

# High Discounts and High Unemployment \*

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## Abstract

In recessions, all types of investment fall, including employers' investment in job creation. The stock market falls more than in proportion to corporate profit. The discount rate implicit in the stock market rises, and discounts for other claims on business income also rise. According to the leading view of unemployment—the Diamond-Mortensen-Pissarides model—when the incentive for job creation falls, the labor market slackens and unemployment rises. Employers recover their investments in job creation by collecting a share of the surplus from the employment relationship. The value of that flow falls when the discount rate rises. Thus high discount rates imply high unemployment. This paper does not explain why the discount rate rises so much in recessions. Rather, it shows that the rise in unemployment makes perfect economic sense in an economy where, for some reason, the discount rises substantially in recessions.

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The search-and-matching paradigm has come to dominate theories of movements of unemployment, because it has more to say about the phenomenon than merely interpreting unemployment as the difference between labor supply and labor demand. The ideas of Diamond, Mortensen, and Pissarides promise a deeper understanding of fluctuations in unemployment, most recently following the worldwide financial crisis that began in late 2008. But connecting the crisis to high unemployment according to the principles of the DMP model has proven a challenge.

In a nutshell, the DMP model relates unemployment to job-creation incentives. When the payoff to an employer from taking on new workers declines, employers put fewer resources into recruiting new workers. Unemployment then rises and new workers become easier to find. Hiring returns to its normal level, so unemployment stabilizes at a higher level and remains there until job-creation incentives return to normal. This mechanism rests on completely solid ground.

The question about the model that is unresolved today, 20 years after the publication of the canon of the model, Mortensen and Pissarides (1994), is: What force depresses the payoff to job creation in recessions? In that paper, and in hundreds of successor papers, the force is a drop in productivity. But that characterization runs into three problems: First, unemployment did not track the movements of productivity in the last three recessions in the United States. Second, as Shimer (2005) showed, the model, with realistic parameter values, implies tiny movements in unemployment in response to large changes in productivity. Third, productivity evolves as a random walk, and the DMP model predicts no response of unemployment to the innovations in a random walk.

This paper considers a different driving force, the discount rate employers apply to the stream of benefits they receive from a new hire. Discount rates rise dramatically in recessions—a recent paper by two financial economists finds “...value-maximizing managers face much higher risk-adjusted cost of capital in their investment decisions during recessions than expansions” (Lustig and Verdelhan (2012)).

A simple model lays out the issues. The economy follows a Markov process between a normal state, numbered  $i = 1$ , and a depressed state, numbered  $i = 2$ . I pick parameter values to approximate the U.S. labor market. The probability of exiting the normal state is  $\pi_1 = 0.0083$  per month and the probability of exiting the depressed state is  $\pi_2 = 0.017$  per month. The expected duration of a spell in the normal state is 10 years and the expected

duration in the depressed state is 5 years. A worker has productivity 1 and receives a wage  $w = 0.94$ . Workers separate from their jobs with monthly hazard  $s = 0.035$ . Agents discount future profit  $1 - w$  at the rate  $r_i$ , with  $r_1 = 0.0083$  (10 percent per year) and  $r_2 = 0.042$  (50 percent per year). The value of a worker to a firm is

$$J_1 = \frac{1}{1 + r_1} \{1 - w + (1 - s)[(1 - \pi_1)J_1 + \pi_1 J_2]\} \quad (1)$$

and similarly for  $J_2$ . The solution is  $J_1 = 1.29$  and  $J_2 = 0.87$ .

The labor market operates according to the search-and-matching principles of DMP. The matching function is Cobb-Douglas with equal elasticities for vacancies and unemployment. The monthly cost of maintaining a vacancy is  $c = 1.53$ . The market is in equilibrium when the cost of recruiting a worker equals the value of the worker:

$$cT_1 = J_1 \quad (2)$$

and similarly for  $i = 2$ . The expected duration of a vacancy is  $T_i$  months ( $T_1 = 0.85$  months and  $T_2 = 0.57$  months). The job-finding rate is  $f_i = \mu^2 T_i$ , where  $\mu$  is the efficiency parameter of the matching function. Its values are  $f_1 = 0.66$  and  $f_2 = 0.44$ . The stationary unemployment rate is

$$u_i = \frac{s}{s + f_i}, \quad (3)$$

with  $u_1 = 5.1$  percent and  $u_2 = 7.4$  percent.

Unemployment rises in the depressed state because of the higher discount rate. This paper is about the depressing effect in the labor market of higher discounts. Two major research topics arise. First, I demonstrate that Nash bargaining cannot determine the wage. Not only must the wage be less responsive to the tightness of the labor market than it would be with Nash bargaining—a point well understood since Shimer (2005)—but the wage must move in proportion to productivity. This finding is new. The proportionality property finds support in an important new paper, Chodorow-Reich and Karabarbounis (2014), on the time-series behavior of the opportunity cost of labor to the household.

Second, I demonstrate that the increase in the discount rate needed to generate a realistic increase in unemployment in a depressed period is probably substantial, in excess of any increase in real interest rates. Thus the paper needs to document high discount rates in depressed times.

The causal chain I have in mind is that some event creates a financial crisis, in which risk premiums rise so discount rates rise, asset values fall, and all types of investment decline. In

particular, the value that employers attribute to a new hire declines on account of the higher discount rate. Investment in hiring falls and unemployment rises. Of course, a crisis results in *lower* discount rates for safe flows—the yield on 5-year U.S. Treasury notes fell essentially to zero soon after the crisis of late 2008. The logic pursued here is that the flow of benefits from a newly hired worker has financial risk comparable to corporate earnings, so the dramatic widening of the equity premium that occurred in the crisis implied higher discounting of benefit flows from workers at the same time that safe flows from Treasuries received lower discounting. In the crisis, investors tried to shift toward safe returns, resulting in lower equity prices from higher discount rates and higher Treasury prices from lower discounts. In other words, the driving force for high unemployment is a substantial widening of the risk premium for the future stream of contributions a new hire makes to an employer.

Appendix A discusses some of the large number of earlier contributions to the DMP and finance literatures relevant to the ideas in this paper. The proposition that the discount rate affects unemployment is not new. Rather, the paper’s contribution is to connect the labor market to the finance literature on the volatility of discount rates in the stock market and to identify parameters of wage determination that square with the high response of unemployment to discount fluctuations and the low response of unemployment to productivity fluctuations.

The paper makes a couple of side contributions to the empirical foundations of the DMP model. First, it measures the separation hazard as a function of tenure and shows that it declines rapidly, contrary to the universal assumption in DMP modeling that the hazard is constant with tenure. Second, it shows that the average productivity per worker, the driving force in the canonical DMP model, is a random walk, and therefore is an unlikely candidate to serve as a driving force.

## 1 The Job Value

The job value  $J$  is the present value, using the appropriate discount rate, of the flow benefit that an employer gains from an added worker, measured as of the time the worker begins the job. A key idea in this paper is that information from the labor market—the duration of the typical vacancy—reveals a financial valuation that is hard to measure in any other way.

## 1.1 The job value and equilibrium in the labor market

The incentive for a firm to recruit a new worker is the present value of the difference between the marginal benefit that the worker will bring to the firm and the compensation the worker will receive. In equilibrium, with free entry to job creation, that present value will equal the expected cost of recruitment. The cost depends on conditions in the labor market, measured by the number of job openings or vacancies,  $V$ , and the flow of hiring,  $H$ . A good approximation, supported by extensive research on random search and matching, is that the cost of recruiting a worker is

$$\kappa + \frac{c}{q}. \quad (4)$$

Here  $x$  is labor productivity and  $q$  is the vacancy-filling rate,  $H/V$ . The reciprocal of the vacancy-filling rate  $1/q$  is the expected time to fill a vacancy, so the parameter  $c$  is the per-period cost of holding a vacancy open, stated in labor units. To simplify notation, I assume that the costs are paid at the end of the period. The equilibrium condition is

$$\kappa + \frac{c}{q} = \bar{J}. \quad (5)$$

$\bar{J}$  is the present value of the new worker to the employer. I let  $J = \bar{J} - \kappa$ , the net present value of the worker to the employer, so the equilibrium condition becomes

$$\frac{c}{q} = J. \quad (6)$$

The DMP literature uses the vacancy/unemployment ratio  $\theta = V/U$  as the measure of tightness. Under the assumption of a Cobb-Douglas matching function with equal elasticities for unemployment and vacancies (hiring flow =  $\mu\sqrt{UV}$ ), the vacancy-filling rate is

$$q = \mu\theta^{-0.5}. \quad (7)$$

## 1.2 Pre- and post-contract costs

The DMP model rests on the equilibrium condition that the employer anticipates a net benefit of zero from starting the process of job creation. An employer considering recruiting a new worker expects that the costs sunk at the time of hiring will be offset by the excess of the worker's contribution over the wage during the ensuing employment relationship. The model makes a distinction between costs that the employer incurs to recruit job candidates and costs incurred to train and equip a worker. In the case that an employer incurs training

costs, say  $K$ , immediately upon hiring a new worker, and then anticipates a present value  $\tilde{J}$  from the future flow benefit—the difference  $x - w$  between productivity and the wage—the equilibrium condition would be

$$\tilde{J} - K - \frac{c}{q} = 0. \quad (8)$$

In this case, the job value considered here would be the net, pre-training value,  $J = \tilde{J} - K$ . The job value  $\tilde{J}$  rises by the amount  $K$  when the training cost is sunk.

Notice that training costs have a role similar to that of the constant element of recruiting,  $\kappa$ . The definition of  $J$  used here isolates a version of the job value that is easy to observe and moves the hard-to-measure elements to the right-hand side. Thus training and other startup costs and the fixed component of recruiting cost are deductions from the present value of  $x - w$  in forming  $J$  as it is defined here.

Costs not yet incurred at the time that the worker and employer make a wage bargain are a factor in that bargain. The employer cannot avoid the pre-contract cost of recruiting, whereas the post-contract training and other startup costs are offset by a lower wage and so fall mainly on the worker under a standard calibration of the bargaining problem.

## 2 Discount Rates

### 2.1 Discount rates and the stochastic discount factor

Let  $Y_t$  be the market value of a claim to the future cash flows from one unit of an asset, where the asset pays off  $\rho_\tau y_{t+\tau}$  units of consumption in future periods,  $\tau = 1, 2, \dots$ . The sequence  $\rho_\tau$  describes the shrinkage in the number of units of the asset that occurs each period, normalized as  $\rho_1 = 1$ . Let  $m_{t,t+\tau}$  be the marginal rate of substitution or stochastic discount factor between periods  $t$  and  $t + \tau$ . Then the price is

$$Y_t = \mathbb{E}_t m_{t,t+1} y_{t+1} + \rho_2 \mathbb{E}_t m_{t,t+2} y_{t+2} + \dots \quad (9)$$

The *discount rate* for a cash receipt  $\tau$  periods in the future is the ratio of the expected value of the receipt to its discounted value, stated at a per-period rate, less one:

$$r_{y,t,\tau} = \left( \frac{\mathbb{E}_t y_{t+\tau}}{\mathbb{E}_t m_{t,t+\tau} y_{t+\tau}} \right)^{1/\tau} - 1. \quad (10)$$

For assets with cash payoffs extending not too far into the future, the assumption of a constant discount rate may be a reasonable approximation:  $r_{y,t,\tau}$  does not depend on  $\tau$ . In

that case, the value of the asset is

$$Y_t = \frac{\mathbb{E}_t y_{t+1}}{1 + r_{y,t}} + \rho_2 \frac{\mathbb{E}_t y_{t+2}}{(1 + r_{y,t})^2} + \dots . \quad (11)$$

And if  $y_t$  is a random walk,

$$Y_t = y_t \left[ \frac{1}{1 + r_{y,t}} + \rho_2 \frac{1}{(1 + r_{y,t})^2} + \dots \right]. \quad (12)$$

Given the current asset price  $Y_t$  and current cash yield,  $y_t$ , one can calculate the discount rate as the unique root of this equation.

Risky assets are those whose values are depressed by the adverse correlation of their returns with marginal utility, with high returns when marginal utility is low and low returns when it is high. They suffer discounts in market value relative to expected payoffs. Two important principles flow from this analysis. First, each kind of asset has its own discount rate. The stochastic discounter is the same for all assets, but the discount rate depends on the correlation of an asset's payoffs with the stochastic discounter. Second, discounts vary over time. They are not fixed characteristics of assets.

## 2.2 Expected future values

Later in the paper I will show that productivity per worker,  $x_t$ , is a trended random walk. Exploiting this fact simplifies this paper's model considerably. Productivity is a state variable of the model. I assume that all of the variables taking the form of values are proportional to  $x$ . I further assume that the only expected change in the economy is the trend growth in productivity—the discount rate is a random walk. Later I discuss the foundations for these assumptions. I derive the model under the normalization that  $x = 1$ . To put it differently, average output per worker is the numeraire of the economy. The growth rate of the trend in productivity is  $g$ , so, for example,

$$\mathbb{E}_t J_{t+\tau} = (1 + g)^\tau J_t. \quad (13)$$

All of the discounted variables in the model grow at rate  $g$ , so growth and discounting can be combined in a growth-adjusted discount,

$$\frac{r_J - g}{1 + g}. \quad (14)$$

## 2.3 The discount rate in the DMP model

For a firm's investment in an employment relationship, the asset price is the job value,  $J_t$ . For what follows, it is convenient to break the job value into the difference between the present value of a worker's productivity and the present value of wages:

$$J = P(r_P) - W(r_W). \quad (15)$$

In view of the assumption that the variables in the model are expected to remain unchanged except for trend productivity growth, I drop the time subscript at this point. In general, the discount rate for productivity,  $r_P$ , and the discount rate for wages,  $r_W$ , are different. Under the assumptions that make all the values proportional to productivity, it seems reasonable to assume that the two discount rates are the same. I denote their common value, adjusted for growth, as  $r$ .

Forming the present value of productivity,  $P$ , requires the survival probability of a job—the probability that a worker will remain on the job  $\tau$  periods after being hired. Let  $\rho_\tau$  denote this probability. Let  $\eta_\tau$  be the probability that a job ends  $\tau$  periods after it starts. The survival probability is

$$\rho_\tau = \eta_{\tau+1} + \eta_{\tau+2} + \dots \quad (16)$$

The function for the present value of productivity is

$$P(r) = \frac{1}{1+r} + \rho_1 \frac{1}{(1+r)^2} + \rho_2 \frac{1}{(1+r)^3} + \dots \quad (17)$$

One natural approach would be to form the present value of the wage,  $W(r)$ , the same way, based on the observed wage. I discuss the obstacles facing this approach later in the paper. Instead, I use a model of wage formation to construct the function.

## 2.4 The present value of the wage of a newly hired worker

The original DMP model adopted the Nash bargain as the principle of wage formation. It posits that a bargaining worker regards the alternative to the bargain to be returning to unemployment. Shimer (2005) uncovered the deficiency of the resulting model. The Nash-bargained wage is quite sensitive to the job-finding rate—if another job opportunity is easy to find, the Nash bargain rewards the worker with a high wage. Hall and Milgrom (2008) generalized the Nash bargain along the lines of the alternating-offer bargaining protocol of Rubinstein and Wolinsky (1985). Our paper points out that a jobseeker's threat to break

off wage bargaining and to continue to search is not credible, because the employer—in the environment described in the basic DMP model with homogeneous workers—always has an interest in making a wage offer that beats the jobseeker’s option of breaking off bargaining. Similarly, the jobseeker always has an interest in making an offer to the employer that beats the employer’s option of breaking off bargaining and forgoing any profit from the employment opportunity. Neither party, acting rationally, would disclaim the employment bargain when doing so throws away the joint value. We alter the bargaining setup in an otherwise standard DMP model to characterize the alternative open to a worker upon receiving a wage offer as making a counteroffer, rather than disclaiming the bargain altogether and returning to search. Employers also have the option of making a counteroffer to an offer from a jobseeker. Our paper shows that the resulting bargain remains sensitive to productivity but loses most of its sensitivity to labor-market tightness, because that sensitivity arises in the Nash setup only because of the unrealistic role of the non-credible threat to break off bargaining and return to searching.

The model generates complete insulation from market conditions in its simplest form. Our credible-bargaining model adds a parameter, called  $\delta$ , which is the per-period probability that some external event will destroy the job opportunity and send the jobseeker back into the unemployment pool. If that probability is zero, the model delivers maximal insulation from tightness, whereas if it is one, the alternating-offer model is the same as the Nash bargaining model with equal bargaining weights. Notice the key distinction between a *sticky* wage—one less responsive to all of its determinants—and a *tightness-insulated* wage. The latter responds substantially to driving forces by attenuating the Nash bargain’s linkage of wages to the ease of finding jobs. Something like the tightness-insulated wage is needed to rationalize the strong relation between the discount rate and the unemployment rate discussed in this paper. With  $\delta = 0$ , tightness-insulation is maximal.

I sketch the model here in a simple version—see our paper and Rubinstein and Wolinsky (1985) for deeper explanations. A crucial and realistic simplification is the assumption that productivity evolves as a random walk whose trend is absorbed into the discount rate. Current values and expected future values of the variables that move in proportion to productivity are the same. I normalize productivity at one. Bargaining occurs over  $W$ , the present value of wages over the duration of the job. During alternating-offer bargaining, the worker may formulate a counteroffer  $W_K$  to the employer’s offer  $W_E$ . The counteroffer makes the

worker indifferent between accepting the pending offer or making the counteroffer—a failure of indifference would imply that either the worker or the employer was leaving money on the table. The equation expressing the indifference has, on the left, the value of accepting the current offer from the employer; and on the right, the value of rejecting the employer’s offer and making a counteroffer:

$$W_K + V = \delta U + (1 - \delta) \left[ z + \frac{1}{1+r}(W_E + V) \right]. \quad (18)$$

Here  $V$  is the value of the worker’s career subsequent to the job that is about to begin and  $U$  the value associated with being unemployed,  $\delta$  is the per-period probability that the job opportunity will disappear, and  $z$  is the flow value of time while bargaining. I take  $z$  to be constant, meaning that it moves in proportion to productivity. See Appendix C for a rationalization of this assumption, which rests on the constancy of the elasticity of utility with respect to hours of work and constancy of the elasticity of the production function with respect to labor input.

The indifference condition for the employer has, on the left, the value of accepting the current offer from the worker; on the right, the value of rejecting the worker’s offer and making a counteroffer.

$$P - W_E = (1 - \delta) \left[ -\gamma + \frac{1}{1+r}(P - W_K) \right]. \quad (19)$$

Here  $\gamma$  is the flow cost to the employer of delay in bargaining. This is also a constant, so the cost moves in proportion to productivity.

The difference between the two indifference conditions, with  $W$ , the average of the two offers, taken as the wage paid, is

$$2W = W_K + W_E = \frac{1+r}{r+\delta} [\delta U + (1-\delta)(z+\gamma)] + P - V. \quad (20)$$

Here  $P$  is the present value of productivity, from equation (17). The Bellman equations for the unemployment value and the subsequent career value are:

$$U = z + \frac{1}{1+r} [\phi \cdot (W + V) + (1 - \phi)U]. \quad (21)$$

$$V = \left[ \eta_1 \frac{1}{1+r} + \eta_2 \frac{1}{(1+r)^2} + \dots \right] U. \quad (22)$$

Given the value of  $P$  from equation (17) and the observed value of labor-market tightness  $\theta$ , together with a specified value of  $r$ , equation (20), equation (21), and equation (22) form a

linear system of three equations in three unknowns defining the function  $W(r)$ . The discount rate is the unique solution to

$$J = P(r) - W(r). \tag{23}$$

Notice that this solution imposes the zero-profit condition:

$$(P - W)q = c \tag{24}$$

because  $q(\theta)J = c$ . The cost of maintaining a vacancy,  $c$ , is constant in productivity units. Thus the vacancy-filling rate,  $q(\theta)$ , and consequently tightness  $\theta$  itself, are unaffected by changes in productivity. This property of the model cuts across the grain of almost all earlier thinking about the DMP model—I discuss it further in the empirical part of the paper.

## 2.5 Graphical discussion

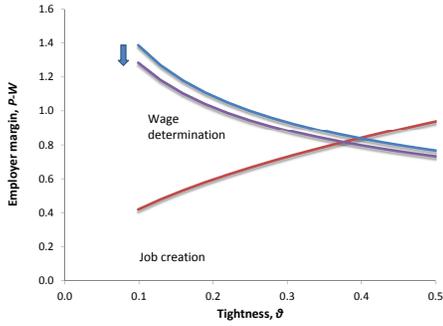
Figure 1 illustrates how the model responds to discount increases for different values of the tightness-response parameter  $\delta$ . Both graphs show an upward-sloping job creation curve that relates the employer’s margin,  $P - W$ , to market tightness  $\theta$ . It is

$$P - W = \frac{c}{q(\theta)}. \tag{25}$$

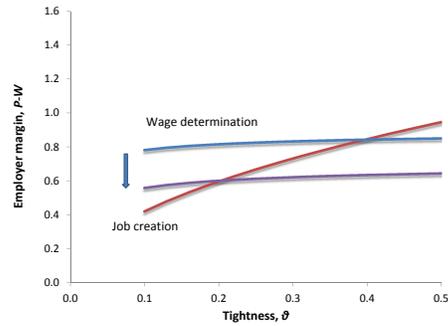
The job-creation curve does not shift when the discount rate rises.

The graphs also show the function  $P(r) - W(r)$  derived earlier, labeled *wage determination*, which is a function of market tightness  $\theta$ . A rise in the discount rate shifts this curve downward—the increase shown is from 10 percent per year to 30 percent per year. Graph (a) describes the model with Nash bargaining ( $\delta = 1$ ) hit by an increase in the discount rate. The wage curve shifts downward only slightly, reflecting the strength of the negative feedback through the tightness effect on the wage. Graph (b) describes an economy where wage determination is less responsive to tightness ( $\delta = 0.05$ ). The downward shift in the wage-determination curves is large, so the effect of a discount increase is large.

In the Nash case, with  $\delta = 1$ , it takes huge movements in the discount rate to explain the observed volatility of tightness. A calculation of the implied discount rate needed to rationalize the observed movements in labor-market tightness, with strong feedback from tightness, will have huge volatility. The finding of high volatility with  $\delta = 1$  is a restatement of Shimer’s point. On the other hand,  $\delta = 0.05$  kills most of the tightness feedback and



(a) Nash:  $\delta = 1$



(b) Tightness-isolated:  $\delta = 0.05$

Figure 1: Effects of Increase in the Discount Rate for Nash and Tightness-Isolated Wage Determination

makes tightness highly sensitive to the discount rate. With that value of  $\delta$ , the implied volatility of the discount rate is correspondingly lower.

In the decade since Shimer’s finding altered the course of research in the DMP class of models, numerous rationalizations of sticky wages have appeared—way too numerous to list here. Many achieved the needed stickiness by limiting the response of the wage to labor-market tightness, as in this model with low  $\delta$ .

## 2.6 Assumptions

Here I summarize and comment on the assumptions underlying the analysis in this paper:

1. Productivity is a trended random walk. I present evidence that supports this assumption in the next section.
2. The term structure of discounts is flat. Measurement of discounts is sufficiently elusive that I have no direct evidence on their term structure. The mean reversion rate of measured discounts is essentially the same as for labor-market tightness. Under standard financial models, that fact would imply declining forward discount rates when the current rate is high. However, given the finding of substantial isolation of wage determination from labor-market conditions, so that the discount in long forward discount in  $V$  is unimportant, the one that matters is in  $J$ , and the evidence in the next section shows that little long-forward discounting occurs because of the low incidence of long-lasting jobs.

3. The following values move in proportion to productivity: the flow value  $z$  associated with unemployment, the flow cost  $c$  of maintaining a vacancy, and the employer's bargaining-delay cost  $\gamma$ . The absence of a trend in unemployment is generally supportive of the assumption. Evidence in Chodorow-Reich and Karabarbounis (2014) supports the assumption for  $z$ .

## 3 Measuring the Implied Volatility of the Discount Rate

### 3.1 Measuring the job value

The labor market reveals the job value from the condition that the value equals the cost of attracting an applicant, which is the per-period vacancy cost times the duration of the typical vacancy:  $J = c/q$ . Later in this section I estimate the cost  $c$  of maintaining a vacancy to be \$4811 per month. The BLS's Job Openings and Labor Turnover Survey (JOLTS) reports the hiring rate and number of vacancies. The vacancy filling rate  $q$  is the ratio of the two. Figure 2 shows the result of the calculation for the total private economy starting in December 2000, at the outset of JOLTS, through the beginning of 2013. The average job value over the period was \$3,919 per newly hired worker. The value started at \$5,155 in late 2000, dropped sharply in the 2001 recession and even more sharply and deeply in the recession that began in late 2007 and intensified after the financial crisis in September 2008. The job value reached a maximum of \$4,882 in December 2007 and a minimum of \$2,480 in July 2009. Plainly the incentive to create jobs fell substantially over that interval. Hall and Schulhofer-Wohl (2013) compare the hiring flows from JOLTS to the total flow into new jobs from unemployment, those out of the labor force, and job-changers. The level of the flows is higher in the CPS data and the decline in the recession was somewhat larger as well. But none of the results in this paper would be affected by the use of the CPS hiring flow in place of the JOLTS flow.

Figure 3 shows similar calculations for the industries reported in JOLTS, based on the assumption that vacancy costs are the same across industries. Average job values are lowest in construction, which fits with the short duration of jobs in that sector. The highest values are in government and health. Large declines in job values occurred in every industry after the crisis, including health, the only industry that did not suffer declines in employment

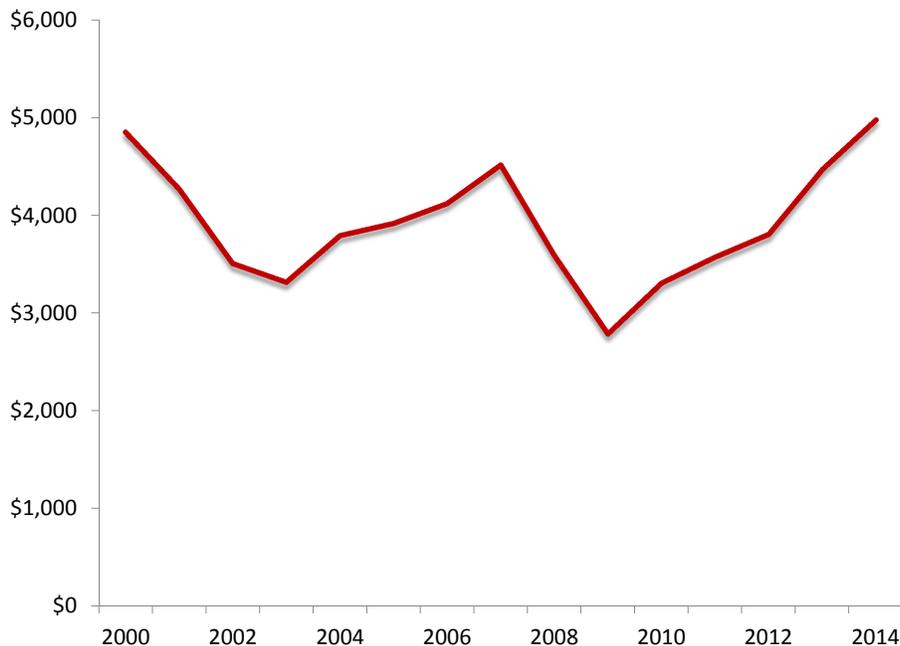


Figure 2: Aggregate Job Value, 2001 through 2014

during the recession. The version of the DMP model developed here explains the common movements of job values across industries, including those that have employment growth, as the common response to the increase in the discount rate.

Lack of reliable data on hiring flows prevents the direct calculation of job values prior to 2001. Data are available for the vacancy/unemployment ratio. I will discuss this source shortly. From it, the vacancy-filling rate is

$$q = \mu\theta^{-0.5}, \tag{26}$$

using the years 2001 through 2007 to measure matching efficiency  $\mu$  (efficiency dropped sharply beginning in 2008). Figure 4 shows the job-value proxy. It is negatively highly correlated with unemployment.

### 3.2 The relation between the job value and the stock market

Kuehn, Petrosky-Nadeau and Zhang (2013) show that, in a model without capital, the return to holding a firm's stock is the same as the return to hiring a worker. In levels, the same proposition is that the value of the firm in the stock market is the value of what it owns. Under a policy of paying out earnings as dividends, rather than holding securities or borrowing, the firm without capital owns only one asset, its relationships with its workers.

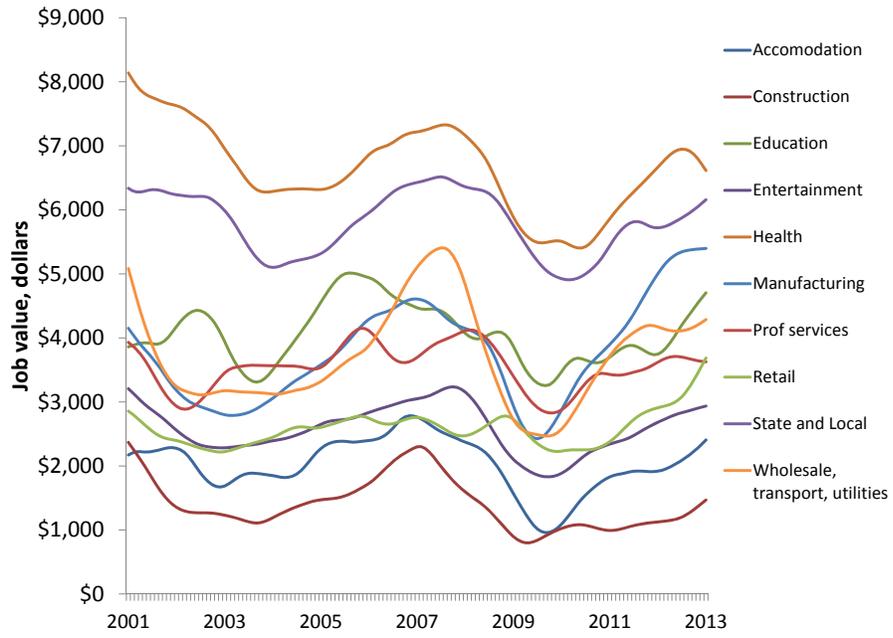


Figure 3: Job Values by Industry, 2001 through 2013

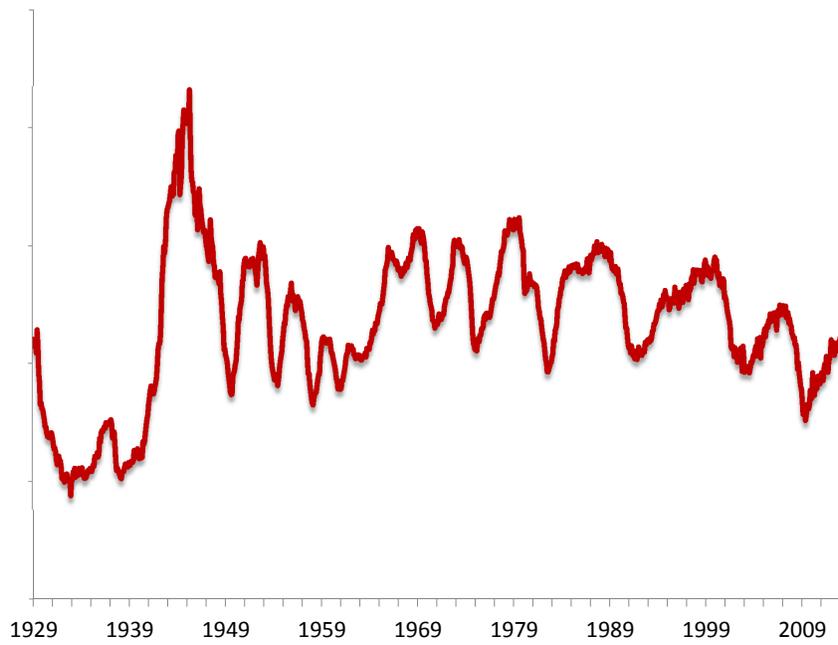


Figure 4: Proxy for the Job Value, 1929 through 2014

The stock market reveals the job value of workers (the amount  $c/q$ ) plus any other costs the firm incurred with the expectation that they would be earned back from the future difference between productivity and the wage. Of course, in reality firms also own plant and equipment. One could imagine trying to recover the job value by subtracting the value of plant and equipment and other assets from the total stock-market value. Hall (2001) suggests that the results would not make sense. In some eras, the stock-market value falls far short of the value of plant and equipment alone, while in others, the value is far above that benchmark, much further than any reasonable job value could account for. Appendix A discusses Merz and Yashiv's (2007) work relating plant, equipment, and employment values to the stock market.

### 3.3 Comparison of the job value to the value of the stock market

Figure 5 shows the job value calculated earlier, together with the S&P 500 index of the broad stock market, deflated by the Consumer Price Index scaled to have the same mean as the job value. The S&P 500 includes about 80 percent of the value of publicly traded U.S. corporations but omits the substantial value of privately held corporations. The similarity of the job value and the stock-market value is remarkable. The figure strongly confirms the hypothesis that similar forces govern the market values of claims on jobs and claims on corporations.

Figure 6 shows the relation between the job-value proxy and the detrended S&P stock-market index (now the S&P 500) over a much longer period. I believe that the S&P is the only broad index of the stock market available as early as 1929. The figure confirms the tight relation between the job value and the stock market in the 1990s and later, and also reveals other episodes of conspicuous co-movement. On the other hand, the figure is clear that slow-moving influences differ between the two series in some periods. During the time when the stock market had an unusually low value by almost any measure, from the mid-70s through 1991, the two series do not move together nearly as much.

Figure 7 shows the co-movement of the job value and the stock market at business-cycle frequencies. It compares the two-year log-differences of the job-value proxy and the S&P index. It supports the conclusion that the two variables share a common cyclical determinant.

The similarity of the movements of the two variables indicates that the job value—and therefore the unemployment rate—shares its determinants with the stock market. This

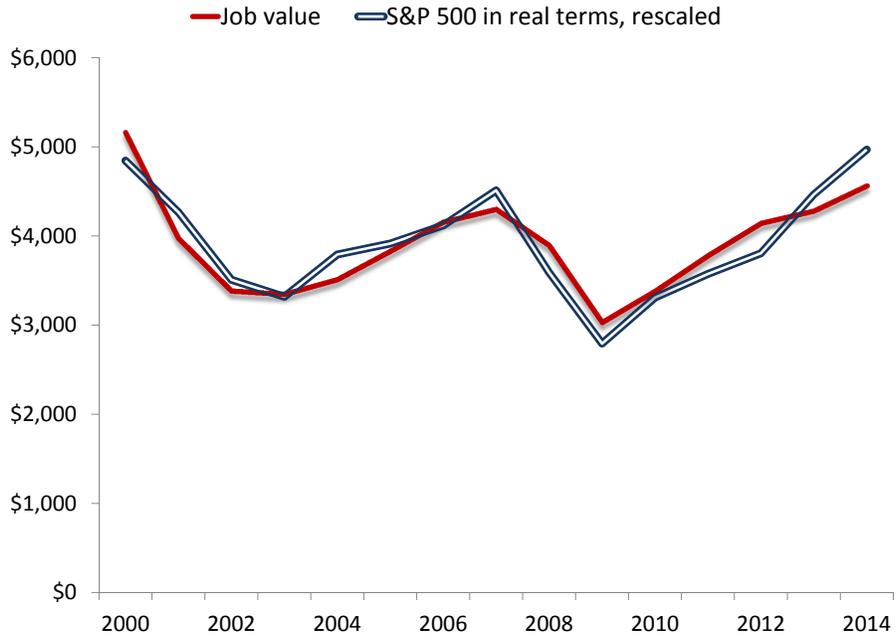


Figure 5: Job Value from JOLTS and S&P Stock-Market Index, 2001 through 2014

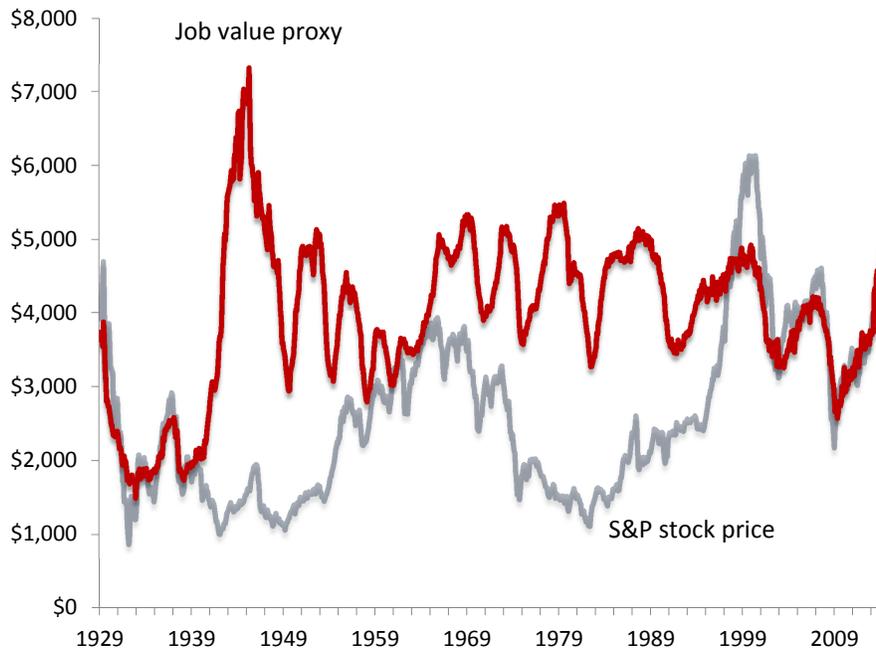


Figure 6: Job-Value Proxy and the S&P Stock-Market Index

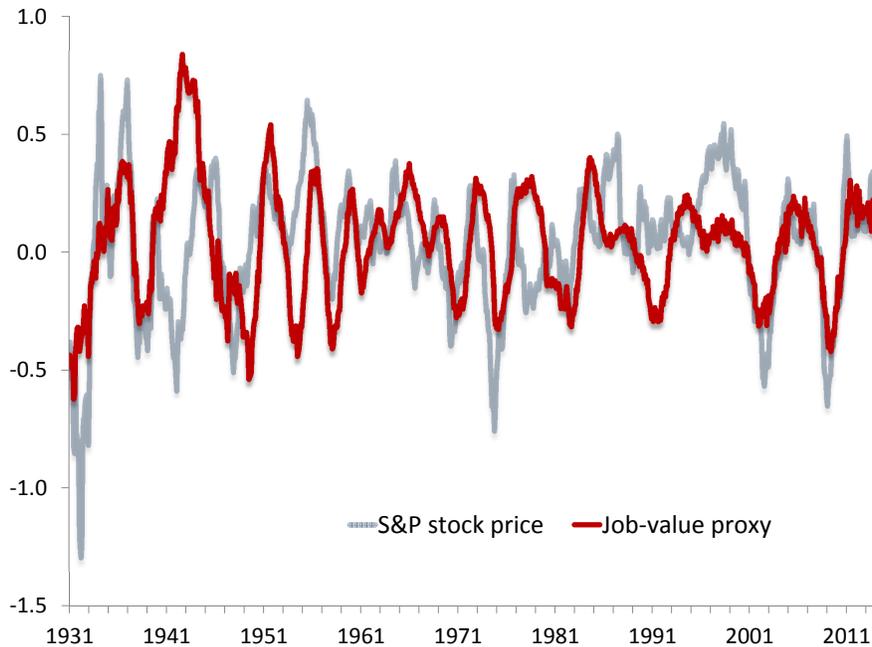


Figure 7: Two-Year Log-Differences of the Job Value and the S&P Stock-Market Price Index

finding supports the hypothesis that rises in discount rates arising from common sources, such as financial crises, induce increases in unemployment. In both the labor market and the stock market, the value arises from the application of discount rates to expected future flow of value. The next step in this investigation is to consider the discount rates and the value flows subject to discount separately.

### 3.4 The random walk of productivity

I calculate output per worker in the business sector as the ratio of BLS series PRS84006043 to series PRS84006013. Output per worker is the appropriate concept for the DMP class of models, rather than output per hour, because the payoff to an employer is the profit margin earned from hiring a worker. Figure 8 shows the resulting time series. Its units are arbitrary because it is the ratio of two indexes.

Though there are occasional episodes of possible mean reversion around an upward trend, statistical testing shows that the random character of the series is quite close to, and statistically indistinguishable from, a trended random walk. The  $p$  value for the Dickey-Fuller test with a linear time trend is 0.98, indicating no perceptible evidence in favor of mean reversion.

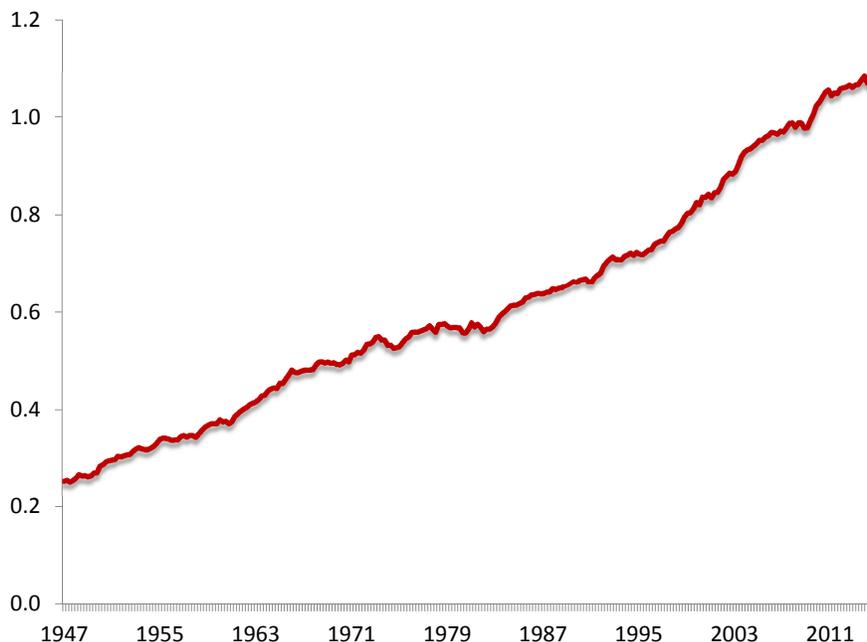


Figure 8: Output per Worker, U.S. Business

Many authors in the DMP tradition have used the higher-frequency component of a filter that separates low from high frequency movements. They treat that component as the driving force of the business cycle. An inevitable consequence of that procedure is mean reversion in the high-frequency component. That mean reversion is not evidence in favor of the view that productivity itself is mean-reverting.

The finding that productivity evolves as a random walk takes it off the table as a potential driving force for unemployment in almost any DMP-type model. The current value of productivity is the long-run level, apart from the trend. If unemployment responds positively to the permanent level of productivity, there would be a downward trend in unemployment to accompany the upward trend in productivity. But unemployment has no trend.

### 3.5 Other data and parameter values

I use annual data for 1948 through 2013. JOLTS measures the stock of vacancies. I divide the number of vacancies in all sectors including government (BLS series JTU00000000JOL) by the number of unemployed workers (BLS series LNS13000000), to obtain  $\theta$  for the years after 2000. For the earlier years, Petrosky-Nadeau and Zhang (2013) have compiled data on the job vacancy rate beginning in 1929. For these years, I take the ratio of their vacancy rate to the unemployment rate as a proxy for  $\theta$ , which I rescale to match the JOLTS-based

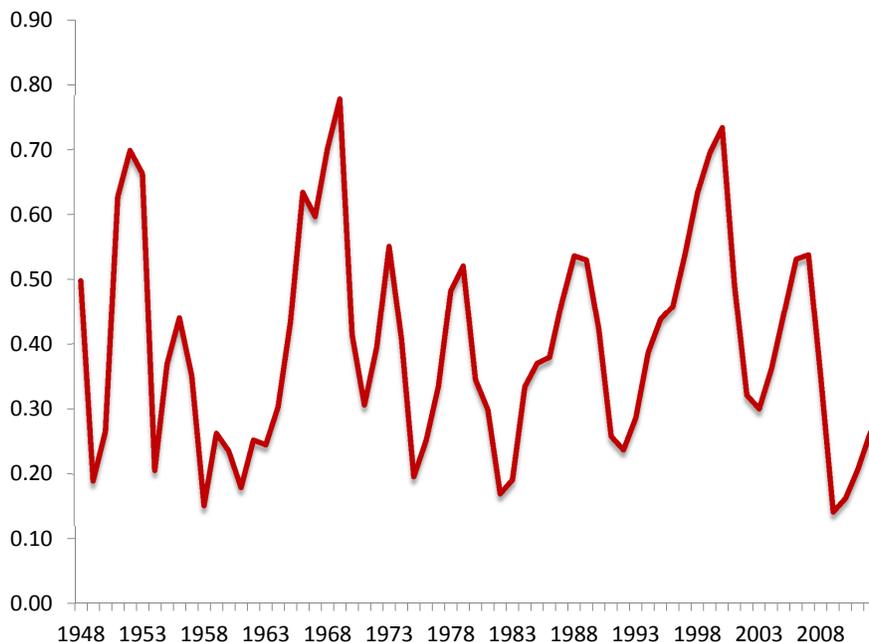


Figure 9: The Vacancy/Unemployment Ratio,  $\theta$

estimates of  $\theta$  during the later years. The resulting series for  $\theta$  has a downward trend, reflecting declining matching efficiency. I remove the trend with a regression of  $\log \theta_t$  on a time trend and restate earlier years at the average level of recent years. Figure 9 shows the resulting series.

Tightness  $\theta$  and productivity have low correlation. In first differences, the correlation is 0.28 and in deviations from trend, -0.02. Plainly  $x$  is not the sole determinant of labor-market tightness. Figure 10 shows the scatter plot of the first differences of the two variables from 1948 through 2013. The low correlation is not the result of a highly nonlinear close relationship, but must be the result of other influences, notably shifts in the discount rate.

The job-survival function plays an important role in the calculations of the discount rate. To my knowledge, all work in the DMP framework has taken the separation hazard to be a constant, though it is well known that the hazard declines dramatically with tenure. Appendix B describe how I derive the distribution from the periodic tenure surveys in the Current Population Survey.

I calibrate the model at a monthly frequency. I take  $r = 0.10/12$ . The average vacancy/unemployment ratio starting in 1948 is  $\theta = 0.397$ , which I use as the calibration point for tightness. The implied values of the turnover parameters are: matching efficiency  $\mu = 0.88$ , job-finding rate  $\phi = 0.55$  per month, job-filling rate  $q = 1.39$  hires per vacancy per

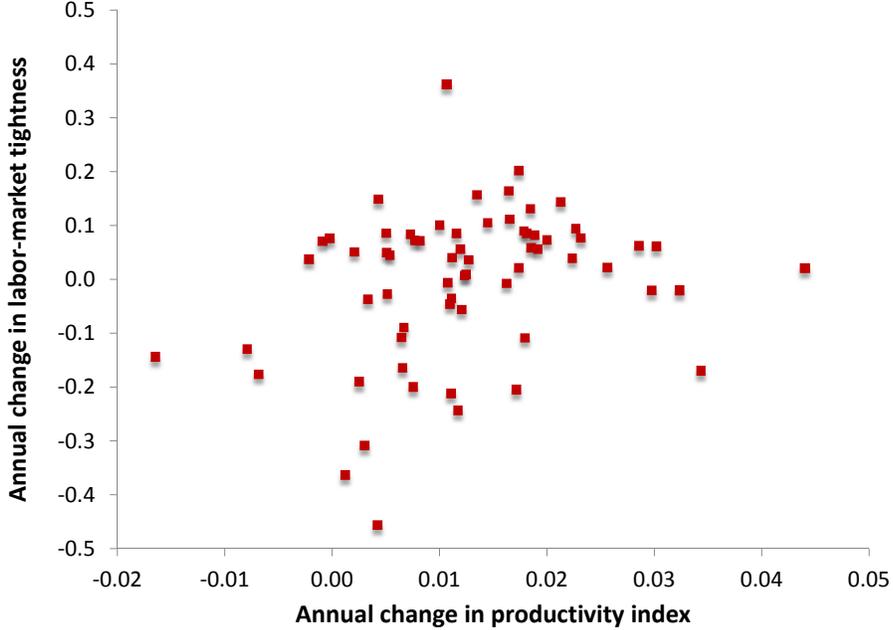


Figure 10: First Differences of Tightness  $\theta$  and Productivity  $x$ , 1948 through 2013

month, and vacancy duration  $T = 0.72$  months. I take the flow value of unemployment to be  $z = 0.41$ . See Appendix C for the rationale. For  $\delta < 1$ , I choose the flow delay cost  $\gamma$  to yield the same wage as for  $\delta = 1$ , where  $\gamma$  is irrelevant. Details about the calibration appear in Appendix D.

### 3.6 Results on implied volatility of the discount rate

For any value of  $\delta$ , the time series  $r_t$  that solves the equilibrium condition,

$$J_t = P(r_t) - W(r_t), \quad (27)$$

is the discount rate that accounts for the values of tightness  $\theta_t$  in each year. For example, if the labor market is tight, with a high  $\theta_t$ , the calculation infers that a low discount rate accounts for employers' enthusiasm in recruiting workers.

Figure 11 shows the implied percent standard deviations at annual rates of the discount rate as a function of  $\delta$ . The results reject values of  $\delta$  above about 0.05 per month. The evidence in favor of stickiness in the sense of isolation of wages from tightness is strong. At  $\delta = 0$ , the credible-bargaining model makes tightness extremely sensitive to the driving forces, which is why the observed volatility of  $\theta$  can be explained by a discount rate with a standard deviation of less than one percent. The evidence that discount rates for other

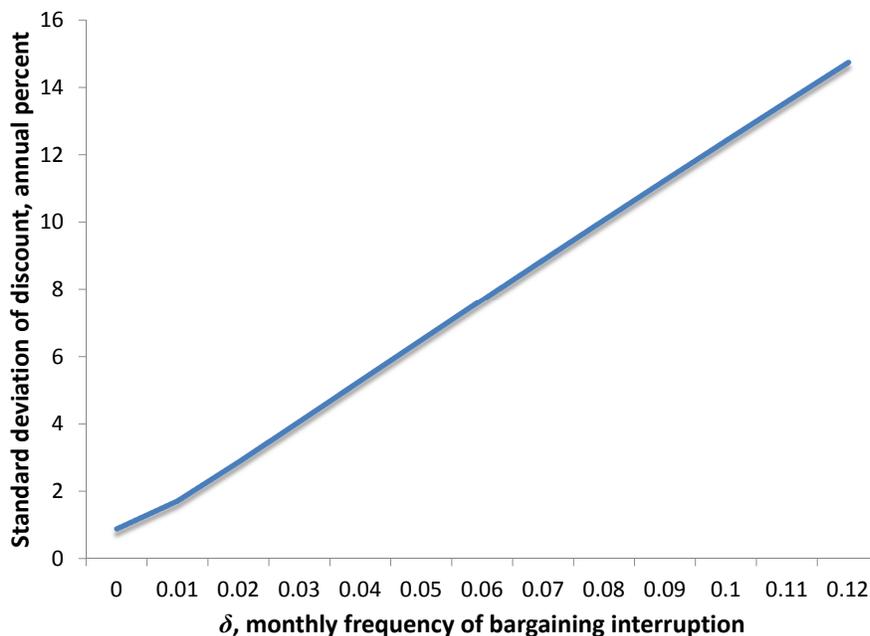


Figure 11: Standard Deviations of Implied Discount Rates as a Function of  $\delta$ , Percents at Annual Rates

claims on business income have standard deviations around 7 percent suggests that the wage is somewhat more flexible, so the driving force needs higher volatility to explain the observed volatility of tightness, perhaps around  $\delta = 0.05$ . Figure 12 shows the calculated discount rate for that value.

The calculation of the implied discount creates a driving force that, by construction, does a good job of explaining the movements of tightness. The ultimate test of the model is whether the implied discount rate resembles discount rates constructed from other sources. The next section provides evidence that this series resembles discounts for financial instruments, not only in volatility, but in its individual movements over the business cycle.

## 4 Discount Rates in the Stock Market

An intuitive but not quite obvious result of finance theory is that the discount rate for a future cash flow is the expected rate of return to holding a claim to the cash flow. Discount rates are specific to a future cash flow—the discount rate for a safe cash flow, one paying as much in good times as in bad times, is lower than for a risky cash flow, one paying more in good times than in bad times. The discount rate reflects the risk premium associated with a future cash flow.

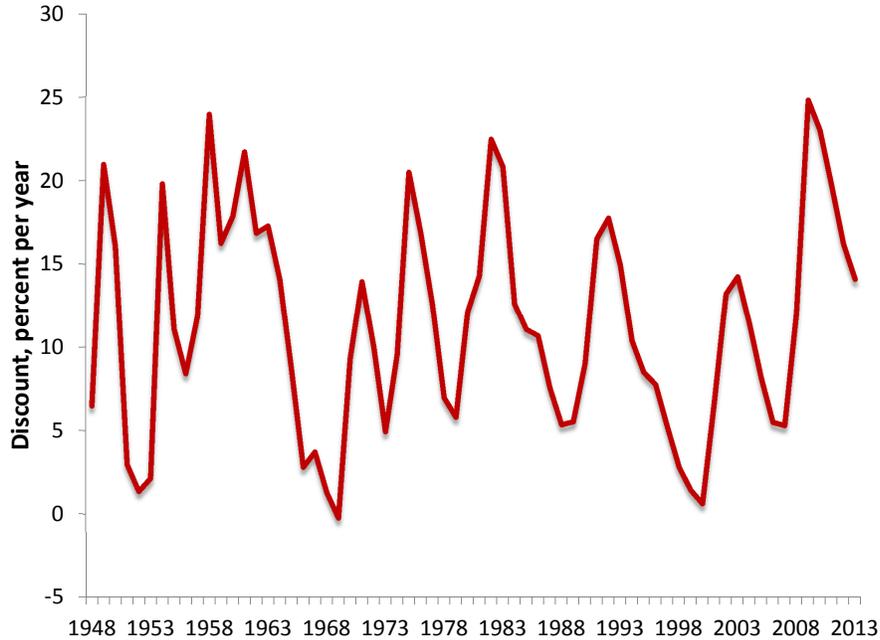


Figure 12: Discount Rate for Wage Flexibility Parameter  $\delta = 0.05$

This paper does not explain why risky flows receive higher discounts in recessions (but see Bianchi, Ilut and Schneider (2012) for a new stab at an explanation). Rather, it documents that fact by extracting the discount rates implicit in the stock market.

#### 4.1 The discount rate for the S&P stock-price index

The issue of the expected return or discount rate on broad stock-market indexes has received much attention in financial economics since Campbell and Shiller (1988). Cochrane (2011) provides a recent discussion of the issue. Research on this topic has found that two variables, the level of the stock market and the level of consumption, are reliable forecasters of the return to an index such as the S&P. Figure 13 shows the one-year ahead forecast from a regression where the left-hand variable is the one-year real return on the S&P and the right-hand variables are a constant, the log of the ratio of the S&P at the beginning of the period to its dividends averaged over the prior year, and the log of the ratio of real consumption to disposable income in the month prior to the beginning of the period. The graph is quite similar to Figure 3 in Cochrane’s paper for his equation that includes consumption.

The standard deviation of the discount rate in Figure 13 is 7.2 percentage points at an annual rate. This is an understatement of the true variation, because it is based on an

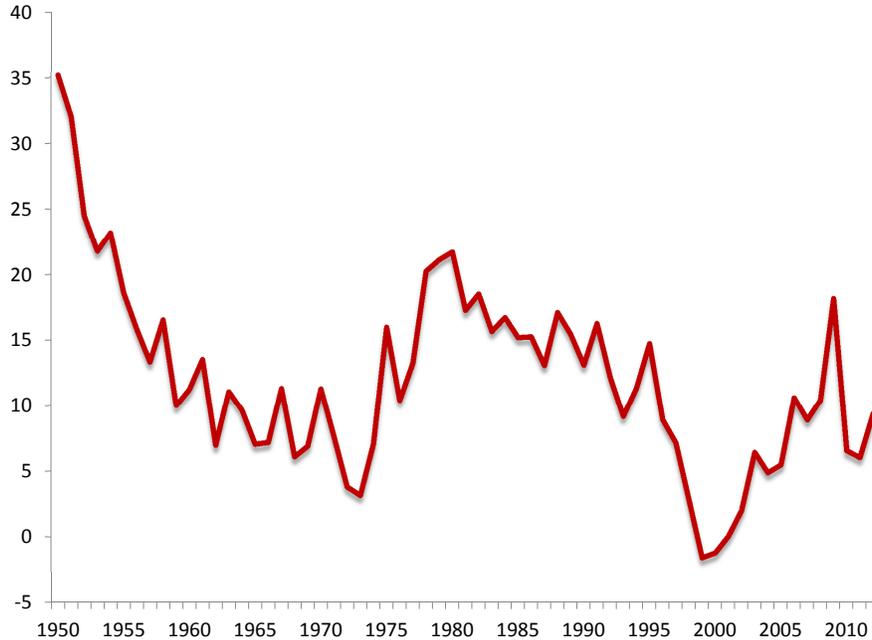


Figure 13: Econometric Measure of the Discount Rate for the S&P Stock-Price Index

econometric forecast using only a subset of the information available at the time the forecasts would have been made.

Lettau and Ludvigson (2001) created a variable, *cay*, from consumption, asset, and income data, that has considerable forecasting power for the return to the S&P index. It is available from Lettau’s website for years starting in 1952. The standard deviation of the discount rate measured as the fitted value from the regression of the annual real return to the S&P index on the value of *cay* at the end of the previous year is 5.8 percent.

Another source of evidence on the volatility of expected returns in the stock market comes from the Livingston survey, which has been recording professional forecasts of the S&P stock-price index since 1952. The standard deviation of the one-year forward expected change in the index in real terms plus the current dividend yield is 5.8 percent.

So far I have considered the volatility of the expected return in the stock market for an investment held for one year. The future cash flow subject to discount is the value from selling the stock in a year, inclusive of the dividends earned over the year reinvested in the same stock. Most of the risk arises from fluctuations in the price of the stock rather than from the value of the dividends, so the risk under consideration in calculating the expected return arises from all future time periods, not just from the year of the calculation. The stock market looks much further into the future than does a firm evaluating the benefit from

hiring a worker, as most jobs last only a few years. One way to deal with that issue is to study the valuation of claims to dividends accruing over near-term intervals. Such claims are called “dividend strips” and trade in active markets. Because dividends are close to smoothed earnings, values of dividend strips reveal valuations of near-term earnings. Jules van Binsbergen, Brandt and Koijen (2012) and van Binsbergen, Hueskes, Koijen and Vrugt (2013) pioneered the study of the valuation of dividend strips, with the important conclusion that the volatility of discount rates for near-term dividends is comparable to the volatility of the discount rate for the entire return from the stock market over similar durations.

These authors study two bodies of data on dividend strips. The first infers the prices from traded options. Buying a put and selling a call with the same strike price and maturity gives the holder the strike price less the stock price with certainty at maturity. Holding the stock as well means that the only consequence of the overall position is to receive the intervening dividends and pay the riskless interest rate on the amount of the strike price. The second source of data comes from the dividend futures market. The latter provides data for about the last decade, whereas data from options markets are available starting in 1996. Jules van Binsbergen et al. (2012) published the options-based dividend strip data on the AER website, for six-month periods up to two years in the future.

The market discount rate for dividends payable in 13 through 24 months is

$$r_t = \frac{\mathbb{E}_t \sum_{\tau=13}^{24} d_{t+\tau}}{p_t} - 1, \quad (28)$$

where  $d_t$  is the dividend paid in month  $t$  and  $p_t$  is the market price in month  $t$  of the claim to future dividends inferred from options prices and the stock price. Measuring the conditional expectation of future dividends in the numerator is in principle challenging, but seems not to matter much in this case. I have experimented with discount rates for two polar extremes. First is a naive forecast, taking the expected value to be the same as the sum of the 6 most recently observed monthly dividends as of month  $t$ . The second is a perfect-foresight forecast, the realized value of dividends 13 through 24 months in the future. The discount rates are very similar. Here I use the average of the two series.

The main point of van Binsbergen et al. (2012) and van Binsbergen et al. (2013) is that the discounts (expected returns) embodied in the prices of near-future dividend strips are remarkably volatile. Many of the explanations of the volatility of expected returns in the stock market itself emphasize longer-run influences and imply low volatility of near-term discounts, but the fact is that near-term discount volatility is about as high as overall

<i>Measures</i>	<i>Correlation</i>	<i>Years</i>
Dividends, stock price	-0.32	1996-2009
Dividends, Livingston	0.37	1996-2009
Stock price, Livingston	-0.14	1952-2012

Table 1: Correlations among the Three Measures of Discount Rates

discount volatility. In the earlier years, some of the volatility seems to arise from pricing errors or noise in the data. For example, in February 2001, the strip sold for \$9.37 at a time when the current dividend was \$16.07 and the strip ultimately paid \$15.87. The spike in late 2001 occurred at the time of 9/11 and may be genuine. No similarly suspicious spikes appear in the later years.

Over the period when these authors have compiled the needed options price, from 1996 through 2009, the standard deviation of the market discount rate on S&P 500 dividends to be received 13 to 24 months in the future, stated at an annual rate in real terms, is 10.1 percent. The standard deviations of the discount rate for the stock market over the same period are 5.4 percent for the econometric version of the return forecast and 6.2 percent for the return based on the Livingston survey.

Figure 14 shows the three series for the discount rates implicit in the S&P stock price and in the prices of dividend strips for that portfolio. On some points, the three series agree, notably on the spike in the discount rate in 2009 after the financial crisis. In 2001, the Livingston forecasters and the strips market revealed a comparable spike, but the econometric forecast disagreed completely—high values of the stock market and consumption suggested a low expected return. From 1950 to 1960, the reverse occurred. The Livingston panel had low expectations of a rising price, whereas the econometric forecast responded to the low level of the stock price relative to dividends, normally a signal of high expected returns. Table 1 shows the correlations of the three measures.

The three measures of discount rate related to the S&P portfolio all have similar volatility, in the range from 6 to 10 percent at annual rates. Contrary to expectation, the three are not positively correlated. Two of the three correlations are negative, though measured over a brief and partly turbulent period. Finance theory imposes no restrictions on the correlations of discount rates for different claims on future cash, because the discounts incorporate risk premiums that may change over time in different ways for different claims. Explaining

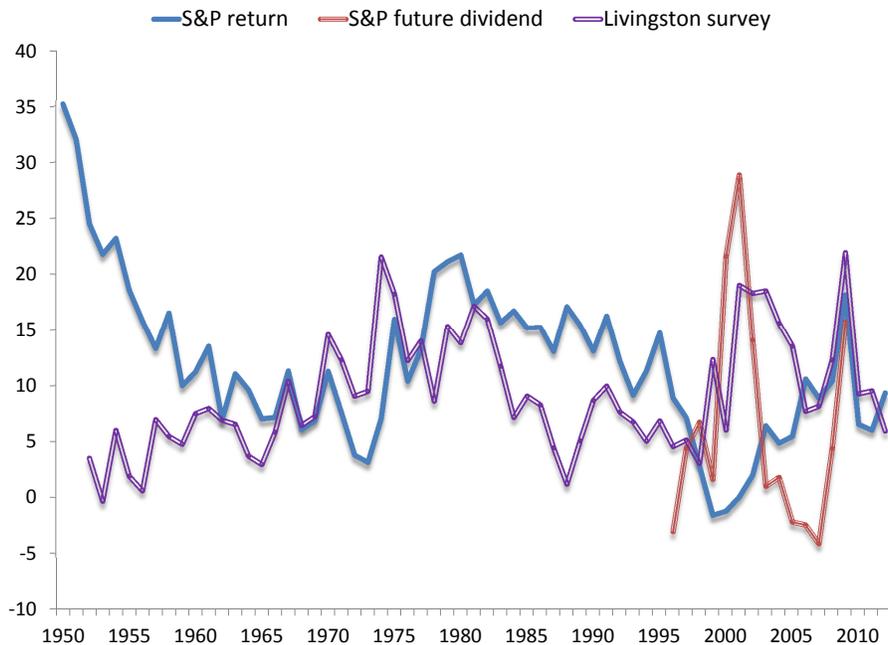


Figure 14: Three Measures of Discount Rates Related to the S&P Stock Price Index Portfolio

the dramatic differences between regression-based measures of expected returns and those obtained from surveys of experts about the same expected returns involves many other considerations about the limitations of the information available to the econometrician, biases from specification search, and the use of information not available to market participants, together with questions about the reliability of an expert panel’s forecasts if they are not actively involved in trading the portfolio. See Greenwood and Shleifer (2014) for a discussion of this finding. Their study does not include the Livingston survey, however.

For this paper, the key conclusions from this review of financial discount rates are, first, their fairly high volatilities, and, second, their low and negative correlations correlations with each other. In view of this evidence, it would not be realistic to adopt any one of the measures derived from the stock market and plug it into the DMP model.

## 5 The Plausibility of the Calculated Discount Rate for Hiring

Table 2 shows the correlations of the labor-market discount rate corresponding to the preferred case  $\delta = 0.05$ , as discussed in Section 3, and the three discounts inferred from the stock market. By the standard of the correlations among those three, the correlations with

<i>Measure</i>	<i>Correlation with labor market</i>	<i>Years</i>
Dividends	0.10	1996-2009
Stock price	0.18	1950-2009
Livingston	0.30	1952-2012

Table 2: Correlations of the Discount Rate in the Labor Market with Stock-Market Rates

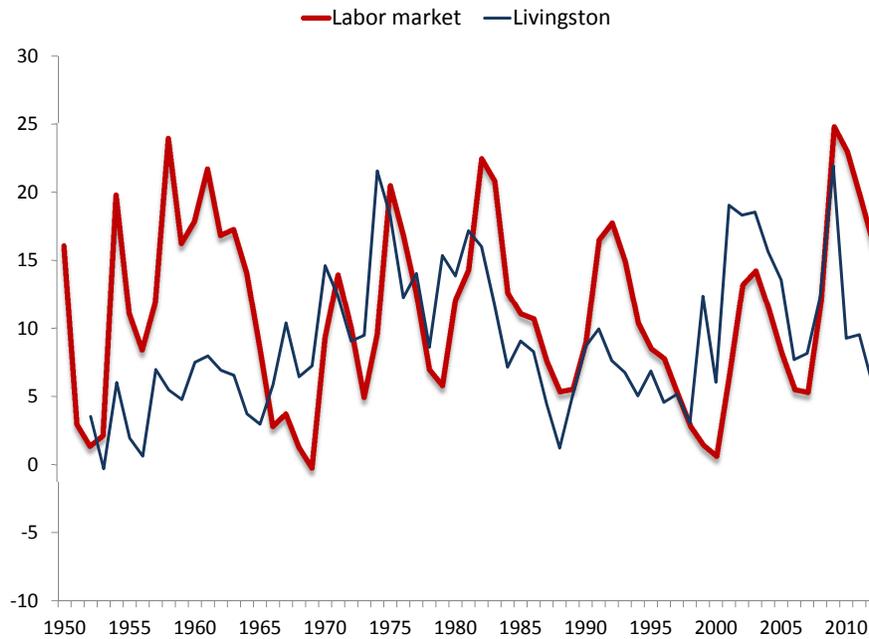


Figure 15: Discount Rate for the Labor Market and the Livingston Panel's Rate for the Stock Market

the labor market are impressive. Figure 15 plots the time series for the labor-market  $r_t$  and the discount rate derived from the Livingston forecasts. The relation between the two is quite apparent after 1970. Spikes in both discount rates occur regularly in recessions, in 1970, 1974-75, 1980-82 (two recessions), 1990, 2001, and 2008-09.

Lustig and Verdelhan (2012) demonstrate that realized returns in the stock market spike after recessions and argue that expected returns do as well. Their work supports the proposition that discounts are not only quite volatile, but that they rise in times of low hiring and other forms of investment.

Because the choice of  $\delta = 0.05$  roughly matched the volatility of the S&P discount, the expected return in the labor market rises about the same amount in response to an adverse

shock as does the expected return in the stock market. As Figure 5 shows, the job value and stock price also have roughly equal volatility. The job value is the expected flow value of a new worker discounted by the expected return in the labor market; the stock price is the expected flow of dividends or profit discounted by the expected return in the stock market. Nothing in the construction of the discount rate for the labor market guarantees the fairly high correlation visible in Figure 15, however. Both discounts reflect valuations of cash flows derived from business activities. Their similarity is moderately persuasive evidence that the construction of the discount for employment relationships is on the right track.

I conclude that financial economics confirms the visual impression in Figure 5 that the same principles influence the valuation of the employer's net flow value from an employment relationship as influence the stock market's valuation of corporate profits. Thus events such as a financial crisis increase the discount rates applied to both flows. In the labor market, employers respond by cutting back on job creation because the capital value of a new employment relationship is the driving force for job creation. The data support this view without any stretch in terms of parameter values.

The DMP framework provides a robust way to measure the discounted value of an employment relationship, the job value  $J$ , through its revelation as the cost of recruiting a new worker. A direct comparison of  $J$  with the value of the U.S. stock market shows a remarkable similarity over the past two decades. The comparison based on finance theory confirms what the naked eye sees—that the job value fell after the financial crisis in line with the discounts implicit in the stock market. To put it differently, the crisis caused a large increase in the equity premium that applied to the net benefit of hiring a new worker as well as to the stock market.

## 6 Direct Measurement of the Flow Value of a New Worker

This paper uses the model of Section 2 to find the relation between the discount rate and the present value of the worker's flow contribution. A natural question is the feasibility of a direct attack on the measurement of the flow value. Why not measure the wage from data on employee earnings instead? I am skeptical that such an approach would work. Most of workers' earnings are Ricardian rents to a primary factor. Thus the gross benefit of a new hire is just a bit higher than the wage. The difference between a necessarily noisy measure

of the gross benefit (the product) and the wage, also measured with noise, would be almost entirely noise.

Suppose that a newly hired worker faces a constant monthly hazard  $s = 0.035$ , of separation, as documented earlier, and the discount rate applicable to the financial risk of the worker's contribution is 10 percent per year or 0.0083 per month. The capitalization factor for a monthly flow is then

$$\frac{1}{0.035 + 0.0083} = 23 \tag{29}$$

From Figure 2, the decline in the job value that occurred in the Great Recession was about \$800. Thus the decline in the monthly net flow to the employer was  $800/23 = \$35$  per month. The median hourly wage in 2011 was \$23, so the decline in the monthly flow was equal to about 90 minutes of wage earnings or a fraction 0.009 of monthly full-time earnings.

Because the change in the net flow value of a newly hired worker needed to rationalize the observed increase in unemployment following the crisis is tiny compared to earnings and other flows, it appears hopeless to measure the job value by determining the flow and calculating its capital value to the employer. Haefke, Sonntag and van Rens (2012), in an ambitious attempt to estimate the response of wages to productivity, concluded that it was not possible to pin it down with a sufficiently small standard error to resolve the subtle question of the cyclical variability of the flow.

Other reasons that direct measurement of the flow value of worker is impractical are (1) training costs are a deduction from productivity and so need to be measured separately, and (2) as Yashiv (2013) observes, labor adjustment costs are a deduction from the flow value.

## 7 Concluding Remarks

The suggestion in this paper that the discount rate is a driving force of unemployment is not new. In addition to the work of Pissarides, Yashiv, and Merz in the DMP framework already mentioned, Phelps (1994), pages 61 and 171, considers the issue in a different framework. Mukoyama (2009) is a more recent contribution focusing on discount volatility in the stock market. Still, most recent research in the now-dominant DMP framework concentrates on productivity as the driving force. The conclusion of this paper with respect to fluctuations in productivity is rather different. Because the evidence favors sticky wages in the sense of almost complete insulation of the wage from tightness, if productivity fell by one or two percentage points while the flow value of unemployment,  $z$ , remained unchanged, unemploy-

ment would rise sharply. But the conclusion of the paper and the work of Chodorow-Reich and Karabarbounis (2014) is that  $z$  falls in proportion to productivity, implying that such a decline in productivity has little effect on unemployment. Sticky wages co-exist with small responses of unemployment to the modest changes in productivity that occur in the U.S. economy. I believe that no researcher has tried to make the case that any actual decline in productivity occurred following the financial crisis is anywhere near large enough or timed in the right way to explain the high and lingering unemployment rate in the U.S., much less in countries like Spain where unemployment rose into the 20-percent range.

The novelty in this paper is its connection with the finance literature that quantifies the large movements in the discount rates in the stock market. This literature has reached the inescapable conclusion that the large movements in the value of the stock market arise mainly from changes in discount rates and only secondarily from changes in the profit flow capitalized in the stock market. The field is far from agreement on the reasons for the volatility of discount rates.

In view of these facts, it is close to irresistible to conclude that whatever forces account for wide variations in the discount rates in the stock market also apply to the similar valuation problem that employers face when considering recruiting. If so, even the highly stable net flow value of a worker found in this paper generates fluctuations consistent with the observed large swings in unemployment.

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# Appendix, for online publication (at least in major parts)

## A Related Research

### A.1 Driving forces

Research in the DMP framework has considered five driving forces, apart from productivity:

- Declines in product demand cause firms to move down their marginal cost curves. The firms have sticky prices, so the marginal revenue product of labor falls. The consequences in the DMP model are then the same as for a decline in productivity.
- Declines in price inflation raise real wages. If the bargain between a newly hired worker and an employer involves an expected rise in the nominal wage that is sticky, but the growth of prices falls to a lower level, the benefit of a new hire to an employer falls and unemployment rises, according to standard DMP principles.
- Increases in the flow value of unemployment,  $z$ , on account of more generous unemployment insurance benefits, raise unemployment.
- Frictions in product markets lower the value of the contribution of a newly hired worker.
- Financial frictions lower the value of a new hire or raise the cost of recruiting new workers.

#### A.1.1 Sticky prices

Walsh (2003) first brought a nominal influence into the DMP model. Employers in his New Keynesian model have market power, so the variable that measures the total payoff to employment is the marginal revenue product of labor in place of the marginal product of labor in the original DMP model. Price stickiness results in variations in market power because sellers cannot raise their prices when an expansive force raises their costs, so the price-cost margin shrinks. Rotemberg and Woodford (1999) give a definitive discussion of the mechanism, but see Nekarda and Ramey (2013) for negative empirical evidence on the cyclical behavior of margins. Hall (2009a) discusses this issue further. The version of the New Keynesian model emphasizing price stickiness suffers from its weak theoretical foundations and has also come into question because empirical research on individual prices reveal more

complicated patterns with more frequent price changes than the model implies. Christiano, Eichenbaum and Trabandt (2013) uses the wage-setting model of Hall and Milgrom (2008) to amplify effects of sticky prices. Hall (2013) finds evidence against higher margins in slumps because advertising should rise substantially with margins but in fact advertising falls dramatically in recessions.

Walsh adopts the Nash wage bargain of the canonical DMP model, which implies that his model may generate low unemployment responses for the reason that Shimer (2005) pointed out. Conceptually, it remains the case that Walsh was the first to resolve the clash between Keynesian models with excess product supply and the DMP model of unemployment.

Mortensen (2011) established a direct connection between drops in product demand and the payoff to new hires. The paper makes the simple assumption that firms stick to their earlier prices when demand drops, so that firms are quantity-takers. It uses a Dixit-Stiglitz setup to map the consequences back into the labor market and shows that the fixity of output results in potentially large declines in the net benefit of a new hire.

### **A.1.2 Sticky wages**

Another approach introduces a nominal element into wage determination. The canon of the modern New Keynesian model, Christiano, Eichenbaum and Evans (2005), has workers setting wages that are fixed in nominal terms until a Poisson event occurs, mirroring price setting in older versions of the New Keynesian model. That paper does not have a DMP labor market. Gertler, Sala and Trigari (2008) (GST) embed a DMP labor-market model in a general-equilibrium model, overcoming Shimer's finding by replacing Nash bargaining at the time of hire with a form of wage stickiness. Gertler and Trigari (2009) developed the labor-market specification. A Poisson event controls firm-level wage bargaining, which takes the Nash form. Between bargaining times, the wage of newly hired workers adheres to the most recent bargain. If labor demand turns out to be higher than expected at bargaining time, the part of the surplus captured by the employer rises and the incentive to recruit workers rises. By standard DMP principles, the labor market tightens and unemployment falls. Though the model is Keynesian in the sense of sticky wages, it describes an equilibrium in the labor market in the sense of Hall (2005)—the relation between workers and an employer is privately efficient. GST build a model of the general-equilibrium response to monetary and other shocks in a version of the Gertler-Trigari setup where the wage bargain is made

in nominal terms. The GST paper resolves the clash by making the DMP determination of unemployment sensitive to the rate of inflation.

A key idea in Gertler and Trigari (2009), put to work in the GST paper, is that workers hired between bargaining times inherit their wage terms from the most recent bargain. In principle, this setup could violate the private efficiency criterion by setting the wage too high to deliver a positive job value to the employer or too low to deliver a job value below the job candidate's reservation level, but, again, in practice this is not likely to occur. If it were an issue, the introduction of state-dependent bargaining would solve the problem, at the cost of a more complicated model.

The GST model assumes that the wage bargain is made in money terms, as the traditional Keynesian literature likes to say. The substance of the assumption is that a state variable—the most recently bargained nominal wage—influences the job value for new hires until the next bargain occurs. This assumption has had a behavioral tinge in that literature—the role of the stale nominal wage arises from stubbornness of workers or employers or from money illusion. From the perspective of bargaining theory, however, as long as the stale wage keeps the job value in the bargaining set, that wage is an eligible bargain. See Hall (2005) for further discussion, not specifically in the context of a nominal state variable. There's no departure from strict rationality in the GST model.

The implications of a model linking the current job value to a stale nominal variable are immediate: The more the price level rises from bargaining time to the present, the higher is the job value in real terms.

### **A.1.3 Unemployment insurance**

Recent papers by Nakajima (2012), Valletta and Kuang (2010), Fujita (2011), and Daly, Hobijn, Şahin and Valletta (2011), culminating in Farber and Valletta (2013), ask whether higher UI benefits result in lower search effort and higher reservation wages, both of which would raise unemployment in a standard DMP model. This research compares the job-finding rates of covered workers to uncovered workers. The answer is fairly uniformly that the effects of UI enhancements during times of high unemployment in raising unemployment still further are quite small, in the range of 0.3 percentage points of extra unemployment.

Hagedorn, Karahan, Manovskii and Mitman (2013) (HKMM) tackle a more challenging question, whether more generous UI benefits result in higher wages and higher unemployment by raising the flow value of unemployment  $z$  and thus shrinking the gap between productivity

and  $z$  that measures the fundamental force that determines the unemployment rate. They compare labor markets with arguably similar conditions apart from the UI benefits regime. In their work, the markets are defined as counties and the similarity arises because they focus on pairs of adjacent counties. The difference in the UI regimes arises because the two counties are in different states and UI benefits are set at the state level and often differ across state boundaries. The research uses a regression-discontinuity design, where the discontinuity is the state boundary and the window is the area of the two adjacent counties. The authors conclude that, absent the increase in UI benefits, unemployment in 2010 would have been about 3 percentage points lower.

Many commentators have dismissed HKMM's conclusion on the grounds that the research implies that unemployment would have hardly risen at all absent the extension of UI benefits, despite the financial crisis and resulting collapse of product demand. But the dismissal is unwarranted. HKMM's work fully recognizes that the enhancements of UI benefits was itself the result of the forces that caused the Great Recession. The proper interpretation, with the framework of the paper, is that feedback from enhanced UI benefits was a powerful amplification mechanism of a negative impulse arising from the crisis.

The issues that arise in evaluating the paper are those for any regression-discontinuity research design: (1) Are there any other sources of discontinuous changes at the designated discontinuity points that might be correlated with the one of interest? (2) Is the window small enough to avoid contamination from differences that do not occur at the discontinuity point but rather elsewhere in the window? The authors explore a number of state-level economic policies that could generate cross-border effects that might be correlated with the UI effects, but none seem to matter. The authors are less persuasive on the second point. Many counties are large enough to create substantial contamination. Far from being atoms, single counties are often large parts of their states, both geographically and in terms of the share of the population. The extreme case is Washington, DC, treated as a state with only one county.

The HKMM paper rests on the hypothesis that the extension of benefits raised the flow value of unemployment  $z$ , contrary to Chodorow-Reich and Karabarbounis's (2014) conclusion that  $z$  was close to unchanged after the crisis.

HKMM have ignited an important debate. Further evidence may help resolve the issue of the reliability of their finding of such large effects on wages and unemployment.

#### **A.1.4 Product-market frictions**

Bai, Ríos-Rull and Storesletten (2012) study product-market frictions with a Walrasian labor market. Gourio and Rudanko (2014) develop a DMP-style product market with directed search. Petrosky-Nadeau and Wasmer (2014) is a comprehensive model with product and financial frictions, linked to a DMP model of the labor market. Kaplan and Menzio (2013) develop a model with both product- and labor-market frictions, with sufficiently strong complementarity to generate multiple equilibria.

#### **A.1.5 Financial frictions**

Petrosky-Nadeau (2014) considers the cost of maintaining a vacancy as a driving force for unemployment fluctuations. In his model, rising credit frictions discourage recruiting and thus raise unemployment through standard DMP principles.

Kehoe, Midrigan and Pastorino (2014) follows up the basic idea in this paper by considering the amplification of the discount effect that arises if the cash flows from a new hire are backloaded. The paper derives the volatility of the discount from financial frictions.

### **A.2 Forming the present value of a newly hired worker's net benefit to the employer**

Yashiv (2000) undertook the task I declare to be impossible in the body of this paper: forming the present value of the difference between a worker's marginal product and wage. Equation (4) in his paper is equivalent to equation (6) here. On page 492, Yashiv notes the analogy between the valuation of a worker's net contribution and valuation in the stock market of a stream of dividends. One important difference between his approach and mine is that he takes the hiring cost to be strongly convex in the flow of hires at the level of the firm, whereas I adopt the linearity that is that standard property of the DMP class of models. Under linearity, the asset value of the employment relationship is observed directly. By contrast, Yashiv uses GMM to infer the marginal hiring cost. A second important difference is that Yashiv's approach does not distinguish between hiring costs incurred prior to a wage bargain and those following the bargain.

### **A.3 Variations in discounts**

The basic proposition that the stock market varies largely because of changes in discount rates is the conclusion of a famous paper, Campbell and Shiller (1988). Cochrane (2011) discusses the finding extensively.

Greenwald, Lettau and Ludvigson (2014) decompose movements of expected stock-market returns and assign a large fraction of the variation to shifts in discounts not affiliated with other variables, such as consumption growth.

Gourio (2012) builds a model where a small probability of a disaster generates substantial variations in discounts, which influence employment through a standard labor-supply setup. The model does not include unemployment.

### **A.4 Joint movements of labor-market variables and the stock market**

Kuehn et al. (2013) is an ambitious general-equilibrium model that combines a DMP labor market with a full treatment of financial markets. Its goal is roughly the reverse of the goal of this paper. It makes the case that volatility in real allocations resulting from amplification of productivity shocks in the labor market causes financial volatility. In particular, the model can generate episodes that look like financial crises, with dramatic widening of the equity premium. The paper provides an endogenous source of economic disasters, an advance over the existing literature that takes large declines in output and consumption to be the result of exogenous collapses of productivity.

Kuehn and coauthors build in a number of the ideas from the post-Shimer literature to gain high amplification in the labor market from productivity shocks. These include (1) adding a fixed cost to the pre-bargain recruiting cost, on top of the cost that varies with the time required to fill a job, (2) assigning the worker a tiny bargaining weight, and (3) assigning a high value to the worker's activities while unemployed, apart from the value of search. They also build in ideas from modern finance that generate a high and variable equity premium along with a low and stable real interest rate. These are (1) an extremely high coefficient of relative risk aversion and (2) a quite high elasticity of intertemporal substitution. The paper briefly surveys related earlier contributions linking asset-price volatility to unemployment volatility: Danthine and Donaldson (2002), Uhlig (2007), Gourio (2007), and Favilukis and Lin (2012).

Farmer (2012) noted the relationship between the levels of the stock market and unemployment. He adopts the traditional view that unemployment is simply the difference between labor supply and demand, thus sidestepping the issues considered in this paper.

Merz and Yashiv (2007) study investment, hiring, and the stock market jointly. Adjustment costs for both inputs result in values of Tobin's  $q$  for both inputs. They estimate a three-equation system comprising dynamic first-order conditions for investment and hiring and the equality of the market value of the firm to its capital stock and employment level valued by their respective  $qs$ . They find a high correlation of their fitted value of the U.S. corporate sector with the actual value.

Hall (2001) considered the same evidence about the market value of the corporate sector as Merz and Yashiv (they adopted my data for the value), but reached rather a different conclusion. My paper rejected the assumption that the value arises only from rents associated with investment adjustment costs. It entertained the hypothesis that the corporate sector acquired highly valuable intangible capital during the run-up of the stock market in the 1990s. The value of that inferred intangible capital collapsed between the writing of the first version of the paper and its appearance in print.

The relation between Merz and Yashiv's work and the approach in this paper is that they rely on the strong assumption that the market value of a firm arises solely from its investments in plant, equipment, and employees. This paper makes the weaker assumption that corporate profits arise from many sources, including its capital stocks, and uses evidence about how the stock market discounts the profit stream to rationalize the observed value of one element of the one part of the profit flow, that arising from the pre-bargain investment that employers make in recruiting workers.

Yashiv (2013) extends his earlier work using a similar specification for joint adjustment costs of investment and hiring. In place of employment levels, the specification uses hiring flows, capturing gross rather than net additions to employment. The hiring costs combine a quadratic term and a DMP-style vacancy holding cost. He computes a Campbell-Shiller-style decomposition of the returns on capital and labor that confirms the importance of variations in discount rates. The paper holds out the promise of helping DMP-type models better characterize the flow value of a newly hired worker to a firm.

## B The Survival Distribution for Jobs

Let  $\rho(\tau)$  be the survival probability, the fraction of workers still on the job  $\tau$  months after hiring. The job duration density is  $-\dot{\rho}(\tau)$ . The separation rate (or separation hazard) is the density of separations in month  $\tau$  conditional on not having separated as of the beginning of that month:

$$s(\tau) = \frac{-\dot{\rho}(\tau)}{\rho(\tau)}. \quad (30)$$

The universal assumption in the DMP literature is a constant separation hazard  $s$ . In that case, the survival probability is  $\rho(\tau) = e^{-s\tau}$  and the duration distribution is  $se^{-s\tau}$ .

A quite separate body of research studies the distribution of tenure among workers and invariably finds large departures from the assumption of a constant separation hazard, in the direction of lower hazards for higher tenure. Suppose that  $N_{\tau,t}$  workers have  $\tau$  months of tenure at time  $t$ . Hires are  $H_t$ . The survival rate is  $\rho_\tau = N_{\tau,t}/H_{t-\tau}$ . Actual observations are made over intervals of tenure and corresponding intervals of earlier hire dates.

The Bureau of Labor Statistics collected data on employment by tenure in the Current Population Survey on an irregular schedule until 1996, and every two years since then. The BLS tabulates the results in a reasonably fine set of categories of tenure, though the agency only publishes data on broad categories. The data tend to clump at salient points, so it would probably not be worthwhile to use the microdata to refine the categories beyond those in the unpublished tabulations.

To make use of the data by categories, I assume that the survival distribution  $\rho(\tau)$  is piecewise exponential and continuous. Thus the separation hazard  $s_i(\tau)$  is constant at  $s_i$  within a category running from  $\tau_i$  to  $\tau_{i+1}$ . The previously calculated probability of being employed in month  $\tau_i$  is  $\rho(\tau_i)$ , with  $\rho(0) = 1$ . The survival probability within category  $i$  is

$$\rho(\tau) = \rho(\tau_i)e^{-s_i(\tau-\tau_i)}. \quad (31)$$

Under the assumption that the density of hiring is constant over the relevant interval, the average survival probability within the category is

$$\bar{\rho}_i = \frac{\rho(\tau_i)}{\tau_{i+1} - \tau_i} \frac{1 - e^{-s_i(\tau_{i+1}-\tau_i)}}{s_i} \quad (32)$$

From the tabulated data on  $\bar{\rho}_i$ , one can solve this equation for the  $s_i$ s recursively.

The Matlab and Excel code available from my website best explain the details of the calculations. For the period 1996 through 2012, the BLS produces a tabulation of workers

by tenure in 13 categories of tenure. To determine the number of historical hires, I use the JOLTS new hire data starting with the onset of JOLTS at the end of 2000. For the period from July 1967 through November 2000, I use the fitted value from a regression of the JOLTS hire rate (ratio of hires to workers) on unemployment, employment growth, and new unemployment benefit claims. For the earlier months beginning in August 1948, I use a similar regression with unemployment in the lowest duration category replacing new UI claims, a series that began in 1967.

The resulting survival probabilities by tenure category,  $\bar{\rho}_i$ , have a good deal of random variation, together with anomalies relating to challenges in interpreting answers to the tenure question that may be in either months or years. Taking the average of the probabilities over the nine surveys helps with the sampling errors. The primary anomaly is a substantial shortfall in the survival probability for the category for 13 to 23 months. I raise it from 0.79 to 0.300, so that it falls on a smooth curve defined by its neighbors. I apply the method derived above to calculate the separation hazards from the adjusted average survival probabilities. The results have a saw-tooth pattern across the tenure categories. I accept the high separation hazard (0.153 per month) for the first 6 months. For categories 2 through 13 I apply a moving-average filter with weights of 0.25 to the adjacent categories and 0.5 to the calculated figure for the category to recover a smooth curve. For all of the remaining categories, I use the average hazard of 0.017 per month across the categories. Figure 16 shows the resulting survival distribution. It departs substantially from the survival function implied by a constant hazard of around 0.035 per month used in existing DMP models, also shown in the figure.

## C Measuring $z$

Chodorow-Reich and Karabarbounis (2014) (CRK) study the movements of the flow value of unemployment,  $z$ , or, as they term the concept, the opportunity cost of work. I believe that theirs is the only contribution on this subject. They conclude that  $z$  moves at cyclical frequencies in proportion to productivity. They start from an expression for  $z$  in Hall and Milgrom (2008) with two components. The first is the level of unemployment-conditioned benefits. The second measures the remaining impact on family welfare from shifting a worker from non-market to market activities, counting the lost flow value of home production, the increase in consumption allocated to workers compared to non-workers, and the change in

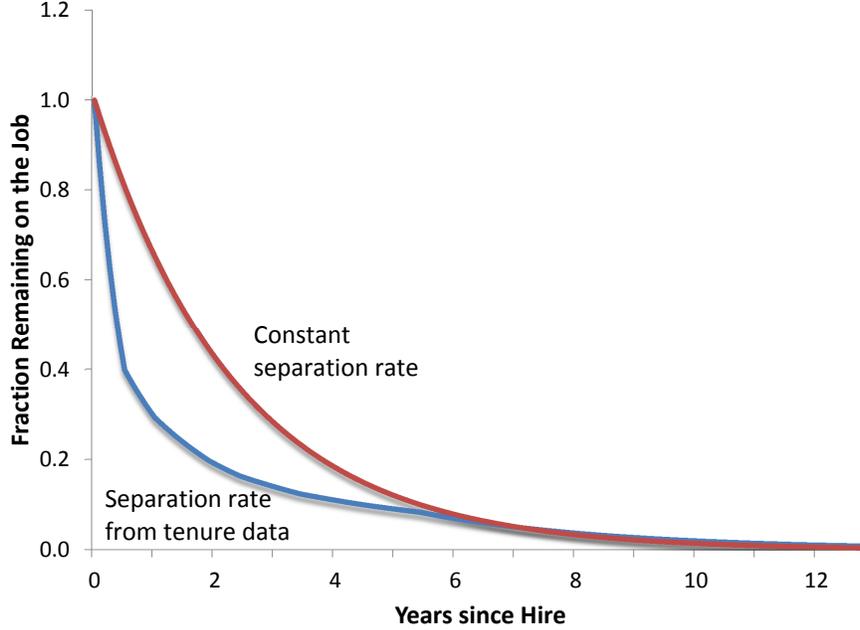


Figure 16: Job Survival Probability Estimated from CPS Tenure Data Compared to Constant Separation Rate

flow utility for a family member moving from non-market activities to market work. Though unemployment insurance rises dramatically in recessions, some of which occur at the same time as drops in productivity, a decline in other types of unemployment-conditioned benefits offsets this effect. And the second component rises in proportion to productivity. Their research supports the hypothesis that the wage is a markdown on productivity because  $x - z$  is stable at cyclical frequencies.

The formula in Hall and Milgrom, further developed by CRK, gives the opportunity cost of taking a job, in a family large enough to provide full insurance against individual unemployment risk, as

$$z = b + \Delta c - \frac{\Delta U(c, h)}{\lambda}. \quad (33)$$

Here  $b$  is the flow of unemployment benefits,  $\Delta$  refers to the difference between employed and unemployed family members,  $c$  is consumption per person,  $h$  is hours of work per person (taken as zero for the unemployed), and  $\lambda$  is the marginal utility of consumption. It appears that taking utility to be separable between consumption and hours gives a reasonable approximation to  $z$ , though the evidence in favor of complementarity is fairly strong. Under separability,

$$U(c, h) = \chi(c) - v(h). \quad (34)$$

I normalize  $v(0)$  at zero. Further,  $\Delta c = 0$  under separability. Thus

$$z = b + \frac{v(h)}{\lambda}. \quad (35)$$

The Frisch ( $\lambda$ -constant) first-order condition for the choice of hours is

$$v'(h) = \lambda w. \quad (36)$$

Combining the two to eliminate  $\lambda$  yields

$$\begin{aligned} z &= b + w \frac{v(h)}{v'(h)} \\ &= b + wh \frac{v}{hv'(h)} \\ &= b + \frac{wh}{\epsilon}, \end{aligned} \quad (37)$$

where  $\epsilon$  is the elasticity of  $v(h)$  with respect to  $h$ . In the case where  $v(h)$  has constant elasticity, so  $\epsilon$  is a parameter and

$$v(h) = h^\epsilon = h^{1+1/\psi}, \quad (38)$$

where  $\psi$  is the Frisch elasticity of hours supply. Thus if  $v(h)$  is constant-elastic, the Frisch elasticity is  $1/(\epsilon - 1)$ . If  $v(h)$  is not constant-elastic, there is no fixed relation between its elasticity at a point  $h$  and the Frisch elasticity at that point—the Frisch elasticity is the reciprocal of the elasticity of marginal utility.

The quantity  $wh$  is the wage per worker and is the same as the worker's contribution to the employer,  $x$ , under competition and with the wage measured in output units, so

$$z = b + \frac{x}{\epsilon} \quad (39)$$

and

$$\frac{z}{x} = \frac{b}{x} + \frac{1}{\epsilon}. \quad (40)$$

Variations over time in  $z/x$  occur only because of variations in the replacement rate  $b$  and in the elasticity of the disamenity of hours of work,  $\epsilon$ .

CRK add another term to their version of the formula for  $z$ , measuring the home production the household foregoes when a member enters market work. They do not try to measure the term. They implicitly assume that  $U(c, h)$  measures the pure disamenity of time spent in the market,  $h$ , and not the foregone home production. In my view, the utility

function is a reduced form for family decisions about the allocation of time. It presumes that the reduction in total time that occurs when  $h$  rises takes the form of some foregone leisure and some foregone work at home, where the disamenity of work at home may be less than the disamenity of market work. The utility function accounts for foregone leisure and the foregone gap between the two disamenities as a function of market hours. No separate accounting for home production is needed.

CRK make an intensive investigation of the value of the unemployment benefits,  $b$ . An important factor in their estimate is the evidence that most of the unemployment insurance benefits paid to jobseekers are offset in value by the time costs and disamenities of collecting benefits. Their average estimate of  $b$  is only 0.04. They find some cyclical variations, but they are small because the level of  $b$  is so small.

I use the estimate of the Frisch elasticity of labor supply from Pistaferri (2003) of 0.7. Hall (2009b) discusses the evidence on the size of this parameter. The resulting value of  $z$  is 0.41.

## D Calibration

The calibration strategy is to start with values for  $r$ ,  $\theta$ ,  $z$ , and  $q$ , then solve the Nash version ( $\delta = 1$ ) of the model for  $\mu$  and  $c$  together with the values of the variables.

The equations are:

$$q = \mu\theta^{-0.5} \tag{41}$$

$$\phi = \mu\theta^{0.5} \tag{42}$$

$$P = \frac{1}{1+r} + \rho_1 \frac{1}{(1+r)^2} + \rho_2 \frac{1}{(1+r)^3} + \dots \tag{43}$$

$$qJ = c \tag{44}$$

$$J = P - W \tag{45}$$

$$W = 0.5(P + U - V) \tag{46}$$

$$V = \left[ \eta_1 \frac{1}{1+r_J} + \eta_2 \frac{1}{(1+r_J)^2} + \dots \right] U \quad (47)$$

$$U = z + \frac{1}{1+r} [\phi \cdot (W + V) + (1 - \phi)U]. \quad (48)$$

This system of 8 equations has 8 unknowns:  $\mu$ ,  $\phi$ ,  $c$ ,  $P$ ,  $J$ ,  $W$ ,  $U$ , and  $V$ .