Employment Fluctuations with a Persistent Nominal Wage Norm *

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Abstract

Recent high unemployment in the U.S. and other advanced economies is not the result of a large and persistent decline in productivity. In the canonical Diamond-Mortensen-Pissarides model, such a productivity decline is the only plausible source of high and persistent unemployment. Extending the DMP model to include nominal influences in the wage bargain seems a promising resolution to this puzzle. Economic fundamentals only restrict the bargained wage to lie within the parties' bargaining set. Nash bargaining is only one of many bargaining protocols and is not a basic element of DMP. Gertler, Sala, and Trigari exploited this idea in a setup where the wage of newly hired workers follows a state variable interpreted as a nominal wage norm. The state variable is the stale nominal wage negotiated earlier in episodic bargaining. Here, I take a less structured approach to the same issue. I calculate the wage paid to newly hired workers by applying the zero-profit condition of the DMP model. Then I estimate the lag relation between that wage and the value of the marginal product of labor, the driving force of wage determination in the DMP model. The results show that a substantial fraction of newly hired workers receive a flexible wage while the remaining small fraction are under the influence of a highly persistent state variable, again interpreted as a nominal wage norm. Nonetheless, the equation accounts fully for the large fluctuations in unemployment over the past decade.

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Beginning in 2007, the U.S. economy experienced a substantial downward shift in product demand. First house building collapsed and later, under the influence of the financial crisis, consumption expenditure fell far below its growth path. Unemployment rose by more than 4 percentage points to levels not seen since the sharp contraction of 1981 and 1982.

The first point of this paper is that the increase in unemployment escapes explanation in the leading theory of unemployment, that of Diamond, Mortensen, and Pissarides. That theory, as explained in Mortensen and Pissarides (1994) and more recently in Shimer (2005), sharply circumscribes the variables that determine the unemployment rate. In a nutshell, unemployment reflects the positive effect of labor's ability to produce output and the negative effect of labor's alternative productivity at home, amplified by unemployment benefits. Fluctuations in product demand play only a small role.

Authors building general-equilibrium models incorporating the DMP theory of the labor market, notably Walsh (2003) and Gertler, Sala and Trigari (2008), have focused on an extension of the DMP model in a common direction. Their models add the rate of inflation to the set of variables capable of altering unemployment in the DMP setting. Walsh has producers selling at stale prices. Because the producers have market power, those with the most stale prices continue to make positive sales when inflation is below earlier expectations, so that the stale prices are above the profit-maximizing levels. Similarly, these sellers do not take over the entire market when their stale prices are below the levels of their rivals because inflation has turned out to be higher than expected. When realized inflation is above earlier expectations, aggregate market power is lower than usual. Labor's contribution to revenue in the presence of market power—the marginal revenue product of labor—rises on this account. The DMP model implies a lower unemployment rate, just as it would under competition if the marginal product of labor rose.

Gertler and co-authors invoke stale pricing of labor rather than output. Workers and employers make Nash wage bargains episodically. Between bargaining times, new workers receive, as a matter of convention, the stale nominal wage most recently bargained. Inflation occurring after the moment of bargaining raises the present value of the match to the employer and tightens the labor market.

Stale pricing is a special case of sticky pricing. Stale pricing results in temporary bulges of high unemployment. Absent further adverse shocks, an economy with stale prices or nominal wages will eventually bring prices or wages back to normal levels and unemployment will return to normal. Prices and wages could be sticky in other ways. For example, they could respond immediately but by less than needed to keep unemployment at normal levels. Or they could move immediately in the wrong direction. Within the New Keynesian literature, I believe it is fair to equate sticky pricing with stale pricing.

With responsive monetary policy, shifts in product demand have no effect on unemployment or inflation. Under the guidance of any policy rule that has the aim of stabilizing some combination of inflation and unemployment, the central bank—by adjusting the interest rate—can keep both at target levels in the face of an incipient shock to product demand. Thus the question of the effects of product-demand shocks arises exclusively under the circumstance that the zero lower bound on the interest rate disables monetary policy.

My second point is that pricing needs to be quite stale to generate realistic movements of unemployment and inflation at the zero lower bound. As recent experience has shown, a large rise in unemployment results accompanies a relatively small decline in inflation. With less stale pricing, the response of inflation would be unrealistically high. Further, as I will show, if the influence of stale pricing is below a critical threshold level, inflation *rises* when product demand declines. Around that threshold, unemployment is far more sensitive to shifts in product demand than is remotely plausible.

Having framed the role of stale pricing in understanding how a drop in product demand—not corrected by responsive monetary policy—raises unemployment, I turn to an empirical investigation of the dependence of wages on stale determinants. I limit my investigation to the hypothesis that it is stale pricing of labor that accounts for wide fluctuations in unemployment. Nekarda and Ramey (2010) have reached negative conclusions about countercyclical markups, thus casting doubt on the hypothesis of stale product pricing.

I exploit the fact that the DMP model makes the present value of the benefit that an employer receives from a new hire directly calculable from two pieces of known data. These are the daily probability that a job vacancy will fill and the cost per day of maintaining a vacancy. Then, under simple but reasonable assumptions, I calculate the starting wage of newly hired workers. The employer benefit is the present of the difference between the value of the marginal product of the worker and the wage paid. The stale-wage hypothesis is that the wage of a new hire is under the influence of a wage bargained some time in the past. Under the assumption that the bargained wage is a function of the contemporaneous value of the marginal product of labor (a good approximation to the Nash bargain), the wage of new hires is a distributed lag on the earlier VMPL. The lag distribution reflects the distribution of times between bargains. Under GST's assumptions, the lag distribution is exponential.

The distribution I find is anything but exponential. Rather, it puts a heavy weight on the current VMPL and a mixture of positive and negative weights on lagged values. The negative weights would be consistent with an extrapolative element in the formation of the current wage from historical values. Although the large weight without a lag appears to suggest that many new hires occur at current, not stale, wages, the explanatory power of relatively long lags is impressive, especially for the past 10 years.

1 The Basic Issue

In this section, I demonstrate the issues of the paper in the simplest reduced forms.

Technology is a proportional relation between output y and employment n:

$$y = An. \tag{1}$$

Unemployment is

$$u = 1 - \frac{n}{\bar{n}} = 1 - \frac{y}{A\bar{n}}. \tag{2}$$

The reduced form of the DMP model of unemployment maps productivity A into the unemployment rate u:

$$u = U(A). \tag{3}$$

In principle, the interest rate also enters U, but nothing of importance is lost by neglecting that dependence.

Product demand is a strictly decreasing function of the real interest rate r:

$$y = D(r). \tag{4}$$

Thus

$$u = 1 - \frac{D(r)}{A\bar{n}}. \tag{5}$$

The equilibrium real interest rate r^* satisfies

$$U(A) = 1 - \frac{D(r^*)}{A\bar{n}}. \tag{6}$$

At the zero lower bound, the real rate is minus the inflation rate: $r = -\pi$. If $-\pi > r^*$, the zero lower bound binds—the real rate exceeds its equilibrium value. The lower is inflation, the more likely the bound is to bind. When the bound does bind, the unemployment rate on the left side of equation (6), derived from the DMP model, differs from the unemployment rate on the right side, derived from the product market.

1.1 The central bank's influence over inflation

Suppose the central bank has a policy lever that controls the rate of inflation π without shifting either side of equation (6). Any reasonable central bank would pick a rate of inflation that exceeded minus the equilibrium real interest rate ($\pi > -r*$), so that the nominal rate would be positive in equilibrium and the zero bound would cause no mischief. The zero lower bound binds when the central bank loses control of the rate of inflation. A substantial literature, outside the scope of this paper, deals with the question of how a central bank might retain control of inflation in an economy susceptible to episodes of a binding zero lower bound. No central bank in the world has paid any attention to the advice from that literature, it would appear.

For the remainder of the paper, I will leave the central bank out of the story, except that its policy of keeping reserves and currency at par is the source of the zero lower bound, as explained in Buiter (2009) and Hall (2011). I recognize that the assumption that the central bank has no influence at all over the rate of inflation is an overstatement, but I believe it is close to true and it certainly gains a great simplification in the analysis.

Although I take the rate of inflation as outside the influence of the central bank, it remains an endogenous variable in the remainder of the discussion.

1.2 How inflation could equilibrate

If the rate of inflation is a free variable, it will equate the two sides of equation (6) by rising to $-r^*$. Of course, it could be even higher, but in that case the nominal interest rate would escape the bound and the central bank would be back in business and could influence inflation. To avoid that complication, I will consider only the cases where $\pi \leq -r^*$. Today inflation π is slightly positive but r^* is quite negative, so the inequality definitely holds. As I noted earlier, the issue of how the economy might respond to a drop in product demand is moot when the nominal rate is above zero, as the central bank has the power to offset the drop by lowering the rate.

Figure 1 shows equilibration through the inflation rate. The line labeled "Labor market"

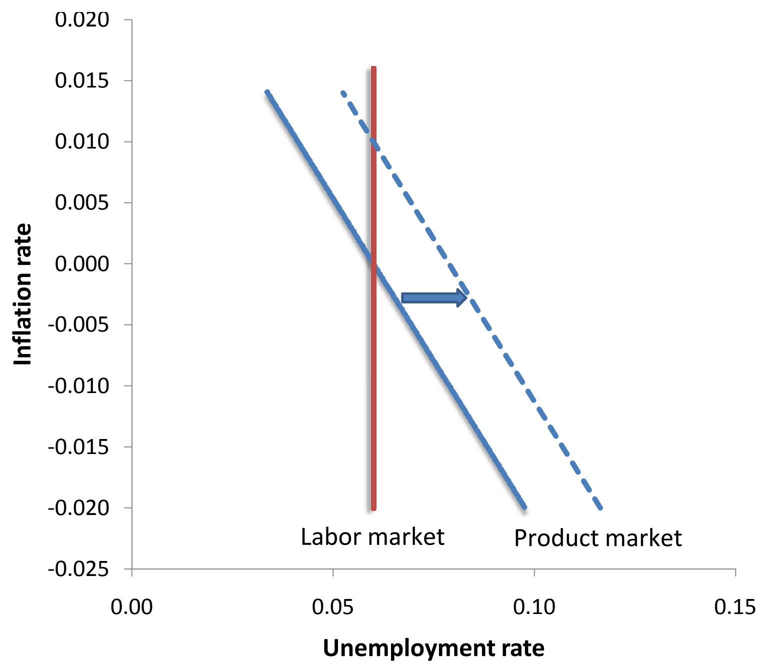

Figure 1: Equilibration through the Inflation Rate without Special Features

shows the left side of equation (6), a constant independent of the rate of inflation. The solid line labeled "Product market" slopes downward because a higher inflation rate corresponds to a lower real interest rate, more output, more employment, and thus less unemployment. The dashed line to its right shows the effect of a decline in current product demand—unemployment is higher for a given level of inflation.

Figure 1 seems completely incapable of accounting for the actual behavior of the economy in times of a binding zero lower bound. First, the decline in product demand leaves unemployment unchanged. Second, the rate of inflation *rises* when the economy softens, contrary to the evidence that inflation slows down, though not by much in recent experience, when unemployment rises.

To introduce a class of alternative models with more realistic implications for the effect of a decline in product demand, I extend the DMP model to make unemployment depend on inflation π as well as productivity A:

$$u = U(A, \pi). \tag{7}$$

The dependence is negative. Higher inflation raises employers' incentives to recruit new workers. Most of the rest of the paper is about the mechanism underlying the negative dependence.

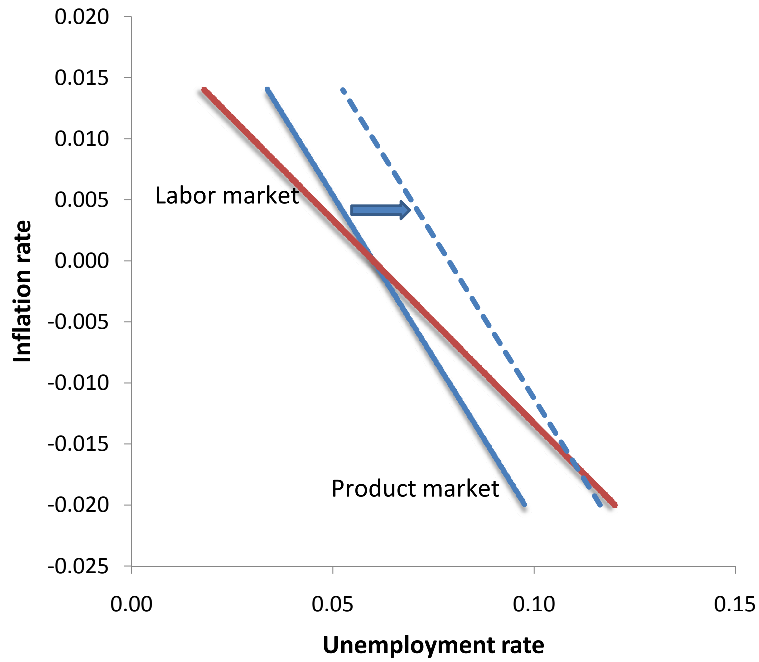

Figure 2: Equilibration through the Inflation Rate with a Negative Dependence of DMP Unemployment on Inflation

Figure 2 illustrates the effect of a decline in product demand in the altered model. The line describing the relation between inflation and unemployment in the DMP part of the model is now flatter than is the unchanged relation from the product-market part of the model. A decline product demand has the expected effect—a large increase in unemployment and a decline in inflation.

I conclude: *To explain the observation that inflation falls when unemployment rises by introducing a dependence of DMP unemployment on the inflation rate, the DMP labor-market curve must be flatter than the product-market curve.*

1.3 Modifications of the DMP labor market

Here I adopt a simple version of the DMP theory of unemployment. I simplify the treatment of labor-market dynamics by considering the stochastic equilibrium of labor turnover, which means that the unemployment rate u measures the tightness of the labor market. The vacancy rate enters the picture only in fast transitional dynamics of the matching process, which can be ignored when studying persistent slumps. Thus the recruiting success rate is an increasing function $h(u)$ of the unemployment rate. Success is higher when unemployment is higher and employers find qualified job-seekers more easily. Hall (2009b) discusses this approach more fully.

Without loss of generality, I decompose the wage paid to the worker into two parts, corresponding to a two-part pricing contract (the decomposition is conceptual, not a suggestion that actual compensation practices take this form). The worker pays a present value J, the *job value*, to the employer for the privilege of holding the job and then receives a flow of compensation equal to the value of the worker's marginal product.

A pair of equations involving the job value capture the essence of the DMP model of unemployment. The first holds that, in equilibrium, firms expect zero profit from recruiting workers. The cost of recruiting (holding a vacancy open) is γ per period, taken to be constant in output terms. The zero-profit condition for recruiting equates the expected benefit of recruiting for one period to its cost:

$$h(u)J = \gamma. \tag{8}$$

Thus unemployment rises if the job value J falls. In slack markets with lower J, a worker pays less for a job. Because $h(u)$ is a stable function of unemployment alone and γ is a constant, the DMP model implies a stable relationship, $J_Z(u)$, between unemployment and the job value.

The second equation—which I call *wage determination*—states the job value $J = J_D(u, \eta)$ as a function of u and certain other determinants contained in the vector η. In Mortensen and Pissarides (1994), a worker and an employer make a Nash bargain that sets a wage to divide their joint surplus in fixed proportion. Unemployment is one of the determinants of the Nash job-value function—when unemployment is high, the match surplus arising from labor-market frictions is greater. The job value, a fixed share of that surplus, is also higher. The worker has to pay more for the job because jobs are harder to find. Two other variables—the value of the marginal product of labor, p, and the flow value of time spent not working (as an improvement over working), z, also enter the Nash job-value function. These are the two elements of the vector η in $J_D(u, \eta)$. The DMP literature has concentrated on explaining movements in unemployment as responses to changes in total factor productivity, which is the fundamental underlying determinant of the marginal product of labor. Movements in the flow value of not working, z, rarely figure in explanations of cyclical fluctuations in unemployment.

Figure 3 shows the DMP account of the increase in a recession as explained in Mortensen and Pissarides (1994). In consequence of a drop in productivity, the Nash wage determination

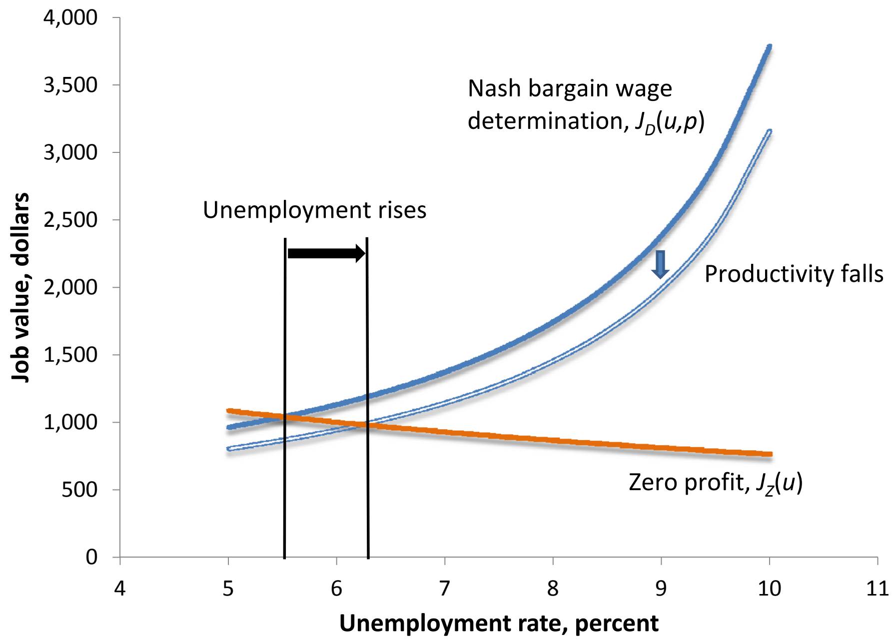

Figure 3: DMP Account of an Increase in Unemployment Caused by a Decline in Productivity

curve shifts downward. The new equilibrium occurs down and to the right along the stable zero-profit curve.

Two developments have cast doubt on the relevance of the recession mechanism of Figure 3. First, Shimer's (2005) influential paper showed that it would take a gigantic drop in productivity to cause the rise in unemployment in a typical recession, based on realistic values of the parameters of the DMP model. Second, movements in unemployment have not tracked movements in productivity in recent years.

Shimer's paper has stimulated an interesting literature—surveyed in Rogerson and Shimer (2010)—that alters the canonical DMP model to boost the response of unemployment to productivity and other driving forces. But it remains hard to square the behavior of the U.S. economy with the DMP model if productivity alone is taken as the driving force.

Like much of the recent literature on the DMP model, I consider modes of wage determination different from the Nash bargain of the canonical model of Mortensen and Pissarides (1994). The starting point for the modifications I consider is the point in Hall (2005) that any wage that generates a job value between zero and the entire surplus of the job is potentially the outcome of a bargain between worker and employer. Such a wage is the basis for a privately efficient relationship between the two parties. In the standard Edgeworth-box portrayal of bilateral bargaining, the same point is that the bargain can lie anywhere along

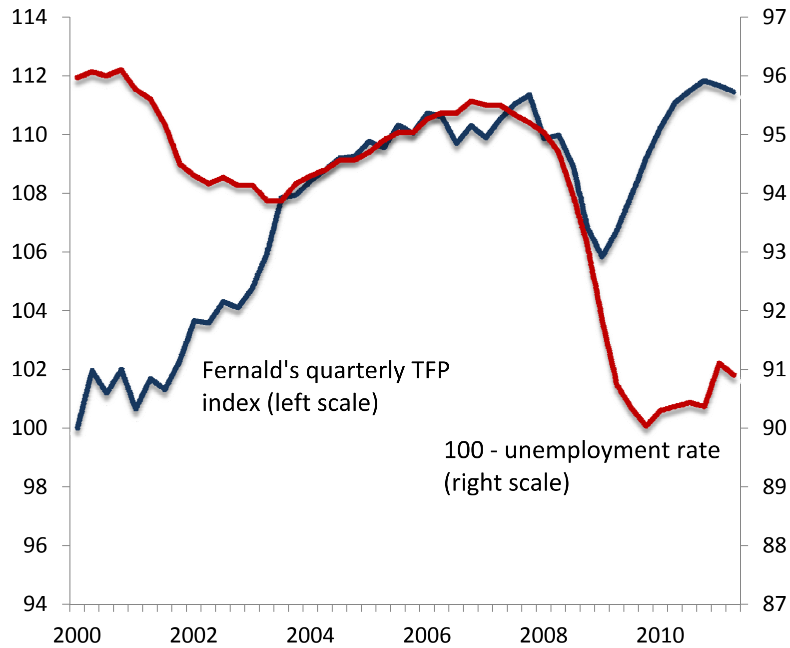

Figure 4: Total factor productivity and productivity

the contract curve within the bargaining set.

The goal of modifying the DMP model is to develop a wage-determination function that delivers a low job value under the conditions that cause unemployment to be high. Many approaches come to mind. For example, unemployment benefits raise the value of the worker's outside option in the wage bargain—a feature of the DMP model from its beginnings. A dramatic increase in benefits could raise unemployment substantially, even to its current rate of around 9 percent.

In view of the connection of inflation with the zero lower bound, outlined earlier this paper, the sources of movements in the job value that I pursue here are nominal—the behavior of the price level matters in wage determination in a way excluded from the original DMP model.

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 (2010) 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. Further, 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.

The second proposal—and the more widely accepted currently—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 et al. (2008) introduced nominal wage stickiness to the DMP framework. The model retains the Nash wage bargain of the canonical DMP model, but bargaining occurs at random intervals. Between bargaining moments, new workers receive the stale wage from the most recent bargain. The resulting wage stickiness overcomes Shimer's finding that up-to-date Nash bargaining results in almost no response of unemployment to fluctuations in the contribution that a new worker makes to the employer's revenue—the wage absorbs essentially all of those fluctuations, leaving the job value essentially unchanged.

Gertler and Trigari (2009) developed the labor-market specification that GST embed in their general-equilibrium model. A Poisson event controls the timing of firm-level Nash wage bargaining. 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.

In principle, the Gertler-Trigari setup could violate private efficiency 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 in practice this is not likely to occur. If there were a danger that the wage fell outside the bargaining set, 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 sticky nominal wage links inflation and unemployment in the way required by Figure 2. Among the existing modifications of the DMP model that may aid understanding of high unemployment in the zero lower bound, I believe that GST's is the most promising.

2 Is the Nominal Shift in the DMP Model Big Enough to Account for the Bulge in Unemployment?

This section investigates whether the condition derived earlier, that the labor-market curve in Figure 2 be flatter than the product-market curve, is likely to hold. I consider the two underlying questions: (1) Is the effect of the stickiness of the nominal wage in a GST-type model large enough to twist the labor-market curve enough from its vertical slope in the standard DMP model? and (2) is the product-market curve sufficiently sloped so that the labor-market curve is flatter?

2.1 Slope of the labor-market curve

The structural relation between inflation and unemployment in a GST-style model depends only on the DMP block of the model. I approach its derivation in two steps. The first is to find the relation between the job value J and the unemployment rate. This relation depends on the matching function and the cost of recruiting. The second is to find the relation between inflation and the job value. This relation depends on how long the nominal state

		Intercept	*Slope*	*Trend*	*Standard error of the regression*
Daily recruiting sucess rate	$h(u)$	0.0371 (0.0020)	0.545 (0.037)	-0.000082 (0.000013)	0.0037
Daily job-finding rate	$\varphi(u)$	0.064219 (0.001173)	-0.593 (0.022)	-0.000019 (0.000008)	0.0022

Table 1: Estimates of Parameters of the Hiring and Job-Finding Functions

variable influences the wage paid to newly hired workers.

First step: The daily hiring success rate h is

$$h_t = \frac{H_t}{21V_t}, \tag{9}$$

where H_t is the number of hires during a month and V_t is the average number of vacancies open during the month, approximated as openings at the beginning of the month. Both series are from the BLS's Job Openings and Labor Turnover Survey (JOLTS). I divide by 21 as the number of working days in a month.

Unemployment u solves the zero-profit condition,

$$h(u)J = \gamma. \tag{10}$$

Under the assumption that the hiring-rate function is linear,

$$h(u) = h_0 + h_1 u, \tag{11}$$

the relation between J and u is

$$u = \frac{\frac{\gamma}{J} - h_0}{h_1}. \tag{12}$$

To estimate the hiring success rate function $h(u)$, I regress h_t on the unemployment rate u_t from the Current Population Survey for the period from December 2000 (the onset of JOLTS) through June 2009 (omitting data from the anomalous period in the second half of 2009 and 2010). I also include a linear trend. The identifying assumption is a lack of correlation between the unemployment rate and the disturbance in the hiring rate. The regression appears in the top panel of Table 1. It shows a robust positive relationship between the recruiting success rate and the unemployment rate.

Hall and Milgrom (2008) calculate that the daily cost of maintaining a vacancy is 0.43 days of pay, based on data from Silva and Toledo (2008), or $\gamma = \$66$ per day for the average

U.S. employee in January 2011. Equation (12) then provides the needed relation between unemployment and the job value.

Second step: The goal is to find the relation between inflation and the job value in a stationary setting. I let m be the marginal product of labor, taken as a constant for the purposes of this calculation, and $\bar{w}$ be the real wage that emerges from bargaining, prior to any subsequent erosion or increase from inflation or deflation. I take $\bar{w}$ to be the average hourly wage among U.S. workers in January 2011, \$19.07 per hour. I take

$$m = \bar{w} + (r + s)J^*, \tag{13}$$

where $J^* = \$1066$ is the normal job value from the first step, corresponding to 5.5 percent unemployment, r is the daily discount rate (taken to be 5 percent per year) and s is the daily separation rate (4.2 percent from JOLTS at a monthly rate).

The job value J_t is the present value of the difference between the marginal product and the wage for a firm that is t periods past bargaining. It satisfies the recursion

$$J_t = m - (1 + \pi)^{-t}\bar{w} + \frac{1 - s}{1 + r}\left[(1 - \theta)J_{t+1} + \theta J_0\right]. \tag{14}$$

Here π is the rate of inflation, taken to be constant, and θ is the hazard of bargaining. Conditional on the job continuing, with probability $1 - s$, the job value advances to J_{t+1} because the stale wage continues in place (with probability $1 - \theta$) or pops to J_0 because bargaining restores the real wage $\bar{w}$ (probability θ). Straightforward algebra solves for J_t. Finally, in the stationary state, a fraction $\theta(1 - \theta)^t$ of firms are t periods from their most recent bargain. I calculate the weighted average of the J_t using these fractions as weights to find the mean job value $\bar{J}(\pi)$ as a function of the inflation rate.

I take the hazard rate for re-bargaining to 0.283 at a quarterly rate, so the average time between bargains 3.5 quarters, as GST report in their Table 2. The slope of the labor market curve, as in Figure 2, implied by this and the other parameters is 3.8 percentage points of unemployment per percentage point of diminished inflation, measured at an annual rate.

As a second estimate, I have calculated the slope of the price- and wage-adjustment block in GST. I measure the slope by treating a product demand shock—specifically, what they call the monetary shock—as an instrumental variable that moves the model along its price-wage adjustment curve without shifting that curve. The corresponding measure is the ratio of (1) the impulse response function of unemployment to the monetary shock to (2) the impulse response function of inflation to the monetary shock. At four quarters past the shock, the ratio is 3.3 percentage points of increased unemployment per percentage point of decreased inflation.

As a third estimate, I look at recent behavior resulting from the large negative shock to product demand resulting from the financial crisis. Between October 2008 and October 2009, unemployment rose 3.5 percentage points and inflation fell by 0.46 percentage points, for a slope of 7.6, on the reasonable assumption of no shift of the labor-market curve.

The third estimate is based on only very recent data and the first and second are based on GST's estimate of the re-bargaining hazard, inferred from several decades of U.S. history, including times of higher and less stable inflation. A reasonable explanation for the difference is that the re-bargaining hazard was higher in earlier decades, which influence GST's estimates, because inflation was substantially higher early in their sample period. The episode that I consider, 2008 to 2009, followed a period of low and stable inflation, so it is reasonable to conclude that the re-bargaining hazard was lower, making unemployment more sensitive to a decline in the inflation rate.

2.2 Slope of the product-market curve

I use a similar logic to find the slope of the product-market curve in the GST model. I use the labor-bargaining-power shock as an instrument for the product market. That shock moves the model along its product-market curve without shifting the curve. There is one further detail—I need to measure the slope with respect to the real interest rate, but the model deals with the nominal rate and the rate of inflation. I compute the slope as

$$\frac{f_{u,\eta}}{f_{r,\eta} - f_{\pi,\eta}}, \tag{15}$$

where $f_{u,\eta}$ is the impulse response function 4 quarters out for the effect of the wage markup shock η on unemployment u, and similarly for the nominal interest rate r and the rate of inflation π.

The wage-markup shock lowers output, raises inflation, and raises the nominal interest rate by less than the increase in inflation, so the shock lowers the real interest rate. The ratio of the unemployment response to the real-interest-rate response is 0.6, which is substantially less than the 3.3 for the labor-market curve. Thus the GST model easily satisfies the criterion for resolving the clash between the product market and the labor market.

3 U.S. Unemployment and Inflation, 2008 to 2009

Figure 5 summarizes the entire analysis of this paper in terms of the huge rise in unemployment following the financial crisis. In October 2008, when the Federal Reserve lowered its policy rate to essentially zero, the unemployment rate was 6.6 percent and the rate of inflation was 1.9 percent, measured by the average one-year-ahead forecast for the Consumer Price Index in the Survey of Professional Forecasters (other measures of inflation were quite similar). In October 2009, inflation was 0.4 percentage points lower at 1.5 percent and unemployment was 3.5 percentage points higher at 10.1 percent, . The figure portrays these two pairs of values as occurring at the intersection of the product-market and labor-market curves of Figure 2.

Figure 5 make the reasonable assumption that no shift occurred in the labor-market curve—the impetus for the contraction came entirely from the adverse developments in the product market. These include the consumption decline resulting from household deleveraging, the collapse of homebuilding, and the cutback in producer and consumer durables purchases resulting from the increase in financial frictions from the crisis. Based on that assumption, I take the labor-market curve to be the line connecting the two observed points, with the slope mentioned earlier of 7 percentage points of unemployment per percentage point of decreased inflation.

I take the slope of the product-market curve to be the estimate from GST of 0.7 percentage points of unemployment per percentage point increase in the real interest rate, or, in terms of the figure, with a nominal rate pinned at zero, 0.7 percentage points of increased unemployment per percentage point decrease in the rate of inflation. The figure shows the 2008 product-market curve as the solid line with this slope passing through the observed inflation-unemployment point. It shows the 2009 product-market curve as the dashed line with the same slope passing through the 2009 inflation-unemployment point.

The rightward shift of the product-market curve is 3.2 percentage points. If the rate of inflation had remained constant despite the recession, the unemployment rate would have risen from 6.6 percent to 9.8 percent rather than to 10.1 percent. The downward slope of the labor-market curve somewhat amplified the effect of the negative shock to product demand, from 3.2 percentage points of unemployment to 3.5 points.

The notion that expectations of lower inflation amplify negative shocks when the nominal rate is at the zero lower bound has a long history in macroeconomic thought. DeLong and

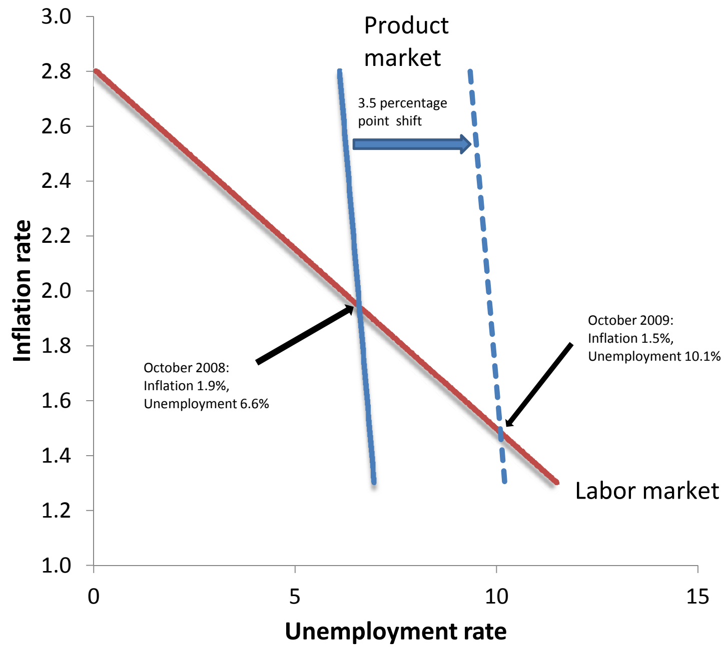

Figure 5: The U.S. Economy in October 2008 and October 2009

Summers (1986) is a prominent treatment with an extensive discussion of the analysis of Irving Fisher and others during the Great Depression. Eggertsson (2008) is a more recent discussion of the topic in a New Keynesian framework. According to the calculations in Figure 5 model, the amplification is quite modest, however. Based on the experience from 2008 to 2009, inflation responds only slightly to increased unemployment in the context of the current U.S. economy. Further, the feedback from the small decrease in inflation to product demand is weak, according to the GST model. I have made similar calculations based on the stronger feedback in the model of Smets and Wouters (2003), but the amplification still remains weak because of the flatness of the labor-market curve inferred from the recent behavior of unemployment and inflation. In an environment of less stable prices, such as the U.S. in 1929 to 1933, the analysis could be altogether different, as Eggertsson has emphasized.

Because the product-market and labor-market curves both slope downward, the economy faces the danger that their slopes might be almost equal, in which case a negative shock would cause a deflationary collapse. The figures in this paper make it clear that the danger is maximal not when inflation is highly responsive to negative shocks, but rather at the point where the labor-market curve is just slightly flatter than the product-market curve. Figure 6 shows the elevation of unemployment from a shock that displaces the product-market curve 4.4 percentage points to the right as a function of the labor-market slope. As that slope

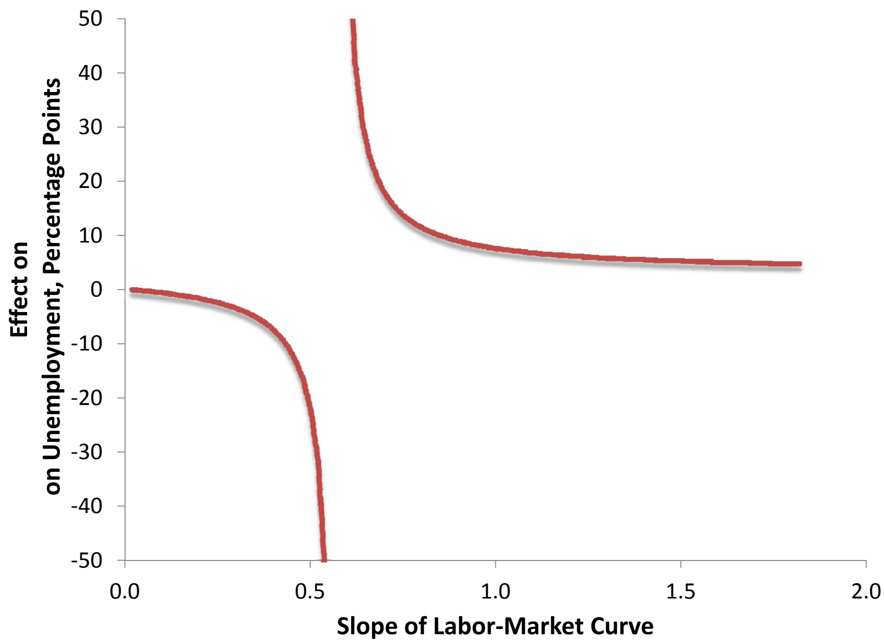

Figure 6: Effect of Product-Demand Shock on Unemployment as a Function of the Slope of the Labor-Market Curve

approaches the product-market slope from below, the elevation of unemployment approaches infinity. On the other side, where the basic slope condition derived at the beginning of this paper fails, the same 4.4-percentage point shock *lowers* unemployment substantially. Finally, as the slope approaches zero, Figure 1 takes over and the effect on unemployment approaches zero.

4 Evidence on the Influence of Stale Determinants of the Wage

Recall that the equilibrium of the DMP model, as portrayed in this paper, occurs at the point of equality of J_Z, the break-even job value such that employers just cover their recruiting cost, and J_D, the present value of the difference between a worker's revenue contribution p and wage w. The break-even value is the cost of maintaining a vacancy for one period, γ multiplied by the expected duration of the vacancy, which is the reciprocal of the job-filling rate $h(u)$. I assume that the present value is a capitalization factor κ times the current profit contribution $p - w$. The capitalization factor takes account of the distribution of the duration of employment, any tendency for the wage to drift toward or away from p as tenure accumulates, and financial discounting. Thus the equilibrium condition of the model is

$$\frac{\gamma}{h(u)} = \kappa \cdot (p - w). \tag{16}$$

4.1 Model

The simplest model of stale determination takes the wage to depend on past values of its fundamental determinant, the worker's value contribution p:

$$w_t = \psi_0 p_t + \psi_1 p_{t-1} + \cdots . \tag{17}$$

A simple example, motivated by the constant rebargaining hazard in the GST model, takes $\psi_i = (1-\rho)^i$, where ρ is that hazard.

Note that the coefficients ψ_i are not necessarily positive. One interesting possibility is that the wage is formed recursively as

$$w_t = \mu\theta p_t + (1-\theta)(w_{t-1} + \Delta w_{t-1}). \tag{18}$$

In this specification, the current value contribution p_t enters with a weight θ and the previous wage, w_{t-1}, updated by the previous change, Δw_{t-1}, with weight $1-\theta$. Solving for the implied relation between w_t and lagged values p_{t-i} reveals first positive coefficients and then negative coefficients, reflecting the extrapolation of lagged rates of change of p_{t-i}. Figure 7 shows the coefficients for $\mu = 0.9$ and $\theta = 0.1$.

Putting the pieces together yields the following estimation equation:

$$y_t = \frac{\gamma_t}{\kappa h(u_t)} = (1-\psi_0)p_t - \psi_1 p_{t-1} - \cdots . \tag{19}$$

Here γ_t is current-dollar recruiting cost.

4.2 Stochastic specification and econometrics

For the purposes of this subsection, I let $\tilde{p}_t$ designate the true values of the revenue contribution and $p_t = \tilde{p}_t + m_t$ be the observed values with measurement errors m_t. I let $\beta_0 = 1 - \psi_0$ and $\beta_i = -\psi_i$ for $i > 0$.

The serial correlation of p_t is sufficiently high to rule out any but a tiny white-noise measurement error. Accordingly, I assume that measurement error follows a random walk:

$$m_t = m_{t-1} + \epsilon_t. \tag{20}$$

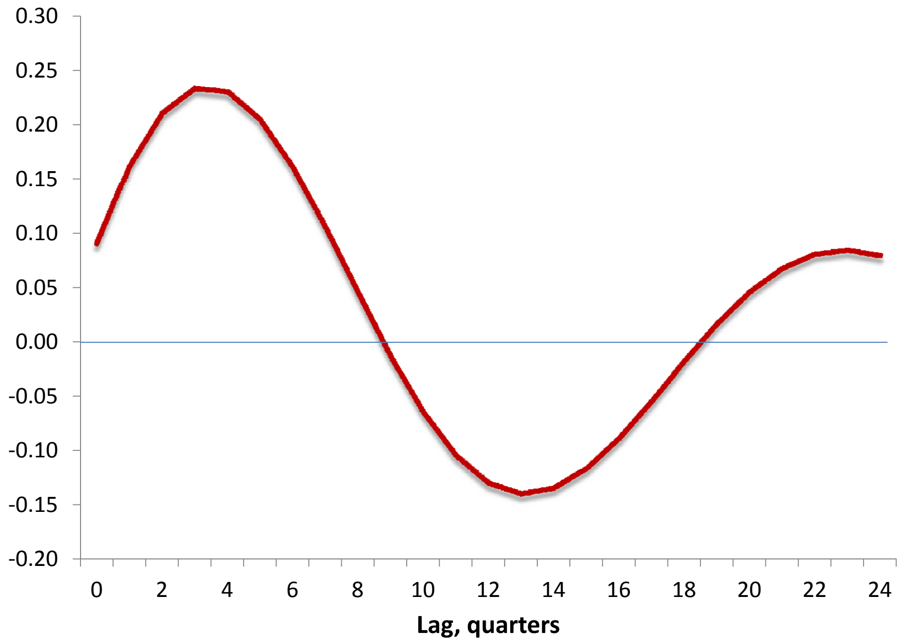

Figure 7: Coefficients with Updating

The estimating equation becomes

$$\Delta y_t = \beta_0 \Delta \tilde{p}_t + \beta_1 \Delta \tilde{p}_{t-1} + \cdots \,. \tag{21}$$

The estimator for β is

$$\hat{\beta} = (\tilde{P}'\tilde{P})^{-1}\tilde{P}'z, \tag{22}$$

where $\tilde{P}$ is the matrix of lagged values of $\Delta\tilde{p}_t$ arranged in the obvious way and z is the vector of values of Δy_t. I assume that the measurement errors ϵ_t are uncorrelated with each other and with the current and lagged values of $\tilde{p}_t$ and z_t. I further assume

$$V(\epsilon_t) = v. \tag{23}$$

I let P be the matrix of lagged values of the observed values of Δp_t. Then

$$P'P = \tilde{P}'\tilde{P} + vI \tag{24}$$

and

$$\tilde{P}'z = P'z. \tag{25}$$

Here, as usual in asymptotic statistical theory, I neglect the difference between realizations and probability limits. The estimator, stated in terms of the observable variables, is

$$\beta = (P'P - vI)^{-1}P'z. \tag{26}$$

4.3 Data

I take

$$\kappa = \frac{1}{r+s}, \tag{27}$$

where r is the real interest rate, 0.05 at annual rates, and s is the separation rate, taken to be its average from JOLTS from December 2000 through April 2011 of 4.2 percent per month or 0.00020 per day.

Section 2 describes the basis for my value of the daily cost of maintaining a vacancy, $\gamma = \$66$ and the estimated coefficients of the function $h(u)$. I calculate the current dollar vacancy cost as

$$\gamma_t = \frac{p_t^Y}{\bar{p}^Y}\gamma, \tag{28}$$

where p_t^Y is the GDP deflator and $\bar{p}^Y$ is its value in the second quarter of 2007.

To measure the daily revenue contribution of a worker, p, I start with nominal GDP, NIPA Table 1.7.5, and subtract production taxes reported in the same table, to get total revenue accruing to employers. I multiply this quantity by an estimate of α, the elasticity of output with respect to labor input. I then deduct contributions for government social insurance to place it on a basis comparable to take-home pay. I divide the result by 52 times total nonfarm employment from the Current Employment Statistics of the BLS (the payroll survey) times weekly hours of all non-farm employees from the Current Population Survey (series LNU02033120). The result is the gross contribution to employer revenue per hour of work on the assumption of Cobb-Douglas technology. I multiply by 8 to place it on a daily basis, because it appears that the estimate of γ is for full-time workers.

I estimate α as the ratio of employee compensation inclusive of contributions to government social insurance programs to GDP less production taxes, from the same sources.

Figure 8 shows the values of the daily revenue contribution from 2001 through the first quarter of 2011.

5 Results

In this version of the paper, I report results for the period from the first quarter of 2001 through the first quarter of 2011.

I take the variance of the measurement error in the revenue contribution p to be a fraction ω of the variance of the first difference of p at the same lag. The upper limit of ω is the value

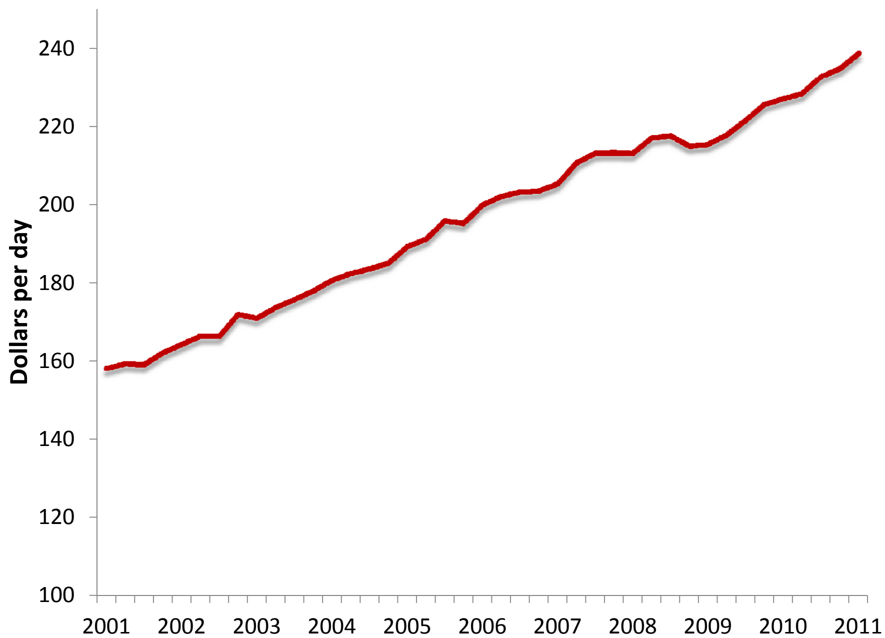

Figure 8: Daily Revenue Contribution per Worker, 2001 to 2011

that makes the matrix $P'P - \omega D(P'P)$ singular, where $D()$ is the diagonal of the matrix and zeros elsewhere. As ω approaches this value, the elements of $(P'P - \omega D(P'P))^{-1}$ become indefinitely large. The upper-bound value is $\omega = 0.036$.

Figure 9 shows the estimated value of the contemporaneous coefficient ψ_0 as a function of the index of measurement error ω, along with dashed lines showing the one standard deviation confidence intervals. The coefficient is reliably estimated to be just under one for all but the highest permissible values of ω. The high value of ψ_0 is the main empirical finding of the paper. Future versions will document that it is a stable finding across periods of estimation and alternative parametric restrictions on the remaining lag coefficients ψ_i.

Recall that the coefficient of the projection of the left-hand variable (the net flow value of a worker to the employer inferred from the unemployment rate) on the first right-hand variable (the current revenue contribution of a worker), in the presence of lagged values of the right-hand variable, is $1 - \psi$. Thus the finding that ψ is almost one—meaning that the wage of new hires adapts almost fully to current p—implies that the projection of unemployment on p picks up only a small contemporaneous effect. In other words, wages seem to be highly flexible in the sense that they respond contemporaneously to the value of the marginal product of labor p and, as a result, movements in p do not induce much movement in unemployment.

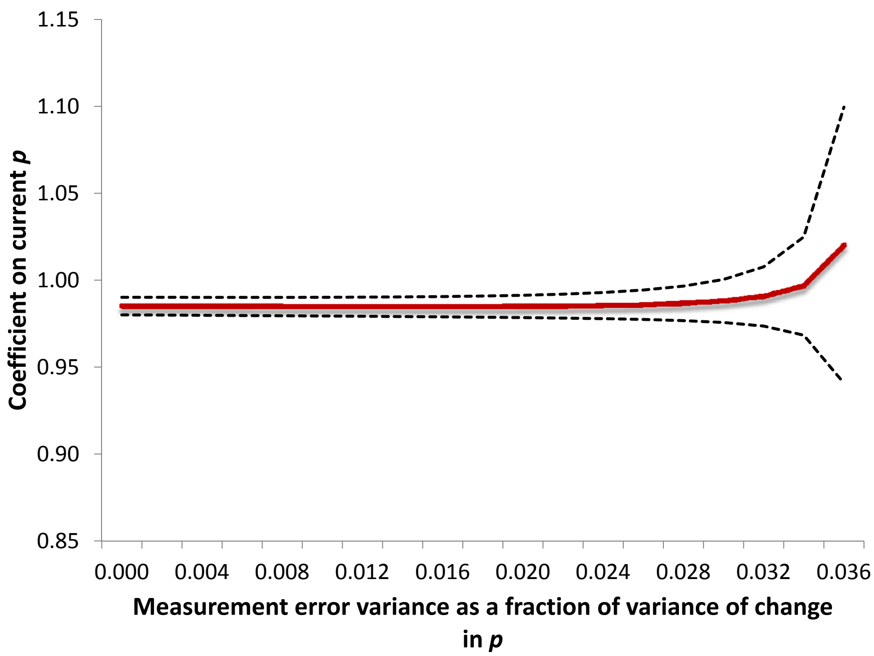

Figure 9: Coefficients on Current Value of p, the Contribution of a Worker to Revenue, by Variance of Measurement Error

By contrast, in a model that is a drastic simplification of the GST model, where the current wage of new hires is linked to the stale values of p, the estimated distribution has geometric decay. Although the contemporaneous coefficient ψ_0 should be the largest, it should be only moderately greater than ψ_1. That hypothesis is plainly overwhelmingly rejected by the data.

Figure 10 shows the coefficients on the lagged values of p under the assumption of no measurement error—these are the coefficients of an OLS regression of the transformed unemployment rate on current and lagged p. The dashed lines again show one-standard-error confidence bands. The coefficients begin slightly negative, rise to positive values ar 11 quarters lag, turn negative again, and finally turn positive past 20 quarters. As I noted earlier, negative values do not contradict the model, though I have not yet found a specification that makes complete sense out of the estimated pattern.

Figure 11 shows the same coefficients estimated under the assumption that measurement error is 3 percent of the variance of the change in p ($\omega = 0.03$). As expected, adjusting for measurement error raises the magnitudes of the coefficients, though the pattern remains much the same—a peak at 11 quarters, a trough at 17 quarters, and a weaker peak at 21 quarters.

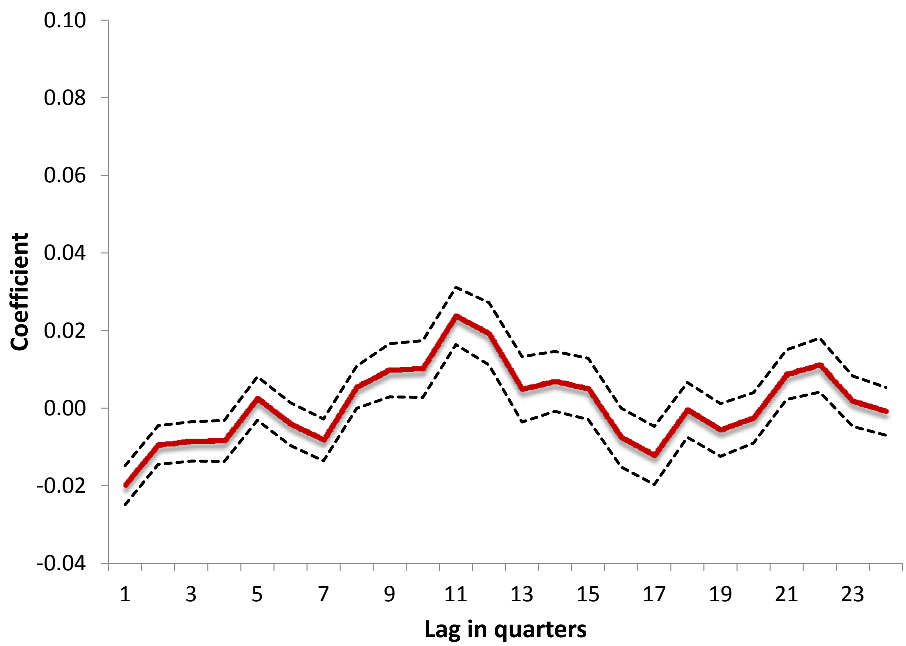

Figure 10: Coefficients on Lagged Values of p, Assuming No Measurement Error

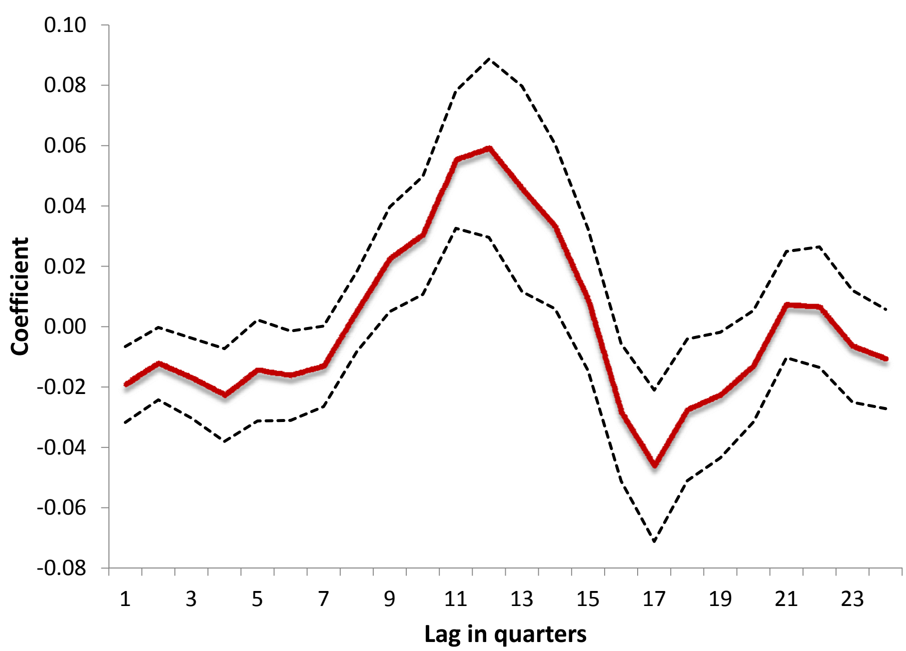

Figure 11: Coefficients on Lagged Values of p, Assuming Measurement Error is 3 Percent of Variance of Change in p

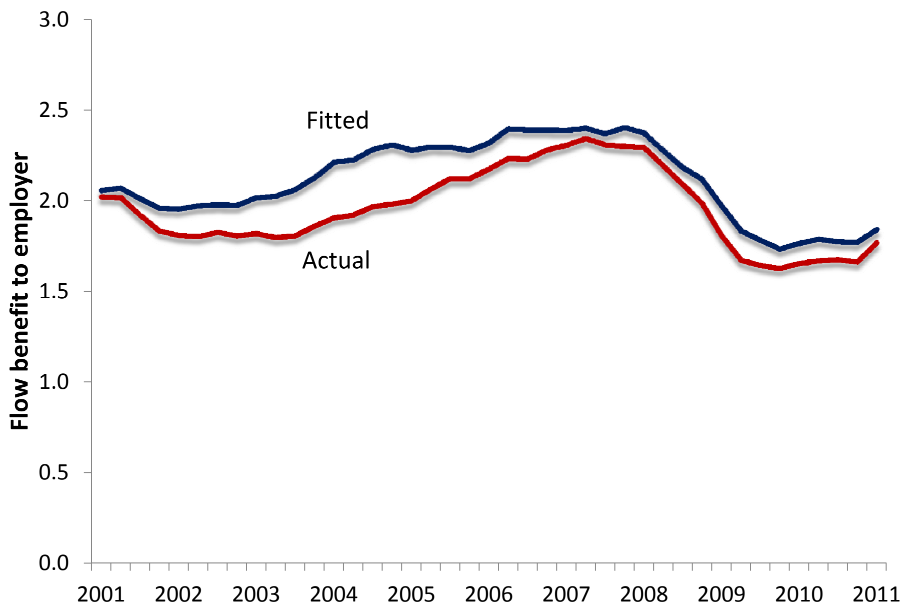

Figure 12: Actual and Fitted Values of the Flow Value of the Worker, Assuming No Measurement Error

A remarkable fact about the estimates is that they account for the actual movements of the left-hand unemployment-derived variable, notwithstanding the strong implication of wage flexibility. Figure 12 shows the actual and fitted values of the left-hand variable, which moves in the opposite direction from unemployment. The coefficients on current and lagged values of p enable the equation to track the actual movements of unemployment remarkably well. Figure 13 shows the fitted values for the estimates based on 3 percent measurement error. The volatility of the fitted value is higher (by necessity, since the OLS results have the best least-squares fit by definition), but still track the movements, especially the decline in the left-hand variable corresponding to the rapid growth of unemployment after the financial crisis.

6 Concluding Remarks

The DMP model in its canonical form, Mortensen and Pissarides (1994), cannot explain the huge increase in unemployment that has occurred in the United States since 2007, for it contains no variable that has shifted enough to deliver such a large change. A promising alteration to the DMP model makes the wage depend on a stale nominal variable, as GST proposed. In the resulting version of the DMP model, unemployment rises if inflation falls,

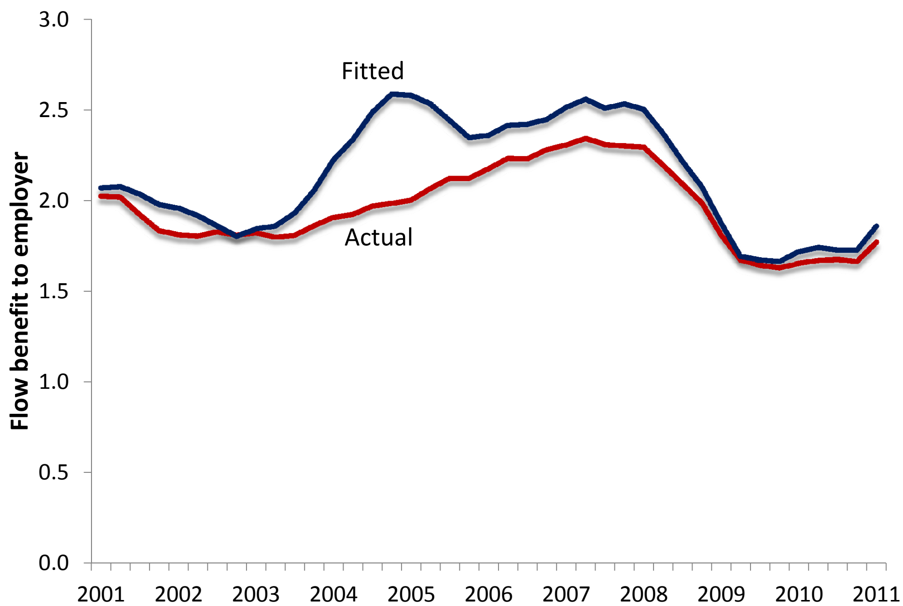

Figure 13: Actual and Fitted Values of the Flow Value of the Worker, Assuming Measurement Error is 3 Percent of Variance of Change in p

because lower inflation raises the real wage paid to the worker and erodes the employer's incentive to create jobs.

Unless the influence of the stale nominal variable exceeds a threshold, a decline in product demand will lower unemployment. Calculations based on some simple assumptions suggest that the inflation effect in the modified DMP model is strong enough to clear the threshold.

The rather modest decline in inflation that occurred between the end of 2007 and the end of 2009—less than a percentage point—was not enough to amplify the effect of the decline in product demand substantially. The economy was not in danger of a deflationary collapse comparable to the one that occurred in 1929 through 1933, when price changes were far more responsive to slack conditions.

Simple models of stale nominal determinants of the wages of newly hired workers are inconsistent with estimates that put no restrictions on the shape of the lag distribution. The estimates appear to be consistent with rapid adjustment most of the wage, together with a highly persistent small component that explains the large observed fluctuations, despite the high flexibility.

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