t$ | 0.1920*** | | 0.1994*** | |
| | (0.0047) | | (0.0050) | |
| $S_{h_i,f,t-1}$ | 0.0117*** | 0.0055* | 0.0118*** | 0.0047* |
| | (0.0022) | (0.0022) | (0.0022) | (0.0022) |
| $y_t \cdot S_{h_i,f,t-1}$ | -0.0004 | | -0.0008 | |
| | (0.0005) | | (0.0006) | |
| $y_t^+$ | | 0.1869*** | | 0.1754*** |
| | | (0.0090) | | (0.0114) |
| $y_t^+ \cdot S_{h_i,f,t-1}$ | | 0.0026** | | 0.0045*** |
| | | (0.0009) | | (0.0010) |
| $y_t^-$ | | 0.2016*** | | 0.2264*** |
| | | (0.0118) | | (0.0125) |
| $y_t^- \cdot S_{h_i,f,t-1}$ | | -0.0061*** | | -0.0069*** |
| | | (0.0014) | | (0.0014) |
| # obs | 2,317,178 | 2,317,178 | 2,317,178 | 2,317,178 |
| W + F FEs | ✓ | ✓ | ✓ | ✓ |

This table reports estimated coefficients and standard errors of the regression results of heterogeneity in wage cyclicality across worker span of control. The main independent variable is the growth rate of GDP per capita in column (1)-(2) and the growth rate of GDP in column (3)-(4). From column (1) to (4) the dependent variables include age, age squared, tenure (total), lagged log of real wages, firm age, lagged log of firm employment, lagged share of high skilled workers at firm level, and time trend $t$ and $t^2$. In all the regressions, we restrict the sample to all workers in firms with more than 20 employees in a given year. We also include worker and firm fixed-effects. Standard errors are clustered at worker level. Wages are deflated by annual CPI (2015 = 100). $+\ p < 0.1$, $*\ p < 0.05$, $**\ p < 0.01$, $***\ p < 0.001$. The span of control of executives have mean 48.5 and standard deviation 107 across firms with more than 20 employees and 3 layers.

Table 4: Wage Cyclicality Across Organizations (>20 employees)

| | $\Delta$GDP $pp_t$ | | $\Delta GDP_t$ | |
|---|---|---|---|---|
| $y_t$ | 0.0896*** | | 0.1025*** | |
| | (0.0133) | | (0.0135) | |
| $\mathbf{1}\{O_{f,t-1}=1\}$ | -0.5881*** | -0.9466** | -0.5973*** | -1.1147*** |
| | (0.1014) | (0.1090) | (0.1014) | (0.1107) |
| $\mathbf{1}\{O_{f,t-1}=2\}$ | -0.6869*** | -0.8422** | -0.6881*** | -1.1058*** |
| | (0.1140) | (0.1199) | (0.1140) | (0.1214) |
| $y_t \times \mathbf{1}\{O_{f,t-1}=1\}$ | -0.0164 | | -0.0081 | |
| | (0.0157) | | (0.0163) | |
| $y_t \times \mathbf{1}\{O_{f,t-1}=2\}$ | 0.1532*** | | 0.1672*** | |
| | (0.0146) | | (0.0151) | |
| $y_t^+$ | | -0.0360 | | -0.1251*** |
| | | (0.0258) | | (0.0307) |
| $y_t^+ \times \mathbf{1}\{O_{f,t-1}=1\}$ | | 0.1870*** | | 0.3558*** |
| | | (0.0296) | | (0.0354) |
| $y_t^+ \times \mathbf{1}\{O_{f,t-1}=2\}$ | | 0.2422*** | | 0.4126*** |
| | | (0.0279) | | (0.0331) |
| $y_t^-$ | | 0.2638*** | | 0.3465*** |
| | | (0.0316) | | (0.0329) |
| $y_t^- \times \mathbf{1}\{O_{f,t-1}=1\}$ | | -0.3040*** | | -0.3978*** |
| | | (0.0373) | | (0.0385) |
| $y_t^- \times \mathbf{1}\{O_{f,t-1}=2\}$ | | 0.0296 | | -0.0973** |
| | | (0.0350) | | (0.0361) |
| # obs | 1,783,028 | 1,783,028 | 1,783,028 | 1,783,028 |
| W + F FEs | ✓ | ✓ | ✓ | ✓ |

This table reports estimated coefficients and standard errors of the regression results of heterogeneity in wage cyclicality across firm with different number of total layers. The main independent variable is the growth rate of GDP per capita in column (1)-(2) and the growth rate of GDP in column (3)-(4). From column (1) to (4) the dependent variables include age, age squared, tenure (total), lagged log of real wages, firm age, lagged log of firm employment, lagged share of high skilled workers at firm level, and time trend $t$ and $t^2$. In all the regressions, we restrict the sample to all workers in firms with more than 20 employees in a given year. We also include worker and firm fixed-effects. Standard errors are clustered at worker level. Wages are deflated by annual CPI (2015 = 100). $+\ p < 0.1$, $*\ p < 0.05$, $**\ p < 0.01$, $***\ p < 0.001$. The span of control of executives have mean 48.5 and standard deviation 107 across firms with more than 20 employees and 3 layers.

Table 5: Wage Cyclicality and Executive Span of Control (>20 employees)

| | ΔGDPpp | | ΔGDP | |
|---|---|---|---|---|
| $y_t$ | 0.2576*** | | 0.2779*** | |
| | (0.0070) | | (0.0001) | |
| $S_{2,f,t-1}$ | 0.0013*** | 0.0015*** | 0.0012*** | 0.0013*** |
| | (0.0001) | (0.0001) | (0.0001) | (0.0001) |
| $y_t \cdot S_{2,f,t-1}$ | -0.0002 | | 0.0000 | |
| | (0.0000) | | (0.0000) | |
| $y_t^+$ | | 0.1680*** | | 0.2110*** |
| | | (0.0124) | | (0.0166) |
| $y_t^+ \cdot S_{2,f,t-1}$ | | -0.0001*** | | -0.0001* |
| | | (0.0000) | | (0.0000) |
| $y_t^-$ | | 0.3678*** | | 0.3462*** |
| | | (0.0187) | | (0.0194) |
| $y_t^- \cdot S_{2,f,t-1}$ | | 0.0002*** | | 0.0001* |
| | | (0.0000) | | (0.0000) |
| # obs | 1,106,292 | 1,106,292 | 1,106,292 | 1,106,292 |
| W + F FEs | ✓ | ✓ | ✓ | ✓ |

This table reports estimated coefficients and standard errors of the regression results of heterogeneity in wage cyclicality across firm with different executive span of control. The main independent variable is the growth rate of GDP per capita in column (1)-(2) and the growth rate of GDP in column (3)-(4). From column (1) to (4) the dependent variables include age, age squared, tenure (total), lagged log of real wages, firm age, lagged log of firm employment, lagged share of high skilled workers at firm level, and time trend $t$ and $t^2$. In the regressions, we restrict the sample to production workers in firms with more than 20 employees and top managing departments in a given year. We also include worker and firm fixed-effects. Standard errors are clustered at worker level. Wages are deflated by annual CPI (2015 = 100). $+\ p < 0.1$, $*\ p < 0.05$, $**\ p < 0.01$, $***\ p < 0.001$. The span of control of executives have mean 48.5 and standard deviation 107 across firms with more than 20 employees and 3 layers.

Table 6: Wage Cyclicality and Span of Control (firms with CEOs and with >20 employees)

| | ΔGDPpp | | ΔGDP | |
|---|---|---|---|---|
| $y_t$ | 0.2485*** | | 0.2590*** | |
| | (0.0062) | | (0.0067) | |
| $S_{h_i,f,t-1}$ | 0.0107*** | 0.0046+ | 0.0108*** | 0.0044+ |
| | (0.0024) | (0.0024) | (0.0023) | (0.0023) |
| $y_t \cdot S_{h_i,f,t-1}$ | -0.0006 | | $-0.0011^{+}$ | |
| | (0.0005) | | (0.0006) | |
| $y_t^+$ | | 0.1591*** | | 0.1178*** |
| | | (0.0116) | | (0.0150) |
| $y_t^+ \cdot S_{h_i,f,t-1}$ | | 0.0022* | | 0.0036** |
| | | (0.0009) | | (0.0011) |
| $y_t^-$ | | 0.3805*** | | 0.4168*** |
| | | (0.0155) | | (0.0164) |
| $y_t^- \cdot S_{h_i,f,t-1}$ | | -0.0062*** | | -0.0067*** |
| | | (0.0016) | | (0.0015) |
| # obs | 1,524,475 | 1,524,475 | 1,524,475 | 1,524,475 |
| W + F FEs | ✓ | ✓ | ✓ | ✓ |

This table reports estimated coefficients and standard errors of the regression results of heterogeneity in wage cyclicality across workers with different span of control. The main independent variable is the growth rate of GDP per capita in column (1)-(2) and the growth rate of GDP in column (3)-(4). From column (1) to (4) the dependent variables include age, age squared, tenure (total), lagged log of real wages, firm age, lagged log of firm employment, lagged share of high skilled workers at firm level, and time trend $t$ and $t^2$. In the regressions, we restrict the sample to all workers in firms with more than 20 employees and top managing departments in a given year. We also include worker and firm fixed-effects. Standard errors are clustered at worker level. Wages are deflated by annual CPI (2015 = 100). $+\ p < 0.1$, $*\ p < 0.05$, $**\ p < 0.01$, $***\ p < 0.001$. The span of control of executives have mean 48.5 and standard deviation 107 across firms with more than 20 employees and 3 layers.

# A Data Appendix

This appendix provides details on the construction of the main dataset used in the paper. Section A.2 starts with the hierarchical definition in Caliendo et al. (2015), and then discusses the conversion into the definition in Table 1. Section ...

## A.1 Wage Imputation

We fit wages on worker characteristics for each demographic groups separately and use average wages as proxies for worker and firm fixed effects. Similar imputation methods have been widely used in the literature; see for example Dustmann et al. (2009) and Card et al. (2013).

## A.2 Hierarchy definitions

Using French administrative data, Caliendo et al. (2015) classifies workers into four layers based on PCS-ESE occupation classification: (1) production workers including clerks and blue-collar workers; (2) supervisory level workers; (3) managers including senior staff and top management positions; and (4) executives who are top-level workers (including firm owners).

Following Gumpert et al. (2022), we first transfer the French PCS-ESE occupation classification in Caliendo et al. (2015) to the German occupation classification KldB1998. Table A.1 provides the exact mapping between the occupation codes and the layers.

For later reference, firms that satisfy the consecutive hierarchy criterion are labeled as "RH" firms, while those failing the criterion are labeled as "Non-RH" firms.

We start by examining the differences across workers. Overall, workers employed in RH firms are comparable to their counterparts in Non-RH firms, both in terms demographics (age and gender) and ability measures (education and task complexity). However, workers in RH firms receive on average higher wages. Moving on to the comparison within RH firms, we find that when firms have more layers, workers are on average more educated, performing more complicated tasks and receiving higher wages.

With regard to firm characteristics, RH firms are slightly younger. Moreover, due to the concentration of production workers in single-layer firms, RH firms on average have lower share of workers with university degrees, and are also paying less. Overall, the decomposition of worker and firm characteristics shows that the classification is in line with Caliendo et al. (2015).

## A.3 Summary Statistics

Table A.2 shows the summary statistics of worker characteristics across hierarchy layers, restricting the sample to workers in establishments with more than 20 employees. We include 5 worker characteristics: age, tenure, share of female workers, average education level, task complexity, and log of real wage. Here, the variable tenure represents the total years of work experience. The education level is defined as a dummy that equals 3 if the worker has a degree above college (e.g., master's or doctoral), equals 2 if the worker has had vocational training, and equals 1 if the worker has a degree below or equal to high school. The task complexity represents whether the tasks for this job require high skills, and this variable takes a discrete value from 1 to 4, where 4 is the highest. Overall, workers of higher hierarchical layers, meaning workers that are middle to top managers, are older, have longer working experience, and are less likely to be women. They do not necessarily have higher average education levels because having a college degree was more rare one or two decades ago. In the end, their task complexity is higher, and so are their average wages.

Table A.5 shows the summary statistics of worker characteristics across firm hierarchies, restricting the sample to workers in establishments with more than 20 employees. [6] We include the same 5 worker characteristics as in Table A.2. The first observation is that 3-layer firms account for more than half of the total employment. Their employment share

[6] Table A.3 displays the same summary statistics for all firms. Notice that most of the firms with employment less than 20 are single-layer firms or have at most middle-managers. The comparisons between workers in different firms do not change.

reduces to around one-third if we include small single-layer and 2-layer firms as in Table A.3. Secondly, workers in multilayer firms are less likely to be women. They have higher average education levels, task complexity, and wages.

The comparisons of workers across firm hierarchies may only reflect the composition effect, that is, there are more older, experienced, and skilled workers in multilayer firms. Therefore, in Table A.7, we show the summary statistics of worker characteristics across firm hierarchies, restricting the sample to workers of the lowest layer in establishments with more than 20 employees. Firstly, lower-layer workers account for most of the total employment in all types of firms. Second, when restricting to low-layer workers, the differences in gender ratio and education levels disappear, suggesting that middle-managers and top managing departments tend to be more educated and less likely to have women in their ranks. Third, on average, workers in multilayer firms are older, have longer experience, higher task complexity, and higher wages.

Table A.6 shows the summary statistics of firm characteristics across firm hierarchies, restricting the sample to workers in establishments with more than 20 employees. [7] We include 5 firm characteristics: firm size, firm age, the average log of real wages, age, and share of high skills among workers. Here, the variable firm size represents the number of workers who work more than 3 months in the firms. Overall, multilayer firms are larger and older. Workers in these firms are older, earn higher wages, and are more likely to be college graduates.

Overall, unconditionally, compared to low-ranking workers, middle and top managers are older, more educated, and experienced. Their tasks are more complex, and they earn higher wages. Among all workers, those in multilayer firms are also older, more educated, and experienced. However, they do not differ from those in single-layer firms in gender ratio and education level. At the firm level, multilayer firms are larger and older.

[7] Table A.4 displays the same summary statistics for all firms. Notice again that most of the firms with employment less than 20 are single-layer firms or have at most middle-managers. The comparisons between workers in different firms do not change.

# Appendix tables and figures

Table A.1: Occupation and Hierarchy Mapping

| Layer | KldB1998 | Examples |
| --- | --- | --- |
| 3 | 751 | Entrepreneurs, managing directors and division managers (751) |
| 2 | 629, 721, 722, 724, 752, 753, 761, 762, 763 | Forepersons and other operations managers (629); Navigators, nautical ships officers and pilots (721); Management, personnel and other business consultants (752); Senior and administrative state officials (762) |
| 1 | 31, 32, 601, 602, 603, 604, 605, 606, 607, 611, 612, 621, 622, 623, 624, 625, 626, 627, 628, 633, 687, 811, 812, 813, 822, 841, 842, 843, 844, 851, 852, 853, 855, 862, 863, 871, 872, 873, 874, 875, 881, 882, 883, 891, 892, 893, 922 | Architects, civil and structural engineers (603); Physicists, physics engineers, mathematicians (612); Mechanicalengineering technicians (621); Judges and prosecutors (811); Lawyers, notaries, legal representatives, advisors and other legal professionals (813); Economists, psychologists, sociologists, political scientists, statisticians (881) |
| 0 | All others | Cement, stone and other building material producers (011); Pet groomers, animal care workers and related occupations (044); Judges, lawyers, legal professionals and executory officers (081); Tyre vulcanizers (144); Type setters, pre-press workers (171); Wire moulder, cable splicers (212); Motor vehicle repairers (281); Weavers and weaving-machine operators (342); Fish-processing-machine operators (403); Pattern and mold carpenters (502); Shop, stall and market salespersons and demonstrators (682); Finance, stock, trade, ship, real estate, insurance brokers (704); Film, stage and related directors, actors, singers and dancers (835); |

Table A.2: Worker Characteristics by Hierarchy(FIRM SIZE>=20)

| hierarchy | variable | N | mean | sd | p25 | p50 | p75 | p95 |
|---|---|---|---|---|---|---|---|---|
| 0 | age | 5,196,335 | 40.80 | 9.72 | 32 | 40 | 49 | 57 |
| | tenure | 5,196,335 | 6.47 | 5.98 | 1.98 | 4.54 | 9.35 | 19.01 |
| | gender | 5,196,335 | 0.31 | 0.46 | 0 | 0 | 1 | 1 |
| | education | 5,118,514 | 1.86 | 0.48 | 2 | 2 | 2 | 3 |
| | complexity | 5,052,962 | 2.07 | 0.49 | 2 | 2 | 2 | 3 |
| | (log) wage | 5,152,851 | 4.59 | 0.39 | 4.39 | 4.59 | 4.80 | 5.21 |
| 1 | age | 954,607 | 40.19 | 9.33 | 32 | 39 | 47 | 57 |
| | tenure | 954,607 | 6.16 | 5.87 | 1.75 | 4.00 | 9.01 | 18.68 |
| | gender | 954,607 | 0.26 | 0.44 | 0 | 0 | 1 | 1 |
| | education | 950,980 | 2.43 | 0.53 | 2 | 2 | 3 | 3 |
| | complexity | 954,607 | 3.31 | 0.73 | 3 | 3 | 4 | 4 |
| | (log) wage | 948,650 | 4.98 | 0.46 | 4.70 | 4.95 | 5.25 | 5.76 |
| 1' | age | 161,128 | 41.40 | 9.49 | 33 | 41 | 49 | 57 |
| | tenure | 161,128 | 6.67 | 6.19 | 2 | 4.58 | 9.76 | 19.90 |
| | gender | 161,128 | 0.18 | 0.39 | 0 | 0 | 0 | 1 |
| | education | 159,916 | 2.35 | 0.54 | 2 | 2 | 3 | 3 |
| | complexity | 161,128 | 3.39 | 0.58 | 3 | 3 | 4 | 4 |
| | (log) wage | 160,326 | 5.05 | 0.47 | 4.78 | 5.03 | 5.33 | 5.83 |
| 2 | age | 148,479 | 44.64 | 8.82 | 38 | 45 | 52 | 58 |
| | tenure | 148,479 | 6.59 | 6.11 | 2 | 4.51 | 9.65 | 19.35 |
| | gender | 148,479 | 0.16 | 0.37 | 0 | 0 | 0 | 1 |
| | education | 146,660 | 2.30 | 0.50 | 2 | 2 | 3 | 3 |
| | complexity | 148,479 | 3 | 0 | 3 | 3 | 3 | 3 |
| | (log) wage | 148,043 | 5.07 | 0.52 | 4.83 | 5.13 | 5.37 | 5.79 |

Table A.3: Worker Characteristics by Firm Organization (All Firms)

| MaxLayer | variable | N | mean | sd | p25 | p50 | p75 | p95 |
|---|---|---|---|---|---|---|---|---|
| RH firms | age | 8,490,805 | 40.98 | 9.79 | 33 | 41 | 49 | 57 |
| | gender | 8,490,805 | 0.32 | 0.46 | 0 | 0 | 1 | 1 |
| | education | 8,371,053 | 2.00 | 0.52 | 2 | 2 | 2 | 3 |
| | complexity | 8,308,909 | 2.29 | 0.74 | 2 | 2 | 2 | 4 |
| | (log) wage | 8,422,738 | 4.62 | 0.51 | 4.38 | 4.62 | 4.89 | 5.43 |
| Non-RH firms | age | 1,951,881 | 40.55 | 9.79 | 32 | 40 | 48 | 57 |
| | gender | 1,951,881 | 0.33 | 0.47 | 0 | 0 | 1 | 1 |
| | education | 1,922,843 | 2.00 | 0.50 | 2 | 2 | 2 | 3 |
| | complexity | 1,913,562 | 2.33 | 0.73 | 2 | 2 | 3 | 4 |
| | (log) wage | 1,935,778 | 4.58 | 0.47 | 4.32 | 4.57 | 4.84 | 5.35 |
| 0 | age | 2,442,532 | 39.84 | 9.89 | 31 | 39 | 48 | 57 |
| | gender | 2,442,532 | 0.38 | 0.49 | 0 | 0 | 1 | 1 |
| | education | 2,395,379 | 1.92 | 0.38 | 2 | 2 | 2 | 2 |
| | complexity | 2,398,458 | 2.00 | 0.38 | 2 | 2 | 2 | 2 |
| | (log) wage | 2,418,220 | 4.29 | 0.51 | 4.05 | 4.38 | 4.60 | 4.98 |
| 1 | age | 1,383,989 | 40.88 | 9.88 | 32 | 40 | 49 | 57 |
| | gender | 1,383,989 | 0.38 | 0.48 | 0 | 0 | 1 | 1 |
| | education | 1,368,642 | 2.04 | 0.50 | 2 | 2 | 2 | 3 |
| | complexity | 1,362,824 | 2.34 | 0.82 | 2 | 2 | 3 | 4 |
| | (log) wage | 1,370,628 | 4.56 | 0.43 | 4.36 | 4.58 | 4.78 | 5.23 |
| 1’ | age | 940,488 | 41.79 | 9.86 | 33 | 42 | 50 | 58 |
| | gender | 940,488 | 0.31 | 0.46 | 0 | 0 | 1 | 1 |
| | education | 933,774 | 2.00 | 0.54 | 2 | 2 | 2 | 3 |
| | complexity | 921,579 | 2.33 | 0.77 | 2 | 2 | 2 | 4 |
| | (log) wage | 933,604 | 4.67 | 0.38 | 4.46 | 4.64 | 4.85 | 5.33 |
| 2 | age | 3,723,796 | 41.57 | 9.59 | 33 | 41 | 49 | 57 |
| | gender | 3,723,796 | 0.25 | 0.43 | 0 | 0 | 1 | 1 |
| | education | 3,673,258 | 2.04 | 0.59 | 2 | 2 | 2 | 3 |
| | complexity | 3,626,048 | 2.44 | 0.81 | 2 | 2 | 3 | 4 |
| | (log) wage | 3,700,286 | 4.84 | 0.43 | 4.57 | 4.80 | 5.09 | 5.63 |

Table A.4: Firm Characteristics by Firm Organization (All Firms)

| MaxLayer | variable | N | mean | sd | p25 | p50 | p75 | p95 |
|---|---|---|---|---|---|---|---|---|
| RH firms | firm size | 719,744 | 11.80 | 108.46 | 1 | 2 | 5 | 30 |
| | firm age | 719,744 | 11.48 | 9.93 | 3 | 9 | 17 | 32 |
| | (log) wage | 718,169 | 4.18 | 0.52 | 3.91 | 4.28 | 4.53 | 4.87 |
| | worker age | 719,744 | 39.80 | 7.74 | 34 | 40 | 45 | 54 |
| | high skill share | 719,744 | 0.06 | 0.18 | 0.00 | 0.00 | 0.00 | 0.50 |
| Non-RH firms | firm size | 130,459 | 14.96 | 50.02 | 2 | 4 | 13 | 61 |
| | firm age | 130,459 | 11.28 | 10.16 | 3 | 8 | 17 | 33 |
| | (log) wage | 130,336 | 4.51 | 0.47 | 4.28 | 4.54 | 4.78 | 5.20 |
| | worker age | 130,459 | 40.53 | 6.95 | 36 | 40 | 45 | 50 |
| | high skill share | 130,459 | 0.20 | 0.33 | 0.00 | 0.00 | 0.27 | 1.00 |
| 0 | firm size | 606,265 | 4.03 | 8.41 | 1 | 2 | 4 | 13 |
| | firm age | 606,265 | 11.00 | 9.66 | 3 | 8 | 16 | 31 |
| | (log) wage | 604,705 | 4.12 | 0.52 | 3.84 | 4.21 | 4.47 | 4.79 |
| | worker age | 606,265 | 39.67 | 8.10 | 34 | 39 | 45 | 55 |
| | high skill share | 606,265 | 0.04 | 0.16 | 0.00 | 0.00 | 0.00 | 0.25 |
| 1 | firm size | 110,544 | 23.31 | 89.25 | 4 | 8 | 19 | 80 |
| | firm age | 110,544 | 13.82 | 10.75 | 5 | 11 | 21 | 36 |
| | (log) wage | 110,541 | 4.50 | 0.34 | 4.32 | 4.53 | 4.71 | 5.01 |
| | worker age | 110,544 | 40.28 | 5.46 | 37 | 40 | 44 | 49 |
| | high skill share | 110,544 | 0.19 | 0.24 | 0.00 | 0.08 | 0.33 | 0.67 |
| 2 | firm size | 41,498 | 115.33 | 420.87 | 15 | 36 | 89 | 391 |
| | firm age | 41,498 | 14.42 | 11.45 | 5 | 12 | 22 | 38 |
| | (log) wage | 41,498 | 4.71 | 0.30 | 4.52 | 4.70 | 4.89 | 5.23 |
| | worker age | 41,498 | 41.08 | 4.06 | 38 | 41 | 44 | 58 |
| | high skill share | 41,498 | 0.19 | 0.23 | 0.02 | 0.09 | 0.27 | 0.71 |

Table A.5: Worker Characteristics by Firm Organization (FirmSize>=20)

| MaxLayer | variable | N | mean | sd | p25 | p50 | p75 | p95 |
|---|---|---|---|---|---|---|---|---|
| 0 | age | 546,818 | 40.37 | 9.83 | 32 | 40 | 48 | 57 |
| | tenure | 546,818 | 5.23 | 5.40 | 1.17 | 3.11 | 7.36 | 16.95 |
| | gender | 546,818 | 0.30 | 0.46 | 0 | 0 | 1 | 1 |
| | education | 537,653 | 1.86 | 0.43 | 2 | 2 | 2 | 2 |
| | complexity | 531,955 | 1.97 | 0.33 | 2 | 2 | 2 | 2 |
| | (log) wage | 541,444 | 4.44 | 0.43 | 4.23 | 4.48 | 4.68 | 5.09 |
| 1 | age | 1,714,133 | 41.08 | 9.79 | 33 | 41 | 49 | 57 |
| | tenure | 1,714,133 | 6.30 | 5.90 | 1.89 | 4.28 | 9.00 | 18.86 |
| | gender | 1,714,133 | 0.33 | 0.47 | 0 | 0 | 1 | 1 |
| | education | 1,699,036 | 1.97 | 0.52 | 2 | 2 | 2 | 3 |
| | complexity | 1,684,311 | 2.26 | 0.75 | 2 | 2 | 2 | 4 |
| | (log) wage | 1,699,366 | 4.60 | 0.39 | 4.41 | 4.60 | 4.79 | 5.24 |
| 2 | age | 3,705,747 | 40.93 | 9.55 | 33 | 41 | 49 | 57 |
| | tenure | 3,705,747 | 6.89 | 6.14 | 2.00 | 5.00 | 10.00 | 19.52 |
| | gender | 3,705,747 | 0.27 | 0.44 | 0 | 0 | 1 | 1 |
| | education | 3,651,936 | 1.98 | 0.57 | 2 | 2 | 2 | 3 |
| | complexity | 3,600,985 | 2.44 | 0.81 | 2 | 2 | 3 | 4 |
| | (log) wage | 3,679,869 | 4.76 | 0.43 | 4.51 | 4.73 | 5.00 | 5.53 |

Table A.6: Firm Characteristics by Firm Organization (Firm Size>=20)

| MaxLayer | variable | N | mean | sd | p25 | p50 | p75 | p95 |
|---|---|---|---|---|---|---|---|---|
| 0 | firm size | 15,600 | 39.65 | 32.58 | 23 | 29 | 42 | 96 |
| | firm age | 15,600 | 14.03 | 10.64 | 5 | 12 | 21 | 34 |
| | (log) wage | 15,600 | 4.43 | 0.31 | 4.25 | 4.47 | 4.62 | 4.91 |
| | worker age | 15,600 | 40.56 | 3.93 | 38 | 41 | 43 | 47 |
| | high skill share | 15,600 | 0.03 | 0.08 | 0.00 | 0.00 | 0.04 | 0.14 |
| 1 | firm size | 26,487 | 75.33 | 172.10 | 26 | 38 | 69 | 216 |
| | firm age | 26,487 | 16.06 | 11.32 | 6 | 14 | 24 | 37 |
| | (log) wage | 26,487 | 4.59 | 0.27 | 4.45 | 4.60 | 4.74 | 5.01 |
| | worker age | 26,487 | 41.43 | 3.76 | 39 | 42 | 44 | 47 |
| | high skill share | 26,487 | 0.13 | 0.19 | 0.01 | 0.05 | 0.15 | 0.58 |
| 2 | firm size | 27,910 | 166.34 | 505.39 | 35 | 64 | 136 | 539 |
| | firm age | 27,910 | 15.83 | 11.67 | 6 | 14 | 24 | 39 |
| | (log) wage | 27,910 | 4.70 | 0.29 | 4.52 | 4.69 | 4.87 | 5.21 |
| | worker age | 27,910 | 41.24 | 3.52 | 39 | 41 | 44 | 47 |
| | high skill share | 27,910 | 0.17 | 0.21 | 0.03 | 0.08 | 0.22 | 0.65 |

Table A.7: Production Worker Characteristics by Firm Organizations(FIRM SIZE>=20)

| MaxLayer | variable | N | mean | sd | p25 | p50 | p75 | p95 |
|---|---|---|---|---|---|---|---|---|
| 0 | age | 538,549 | 40.34 | 9.78 | 32 | 40 | 48 | 57 |
| | tenure | 538,549 | 5.23 | 5.40 | 1.16 | 3.12 | 7.34 | 16.95 |
| | gender | 538,549 | 0.30 | 0.46 | 0 | 0 | 1 | 1 |
| | education | 529,556 | 1.86 | 0.42 | 2 | 2 | 2 | 2 |
| | complexity | 523,874 | 1.99 | 0.31 | 2 | 2 | 2 | 2 |
| | (log) wage | 533,242 | 4.44 | 0.43 | 4.23 | 4.48 | 4.68 | 5.10 |
| 1 | age | 1,361,737 | 41.31 | 9.82 | 33 | 41 | 49 | 57 |
| | tenure | 1,361,737 | 6.42 | 5.92 | 2 | 4.59 | 9.01 | 19.01 |
| | gender | 1,361,737 | 0.32 | 0.47 | 0 | 0 | 1 | 1 |
| | education | 1,348,300 | 1.87 | 0.46 | 2 | 2 | 2 | 3 |
| | complexity | 1,332,782 | 2.04 | 0.49 | 2 | 2 | 2 | 3 |
| | (log) wage | 1,349,784 | 4.55 | 0.35 | 4.39 | 4.56 | 4.73 | 5.06 |
| 2 | age | 2,876,802 | 40.85 | 9.63 | 33 | 40 | 49 | 57 |
| | tenure | 2,876,802 | 6.97 | 6.17 | 2.00 | 5.00 | 10.01 | 19.61 |
| | gender | 2,876,802 | 0.29 | 0.45 | 0 | 0 | 1 | 1 |
| | education | 2,827,298 | 1.85 | 0.51 | 2 | 2 | 2 | 3 |
| | complexity | 2,787,942 | 2.10 | 0.52 | 2 | 2 | 2 | 4 |
| | (log) wage | 2,854,831 | 4.67 | 0.38 | 4.46 | 4.66 | 4.87 | 5.30 |

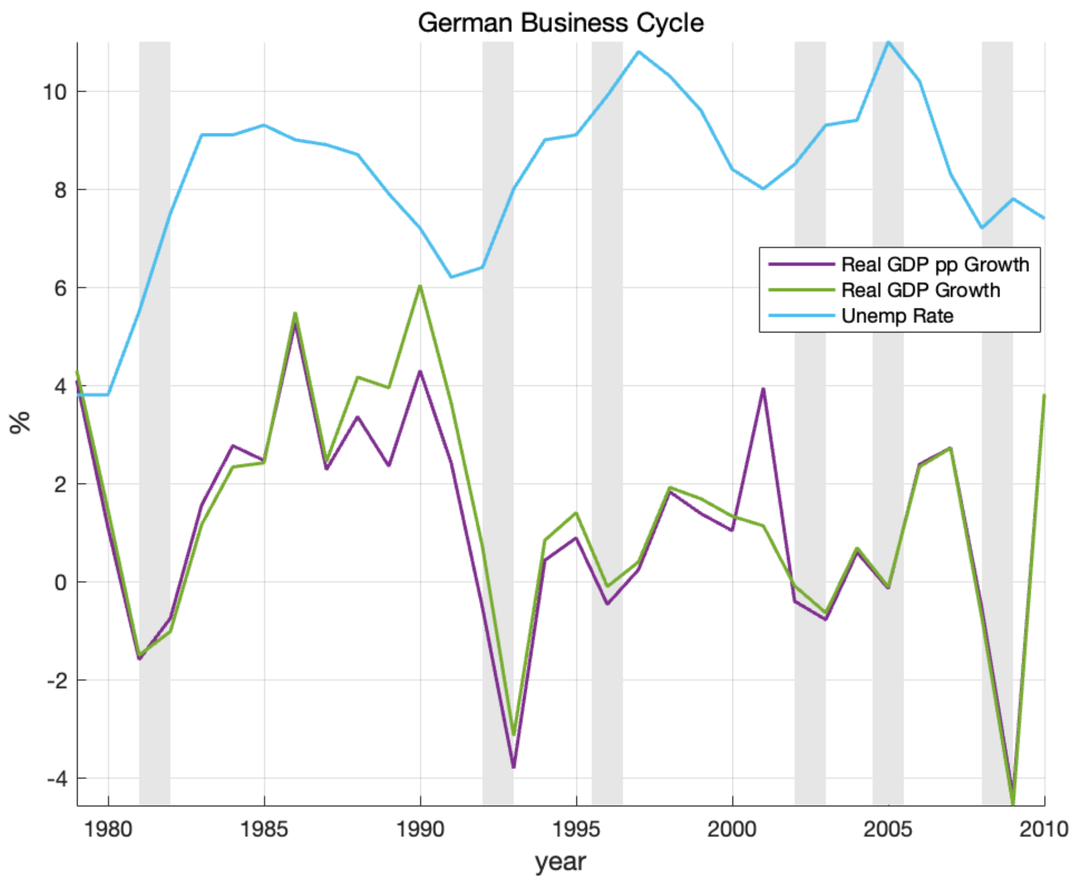
## A.4 Additional results on worker hierarchy

Table A.8: Employment Cyclicality and span of control (FirmSize>=10)

| | emp | | days | |
|---|---|---|---|---|
| UR | -0.1136*** | -0.0611 | -1.0671*** | -1.2768*** |
| | (0.0153) | (0.0426) | (0.0699) | (0.1974) |
| UR*Span | -0.0004 | -0.0002 | -0.0007 | -0.0006 |
| | (0.0003) | (0.0003) | (0.0021) | (0.0023) |
| UR*FirmAge | | 0.0023+ | | 0.0214*** |
| | | (0.0013) | | (0.0055) |
| UR*FirmSize | | -0.0214* | | -0.0223 |
| | | (0.0092) | | (0.0496) |
| UR*UniShare | | -0.1119+ | | -0.4519 |
| | | (0.0659) | | (0.3178) |
| # obs | 193,897 | 193,897 | 192,452 | 192,452 |
| Firm FE | ✓ | ✓ | ✓ | ✓ |
| industry FE | ✓ | ✓ | ✓ | ✓ |
| state FE | ✓ | ✓ | ✓ | ✓ |

$+\ p < 0.1,\ *\ p < 0.05,\ **\ p < 0.01,\ ***\ p < 0.001.$

Note: This table reports the results of regressing net employment growth rates and employment days growth rates on the business cycle indicator and its interactions with the span of control of each hierarchy. UR stands for the unemployment rate, Span, FirmSize and UniShare are all one-year lagged values. We omit the coefficients for control variables, including span of control, firm age, firm size, the share of workers with university degree, and linear and quadratic time trends. All controls are in lagged values except for the firm age. Standard errors clustered at the firm level are reported in parentheses.


German Business Cycle
10
8
6
4
2
0
-2
-4
%
1980
1985
1990
1995
2000
2005
2010
year
Real GDP pp Growth
Real GDP Growth
Unemp Rate