Clashing Theories: Why Is Unemployment So High When Interest Rates Fall to Zero?*

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September 13, 2011

Abstract

General-equilibrium models for studying the zero lower bound on the nominal interest rate contain implicit theories of unemployment. In some cases, the theory is explicit. When the nominal rate is above the level that clears the current market for output, the excess supply shows up as diminished output, lower employment, and higher unemployment. Quite separately, the Diamond-Mortensen-Pissarides model is a widely accepted and well-developed account of turnover, wage determination, and unemployment. The standard DMP model is a clashing theory of unemployment, in the sense that its determinants of unemployment do not include any variables that signal an excess supply of current output. Altering the DMP model by allowing the rate of inflation to influence unemployment, as several authors have proposed, resolves the clash. I derive the condition needed to achieve the resolution when the zero lower bound is binding and thus to explain high unemployment in recent years. The condition implies that stale nominal values have a strong effect on the wages of new hires. It appears to be satisfied by existing models and is supported by the small decline in inflation that has occurred in the U.S. between 2007 and 2009.

JEL E12 E22 E32

*I am grateful to Dale Mortensen, Robert Shimer, Michael Woodford, and members of the NBER RSW workshop for comments on a rather different earlier version.

With the short-term nominal interest rate near its minimum feasible value of zero in the U.S. and some other advanced economies for the past few years, macroeconomics has renewed and advanced the study of the implications of the zero lower bound for economic activity in general and unemployment in particular. According to the models, when the interest rate is held above its market-clearing level, the supply of current output exceeds demand. Actual current output falls short of its market-clearing level and unemployment is above its normal level. The models provide a widely accepted account of the low levels of output and high levels of unemployment in recent years.

At the same time, the Diamond-Mortensen-Pissarides (DMP) model of unemployment is widely accepted as the most realistic account of unemployment based on a careful and full statement of the underlying economic principles governing labor turnover and wage determination. The DMP model prescribes the unemployment rate as a function of a limited set of variables. As originally developed, the DMP model does not connect excess supply in the product market with high unemployment.

The two theories of unemployment clash.

1 The Basic Issue

In this section, I demonstrate the clash of unemployment theories using 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. The clash arises.

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 (2011b). 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

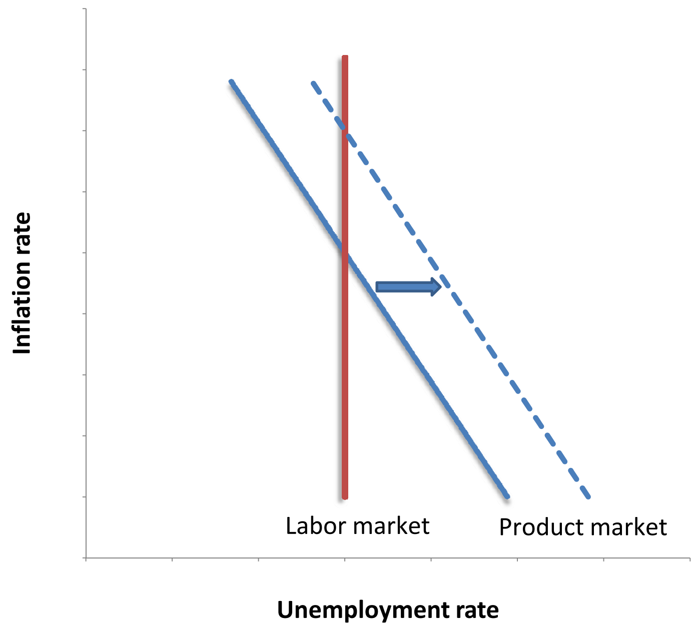

Figure 1: Equilibration through the Inflation Rate without Special Features

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.

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

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

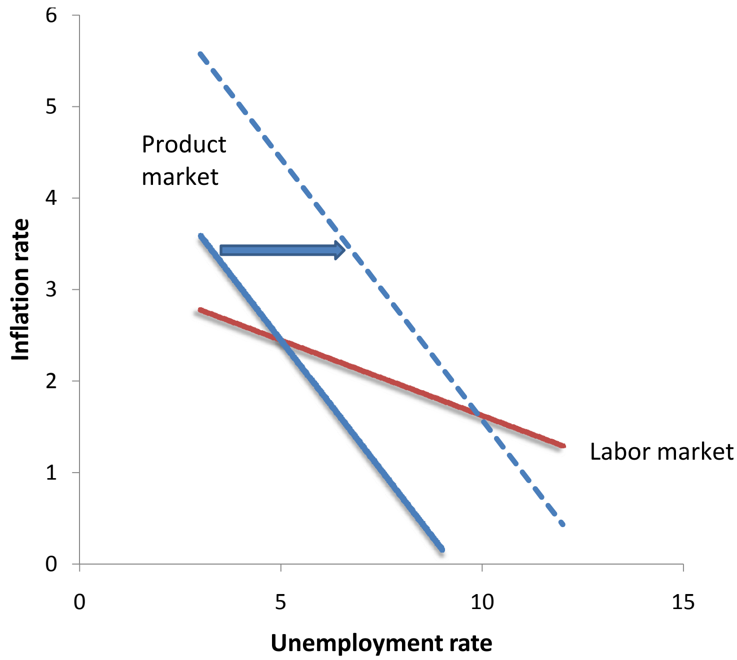

Figure 2: Equilibration through the Inflation Rate with a Negative Dependence of DMP Unemployment on Inflation

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

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 resolve the clash between theories of unemployment by introducing a dependence of DMP unemployment on the inflation rate, the DMP labor-market curve must be flatter than the product-market curve.*

2 Contributions to the Literature on the Zero Lower Bound Considered in this Paper

I consider a selected group of influential papers related to the zero lower bound and especially to modeling the effects of the bound in the DMP labor market. My discussion is organized by analytical issues, not by paper, so I begin with quick summaries of the papers.

1. Krugman (1998) is the foundation of modern work on the zero lower bound. The paper considers an economy without labor input, so the issue of unemployment does not arise. In the key section of the paper, the current price level is fixed. Productive capacity will be lower in the future than it is currently. All output is consumed; the economy has no way to pass resources into the future with storage or productive capital. Consequently, full resource utilization requires declining consumption, which implies a low or even negative real interest rate. Once a monetary expansion drives the nominal rate to zero, it has no further effect. If the public expects less than a critical rate of inflation, the corresponding real rate (minus the expected rate of inflation) will exceed the full-utilization real rate. Excess supply of current output will prevail because of the public's desire to defer consumption. To bring consumption into equilibrium, current output and thus current consumption falls to below the full-utilization value. The zero lower bound causes a depressed economy. Krugman's paper brought clarity to the subject of the liquidity trap-zero lower bound, the subject of an earlier rather confused literature. All subsequent papers have followed the same basic logic—an excess real interest rate resulting from some negative force that causes a low equilibrium rate implies that the negative force causes a drop in current resource utilization.

2. Eggertsson and Woodford (2003) enriched the literature considerably. Their model is fully dynamic. Price stickiness enters in the New Keynesian framework where sellers retain prices until a Poisson event occurs, at which time sellers reset prices optimally. Labor is an input and employment falls to low levels when the zero lower bound binds. The model has no explicit treatment of unemployment. The force that causes households to seek to defer consumption is a shift in preferences toward future consumption. That shift drives the equilibrium real interest rate to low or negative levels. Output and employment fall according to the logic of Rotemberg and Woodford (1999)—a slack current product market resulting from the desire to defer consumption results in lower inflation than previously expected. Sellers maintain higher prices while their costs are moderated, so profit margins rise. The wedge of higher market power results in a decline in economic activity.

3. Walsh (2003) was the first paper to introduce the DMP model of unemployment (or any treatment of unemployment, for that matter) in the New Keynesian model. The paper also has New Keynesian sticky prices. It does not focus explicitly on the zero lower bound, but it contains all the mechanisms needed to describe how the zero bound would operate to inhibit economic activity. An excess supply of current output—resulting from expectations of rising government purchases or from a preference shift—raises market power as noted above. The driving force of unemployment, with market power, is the marginal revenue product of labor, which falls with rising market power. The DMP model generates higher unemployment with a lower marginal revenue product. 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.

4. Gertler, Sala and Trigari (2008) (GST) also 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. This paper resolves the clash by making the DMP determination of unemployment sensitive to the rate of inflation. It does not treat the zero lower bound on the nominal interest rate explicitly, though it contains all the elements necessary for that analysis.

5. Christiano, Eichenbaum and Rebelo (2011) study the zero lower bound in a pair of existing New Keynesian models. The second is the model of Christiano, Eichenbaum and

Evans (2005), which incorporates a labor market with a sticky nominal wage. It does not describe unemployment explicitly, but its elastic labor-supply assumption probably allows it to mimic the employment volatility of a sticky-wage DMP specification such as Gertler-Trigari. In that sense, the paper resolves the clash between its product-market sub-model and its labor-market sub-model, by introducing inflation as a determinant of labor supply. When the price level is higher than was expected when the nominal wage was set, the real wage is lower and labor demand is higher. The model makes the standard Keynesian assumption that households are willing to supply all the labor that employers desire given the current real wage. Thus the labor-market specification lacks the equilibrium character of Gertler-Trigari.

6. Eggertsson and Krugman (2011), Guerrieri and Lorenzoni (2011), and Hall (2011b), focus on the general-equilibrium effects of the zero lower bound in the context of the financial crisis of 2008 and subsequent recession and persistent slump. The key point of the papers is that a cutback in the availability of consumer credit—as plainly occurred after the crisis—results in a period of low or negative real interest rates. Deleveraging causes the more liquidity-constrained households to cut consumption back sharply. When lenders demand their money back from these households, the only way the households can comply is to divert income from consumption to debt repayment. Hall demonstrates that cash flows from households to financial institutions grew sharply immediately around the crisis. As deleveraging continues, the repayment burden lessens and consumption of constrained households begins to rise. Interest rates fall and the consumption of unconstrained households jumps up. Consistent with the low rates, consumption growth of unconstrained households is low and possibly negative. The expectation of rising consumption of constrained households plays the same role as the expected decline in the endowment in Krugman's original model. It generates low or negative interest rates for essentially the same reason. Guerrieri and Lorenzoni refine the analysis considerably within the framework of the standard stochastic consumption model with a bound on borrowing.

3 Elements of the Macroeconomics of the Zero Lower Bound

3.1 Sources of low equilibrium interest rates

Consumer optimization equates the marginal rate of substitution between current and future consumption to one plus the real interest rate:

$$\frac{u'(c_t)}{\beta u'(c_{t+1})} = 1 + r. \tag{8}$$

Here $u(c)$ is period utility as a function of consumption c and β is the utility discount factor. The interest rate will be low when (1) some force causes future marginal utility to exceed current marginal utility; that is, causes future consumption to fall relative to current consumption, or (2) the discount factor β is high. The literature on the zero lower bound has invoked both of these sources of low equilibrium interest rates.

Krugman (1998) generated expected consumption shrinkage in the simplest possible way. The economy has an exogenous production capacity which is lower in the future than today. The equilibrium real rate is low because consumption tracks production capacity. Eggertsson and Woodford (2003) introduced upward fluctuations of the discount factor as a source of negative equilibrium rates and Christiano et al. (2011) adopt the same source. Eggertsson and Krugman (2011), Guerrieri and Lorenzoni (2011), and Hall (2011b) look to the household's response to cutbacks in consumer credit to generate low equilibrium real rates. Guerrieri and Lorenzoni have the cleanest setup, based on the Bewley-Aiyagari-Huggett model of the household with incomplete markets (uninsurable idiosyncratic income shocks) and a borrowing limit. A period of exogenous decline in the borrowing limit causes households who were previously close to the borrowing limit to cut back consumption substantially so that they can limit the probability of a personal consumption disaster. This group is strongly precautionary—they plan consumption growth even at low interest rates. In equilibrium, households with higher levels of liquid wealth take advantage of the low consumption of the other households by gaining high levels of consumption. As the effect of the credit cutback subsides, consumption at the bottom of the wealth distribution rises and consumption at the top falls. Those closer to the top lack any significant precautionary bias in their Euler equations, so the equilibrium interest rate is low, in accord with their planned declines in consumption.

Discussions of the deep slump in the U.S. economy that began at the end of 2007 include two other factors beyond household deleveraging. The first is the overhang of household capital that resulted from a binge of homebuilding and car-buying in the middle of the 2000s (see Figure 4 in Hall (2011b)). A neoclassical model given starting conditions with household capital well above its steady-state relation to output will have a period of several years of unusually low interest rates while the abnormal level of household capital gradually returns to normal.

The second factor is the damage the financial crisis did to financial institutions. The analysis in Bernanke, Gertler and Gilchrist (1999) and a large related literature shows that the depletion of capital resulting from declining asset values (mostly real-estate related, in this crisis) worsens agency frictions in financial intermediation. Hall (2011a) shows that worsening financial frictions have substantial adverse effects on product demand.

3.2 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 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:

$$h(u)J = \gamma. \quad (9)$$

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 $J = \tilde{J}(u, \eta)$ 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 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 $\tilde{J}(u, \eta)$. 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 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 determi-

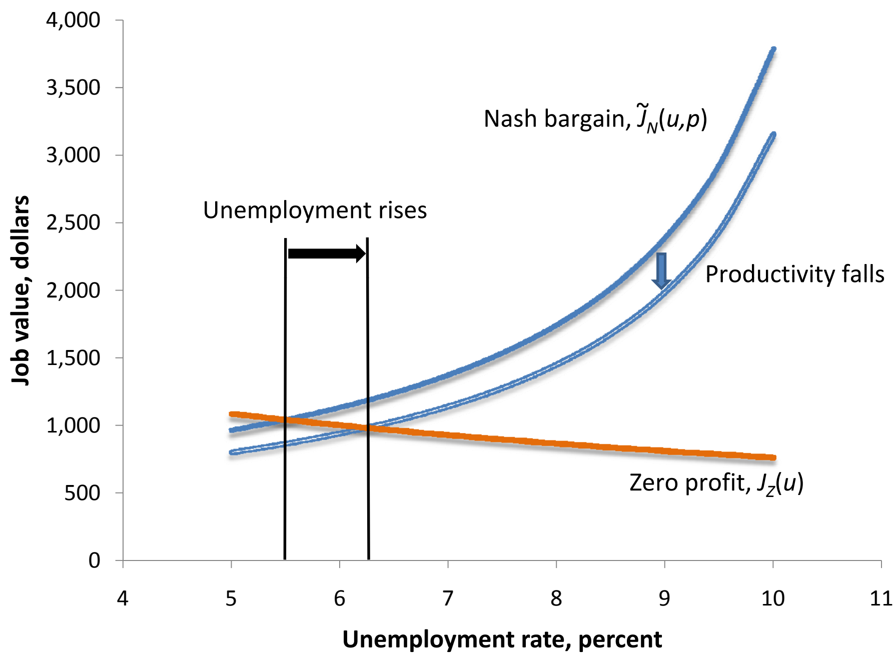

Figure 3: DMP Account of an Increase in Unemployment Caused by a Decline in Productivity

nation 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 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 at the beginning of this paper, the sources of movements in the job value that I pursue here are nominal—the recent 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.

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 et al. (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) introduces nominal stickiness to the DMP framework. The model retains the Nash wage bargain of the canonical DMP model, but bargaining occurs at random intervals. The frequency of bargaining for incumbent workers has little importance in the DMP model, because unemployment depends on the expected payout to newly hired workers. Wage changes after the match is formed need to satisfy the criterion for private efficiency—the job value needs to fall inside the bargaining set, but that criterion is easy to satisfy in practice. Apart from that criterion, all that matters is the job value at the time the match is formed.

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 sticky nominal wage links inflation and unemployment in the way required by Figure 2. Among the 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.

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

The GST model appears to me to be the most coherent model that embodies the logic of Figure 2. This section investigates whether the condition derived earlier, that the labor-market curve in that diagram 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?

4.1 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 variable influences the wage paid to newly hired workers.

		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

First step: The daily hiring success rate h is

$$h_t = \frac{H_t}{21V_t}, \tag{10}$$

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,

$$h(u)J = \gamma. \tag{11}$$

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

$$h(u) = h_0 + h_1 u, \tag{12}$$

the relation between J and u is

$$u = \frac{\frac{\gamma}{J} - h_0}{h_1}. \tag{13}$$

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 (13) 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

$$m = \bar{w} + (r + s)J^*, \tag{14}$$

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

$$J_t = m - (1 + \pi)^{-t}\bar{w} + \frac{1 - s}{1 + r}\left[(1 - \theta)J_{t+1} + \theta J_0\right]. \tag{15}$$

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.

For comparison, 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.

4.2 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

$$\frac{f_{u,\eta}}{f_{r,\eta} - f_{\pi,\eta}}, \tag{16}$$

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.

5 U.S. Unemployment and Inflation, 2007 through 2009

Figure 4 summarizes the entire analysis of this paper in terms of the huge rise in unemployment that began in 2007. In December 2007, the unemployment rate was 5.0 percent and the rate of inflation was 2.4 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 December 2009, inflation was 0.8 percentage points lower at 1.6 percent and unemployment was 4.9 percentage points higher. 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 4 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

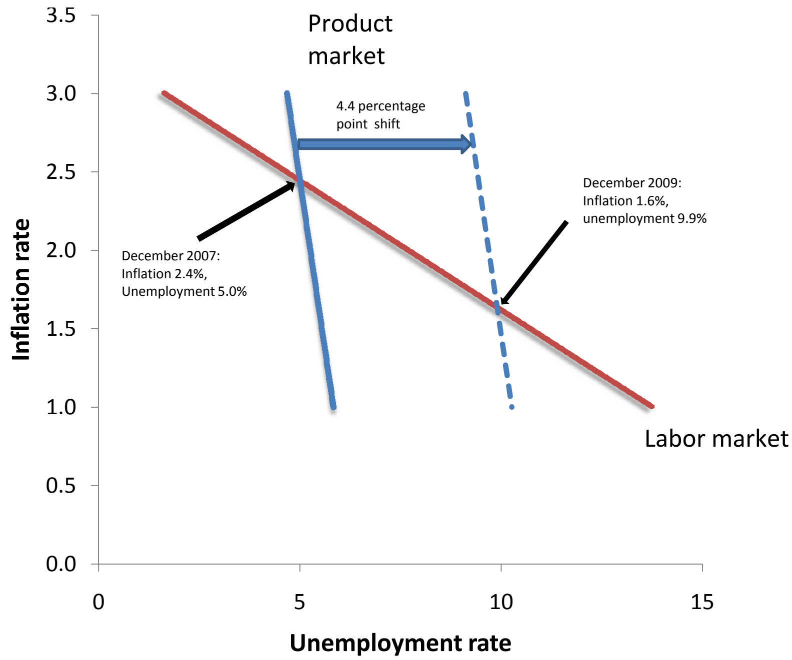

Figure 4: The U.S. Economy in December 2007 and December 2009

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. The slope of the line is 6 percentage points of unemployment per percentage point of decreased inflation, substantially flatter than the 3.8 calculated earlier. A reasonable explanation for the difference is that the earlier calculation used GST's estimate of the re-bargaining hazard, inferred from several decades of U.S. history, including times of higher and less stable inflation. The period that I consider, 2007 to 2009, followed a period of low and stable inflation, so it is reasonable to conclude that the re-bargaining hazard fell, making unemployment more sensitive to a decline in the inflation rate.

I take the slope of the product-market curve to be 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 2007 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 4.4 percentage points. If the rate of inflation had remained constant despite the recession, the unemployment rate would have risen from 5.0 percent to 9.4 percent rather than to 9.9 percent. The downward slope of the labor-market curve somewhat amplified the effect of the negative shock to product demand, from 4.4 percentage points of unemployment to 4.9 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 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 4 model, the amplification is quite modest, however. Based on the experience from 2007 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 5 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 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.

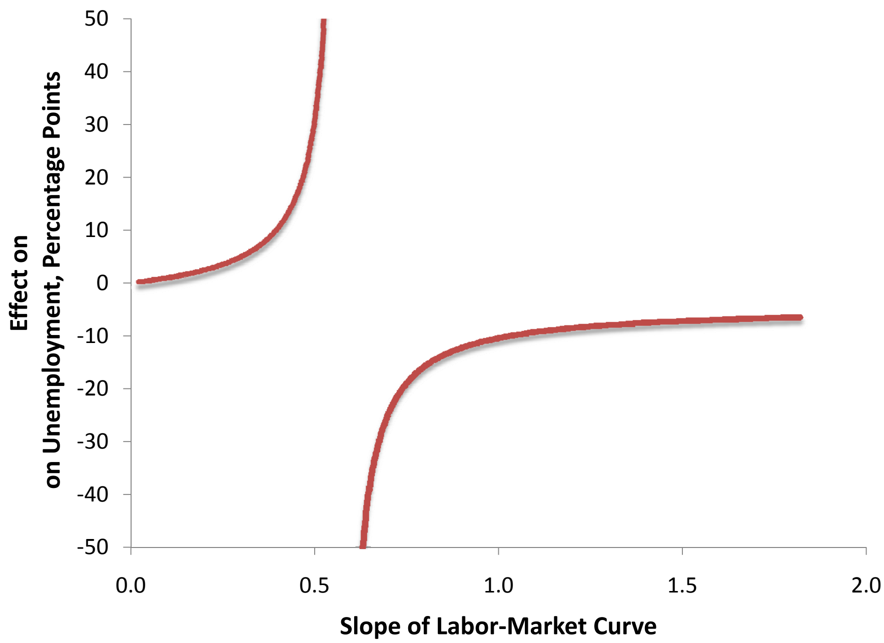

Figure 5: Effect of Product-Demand Shock on Unemployment as a Function of the Slope of the Labor-Market Curve

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. The most 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, 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.

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Bibtex: @UNPUBLISHED{Hall:CTU,author = {Hall, Robert E.}, title = {Clashing Theories: Why Is Unemployment So High When Interest Rates Fall to Zero?},note = {Hoover Institution, Stanford University},month = {September},year = {2011}}