Wage Dispersion over the Business Cycle

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Abstract

In this paper, I establish a positive correlation between wage dispersion and GDP at business cycle frequencies. Moreover, I provide a rationale for the procyclical properties of wage dispersion by studying a dynamic search model with wage-posting in which workers can get multiple job offers each period. I analyze the channels through which the business cycle influences the shape of the wage distribution. The presence of search frictions gives firms monopsony power, i.e., power to impose wage levels on workers, and generates differences in wage policy across firms. The speed at which workers can move to other jobs affects the degree of firms competition over workers and impacts the extent to which firms exploit their monopsony power. Therefore, in booms, the value of workers' outside option goes up as the quantity and the quality of job offers increase, and this, in turn, erodes the firms' monopsony power in wage setting. In consequence, firms post more high-paying vacancies. This strategic reaction of firms thickens the upper tail of the wage distribution, shifts the mass of the wages to the right and, as a result, generates a larger wage dispersion.

Keywords: Monopsony; Wage differentials; Cycles
JEL classification: J42; J31; E32

1 Introduction

This paper empirically documents and theoretically grounds the cyclical behavior of wage dispersion. The interest in this issue is motivated by the fact that, while a consensus seems to exist about the countercyclicality of income inequality,[1] [2] the empirical analysis undertaken in the present paper suggests that wage dispersion behaves procyclically over the period 1967-2005. Such procyclical properties of wage dispersion have normative implications. Many labor market institutions (minimum wage, unemployment benefits, public education) and fiscal policies (progressive taxation) are designed to reduce economic inequality. Moreover, wage dispersion is identified as the most important driver of income inequality,[3] and, in turn, transmits into consumption inequality. The prominent role played by wage dispersion in driving economic inequality, and the linkage between wage dispersion and the design of optimal redistributive measures suggest the importance of enhancing the understanding of wage dispersion, not only by analyzing its level but also by examining its dynamics and cyclical properties.

Using US CPS - March data, I show that wage dispersion, measured by the variance of log wages and percentile ratios, is positively correlated with GDP and negatively correlated with the unemployment rate. This observation indicates the procyclicality of wage dispersion. I isolate the residual component of the overall wage dispersion by controlling for demographic characteristics of workers in order to obtain the residual wage dispersion, i.e., the wage dispersion observed among workers sharing similar observable characteristics. By comparing the cyclical components of wage dispersion and of residual wage dispersion, I find that the cyclical fluctuations in wage dispersion are almost entirely driven by the fluctuations in residual wage dispersion. Therefore, I argue that residual wage dispersion not only accounts for most of the level and trend of overall wage dispersion,[4] but also for its cyclical properties.

Empirical evidence suggests that the degree of wage dispersion prevailing among similar workers increases during booms and lessens during recessions. This fact, in

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[1]The definition of income generally includes items such as social security benefits, unemployment compensation, public assistance, retirement benefits, and dividends, in addition to wages.

[2]See Storesletten, Telmer, and Yaron (2004), Castaneda, Diaz-Gimenez, and Rios-Rull (1998), Bonhomme and Hospido (2012) and Guvenen, Ozkan, and Song (2012)

[3]The recent OECD (2011) report on the rise in inequality observed for the past fifty years identifies greater inequality in wages and salaries as the main factor that caused an intensification of economic inequality within OECD countries.

[4]See Krueger and Summers (1988) and Mortensen (2005) for an estimation of the magnitude of residual wage dispersion. See Eckstein and Éva Nagypál (2004) and Katz and Autor (1999) for an assessment of the importance of residual wage dispersion in driving the long run growth of wage inequality. More details in Section 3.

turn, motivates the development of a dynamic model of the labor market enabling analysis of channels through which the business cycle affects residual wage dispersion. The present paper develops a tractable dynamic stochastic general equilibrium model of the labor market. This model draws together monopsonistic firms which unilaterally set wages and compete for workers, and homogeneous workers who derive some market power from this inter-firm competition. Search frictions prevailing in the labor market render the matching process between workers and firms costly and time-consuming. Thus, by limiting the number of job offers that workers receive, search frictions give firms some monopsony power, i.e., the ability to impose wage levels on workers. Firms exploit their monopsony power when setting wages below the frictionless (competitive) wage level. Given that the extent to which firms exercise their monopsony power affects their hiring and turnover rates, firms face a trade-off between the profit that they realize for each worker and the relative ease with which they hire and retain their workers.[5] Consistently with the existing literature, this trade-off leads to differential wage-setting strategies across firms, and thus to residual wage dispersion.[6] Moreover, because I allow for match specific investment by firms in line with Mortensen (1998), the equilibrium residual wage distribution is unimodal and positively skewed, as empirically observed.

I establish that business cycle fluctuations translate into procyclical fluctuations in residual wage dispersion through the following two-step mechanism. First, the business cycle affects the firms' monopsony power by altering the value of workers' outside option. In booms, the jump in vacancies brings workers to receive more and better job offers. Consequently, the competition across firms over workers becomes tougher. Firms face a drop in the probability of acceptance of their job offers, and their market power therefore erodes. Second, firms strategically react to this change in labor market conditions by modifying their vacancy posting decisions. During a boom, the vacancy filling duration increases for all vacancy types, but increases relatively more for low-paying vacancies, lowering the incentive of firms to propose these vacancies. Therefore, the composition of vacancies changes as the proportion of highly paying vacancies rises. This change translates into a rightward shift of the mass and a thickening of the upper tail of the residual wage distribution. As a result, the change in the shape of the residual wage distribution generates a widening of the residual wage structure and a rise in residual wage dispersion. The opposite mechanism operates during recessions. The model therefore predicts that residual wage dispersion acts procyclically, and hence, can account for the empirical

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[5]Using Danish data, Christensen, Lentz, Mortensen, Neumann, and Werwatz (2005) empirically show that the search effort of employed workers declines with the wage they earn.

[6]For a literature review on earlier analyses of the residual wage dispersion, see Appendix A.

evidence of positive co-movement between (residual) wage dispersion and GDP at business cycle frequencies.

The endogenous nature of the inter-firm competition, stemming from the endogenous number of offers that workers receive each period, is a crucial feature of the model, since such competition plays a main role in shaping wage distribution. Inter-firm competition is an essential determinant of the rent-sharing process between firms and workers.[7] So, incorporating it into a search and matching framework allows a better understanding of what drives firms to exploit their monopsony power and why the intensity with which they exploit it evolves with the business cycle. Moreover, assessing the sensitivity of the firms' monopsony power to the business cycle is an indispensable step in investigating the channels through which the business cycle affects residual wage dispersion. For this reason, I endogenize the average number of job offers, and in so doing, I endogenize the out-of-unemployment and the job-to-job flows. I solve for the dynamics of the model by making use of the free entry equilibrium condition which states that the value of posting a vacancy must be equal to zero in equilibrium for any wage level in the range of offered wages. These flows have previously been endogenized by Menzio and Shi (2010a, 2010b) in models with directed search. This assumption of directed search is indeed necessary to obtain dynamic predictions of models in which the free entry condition does not hold, but considerably narrows the range of interactive strategies between firms and workers.

This paper is, to my knowledge, the first study that documents the procyclicality of wage dispersion and develops a dynamic stochastic general equilibrium model of the labor market to examine the channels through which the business cycle shapes the residual wage distribution, and thus, alters residual wage dispersion. I seek to contribute to two strands of the literature. First, my paper adds on to the growing literature on dynamic search and matching with wage dispersion. Following Burdett and Mortensen (1998), several authors have proposed deterministic models of wage dispersion,[8] and only a few of them extended the analysis to stochastic

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[7]See Cahuc, Postel-Vinay, and Robin (2006) for a study of the determinants of the wage-setting process. Using a panel of French administrative data, they find that inter-firm competition is an essential determinant of the workers' market power and results in a large rise in wages above the reservation level.

[8]See for example Mortensen (1990), Green, Machin, and Manning (1996), Mortensen (1998) and Acemoglu (2001). An important contribution is the paper by Postel-Vinay and Robin (2002), which distinguishes three sources of wage dispersion: productive heterogeneity of workers, productive heterogeneity of firms and search frictions. The importance of search frictions, and hence of the threat of inter-firm competition, in pushing wages up is also taken into consideration by Carrillo-Tudela and Smith (2009). In both papers, the resulting wage dispersion is in keeping with empirical regularities.

models.[9] Based on a dynamic stochastic model with heterogeneous agents and wage bargaining, Robin (2011) studies the cyclical behavior of the labor market. He highlights the differential volatility and productivity elasticity of each decile of the wage distribution and shows that low and high wages are more elastic and volatile than intermediate wages, without providing an investigation of the cyclical properties of wage dispersion.

Second, I contribute to the literature on wage and income dispersion.[10] Existing studies mainly point towards income inequality behaving countercyclically. Using CPS data, Castaneda, Diaz-Gimenez, and Rios-Rull (1998) find that the lowest quintile of the income distribution in the US is both the most volatile and the most procyclical. The procyclicality of the income shares then decreases monotonically and increases for the top 5 percent. This results suggest that income dispersion lessens in booms.[11] The literature seems much more silent on the issue of the cyclical properties of wage dispersion. Yet, wage dispersion is, together with the unemployment rate, transfers and hours worked, a main source of income inequality. An exception is the paper by Bonhomme and Hospido (2012) which documents the evolution of labor earnings inequality in Spain from 1988 to 2010 and find that male earnings inequality was strongly countercyclical during that period. Our methodologies differ manifold. First, the authors do not isolate the cyclical component of wage inequality and provide both long-run and short-run explanations to the evolution of wage inequality over time. Second, due to data limitations, the authors use daily earnings as their main earnings measure instead of hourly wages. This choice which might enhance the procyclicality of wages and, depending on the workers category most hit by fluctuations in hours worked, might intensify the countercyclicality of wage dispersion.

The present paper also complements the literature on wage and income risk, generally defined as the variance of individual labor income changes. Using PSID data, Storesletten, Telmer, and Yaron (2004) obtain that the idiosyncratic labor-market risk, as measured by the variance of the random component of a household's income, is countercyclical. Using the same dataset and a multilevel Bayesian model, MacKay and Papp (2012) find similar results. To complement their empirical anal-

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[9]Moscarini and Postel-Vinay (2010) perform the first analysis of aggregate stochastic dynamics in the class of search wage-posting models originating with Burdett and Mortensen (1998).

[10]I refer to wage dispersion as the wage dispersion that exists among employed workers and to income dispersion or income inequality as the dispersion of income (transfers included) that exists among all types of workers (unemployed and employed). Income dispersion therefore contains wage dispersion.

[11]The authors define income as all monetary income earned before personal taxes. It includes items such as social security benefits, unemployment compensation, public assistance, retirement benefits, and dividends, but it excludes non-cash benefits, such as health benefits.

ysis, the authors also propose a partial equilibrium analysis of a steady-state model with on-the-job search in which the job offer and separation rates as well as the distribution of offered wages are taken as given. The countercyclical behavior of wage risk is mostly driven by the procyclical fluctuations in the reservation wage. Guvenen, Ozkan, and Song (2012), who make use of a confidential database containing uncapped earnings data, distance themselves from the literature with their finding that income shocks are acyclical. Nonetheless, they observe that the left-skewness of shocks is strongly countercyclical.

The paper proceeds as follows. Section 2 provides empirical evidence on the procyclicality of wage dispersion and residual wage dispersion. Section 3 presents the model embedding wage posting into a search and matching model in which job searchers can get multiple job offers each period. I show how residual wage dispersion arises in such a framework and explain the source of the firms' monopsony power. Section 4 describes the equilibrium and Section 5 displays the calibration strategy. Section 6 explains how I solve for the dynamics of the model out of the steady state and presents a dynamic analysis of the labor market, with an emphasis on the cyclical properties of firms' monopsony power and of the residual wage dispersion. Section 7 concludes.

2 Empirical evidence of the procyclicality of wage dispersion

I start by presenting several stylized facts on the evolution of (residual) wage dispersion. I complete the empirical analysis by examining the cyclical behavior of (residual) wage dispersion over the period 1967-2005.

2.1 Wage dispersion and residual wage dispersion

I make use of the CPS - March database constructed by Heathcote, Perri, and Violante (2010) for their empirical analysis of the rise in inequality from 1967 to 2005. I construct an hourly wages series by dividing annual earnings by the total number of hours worked. By construction, hourly wages are therefore over-sensitive to the number of hours worked. Hence, I restrict the sample to full-time workers (total hours per year > 1750) in order to minimize the effect of changes in hours

worked on the evolution of and fluctuations in the measure of hourly wages.[12] [13] Moreover, I restrict the sample to male household-head workers.

Figure 1 displays the evolution of wage dispersion over the period 1967-2005. Wage dispersion is measured by the variance of log hourly real wages of full-time male workers. My main observations are twofold. First, the US wage distribution widened substantially over the period analyzed. A large literature has emerged documenting this trend, and proposing theoretical grounds for comprehending it. [14] Its sources have been clarified by splitting overall inequality into between-group and within-group wage differentials. Changes in the relative wages of different groups of workers, distinguished by observable characteristics such as gender, education, experience, or race, have played some role in shaping the increasing trend of wage dispersion.[15] [16] However, most of the overall wage dispersion cannot be accounted for by workers' characteristics differentials.[17] More importantly, most of the long run growth in wage dispersion cannot be accounted for by changes in these observable characteristic differentials.[18] This means that residual wage dispersion, i.e. dispersion of wages within narrowly defined demographic and skill groups of workers, has driven most of the level and trend of overall wage inequality. This result is confirmed by Figure 1, which displays both the evolution of wage dispersion and residual wage dispersion over time.

Second, wage dispersion features sizable deviations from its trend. This observation is brought out in Figure 2, which plots the cyclical component of wage dispersion obtained by HP-filtering the series. I estimate a Mincerian wage regression controlling for demographic variables: gender, race, age, education, marital status and composition of the household. Because of the increasing trend in wages,

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[12]This restriction also allows me to minimize the noisiness of the estimate of total hours worked documented by Autor, Katz, and Kearney (2005) and Lemieux (2006)

[13]The results displayed in the next paragraph are not sensitive to this assumption. The cross correlations results are qualitatively and quantitatively very similar.

[14]See, for example, Heathcote, Perri, and Violante (2010), Autor, Katz, and Kearney (2008), Card and DiNardo (2002), Lemieux (2006) and Katz and Murphy (1992).

[15]The increasing college/high school wage premium that has mainly been observed since the 1970s has been proposed as a source of the widening of wage dispersion. See Bound and Johnson (1992) and Katz and Murphy (1992).

[16]See Katz and Autor (1999) and Eckstein and Éva Nagypál (2004) for an analysis of changes in wage differentials between groups.

[17]Krueger and Summers (1988) examine the magnitude of wage differentials for equally skilled workers and find that there are important variations in wages which cannot be explained by human capital differences. See also Mortensen (2005) for an estimation of the relative importance of workers' characteristics and firms' characteristics in explaining wage dispersion; hence an estimation of the magnitude of residual wage dispersion.

[18]See, for example, Eckstein and Éva Nagypál (2004). They control for occupational categories in addition to education, experience, gender, region and race.

I run this regression for each year.[19] By plotting the cyclical component of residual wage dispersion as obtained by the Mincerian regression, I can compare the short-run fluctuations of these two series. Importantly, the fluctuations in wage dispersion seem to be almost entirely driven by the fluctuations in residual wage dispersion. This result indicates that residual wage dispersion not only accounts for most of the level and trend of the overall wage dispersion, but also for its cyclical properties. Therefore it is necessary to understand the source of the short-run fluctuations in residual wage dispersion in order to assess the cyclical properties of wage dispersion.

Figure 1: Wage dispersion, residual wage dispersion and trends over time
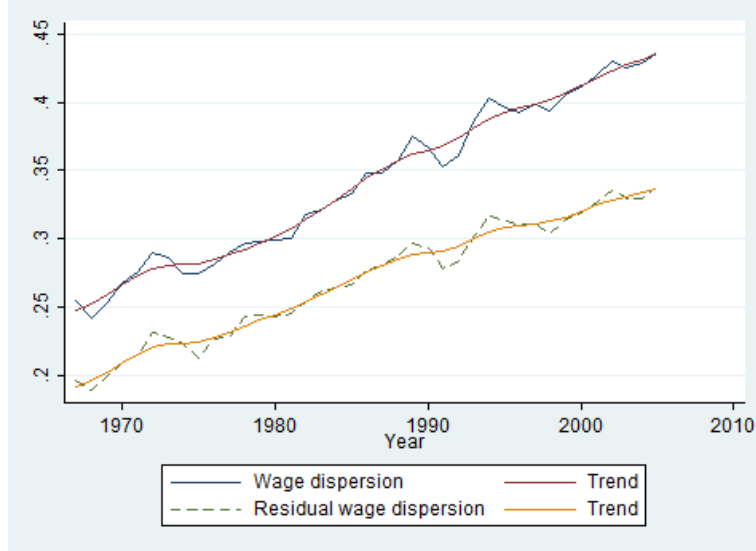
Note: The trends of wage dispersion and residual wage dispersion are obtained by detrending both time series using an HP-filter of parameter 6.25.

2.2 Cyclical properties of wage dispersion and residual wage dispersion

I focus on four inequality concepts: the variance of log wages, the ratio between the 90th and the 10th percentile, the ratio between the 90th and the 50th percentile and the ratio between the 50th and the 10th percentile. The decomposition of the 90/10 P-ratio into the 90/50 and 50/10 P-ratios allows for a sharper picture of inequality in different parts of the distribution and permits an assessment of the relative importance of changes in the lower and upper halves of the wage distribution to changes in the overall wage inequality.

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[19]As a robustness check, I perform the same exercise without this time trend in the regression. Results are displayed in Table 4 (in Appendix). The results hold.

The analysis of the cyclical properties of these inequality measures requires the series to be stationary. I perform Dickey-Fuller stationarity tests[20] on each of the four inequality series, both for wage inequality and residual wage inequality. All these series are non-stationary, a result which is consistent with the observed increasing trend in wage inequality. I apply an HP-filter of parameter 6.25 on the inequality series in order to study the co-movements at business cycle frequencies between inequality and two HP-filtered macroeconomic times series, real GDP and the unemployment rate,[21][22] which are two indicators of the business cycle. The cross-correlations between these HP-filtered inequality measures and the business cycle indicators are presented in Tables 1 and 2. All the inequality measures are positively correlated with real GDP and negatively correlated with the unemployment rate, indicating that both wage dispersion and residual wage dispersion behaved procyclically over the period 1967-2005. Moreover, wage inequality movements are synchronized with GDP and are synchronized with or tend to lead the unemployment rate. This leading property can be explained by the slight lag with which the unemployment rate itself responds to GDP. The correlations between the business cycle and the skewnesses of the density functions of the wage distribution and the residual wage distribution are negative. This result points towards a rightward shift of the mass of the wage distributions during periods of growth. However, the correlation is not significantly different from zero.

As a robustness check, I apply other detrending procedures, namely, an HP-filter with parameter 100, first differencing and a Baxter and King band pass filter. Table 5 (in the Appendix) displays the cross-correlations between the four inequality measures and GDP. The results are qualitatively and quantitatively very similar.

In order to highlight the positive correlation between residual wage dispersion and real GDP, I plot the evolution of the cyclical components of these two series over the period 1967-2005 (Figure 3). Except for the 1980-1982 recession, residual wage dispersion and real GDP positively co-move, an observation which confirms the results displayed in Table 1. Moreover, Figure 3 shows the symmetry in the magnitude of the residual wage dispersion's fluctuations in periods of growth compared to periods of recession. Finally, one can note the slight asymmetry in the correlation between the two series, the strength of the co-movement being higher in periods of growth compared to periods of recessions.

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[20]Given the sensitivity of the Dickey-Fuller test, I perform the test with different options: default specification, no constant and trend.

[21]Source: BLS, Major Sector Productivity and Costs, Real gross domestic product in the non-farm business sector.

[22]Source: BLS, Labor Force Statistics from the Current Population Survey, Unemployment rate, Civilian non-institutional population 16 years old and over.

Figure 2: Wage dispersion and residual wage dispersion – Cyclical components
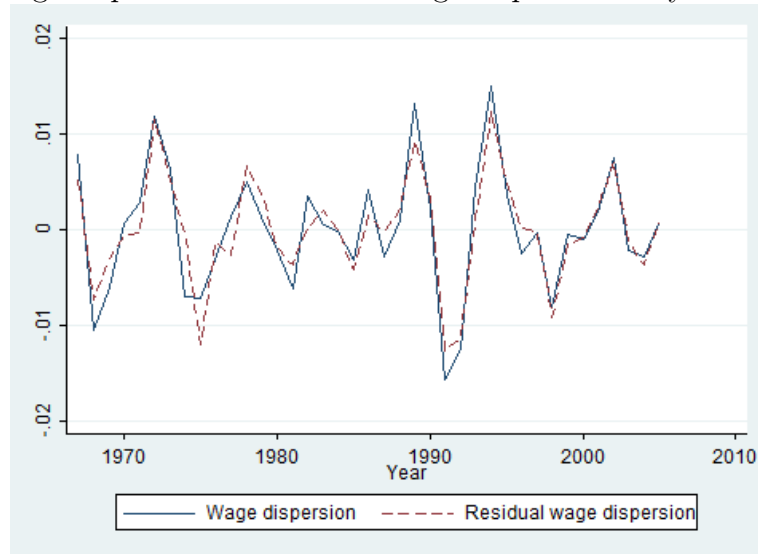
Note: The cyclical components of wage dispersion and residual wage dispersion are obtained by detrending both time series using an HP-filter of parameter 6.25.

Figure 3: Residual wage dispersion and Real GDP – Cyclical components
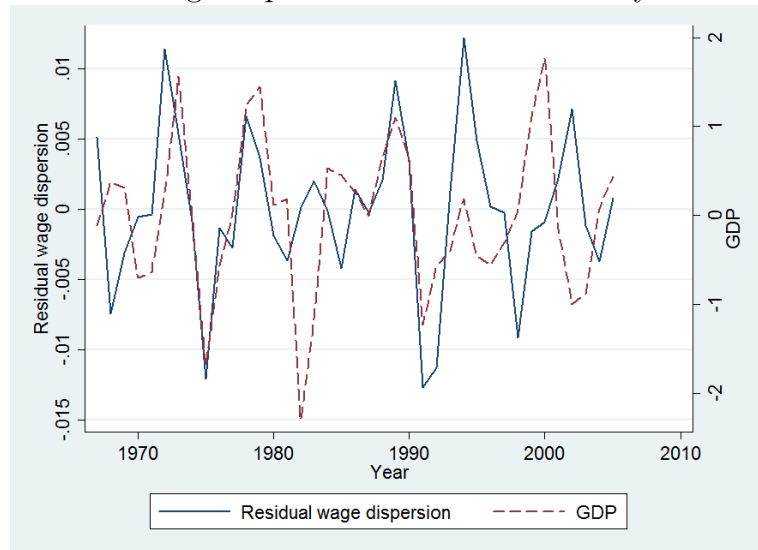
Note: The cyclical components of residual wage dispersion and GDP are obtained by detrending both time series using an HP-filter of parameter 6.25.

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Table 1: Cross-correlations

Correlation with GDP

	Mean	Log wages				Wages in level			
		$t-1$	t	$t+1$	$t+2$	$t-1$	t	$t+1$	$t+2$
Wage inequality									
varlogs	0.3414	0.2260	0.2389	−0.0006	−0.2544	—	—	—	—
90/10 P-ratio	1.4257	0.0022	0.3688**	0.0644	−0.3240	−0.0246	0.3566**	0.0792	−0.2874
90/50 P-ratio	0.6676	−0.0419	0.2248	−0.0414	−0.3506	−0.0475	0.2306	−0.0242	−0.3283
50/10 P-ratio	0.7581	0.0586	0.2885*	0.1567	−0.0555	0.0530	0.2796*	0.1516	−0.0473
Skewness	2.8922	—	—	—	—	0.0224	−0.0143	−0.1416	0.1418
Residual **wage inequality**									
varlogs	0.2699	0.1445	0.3122*	0.0646	−0.2000	—	—	—	—
90/10 P-ratio	1.2368	0.2056	0.4092**	0.1756	−0.3163	0.1724	0.3951**	0.1861	−0.2931
90/50 P-ratio	0.5631	0.1113	0.3336**	0.3082*	−0.2304	0.0937	0.3281**	0.3142	0.3142*
50/10 P-ratio	0.6737	0.2304	0.3329**	−0.0437	−0.2880	0.2255	0.3333**	−0.0413	−0.2856
Skewness	2.9040	—	—	—	—	−0.0268	−0.0844	0.0754	0.1844

Note: *: significant at the 10% level, **: significant at the 5% level. The time series of the four inequality measures as well as log GDP are detrended using an HP-filter of parameter 6.25. Wage inequality: *varlogs* refers to the variance of log wages of male household-head full-time workers. *i/jP − ratio* is the difference between the ith percentile and the jth percentile of log wages. Residual wage inequality: *varlogs* refers to the variance of the residual log wages of male household-head full-time workers. *i/jP − ratio* is the difference between the ith percentile and the jth percentile of the residual log wages.

Table 2: Cross-correlations

Correlation with the unemployment rate

	Mean	Log wages				Wages in level			
		$t-1$	t	$t+1$	$t+2$	$t-1$	t	$t+1$	$t+2$
Wage inequality									
varlogs	0.3414	−0.3684**	−0.2871*	0.1187	0.2775	—	—	—	—
90/10 P-ratio	1.4257	−0.1863	−0.1422	0.1264	0.2991	−0.3399**	−0.3627**	0.1600	0.3843*
90/50 P-ratio	0.6676	−0.0317	−0.3362**	0.1718	0.4079*	−0.2437	−0.3164**	0.2378	0.3042
50/10 P-ratio	0.7581	−0.2535	−0.1922	0.2527	0.3119	−0.0339	−0.1911	−0.0575	0.2278
Skewness	2.8922	—	−0.2798*	−0.0612	0.2373	−0.1639	0.0484	0.1512	−0.1010
Residual wage inequality									
varlogs	0.2699	−0.3709**	−0.3293**	0.1187	0.2775	—	—	—	—
90/10 P-ratio	1.2368	−0.3655**	−0.3778**	0.0914	0.0914	−0.1723	−0.3627**	0.0847	0.4189*
90/50 P-ratio	0.5631	−0.2610	−0.2836*	−0.0202	0.1817	−0.2480	−0.3204**	−0.0252	0.3463*
50/10 P-ratio	0.6737	−0.3393**	−0.2851*	0.1817	0.3467*	−0.2711*	−0.2851*	0.1819	0.3499*
Skewness	2.9040	—	−0.2798*	−0.0612	0.2373	0.0194	0.0545	−0.1428	−0.1865

Note: *: significant at the 10% level, **: significant at the 5% level. The time series of the four inequality measures as well as log GDP are detrended using an HP-filter of parameter 6.25. Wage inequality: *varlogs* refers to the variance of log wages of male household-head full-time workers. $i/jP - ratio$ is the difference between the ith percentile and the jth percentile of log wages. Residual wage inequality: *varlogs* refers to the variance of the residual log wages of male household-head full-time workers. $i/jP - ratio$ is the difference between the ith percentile and the jth percentile of the residual log wages.

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The institutional factors,[23] the non-market factors[24] and the market factors linked to changes in production technology,[25] which have been proposed as possible drivers of the widening of the cross-sectional wage distribution over time, are either long-run evolutions or episodic events. For this reason, these arguments cannot be used to explain the cyclical properties of wage dispersion. In the following section, I develop a theoretical framework which allows me to examine the sources of fluctuations in wage dispersion, and I show how changes in aggregate productivity can drive these fluctuations.

3   The model

The previous section presented empirical evidence for the procyclical behavior of wage dispersion and residual wage dispersion. The rest of the paper develops a dynamic model of the labor market with on-the-job search which accounts for these cyclical properties. This theoretical framework allows me to detail and explain the channel through which the business cycle impacts equilibrium wage distribution.

3.1   General set-up

3.1.1   Overview

The theoretical setting builds on Burdett and Mortensen (1998)'s model. I maintain the assumption of an imperfect labor market due to search frictions and the assumption of on-the-job search which enables workers to switch to better jobs. Unlike Burdett and Mortensen (1998), time is discrete and job seekers can receive multiple job offers during each period. This assumption has valuable advantages. First, it allows me to distinguish between the meeting process and the matching one. Firms make take-it-or-leave-it wage offers to workers and matches are formed only when these offers are accepted by the workers. This allows analysis of the extent to which the workers' job-acceptance decisions constrain firms' wage setting decisions, in a setting which disregards any type of explicit bargaining. Second,

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[23]Card and DiNardo (2002) stress the importance of non-market factors, specifically the falling real minimum wage, in explaining the rise in inequality during the 1980s.

[24]Lemieux (2006) argues that most of the growth in residual wage dispersion is mechanically accounted for by changes in the workforce composition, that is by the increasing employment share of specific groups of workers (typically college graduates) which is characterized by more dispersed wages.

[25]Autor, Katz, and Kearney (2008) challenge these claims and propose a multi-causal interpretation where market-driven shifts in demand for skills, imputable to skill-biased technical changes, played a central role in modelling the long run pattern displayed by wage inequality over the last four decades.

I am proposing a richer framework in which firms' wage-setting decisions are not only constrained by the strategic behavior of employed workers, who can choose to keep or to quit their current job, but also by the strategic behavior of unemployed workers: each unemployed worker getting more than one job offer will opt for the best wage contract and the remaining vacancies will be left idle.

Firms post take-it-or-leave-it wage offers. Once a wage contract is accepted by a worker, the wage remains constant during the whole employment relationship duration. Firms are committed to the wage contract that they propose, in the sense that they cannot renegotiate it in periods in which aggregate productivity is so low that the firm's surplus lies below the vacancy cost. Similarly, workers cannot quit in periods in which the current reservation wage exceeds the wage which has been accepted at the beginning of the employment spell. This assumption allows me to rule out discontinuity issues when analyzing the Bellman equation of the firms' surplus.

Time is discrete. Each period is characterized by the following sequence of events: exogenous separation, meeting process, matching process and production. At the beginning of the period, a proportion λ of the existing matches exogenously splits up. Subsequently, the meeting process takes place. Due to search frictions, each searching worker only meets a limited number of vacant firms each period. Firms make take-it-or-leave-it offers to job candidates. In the case of acceptance, matches are created. At the end of the period, production takes places and salaries and unemployment benefits are paid.

The level of aggregate productivity z follows an $AR(1)$ process and is revealed at the beginning of each period. The state of the economy at the beginning of time t is therefore summarized by the triple $(z_t, u_t, G_{t-1}(w))$, where u_t denotes the beginning-of-period unemployment rate and $G_{t-1}(w))$ denotes the share of employed workers earning less than the wage w at the end of period $t-1$.

3.2 Workers

Meeting process. A continuum of identical workers of measure 1 participates in the labor market. In each period, unemployed and employed workers look for a job. Due to the search frictions which characterize the labor market, job seekers make contact with a limited number of firms. For the sake of simplicity, I assume that frictions are such that each vacant firm only contacts one candidate per period.[26] I

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[26]It could easily be extended to more complex cases. An intuitive pattern would be that firms are able to contact a higher number of job applicants during economic slowdowns. Such a countercyclical average number of candidates would strengthen the results.

denote by s_t the average number of offers that job seekers receive.

I assume random matching. Unemployed and employed workers are therefore contacted by any firm. The number of offers O_t received by a worker follows a binomial distribution of parameters $(v_t, \frac{s_t}{v_t})$, where v_t denotes the level of vacancies, and can be approximated by a Poisson distribution of parameter s_t for large values of v_t. The probability that an employed or unemployed worker receives k offers is therefore:

$$P(O_t = k) = \frac{e^{-s_t} s_t^k}{k!}$$

Offer acceptance decision. As in Burdett and Mortensen (1998), I propose a matching process whereby employers do not respond to the job offers that their employees receive from poaching firms.[27]

The job acceptance rules are as follows. If an unemployed worker only receives one offer during the period, he accepts it with probability one, as long as the proposed wage provides welfare that exceeds the value of unemployment. However, if the unemployed worker receives k offers, he accepts one offer w^o (the superscript o denotes wage/job offers) only if it is the highest, which occurs with probability $F_t(w^o)^{k-1}$, where $F_t(w)$ is the cumulative distribution function of wage offers at time t. The probability $a_t^U(w^o)$ that an unemployed worker accepts an offer w^o, conditional on getting at least one offer, is therefore:

$$a_t^U(w^o) = \sum_{k=1}^{\infty} \frac{P^U(O_t = k)}{P^U(O_t \geq 1)} F_t(w^o)^{k-1}$$

$$a_t^U(w^o) = \frac{e^{-s_t(1-F_t(w^o))} - e^{-s_t}}{F_t(w^o)(1 - e^{-s_t})} \tag{1}$$

(see Appendix B for the derivation details), and the probability of flowing out of

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unemployment is:

$$p_t^U = 1 - P^U(O_t = 0)$$

$$p_t^U = 1 - e^{-s_t} \tag{2}$$

For employed workers who are looking for a job, the wage acceptance rule is as follows. An employed worker accepts the highest wage offer obtained during the period on condition that it is higher than the wage he is earning in his current job. The conditional probability $a_t^E(w^o)$ that an unemployed worker who currently earns a wage w accepts an offer w^o is therefore:

$$a_t^E(w^o) = \mathbf{1}_{w^o > w} \sum_{k=1}^{\infty} \frac{P^E(O_t = k)}{P^E(O_t \geq 1)} F_t(w^o)^{k-1}$$

$$a_t^E(w^o) = \mathbf{1}_{w^o > w} \frac{e^{-s_t(1 - F_t(w^o))} - e^{-s_t}}{F_t(w^o)(1 - e^{-s_t})} \tag{3}$$

Empirical evidence shows that the proportion of employed workers searching for a job is low, and relatedly, that the job-to-job rate is much smaller than the out-of-unemployment rate.[28] Therefore, I assume that all unemployed workers look for a job with probability one but that each employed worker has a certain probability $e(w) \in (0,1)$ with $\partial e(w)/\partial w < 0$ to be searching for a job. I assume the following functional form for $e(w)$:

$$e(w) = \left(\frac{1 - w}{1 - \underline{w}}\right)^{\alpha}$$

where $\alpha \geq 0$. Workers who are employed at the lowest wage $\underline{w}$ have a probability of one of looking for a job. This probability is decreasing and approaching 0 for employed workers in the upper tail of the distribution.

Consequently, the probability of quitting the current job paying w (or probability of getting a job offer paying at least w) is:

$$p_t^E(w) = e(w) \sum_{k=0}^{\infty} P^E(O_t = k)(1 - F_t(w)^k)$$

$$p_t^E(w) = e(w)\left(1 - e^{-s_t(1 - F_t(w))}\right) \tag{4}$$

As a result, the vacancy filling rate for a firm proposing a wage w^o can be

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[28]From SIPP data, Nagypal (2008) estimates the average job-to-job rate to be 0.022. Using CPS data, Fallick and Fleischman (2004) and Nagypal (2008) respectively find this rate equal to 0.027 and 0.029. Moscarini and Thomsson (2006) find a slightly higher rate, 3.2%, by treating missing observations.

expressed as follows:

$$q_t(w^o) = \frac{u_t}{u_t + \bar{e}(1 - u_t)} a_t^U(w^o) + \frac{\bar{e}(1 - u_t)}{u_t + \bar{e}(1 - u_t)} G_{t-1}(w^o) a_t^E(w^o) \qquad (5)$$

where $\bar{e}$ is the average job searching probability among employed workers, $G_t(w)$ is the end-of-period cumulative distribution function of wages and, accordingly, $G_t(w^o)$ is the fraction of employed workers earning a wage lower than w^o.

Lowest wage rate. $\underline{w}_t$ denotes the lowest wage rate that an unemployed worker will accept. Given that no worker would accept a wage providing a lower utility than the utility of unemployment, $\underline{w}_t$ is obtained from the following equality:

$$W_t(\underline{w}_t) = U_t \qquad (6)$$

where $W_t(w)$ is the value to the worker of working for a wage w and U_t is the value of unemployment. U_t and $W_t(w)$ are defined as:

$$U_t = b + E_t\left[\beta p_{t+1}^U \int_{\underline{w}_{t+1}}^{\bar{w}_{t+1}} W_{t+1}(w_{t+1}) dF_{t+1}(w_{t+1}) + \beta(1 - p_{t+1}^U)U_{t+1}\right]$$

and

$$W_t(w) = w + E_t\Big[\beta(1 - \lambda)(1 - p_{t+1}^E(w))W_{t+1}(w)$$
$$+ \beta(1 - \lambda)p_{t+1}^E(w) \int_{w}^{\bar{w}_{t+1}} W_{t+1}(w_{t+1}) dF_{t+1}(w_{t+1})$$
$$+ \beta\lambda p_{t+1}^U \int_{\underline{w}_{t+1}}^{\bar{w}_{t+1}} W_{t+1}(w_{t+1}) dF_{t+1}(w_{t+1})$$
$$+ \beta\lambda(1 - p_{t+1}^U)U_{t+1}\Big]$$

An employed worker receiving a wage w becomes unemployed if his employment relationship exogenously ends and if he does not find a job straight off. With a probability $(1 - \lambda)p_{t+1}^E(w)$, the worker gets poached by a more generous firm. If he neither get poached nor resigns, the employment relationship proceeds at rate w.

3.3 Firms

Vacancy posting decision. In order to avoid issues linked to intra-firm wage heterogeneity, I consider one-job firms. As in Mortensen (1998), firms are ex-ante homogenous but ex-post heterogeneity in productivity arises because of inter-firm differential in capital investment. $k_t(w)$ represent the specific capital a firm invests

in a match formed at time t and proposing a wage w. This investment is realized once the worker and the firm are matched. $f(k_t(w))$ denotes the idiosyncratic match productivity, with $f'_{k_t(w)}(k_t(w)) > 0$ and $f''_{k_t(w)}(k_t(w)) < 0$.

Employers play an active role not only as job creators but also as wage-setters. Wages are set so as to maximize the value of a vacancy. Free entry, however, ensures that, in equilibrium, this value is equal to zero at any time t. The value of posting a vacancy paying w is equal to:

$$V_t(w) = -c + q_t(w)(J_t(k_t(w), w) - k_t(w)) + E_t\beta(1 - q_t(w))V_{t+1}(w)$$

where c is the cost of posting a vacancy, β is the discount rate and $J_t k_t(w)$ is the time t value of a job for a firm proposing a wage w and investing $k_t(w)$ in the match . $J_t(k_t(w), w)$ can be written:

$$\begin{aligned} J_t(k_t, w) =& z_t f(k_t) - w + E_t\Big[\beta(1 - \lambda)(1 - p^E_{t+1}(w))J_{t+1}(k_t(w), w) \\ & + \beta[\lambda + (1 - \lambda)p^E_{t+1}(w)]V_{t+1}(w)\Big] \end{aligned}$$

where z_t is the aggregate productivity level. Note that $V_t(w)$ is the value of a vacancy for the firm at the moment the vacancy is posted, i.e., before the matching process. In contrast, $J_t(k_t(w), w)$ is the value of employment for the firm at the moment production takes place, i.e., after the matching process.

In equilibrium, free entry drives the value of a vacancy V_t to zero for any wage level. Plugging this condition into the value functions of a vacancy and a job, I obtain the job creation curve:

$$J_t(k_t(w), w) = \frac{c}{q_t(w)} - k_t(w) \tag{7}$$

$$= z_t f(k_t(w)) - w + E_t\beta(1 - \lambda)(1 - p^E_{t+1}(w))(\frac{c}{q_{t+1}(w)} - k_t(w)) \tag{8}$$

The optimal investment given that the wage w is offered is:

$$k_t(w) = argmax(J_t(k_t(w), w) - k_t(w)) \tag{9}$$

$$k_t(w) = f'^{-1}((1 - E_t\beta(1 - \lambda)(1 - p^E_{t+1}(w)))/z_t) \tag{10}$$

Given that the job-to-job rate decreases with the wage, the optimal investment level is an increasing function of the wage. Indeed, firms proposing relatively high wages have an incentive to make larger match-specific investments as their jobs

remain filled for a longer period of time. As a result, high-paying firms have a higher capital labor ratio and are more productive. Such heterogeneity in productivity is endogenous and arises even though firms are ex-ante similar.

Plugging Equation 9 into Equation 7, I can rewrite the job creation curve as such:

$$\frac{c}{q_t(w)} = z_t g_t(w) - w + E_t \beta (1 - \lambda)(1 - p_{t+1}^E(w)) \frac{c}{q_{t+1}(w)} \tag{11}$$

where $g_t(w) = f(k_t(w)) - f'(k_t(w))k_t(w)$ with $g'_w(w) > 0$.

Highest wage rate. $\bar{w}_t$ is the upper bound of the range of wage rates for which the zero-value vacancy equilibrium condition is respected. Above this threshold, the value of a filled vacancy $J_t(\bar{w}_t + \epsilon)$ would lie below $c/q_t(\bar{w}_t + \epsilon)$ so that either the time t value of the vacancy would be negative or the time $t + 1$ value of the vacancy would be required to be positive.

3.4 Stocks and flows

u_t denotes the beginning-of-period rate of unemployment, whereas n_t denotes the employment rate once the matching process has taken place. Therefore:

$$n_t = 1 - (1 - p_t^U)u_t \tag{12}$$

and

$$u_t = 1 - (1 - \lambda)n_{t-1} \tag{13}$$

Plugging equation (12) into (13), I obtain the law of motion of the end-of-period employment rate:

$$n_t = (1 - \lambda)n_{t-1} + p_t^U(1 - n_{t-1}(1 - \lambda))$$

Turning now to the job-to-job flows, notice that $n_t G_t(w)$ represents the end-of-period number of employed workers currently earning less than w. This specific pool of workers increases with the flow of unemployed workers finding a job paying less than w and decreases with the flow of employed workers previously in that pool whose contract exogenously ends or who switch to a new job paying more than w:

$$n_t G_t(w) = n_{t-1} G_{t-1}(w)(1 - \lambda)(1 - p_t^E(w)) + u_t p_t^U F_t(w) \tag{14}$$

Note that, as on-the-job movements takes place up the ladder, the distribu-

tion of wages earned over employed workers first-order stochastically dominates the distribution of wages offered to job seekers.[29]

3.5   Equilibrium wage dispersion

The free entry condition also states that each vacancy type is equally valuable, which allows the possibility of wage dispersion in equilibrium. Indeed, for any wage offer in the bargaining set, the corresponding vacancy filling rate and job-to-job rate ensure the equilibrium condition. To see this, consider equation (7). Wage dispersion arises due to the fact that firms play a mixed strategy in the wage posting game, trading-off between the current profit per worker ($\frac{\partial z_t f(k_t(w)) - w}{\partial w} < 0$), on the one hand, and the vacancy filling rate ($\frac{\partial q_t(w)}{\partial w} > 0$) and the quitting rate ($\frac{\partial p_t^E(w)}{\partial w} < 0$), on the other. As a result, an equilibrium can be supported in which each vacancy type is equally valuable. In particular, we have:

$$V_t(w) = V_t(\underline{w}_t) = 0 \qquad \forall w$$

which can be rewritten as follows:

$$q_t(w)(J_t(w) - k_t(w)) = q_t(\underline{w}_t)(J_t(\underline{w}_t) - k_t(\underline{w}_t)) \qquad \forall w \qquad (15)$$

The ratio of vacancy durations equals the ratio of expected profits from opening a vacancy. This last equation pins down $F_t(w)$, which is the equilibrium wage offer distribution function. Once $F_t(w)$ is determined, nature chooses the type of each firm.

The continuity of the equilibrium wage offer distribution is a condition that must be satisfied. In order to understand the reason for this, let us consider a mass point at the wage level $w^* \in]\underline{w}_t, \bar{w}_t]$. Firms proposing such a wage have an incentive to deviate by proposing a slightly lower wage. In so doing, they only slightly decrease the probability of finding a worker (given the absence of mass at the wage level $w^* - \epsilon$) and increase their per period profit. The possibility of a mass point at the reservation wage is also ruled out. A slight increase in the proposed wage would decrease the per period profit but would greatly increase the probability of filling the vacancy.

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[29]See Mortensen (1990) for a demonstration.

4 Solving the model

In this section, I first define the decentralized equilibrium. Then, I present my calibration strategy. Finally, I describe how I solve for the dynamics of the model.

4.1 Equilibrium

The economy is in a decentralized equilibrium at all times; that is, all firms maximize their profits and all workers optimally choose the wage offer to accept.

Definition: *A decentralized equilibrium is a sequence of optimal vacancy posting decisions $\{s_t\}_{t=0}^{\infty}$, wage offer dispersions and wage dispersions $\{F_t(w), G_t(w)\}_{t=0}^{\infty}$, acceptance rates $\{a_t^U(w), a_t^E(w)\}_{t=0}^{\infty}$, out-of-unemployment and job-to-job rates $\{p_t^U, p_t^E(w)\}_{t=0}^{\infty}$, vacancy filling rates $\{q_t(w)\}_{t=0}^{\infty}$, reservation rates $\{\underline{w}_t\}_{t=0}^{\infty}$, employment and unemployment rates $\{n_t, u_t\}_{t=0}^{\infty}$ such that the following conditions are satisfied:*

1. *From the free entry condition, each vacancy type in $(\underline{w}_t, \bar{w}_t)$ has zero value. Outside this range, the value of posting a vacancy is negative.[30] The job creation curve (11) determines the equilibrium level of overall vacancies (or average number of job offers).*

2. *The time t value of the equilibrium wage offer distribution at the wage level w is pinned down by equation (15).*

3. *The law of motion of the cumulative distribution function of current wages $G_t(w)$ is presented by equation (14).*

4. *The sequence of reservation wages is determined by equation (6).*

5. *Unemployed and employed workers accept job offers as described by equations (1) and (3).*

6. *The out-of-unemployment and the job-to-job flows are framed by equations (2) and (4).*

7. *The vacancy filling rate satisfies equation (5).*

8. *Unemployment and employment stocks evolve according to equations (12) and (13).*

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[30]A firm proposing a wage below $\underline{w}_t$ would pay a cost for posting a vacancy which has a zero probability of being filled. A firm proposing a wage above $\bar{w}_t$ would get a profit which would be too small to compensate the vacancy cost.

The dynamics of the model are obtained by taking a log-linear approximation of the aggregate productivity process and of equations (1), (2), (3), (4), (5), (6), (12), (13), (14), (11) and (15) around the steady state.

5   Calibration

Table 3: Calibration

Description	Parameter	Value
Stochastic process for labor productivity		
Autocorrelation	ρ	0.98
Standard deviation	σ	0.0086
Mean labor productivity	z	1
Other parameters		
Discount rate	β	$0.99^{1/3}$
Exogenous separation rate	λ	0.1/3
Unemployment income	$\bar{b}$	set to target $b/E(w) = 0.6$
Vacancy posting cost	c	0.3026 set to target $p^U = 0.45$
Curvature of the searching effort	α	set to target $E(p^E(w)) = 0.026$
Function		
Firm heterogeneity	$g_0(w)$	set to target a log normal res. wage distribution of param. (-0.45,0.12)

Note: Monthly calibration.

The calibration of the model is described in Table 3. These values are chosen to match US data.

I interpret a period as a month. The discount factor is set to $0.99^{1/3}$ which corresponds to a yearly interest rate of 4% commonly used in the macro-RBC literature.

The log productivity level z_t is assumed to follow an AR(1) process: $\log(z_t) = \rho \log(z_{t-1}) + \epsilon_t$ where $\epsilon \sim N(0, \sigma^2)$. The persistence of the technology shock is set to $\rho = 0.98$ and the standard deviation to $\sigma = 0.0086$. This standard calibration is used by Rogerson and Shimer (2010) and is based on the estimations of Cooley and Prescott (1995). The mean of z is normalized to one.

Each match has a probability of ending λ set to 0.1/3. This value is within the broadly accepted range of $8\% - 10\%$ proposed by Hall (2005) and is similar to that

of Shimer (2005), who measures this exit probability at 0.1/3 on average in the US. I target the probability p^U that an unemployed worker forms a match in the period to 45%, implying unemployment spells of around two months. This choice is consistent with Hall (2005), who estimates a monthly job finding rate of 0.48% and in line with the measure of this rate presented by Rogerson and Shimer (2010) for the US for the period 1948-2009.

I target the average job-to-job flow rate $E(p^E(w))$ at 0.026, which is consistent with the most recent empirical evidences.[31]

In contrast with the other parameters and targets, there exists a debate about the value of non-work activity $\bar{b} = b/E(w)$, revived by the paper by Hagedorn and Manovskii (2008). This paper proposes a new estimate of this value at 0.95. Unlike Shimer (2005), who restricts the value of non work activity to unemployment benefits and sets $\bar{b}$ equal to 0.4, Hagedorn and Manovskii (2008) additionally integrate home production and the value of leisure. Delacroix (2006) similarly distinguishes a home production of 0.3 and unemployment benefit of 0.3 to obtain an overall value of 0.6. In order to keep my results as plausible as possible, I choose an average value of 0.6.

The function $g_0(w)$ mapping the idiosyncratic match productivity levels to wages is calibrated as follows. I start by approximating the observed residual wage distribution with a log normal distribution. Figure (4) compares the density function of the observed residual wages and the density function of the log normal distribution of parameters (-0.45,0.12) which I use in the calibration. I break the wage range down by placing a 500-point grid on it. I set my model at its steady state level and solve it at each grid point taking the (-0.45,0.12) log normal wage distribution as given. In so doing, I obtain the value of the function $g_0(w)$ for each wage level.
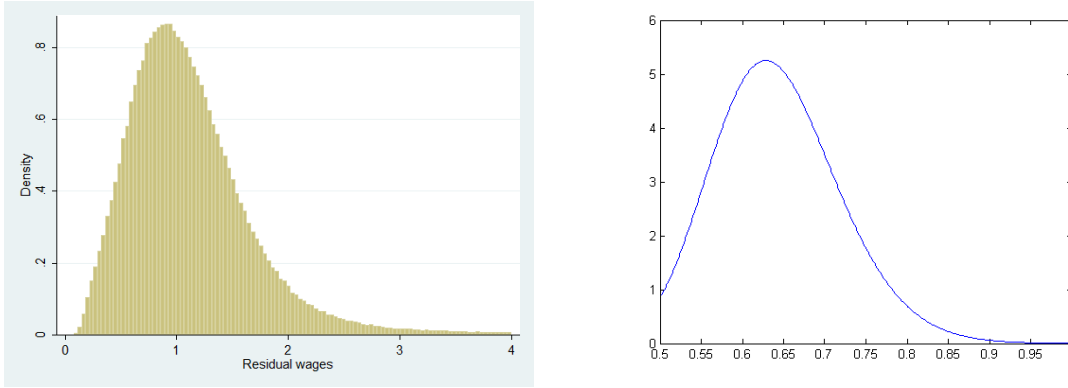
6   Dynamics

6.1   Solving the model

In order to solve for the dynamics of the model, and more specifically for the dynamics of the wage dispersion, I make the restrictive assumption that the reservation wage is constant over time. Which such an assumption and given the specificity of the model, I obtain that $\underline{w}_t = \underline{w} = b$. Moreover, I make use of the fact that

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[31]From SIPP data, Nagypal (2008) estimates the average job-to-job rate to be 0.022. Using CPS data, Fallick and Fleischman (2004) and Nagypal (2008) respectively find this rate equal to 0.027 and 0.029. Moscarini and Thomsson (2006) find a slightly higher rate, 3.2%, by treating missing observations.

Figure 4: Residual wage distribution

the free entry condition is satisfied at any wage level. This equilibrium condition is crucial as it allows me to reduce the dimension of the state space considerably. The reasoning is as follows. First, the dynamics of the variables which do not depend on any wage level (i.e. n_t, u_t, s_t and p_t^U) are obtained by solving a partition of the model including only the equations for these variables and the job creation curve of the firm proposing the reservation wage (equations 2, 12, 13, as well as equations 1, 5 and 11 expressed at the reservation wage), which is characterized by the fact that the cumulative distribution function of offered wages and of wages are both equal to zero. Second, by making use of the free entry condition and by equalizing the value of a vacancy proposing a wage w and the value of the vacancy proposing the lowest wage, I am able to solve for the dynamics of the value of the cumulative distribution function of wages at each wage level. Using an N-point ($N. = 500$) grid for the wage range, I use the vacancy value equalizing condition (equation 15) $N - 1$ times. In so doing, I reduce the problem to a fixed point problem, where only the past and future values of the cumulative distribution function of wages at a specific wage level are needed to solve for the problem of the firms proposing that specific wage level. Note that I do not solve for the dynamics of the functional form of the wage distribution but rather for the dynamics of the wage distribution for each wage level.

6.2 Results

6.2.1 General picture

Figure 5 shows the response of a specific labor market ($w = median\ wage \approx 0.64$) to a positive productivity shock of one standard deviation. In a period of expansion, the firms' surplus increases, which leads to a jump in the value of posting vacancies and hence to an increase in vacancies and in the average number of job offers that

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unemployed and employed workers receive. The labor market becomes tighter. Job seekers become choosier as they get more job offers and of better quality. As a result, firms record a decline in the job offer acceptance rates coming from both categories of workers. The vacancy duration rises, which brings the value of vacancies back to zero.

Figure 5: Impulse responses to a positive productivity shock
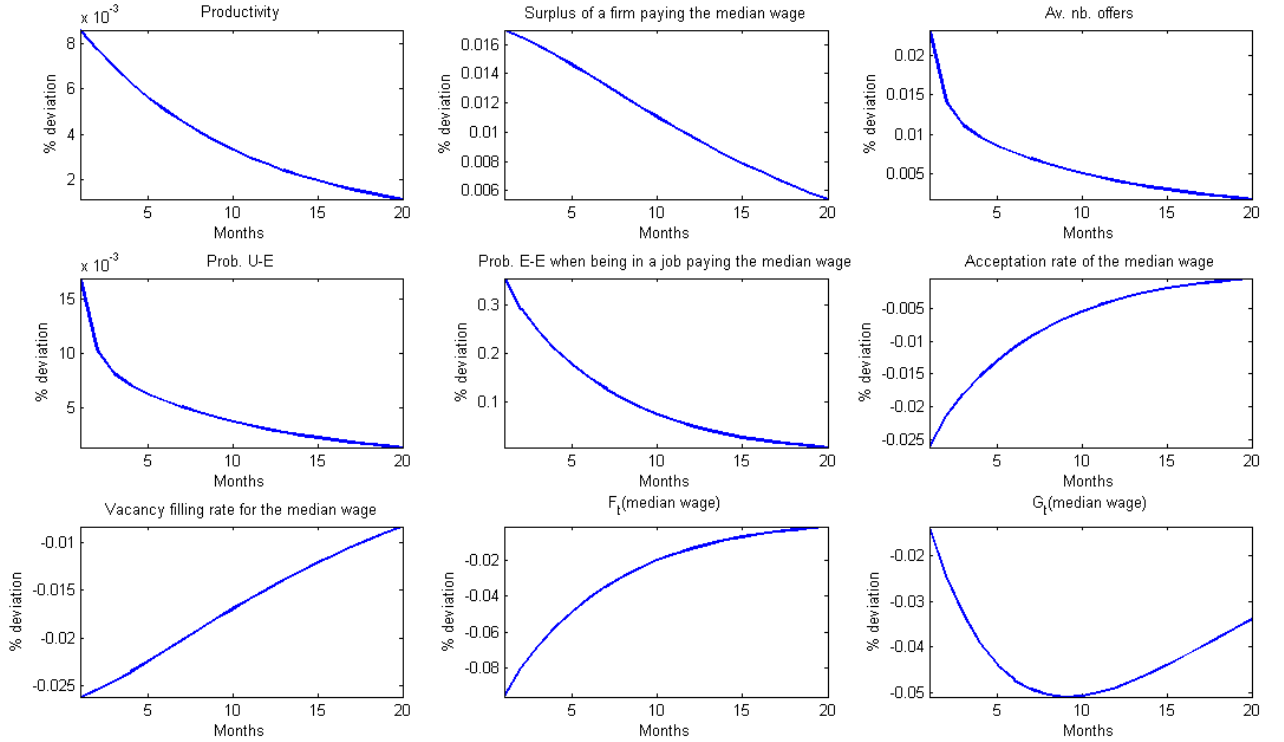
Note: Percentage deviation from the steady state following a positive productivity shock of one standard deviation. I set $w = median\ wage \approx 0.64$ in this illustration.

Note that the values of the cumulative distribution function of both offered wages and wages at the median wage decrease, suggesting that the probability that workers receive and accept relatively bad offers falls in good times. I explain this result in the following section.

6.2.2 Wage offer distribution

In order to understand how firms react to a change in productivity, I examine how the firms' surplus changes for different levels of wage. As discussed by Hagedorn and Manovskii (2008), what gives the firms the incentive to post vacancies is the size of the percentage change in profit in response to the change in productivity.

Figure 6, left-hand panel, presents the percentage change in the firms' surplus for all wage levels at the moment of the shock, and shows the following disproportional effect: the higher the wage, the larger the percentage change in profit, the bigger the incentive to post vacancies. As a result, firms have a large incentive to post relatively good vacancies following an increase in productivity. The intuition behind this result is linked to the change in the workers' behavior. Indeed, the increase in productivity pushes up the value of all types of vacancies, but the jump in vacancies makes workers choosier and exacerbates inter-firm competition over workers. Therefore, firms proposing relatively low wages face greater difficulties in filling their vacancies and retain their workers. This second effect attenuates the rise in the value of the vacancy due to the increase in productivity. As a result, the percentage change in the firms' surplus is lower for low-paying firms and the firms' incentive to post low-paying vacancies lessens. The distribution of offered wages changes accordingly, as can be seen in Figure 6, right-hand panel. Following the positive shock, the wage distribution shifts downwards, illustrating the fact that the composition of vacancies leans more towards good vacancies compared to before the shock.

Figure 6: Impulse response to a positive productivity shock
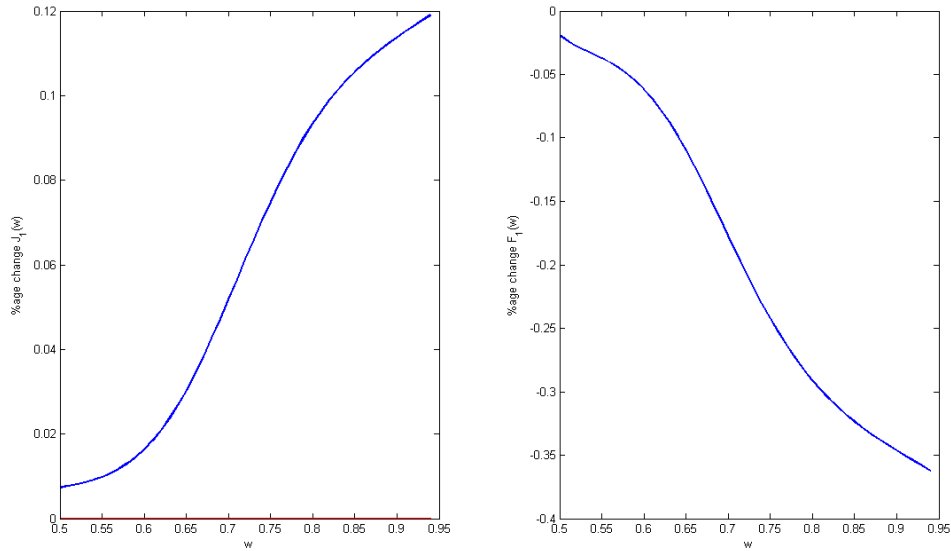
Note: Left-hand panel: Immediate (t=1) percentage change in the firms' surplus $J_1(w)$ in response to a positive shock of one standard deviation for each wage level. Right-hand panel: Immediate (t=1) percentage change in the cumulative distribution function of offered wages ($F_1(w)$) in response to a positive shock of one standard deviation for each wage level.

6.2.3 Wage dispersion

In expansion, the disproportionate increase in high-paying vacancies modifies the wage structure and gives way to a downward shift of the wage distribution function, as displayed in Figure 7. This downward shift indicates that firms have more incentive to propose relatively high paying vacancies, and that this strategic decision impacts the distribution function of accepted vacancies. Figure 8 shows the evolution of the wage density function at the moment of the shock, relative to the steady-state wage density function. This figure suggests that, in good times, as the proportion of high paying vacancies increases, the upper tail of the wage density function thickens and the mass of the wage distribution shifts rightward. This change in the shape of the wage distribution, in turn, generates a rise in wage dispersion. Figure 9 displays the percentage change in the variance of wages for the ten periods following a positive productivity shock. Wage dispersion clearly behaves procyclically.

Figure 7: Rightward shift of the mass of the wage distribution
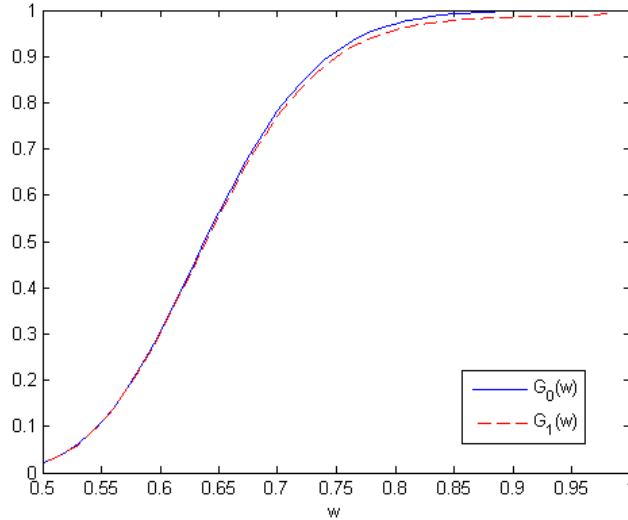
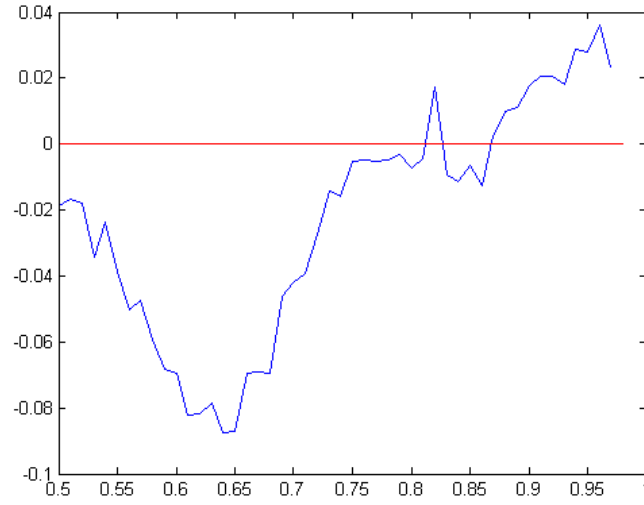Note: Steady state wage distribution function and t=1 wage distribution function ($G_1(w)$).

### 6.2.4 Job-to-job rate and composition of hirings

Figure 6.2.4 shows the immediate percentage change in the job-to-job rate for different levels of wages in response to a positive productivity shock. One can notice the disproportionate jump in this rate for high levels of wages. The rationale behind

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Figure 8: Rightward shift of the mass of the wage distribution

Note: Difference between the immediate (t=1) wage density function and the steady-state wage density function.

Figure 9: Wage dispersion: impulse response to a positive productivity shock
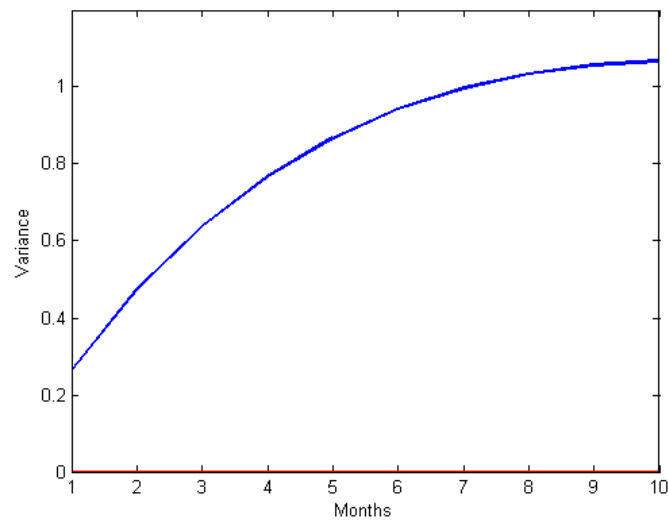
Note: Percentage deviation from the steady state of the variance of wages following a positive productivity shock of one standard deviation.

this result is grounded on the change in the quality of vacancies. For an unchanged probability of looking for a job, the probability that the offered wage exceeds the current one increases more the higher the wage. Two results are obtained. First, the job-to-job rate behaves procyclically, a result which is consistent with empirical evidence.[32] Second, given that the procyclicality of the job-to-job rate exceeds that of out-of-unemployment, the composition of hiring is modified towards employed workers in good times.

Figure 10: Job-to-job rate: impulse response to a positive productivity shock
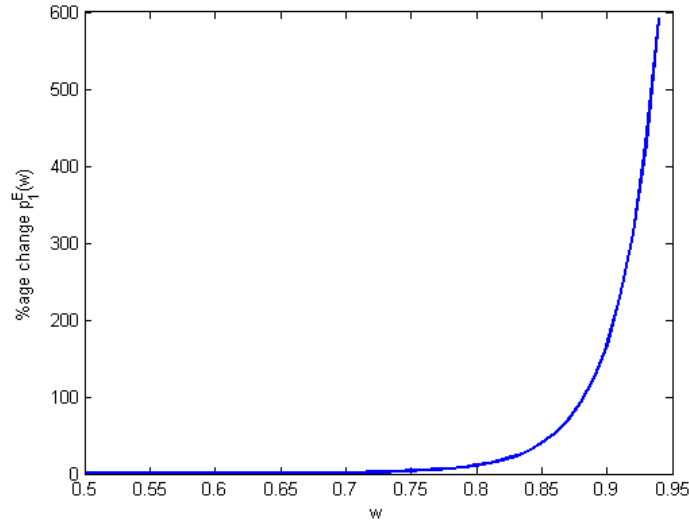
Note: Immediate (t=1) percentage change in the job-to-job rate in response to a positive shock of one standard deviation for each wage level.

7   Conclusion

This paper is, to my knowledge, the first study that documents the procyclicality of wage dispersion and develops a dynamic stochastic general equilibrium model of the labor market to examine the channels through which the business cycle shapes the residual wage distribution and thus, alters residual wage dispersion. The empirical evidence presented in the paper first indicates that the short-run fluctuations in wage dispersion are mainly driven by the short-run fluctuations in residual wage dispersion. Second, the empirical analysis also shows that, in the US, wage inequality is positively correlated with GDP and negatively correlated with the

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[32]See, for example, Sherk (2008).

unemployment rate. These results therefore suggest that wage dispersion behaves procyclically. The dynamic search wage-posting model that I develop accounts for this stylized fact.

The mechanism through which the business cycle shapes residual wage dispersion is the following. As a consequence of market frictions, every firm has some power to impose a wage level on its workers. The business cycle, by affecting both the quantity and quality of job offers, alters the extent to which firms exploit their monopsony power. In booms, workers become choosier and the monopsony power of firms erodes. As firms face a drop in their job acceptance rates, they strategically modify their wage-setting decisions and post disproportionately more high-paying vacancies. The upper tail of the distribution of wage offers thickens and the mass shifts rightwards. Similar changes are observed in the distribution of wages. Consequently, wage dispersion rises.

While much literature has recently emerged documenting the reasons for the level and the trend of wage dispersion, the literature is almost silent on the behavior of wage dispersion over the business cycle. Yet, wage dispersion is a primary driver of income dispersion and, as such, spreads over consumption inequality and impacts the welfare of individuals and households. The analysis of its cyclical properties undertaken in this paper is therefore essential to reaching a full understanding of wage dispersion. Moreover, despite being an important component of income dispersion, wage dispersion and income dispersion seem to have opposite cyclical properties.[33] This observation indicates that factors other than wages are driving the cyclical properties of income inequality and that these factors are important enough to counteract the procyclical movements induced by wage dispersion. A possible candidate for such a driving force is the change over the business cycle in the employed/unemployed composition of workers. The rise (fall) in the share of unemployed workers during recessions (booms) pushes income dispersion up (down). This composition effect could potentially play an important role in causing the countercyclicality of income dispersion. As such, it needs to be related to the price (wage) effect documented in the present paper in order to examine how wage dispersion spreads over income inequality at business cycle frequencies. Such an investigation will be undertaken in future research.

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[33]Apart from the work by Guvenen, Ozkan, and Song (2012), the existing studies on this issue all point towards income inequality being countercyclical.

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A Explaining residual wage dispersion

The presence of sizable frictions in the labor market is recognized in the literature. Diamond (1971) emphasizes the role of search frictions in rising prices from competitive to monopoly levels. As long as frictions are large enough so that a price increase does not cause the buyer to pay for another search cost in order to get an alternative price quotation, sellers get full monopoly power. Burdett and Judd (1983) complete this analysis and point out that, in the case that there is a positive - but not certain, as in Diamond - probability that each job searcher knows only one price, firms do not all set their prices at the monopoly level, but instead have the incentive to offer differing prices. With a specific focus on the labor market, Manning (2003) argues that the firms behave like monopsonies, not in the sense that they each stand alone in different sub-markets, but because the supply of labor to each individual firm is not infinitely elastic.[34] Indeed, search frictions are such that both the worker and the firm would be worse off if their employment relationship were to come to an end. Therefore, as long as the wage provides a utility which is greater than the value of unemployment, a slight decrease in the wage does not lead to the worker's resignation. Also, a job seeker might accept a relatively bad wage offer if he only gets that offer during a certain time span. Hence, search frictions give firms some monopsony power, a power which is exploited when the wage is set below the competitive level. Furthermore, wage dispersion at equilibrium naturally emerges from this setting. Indeed, the extent to which firms exercise their monopsony power affects their hiring and turnover rates, but, as long as the proposed wage remains above the reservation level, each firm eventually does find workers. Therefore, the trade-off between the profit per worker and the relative ease with which firms manage to get and retain workers leads to differential wage-setting strategies across firms. This mechanism is at the core of the model developed by Burdett and Mortensen (1998). Their pioneering study shows how wage dispersion at equilibrium can be generated when search frictions are combined with on-the-job search, in a framework where workers and firms are perfectly homogeneous and have perfect information.[35]

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[34]Mortensen (1972) has first shown that search behavior induces an upward-sloping supply curve to individual firms.

[35]Parallel to this stream of literature, some authors argue that the equilibrium wage differential results from unobservable workers heterogeneity (heterogeneity in preferences over non-wage job characteristics (Bhaskar, Manning, and To (2002)), heterogeneity in unobservable ability (Murphy and Topel (1987), Postel-Vinay and Robin (2002))) or workers' incomplete information about the wage distribution (Winter-Ebmer (1998)).

B   Job offer acceptance rate and labor market tightness

$$a_t^U(w^o) = \sum_{k=1}^{\infty} \frac{P(O_t = k)}{P(O_t \geq 1)} F_t(w^o)^{k-1}$$

$$a_t^U(w^o) = \frac{1}{1 - P(O_t = 0)} \sum_{k=1}^{\infty} P(O_t = k) F_t(w^o)^{k-1}$$

$$a_t^U(w^o) = \frac{1}{(1 - P(O_t = 0)) F_t(w^o)} \sum_{k=1}^{\infty} P(O_t = k) F_t(w^o)^{k}$$

$$a_t^U(w^o) = \frac{1}{(1 - P(O_t = 0)) F_t(w^o)} \left(\sum_{k=0}^{\infty} P(O_t = k) F_t(w^o)^{k} - P(O_t = 0) \right)$$

$$a_t^U(w^o) = \frac{1}{(1 - e^{-s_t}) F_t(w^o)} \left(\sum_{k=0}^{\infty} \frac{e^{-s_t} s_t^{k}}{k!} F_t(w^o)^{k} - e^{-s_t} \right)$$

$$a_t^U(w^o) = \frac{1}{(1 - e^{-s_t}) F_t(w^o)} \left(e^{-s_t(1 - F_t(w^o))} \sum_{k=0}^{\infty} \frac{e^{-s_t F_t(w^o)} s_t F_t(w^o)^{k}}{k!} - e^{-s_t} \right)$$

$$a_t^U(w^o) = \frac{e^{-s_t(1 - F_t(w^o))} - e^{-s_t}}{(1 - e^{-s_t}) F_t(w^o)}$$

which is similar to equation 1.

C   Additional tables

Table 4: Cross-correlations (No time trend in the regression)

	Mean	Correlation with GDP				Correlation with the unemployment rate			
		$t-1$	t	$t+1$	$t+2$	$t-1$	t	$t+1$	$t+2$
Wage inequality									
varlogs	0.3414	0.2260	0.2389	−0.0006	−0.2544	−0.3684**	−0.1422	0.1264	0.2991
90/10 P-ratio	1.4257	0.0022	0.3688***	0.0644	−0.3240	−0.1863	−0.3362**	0.1718	0.4079*
90/50 P-ratio	0.6676	−0.0419	0.2248	−0.0414	−0.3506	−0.0317	−0.1922	0.2527	0.3119
50/10 P-ratio	0.7581	0.0586	0.2885*	0.1567	−0.0555	−0.2535	−0.2798*	−0.0612	0.2373
Skewness	2.8922	0.0224	−0.0143	−0.1416	0.1418	−0.1639	0.0484	0.1512	−0.1010
Residual wage inequality									
varlogs	0.2699	0.1445	0.3323**	0.0646	−0.2000	−0.3426**	−0.3220**	0.1054	0.2735
90/10 P-ratio	1.2368	0.1003	0.4028**	0.2335	−0.2482	−0.2788*	−0.4058***	0.0353	0.3760*
90/50 P-ratio	0.5631	0.0515	0.3625***	0.3435**	−0.2112	−0.2112	−0.3410**	−0.0269	0.3316*
50/10 P-ratio	0.6737	0.1115	0.2842*	0.0271	−0.1856	−0.2398	−0.3110*	0.0856	0.2688
Skewness	2.9040	0.0932	−0.0327	−0.1943	−0.1318	−0.2200	0.0587	0.2717*	0.1388

Note: *: significant at the 10% level, **: significant at the 5% level. The regression of wages on observable characteristics does not include a time trend. The time series of the four inequality measures as well as log GDP are detrended using an HP-filter of parameter 6.25. Wage inequality: *varlogs* refers to the variance of log wages of male household-head full-time workers. $i/jP-ratio$ is the difference between the ith percentile and the jth percentile of the residual log wages.

Table 5: Cross-correlations (other detrending procedures)

| | Contemporaneous correlation with GDP | | | | | |
| | HP-filter of parameter 100 | | First difference | | Band-pass filter | |
	Log wages	Wages in level	Log wages	Wages in level	Log wages	Wages in level
Wage inequality						
varlogs	0.2223	–	0.1496	–	0.2942*	–
90/10 P-ratio	0.3042*	0.2960*	0.3310*	0.3178*	0.4145**	0.3939**
90/50 P-ratio	0.1503	0.1600	0.2012	0.2019	0.2592	0.2597
50/10 P-ratio	0.2897*	0.2818*	0.2255*	0.2185*	0.3072*	0.2955*
Skewness	–	−0.0143	–	0.0618	–	0.0299
Residual wage inequality						
varlogs	0.2892*	–	0.2791*	–	0.3673**	–
90/10 P-ratio	0.3645**	0.3549**	0.2710*	0.2586*	0.4237**	0.4031**
90/50 P-ratio	0.3115*	0.3075*	0.1416	0.1375	0.3060*	0.2998*
50/10 P-ratio	0.2845*	0.2847*	0.2629*	0.2633*	0.3960**	0.3919**
Skewness	–	−0.0844	–	−0.1164	–	−0.0728

Note: *: significant at the 10% level, **: significant at the 5% level. The time series of the four inequality measures as well as GDP are detrended using I) an HP-filter of parameter 100, II) first difference and III) a Baxter and King band pass filter (parameters 2, 8, 3). Wage inequality & Log wages: $varlogs$ refers to the variance of log wages of male household-head full-time workers. $i/jP-ratio$ is the difference between the ith percentile and the jth percentile of log wages. Wage inequality & Wages in level: $i/jP-ratio$ is the ratio between the ith percentile and the jth percentile of wages. $Skewness$ is the skewness of the density function of log wages. Residual wage inequality & Log wages: $varlogs$ refers to the variance of the residual log wages of male household-head full-time workers. $i/jP-ratio$ is the difference between the ith percentile and the jth percentile of the residual log wages. Residual wage inequality & Wages in level: $i/jP-ratio$ is the ratio between the ith percentile and the jth percentile of the residual log wages. $Skewness$ is the skewness of the density function of the exponentiated series of residual log wages.