

ABSTRACT

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In this work I study recent developments in firm employment and earnings instability in the US economy over the last 30 years. Despite the decline in aggregate and firm level volatility, earnings instability has increased steadily for job stayers since the late seventies. I measure and model these phenomena as a result of a decline in labor market institutions that compress wage volatility, and an increase in the incidence of compensation schemes that attach wages to worker performance.

STABLE FIRMS AND UNSTABLE WAGES

By

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CHAPTER 1

Trends in Employment and Wage Instability

1.1. Introduction

The purpose of this dissertation is twofold. In the first two chapters I study the rise of earnings instability in light of recent changes in volatility both at the macroeconomic and the firm level. Despite the moderation in the variance of macroeconomic and firm outcomes from 1979 to 2007, earnings instability for job stayers increased over the same sample period. I present both theory and evidence on these apparently contradictory phenomena. I find that earnings instability for job stayers increased over the same sample period using the Matched March CPS. I also measure earnings instability using the PSID from 1976 to 1996. I find that jobs that received some form of bonus or commission have higher wage volatility than jobs with wages subject to collective bargaining. I use my empirical findings in order to guide construction and simulation of a model of the labor market that explains increased wage volatility by combining a decline in labor market institutions that compress wage volatility and an increase in the use of pay schemes attached to worker performance. I calibrate the model to match standard

moments of the US labor market such as unemployment and job turnover, but also values of size, standard deviation of bonus pay, and incidence of performance related payment in the PSID. Simulations results suggest that moving the economy from unionized markets to performance pay arrangements explain the bulk of the decline in firm volatility, and 29% of the increase in wage instability present in the data in the last 30 years.

In the third chapter I turn to the analysis of a model of business cycle with performance pay contracts. Extensive empirical evidence documents that worker and job flows are high and variable even for narrowly defined industries. Gross reallocation rates are large both in booms and recessions, suggesting a constant reshuffling of resources taking place in the economy (Davis, Haltiwanger and Schuh, 1996). I extend a standard search model to include performance pay contracts and analyze whether the uncertainty in employment relationships brought by contracts help explain high frequency moments of compensation schemes, vacancies, and unemployment in the US economy. I use a non-standard set of moments to calibrate the model: values of size, incidence, and cyclicity of bonus payment in the PSID. I find that a model that targets the moments of compensation schemes can explain at least half of the high frequency variation in unemployment and vacancies in the economy. I develop in the model bundled shocks. Besides the standard labor productivity variation, I include in the model uncertainty shocks, represented by

time varying private information at the employment level. Uncertainty affects the value of employment by changing incentives and effort in contracts, and decreases the value of a job by making it harder to assess outcomes. Economic downturns correspond to periods with increasing noise in the principal-agent problem in the economy. To that extent, I develop a theory of recessions based on uncertainty in employment relationships. Simulation results suggest that uncertainty shocks are capable of generating high frequency variation in unemployment and vacancies without resorting to high variance in labor productivity shocks, overcoming a well known problem of labor search models (Shimer, 2003).

1.1.1. Empirical Evidence on Firm and Earnings Instability

Macroeconomic outcomes in the US and other major developed countries became less volatile in the mid-1980's and volatility remained low through 2006. This widely discussed phenomenon, known as the Great Moderation, is reflected in the decline in the variance of GDP, inflation and other aggregate series. This trend in macroeconomic outcomes has been accompanied by a decline in business growth rate volatility. In this work, I focus on an aspect of the economy that has not been touched by increasing stability : labor market earnings. Evidence from a variety of sources over the last 25 years shows a rise in the variance of household earnings

in the US. Greater heterogeneity in job outcomes manifests itself in different ways besides variability of wages. Lower average tenure, higher occupational mobility, and a greater job loss rate in previously secure high-skilled positions all suggest a more fluid labor market. I search in this work for ways to reconcile evidence that earnings volatility has increased while firm volatility has decreased over the last two decades.

My work provides an extended empirical analysis using Matched March CPS data from 1980 to 2008. In a sample of job stayers in private non-farm jobs, I find that volatility in both hourly earnings and total earnings displays an upward trend. The increase in hourly earnings instability for job stayers over this period is 35%. I also measure earnings instability using the PSID from 1976 to 1996. I find that jobs that receive some form of bonus or commission have higher volatility than jobs with wages subject to collective bargaining.

To attempt to understand these patterns in the data, I develop a general equilibrium model of the labor market with worker and firm heterogeneity. I extend the frictional labor market model of Lucas and Prescott (1974). My extensions involve the inclusion of different pay setting mechanisms in different sectors or islands in the labor market. The way the model works is as follows. Due to search frictions, wages and employment are heterogeneous in separated local labor markets. In

some markets, wages are awarded according to performance, while in other markets institutional arrangements prevent wages from being equal to the marginal product of labor in all states of the world. The institutions that I emphasize are unions and wage norms, both of which tend to compress the wage distribution and decrease wage instability. These institutions were prevalent in the early eighties, but have declined in importance since.

I postulate that the driving force of this change in labor market arrangements is a decrease in the cost of monitoring workers. Improvements in information technology have allowed for better evaluation of worker performance and make it easier to offer wages aligned to productivity. New IT diminishes the asymmetry of information between firms and workers and raises the gains from operating under performance pay arrangements. Since compensation becomes more responsive to idiosyncratic conditions under performance pay, the cross section dispersion of wage growth increases. This mechanism is consistent with the empirical evidence discussed below that reports an increase over the last 30 years in the use of compensation arrangements attached to worker performance.

Theory and measurement are linked since the model is used to illustrate how technological change affects employment and wage instability. I calibrate the model to match standard moments from the labor market in the 2000's. The main goal of

the simulation exercise is to evaluate the ability of changes in labor market institutions to explain the path of wage volatility. I perform this exercise by keeping the underlying idiosyncratic shock process constant and changing only the technology of compensation in the economy. Simulation results suggest that a model with new compensation technologies that attach wages to worker performance works qualitatively in the right direction of explaining the diverging trends in firm and wage instability, and appears to account for a substantial fraction of the quantitative change observed in the data.

There are a number of recent papers that motivate my consideration of alternative pay arrangements. The first paper is Lemieux, MacLeod and Parent (2009a, henceforth LMP). The authors test the effect of performance pay on wages in the PSID and ask whether returns to worker and job characteristics differ according to pay schemes. They find that compensation in performance pay jobs is more closely tied to both observed (by the econometrician) and unobserved productive characteristics of workers. The increase in the incidence of performance pay over time provides an important channel through which technological changes in the cost of monitoring and in returns to skill affect wage inequality. Performance pay is closely linked to the idea that wages are tied to effort and productivity of the

worker. A shift to paying wages that equal performance outcomes means potentially more flexible wages and a departure from norms and rigidity that could regulate behavior in the labor market.

A change in the technology of compensation is central to the explanation I advance for the increase in earnings instability. The second set of papers relevant to my hypothesis include Hubbard (2000) and MacLeod and Parent (1999). Hubbard argues that the use of on-board computers in the trucking industry provided managers with a better way to monitor production processes. IT in monitoring is productivity enhancing and potentially capable of explaining changing wage incentives. MacLeod and Parent use several data sources to document the relationship between type of job and compensation. The authors find that jobs with high power incentives (piece or commission rates) tend to be associated with more worker autonomy and that tight labor market conditions increase the use of bonuses and promotions. Moreover, the authors report anecdotal evidence that shows an increasing use of software for evaluating worker performance and a boom of services for monitoring workers. Lemieux, MacLeod and Parent (2009b) argue that performance pay jobs seem to be associated with higher wage flexibility, and that wages respond more to conditions in their local labor markets. Based on the evidence from those papers and evidence below, I allow different wage schemes in

my model and show how declining costs of monitoring can move the economy from "rigid" compensation schemes to an increased use of pay-for-performance.

1.1.2. Evidence on macroeconomic and firm-level instability

The variances of GDP, investment, and aggregate income began declining in the mid-eighties. Stock and Watson (2003) report that the standard deviation of four-quarter GDP per capita growth in the US declined about forty percent comparing the 20-year-windows before 1984 and after 1984. Several papers document and discuss the causes of the increased aggregate stability that followed the eighties (Kim and Nelson, 1999, Stock and Watson, 2005, Blanchard and Simon, 2001). More interesting for our purposes are the trends in job turnover and business volatility for the same period. Turnover rates, as measured by creation and destruction of jobs, have decreased steadily in the US economy after the 1983 recession. A similar trend is observed by Davis, Faberman and Haltiwanger (2006) for the entire economy in the nineties using Business Employment Dynamics data. In the same vein, Davis, Haltiwanger, Jarmin and Miranda (2006, henceforth DHJM) report an overall decrease in the volatility of growth rates of businesses in the US beginning in the late 70's.¹

¹Previous work - Comin et al (2006) - focused on publicly traded firms, which display rising volatility in recent years. Davis, Haltiwanger, Jarmin and Miranda (2006) partially overturn the results of Comin et al (2006) for firm volatility with COMPUSTAT data, showing that once the

Figures 1 to 3 show the secular decline in business volatility and turnover rates in the US economy over the period 1976 to 2005. I present the evidence on firm volatility using different measures and data sources to demonstrate that the decline in firm instability is a robust feature of the data. Figure 1 displays the cross section standard deviation of the growth rate of employment, computed using the Longitudinal Business Database (LBD), which contains annual observations on employment and payroll for all U.S. businesses.² This measure of firm volatility is cyclical, and displays its highest level in the pre-nineties period. There is a declining trend in volatility when we compare the periods before and after the early eighties.

Figure 2 shows turnover rates measured using job flows data from the LBD. Job creation and destruction rates represent the amount of job churning in the economy. Both series display a steady decreasing trend over my sample period.³

Figure 3 shows the quarterly excess job reallocation rate for the whole private sector calculated using the BLS Business Employment Dynamics (BED) database. The excess job reallocation rate provides a measure of cross sectional dispersion in establishment growth rates. It measures the amount of turnover that exceeds what

sample is increased to include both private and publicly owned firms, there has been an overall decrease in firm level volatility.

²Source: Davis, Faberman and Haltiwanger (2006a).

³Source: DFHJM.

is necessary to account for the net employment growth in the economy.⁴ Note that despite the different data source and measure, we still see a decline in business volatility over the sample period.

Labor market outcomes are the result both of churning jobs between firms, and of churning workers across labor market states. There is no long, consistent time series measuring worker flows for the US economy, which makes it hard to identify long run trends in overall accessions and separations. It is possible, however, to document trends for the subset of worker transitions in and out of employment using data from the Current Population Survey (CPS). Figure 4 shows quarterly averages of unemployment inflows and outflows using the CPS from 1976 to 2008. Worker flows fell almost by half from the early 1980s to the mid 1990s and thereafter. The evidence discussed below of decreases in tenure and increases in residual inequality and earnings volatility has not been associated with rising instability of firm employment, or with higher job and worker flows.

⁴Excess job reallocation equals the sum of gross job creation and destruction less the absolute value of net employment growth. The excess reallocation rate is equivalent to the employment-weighted mean absolute deviation of establishment growth rates about zero. See Davis, Haltiwanger and Schuh (1996). I use a similar measure for change in earnings in the CPS in Section 2 in order to calculate wage instability.

1.1.3. Evidence on earnings instability

Since the work of Gottschalk and Moffitt (1994) calculating labor earnings instability using the PSID, several papers have devoted attention to documenting recent trends in earnings volatility in the US economy.⁵ Despite differences in results, methods, and measurement, overall the evidence suggests that the labor market is becoming more unstable; workers seem less able now to hold jobs with predictable earnings.

Dynan, Elmendorf and Sichel (2008), using the PSID, document a steady rise in instability of household earnings since the late 70's. The authors find an increasing trend in the standard deviation of percentage changes in several measures of earnings, such as total household income, household head earnings, combined head and spouse earnings, head annual hours and head real earnings per hour.⁶ Below, I present similar evidence using Matched March CPS data from 1980 to 2008.

A related result is analyzed in Cunha and Heckman (2007). The authors separate trends in the predictable and unpredictable components of earnings at the time agents make relevant job market decisions. They estimate that the variance

⁵See Cameron and Tracy (1998), Haider (2001), and Hertz (2006) for examples.

⁶Shin and Solon (2008) repeat the exercise of Dynan et al (2008) using different earnings measures and find a smaller increase in wage instability.

in the unpredictable part of earnings at the time of schooling choice has increased when comparing cohorts born in the sixties and late seventies.

Two additional facts about recent US labor market trends are noteworthy in this context: first, occupational mobility increased up to the mid 90's and stabilized thereafter (Moscarini and Thomsson, 2007). Second, wage inequality increased in overall measures prior to the early 90's.⁷ Several papers study the evidence of rising wage inequality in the US (Katz and Autor, 1999, Acemoglu, 1999, 2002, Violante, 2002, Piketty and Saez, 2003). The empirical evidence clearly suggests that recent earnings gains have been highest in the highest wage percentiles. Increases are also evident in other measures of inequality including the 90/10 gap, college/high school gap and residual inequality (accounting for age, gender, experience and education). In this paper I focus on instability rather than inequality. Though these two phenomena are likely to have similar origins, they do not follow the same trend over time. Hence I treat them as separate pieces of evidence.

1.1.4. Alternative explanations for the rise in earnings instability

⁷According to Autor, Katz and Kearney (2005), wage inequality kept increasing for the 90-50 wage percentiles after the mid-90s, but remained stable or decreased for some groups in the lower half of the wage distribution.

Like most complex events, the recent rise in earnings instability can accommodate several possible explanations. I discuss here several possible explanations related to secular changes in the labor force or higher "turbulence" in the labor market.

The composition of the US labor force has changed over the last 30 years. The population is aging even while the tenure distribution is apparently decreasing (Farber, 2008). Also, skilled workers occupy a growing share of jobs (Autor, Katz and Kearney, 2005). It is unlikely that these changes in labor force composition can provide a consistent explanation of rising earnings instability, since experienced and skilled workers should be less susceptible to wage instability than other groups.

Financial innovation has allowed households to self-insure against increasing wage instability, according to Dynan, Elmendorf and Sichel (2008). Though the authors argue that this link is important in explaining the Great Moderation, they are silent about the events in the labor market that could have triggered higher income instability. Financial innovation has affected both firms and workers, and financial constraints can make employment more sensitive to shocks.⁸ However, it is unclear a priori why financial innovation would change compensation schemes used in the labor market.

⁸See Chugh (2009).

Cunha and Heckman (2007) find that the variance in the unpredictable part of earnings at the time of schooling choice has increased over the last 20 years. They speculate that this is linked to higher "turbulence" or skill depreciation after job loss (Ljungqvist and Sargent, 2004). Earnings losses of displaced workers have been detected by several authors in the literature (see Farber, 2005 for a summary). Though Ljungqvist and Sargent use turbulence to explain rising European unemployment, it can also explain rising earnings uncertainty if the rate of skill loss has increased. The main drawback of this reasoning is that the rate of involuntary job loss, the type most likely to lead to declines in earnings, has if anything decreased since the early eighties (Davis, 2008). It would take a large increase in the loss in skills following job loss to offset that trend.

Another plausible source of higher volatility is discussed in Violante (2002). The author uses a model with search frictions that links new vintage specific skills to workers matched to different machines. He shows that in such a model an increase in the pace of technological change spreads the wage distribution of similar workers. Workers face losses from separation since they have to learn new vintage abilities, and uncertainty in outcomes increases with turnover.

As discussed by Comin, Groshen and Rabin (2006), several models imply that higher turbulence for firms will lead to more turbulent wages. Coincident firm and worker trends can be explained as resulting from "bad luck" - larger idiosyncratic

firm shocks translate into unstable wages. Since the firm evidence discussed in the previous section does not suggest higher idiosyncratic firm shocks, however, a story based on changes in the size and variance of the shock process affecting firms is unlikely to explain simultaneous occurrence of rising wage instability and declining firm instability. Models in which shocks to occupations, jobs or vintages accelerated generally imply that both worker and firm instability should have gone in the same direction. The literature has yet to come to grips with the conflict between trends in labor market and in firm outcomes.⁹

The evidence highlighted above is discussed in Davis and Kahn (2008). Despite the ongoing volume of research on the Great Moderation and its relationship to firm behavior, little attention has been given to reconciling the evidence of macroeconomic and firm moderation with evidence of growing earnings instability. Davis and Kahn suggest an explanation based on employment relationships having become more flexible. They argue that employers are increasingly capable of using wages as a margin of adjustment. Less unionization, weakening restrictions on

⁹I do not consider the problem of consumption volatility and its response to income shocks. As argued in Krueger and Perri (2009), consumption response to income shocks is higher for individuals who do not own real state or business. This suggests that financial constraints matter for the transmission of earnings volatility to consumption and wealth volatility. Whether the increase in earnings instability is related to changes in the trends of consumption volatility for the US economy is an open question. To the extent the financial innovation has increased since the early eighties, the connection between the two volatility outcomes is likely to have decreased with better access to financial markets.

minimum wages, and more flexible pay schemes are consistent with fewer job flows and more earnings volatility. Davis and Kahn suggest this explanation without explicitly modeling it. If wage institutions are the key to explaining the puzzle, we need to model the underlying factors that have led to the adoption of pay schemes under which workers face more variability.

1.2. New evidence from the March CPS

The ideal data to study the relationship between the volatilities in firm and earnings outcomes is matched longitudinal data on firms and their employees. To the best of my knowledge, Comin, Groshen and Rabin (2006) is the only work in this vein. They use the Federal Reserve Bank of Cleveland's Community Salary Survey (wages and employment for specific occupations for identified firms) to link higher firm volatility and the rising variance of wages. The result is in line with their previous work with firm volatility in the COMPUSTAT data. However, as mentioned above, DHJM find that firm volatility has declined over time in a more representative sample of firms.

I adopt a route that is more roundabout but that does not require as much information. I use matched March CPS data to construct measures of earnings growth for short panels. The cross sectional variation in the earnings growth data allows me to answer questions such as: Are trends for job stayers and job

movers different? Do labor market conditions like the unemployment rate matter for volatility? I use answers to such questions to guide my model construction.

The data I use are the March CPS files from 1980 to 2008. The CPS was not designed for longitudinal analysis. Groups are interviewed for 4 consecutive months, dropped from the sample for 8 months, then reinterviewed for another 4 months. Given this structure, around half of the sample in each month will appear again a year later and can potentially be matched. I match rotation groups from March to March in order to construct short panels that give earnings growth for a relatively large sample. Mandrian and Lefgren (1999) develop an algorithm to match observations and evaluate the quality of the match results from 1980-98, which I extend up to 2008. I link individuals based on their CPS identification codes. Since there is some level of mismatch, I further restrict observations to matches that have the same sex and race across the two observations.

There are some advantages in using the CPS instead of other data previously analyzed for similar questions, such as the PSID. The CPS is used to study both standard micro labor topics and aggregate flows in and out of employment. It collects earnings information not only from heads and spouses, as in the PSID, but from all members of the household. The sample size is also larger and more

representative of the labor force. Hence, using the CPS allows me to address competing explanations that rely on compositional changes in the labor market.

These advantages come at a cost. Matched CPS data only provide information for one-year changes. None of the intertemporal structure discussed in the work that initiated the study of variance in transitory and permanent components of earnings (Gottschalk and Moffitt, 1994) can be captured with the CPS. I am forced to focus only on short-term changes.

A more worrisome problem is that the CPS does not provide tenure information. The tenure distribution has likely changed over my sample period. Farber (2008) presents evidence on tenure using CPS Tenure Supplements from 1973 to 2006. The results are puzzling - job tenure is decreasing while the job loss trend as measured with the Displaced Worker Survey (DWS) is not increasing. Farber argues that the DWS might not be capturing all instances of separations. This explanation is unlikely to capture the entire story since other measures also point to lower job loss in the last 20 years (Davis, 2008).

The lack of information on tenure makes it harder to evaluate competing explanations of earnings instability that rely on increased mobility. There is evidence that job-to-job and occupational mobility have increased since the late 70's (see Moscarini and Thomsson, 2007, and Fallick and Fleishman, 2004, for evidence with

monthly CPS, and Kambourov and Manouskii, 2007, for evidence with the PSID). Nevertheless, mobility trends are more cyclical than the results I present later for earnings instability for job stayers. While earnings instability increased steadily over my sample period, Bjelland et al (2008) report that the pace of employer-to-employer flows as a fraction of employment and separations has remained low in the post-2001 period following the recession.

One should worry whether the matched sample is representative of the overall labor force for which I want to measure the trend in volatility. The probability of being matched in two consecutive March interviews depends on observables such as marital status, age, employment, etc. I correct for such selection in the following exercises by using propensity score weights in all weighted measures. See the Appendix on sample selection for details on this method.¹⁰

The variables used in the analysis are total annual wage and salary earnings, hourly earnings and total annual hours worked. Those variables are either asked directly in the March Supplement or can be constructed, and refer to the previous

¹⁰Each year is matched to the following year' survey. For instance, 1980 refers to the merge of 1980-81 and corresponds to calendar years 1979-1980. Years 1985-86 and 1995-1996 could not be matched due to problems with the household identifiers. The exercises reported exclude married women from the sample for reasons discussed in Footnote 12. For more details on matching and sample selection, see Appendix 1.

calendar year.¹¹ With the short panels, I calculate measures of the dispersion in growth rates in earnings and hours for different groups. Assume we have earnings e for person i in periods t and $t+1$. The growth rate of e is given by $G_{eit} = \frac{e_{it+1} - e_{it}}{.5(e_{it+1} + e_{it})}$.

The first exercise is similar to Davis and Kahn (2008).¹² I measure instability as the cross-section weighted average of absolute growth rates. This measure is analogous to the excess job reallocation rate calculated at the firm level.

$$(1.1) \quad \sigma_t = \textit{Weighted_Average}(|G_{eit}|)$$

Figure 5 shows this measure of hourly earnings instability and total hours instability for the sample of private non-farm workers (excluding married women¹³)

¹¹Total household income, Total earnings, Hours worked in the previous year and Weeks worked in the previous year are asked directly. From these I construct Total hours worked= Hours worked per weekX Weeks worked, and Hourly earnings=Total earnings/ Total hours worked.

¹²Davis and Kahn (2008) measure consumption volatility using quarterly data from the interview segment of the Consumer Expenditure Survey. The authors compute the absolute value of the log change in consumption expenditures for each household and then average over households. This average value for the magnitude of household-level consumption changes is their measure of consumption volatility. In results not reported I calculate two other dispersion measures: the weighted average of individual growth rates demeaned by the year average growth rate, and the cross section standard deviation of growth rates. All measures display similar results for the trend in earnings instability.

¹³I exclude married women from the sample. The trend for total hours instability in the sample including married women shows a decline in hours volatility. This is likely due to the increase in labor force attachment for this group over the sample period. The exclusion of married women from the sample does not change results for earnings volatility substantially and has the advantage of not confounding long term changes in the composition of the labor force with changes in the stability of earnings within employment relationships.

from 1980 to 2007. There is no notable trend in total hours instability, but hourly earnings instability displays an increasing trend.

Figures 6 and 7 separate workers between job stayers and job movers/losers. Job stayers are defined as workers who report in both March interviews being employed and having worked full time full year in the previous year without changing employers.¹⁴ As of March of their second interview, stayers have at least two years of job tenure. Job movers/losers are workers who report experiencing unemployment or job change prior to one of the March interviews.¹⁵ Figure 6 shows an increase in total earnings instability for job stayers. Figure 7 shows no increase

¹⁴March CPS data are retrospective, and I infer worker flows from 3 variables: 1) "For how many employers did ...work in 20..? If more than one at same time, only count it as one employer". 2) "Weeks was ... looking for work or on layoff from a job? ". 3) "Were the weeks ... was looking for work (or on layoff) all in one stretch?". For full time full year workers with one employer in each period, the problem is immaterial, since these workers stay in the same job. A more comprehensive measure of job stayers includes part time part year workers with no more than one employer in each period and no weeks looking for a job or on layoff. Those might not be stayers in case they exited the labor force at the end of period t and reentered in t+1 with a different employer. Results with the comprehensive measure of stayers are virtually the same as with full time full year workers. The fraction of job stayers does not display a trend over time in my sample. Job movers/losers are workers that report unemployment or more than one employer in the previous year in one or two March interviews. There might be some stayers in this group if they are in the beginning of their job tenure in the beginning of t or the end of their tenure in the end t+1. The fraction of those workers is no more than 5% of the overall sample in each year, and also displays no trend over time. The comprehensive measure of job stayers and the job movers/losers constitute two mutually exclusive groups.

¹⁵Note that I am not separating job movers into those that experience unemployment and those that transit directly between different employers. The consequences for wage instability are potentially different since displaced workers are more likely to experience earnings losses (Jacobson et al, 1993).

in total earnings instability for job movers/losers. Hourly earnings instability increased for both groups of workers. The lack of trend in total earnings instability for job movers/losers is probably due to two opposing effects: higher hourly earnings instability and smaller worker and job flows.

In order to compute the long-run change in instability over the entire period I estimate linear trends using individual σ_{it} as the dependent variable. Tables 1 and 2 give coefficients for the linear trend and implied cumulative growth of instability.¹⁶ Table 1 reports results for the entire sample of private non-farm workers, job stayers and job movers/losers. Total earnings and hourly earnings instability increased for both the full sample and job stayers. Job movers display rising instability in hourly earnings but a decrease in total earnings and total hours instability.

In table 2, I examine job stayers with high school or less education and job stayers who are less than 45 years old. The increase in earnings instability for the samples of younger and less educated job stayers is higher than the increase in instability for the overall sample of stayers. Younger and less educated workers are

¹⁶I calculate the total increase in instability using the value of the coefficient, β , of the time trend in a linear regression. For instance, the increase in instability for total earnings for the full sample over 28 years is given by $28 * \hat{\beta} = .029$, where $\hat{\beta}$ is the estimated coefficient on the time trend for total earnings instability.

a declining fraction of the population over the sample period. This decline along with their higher and increasing instability dampens the overall instability trend for job stayers.

My last exercise looks at differences between performance pay and non-performance pay jobs. The March CPS does not provide detailed information about the type of pay, which prevents the identification of performance pay jobs. I replicate to the extent possible the CPS instability measures by calculating one-year percent changes in hourly earnings in the PSID from 1976 to 1996 for job stayers.¹⁷

Following the literature, I define performance pay jobs as those receiving some pay in the form of a commission, bonus or piece-rate over the duration of the

¹⁷I thank Daniel Parent for providing the data from LMP. The sample consists of male heads of the household aged 18 to 65 with average hourly earnings between \$1.00 and \$100.00 (in \$79). Due to the longitudinal feature of the PSID, I can define job stayers as workers that remain in the same job match. I construct one-year changes in hourly earnings for job stayers using worker that remained in the same job match. Note that in the case that the job match is observed for more than one year, I have the growth rate for the same individual in more than one time period. In the CPS I only observe the growth rate of an individual once, when she is matched across two consecutive interviews. See appendix for details on the CPS and PSID samples.

worker-firm match.¹⁸¹⁹ I also look at unionized jobs, defined as jobs with wages subject to collective bargaining. I separate jobs into four mutually exclusive groups: workers in performance pay with no collective bargaining, workers with collective bargaining and no performance pay, workers not in performance pay or collective bargaining, and workers in both collective bargaining and performance pay.²⁰ Table 3 presents mean hourly earnings instability for those four groups over the sample period. Table 3 also presents t-statistics for differences in mean instability between

¹⁸As in the literature, I define performance-pay jobs as employment relationships in which part of the worker's total compensation includes a variable pay component (bonus, a commission, piece-rate) at least once during the course of the relationship.

The issue of measuring incidence of performance-pay in the beginning and end of the sample arises. The classification of jobs according to pay understates the fraction of performance pay in the two end points of the sample. Conditional on job duration, a job is observed fewer times at the two ends, thus it is less likely to display positive bonus, commission, or piece-rate. One solution to this problem is to rebalance the sample using regression methods. As indicated in Lemieux et al (2009), reweighting the sample does not affect substantially incidence graphs or regression results using performance pay dummies.

¹⁹Tips are not included in the definition of performance pay jobs. Though they constitute a form of incentive pay (done by the consumer and not the employer), the questions about form of pay change over time in the PSID. For interview years 1976-1992, the question about pay refers specifically to any amounts earned from bonuses, overtime, or commissions in addition to wages and salaries earned. Starting with interview year 1993, there are separate questions about the amounts earned in bonuses, commissions, tips, and overtime for the previous calendar year. For the sake of comparability, overtime and tips are excluded from the definition of performance pay. This procedure is likely to understate the incidence of performance pay jobs, and causes a bias if the fraction of workers receiving tips is changing over time. Using the data starting in 1993, I compare incidence of performance pay and size of incentive in terms of total wages between the full sample and the sample without jobs reporting positive tips. I find no significant change in results.

²⁰The sample size is too small to calculate separate time trends for these subgroups. I choose to pool all observations. I compute $Mean(|g_{it}|)$ using growth rates in hourly earnings for each job group. Results use PSID sampling weights.

groups. The results indicate that earnings instability is significantly higher for non-union performance pay jobs than for union non-performance pay jobs. For non-union jobs there is no significant difference in instability between performance and non-performance pay jobs. Union jobs display less variability than non-union jobs regardless of whether performance pay is observed.

Mean differences in wage instability can obscure the effect of performance pay and unions on volatility if performance pay or union status are correlated with other factors that are potentially associated with instability. I use the following regression exercise to net out the effect of worker and job match characteristics as well as conditions in the local labor market. I regress individual $|g_{it}|$ on a dummy for performance pay jobs and a dummy for collective bargaining. The control variables used are worker fixed effects, tenure, experience, year effects, 1-digit occupation and industry dummies, unemployment at the county level and a measure of 1-digit industry-level firm instability.²¹ The coefficients for the performance pay dummy and union dummy are presented in Table 4. Column 1 presents results without worker fixed effects and characteristics. The dummy for unionized job is negative and statistically different from zero. Column 2 presents results including worker fixed effects and characteristics. Regression results in Column 2 indicate

²¹Standard errors are clustered at the job match level. The data for firm-level instability come from DJHM (2006). See their paper for definitions of volatility and dispersion in firm outcomes and data construction.

that the effect of performance pay on wage instability is positive when control variables are included (column 2), but not when control variables are excluded (column 1). The effect of the union dummy is not statistically different from zero once I include controls in the regression. This suggests that job stayers in performance pay jobs have characteristics such as higher educational level and tenure that decreases their wage instability. Nevertheless, the effect of bonus or commission on instability is positive.

Figure 8 displays the incidence of performance pay jobs in the PSID over time for my sample period. It also shows the fraction of jobs that received a bonus, commission or piece-rate in a given year, and the fraction of unionized jobs.²² One can see a clear rise in the incidence of performance pay jobs, which is accompanied by a decline in unionization. A simple back-of-the-envelope calculation using the average instability for each group over the period, and the change in incidence of wage setting institutions from 1976 to 1996, gives an increase of 1.27% in hourly earnings instability.²³

²²Note that not all performance pay jobs receive a bonus in a particular year. Performance pay jobs are defined as jobs that get a bonus sometime during the job match.

²³In the back-of-the-envelope calculation I take the average value of wage instability in each group, and weight each group by their fraction in the PSID sample in 1976 and 1996. The difference between the instability in the two time periods measures the portion of the increase in wage instability due to a change in composition of wage schemes. I also estimate the time trend coefficient for the regression on wage instability with the sample of job stayers in the PSID. The total increase in wage instability the estimated time trend is 7.2%.

To summarize our results, the main message we take is that rising wage instability reached several segments of the labor market. This phenomenon is unlikely to represent a figment of the data, since the results are robust to different data sources and methods. Nevertheless, aggregate measures mask large degrees of heterogeneity between groups.

The change I report is more related to the behavior of earnings than hours. While earnings instability is cyclical, especially for job movers/losers, the long-term rising trend in instability cannot be due to increased transitions in and out of unemployment. As discussed in the previous section, worker and job flows seem to be decreasing over the same period.

The most important result concerns job stayers in the March CPS. Those workers do not report any major job transitions and are thus by definition in a "stable" employment relationship. The fact that dispersion for this group displays a substantial trend increase gives more confidence that the phenomenon of rising instability affects ongoing employment relationships. Secular changes in mobility, skill loss after displacement and demographic characteristics of the labor force could still matter for instability. Nevertheless, given that the rise in hourly earnings instability is large for job stayers, I choose to focus on the latter group for the remainder of this paper.

Lastly, the exercise with the PSID indicates that jobs with some form of bonus pay have higher wage instability than other jobs. This suggests that the form of pay matters for wage instability outcomes. Based on that, I argue in the next section that main mechanism driving the increase in earnings instability is an institutional change in wage determination. The model is built upon this conjecture.

The dissertation proceeds as follows. The remainder of Chapter 1 discusses the evidence on firm and wage instability. Chapter 2 presents a model of performance pay and unionized markets in order to tackle the diverging long run trends in employment and wage instability. Chapter 3 presents a business cycle model of performance pay with uncertainty shocks.

CHAPTER 2

Stable Firms and Unstable Wages

What I refer to as an institutional change in wage setting is a shorthand for a series of events in the labor market that have happened in the past three decades: less unionization, fewer restrictions on minimum wages, and more flexible pay schemes attached to firm and worker performance. Institutional changes have been proposed as an explanation for the rise in wage inequality in the US. I argue below that the same changes might help to explain increased earnings instability of job stayers.

My conjecture is that there are two equilibria in wage setting institutions. The first prevailed during the eighties, when monitoring worker productivity was too costly and the wage had to be tied to job characteristics. The second is the current labor market in which information technology has allowed for performance based pay schemes. Some institutions naturally belong to the eighties steady-state, such as minimum wages and unions. Performance pay is more related to recent events, so can be identified with the 2000's model.

2.1. An island model of the labor market

I move below to a structural general equilibrium model of the labor market. I start with an indirect search version of the Lucas and Prescott (1974) model of frictional labor markets. That set up is used in several wage inequality and unemployment studies (Jovanovic, 1987, Alvarez and Veracierto, 1999, Veracierto, 2008, Kambourov and Manovskii, 2007). I choose to build on Alvarez and Veracierto (1999).

I describe first the features of the environment that hold in all sectors of the economy, regardless of their choice of pay scheme. Then I proceed to discuss the specific elements that apply to firms that use performance pay contracts versus those that use union/norm wage setting.

Environment:

There is a continuum of local labor markets dubbed islands that are separated geographically. Islands are constantly hit by idiosyncratic productivity shocks and movement of workers between islands requires one period of search.

Islands have an idiosyncratic productivity process, ε , that follows a Markov process that can take values $\varepsilon_1 < \varepsilon_2 < \dots < \varepsilon_m$ and has transition matrix $Q(\varepsilon, \varepsilon')$. At the beginning of every period, each island is characterized by a pair (x_t, ε_t) where x is the labor force and ε the current productivity shock. Accordingly, feasibility

in the market implies that $g(x, \varepsilon) \leq x$, where $g(x, \varepsilon)$ is employment, and the labor force in the island evolves with the arrival of new agents from unemployment, U , joining those that worked in the previous period, such that $x' = U + g(x, \varepsilon)$. The employment rule and the Markov process for idiosyncratic productivity generate an invariant distribution of islands over labor force and productivity given by $\Omega(X', \Sigma') = \int_{\{(x, \varepsilon): U + g(x, \varepsilon) \in X'\}} Q(\varepsilon, \Sigma') \Omega(dx \times d\varepsilon)$.

There is a measure one of potential workers with linear preferences over consumption, c_t . I assume complete markets. The timing is such that after observing (x, ε) and total compensation, $w(g(x, \varepsilon), \varepsilon)$, workers decide on whether to stay or leave their local labor market. Search is indirect, hence workers who leave their market face one period of searching and arrive randomly next period to a new island. Those who stay work at the given wage rate. I denote the expected value of unemployment as ϕ , and the expected value of employment as $v(x, \varepsilon)$. The agents problem is described by $v(x, \varepsilon) = \max\{\phi, w(g(x, \varepsilon), \varepsilon) + \beta E \int v(U + g(x, \varepsilon), \varepsilon') Q(\varepsilon, d\varepsilon')\}$, where agents take $g(x, \varepsilon)$ and the wage determination as given.

Each island has a continuum of producers that share a common island-specific productivity shock. The production technology uses labor, g , effort, a , and has decreasing returns to scale, α , where $0 \leq \alpha \leq 1$ indexes the elasticity of output

with respect to g . Output is given by $F(g, \varepsilon) = \varepsilon g^\alpha$. I assume there are two types of productive arrangements. In performance pay jobs the worker exerts positive effort and output is given by $F(g, \varepsilon) = (1 + \varsigma a)\varepsilon g^\alpha$, where a stands for worker effort and ς is the marginal contribution of effort to output. The performance pay job uses monitoring and sets up a contract to define compensation. In unionized jobs effort is zero and output is given by $F(g, \varepsilon) = \varepsilon g^\alpha$, which is equivalent to setting ς equal to zero.¹ Unions are the case when no monitoring technology is used. We can interpret the productive arrangement in the unionized case as if the worker exerts an "ordinary" level of effort, which I normalize to zero. I denote the marginal product of labor by $f(g, \varepsilon) = (1 + \varsigma a)\alpha\varepsilon g^{\alpha-1}$.

In equilibrium, employment in the island has to be consistent with individual decisions. If $v(x, \varepsilon) > \theta$, all individuals in the market are strictly better staying than leaving, and $g(x, \varepsilon) = x$. If $v(x, \varepsilon) = \theta$, agents are indifferent between staying and leaving, and $g(x, \varepsilon) = \bar{g}(\varepsilon)$, where $\bar{g}(\varepsilon)$ solves $\phi = w(\bar{g}(\varepsilon), \varepsilon) + \beta E \int v(U + \bar{g}(\varepsilon), \varepsilon')Q(\varepsilon, d\varepsilon')$. Using $g(x, \varepsilon) = x$ if $v(x, \varepsilon) > \theta$, and $g(x, \varepsilon) = \bar{g}(\varepsilon)$ if $v(x, \varepsilon) = \theta$, in the agents problem we obtain the functional equation $v(x, \varepsilon) = \max\{\phi, w(x, \varepsilon) + \beta E \int v(U + g(x, \varepsilon), \varepsilon')Q(\varepsilon, d\varepsilon')\}$. The employment rule for this problem is such that $g(x, \varepsilon) = \min\{x, \bar{g}(\varepsilon)\}$.²

¹We can interpret the productive arrangement in the unionized case as the case that the worker exerts an "ordinary" level of effort, which I normalize to zero.

²See Alvarez and Veracierto (1999) for a complete derivation of the problem.

I model below two types of labor markets according to their wage setting institutions: markets with only performance pay jobs and markets with only unionized jobs. Both market types are in the same framework, but differ on how total compensation or the wage rate is determined.

Wage setting in performance pay markets: The performance pay model I use is based on Baker, Gibbons and Murphy (1994). I extend the baseline set up in the island model in order to include an effect of worker choice of effort on output outcomes. Assume that the marginal contribution of worker effort to firm output is given by m . Wage contracts between firms and workers cannot be written on m , since it is too complex to be objectively assessed. However, there is a verifiable performance measure, P , which is an imperfect measure of m . In order to simplify notation, assume that m can only take values of $\zeta \varepsilon g^\alpha$ or 0, and P can take values of $\zeta \varepsilon g^\alpha$ or 0. The firm observes P and m , but only P is contractible.

At each period, the worker can choose an action that stochastically determines both output and performance. The relationship between worker effort, a , and the firm's outcome is such that $\text{Pr ob}(m = \zeta \varepsilon g^\alpha \mid a) = a$, where a is between 0 and 1. The probability of observing a positive performance measure is given by $\text{Pr ob}(P = \zeta \varepsilon g^\alpha \mid a) = \mu a$, where μ is a random variable with mean $E(\mu)$ and variance $\text{var}(\mu)$, bounded above so that $\text{Pr ob}(P = \zeta \varepsilon g^\alpha \mid a) \leq 1$. We can think of μ as the difference between the effect of effort on performance and output. There

are states of world when μ is large and high effort contributes more to performance measures than to the value of the firm. When μ is small, we have the opposite case, and high effort would likely generate large value for the firm, but would not increase performance measures. I assume that firms do not know μ , while workers observe μ after deciding whether to stay on the island, but prior to choosing effort. From the viewpoint of the firm and the worker, effort and bonus are stochastic prior to the realization of μ . The problem of the firm is to offer a compensation package prior to the realization of μ that aligns effort to productivity, and the problem of the worker is to choose the optimal level of effort once μ is realized.

The sequence of events is such that firms and workers start the period knowing the state of the economy (x, ε) , and the variance and mean of μ . At the island level there is a spot market for binding wage contracts. The assumption of binding contracts is common in the literature, since revelation of μ to the worker and worker effort can be thought of as occurring simultaneously. The contracts stipulate a base pay, and a bonus paid in case a positive performance measure is observed. More specifically, the pay scheme offers a base pay, $w(x, \varepsilon)$, and a bonus, B , paid if $P = \varsigma \varepsilon g^\alpha$.

The firm takes the base pay as given and decides on the size of the bonus and employment. The worker then decides whether to take the contract or not. After hiring takes place, the worker observes μ and chooses effort. The worker is

privately informed about μ , hence the firm has to offer a compensation scheme based on the expected value of μ and the schedule for the worker's optimal choice of effort. Before observing μ , the expected value of the bonus for the worker is given by $E_\mu[\mu a^* B]$. Exerting effort is costly for the worker. I assume that the disutility caused by the effort level a equals γa^2 . I also assume that μ is *iid* and that the firm and the worker are atomistic, taking the base pay as given.

Worker problem:

The Bellman equation for the worker is given by:

$$(2.1) \quad v_p(x, \varepsilon) = \max\{\phi, E_\mu[\max_a w(x, \varepsilon) + \mu a B - \gamma a^2 + \beta E \int v_p(U_p + g(x, \varepsilon), \varepsilon') Q(\varepsilon, d\varepsilon')]\}$$

The choice of effort and bonus is then equivalent to a one period game between the worker and the firm. Optimal effort maximizes the current return from working and is equal to $a^* = \frac{\mu B}{2\gamma}$.

The worker accepts the performance pay job only if it gives an expected value higher than searching. The worker choice of taking the job or searching gives the minimum base pay that clears the local market:

$$(2.2) \quad E_\mu[\max_a w(x, \varepsilon) + \mu a B - \gamma a^2 + \beta E \int v_p(U_p + g(x, \varepsilon), \varepsilon') Q(\varepsilon, d\varepsilon')] \geq \phi$$

$$(2.3) \quad w(x, \varepsilon) \geq E_\mu[\phi - (\mu a^* B - \gamma a^{*2} + \beta E \int v_p(U + g(x, \varepsilon), \varepsilon') Q(\varepsilon, d\varepsilon'))]$$

Firm problem:

The technology is such that $E_\mu[F(g, \varepsilon)] = E_\mu[(1 + \zeta a)\varepsilon g^\alpha]$. On average, worker effort increases output by $E_\mu[\zeta a \varepsilon g^\alpha]$. The firm problem is to choose B and g to maximize profits taking into account the incentive constraint for the worker:

$$(2.4) \quad \pi = \max_{B, g} E_\mu[(1 + \zeta a^*)\varepsilon g^\alpha - wg - \mu a^* Bg]$$

$$(2.5) \quad \text{s.t. } a^* = \frac{\mu B}{2\gamma}$$

The first order conditions are as follows:

$$(2.6) \quad B : E_\mu[\zeta \frac{\mu}{2\gamma} \varepsilon g^\alpha - \frac{\mu^2 B}{\gamma} g] = 0$$

$$(2.7) \quad g : E_{\mu}[(1 + \varsigma \frac{\mu B}{2\gamma})\varepsilon \alpha g^{\alpha-1} - w - \frac{\mu^2 B^2}{2\gamma}] = 0$$

The first order conditions imply:

$$(2.8) \quad B^* = \frac{\varsigma E_{\mu}[\mu \varepsilon g^{\alpha}]}{2 E_{\mu}[\mu^2 g]}$$

$$(2.9) \quad w = E_{\mu}[(1 + \varsigma \frac{\mu B^*}{2\gamma})\varepsilon \alpha g^{\alpha-1} - \frac{\mu^2 B^{*2}}{2\gamma}]$$

From (10), firms pay the expected benefit of effort upfront in the form of base pay, $\varsigma \frac{\mu B^*}{2\gamma} \varepsilon \alpha g^{\alpha-1} - \frac{\mu^2 B^{*2}}{2\gamma}$. After the worker observes μ , she chooses optimal effort.

Equilibrium employment:

The base pay that clears the market depends on supply and demand for labor.³

Using (4) and (10), we have:

³See appendix for the derivation of performance pay market equilibrium conditions.

(2.10)

$$w = E_\mu \left[\left(1 + \zeta \frac{\mu B^*}{2\gamma}\right) \varepsilon \alpha g^{\alpha-1} - \frac{\mu^2 B^{*2}}{2\gamma} \right] \geq E_\mu \left[\phi - (\mu a^* B^* - \gamma a^{*2} + \beta E \int v_p(U + g(x, \varepsilon), \varepsilon') Q(\varepsilon, d\varepsilon')) \right]$$

which can be rearranged as follows:

$$(2.11) \quad E_\mu [\varepsilon \alpha g^{\alpha-1} + (a^* \zeta \varepsilon \alpha g^{\alpha-1} - \gamma a^{*2}) + \beta E \int v_p(U + g, \varepsilon') Q(\varepsilon, d\varepsilon')] \geq \phi$$

In (12), the expected net benefit of effort is given by the second term in parentheses, $a^* \zeta \varepsilon \alpha g^{\alpha-1} - \gamma a^{*2}$. The first best would be for the worker to exert effort until the marginal cost equals marginal benefit, or $a^{FB} = \frac{\zeta \varepsilon \alpha g^{\alpha-1}}{2\gamma}$, independently of μ . Because the worker is privately informed on effort and μ , this outcome cannot be achieved, and effort is given by $a^* = \frac{\mu B^*}{2\gamma}$.⁴

⁴Note that the expected benefit of effort is quadratic in effort. The firm and the worker achieve the maximum benefit in the a^{FB} case. The two extreme cases are when effort is zero, and there is no probability of positive performance or value; and when $a = \frac{\alpha \zeta \varepsilon g^{\alpha-1}}{\gamma}$, and the worker is exerting too much effort in order to increase the chances of receiving a bonus. Note that the existence of a perfect performance measure allows for the implementation of the first best. Assume without loss of generality that $var(\mu) = 0$, $\alpha = 1/2$, and $\mu = 1$, but output is not contractible. The worker chooses effort to maximize the current return $w + ab - \gamma a^2$. Using the fact that in this case $w = (1 + \zeta a) \alpha \varepsilon g^{\alpha-1} - ab$, we have that $a^* = \frac{\zeta \alpha \varepsilon g^{\alpha-1}}{2\gamma}$, which implies $a^* = a^{FB}$. This is a standard result in contract theory. Given the preference assumptions, whenever there is a performance measure that responds to effort in the same way that output responds to effort, the first best can be implemented (see Baker, 1992).

Next consider the optimal bonus choice and the base pay. Since the size of the bonus and employment are decided before the realization of μ , the firm can treat μ as independent of g , so that the optimal bonus can be simplified as $B^* = \frac{E_\mu[\varsigma \frac{\mu}{2\gamma} \varepsilon g^\alpha]}{E_\mu[\frac{\mu^2}{\gamma} g]} = \frac{\varsigma}{2} \frac{E_\mu[\mu] \varepsilon g^{\alpha-1}}{[E_\mu[\mu]^2 + \text{var}(\mu)]}$. When idiosyncratic productivity ε is high or the labor force in the island is low, it pays for both sides of the market to increase the bonus and effort. The bonus is thus sensitive to local labor market conditions. In a similar fashion, for high values of the marginal contribution of effort to output ς , performance pay is a more productive arrangement, and the bonus increases. Also, the higher the variance of the objective measure of performance, the smaller the optimal bonus and the smaller the effect of productivity on pay. When μ has higher variance, the performance measure is a noisier signal of the actual worker contribution to output and the firm has to settle for weak incentives. Weak incentives then induce a smaller effort choice by the worker. The converse is true when the variance of μ is low. In this case, the firm can provide a strong incentive using the bonus.

The variance of μ has a similar effect on base pay. Substituting the optimal bonus into the firm first order condition in equation (10) yields:

$$(2.12) \quad w = \varepsilon \alpha g^{\alpha-1} + \frac{1}{4\gamma} \frac{E_\mu[\mu]^2 (\varsigma \varepsilon g^{\alpha-1})^2}{(E_\mu[\mu]^2 + \text{var}(\mu))} \left(\alpha - \frac{1}{2} \right)$$

The use of incentive pay based on performance affects the marginal product of labor and the base pay. The base pay is decreasing in $var(\mu)$ if $\alpha > \frac{1}{2}$.⁵ The intuition is the same as in the case of the optimal bonus. When P is a noisy signal of the contribution of effort to outcomes, the optimal level of effort and the marginal value of labor are low, which decreases not only the odds of having a positive realization of P but the base pay that clears the market. Note that, neglecting the participation constraint, profits are quadratic in bonus. Optimal bonus level is given by $B^* = \frac{\varsigma}{2\alpha} \frac{E_\mu[\mu] \varepsilon \alpha g^{\alpha-1}}{E_\mu[\mu^2]} = \frac{1}{2\alpha} \frac{E_\mu[\mu]}{E_\mu[\mu^2]} B^{FB}$, where FB denotes first best. The coefficient $\frac{1}{2\alpha} \frac{E_\mu[\mu]}{E_\mu[\mu^2]}$ is the distortion brought by the performance measure. For the case that $\alpha = 1/2$, the firm does not need to compensate the worker in the base pay with the expected marginal return to effort. The firm can offer a base pay $\varepsilon \alpha g^{\alpha-1}$, and a bonus $\frac{E_\mu[\mu]}{E_\mu[\mu^2]} B^{FB}$ with probability μa . This case is equivalent to offering a piece rate on a performance measure scaled to the expected marginal value of effort in the marginal revenue. As the performance measure becomes a

⁵Note that the expected benefit of effort is quadratic in effort. The firm and the worker achieve the maximum benefit in the a^{FB} case. The two extreme cases are when effort is zero, and there is no probability of positive performance or value; and when $a = \frac{\alpha \varsigma g^{\alpha-1}}{\gamma}$, and the worker is exerting too much effort in order to increase the chances of receiving a bonus. Note that the existence of a perfect performance measure allows for the implementation of the first best. Assume without loss of generality that $var(\mu) = 0$, $\alpha = 1/2$, and $\mu = 1$, but output is not contractible. The worker chooses effort to maximize the current return $w + ab - \gamma a^2$. Using the fact that in this case $w = (1 + \varsigma \alpha) \alpha \varepsilon g^{\alpha-1} - ab$, we have that $a^* = \frac{\varsigma \alpha \varepsilon g^{\alpha-1}}{2\gamma}$, which implies $a^* = a^{FB}$. This is a standard result in contract theory. Given the preference assumptions, whenever there is a performance measure that responds to effort in the same way that output responds to effort, the first best can be implemented (see Baker, 1992).

perfect signal of the effect of effort on output ($E_\mu[\mu] \rightarrow 1$ and $E_\mu[\mu^2] \rightarrow 1$), we approach the first best, which is offering a piece rate of one. For $\alpha > 1/2$, effort is very productive. In order to induce effort variation the worker receives more than $\varepsilon\alpha g^{\alpha-1}$ in the base pay. The firm then sinks $E_\mu[\zeta a \varepsilon \alpha g^{\alpha-1} - \mu a B]$ in the base pay and offers a piece rate smaller than one on the scaled performance measure.

The cutoff rule for the level of employment that clears the local market in each island depends on the expected payoff of working under a performance pay regime. If $v_p(x, \varepsilon) > \phi$, all workers stay and $g = x$. Otherwise we have that employment at the island level solves:

$$(2.13) \quad E_\mu[\varepsilon\alpha g^{\alpha-1} + (a^* \zeta \varepsilon \alpha g^{\alpha-1} - \gamma a^{*2}) + \beta E \int v_p(U + g, \varepsilon') Q(\varepsilon, d\varepsilon')] = \phi$$

which can be rearranged as follows:

$$\varepsilon\alpha g^{\alpha-1} + \frac{\zeta^2}{4\gamma} \frac{E_\mu[\mu]^2 (\varepsilon g^{\alpha-1})^2}{(E_\mu[\mu]^2 + \text{var}(\mu))} \left(\alpha - \frac{1}{4} \right) + \beta E \int v_p(U + g^*, \varepsilon') Q(\varepsilon, d\varepsilon') = \phi$$

Whenever $\alpha > \frac{1}{4}$, the expected value of working is decreasing in the variance of the performance measure. The less noisy the performance measure, the easier

it is to align effort to idiosyncratic conditions in the market. Moreover, an increase in the return to effort, ς , leads to a higher expected value of working under performance pay.

Note that an improvement in monitoring technology represented by either a smaller $var(\mu)$ or a higher ς , raises welfare in the economy. The current return to working in a performance pay job is given by $E_\mu [w + aB\mu - \gamma a^2]$. Substituting the optimal choice of effort in the previous equation yields $E_\mu \left[w + \frac{\mu B}{2\gamma} B\mu - \gamma \left(\frac{\mu B}{2\gamma} \right)^2 \right] = E_\mu \left[w + \frac{\mu^2 B^2}{2\gamma} - \frac{\mu^2 B^2}{4\gamma} \right] = E_\mu \left[w + \frac{\mu^2 B^2}{4\gamma} \right]$. Since both terms inside the brackets are decreasing in $var(\mu)$,⁶ the expected value of working increases with improved technology. This effect in general equilibrium raises the reservation wage of unemployed workers and the value of non-employment, ϕ . The value to the worker of the increase in the bonus outweighs the utility cost of the increase in effort.

The goal of the simulation exercise presented in the next section is to evaluate whether the improvement in the technology of compensation translates into more wage instability. In order to build intuition on the results, let's look in partial equilibrium at the expected current return of working under performance pay. Denote $V_{a\varepsilon}$ the variance of the marginal product of effort on output with respect to the productivity shock, and $var(\varepsilon)$ the variance of the idiosyncratic shock. $V_{a\varepsilon} =$

$$6 \frac{\mu^2 B^2}{4\gamma} = \frac{\mu^2}{4\gamma^2} \left(\frac{\varsigma}{2} \frac{E_\mu[\mu]\varepsilon g^{\alpha-1}}{(E_\mu[\mu]^2 + var(\mu))} \right)^2 = \frac{\varsigma^2}{16\gamma} E_\mu[\mu^2] \frac{(E_\mu[\mu]\varepsilon g^{\alpha-1})^2}{(E_\mu[\mu]^2 + var(\mu))^2} = \frac{\varsigma^2}{16\gamma} \frac{E_\mu[\mu]^2 (\varepsilon g^{\alpha-1})^2}{(E_\mu[\mu]^2 + var(\mu))}$$

$(\zeta g^\alpha)^2 \text{var}(\varepsilon)$ is increasing in ζ . Better technology in performance pay means that the worker has more valuable information on how her effort affects the output. This is a standard result in linear performance pay contracts (Baker, 1992). More information for the worker indicates that she can alter significantly effort in order to affect output. The firm wants the worker to use that information to improve outcomes, and gives higher incentives to generate more effort variation. Since effort variation is costly, the firm has to compensate the worker in the base pay, $w = E_\mu[(1 + \zeta a^*)\varepsilon \alpha g^{\alpha-1} - \mu B a^*]$. The higher effort variation induces higher wage instability by making the base pay more responsive to idiosyncratic shocks. In partial equilibrium, the variance of w with respect to ε in equation (12) increases with improvement in technology.⁷ Note that this is an optimal behavior, and the improvement in technology raises the overall return of working under performance pay.

Value of unemployment:

⁷Assume that ε follows an AR(1) with autoregressive coefficient ρ , mean zero, and variance of the innovation σ^2 . Then $\text{var}(w) = \text{var}(\varepsilon \alpha g^{\alpha-1} + \frac{1}{4\gamma} \frac{E_\mu[\mu]^2 (\zeta \varepsilon g^{\alpha-1})^2}{(E_\mu[\mu]^2 + \text{var}(\mu))} (\alpha - \frac{1}{2})) = (\alpha g^{\alpha-1})^2 \text{var}(\varepsilon) + 2 \left(\frac{1}{4\gamma} \frac{E_\mu[\mu]^2 (\zeta g^{\alpha-1})^2}{(E_\mu[\mu]^2 + \text{var}(\mu))} (\alpha - \frac{1}{2}) \frac{\sigma^2}{1-\rho^2} \right)$. In partial equilibrium, the variance of wages with respect to the idiosyncratic shock increases with improvement in the technology of performance pay. The variance of wages captures the increase in effort variation for higher ζ or lower $\text{var}(\mu)$. Note that the variance of wages is increasing in the variance of the innovation to ε . There are two ways that the variance of wages can increase: either the shock process is more volatile, or the parameters ζ and $\text{var}(\mu)$ change such that there is an improvement in performance pay technology.

In the case that only one type of pay scheme exists, the value of unemployment is such that workers who leave their market receive the expected value of arriving anywhere in the invariant distribution, $\Omega_p(dx \times d\varepsilon)$, of performance pay markets.

$$(2.14) \quad \phi = \beta \int v(x, \varepsilon)_p \Omega_p(dx \times d\varepsilon)$$

Equilibrium of the model with performance pay. The competitive equilibrium is a set of prices (B, w) , allocations g , functions $v_p(x, \varepsilon)$, effort level a , numbers ϕ , and U , and invariant distributions, $\Omega_p(dx, d\varepsilon)$ such that:

1) a and B satisfy the firm and worker problem:

$$(2.15) \quad a^* = \frac{\mu B^*}{2\gamma}$$

$$(2.16) \quad B^* = \frac{\varsigma E_\mu[\mu \varepsilon g^\alpha]}{2 E_\mu[\mu^2 g]} = \frac{\varsigma E_\mu[\mu] \varepsilon g^{\alpha-1}}{2 [E_\mu[\mu]^2 + var(\mu)]}$$

2) $v_p(x, \varepsilon)$ is given by:

$$(2.17) \quad v_p(x, \varepsilon) = \max\{\phi, E_\mu[\max_a w(x, \varepsilon) + \mu a B - \gamma a^2 + \beta E \int v_p(U + g(x, \varepsilon), \varepsilon') Q(\varepsilon, d\varepsilon')]\}$$

3) In performance pay markets, $g(x, \varepsilon)$ satisfies

$$g : E_{\mu}[(1 + \varsigma \frac{\mu B}{2\gamma})\varepsilon\alpha g^{\alpha-1} - w - \frac{\mu^2 B^2}{2\gamma}] = 0$$

and w satisfies

$$w = \varepsilon\alpha g^{\alpha-1} + \frac{1}{4\gamma} \frac{E_{\mu}[\mu]^2 (\varsigma\varepsilon g^{\alpha-1})^2}{(E_{\mu}[\mu]^2 + \text{var}(\mu))} \left(\alpha - \frac{1}{2} \right)$$

Employment at the island level satisfies feasibility $0 \leq g \leq x$, and is consistent with individual decisions. Two cases can occur:

i) if $E_{\mu}[w(x, \varepsilon) + \mu a^* B^* - \gamma a^{*2} + \beta E \int v_p(U + g(x, \varepsilon), \varepsilon') Q(\varepsilon, d\varepsilon')] > \phi$, then $g = x$ and wages are given by the FOC of the firm:

$$w = E_{\mu}[(1 + \varsigma \frac{\mu B^*}{2\gamma})\varepsilon\alpha x^{\alpha-1} - \frac{\mu^2 B^{*2}}{2\gamma}]$$

ii) if $E_{\mu}[w(x, \varepsilon) + \mu a^* B^* - \gamma a^{*2} + \beta E \int v_p(U_p + g(x, \varepsilon), \varepsilon') Q(\varepsilon, d\varepsilon')] = \phi$, then wages are given by the FOC of the firm:

$$w = E_{\mu}[(1 + \varsigma \frac{\mu B^*}{2\gamma})\varepsilon\alpha g^{\alpha-1} - \frac{\mu^2 B^{*2}}{2\gamma}]$$

where g satisfies:

$$\varepsilon\alpha g^{\alpha-1} + \frac{\varsigma^2}{4\gamma} \frac{E_\mu[\mu]^2 (\varepsilon g^{\alpha-1})^2}{(E_\mu[\mu]^2 + \text{var}(\mu))} \left(\alpha - \frac{1}{4} \right) + \beta E \int v_p(U + g, \varepsilon') Q(\varepsilon, d\varepsilon') = \phi$$

The numbers ϕ and U , and the invariant distribution Ω_p satisfy:

$$\begin{aligned} \phi &= \beta \int V_p \mu(dx, d\varepsilon) \\ U &= 1 - \int g(x, \varepsilon) \Omega_p(dx \times d\varepsilon) \\ \Omega_p(E', \Sigma') &= \int_{\{(x, \varepsilon): U + g(x, \varepsilon) \in E'\}} Q(\varepsilon, \Sigma') \Omega_p(dx \times d\varepsilon) \end{aligned}$$

The definition of competitive equilibrium for the unionized sector is analogous.

Wage setting in unionized markets. The union can be thought of working in the following fashion: for each level of idiosyncratic productivity, a minimum level of pay, $\underline{w}(\varepsilon)$, is established for workers that stay in unionized islands.⁸ The contract is such that in unionized jobs the level of effort is constant, which I normalize to zero, and output is given by εg^α . Wages equal the marginal product of labor, $w = \varepsilon\alpha g^{\alpha-1}$. When the minimum pay binds, employment is such that $\underline{w}(\varepsilon) =$

⁸See Alvarez and Shimer, 2008, for a model in which the union chooses the minimum pay to maximize the present discounted value of unionized workers. I assume that the minimum is exogenous and calibrate it to reproduce plausible levels of the union wage premium.

$f(\underline{g}(\varepsilon), \varepsilon)$, where $\underline{g}(\varepsilon)$ is the maximum level of employment for idiosyncratic shock level ε , given the minimum wage and firm optimization.

In the case that $x < \underline{g}(\varepsilon)$, the minimum pay constraint does not bind and workers decide between receiving spot wages in their market or searching.

$$(2.18) \quad v_u(x, \varepsilon) = \max\{w + \beta \int v_u(U + g, \varepsilon') Q(\varepsilon, d\varepsilon'), \phi\}$$

In the case that $\underline{g}(\varepsilon) < x$, either some workers leave until the point that $v_u(x, \varepsilon) = \phi$ and the minimum constraint does not bind, or the constraint binds and a fraction of workers is forced to search, so that $\underline{w}(\varepsilon) = w$. A lottery assigns workers to either searching or working in the last case. Workers that search receive the expected value of unemployment, ϕ_u .

The Bellman equation when $\underline{g}(\varepsilon) < x$ is given by:

$$(2.19) \quad v_u(x, \varepsilon) = \max\left\{\frac{x - \underline{g}}{x} \phi + \frac{\underline{g}}{x} \left(\underline{w}(\varepsilon) + \beta \int v_u(U + \underline{g}, \varepsilon, \varepsilon') Q(\varepsilon, d\varepsilon') \right), \phi\right\}$$

where $\underline{g}(\varepsilon)$ is such that $f(\underline{g}(\varepsilon), \varepsilon) = \underline{w}(\varepsilon)$, $\frac{x - \underline{g}}{x}$ is the probability of searching, and $\frac{\underline{g}}{x}$ is the probability of staying.

Value of unemployment:

The value of unemployment under union wage setting is defined as the expected value of arriving anywhere in the invariant distribution, $\Omega_u(dx \times d\varepsilon)$, of unionized markets.

$$\phi = \beta \int v_u(x, \varepsilon) \Omega_u(dx \times d\varepsilon)$$

2.2. Simulation results

2.2.1. Calibration and moments to match

In this section, I address whether a model that matches the changes in wage setting institutions observed in the US economy can generate the observed decline in job and worker flows and the observed increase in volatility in wages. Table 5 presents parameter values and labor market moments that help discipline the calibration of the model. The ultimate test of the model is its ability to reproduce the moments in Table 7, namely the increase in the mean dispersion of wages and the decline in the standard deviation of the employment growth rate, using only changes in the technology of compensation in the economy.⁹

⁹The value for the increase in wage instability comes from the calculations in Table 1 for the sample of job stayers. The value of the decrease in employment instability comes from the LBD for the sample of continuing business.

As is standard in the literature, I assume that the idiosyncratic shock process follows an $AR(1)$, such that $\ln(\varepsilon_{t+1}) = m(1 - \rho) + \rho \ln(\varepsilon_t) + \epsilon_{t+1}$, where $\epsilon_{t+1} \sim N(0, \Phi_\epsilon^2)$. I approximate this $AR(1)$ using a discrete Markov process with the Tauchen (1986) method. The variance in the innovation to productivity is directly linked to the volatility of employment and wages in the model. There is no closed form solution relating the shock process to moments in the model. I calibrate the parameters of the shock process so that it matches the levels of unemployment and job reallocation in Table 6. The value of the standard deviation of labor productivity estimated from plant-level data is around .5 (Syverson, 2003). Also, the standard deviation of the innovation to the idiosyncratic component of firm profitability estimated in search models is around .22 (Cooper et al, 2007). The excess job reallocation rate in the BED data is around .14 in the early 2000s. The average unemployment rate reported by the BLS during the same period is around 5.5%. The time period in the model is equivalent to 3 months and the discount rate corresponds to an annual interest rate of 4%. The labor share in the production function is the value implicit in the NIPA accounts.

I calibrate the private information process and the cost and returns to effort as follows. I assume that μ comes from a symmetric $Beta(p, p)$ ¹⁰ distribution

¹⁰I use $p = .25$ in order to match the moments of the bonus in the simulated data with values obtained from the PSID in the late nineties. In later simulation exercises I use p in the [.05 .25] range in order to check the sensitivity of the bonus moments to this parameter.

with mean $E(\mu)$ and variance $Var(\mu)$. The range of μ is such that for a given draw of the private information and resulting optimal effort level, we have that $prob(P = \varsigma \varepsilon g^\alpha \mid a^*) = \mu a^* \leq 1$, and $a^* = \mu B^*/2\gamma$ is in the interval $[0, 1]$. The payment of the bonus comes from a Bernoulli trial with probability of success μa^* . For each successful draw of the Bernoulli distribution I include the optimal bonus in the total compensation. The size, variance, and incidence of the bonus in the model depend on how productive the performance pay arrangement is.¹¹ I choose ς, γ and $Beta(p, p)$ such that the moments of the bonus paid in the simulation are close to their levels in the PSID for the group of performance pay jobs. As in the literature, I calculate the bonus pay as the sum of earnings received in the form of tips, commission, piece-rate or bonus. The size of the bonus pay is the ratio of the bonus pay to total earnings in a given year. The incidence of bonus pay is the number of jobs that received a bonus in a given year over the total number of jobs classified as performance pay. I calculate the size and incidence of bonus in each year and find that both values present a trend increase, consistent with

¹¹As in the literature, I calculate the bonus pay as the sum of earnings received in the form commission, piece-rate or bonus. The size of the bonus pay is the ratio of the bonus pay to total earnings in a given year. The incidence of bonus pay is the number of jobs that received a bonus in a given year over the total number of jobs classified as performance pay. The standard deviation is the cross section standard deviation of bonus. I calculate the size and incidence of bonus in each year and find that both values present a trend increase, consistent with my hypothesis that the performance pay technology has improved over this time period. See Figure 10 for trend increase in the bonus size.

my hypothesis that the performance pay technology has improved over this time period. I present in Table 5 the incidence, variance and size of the bonus payment estimated using PSID data from 1993 to 1998. Table 6 shows the moments to match in the data and their values in the simulated performance pay model.

The employment and earnings instability measures are computed by simulating a panel of islands in the economy. I compute cross section dispersion measures across islands. The goal of the simulation exercise is to reproduce the moments in Table 7 by changing the technology of compensation, represented by parameters of the private information process μ , and the return to effort ς .

In table 8, I compare the predictions of three island models: a model with performance pay markets; a model with only unionized markets; and a "baseline" model in which wages are equal to the marginal product of labor in all states of the world, and in which effort is normalized to zero, so that $f(\varepsilon, x) = \varepsilon g^\alpha$ and $w(\varepsilon, x) = \alpha \varepsilon g^{\alpha-1}$. I keep the underlying idiosyncratic shock process constant and calculate the same moments using the baseline, performance pay, and the "union" model.¹² In the "union" model I set the lower bound for wages so that the average

¹²The size and incidence of the bonus in the PSID in 1998 are respectively 0.057 and .1705. Note that the model simulation produces quarterly data. I aggregate wage and bonus payments in the simulated data in order to compare them with the annual data in the CPS and PSID. The LBD data are also annual. In Table 8 I calculate the standard deviation of percent change in employment considering time aggregation. Time aggregation does not affect the results for employment instability, but it makes simulated data comparable to the LBD.

wage in the economy reproduces the observed union wage premium when compared to the performance pay model.¹³ The unionized and performance pay models use the wage determination described in the previous section.

The first thing to note is that wage instability is higher and employment instability is lower under the performance pay model compared to the union model. These results hold using either mean absolute changes or the cross section standard deviation of percent changes as the measure of dispersion. Note that the idiosyncratic productivity process is held fixed across the three models. Moreover, since the bonus constitutes a small fraction of total compensation, the difference in wage instability is not an artifact of introducing uncertainty with respect to the bonus pay. The use of incentives also affects the employment margin. Employment instability is lower under performance pay, suggesting that under this wage setting arrangement it is easier to adjust the employment margin. Intuitively, under performance pay, the firm can adjust the base wage downward when productivity is lower, but cannot do so under unions.

Table 8 contains polar cases with the economy operating under only one type of compensation scheme. A more realistic model would allow for unionized and performance pay jobs to coexist. In such a model, technological advance in the

¹³See Newmark and Kawaguchi (2001) for estimates of union wage premium with the March CPS.

form of higher ς or lower $var(\mu)$ would relocate workers to the performance pay sector. I plan to explore such a model in future drafts.

In Table 9 I present simulation results for the case in which only performance pay is used. I change the technology of private information and the return to effort such that the variance of μ decreases and the return to effort increases. Note that Beta (1,1) is a mean preserving spread of Beta (4,4), which in turn is a mean preserving spread of Beta (6,6). As expected, the instability of wages is higher for Beta (6,6) and when ς is equal to .25. The technology of compensation can affect the wage instability in two ways. First, through the bonus payment. Since the size of the bonus is higher when the performance pay arrangement is more productive with higher ς , the level of effort and the probability of receiving a bonus are also higher. More productive islands will offer a higher likelihood of receiving bonus pay and the cross section of wage growth outcomes will become more dispersed. Second, as discussed in the previous section, improvement in technology makes the base pay more responsive to the idiosyncratic shock. Better technology increases optimal effort variation, which is compensated in the base pay. The increase in ς is isomorphic to a model with a physical cost of setting up a performance pay arrangement, and represents better monitoring technology.¹⁴

¹⁴See appendix for the case of positive monitoring cost.

Though ς is a free parameter, there is some discipline in this exercise: the natural boundary of the parameters is imposed by $prob(P = \varsigma \varepsilon g^\alpha | a^*) = \mu a^* \leq 1$. The parameters of performance pay productivity cannot be increased above the range in which the probability of receiving a bonus is smaller than one. Also, higher ς increases the mean, variance and incidence of bonus. For the case that ς equals .25, I reproduce a empirically reasonable size and incidence of the bonus pay in the late nineties.

We can now compare the simulation results with the firm and wage instability changes in the data reported in Table 7. If the economy moves from unionization to performance pay adoption the wage instability increases by .019, and the firm instability decreases by 0.040 in the model simulations. These results represent one fourth of the observed increase in wage instability and nearly all the decrease in firm instability in the data.

2.2.2. Last Remarks

This paper studies the relationship between recent trends in earnings and employment volatility. Evidence from a variety of sources indicates that both firm level instability and aggregate measures of job and worker flows have declined during

the 1976-2007 period, while measures of earnings instability from the March CPS rose over this period. The increase in wage instability in the March CPS is greater for job stayers than for job movers/losers and for the overall sample of private non farm workers. This result suggests that changes inside employment relationships contributed to the rise in earnings volatility. I also measure wage instability for job stayers in the PSID from 1976 to 1996. I find that wage instability is higher for jobs that receive some form of bonus or commission.

I argue that technological change in compensation schemes has allowed firms to adjust wages more easily in response to idiosyncratic shocks, instead of hiring and firing workers. I illustrate this phenomenon in a general equilibrium search model in which total compensation depends on a performance measure. A decrease in the cost of monitoring workers is equivalent to a technological change in compensation. The outcome of the new technology in wage setting is that wages are more aligned to productivity, which implies higher earnings instability and lower employment instability.

The exploration of more sophisticated monitoring technologies and productive arrangements, and modelling coexistence of different pay schemes in the economy, are left for future research.¹⁵

¹⁵An useful extension of theory would be to consider model with both technologies operating over time and endogenous switching between types. Assume that workers can direct search towards a type of market. Though they cannot choose a specific island to go, they can decide on whether to move to the unionized or the performance pay sector. They bear the same cost of searching, which is one period of forgone labor earnings.

Let's consider the case when the two types of wage settings coexist in the economy. The problem of the worker in a performance pay job is the same as before:

$$V_p(x, \varepsilon) = \max\{\phi, E_\mu[\max_a w(x, \varepsilon) + \mu a B - \gamma a^2 + \beta E \int v_p(U_p + g, \varepsilon') Q(\varepsilon, d\varepsilon')]\}$$

The problem of the worker in the unionized sector is analogous:

$$V_u(x, \varepsilon) = \max\{\phi, w(x, \varepsilon) + \beta E \int V_u(U_p + g, \varepsilon') Q(\varepsilon, d\varepsilon')\}$$

The value of unemployment now takes into account that the worker can direct search to markets:

$$\phi = \max\{\beta E \int V_p(U + g, \varepsilon) \mu_p(dx \times d\varepsilon), \beta E \int V_u(U + g, \varepsilon') \mu_u(dx \times d\varepsilon)\}$$

When the variance of μ decreases or ς increases, V_u increases, which sustains a higher value of searching. Unemployed workers increase their reservation wage and the marginal product must increase in unionized islands. In an equilibrium with positive unemployment workers must relocate from unionized to performance pay markets.

CHAPTER 3

Uncertainty in Employment Relationships and the Business Cycle

Several recent papers have raised the question of whether uncertainty affects the business cycle. Aggregate and firm level uncertainty have been shown empirically to behave countercyclically. Bloom (2009) reports various measures of firm employment and stock value instability, all which vary negatively with the cycle. On the household side, Storesletten et al (2004) present evidence with the PSID that idiosyncratic labor income risk has a variance that increases by 75% as the economy moves from peak to trough. Recessions are periods with higher turnover. Figure 7 presents a measure of total earnings instability¹ for workers in the Matched March CPS that experience some form of unemployment or job change. Earnings instability is hump shaped during economic downturns.² Figure 9, from Bloom (2009), presents the Chicago Board of Exchange (CBOE) index of

¹I measure instability as the cross-section weighted average of absolute growth rates. This measure is analogous to the excess job reallocation rate calculated at the firm level.

²A previous literature on job flows has raised the hypothesis that fluctuations in the intensity of shifts in employment opportunities across establishments affects business cycle dynamics. See Davis et al, 1990.

market volatility calculated using volatility of index option prices. One can see a clear spike in the period corresponding to the recent credit crunch. The index is supposed to represent market expectations of volatility in stock prices, and it increases in all major periods of economic turmoil such as the two oil shocks, and the Black Monday. In Table 14 I present evidence on the cyclical nature of uncertainty. The dependent variable is stock market volatility measured with variance of option prices in the Chicago Board of Exchange. The first three regressions come from Bloom (2009) and use as independent variables measures of cross section standard deviation of firm profit growth, firm stock return, and industry TFP growth. The last regression uses monthly unemployment rate from the CPS. All measures are positively correlated with the uncertainty series from the CBOE.

In this work, I address the question of whether more information at the employment relationship level is consistent with more uncertainty in recessions, and particularly in the current downturn. The literature so far has focused on modeling this evidence as reflecting time varying variance in productivity. Models with time varying variance correctly produce countercyclical uncertainty. Nevertheless, anecdotal evidence has shown that the revolution in information technology has decreased the level of uncertainty in employment relationships, bringing the question of how information and uncertainty interact with the cycle. The current papers on uncertainty and the business cycle focus on two types of effects: 1) change in the

real option value of investment and hiring (Bloom, 2009); and, 2) uncertainty as bad news predicting low productivity in the future (Bachmann and Bayer, 2009). I suggest a third mechanism in which uncertainty affects the value of employment by changing incentives and effort in contracts. Uncertainty decreases the value of a job by making it harder to assess outcomes, or by increasing the noise in the principal-agent problem in the economy. There are two types of uncertainty in the literature. The first is used in Bachman and Bayer (2009) and Bloom (2009). Uncertainty in their case is represented by changes in the cross-sectional dispersion of firm-specific Solow residual innovations (variance in TFP). This is related to the idea that the economy is not only hit by TFP level shocks, but the variance of TFP also changes stochastically over time. In terms of modeling choice, the paper closer to my set up is den Haan and Kaltenbrunner (2005), who also use search and matching frictions in the labor market. In den Han and Kaltenbrunner the amount of vacancy posting depends on expectations of future productivity. There is a regime switching between periods of higher and lower productivity growth. Recessions then coincide with expectations of lower productivity growth in the future and affect hiring in the present. I suggest a third mechanism that uses the wage setting in performance pay markets. In those markets there is private information in terms of the effect of worker effort on productivity. I model a second moment shock as time varying variance in the private information process. When

future profits are expected to be higher due to relaxing the private information problem (lower variance of the private information process), more vacancies are posted. The private information determines effort, which enters the production function. Hence, changes in the private information process work indirectly as changes in the total factor productivity including effort as an input. There is not direct evidence of uncertainty in information. Nevertheless, measures of volatility in variance of stock options and in standard deviation of GDP forecasts from the Philadelphia Federal Reserve Bank's biannual Livingstone survey are both counter-cyclical. On the household side, variance of income and measures of cross-section earnings instability covarie positively with unemployment.

I advance a theory of recessions that does not rely on the assumption of time varying variance of productivity. I use in the model a different level of uncertainty that relies on time varying quality of information in employment contracts. More specifically, I model a type of incentive that has increased in relevance in the US economy: performance pay contracts. Figure 2 has the fraction of jobs in the PSID among male heads of the household that receive some form of incentive pay. The proportional of jobs that receive bonus, commission or piece-rate has increased steadily since the late 70'. The benefits of using performance pay contracts are twofold. First, I reproduce in the model simulation moments of the data that can discipline calibration by using the evidence on bonus pay and cyclicity in the

PSID as a benchmark. Second, the contract produces a direct link between uncertainty in information in employment relationships and turnover. This relationship allows for evaluating the effect of uncertainty on business cycles.

The way the model works is as follows. There are search frictions in the economy. The representative firm decides on which employment matches to retain looking at aggregate shocks and the distribution of uncertainty shocks. The wage rate in job matches is defined by a contract that establishes a base pay and a bonus paid in case positive performance is observed. The worker has private knowledge on how she can affect both output and measured performance through effort choice. The firm does not observe effort and cannot contract on output. Hence the need of a performance pay contract to give incentives for the worker to exert more effort in high states of the world.

The source of uncertainty is the process that gives the private information held by the workers. I assume that the process that gives the private information has time varying variance. Recessions are periods when the variance of the private information process is high. Hence economic downturns are characterized by higher difficulty in assessing the value of employment relationships. The uncertainty in information can function as a propagation mechanism in the model by exacerbating the standard effect of the decline in productive during recessions. Since higher variance in private information decreases the value of employment

contracts, the firm decreases hiring and we have unemployment commoving with variance in information. In the limit, if there is no variance in the distribution of the private information, the model reduces to a standard labor search framework with performance pay contracts. The question then is whether the model is consistent with both improvement in information technology and amplification of the business cycle through uncertainty.

3.1. Model

The model structure is based on a standard DSGE framework with labor search frictions (see Lubik and Krause, 2003). I build on it wage contracts as in Baker, Gibbons and Murphy (2004).

The household problem is given by:

$$(3.1) \quad \max_{c_t, asset_t} \sum \beta^t [u(c_t) - n_t \varphi(a_t^*)]$$

st.

$$(3.2) \quad c_t + asset_t = n_t w_t + (1 - n_t) b + R_t asset_{t+1}$$

where c is consumption, w is the wage rate, b is the unemployment benefit, n is the fraction of the labor force working in a given period, and R is the return on assets. The labor force is normalized to one. Hence unemployment is given by $u = 1 - n$.

First order conditions yield the discount factor Ξ :

$$(3.3) \quad \frac{1}{R_t} = E_t \left(\beta \frac{u'(c_{t+1})}{u'(c_t)} \right) = \Xi$$

The firm problem is given by:

$$(3.4) \quad \max_{v_t, n_t} \sum E \Xi (Y_t - \Omega_t n_t - v v_t)$$

st.

$$(3.5) \quad n_t = E_\mu (1 - \rho_t) (n_{t-1} + v_{t-1} q(\theta_{t-1}))$$

where Y is output, Ω is the wage bill, v is the cost of vacancy posting, and v are vacancies. Labor market tightness is $\theta = \frac{v}{u}$, and the fill rate for vacancies

$q(\theta_t)$ comes from the matching process, taken as given by firms and workers. At each period a fraction ρ_t of jobs is destroyed. The creation and destruction of jobs enter the law of motion for employment. Output is subject to both aggregate z_t , and idiosyncratic shock ε . The aggregate shock follows an AR(1) process, and the idiosyncratic shock is drawn every period from a distribution $f(\varepsilon)$ with support $[0, 1]$. The firm chooses at each period a fraction of jobs below the threshold $\bar{\varepsilon}$, which are destroyed. The remaining jobs have average productivity $H(\varepsilon)$ that comes from the truncated distribution $H(\varepsilon) = \int_{\bar{\varepsilon}}^1 \frac{f(\varepsilon)}{1-F(\bar{\varepsilon})} d\varepsilon$. Given the fraction of jobs destroyed, and the exogenous separation rate ρ_x , total job destruction in the economy is equivalent to $\rho_x + (1 - \rho_x)F(\bar{\varepsilon})$. Total output for the effort level equal to zero is given by $z_t H(\varepsilon)n_t$.

First order conditions yield the job creation equation:

$$(3.6) \quad \frac{v}{q(\theta_t)} = E[\Xi E_\mu(1 - \rho_t)((1 + \varsigma a_{t+1}^*) z_{t+1} H(\varepsilon) - \Omega_{t+1} + \frac{v}{q(\theta_{t+1})})]$$

where $y = (1 + \varsigma a_{t+1}^*) z_{t+1} H(\varepsilon)$, a_t^* is optimal effort by the worker, and the parameter ς gives the productivity of performance pay arrangements. Note that the output depends on both effort and ς , which governs the productivity of the performance pay contract. I assume that the marginal contribution m of worker

effort to firm output is given by $\varsigma a_{t+1}^* z_{t+1} \varepsilon_{t+1}$. Wage contracts between firms and workers cannot be written on the marginal contribution, since it is too complex to be objectively assessed. However, there is a verifiable performance measure, P , which is an imperfect measure of m . In order to simplify notation, assume that m can only take values of $\varsigma a_{t+1}^* z_{t+1} \varepsilon_{t+1}$ or 0, and P can take values of $\varsigma a_{t+1}^* z_{t+1} \varepsilon_{t+1}$ or 0. The firm observes P and m , but only P is contractible.

At each period, the worker can choose an action that stochastically determines both output and performance. The relationship between worker effort, a , and the firm's outcome is such that $\Pr ob(m = \varsigma a_{t+1}^* z_{t+1} \varepsilon_{t+1} \mid a) = a$, where a is between 0 and 1. The probability of observing a positive performance measure is given by $\Pr ob(P = \varsigma g^\alpha \mid a) = \mu a$, where μ is a random variable with mean $E(\mu)$, and variance $var(\mu)$, bounded above so that $\Pr ob(P = \varsigma a_{t+1}^* z_{t+1} \varepsilon_{t+1} \mid a) \leq 1$. We can think of μ as the difference between the effect of effort on performance and output. There are states of world when μ is large and high effort contributes more to performance measures than to the value of the firm. When μ is small, we have the opposite case, and high effort would likely generate large value for the firm, but would not increase performance measures. I assume that firms do not know μ , while workers observe μ after deciding whether to stay on the island, but prior to choosing effort. From the viewpoint of the firm and the worker, effort and bonus are stochastic prior to the realization of μ . The problem of the firm is

to offer a compensation package prior to the realization of μ that aligns effort to productivity, and the problem of the worker is to choose the optimal level of effort once μ is realized. The sequence of events is such that firms and workers start the period knowing the state of the economy and the process for μ .

The wage determination uses the flow equations for the value of a job match for the firm J , and the value of employment W and unemployment U for the worker. The worker chooses the level of effort according to:

$$(3.7) \quad W_t = E_\mu(\max_{a_t} w_t + \mu_t B_t a_t - \gamma a_t^2 + E\Xi((1 - \rho_t)W_{t+1} + \rho_t U_{t+1}))$$

First order conditions yield:

$$(3.8) \quad a_t^* = \frac{\mu_t B_t}{2\gamma}$$

where B is the bonus paid in case positive performance is observed and $E_\mu(\mu_t B_t a_t)$ is the expected value of bonus pay.

The firm determines bonus B and base pay w according to:

$$(3.9) \quad \max_{B_t, w_t} J_t = E_\mu(z_t \varepsilon_t (1 + \varsigma a_t^*) - w_t - \mu_t B_t a_t + E\Xi(1 - \rho_{t+1})J_{t+1})$$

st.

$$E_\mu(w_t + \mu_t B_t a_t^* - \gamma a_t^{2*} + E\Xi((1 - \rho_t)W_{t+1} + \rho_t U_{t+1})) \geq$$

$$b + E\Xi(f(\theta_{t+1})(1 - \rho_{t+1})W_{t+1} + (1 - f(\theta_{t+1}))(1 - \rho_{t+1})U_{t+1})$$

$$a_t^* = \frac{\mu_t B_t}{2\gamma}$$

Using the fact that the participation constraint binds and $U = W$, first order conditions yield:

$$(3.10) \quad B_t = \frac{z_t \varepsilon_t \varsigma E \mu_t}{E \mu_t^2}$$

$$(3.11) \quad w_t = b - E_\mu(\mu_t B_t a_t^* - \gamma a_t^{2*})$$

The value of a job is given by:

$$(3.12) \quad J_t = E_\mu(z_t \varepsilon_t (1 + \varsigma a_t^*) - b + \mu_t B_t a_t^* - \gamma a_t^{2*} - \mu_t B_t a_t^* + E\Xi(1 - \rho_{t+1})J_{t+1})$$

The job destruction threshold depends on the condition that the value of the marginal job at $\bar{\varepsilon}$ is zero:

$$z_t \bar{\varepsilon} (1 + \varsigma a_t^*) - b - \gamma a_t^{2*} = 0$$

The aggregate resource constraint is:

$$(3.13) \quad E_\mu(c_t + v v_t) = E_\mu(z_t (1 + \varsigma a_t^*) n_t H(\varepsilon) + u_t b)$$

The competitive equilibrium is a set of prices and numbers $\{c_t, n_t, v_t, u_t, B_t, a_t^*, w_t, R_t, \bar{\varepsilon}_t, \rho_t\}$, and stochastic processes for z , ε , and μ that satisfy the equations below.

I assume that z follows an $AR(1)$ process $\ln z_{t+1} = \rho^z \ln z_t + \varepsilon_{t+1}^z$, p follows an $AR(1)$ process $\ln p_{t+1} = \rho^p \ln p_t + \varepsilon_{t+1}^p$, the private information is drawn from a symmetric $Beta(p, p)$ distribution, and ε_t follows an uniform distribution with support $[0, 1]$.

$$a_t^* = \frac{\mu_t B_t}{2\gamma}$$

$$(3.14) \quad B_t^* = \frac{z_t \varepsilon_t \varsigma E \mu_t}{E \mu_t^2}$$

$$(3.15) \quad w_t = b - E_\mu(\mu_t B_t^* a_t^* - \gamma a_t^{2*})$$

$$z_t \bar{\varepsilon}(1 + \varsigma a_t^*) - b - \gamma a_t^{2*} = 0$$

$$(3.16) \quad E_\mu(c_t + v v_t) = E_\mu(z_t(1 + \varsigma a_t^*) n_t H(\varepsilon) + u_t b)$$

$$(3.17) \quad \frac{1}{R_t} = E_t \left(\beta \frac{u'(c_{t+1})}{u'(c_t)} \right) = \Xi$$

$$(3.18) \quad n_t = E_\mu(1 - \rho_t)(n_{t-1} + v_{t-1}q(\theta_{t-1}))$$

$$(3.19) \quad \frac{v}{q(\theta_t)} = E[\Xi E_\mu(1 - \rho_t)((1 + \varsigma a_{t+1}^*) z_{t+1} H(\varepsilon) - \Omega_{t+1} + \frac{v}{q(\theta_{t+1})})]$$

$$(3.20) \quad u_t = 1 - v_t$$

$$(3.21) \quad \rho_t = \rho_x + (1 - \rho_x)F(\bar{\varepsilon}).$$

I assume that z follows an $AR(1)$ process $\ln z_{t+1} = \rho^z \ln z_t + \varepsilon_{t+1}^z$. The private information is drawn from a symmetric $Beta(p, p)$ distribution. The variance of the private information changes over time. I assume accordingly that p follows an $AR(1)$ process $\ln p_{t+1} = \rho^p \ln p_t + \varepsilon_{t+1}^p$. In periods when p is low the variance of $Beta$ is high and that decreases the bonus and effort. The information structure is

such that agents know p or the distribution of the private information when agreeing on the contract, but do not know the realization of μ . I further assume that draws of μ are *iid* over time, and agents use the process of p to predict only the variance of the private information distribution. Due to the assumption of symmetric process for μ , its mean is 0.5. Given the independence of μ and ε , the average effort in the economy depends on the shocks processes given by $zH(\varepsilon)\mu$. Note that there is still heterogeneity in terms of effort and productivity, but I assume that it aggregates such that we can think of the economy as governed by the values of $zH(\varepsilon)\mu$. There are several assumptions used to obtain the simplification in the aggregation. The first is that all shocks are independent, μ is *iid* and the same for all jobs. The production function is given by $(1 + \zeta a^*) zH(\varepsilon)n$. Second, the individual worker in a job does not internalize his effect on total output. We can decompose output in two independent terms: $z_{t+1}H(\varepsilon)n_t$ which aggregates trivially, and $(1 + \zeta a_{t+1}^*)$. Effort is given by $a_t^* = \frac{\mu_t}{2\gamma} \frac{z_t \varepsilon_t \varsigma E\mu_t}{E\mu_t^2}$. Given the assumptions on the shock processes, we can consider $\frac{\mu_t}{2\gamma} \frac{z_t \varepsilon_t \varsigma E\mu_t}{E\mu_t^2}$ as an aggregate term, and ε for all jobs is given by $\int_{\bar{\varepsilon}}^1 \frac{\varepsilon f(\varepsilon)}{1-F(\bar{\varepsilon})} d\varepsilon = \int_{\bar{\varepsilon}}^1 \frac{\varepsilon}{1-\bar{\varepsilon}} d\varepsilon$. Hence $Y = \left(1 + \zeta \frac{\mu_t}{2\gamma} \frac{z_t \varepsilon_t \varsigma E\mu_t}{E\mu_t^2} \int_{\bar{\varepsilon}}^1 \frac{\varepsilon}{1-\bar{\varepsilon}} d\varepsilon\right) zH(\varepsilon)n$.

Using the expressions for the bonus and effort we have that higher variance of the private information decreases bonus and effort: $B_t = \frac{\varepsilon_t z_t \varsigma E\mu_t}{E\mu_t^2} = \frac{\varepsilon_t z_t \varsigma E\mu_t}{(1+var(\mu))}$, $a_t^* = \frac{\mu_t B_t}{2\gamma} = \frac{\mu_t}{2\gamma} \frac{\varepsilon_t z_t \varsigma E\mu_t}{(1+var(\mu))}$. Total compensation w_{total} is procyclical and given by $w_{total} = w + \mu B a = b + \gamma a^{2*}$. The net effect of higher variance of the private information

on the value of the job is given by $\frac{\partial J_t}{\partial \text{var}(\mu)} = \frac{\partial E_\mu(\varepsilon_t z_t (1 + \varsigma a_t^*) - b - \gamma a_t^{*2} + E\Xi(1 - \rho_{t+1})J_{t+1})}{\partial \text{var}(\mu)}$.

Note that the effect on the current return of the job depends on the productivity of the performance pay contract, ς : $\varepsilon_t z_t \varsigma \frac{\partial a_t^*}{\partial \text{var}(\mu)} - \gamma 2a_t \frac{\partial a_t^*}{\partial \text{var}(\mu)}$. Hence, improvement in monitoring represented by lower $\text{var}(\mu)$ or higher ς technology increases the link between the variance of μ and job creation.

3.2. Calibration and Simulation

Since the main interest is in business-cycle dynamics - the interactions between market structure and aggregate fluctuations in labor demand - I rely on local approximation as a solution method. For business cycle purposes, first and second-order approximations often yield a good picture of model dynamics (Schmitt-Grohe and Uribe, 2004, henceforth SGU). This is of course a simplification of the heterogeneity in employment relationships. Yet, the model produces the elements necessary to evaluate the effect of uncertainty on business cycle: time varying uncertainty, unemployment, and turnover.

Tables 10 and 11 presents the model parameters that have to be calibrated. I take a two step approach to the calibration and simulation. First, I use standard parameters in the labor search literature to pin down the first approximation of all values in Table 1. Second, I minimize a loss function to obtain estimates of

the free parameters of the model. The moments used in the second stage come directly from the PSID data for performance pay jobs.³ There are two reasons for choosing moments of performance pay compensation schemes in order to calibrate the model. First, to the best of my knowledge, the PSID moments use all aggregate data available on wage setting in contracts, helping to pin down parameters that have no counterpart in the literature. Second, I do not assume wage rigidity, which is usually necessary to generate empirically reasonable aggregate properties in standard DSGE labor search models. To the extent that performance pay schemes became pervasive in the US labor market, I use in the model a wage setting that is both flexible and empirically founded.

I use as in the literature a log utility function. The model is quarterly, and the discount rate is set at .99. The steady state vacancy, labor market tightness, the elasticity and constant of the matching function $M = \varpi u^\epsilon v^{1-\epsilon}$ are obtained using data estimates of average unemployment rate (6%) in the economy, the normalization of the labor force to one, and the fill (.7) and finding rate (.6) of jobs. The exogenous separation probability is .08 and total job destruction is 0.10. In the first stage, I guess the remaining parameters.

³See chapter 1 for definitions of PSID variables, and the appendix for a discussion of the data.

I calibrate the productivity and cost of performance pay, the unemployment benefit, the flow cost of vacancy posting, and the variance to the innovation of the uncertainty shock in order to match moments in the PSID such as the size⁴ and incidence of the bonus, and the correlation of total bonus and bonus size with unemployment at business cycle frequency, the correlation of incidence with unemployment and bonus size, and the standard deviation of bonus size and incidence. I do not target the volatility of labor market variables such as unemployment, vacancies, and labor market tightness. The mean of $var(\mu)$ comes from the choice of a symmetric Beta process, with average p normalized to one.

The correlations and standard deviations are analogous to the standard business cycle statistics but make use of the information in the PSID about compensation schemes. I take the linearly detrended series of bonus, bonus size, bonus incidence, and unemployment rate in order to calculate moments. The model mechanism is to change future profits and vacancy posting using the changes in the incentive for effort variation given by bonus. Hence, I use direct evidence on the cyclicity of bonus pay in the data. The goal of the model is to generate labor market volatility through uncertainty. I use the standard deviations as moments of the compensation scheme to discipline the model since introducing excessive

⁴See previous definitions of PSID moments in Chapter 1.

volatility in effort and bonus could generate high levels of variance in labor market aggregates. I also use correlations of incentive pay with unemployment since the model implies as in the data that bonus size and its probability of positive incentive pay in a given period depend on productivity and should decrease in recessions.

The criteria function used to decide on the calibration is given by $\min F(\zeta, b, \gamma, v) = \sum x^2$, where x is the difference between model simulation and data moments. I evaluate F over part of the parameter space around the initial guess.⁵ At this stage I weight all moments equally in the loss function. In principle one should focus on the more reliable moments of the data, and the ones that also better describe the model mechanisms. The solution is supposed to emulate the simulated method of moments. Since relevant parameters of the data such as the shock process for uncertainty and the productivity of contracts cannot be directly calculated from the data, one has to use indirect inference with data moments in order to estimate free parameters.

The idiosyncratic process is assumed uniform with support $[0, 1]$. The values discussed so far cover all parameters in Table 10 and Table 11 except for the aggregate productivity shock. I normalize the mean of the aggregate shock to one.

⁵I also use different initial points in order to check for the problem of local minima in the criteria function. This procedure is restricted by the convergence on internal loops of the simulation. All values of the parameter space evaluated have to lead to convergence of the steady state of the model and approximation functions.

The AR(1) process for z corresponds approximately to TFP in the model. I choose the process for z such that the model without uncertainty shocks reproduces the standard deviation output in the US economy, which is approximately 1,7%. The model is not sensitive to the choice of autocorrelation in the shock process, so I follow the literature and set it to .95.

As in most business cycle models, the variance of innovation to shocks governs the bulk of the volatility of aggregate variables. In principle, any variance of vacancy and unemployment can be obtained with the appropriate choice of shock volatility. I discipline the calibration of the variance in the uncertainty process by using the moments of the bonus pay in the PSID, including the variance and cyclicity of aggregate bonus. I also conduct a sensitivity analysis of the parameters of the shock process by looking at the moments of the bonus as I increase the variance of p .

Table 12 presents results of the baseline model and the data moments. For a reasonable size and cyclicity of bonus pay, the model explains more than twice the volatility of unemployment and more than one half of the volatility of vacancies and labor market tightness. Though the model overshoots the correlation of bonus size and incidence and the standard deviation of incidence, all remaining simulated moments have the right sign and order of magnitude. Unlike in the standard

DSGE labor search model, results do not depend on a large value of the variance of labor productivity shocks or the assumption of wage rigidity. Note that the model is driven by two uncorrelated shocks. As we discuss below, the introduction of uncertainty shocks is key for reproducing the cyclical nature of compensation scheme variables, since the model driven by only TFP shocks performs poorly in several dimensions. The uncertainty shocks work indirectly as a productivity shock, since they lead to more effort variation, which enters the production function and firm's expectation of future profits. Below I discuss the impulse response functions and counterfactual exercises of shutting down the effort mechanism.

The Beveridge curve is not reproduced. In DSGE models with endogenous job destruction the response of destruction to shocks is faster than creation, and the two rates end up with a positive correlation at business cycle frequency. One can get the right Beveridge curve with the model at the cost of assuming a constant destruction rate. This is not a moment target by the model, hence I choose to keep job destruction as a margin of adjustment, since empirically it seems to increase in recessions. As discussed in the literature, the shape of the Beveridge curve is not a priori clear. On the one hand, a shock to productivity increases profits and vacancy creation, reducing unemployment. On the other hand, higher productivity reduces the threshold for destruction and unemployment, increasing labor market

tightness. Higher vacancy to unemployment ratio reduces incentives for vacancy posting. If we shut down the endogenous job destruction margin, only the first effect is at work.

The ultimate test of the model is generating a propagation mechanism for recessions that increases turnover by introducing uncertainty. Since I represent uncertainty as time varying information process in performance pay contracts, the metric for evaluating the model comes from the sensitivity analysis of the two main parameters of the performance pay technology - the productivity of the contract, ς , and the standard deviation of the innovation to the uncertainty shock - and its propagation mechanism - effort variation.

I conduct the following analysis. Both the incidence and size of the bonus present a trend increase in the PSID.⁶ This trend suggests that the technology of performance pay has improved over time. Table 13 displays simulation results for different values of free parameters. Column 1 displays simulation results for a low value of the variance of the innovation to p . From column 1 we can infer that the model driven by TFP shocks performs poorly both at replicating moments of compensation schemes and generating volatility in aggregate variables. When we compare column 1 to column 4, it is clear that uncertainty shocks drive most

⁶See Figure 8 for bonus incidence and Figure 10 for bonus size.

of the cycle. As we move towards column 4, the model fit improves. A model that is driven mostly by TFP shocks (column 1) produces countercyclical bonus, unlike in the data. The introduction of uncertainty shocks flips the sign of the correlation between bonus and unemployment. It also raises the variance of bonus pay. As a by-product, the uncertainty shocks improve the fit of the model in terms of replicating the volatility of aggregate and labor market variables (columns 3 and 4).

Column 3 displays results with the baseline calibration except for the higher value of productivity in performance pay contracts. An increase in the productivity of the contract is in line with the PSID evidence that there is a trend increase in the size and incidence of the bonus. Results in column 3 indicate that improvement in technology is consistent with more aggregate volatility.⁷ Note that the productivity of performance pay is relevant for model fitness. A one percent increase in ζ , all else equal, helps the model explain two percent more of unemployment when compared to the baseline calibration, without raising the volatility of the PSID moments of compensation. This results suggest that the productivity of the contract is relevant for model dynamics, since it affects the volatility of vacancies and unemployment outcomes.

⁷Though column 3 has a lower value for the loss function criteria, it violates the assumption that under the baseline calibration TFP shocks alone reproduce the empirical value of the output standard deviation.

The last experiment concerns the model mechanisms - effort variation. I take the simulated data and perform the following counterfactual. I keep a^* at its mean value and calculate the business cycle moments of the compensation scheme. I also change the job creation equation such that effort is constant in the expectation of future profits. Column 2 presents results for the model without effort variation. It is clear that if effort is kept at an ordinary constant level, the model cannot reproduce moments of the compensation scheme. The reason for that failure is that in the counterfactual exercise we sever the link between the current state of the economy and the probability of the two main events in the model: positive incentive pay, and higher productivity through effort variation. Moreover, with effort constant in the job creation equation, there are no incentives to post more vacancies when the variance of the private information process is low. The results of this counterfactual indicate that effort variation induces variability in labor market aggregates in the model. Note that effort is given by $a_t^* = \frac{\mu_t z_t \varepsilon_t S E \mu_t}{2\gamma E \mu_t^2}$. We can see that the shock in $\ln p_t$ changes the variability of effort, or the variance of the private information in denominator of a^* . This effect is the response of the contract to the second moment shock in the private information process.

A model without uncertainty changes the moments of the bonus, bringing the standard deviation of all variables down and increasing the distance between data

and simulated model correlations (see Table , column 1). Interestingly, the mechanisms that affects the bonus moments is the effort variation. If we perform the experiment of shutting down effort by keeping it at its mean value, we also increase the distance between data and model moments (see Table, column 3).

Figures 11 and 12 show the impulse response function of model variables to a positive innovation in aggregate productivity. Figure 11 displays the response of labor market variables and performance pay outcomes to a 1 std innovation to the uncertainty shock. Figure 12 shows the same variables' reponse to the aggregate shock. It is interesting to note the similarity between Panel A in Figures 11 and 12. A positive shock to p decreases the variance of μ and works as a productivity shock. Panel B in both figures are also similar, but the response of bonus and effort is higher for the uncertainty shock

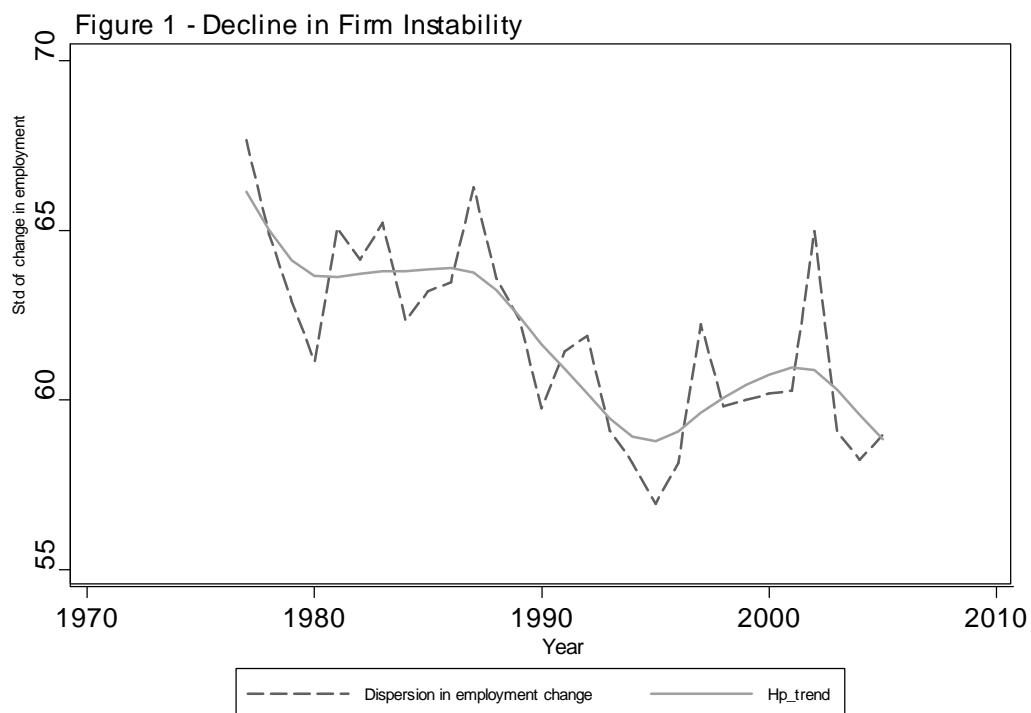
There are some caveats to the analysis above. First, the model is not rich enough to reproduce closely all moments of the data. Second, though the data is measured consistently with model definitions and the literature on performance pay, the time range is short for assessment of time series moments (see the appendix for a discussion of the PSID data).

3.3. Last Remarks

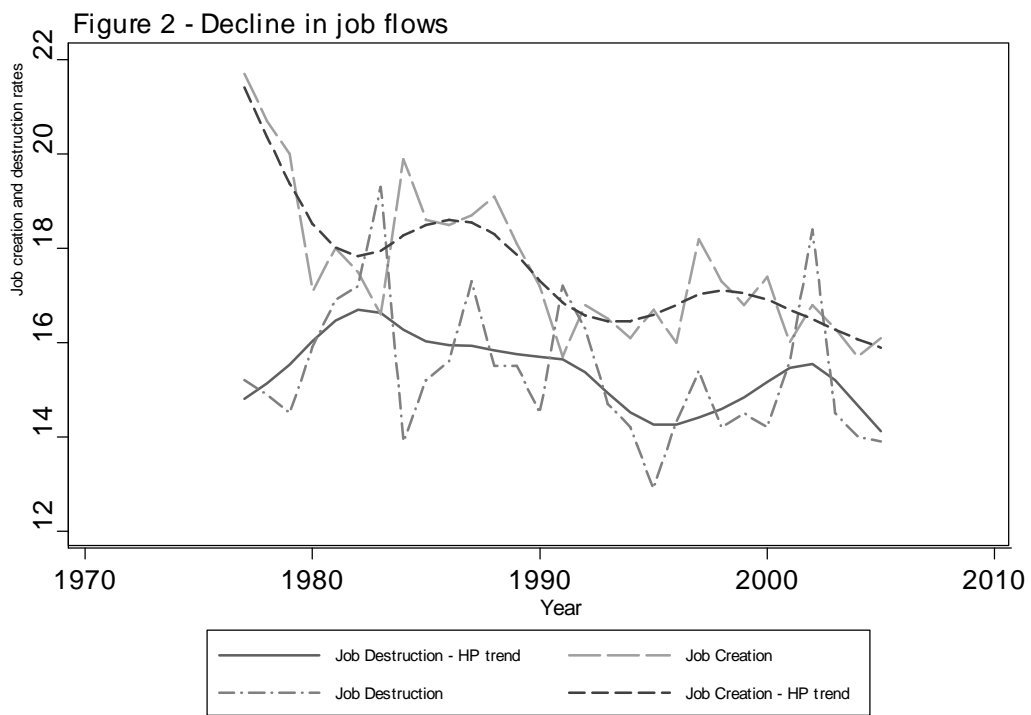
In this Chapter I study the interaction between uncertainty in employment relationships and the business cycle. The current papers on this topic focus on two types of effects: 1) change in the real option value of investment and hiring (Bloom, 2009); and, 2) uncertainty as bad news predicting low productivity in the future (Bachmann and Bayer, 2009). I suggest a third mechanism in which uncertainty affects the value of employment by changing incentives and effort in contracts. I extend a standard search model in order to include performance pay contracts and uncertainty shocks, represented by time varying variance in the process of private information held by workers. I calibrate and simulate the model in order to replicate moments of performance related payment in the US data. Results suggest that uncertainty shocks and improvement in performance pay technology are capable of generating amplification of high frequency variation in labor market outcomes. Overall, as postulated in the motivation, if the technology has improved and the shock size is larger, uncertainty becomes an important channel in recessions, amplifying the high frequency variation in unemployment and vacancies. The simulation results answer positively our initial question of whether business cycles can be driven by uncertainty in employment relationships.⁸

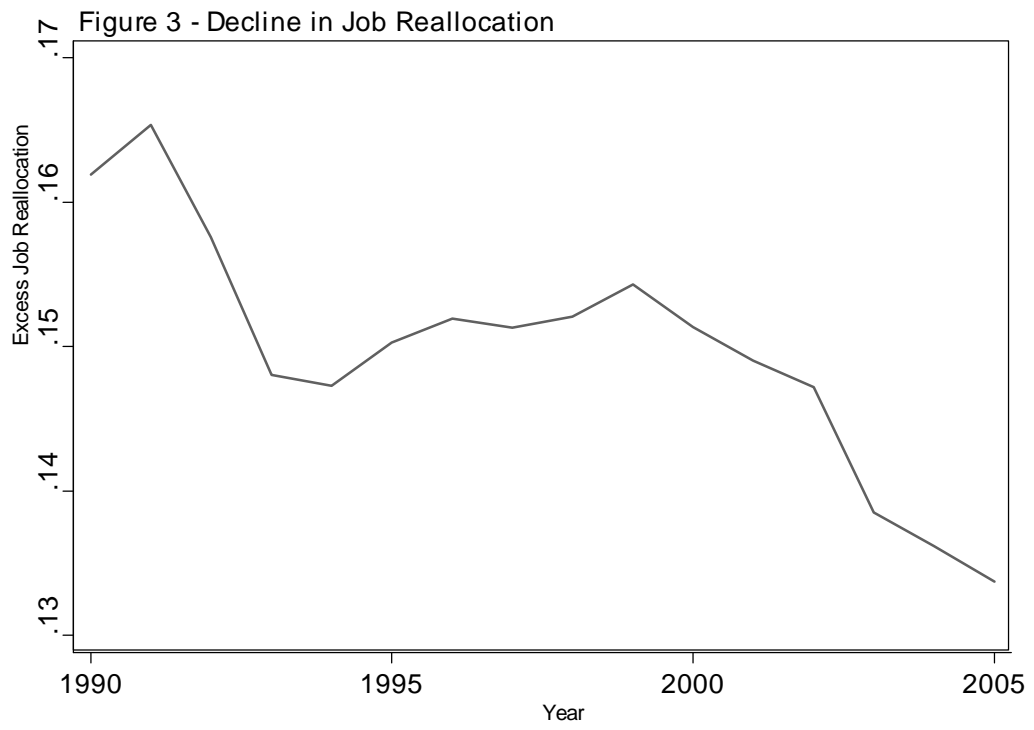
⁸The mechanisms in the model is suitable for explaining the Great Moderation. If we assume that the variance of the innovation to the private information process is decreasing over time, we

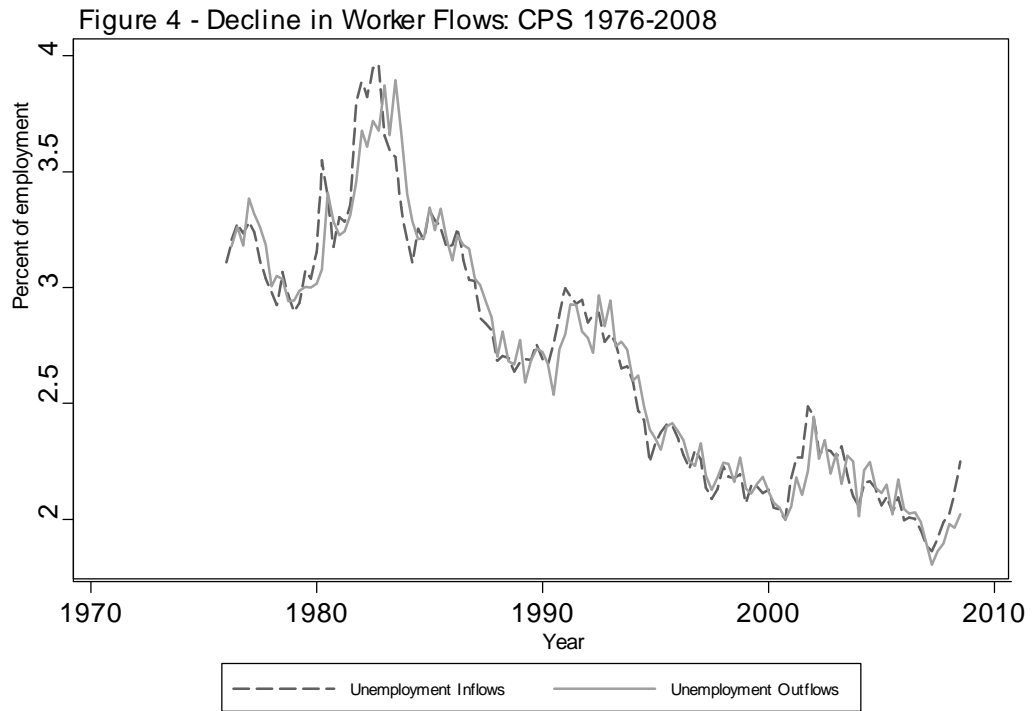
1. Figures and Tables

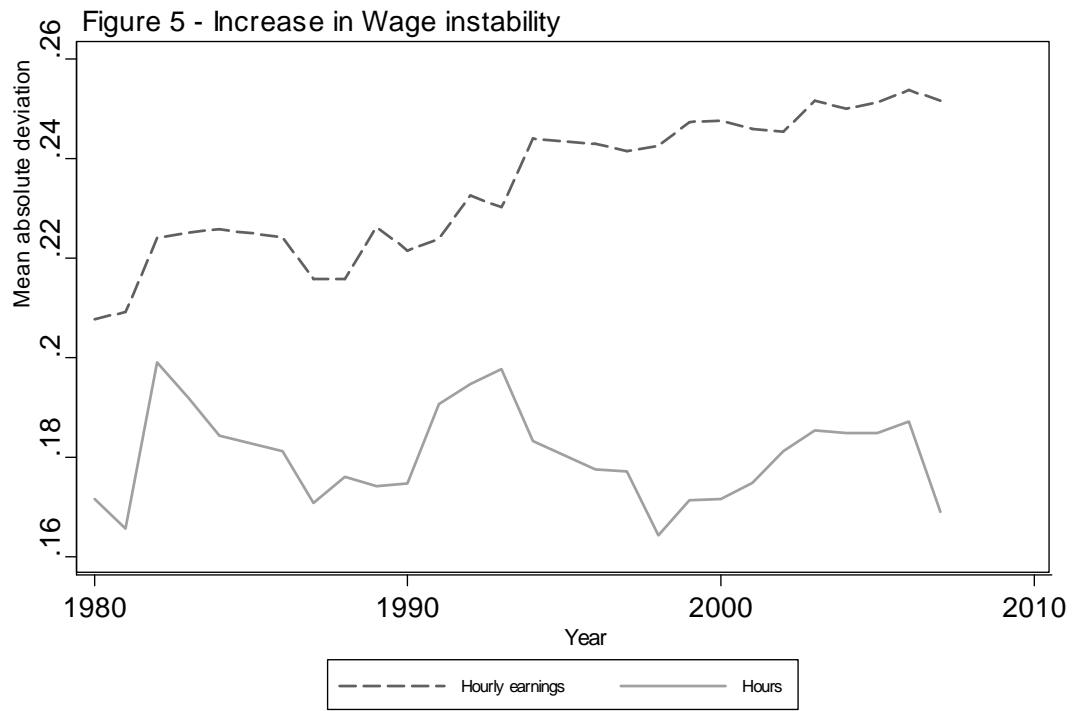


have that aggregate labor market variability decreases. There is one shortcoming to this story. The decline in the variance of information is probably related to a secular change in technology (e.g. the use of computers to monitor workers). Since the adoption of the new technology is not likely to revert in recessions, the mechanisms in the model cannot explain simultaneously the Great Moderation and the Great Recession.

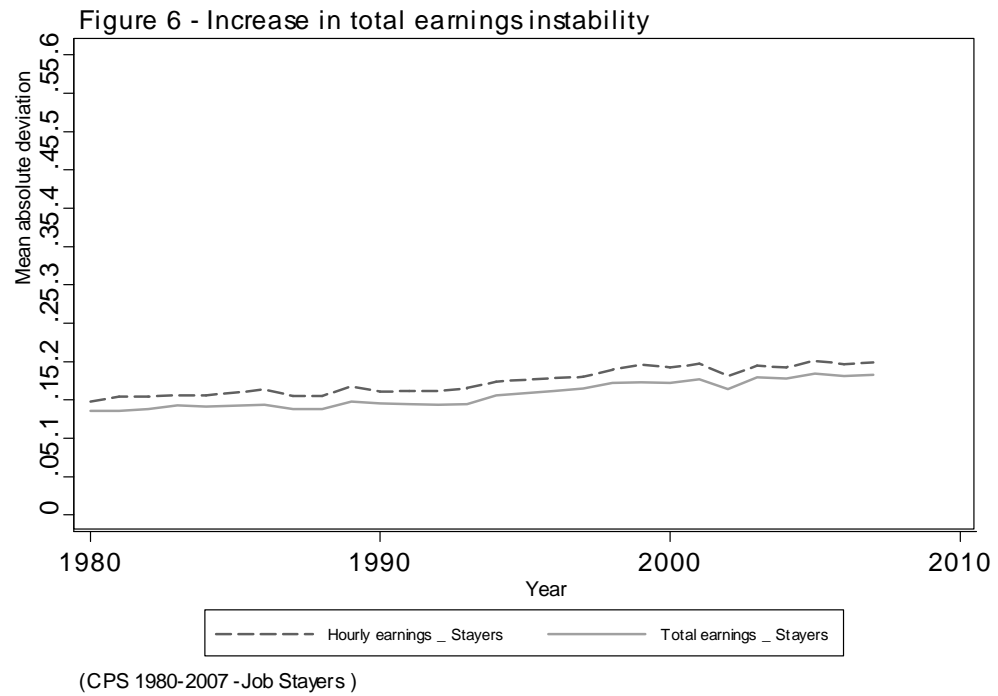


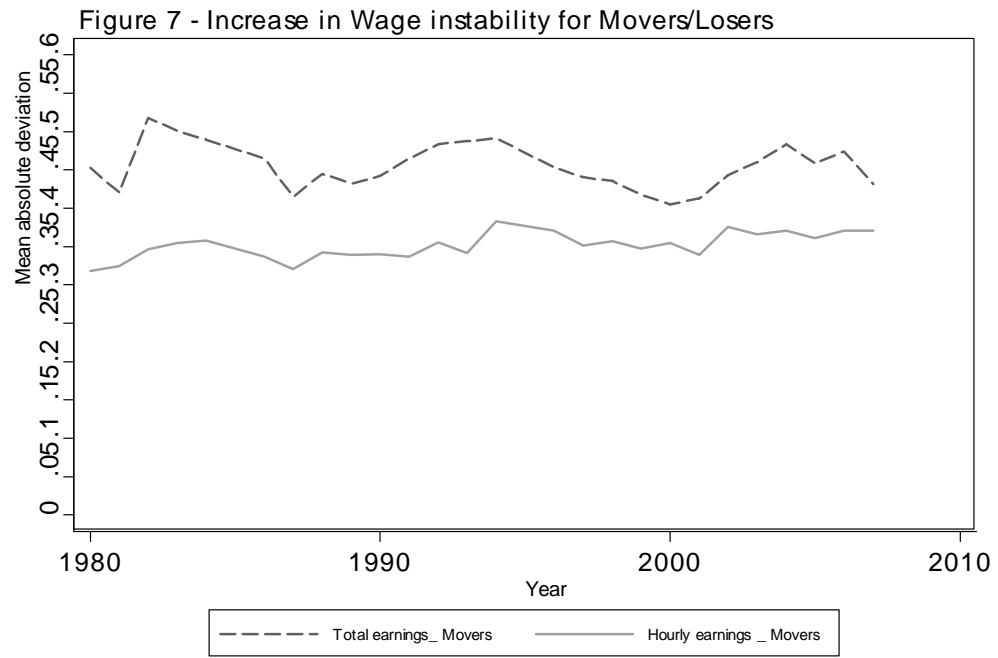






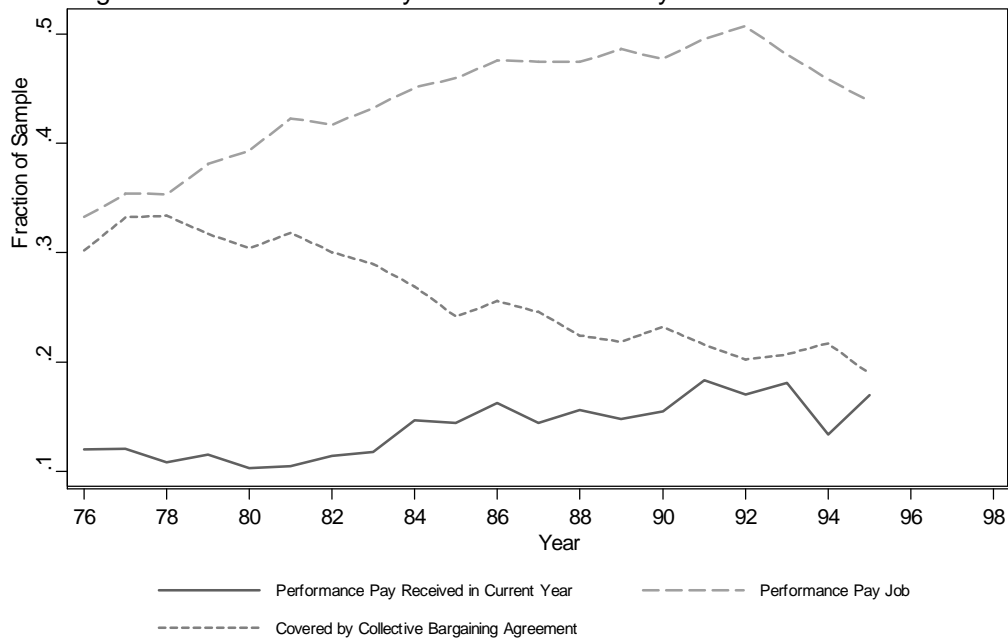
(CPS 1980-2008, private non-farm)



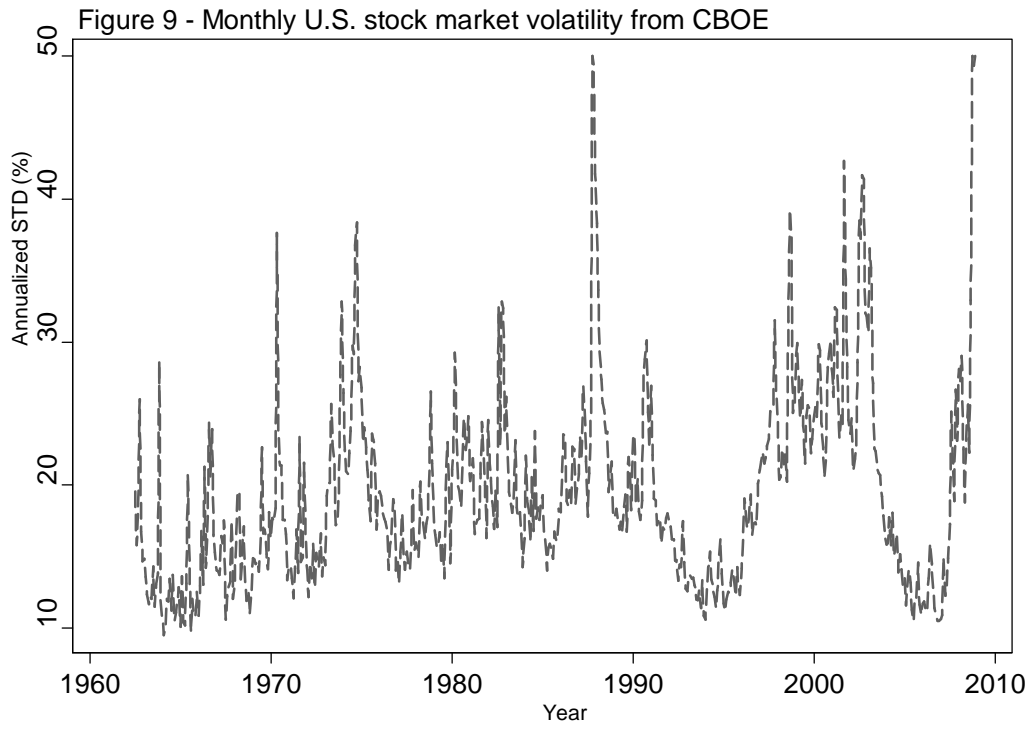


(CPS 1980-2007 - Job Movers/Losers)

Figure 8 - Performance Pay Incidence - Job stayers



(Source: Lemieux, MacLeod and Parent, 2009)



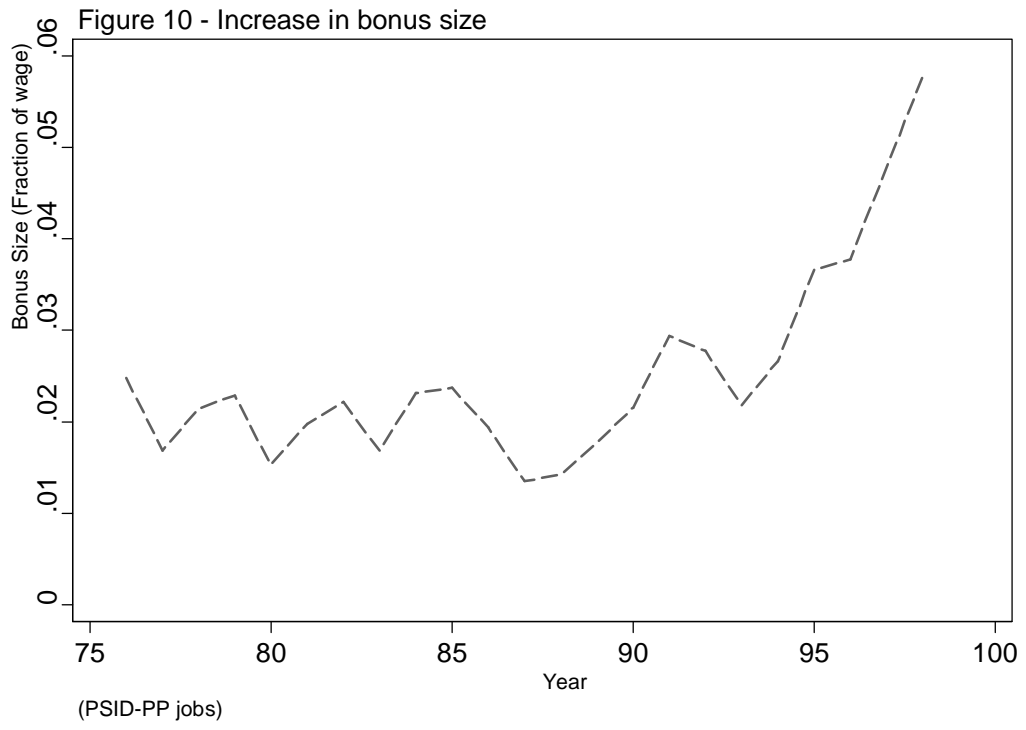
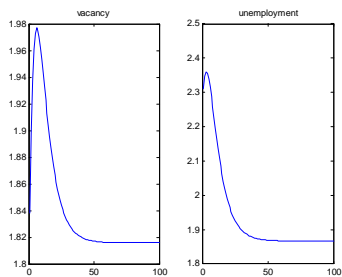
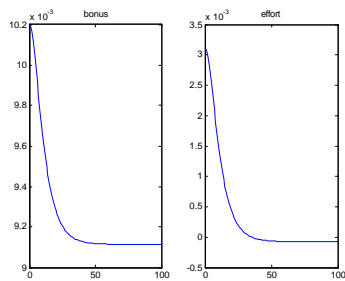


Figure 11 - Impulse Response Function to 1 std shock to z

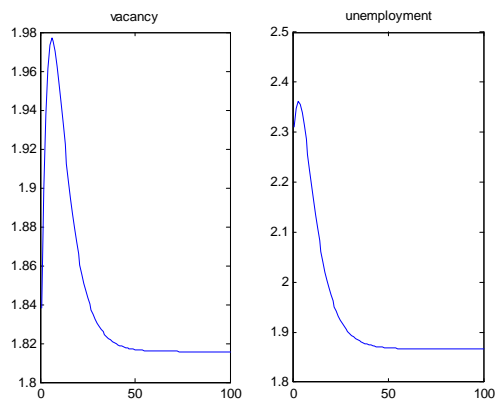


Panel A

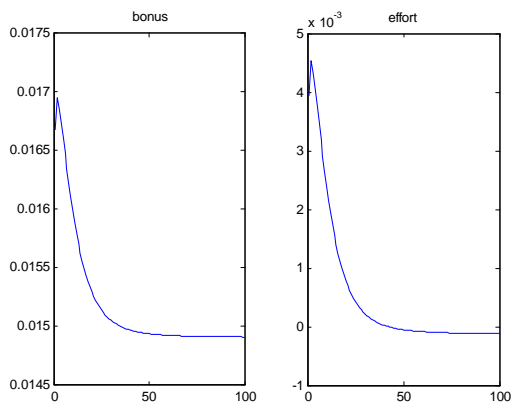


Panel B

Figure 12 -Impulse Response Function to 1 std shock to p



Panel A



Panel B

Table 1- Trend Increase in Earnings instability in the March CPS, 1979 - 2007

Full sample - private non-farm						
Dependent variable (instability measure)	Constant		Regression coefficient for time trend		Cumulative change	Mean of dependent variable
Total earnings	0.24726 (0.00193)	***	0.00107 (0.00019)	***	0.030	0.271
Hourly earnings	0.21111 (0.00150)	***	0.00180 (0.00016)	***	0.050 0.211	0.249
Total hours	0.18152 (0.00176)	***	-0.00019 (0.00016)		-0.005	0.175
Job stayers						
Dependent variable (instability measure)	Constant		Regression coefficient for time trend		Cumulative change	Mean of dependent variable
Total earnings	0.12874 (0.00130)	***	0.00240 (0.00015)	***	0.067	0.172
Hourly earnings	0.14554 (0.00134)	***	0.00233 (0.00015)	***	0.065	0.188
Total hours	0.05376 (0.00067)	***	0.00026 (0.00007)		0.007	0.065
Job movers/losers						
Dependent variable (instability measure)	Constant		Regression coefficient for time trend		Cumulative change	Mean of dependent variable
Total earnings	0.46941 (0.00495)	***	-0.00078 (0.00046)	*	-0.022	0.444
Hourly earnings	0.33114 (0.00372)	***	0.00133 (0.00036)	***	0.037	0.356
Total hours	0.39922 (0.00466)	***	-0.00089 (0.00042)	**	-0.025	0.349

* 10% significance ** 5% significance *** 1% significance
Sample Size: Full sample, 176728. Job stayers, 111641. Break in survey methodology in 1988.
Standard errors in parenthesis. See appendix for matching and sample selection.

Table 2- Trend Increase in Earnings Instability for Different Demographic Groups: Job Stayers in the March CPS from 1979 to 2007

Job stayers less than 45 yrs old						
Dependent variable (instability measure)	Constant		Regression coefficient for time trend		Cumulative change	Mean of dependent variable
Total earnings	0.12791 (0.00166)	***	0.00308 (0.00019)	***	0.086	0.174
Hourly earnings	0.14518 (0.00170)	***	0.00290 (0.00019)	***	0.081	0.189
Total hours	0.05614 (0.00086)	***	0.00023 (0.00009)	**	0.006	0.067
Job stayers with high school or less						
Dependent variable (instability measure)	Constant		Regression coefficient for time trend		Cumulative change	Mean of dependent variable
Total earnings	0.13248 (0.00181)	***	0.00294 (0.00023)	***	0.082	0.181
Hourly earnings	0.14636 (0.00184)	***	0.00279 (0.00023)	***	0.078	0.193
Total hours	0.04932 (0.00010)	***	0.00019 (0.00088)	*	0.005	0.059

Sample Size: with high school or less, 68755. Less than 45yrs. old, 54561. Break in methodology in 1988. See appendix for matching and sample selection.
* 10% significance ** 5% significance *** 1 % significance
Standard errors in parenthesis.

Table 3- Wage instability in different pay schemes in the PSID: 1976 to 1996

<i>Compensation scheme group</i>	<i>Mean dispersion in hourly wages growth</i>	
Not Performance pay and not in Union	0.166	
Performance pay and not in Union	0.173	
Union and Not Performance pay	0.155	
Union and Performance pay	0.162	
<i>Compensation scheme group</i>	<i>Fraction of group in 1976</i>	<i>Fraction of group in 1995</i>
Not Performance pay and not in Union	0.423	0.421
Performance pay and not in Union	0.275	0.390
Union and Not Performance pay	0.245	0.141
Union and Performance pay	0.058	0.049
<i>Compensation scheme groups compared</i>	<i>t test for differences in mean wage volatility in different pay schemes</i>	
Performance pay and not in Union X Not Performance pay and not in Union	0.593	
Union and not in Performance pay X Not Performance pay and not in Union	-2.596***	
Performance pay and not in Union X Union and Not Performance pay	3.055***	

Notes: Sample size, 14267. Male heads of the household.

Table 4 - Regression coefficients in the PSID from 1976 to 1996: effect of performance pay on wage instability

Worker group	Job stayers	Job stayers
Constant	0.10548*** (0.01532)	0.13290 (0.15554)
Performance pay dummy	0.00489 (0.00557)	0.02266** (0.01107)
Union Dummy	-0.01133 ** (0.00557)	-0.00591 (-0.0097)
Tenure		-0.00223** (0.00108)
Tenure²		0.00108** (0.00003)
Education		-0.00256 (0.00789)
Married		0.00560 (0.00865)
Potential experience		0.00534 (0.00575)
Experience²		-0.00026 (0.00014)
Experience³		0.00004** (0.00002)
R-squared	.02	0.3
Controls for worker fixed effects and characteristics	no	yes

Notes: Sample size, 14267, PSID, male heads of household. Standard errors in parenthesis, clustered at the job match level.

***1% significance **5% significance

Table 5 - Calibration of model parameters

<i>Parameters of the idiosyncratic process and production technology</i>	
Log mean of idiosyncratic shock	-0.05
Persistence of idiosyncratic shock	0.947
Std of the innovation of idiosyncratic shock	0.20
Discount rate β	0.99
Labor share in the production function α	0.64
<i>Moments used to calibrate the idiosyncratic shock process</i>	
Excess job reallocation	0.14
Unemployment rate	0.055
<i>Parameters of the performance pay technology</i>	
Marginal value of effort ζ	[.05 0.25]
Marginal cost of effort γ	0.5
Private information process μ	Beta (p,p)
<i>Moments used to calibrate the performance pay technology</i>	
Std bonus	0.13
Bonus size	0.037
Bonus Incidence	0.141
<i>Moments used to calibrate the unionized model</i>	
Union wage premium	0.17

Note: Calculations for the bonus use performance pay jobs in the PSID from 1993-1998. The bonus corresponds to the part of compensation in the PSID reported in the form of bonus, commission or piece-rate. Bonus size is the ratio of bonus to total compensation, and bonus incidence is the fraction of performance pay jobs that received incentive pay in a given year. Unemployment is calculated from the rate reported by the BLS in the 2000's. Labor share in the production function comes from NIPA. Excess job reallocation uses the quarterly BED data.

Table 6 - Simulation results and moments to match

<i>Moments to match</i>	<i>Data moments</i>	<i>Model moments</i>
Excess job reallocation	0.14	0.18
Unemployment rate	0.055	0.07
Std bonus	0.13	0.057
Bonus size in 1998	0.057	0.058
Bonus Incidence in 1998	0.17	0.15
Union wage premium	0.17	0.25

Note: Calculations for the bonus use the PSID from 1993-1998. The bonus corresponds to the part of compensation in the PSID reported in the form of bonus, commission or piece-rate. Bonus size is the ratio of bonus to total compensation, and bonus incidence is the fraction of performance pay jobs that received incentive pay in a given year.

Unemployment is calculated from the rate reported by the BLS in the 2000's.

Excess job reallocation uses the quarterly BED data.

Union wage premium comes from Newmark and Kawaguchi (2001).

The model is simulated quarterly and model moments are aggregated annually for comparison with the PSID data.

Table 7 - Moments to explain

Change in the mean absolute deviation of hourly wage growth rate	0.065
Change in standard deviation of employment growth rate	-0.042

Note: Calculations use the March CPS and LBD . The change for hourly earnings instability uses the cumulative increase estimated with the time trend for job stayers in Table 1. The change in employment instability uses the difference between the 2005 and the 1976 value of the std of cross section employment growth rate in the LBD.

Table 8- Simulated moments with different pay schemes

<i>Statistics</i>	<i>Baseline</i>	<i>Union</i>	<i>Performance Pay</i> <i>Beta (6, 6)</i> <i>$\zeta = .25$</i>
Mean %change wage	0.1513	0.1552	0.1743
Mean %change employment	0.1933	0.2033	0.1833
Std (%change wage)	0.2021	0.2009	0.2285
Std (%change employment)	0.5588	0.6174	0.5765
Average wage	1.53	1.99	1.59
Unemployment	6.8	7.87	7.05
Value of search	152	156	162

Table 9- Simulated moments from performance pay model

<i>Statistics</i>	<i>Parameters of Performance Pay Technology</i>			
	Beta (1,1) $\zeta = .05$	Beta (4,4) $\zeta = .1$	Beta (6, 6) $\zeta = .2$	Beta (6, 6) $\zeta = .25$
Mean %change wage	0.1511	0.1537	0.1652	0.1743
Mean %change employment	0.1762	0.1762	0.1774	0.1833
Std (%change wage)	0.2021	0.2050	0.2189	0.2285
Std (%change employment)	0.5619	0.5618	0.5618	0.5765
Size of the bonus	0.0018	0.0081	0.0318	0.0579
Std of the bonus	0.0047	0.0159	0.0429	0.0575
Bonus Incidence	0.0300	0.0590	0.1197	0.1585
Average wage	1.54	1.56	1.62	1.59
Unemployment	6.85	6.86	6.95	7.05
Value of search	153	154	158	162

Table 10 - Calibration of Parameters

Elasticity of the Matching Function	ϵ	-0.40
Constant in the Matching Function	ω	0.80
Utility function	$u(\cdot)$	log
Discount Rate	β	0.99
Exogenous Destruction Rate	ρ_x	0.08
Total Destruction Rate	ρ	0.10
Returns to Performance Pay	* ζ	0.29
Cost of Performance pay	* γ	1.50
Unemployment Benefit	* b	0.47
Vacancy Cost	* v	0.35
	Beta	Beta
Beta Process	(ρ, ρ)	(1,1)
Process for ϵ	Uniform	Unif[0,1]

Note: *Free parameters of the baseline model chosen with minimization of loss function

Table 11 - Calibration of Autoregressive Shock Processes

Process for Aggregate			
Productivity	Mean	Autocorrelation	Std of Innovation σ_z
	1	0.95	4.80E-04
Process for Private			
Information	Mean	Autocorrelation	
	1	.95	*8E+01

Note: *Free parameter of the baseline model chosen with minimization of loss function

Table 12 - Simulation Results of the Baseline Model

	<i>Moments to match</i>	
	Model	Data
Bonus incidence	0.068	0.17
Size of Bonus	0.065	0.06
Corr(Bonus size, unemployment)	-0.2	-0.17
Corr(Bonus pay, unemployment)	-0.19	-0.14
Corr(Bonus incidence, unemployment)	-0.21	-0.31
Corr(Bonus incidence, Bonus Size)	0.99	0.67
Std Incidence	0.22	0.11
Std Bonus Size	0.39	0.39
Std Aggregate Bonus	0.4	0.4
	<i>Other Key Model Moments</i>	
Beveridge curve	0.97	-0.89
Std of Unemployment	0.39	0.19
Std of Vacancy	0.26	0.2
Std Labor Market Tightness	0.15	0.38

Notes: Simulation in the first column uses parameters in Tables 10 and 11.

Table 13 - Simulation Results for Sensitive Analysis of Key Parameters

	$\sigma_p =$	$a =$	$\zeta =$	Baseline
	0	$mean(a^*)$	0.291	
Bonus incidence	0.02	0.1	0.14	0.068
Size of Bonus	0.02	0.1	0.12	0.065
Corr(Bonus size, unemployment)	0.99	-0.13	-0.2	-0.2
Corr(Bonus pay, unemployment)	0.99	-0.13	-0.18	-0.19
Corr(Bonus incidence, unemployment)	0.99	0	-0.2	-0.21
Corr(Bonus incidence, Bonus Size)	1	0.02	0.99	0.99
Std Incidence	0.02	0	0.218	0.22
Std Bonus Size	0.02	0.23	0.37	0.39
Std Aggregate Bonus	0.016	0.24	0.4	0.4
Beveridge Curve	0.83	0.82	0.97	0.97
Std of Unemployment	0.009	0.01	0.41	0.39
Std of Vacancy	0.0078	0.009	0.27	0.26
Std Labor Market Tightness	0.0052	0.007	0.16	0.15

Note: Simulations in columns 1 and 2 change only the value of σ_p , and optimal effort, respectively. In column 3 I change only the value of ζ by 1%. Baseline model uses parameters in Tables 10 and 11.

Table 14 - Regression Results for Cyclical Uncertainty

<i>Explanatory Variable Is Period by Period</i>	<i>Dependent Variable Is Stock-Market Volatility - b</i>		
<i>Cross-Sectional Standard Deviation of</i>	<i>Coefficient</i>	<i>R squared</i>	<i>Time span</i>
Firm profit growth,c Compustat quarterly	0.5320 (0.0640)	0.287	62Q3–05Q1
Firm stock returns,d CRSP monthly	0.5430 (0.0370)	0.287	62M7–06M12
Industry TFP growth,e SIC 4-digit yearly	0.4290 (0.1190)	0.282	1962–1996
Monthly Unemployment Rate (BLS)g	0.2868 (0.1958)	0.0038	62M7–06M12

Notes: a-Each column reports the coefficient from regressing the time series of stock-market volatility on the within period cross-sectional standard deviation (SD) of the explanatory variable calculated from an underlying panel. All variables normalized to a SD of 1. Standard errors are given in italics in parentheses below. So, for example, column 1 reports that the stock-market volatility index is on average 0.532 SD higher in a quarter when the cross-sectional spread of firms' profit growth is 1 SD higher.

b-The stock-market volatility index measures monthly volatility on the U.S. stock market and is plotted in Figure 1. The quarterly, half-yearly, and annual values are calculated by averaging across the months within the period.

c-The standard deviation of firm profit growth measures the within-quarter cross-sectional spread of profit growth rates normalized by average sales, defined as (profitst- and uses firms with 150+ quarters of data in Compustat quarterly accounts.

d-The standard deviation of firm stock returns measures the within month cross-sectional standard deviation of firm-level stock returns for firm with 500+ months of data in the Center for Research in Securities Prices (CRSP) stock-returns file.

e-The standard deviation of industry TFP growth measures the within-year cross-industry spread of SIC 4-digit manufacturing TFP growth rates, calculated using the five-factor TFP growth figures from the NBER data base.

f-Average units in cross section refers to the average number of units (firms, industries, or forecasters) used to measure the cross-sectional spread.

g- Labor Force Statistics from the Current Population Survey
16 years and over

2. Data Appendix

March CPS Data

The March CPS data used in Figures 1 to 7 were downloaded from the NBER website using years 1980 to 2008. The redesign in 1988 changed the March supplement question about earnings. Before 1989, total earnings from last year were registered under one variable. After 1989, there is a question for earnings from the

primary job and an additional variable for earnings from a secondary job. For the years after 1989 my earnings variable is the sum of primary and secondary earnings. Appendix Table 1 shows that variables used for matching the March CPS across years. Following Mandrian and Lefgen (1999), individuals are matched based on their month-in sample, household identifier, household number and line number. After that, repeated observations due to errors in identifiers are deleted. Also, spurious matches with different sex and race in the two periods are eliminated. I did not do further refinements, since they would come at the cost of eliminating some of the "true" matches.

In 1988 there were two releases of the March supplement. The one in the old format is used in the 1987-88 match. The 1988B release is used in 1988-89. The years 1994-95 are an exception. The first 1994 release contained errors in the identifiers. I use the BLS-corrected `h_idnum`. To account for this problem, this year has to be matched by state of residence along with the four usual identifiers. Some caution is needed when using the matched sample, since not all variables are corrected by this procedure. Years 1985-86 and 1995-96 cannot be matched due to changes in the household identifiers.

After 2002, the March Supplement sample was increased in order to cover a higher number of Hispanic Households and low income families with uninsured children (SCHIP). Since the oversample is taken from different rotation groups,

household identifiers can be repeated, which complicates matching. I eliminate the post 2002 oversample for comparability with earlier years. Appendix Figure 1 presents also match rates for the overall sample and including the SCHIP observations. Two steps are needed to eliminate the oversample. First, I delete individuals with person weight equal to zero from 2002 to 2008. Second, I delete in 2002 and 2003 all observations with `h_seq` higher than the 2003 cutoff value 78864. In 2004 and 2005, I eliminated observations with `h_seq` higher than the 2004 cutoff value 78575.

Lastly, in 2005 the identifiers were redesigned in order to facilitate year-to-year matching: `h_idnum` was renamed `h_idnum1` and a second identifier was created, `h_idnum2`. In the 2004-05, I use only `h_idnum1`. From 2005 on, both `h_idnum1` and `h_idnum2` need to be used to sort and merge observations.

Only half of the March sample can be potentially matched across years (rotation groups 1-4 in period t and 5-8 in $t+1$). Among the successfully matched persons, I classify observations according to their status in the period t and $t + 1$ March interviews. Only individuals currently in the labor force are used. The sample is also restricted from 25 to 64, so not to capture major transitions in and out of the labor force. Further, only individuals classified as `private_nonfarm` workers in their longest job and currently in the labor force are kept in the sample. Values of primary earnings that are topcoded or imputed are also excluded. This leaves

me with a sample of private nonfarm workers ranging from 10000 to 8000 workers in each year. March supplement weights are used in all calculations and nominal variables are deflated using the CPI of the reference year. In the computations for total household income, only heads of household are kept and household weights are used. Appendix Table 2 lists CPS identifiers used in the analysis.

Successive changes in the March Supplement questionnaire do not prevent comparisons across years, but some care is needed in order to guarantee that variables have the same meaning over time. I try to homogenize variables to the extent possible. The changes in data processing in 1988 (reading earnings with the primary and secondary wages separately) seems to have permanently moved the volatility measures to a higher level. In the graphs, I choose to subtract the 1987-88 break from all measures of volatility after 1987. Without this adjustment, the increase in instability could be overstated. In the regression exercise I include a dummy for the post 1987 period. This procedure seems to capture the break and does not affect substantially the estimates for the coefficient of the time trend.

One should worry whether the matched sample is representative of the overall labor force. I use propensity score weights to correct for such bias. The propensity score weights are calculated in the following way: I estimate in each year a probit model of the probability of being matched on observables. The variables used were sex, race, head of household status, age, age squared, dummy for educational

attainment, full time status, private sector job, unemployment in the first or second interview and industry indicators for manufacturing and retail sectors. The final weight used is the inverse of the probability predicted by the model multiplied by the March supplement weight. In Appendix Table 3 I present characteristics of the pooled matched sample at the time of the first March interview.

PSID Data

The PSID data used in Figure 8 and the calibration exercise comes from Lemieux, Bentley and Parent (2009). See their paper for further details. The sample consists of male heads of the household aged 18 to 65 with average hourly earnings between \$1 and \$100 (in \$1979). Workers in the public sector and self-employed are excluded from the sample. Jobs are assigned as performance pay if part of the worker's compensation includes a variable pay component (bonus, commission, piece-rate). From 1976 to 1992, the authors use mainly two questions to construct definitions: the amount of money earned from working overtime, or from bonus, commission or piece-rate, and for workers not paid by the hour or salary exclusively, the form of pay received. All non-overtime workers that report bonus, commission or piece rate are classified as having a performance pay job. After 1993, the interviews include a direct question about the amount earned in bonus, tips, commission and overtime. For the sake of comparability, performance pay jobs are defined as jobs with non-overtime pay but positive bonus, commission or piece-rate.

For some jobs, positive bonus pay is usually not received in every year. The authors define as performance pay any job that received at least once over the duration of the job match pay in form of bonus, commission or piece-rate.

The computation algorithm is as follows. The problem consists of a search for a fixed point in ϕ and U . The algorithm contains an inner loop necessary to solve the dynamic programming island problem and the invariant distribution of islands over the labor force and idiosyncratic shocks, and an outer loop to obtain the fixed point in the expected value of arriving in an island anywhere in the stationary distribution, and the mass of searchers in the economy. See Kambourov and Manovskii (2007) for an example.

3. Derivation of equilibrium in performance pay markets

The firm problem is:

$$\pi = \max_{B,g} E_{\mu} [(1 + \varsigma a^*) \varepsilon g^{\alpha} - wg - \mu a^* Bg]$$

which can be rewritten as:

$$\pi = \max_{B,g} E_{\mu} \left[\left(1 + \varsigma \frac{\mu B}{2\gamma} \right) \varepsilon g^{\alpha} - wg - \frac{\mu^2 B^2}{2\gamma} g \right]$$

The first order conditions are as follows:

$$(.22) \quad B : E_{\mu}[\varsigma \frac{\mu}{2\gamma} \varepsilon g^{\alpha} - \frac{\mu^2 B}{\gamma} g] = 0$$

which implies:

$$B^* = \frac{\varsigma E_{\mu}[\mu \varepsilon g^{\alpha}]}{2 E_{\mu}[\mu^2 g]}$$

$$(.23) \quad g : E_{\mu}[(1 + \varsigma \frac{\mu B}{2\gamma}) \varepsilon \alpha g^{\alpha-1} - w - \frac{\mu^2 B^2}{2\gamma}] = 0$$

which implies:

$$(.24) \quad w = E_{\mu}[(1 + \varsigma \frac{\mu B^*}{2\gamma}) \varepsilon \alpha g^{*\alpha-1} - \frac{\mu^2 B^{*2}}{2\gamma}]$$

Assume μ is *iid* and private information. Since the bonus and employment are decided before the realization of μ , the firm can take μ as independent of g , which simplifies the solution as follows:

$$(.25) \quad B^* = \frac{\varsigma}{2} \frac{E_\mu[\mu] \varepsilon g^{\alpha-1}}{[E_\mu[\mu]^2 + \text{var}(\mu)]}$$

Using (24) in (23) yields:

$$w = \varepsilon \alpha g^{\alpha-1} + E_\mu \left[\varsigma \frac{\mu B^*}{2\gamma} \varepsilon \alpha g^{\alpha-1} - \frac{\mu^2 B^{*2}}{2\gamma} \right]$$

$$w = \varepsilon \alpha g^{\alpha-1} + E_\mu \left[\frac{\mu}{2\gamma} \frac{\varsigma^2}{2} \frac{E_\mu[\mu] \varepsilon g^{\alpha-1}}{[E_\mu[\mu]^2 + \text{var}(\mu)]} \varepsilon \alpha g^{\alpha-1} - \frac{\mu^2}{2\gamma} \left(\frac{\varsigma}{2} \frac{E_\mu[\mu] \varepsilon g^{\alpha-1}}{[E_\mu[\mu]^2 + \text{var}(\mu)]} \right)^2 \right]$$

$$w = \varepsilon \alpha g^{\alpha-1} + \frac{\alpha \varsigma^2}{4\gamma} \frac{E_\mu[\mu]^2 (\varepsilon g^{\alpha-1})^2}{(E_\mu[\mu]^2 + \text{var}(\mu))} - \frac{1}{8\gamma} \frac{E_\mu[\mu]^2 (\varepsilon g^{\alpha-1})^2}{[E_\mu[\mu]^2 + \text{var}(\mu)]}$$

$$(.26) \quad w = \varepsilon \alpha g^{\alpha-1} + \frac{1}{4\gamma} \frac{E_\mu[\mu]^2 (\varepsilon g^{\alpha-1})^2}{(E_\mu[\mu]^2 + \text{var}(\mu))} \left(\alpha - \frac{1}{2} \right)$$

Wage determination:

Combining the first order condition for the firm with the participation constraint of the worker, wages must satisfy:

$$w = E_\mu \left[\left(1 + \varsigma \frac{\mu B^*}{2\gamma} \right) \varepsilon \alpha g^{\alpha-1} - \frac{\mu^2 B^{*2}}{2\gamma} \right] = E_\mu \left[\phi - (\mu a^* B^* - \gamma a^{*2} + \beta E \int v_p(U + g(x, \varepsilon), \varepsilon') Q(\varepsilon, d\varepsilon')) \right]$$

which can be rearranged as follows:

$$(.27) \quad E_\mu [\varepsilon \alpha g^{\alpha-1} + (a^* \varsigma \varepsilon \alpha g^{\alpha-1} - \gamma a^{*2}) + \beta E \int v_p(U + g, \varepsilon') Q(\varepsilon, d\varepsilon')] = \phi$$

where

$$(.28) \quad a^* = \frac{\mu B^*}{2\gamma}$$

$$(.29) \quad B^* = \frac{\varsigma E_\mu [\mu \varepsilon g^\alpha]}{2 E_\mu [\mu^2 g]} = \frac{\varsigma E_\mu [\mu] \varepsilon g^{\alpha-1}}{2 [E_\mu [\mu]^2 + \text{var}(\mu)]}$$

|

Using (26) to (28), employment equilibrium satisfies:

$$E_\mu[\varepsilon\alpha g^{\alpha-1}(1 + \frac{E_\mu[\mu]\zeta^2}{4\gamma} \frac{E_\mu[\mu]\varepsilon g^{\alpha-1}}{(E_\mu[\mu]^2 + var(\mu))}) - \gamma \frac{\mu^2}{4\gamma^2} \left(\frac{\zeta}{2} \frac{E_\mu[\mu]\varepsilon g^{\alpha-1}}{(E_\mu[\mu]^2 + var(\mu))} \right)^2 + \beta E \int v_p(U + g, \varepsilon') Q(\varepsilon, d\varepsilon')] = \phi_p$$

which can be rearranged as follows:

$$\varepsilon\alpha g^{\alpha-1} + \frac{\zeta^2}{4\gamma} \frac{E_\mu[\mu]^2 (\varepsilon g^{\alpha-1})^2}{(E_\mu[\mu]^2 + var(\mu))} \left(\alpha - \frac{1}{4} \right) + \beta E \int v_p(U + g, \varepsilon') Q(\varepsilon, d\varepsilon') = \phi_p$$

3.1. Case of observable effort

Now consider the case in which the impact of effort on performance pay is observable and constant. Without loss of generality, let $\mu = 1$ in all states of the world. The worker chooses effort to maximize $w + aB - \gamma a^2$ and $a^* = \frac{B}{2\gamma}$. The firm can determine the optimal level of effort by choosing a piece rate on effort. Using the fact that $B = 2\gamma a$, we have that:

$$\pi = \max_{a,g} E_\mu[(1 + \zeta a)\varepsilon g^\alpha - wg - 2\gamma a^2 g]$$

The first order conditions are as follows:

$$g : [(1 + \varsigma a)\varepsilon\alpha g^{\alpha-1} - w - 2\gamma a^2] = 0$$

$$w = (1 + \varsigma a)\varepsilon\alpha g^{\alpha-1} - 2\gamma a^2$$

$$(.30) \quad a : [\varsigma\varepsilon g^\alpha - \gamma 4ag] = 0$$

$$(.31) \quad a = \frac{\varsigma\varepsilon g^{\alpha-1}}{\gamma 4}$$

$$(.32) \quad B = 2\gamma a = 2\gamma \frac{\varsigma\varepsilon g^{\alpha-1}}{\gamma 4} = \frac{\varsigma\varepsilon g^{\alpha-1}}{2}$$

By offering the compensation package $w + aB$, the firm always obtains the level of effort $a = \frac{\varsigma\varepsilon g^{\alpha-1}}{\gamma 4}$. Whenever $\alpha = 1/2$, $a = \frac{\varsigma\varepsilon\alpha g^{\alpha-1}}{\gamma 2}$ and the bonus is equal to the marginal value of effort, $B = \frac{\varsigma\varepsilon g^{\alpha-1}}{2} = \frac{\partial f(x, \varepsilon)}{\partial a} = \varsigma\alpha\varepsilon g^{\alpha-1}$.

3.2. Derivation of equilibrium conditions in performance pay markets when there is a monitoring cost

Assume that in order to set up a contract with a bonus pay the firm has to incur the monitoring cost CBg . I derive below the firm problem in order to show that a decline in C has a similar effect of an increase in ς .

$$\pi = \max_{B,g} E_{\mu}[(1 + a^*)\varepsilon g^{\alpha} - wg - \mu a^* Bg - CBg]$$

$$\pi = \max_{B,g} E_{\mu}[(1 + \frac{\mu B}{2\gamma})\varepsilon g^{\alpha} - wg - \frac{\mu^2 B^2}{2\gamma}g - CBg]$$

First order conditions yield:

$$(.33) \quad B : E_{\mu}[\frac{\mu}{2\gamma}\varepsilon g^{\alpha} - \frac{\mu^2 B}{\gamma}g - Cg] = 0$$

$$B^* = \frac{E_{\mu}[\frac{1}{2}\mu\varepsilon g^{\alpha} - Cg\frac{1}{\gamma}]}{E_{\mu}[\mu^2 g]}$$

$$(.34) \quad g : E_{\mu}[(1 + \frac{\mu B}{2\gamma})\varepsilon \alpha g^{\alpha-1} - w - \frac{\mu^2 B^2}{2\gamma} - CB] = 0$$

$$(.35) \quad w = E_{\mu}[(1 + \frac{\mu B^*}{2\gamma})\varepsilon\alpha g^{\alpha-1} - \frac{\mu^2 B^{*2}}{2\gamma} - CB]$$

Assume μ is *iid* and private information. Since bonus and employment are decided before the realization of μ , the firm can take μ as independent of g and simplify the solution such that:

$$(.36) \quad B^* = \frac{\frac{1}{2}E_{\mu}[\mu]\varepsilon g^{\alpha-1} - \frac{C}{\gamma}}{[E_{\mu}[\mu]^2 + var(\mu)]}$$

Using the bonus in the first order condition of the firm gives:

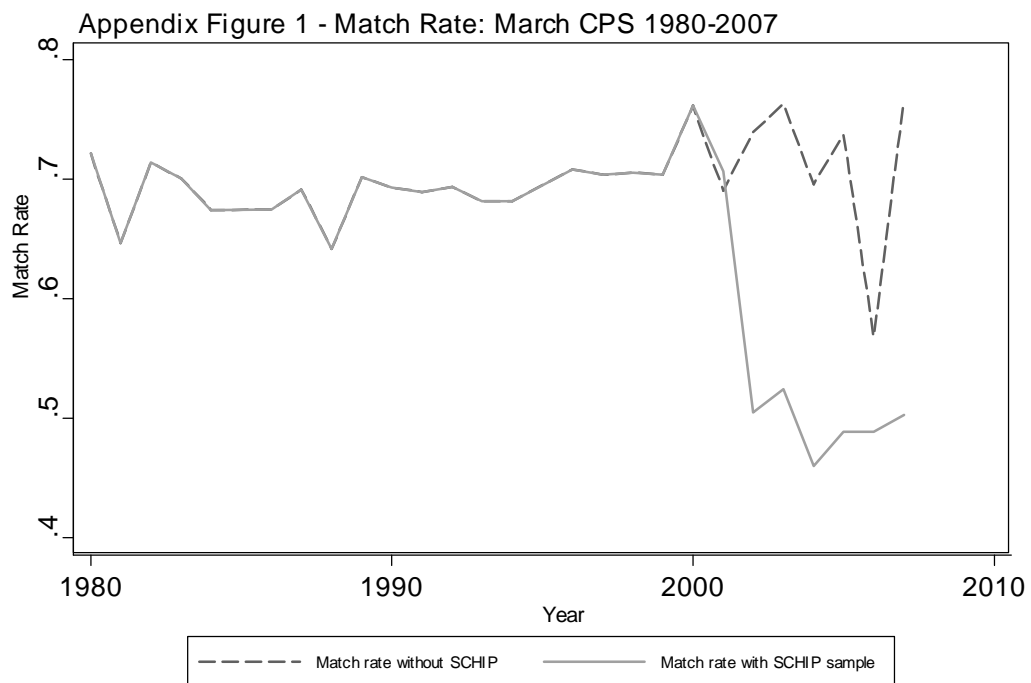
$$w = \varepsilon\alpha g^{\alpha-1} + E_{\mu}[\frac{\mu B^*}{2\gamma}\varepsilon\alpha g^{\alpha-1} - \frac{\mu^2 B^{*2}}{2\gamma} - CB]$$

which can be simplified as follows:

$$w = \varepsilon\alpha g^{\alpha-1} + [B^*(\frac{E[\mu]\varepsilon g^{\alpha-1}}{2\gamma}(\alpha - \frac{1}{2}) + C(\frac{1}{2\gamma^2} - 1))]$$

With a positive cost of using performance pay, and if $[\frac{E[\mu]\varepsilon g^{\alpha-1}}{2\gamma}(\alpha - \frac{1}{2}) - C(1 - \frac{1}{2\gamma^2})] > 0$, both the bonus and the base pay decline with an increase in the cost of

the monitoring technology. Note that when $C \rightarrow 0$, $[B(\frac{E[\mu]\varepsilon g^{\alpha-1}}{2\gamma}(\alpha - \frac{1}{2}) + C(\frac{1}{2\gamma^2} - 1)) > 0$ for $\alpha - \frac{1}{2} > 0$. In this case, we collapse to equation (12) for ς equal to 1, $var(\mu) = 0$ and $\mu = 1$. Also, for high values of C , the bonus is negative, meaning that the performance pay technology is not feasible, since it is too costly to monitor.



(March CPS 1980-2007)

*Appendix Table 1- Variables used for
matching rotation groups across years :
March CPS from 1979 to 2007*

Variable	1980- 1988	1988- 2008
Month-in-sample	mis	h_mis
HH identifier	hhidnum	h_idnum
HH number	item9	h_hhnum
Line number	lineno	a_lineno
State	-	hg_st60
Sex	sex	a_sex
Race	race	a_race
HH sequence number	hhseqnum	h_seq

Note: Change in survey methodology in 1988

*Appendix Table 2- Variables used in the analysis: March CPS
from 1979 to 2007*

Variable	1980-1988	1988-2008
Wages and salaries earnings	i51a	wsal_val
Earnings (self-employed)	i51b	semp_val
LF status	besr	a_lfsr
Weeks worked last year	i34wk	wkswork
Hours worked last year	i38	hrswk
Allocated earnings	incwsflag	i_ernval
Topcoded earnings	flag51a	tcernval
Household weight	hhsupwgt	hsup_wgt
HH total income	hhinctot	htotval
Part-Time Full-Time Status	rwewkrs	wewkrs
Class of worker - longest job	i50cw	weclw
Education	highgrad2	schl1 - a_hga
Age	age	age
Industry - longest job	rwemind	wemind
Head of the HH	relhead	hhdrel
Union member	lumember	a_unmem
More than one employer	i39	phmemprs
Weeks looking or on layoff	i43wk	lkweeks
Weeks looking in one stretch	i44	lkstrch

Note: Change in survey methodology in 1988

Appendix Table 3 - Demographic characteristics of the March CPS sample: rotation groups 1-4 from 1979 to 2007

<i>Demographic characteristic</i>	<i>Percent in the sample</i>
male	47.7
manufacturing job**	12.7
white	85.9
unemployed**	5.3
married	47.9
highschool	66.9
some college	17
in the labor force	49.5
full-time**	78.3
part-time**	18.1
private sector**	67.9
self-employed**	10
imputed wages**	14.7
topcoded wages**	4.1
age <25	33.5
age 25-35	13.4
age 35-45	15.2
age 45-55	13.2
age 55-65	10.6
age 65+	13.8
union member**	3.4

Note: 1,345,109 obs
 ** ratio from In the Labor Force group

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