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by Christopher P. Reicher

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This paper estimates a series of shocks to hit the US economy during the Great Depression, using a New Keynesian model with unemployment and bargaining frictions. Shocks to long-run inflation expectations appear to account for much of the cyclical behavior of employment, while an increase in labor's bargaining power also played an important role in deepening and lengthening the Depression. Government spending played very little role until the rise in military spending effectively brought an end to the Depression in 1941. With the economy at or near the zero interest rate bound, interest rates and monetary aggregates provided a misleading indicator as to the true stance of inflation expectations; in fact, conditions were deflationary all throughout the 1930s in spite of high money growth and low interest rates. The experience of the 1930s offers lessons to modern policymakers who face a similar situation.

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JEL classification: E24, E31, E52, E65.

Kiel Institute for the World Economy
24100 Kiel, Germany
Telephone: +49-8814-300
E-mail:
christopher.reicher@ifw-kiel.de

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Expectations, Monetary Policy, and Labor Markets: Lessons from the Great Depression

Christopher Phillip Reicher^a
Kiel Institute for the World Economy
This version: April 19, 2010

Abstract:

This paper estimates a series of shocks to hit the US economy during the Great Depression, using a New Keynesian model with unemployment and bargaining frictions. Shocks to long-run inflation expectations appear to account for much of the cyclical behavior of employment, while an increase in labor's bargaining power also played an important role in deepening and lengthening the Depression. Government spending played very little role until the rise in military spending effectively brought an end to the Depression in 1941. With the economy at or near the zero interest rate bound, interest rates and monetary aggregates provided a misleading indicator as to the true stance of inflation expectations; in fact, conditions were deflationary all throughout the 1930s in spite of high money growth and low interest rates. The experience of the 1930s offers lessons to modern policymakers who face a similar situation. (Keywords: Great Depression, expectations, deflation, labor wedge, liquidity trap. JEL codes: E24, E31, E52, E65)

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I Introduction

Recent events have caused economists to revisit the Great Depression, in the hope that the Depression can provide lessons for policymakers and researchers. Like the current period, the Depression was characterized by low nominal interest rates and a fall in the velocity of money. The economy can behave unusually in this type of situation; Christiano, Eichenbaum, and Rebelo (2009) find that shocks to inflation expectations or to real demand can have large effects at or near the zero bound. Little work has gone into empirically evaluating the role of shocks to nominal expectations during the Depression, taking low and persistent interest rates into account. To fill this gap, this paper estimates a series of shocks to nominal expectations and interest rates during the interwar years using a New Keynesian model with inflexible interest rates, sticky wages, and search-based unemployment, in the style of Chari, Kehoe, and McGrattan (2007)'s analysis of an RBC economy. It finds that these shocks can account for much of the evolution of employment and output during the 1930s. The model also investigates the role of shocks to government spending, real aggregate demand, productivity, and labor market policies, and it finds a particularly important role for labor market policies in determining the course of the labor market throughout the 1930s.

This is not the first paper to look at the more general issue of expectations during the Depression. Eggertsson (2008) models the 1929-1933 contraction and 1933-1937 recovery periods as a transition between two separate policy regimes, one deflationary and one inflationary. He specifically examines fiscal policy and its potential implications for the price level, and he looks at happens when the economy is hit by an exogenous intertemporal preference (aggregate demand) shock. In comparison with Eggertsson, this paper looks at the role of expectations themselves as generating an impulse to money

demand, and it models other aspects of labor markets and aggregate demand in more detail. Christiano, Motto, and Rostagno (2004) model the Depression as a response to a shock to currency demand, treating bank runs as a negative shock to the transactions technology. They do not model expectations per se, but the issue of expected bank solvency lies in the background. Other researchers, such as Harrison and Weder (2006) explore the role of expectational shocks in models of real indeterminacy with increasing returns to scale. This is an interesting topic but this paper focuses on nominal indeterminacy and constant returns since these assumptions are more standard.

The specification of the labor market also allows for shocks to workers' bargaining power and disutility from work. A number of authors have contended that the interventions of Presidents Hoover and Roosevelt, rather than improving conditions, may have in fact worsened the Depression. They argue that federal policies aimed at strengthening labor's bargaining power and increasing labor income made it unprofitable for firms to hire workers and that this led to persistently depressed rates of employment and job creation. Bordo, Erceg, and Evans (2000), Ohanian (2009), Cole and Ohanian (1999, 2004), and Ebell and Ritschl (2008), to name a few, present narrative and quantitative evidence that this may have been the case. These policy interventions coincide with a drop in vacancy creation, a rise in labor's share, and a fall in the Beveridge Curve, and these facts are only interpretable in a model with labor market frictions. A model with bargaining and with search-based unemployment can provide a natural context to talk about these issues and to disentangle them from the other disturbances to the economy. Including sticky wages allows one to better match the

behavior of labor's share during this time, as Bernanke and Carey (1996) argue, and this is vital to disentangle the effects of sticky wages from the effects of policy interventions.

This paper is structured as follows: Section II discusses the data used in the estimation exercise, and Section III lays out a medium-scale model of search-based unemployment in the presence of wage and price stickiness. Section IV discusses the estimation procedure, and Section V presents the results. The results can be summarized as follows: Shocks to long-run price level expectations and to interest rates explain the largest portions of the contractions of 1929-33 and 1937-38 but they do not explain the slow recovery after 1933. This is explained by shocks to labor's bargaining power and, to a much lesser extent, a rise in the disutility from work. These shocks coincide with an increase in labor's share of income and a persistent downward shift in the Beveridge Curve. Low productivity also exerted a moderate drag on employment, and a rise in government spending in 1941 accounts for the final recovery from the Depression but for very little of the employment dynamics before that. Intertemporal aggregate demand shocks account for very little.

These results also suggest that the money supply was a poor proxy for long-run nominal expectations, and that the dynamics of the post-1933 period were still profoundly deflationary. This is in sharp contrast with the analysis of Eggertsson. A narrow focus on monetary aggregates or on interest rates can cause policymakers to drastically misinterpret long-run expectations. In the current situation, the short-run money supply offers a poor indicator as to the long-run path of the nominal economy since the velocity of money seems to vary based on expectations about future actions.

Policymakers also need to be aware that low interest rates can indicate long-term deflationary pressures which appear to have been prevalent all throughout the 1930s.

II The data

This paper makes use of linearly detrended quarterly observations on eleven variables related to real activity, job flows, and nominal variables from the first quarter of 1923 through the fourth quarter of 1941. Figures 1 and 2 show the data used in this analysis. The GNP series comes from the National Income and Product Accounts and from Kendrick (1961), interpolated using industrial production and real department store sales. The price level is interpolated using the BLS's wholesale price index and the price index for department store sales. Quality-adjusted labor input comes from Kendrick (1961), interpolated by the BLS's series on the employment of production workers in manufacturing. Quarterly nominal investment and government spending come directly from Balke and Gordon (1986); the measure of investment spending used encompasses residential and nonresidential structures, equipment, and inventories. Interest rates are given by the banker's acceptance rate in New York since this is a low-risk interest rate for which good data exist. The money supply comes from Friedman and Schwartz (1963) and equals the sum of adjusted demand deposits and currency held by the public. It is worth noting that the decline in the velocity of money equals the decline in nominal GDP; the real money supply did not change at all during the 1929-33 contraction.

The manufacturing separation and accession rates are those reported by Metropolitan Life and the BLS (from the NBER and various issues of *Employment and Earnings*). They are seasonally adjusted by the author in levels, and the pre-1930 series

is spliced onto the post-1930 series after an amplitude and mean adjustment. Separations and accessions both played an important role in job flows during the 1930s. There is, unfortunately, a break in the way the data were calculated in 1929-30, so one must view these series with extreme caution. The detrended Metropolitan Life help wanted index (a proxy for vacancies) shows a dramatic decline throughout the sample; it showed higher than usual vacancy rates all throughout the 1920s and lower than usual vacancy rates throughout the 1930s. To illustrate this, Figure 3 shows the relationship between unemployment and vacancies known as the Beveridge curve.¹ In the late 1920s, the Beveridge curve shifted drastically downward. Zagorsky (1998) discusses the stability of this series and the related postwar Conference Board series through the 1990s.

The labor share measure used in this paper is labor's share of gross income from the corporate sector, interpolated to a quarterly frequency from annual data. The portion before 1929 was constructed on the basis of annual data provided by Moroney (1964), Osborne and Epstein (1956), Kuznets (1941), and Goldsmith (1955). The portion after 1929 is available in the NIPA. Throughout the 1930s, labor's share seemed particularly high for a long period of time, a fact noted by Johnson (1954) and Solow (1958) and in contrast with the postwar experience. That this coincided with a fallen Beveridge Curve encourages the inclusion of labor market shocks in the model.²

III The model

¹ Normally the Beveridge Curve shows unemployment instead of employment. Due to the unavailability of a reliable unemployment series, Figure 3 uses detrended employment instead, graphed from high to low.

² Gomme and Rupert (2004) find that labor's share has tended to rise at the beginning of postwar recessions as well. The unusual aspect of the labor share in this case is the *persistently* high labor share after 1933.

Walsh (2002, 2005), Trigari (2009), and Cooley and Quadrini (1999) present different models of labor matching in the presence of nominal rigidities, building upon the search and matching model of Mortensen and Pissarides (1994) and den Haan, Ramey, and Watson (2000). Gertler and Trigari (2009) extend this approach to include sticky nominal wages, finding that this modification can better account for cyclical movements in output and wages. This paper proceeds in the spirit of the latter model. This model has eight disturbances: Disturbances to the money supply, government spending, productivity, the long-run price level, labor's bargaining power, the disutility from work, intertemporal preferences, and interest rates. On the household side, it consists of a continuum of infinitely lived consumers. Production and hiring take place in a firm-worker match, with wages responding sluggishly to the bargaining environment. A retail sector aggregates output from the wholesale sector and resets retail prices in a staggered manner. The monetary authority attempts to control the interest rate, but it has the inability to adjust the interest rate more than one-for-one with changes in expected inflation. Instead, short-run nominal variables are determined by a combination of an interest rate peg and expectations concerning the long-run price level. Government spending and fixed investment, with variable utilization, are the other sources of demand.

III.A The household sector

Individuals within households supply labor inelastically; they either work for a set number of hours per week or do not work at all. They also have the choice between consuming in a given period and investing in nominal bonds to consume in the future. They each seek to maximize the objective function

$$E_t \sum_{i=0}^{\infty} \prod_{j=0}^i \beta_{t+j} [\ln(C_{t+i} - hC_{t+i-1}) - \chi_{t+i} A_{t+i}], \quad (1)$$

where C_{t+i} equals the household's period-by-period real consumption and χ_{t+i} is an indicator variable equal to one if the household worked in a given period. β_t is the time-varying rate of time preference which affects aggregate demand. Preferences are separable, exhibit habit persistence, and are consistent with balanced growth. For tractability, households are large and pool consumption efficiently.

Markets operate in three stages per period. In the first stage, shocks are realized and financial markets open. People trade bonds and withdraw money in order to make their consumption purchases. In the second stage, the goods market opens and these purchases happen. In the third stage, income from the second stage is realized and factor payments are made. This delay introduces a cost channel into the model. This makes it possible for low nominal interest rates to directly stimulate production.

The quantity equation, which is normally motivated by forcing people to finance a portion of their spending (or factor incomes) with cash holdings, states that nominal consumption must not exceed end of period money holdings, allowing for variations in the transactions technology:

$$PY_t \leq V_t^{TECH} M_{t+1}. \quad (2)$$

In a low interest rate environment, this constraint may not bind and velocity may be endogenous since the opportunity cost of holding money becomes very low and people can simply hoard it. This would also be true with pathological financial markets. In this standard New Keynesian models under an interest rate policy, nominal spending is based purely on expectations regarding future inflation and interest rates. The observed

hoarding of money and the decoupling of different aggregates during the Depression provide an empirical basis for treating velocity as a forward looking ‘jump’ variable.³

The household’s budget constraint relates household money holdings, total income, bond purchases, money, taxes, and consumption. B_t equals the household’s purchases, at the beginning of the period, of one-period nominal bonds that mature at the beginning of the next period. They earn the gross nominal interest rate R_t . T_t equals the level of net taxes plus government bond purchases, with a Ricardian fiscal policy:

$$M_{t+1} + B_{t+1} + P_t C_t + P_t I_t = P_t Y_t + R_{t-1} B_t + M_t - P_t T_t. \quad (3)$$

The household’s first-order conditions end up looking familiar. Optimization in bonds generates the usual intertemporal asset pricing relationship

$$\lambda_t = E_t \beta_t R_t \frac{P_t}{P_{t+1}} \lambda_{t+1}, \quad (4)$$

where the household’s marginal utilities of consumption and wealth are equal:

$$\frac{1}{C_t - hC_{t-1}} - E_t \frac{\beta h}{C_{t+1} - hC_t} - \lambda_t = 0. \quad (5)$$

Because of market clearing, output equals consumption:

$$Y_t = C_t + G_t + I_t, \quad (6)$$

and the stochastic quantity equation holds, but merely as an accounting identity:

$$P_t Y_t = V_t M_{t+1}. \quad (7)$$

III.B The retail sector and sticky prices

³ Warburton (1945) presents strong evidence that a depressed velocity of money played an important role in the Depression, with Christiano, Motto, and Rostagno (2004) treating this as the outcome of a currency demand shock.

Monopolistically competitive retailers buy output competitively from the wholesale sector and resell it at a markup. They aggregate it according to a Dixit-Stiglitz aggregator. Retailers buy their products y_{jt} competitively from wholesale producers who produce homogeneous intermediate goods. The aggregate level of output is given by

$$Y_t = \left[\int_0^1 y_{jt}^{\frac{\theta-1}{\theta}} dj \right]^{\frac{\theta}{\theta-1}}, \quad (8)$$

for some substitutability parameter θ greater than one. From this expression, each individual retail firm faces a demand curve

$$y_{jt} = \left(\frac{p_{jt}}{P_t} \right)^{-\theta} Y_t, \quad (9)$$

where the aggregate price level P_t equals the CES price index:

$$P_t = \left[\int_0^1 p_{jt}^{1-\theta} dj \right]^{\frac{1}{1-\theta}}. \quad (10)$$

The retailers buy unfinished output from the wholesalers at a price P_t^W and sell it at an aggregate markup $\mu_t \equiv P_t / P_t^W$. Each retailer, in the spirit of Calvo (1983), can only change its price with a probability $1 - \omega$.

Those firms that change their price in a given period do so symmetrically and reset their prices to p_t^* . They maximize expected discounted profits. Letting $D_{t+i,t}$ equal the discount factor given by (4) cumulated forward to time i , the objective function for the price-changers equals

$$E_t \sum_{i=0}^{\infty} \omega^i D_{t+i,t} \left[\left(\frac{p_t^*}{P_{t+i}} \right)^{1-\theta} - \mu_{t+i}^{-1} \left(\frac{p_t^*}{P_{t+i}} \right)^{-\theta} \right] Y_{t+i}. \quad (11)$$

Long-run profit maximization results in the first order condition

$$\left(\frac{p_t^*}{P_t}\right) = \left(\frac{\theta}{\theta-1}\right) \frac{E_t \sum_{i=0}^{\infty} \omega^i D_{i,t+1} \mu_{t+i}^{-1} \left(\frac{P_{t+i}}{P_t}\right)^\theta Y_{t+i}}{E_t \sum_{i=0}^{\infty} \omega^i D_{i,t+1} \left(\frac{P_{t+i}}{P_t}\right)^{\theta-1} Y_{t+i}}, \quad (12)$$

with the aggregate retail price index given by

$$P_t^{1-\theta} = (1-\omega)(p_t^*)^{1-\theta} + \omega P_{t-1}^{1-\theta}. \quad (13)$$

Current prices are a weighted function of lagged prices and the prices set by those firms that could adjust. Conditions (12) and (13), when linearized and combined, describe a New Keynesian Phillips Curve relationship which relates current retail markups to current and expected future inflation.

III.C The wholesale sector

The wholesale sector distinguishes this model from typical sticky-price or sticky-wage models. Workers and firms separate for both exogenous and endogenous reasons, and firms search for workers based on expectations of future profitability.

Using standard notation, $U_t = I - N_t$ equals the number of workers searching for a job at the beginning of the period, with the population normalized to one. There is a constant probability ρ^x that a match will end exogenously. The remaining $(1 - \rho^x)N_t$ matches experience an iid, idiosyncratic productivity shock a_{it} (with a distribution function F) and a systematic permanent productivity shock \bar{z}_t , all of which the worker and firm observe at the beginning of the period. Based on their realizations, the worker and firm decide whether to continue the relationship or to separate. If the relationship continues, the match produces $y_{it} = (a_{it} \bar{z}_t)^{1-\alpha} k_{it}^\alpha$ which is sold at the wholesale price P_t^w

to the retailers. If the relationship separates, production equals zero; the job is destroyed; and the worker becomes unemployed. All productivity shock processes have an unconditional mean of one and are iid over time. The idiosyncratic shocks are also independent and identically distributed over time and across agents.

Matches rent capital in a competitive rental market at a rate ρ_t^k . Denoting the retailer's gross markup μ_t as P_t / P_t^w , the surplus of a match at period t equals the real value of the match's product in time t , minus the disutility of work in product terms, plus the expected discounted continuation value of the match (denoted by q_{it}), minus the match's capital rental payments. Income payments are discounted by the interest rate because of the cost channel induced by monetary frictions:

$$s_{it} = \frac{(a_{it}\bar{z}_t)^{1-\alpha} k_{it}^\alpha}{\mu_t R_t} - \frac{A_t}{\lambda_t} + q_{it} - \frac{\rho_t^k k_{it}}{R_t}.$$

The value of k_{it} is determined optimally by the match, so that:

$$k_{it} = (a_{it}\bar{z}_t) \left[\frac{\alpha}{\mu_t \rho_t^k} \right]^{\frac{1}{1-\alpha}}.$$

As a result, firms and workers bargain over the worker's marginal product:

$$s_{it} = \frac{(1-\alpha)(a_{it}\bar{z}_t)^{1-\alpha} k_{it}^\alpha}{\mu_t R_t} - \frac{A_t}{\lambda_t} + q_{it},$$

so substituting in the firm's capital demand,

$$s_{it} = \frac{(1-\alpha)(a_{it}\bar{z}_t) \left[\frac{\alpha}{\mu_t \rho_t^k} \right]^{\frac{\alpha}{1-\alpha}}}{\mu_t R_t} - \frac{A_t}{\lambda_t} + q_{it}.$$

After consolidating terms, one obtains the expression:

$$s_{it} = \frac{(1-\alpha)(a_{it}\bar{z}_t)}{\mu_t^{1-\alpha}R_t} \left[\frac{\alpha}{\rho_t^K} \right]^{1-\alpha} - \frac{A_t}{\lambda_t} + q_{it}. \quad (14)$$

Since only matches with a nonnegative surplus will continue, for a match to do so, it will require that a_{it} exceed a certain cutoff value \tilde{a}_t . Since the shock a_{it} is iid, the continuation value of the surplus q_{it} will equal the same value q_t across matches. Setting (14) to zero gives the value of this cutoff:

$$\tilde{a}_t = \frac{\mu_t^{1-\alpha}R_t(A_t/\lambda_t - q_t)}{\bar{z}_t(1-\alpha)} \left[\frac{\rho_t^K}{\alpha} \right]^{1-\alpha}. \quad (15)$$

If a_{it} has the distribution F , then the endogenous separation probability ρ_t^n equals

$F(\tilde{a}_t)$ and the aggregate separation rate ρ_t and the match survival rate φ_t are given by:

$$\rho_t = \rho^x + (1 - \rho^x)F(\tilde{a}_t), \quad (16)$$

and

$$\varphi_t = (1 - \rho^x)[1 - F(\tilde{a}_t)] = (1 - \rho_t). \quad (17)$$

In most models of this sort, workers and firms bargain every period. This model instead features wage stickiness. As in Gertler and Trigari (2009), wages are determined through staggered Nash bargaining. With probability $1 - \nu$, wages are bargained such that the worker receives a share η_t of the bilateral surplus, and the firm receives the remainder. Otherwise, the nominal wage does not change. Newly hired workers receive a wage drawn at random from the prevailing wage distribution. In this situation the wage does not directly affect the bilateral surplus or the separation rate between firms and workers but it can affect hiring.

Firms can post vacancies at a fixed cost \mathcal{P}_t^v but face no other barriers to entry.

These vacancies get filled at a gross rate k_t^f . A firm's share of the surplus at any given date is denoted s_{it}^f . Equating the supply and demand for vacancies results in a condition equating the present value of a firm's vacancy posting with the cost of vacancy posting:

$$\mathcal{P}_t^v = (1 - \rho^x) k_t^f \beta_t E_t \frac{\lambda_{t+1}}{\lambda_t} \int_{\bar{a}_{t+1}}^{\infty} s_{it+1}^f dF(a_{it+1}). \quad (18)$$

The probability of the worker actually finding a match equals k_t^w , based on a matching function. These conditions give the continuation value of the surplus:

$$q_t = (1 - \rho^x) \beta_t E_t \frac{\lambda_{t+1}}{\lambda_t} (1 - k_t^w) \int_{\bar{a}_{t+1}}^{\infty} s_{it+1}^f dF(a_{it+1}) + \frac{k_t^w \mathcal{P}_t^v}{k_t^f}. \quad (19)$$

The cost of a vacancy has to grow with productivity in order to keep the vacancy-employment ratio stable over time. The exact way that this is done does not have a significant effect on the results, so posting costs are simply proportional to productivity:

$$\mathcal{P}_t^v = \bar{\mathcal{P}}_t. \quad (20)$$

The firm's share of the surplus is given by:

$$s_{it}^f = \frac{(1 - \alpha)(a_{it} \bar{z}_t)^{1-\alpha} k_{it}^\alpha}{\mu_t R_t} - \frac{w_{it}}{R_t} + (1 - \rho^x) \beta_t E_t \frac{\lambda_{t+1}}{\lambda_t} \int_{\bar{a}_{t+1}}^{\infty} s_{it+1}^f dF(a_{it+1}). \quad (21)$$

Aggregating things, the total number of unemployed in a period equals the starting stock of unemployed plus those who separate at the beginning of the period.

Abstracting from labor force entry and exit, this comes out to

$$u_t \equiv U_t + \rho_t N_t = 1 - (1 - \rho_t) N_t. \quad (22)$$

The number of vacancies posted in a given period equals v_t . Given a constant-returns Cobb-Douglas matching function $m(u_t, v_t) = \mathcal{G} u_t^a v_t^{1-a}$, the vacancy-filling rate is given by

$$k_t^f = \frac{m(u_t, v_t)}{v_t}, \quad (23)$$

and the worker's job-finding rate is given by

$$k_t^w = \frac{m(u_t, v_t)}{u_t}. \quad (24)$$

The number of matches evolves according to the accounting identity

$$N_{t+1} = (1 - \rho_t)N_t + m(u_t, v_t), \quad (25)$$

and the gross output of the matched firms and workers is given by

$$Q_t = \frac{(1 - \rho_t)N_t \bar{z}_t \left[\int_{\tilde{a}_t}^{\infty} a_{it} dF(a_{it}) \right]}{1 - F(\tilde{a}_t)} \left[\frac{\alpha}{\mu_t \rho_t^K} \right]^{1-\alpha}. \quad (26)$$

Output (in value-added terms) equals gross output minus vacancy posting costs:

$$Y_t = Q_t - \mathcal{P}_t^v v_t. \quad (27)$$

To solve for the rebargained real wage, one could note that those firms which pay the rebargained wage W_t^* have an average surplus of $(1 - \eta_t)s_t$. Since wages sometimes deviate from this, firms' actual portion of the surplus may be higher or lower than this value. This difference, in the aggregate, is simply equal to the present value of the wage gap L_t after accounting for the cost channel:

$$L_t = s_t^f - (1 - \eta_t)s_t = E_t \sum_{i=0}^{\infty} D_{t+i,t} \Phi_{t+i,t} \left(\frac{W_{t+i}^* - W_{t+i}}{R_{t+i}} \right).$$

This can be written as a difference equation:

$$L_t = \frac{W_t^* - W_t}{R_t} + E_t \frac{\beta_t \lambda_{t1} \varphi_{t+1} L_{t+1}}{\lambda_t}, \quad (28)$$

where the cumulative match survival probability is given for $i > 0$ by

$$\Phi_{t+i,t} = \prod_{j=1}^{t+i} \varphi_{t+j},$$

and is equal to one for $i = 0$. The average nominal wage rate is given by:

$$P_t W_t = v P_{t-1} W_{t-1} + (1-v) P_t W_t^*. \quad (29)$$

Capital depreciates at a rate $\delta(N_{t+1}^K)^\phi$ and utilization contributes to depreciation.

Capital holdings follow a first-order condition:

$$1 = \beta_t E_t \frac{\lambda_{t+1}}{\lambda_t} \left[1 + \frac{\rho_{t+1}^K N_{t+1}^K - \delta(N_{t+1}^K)^\phi}{R_{t+1}} \right]. \quad (30)$$

Finally, optimal utilization is given by:

$$\rho_t^K = \delta \phi (N_{t+1}^K)^{\phi-1}. \quad (31)$$

III.D Real driving processes

Letting $\bar{\Gamma}$ equal the long-run growth rate of productivity, it is convenient to assume that it follows a highly persistent AR(1) on top of a time trend:

$$\ln(\bar{z}_t) - \bar{\Gamma}t = \rho_{\bar{z}} [\ln(\bar{z}_{t-1}) - \bar{\Gamma}(t-1)] + \varepsilon_t^{\bar{z}}. \quad (32)$$

The level of technology-adjusted government spending, G_t , follows an AR(1):

$$\ln(G_t) = (1 - \rho_G) \ln(G) + (1 - \rho_G) \ln(\bar{z}_t) + \rho_G \ln(G_{t-1}) + \varepsilon_t^G. \quad (33)$$

The bargaining weight η_t and the labor supply parameter A_t as well as the time preference parameter β_t also follow an AR(1):

$$\ln(\eta_t) = (1 - \rho_\eta) \ln(\eta) + \rho_\eta \ln(\eta_{t-1}) + \varepsilon_t^\eta; \quad (34)$$

$$\ln(A_t) = (1 - \rho_A) \ln(A) + \rho_A \ln(A_{t-1}) + \varepsilon_t^A; \quad (35)$$

and

$$\ln(\beta_t) = (1 - \rho_\beta) \ln(\beta) + \rho_\beta \ln(\beta_{t-1}) + \varepsilon_t^\beta. \quad (36)$$

III.E The monetary authority

During the interwar period, the Fed wished to stabilize nominal exchange rates and prices, concentrating upon the nominal price of gold. Other branches of government such as the Treasury directed a large portion of monetary policy as well. With interest rates throughout the 1930s remaining extremely low and evolving into a peg, it seems accurate to treat the movement of interest rates as passive (that is, moving less than one-to-one with inflation) during this period. In particular this paper treats interest rates as following an exogenous persistent autoregressive process akin to an interest rate peg. Given an expected path of interest rates, current nominal variables are determined endogenously by expectations of the long-run price level.

This paper remains agnostic about the exact source of that long-run price level target. Eggertsson (2006, 2008), for instance, suggests that fiscal policy may have affected inflation expectations through a game that fiscal authorities play with their future selves. The Fiscal Theory of the Price Level views the price level as evolving to ensure government solvency under certain assumptions about systematic fiscal consolidation, to enforce consumers' transversality conditions. Alternatively, Friedman (1963) argued that the collapse of the supply of inside money determined long run nominal expectations, while Bernanke and James (1991) emphasize the importance of the gold standard and governments' decision of a nominal anchor. Alternatively, it is possible that these

expectations were simply self-fulfilling. The model used here is consistent with each of these theories. What matters is that expectations are rational.

Letting Θ_t equal the growth rate of the money supply from t to $t+1$, the growth rate of the supply of inside money evolves according to the law of motion

$$\ln(\Theta_t) = (1 - \rho_m) \ln(\bar{\Theta}) + \rho_m \ln(\Theta_{t-1}) + \varepsilon_t^\Theta. \quad (37)$$

The short-run money supply does not matter in determining the equilibrium of the model since only long run expectations matter, but it is an interesting empirical question to see how unexpected movements in the money supply are related to unexpected movements in nominal aggregates. This will indicate how well the monetarist view of the Depression can be reconciled with the New Keynesian view. Near the zero bound, it seems reasonable to treat interest rates as a highly persistent AR(1) process:

$$\ln(R_t) = (1 - \rho_R) \ln(R) + \rho_R \ln(R_{t-1}) + \varepsilon_t^R. \quad (38)$$

Since interest rates cannot respond more than one-for-one to inflation, the model requires more assumptions for closure, or else there are too many valid nonexplosive rational expectations equilibria. To deal with this, this paper introduces an additional process, the expected long run price level, denoted by the exogenous process $P_{\infty,t}$, to which the price level converges in the long run given information at time t . Under the assumption of rational expectations, its logarithm must follow a random walk. The equilibrium is then determined by backward induction from the terminal price level.

For computational reasons, it is simpler to analyze the behavior of the nominal output gap. This gap is just defined as the difference between long-run and actual nominal output, given by $\ln(J_t) = \ln(P_{\infty,t}) + \ln(Y_{\infty,t}) - \ln(P_t) - \ln(Y_t)$. Taking first

differences, one can show, with a random walk long-run productivity process, that the nominal output gap J_t follows the law of motion:

$$\ln(J_t) = \ln(J_{t-1}) - \ln\left(\frac{P_t}{P_{t-1}}\right) - \ln\left(\frac{Y_t}{Y_{t-1}}\right) + \varepsilon_t^p + \varepsilon_t^z. \quad (39)$$

In the calculation of the rational expectations equilibrium, this equation generates a unit eigenvalue. Suppressing it ensures that the nominal output gap is strictly stationary, which enforces the definition of a nominal output gap. Otherwise expected nominal values would drift arbitrarily far away from their long run values.

III.F Equilibrium and solution method

The aggregate household conditions (4) through (7), the New Keynesian retail conditions (12) and (13), the aggregated versions of (14) through (31) from the wholesale sector, and the driving processes (32) through (39) constitute a rational expectations equilibrium for this economy. The method used to estimate the shocks involves taking a log-linear approximation around a steady state. Based on this linearized system, is possible to obtain feedback coefficients using the `gensys.m` program written and discussed by Sims (2002). In this particular situation, the equilibrium exists and is unique in the neighborhood around the steady state. While nonlinear methods may improve the accuracy of the model (ignoring the uncertainty surrounding functional forms and other sources of misspecification), they also impose the need to make additional assumptions about the ordering of shocks and their effects. In addition, they are much more computationally intensive than linear methods in this case.

IV Estimation strategy

IV.A State space approach

The linearized model conveniently lends itself to a state space representation. Given a set of feedback rules and quarterly data on eleven variables, it is fairly simple to use the Kalman Filter to estimate the underlying unobservable states. The filter also delivers the approximate Gaussian likelihood of the model. The first half of the state space approach consists of the reduced-rank VAR representation of the linearized model and those observation errors apart from those of inflation:

$$x_t = A_1 x_{t-1} + B_1 \varepsilon_t, \quad (40)$$

The second half of the state space approach consists of the observation equation relating the variables in the model (plus the inflation observation error) to the eleven observed data series. One can label these series as x_t^* . Algebraically, this idea can be represented by the observation equation:

$$x_t^* = D_1 x_t + \varepsilon_t^*. \quad (41)$$

For estimation reasons it is simpler to stack those observation errors whose variance must be estimated into x_t while the inflation error goes into ε_t^* .

IV.B Calibrated and estimated parameter values

Most of the parameter values follow the calibrations used in Walsh (2002) or Gertler, Sala, and Trigari (2008), unless the data dictate another value. The values used for household preferences are within the range of standard values from the literature on postwar business cycles. Households have a habit persistence coefficient h of 0.7 based on the findings of Gertler et al. The nominal interest rate R equal to 3.75 percent per year, based on real interest rates from 1923 through 1929. Output and consumption per

capita grow at 1.7 percent per year. The rate of inflation is approximately zero on average. Investment (including residential structures but excluding consumer durables) is 15% of output based on NIPA data; depreciation is 1.5% per quarter; and government spending is 8% of output. Steady state utilization is normalized to 1.

Based on Walsh's calibration, the gross retail markup μ equals 1.1, for a value of θ of 11. Retailers change their prices on average once every two quarters, for a value of ω of 0.5. This is based on Bils and Klenow's (2004) estimate of about 0.5. Wages last for a little more than one year, for a value of ν of 0.80, near the value used by Gertler and Trigari. The velocity of M1 shows no strong trend throughout the 1920s. This implies a per-capita nominal money growth rate of roughly 1.7 percent per year as well. This, combined with the real interest rate, implies a value of β of 0.995.

Data on total job flows from the interwar period seem to indicate that hiring and firing in manufacturing have not changed much over the long run, so a conventional postwar calibration is used. The exogenous job separation rate ρ^x equals 0.068 and the total job separation rate ρ equals 0.10 per quarter. These values imply a value of $\rho^n = F(\tilde{a})$ equal to 0.0343 per quarter. The idiosyncratic process a_{it} is lognormal with an arithmetic mean of 1 and an estimated dispersion parameter σ_a of 0.70, for a central location parameter μ_a of -0.245. This delivers a value for \tilde{a} of 0.219.

The likelihood of the model in the baseline setup favors vacancy posting costs equal to 1.68 percent of output; this is higher than the value of one percent used by Hairault (2002) and Andolfatto (1996). Not much solid external evidence exists on this parameter. The unemployment share a of the matching function, in the baseline calibration, equals 0.2. Walsh cites Blanchard and Diamond (1989, 1991) who use

postwar CPS data to derive an estimate of 0.4, but the joint behavior of the vacancy and accession rates during this period, as expressed in the likelihood function, encourages a somewhat smaller value. This is also one parameter which might be sensitive to linearization and the choice of a functional form because the deviations of vacancies and employment are so large during the 1930s.⁴

The steady-state unemployment rate u (after separations) equals 0.06 based on postwar values; no good unemployment data exist from this period. The worker-finding rate k^f equals 0.7 and the job-finding rate k^w equals 0.6, both from Walsh's calibration. These imply that there are 0.0514 vacancies v in the steady state. The baseline calibration implies initial values of 0.324 for labor's bargaining power η and 1.068 for the disutility of work A/λ . This equals 93% of the average wage net of the cost channel.

The long-run productivity process has a coefficient of one, approximated as 0.99999 in order to make things computationally simpler. Labor's bargaining power and the disutility from work have a persistence of 0.96 and 0.999, respectively, while intertemporal preferences have a persistence of 0.97, all based on the likelihood function. Based on observed data, money growth has a persistence ρ_m of 0.75, while interest rates have an autocorrelation of 0.96, and government spending has an autocorrelation of 0.97.

V Estimation results

V.A The driving processes and observation errors

The standard deviations of the seven driving processes and nine observation error processes must be estimated by maximum likelihood. The estimated standard

⁴ This may also be an artifact of the data used to estimate matching functions. There is no historically consistent unemployment series which goes back to the 1930s, so detrended employment was used.

deviations equal 0.0149 for the money supply shocks, 0.0956 for the government spending shocks, 0.0207 for the productivity shocks, 0.0357 for the long-run price level shocks, 0.2005 for the labor bargaining power shocks, 0.0119 for the labor supply shocks, 0.0011 for the interest rate shocks, and 0.0006 for the intertemporal preference shocks. The standard deviations of the observation error processes are 0.001 for inflation (calibrated), 0.0029 for output, 0.0020 for employment, 0.0055 for money supply growth, 0.0004 for interest rates, 0.0242 for the log labor share, 0.3160 for vacancies, 0.1863 for the log separation rate, 0.2116 for the log accession rate, 0 for government spending (calibrated), and 0.0482 for investment.

Table 1 shows the contemporaneous correlation between these shocks. The highest correlation comes between the interest rate and long-run price level shocks, with a correlation of 0.86. Alternative relationships between the shocks to the long run price level and interest rates were tried; they did not materially affect the total effects of these shocks, but they did affect the contribution of each individual shock to the total. As a result, only the total effects of the nominal shocks are reported below. Looking further at the fourth row, bargaining power shocks seem somewhat deflationary as do government spending shocks, while monetary shocks are unrelated to long-run price level shocks. Intertemporal shocks, interestingly, seem related to government spending shocks, but most of the other shocks do not have a high correlation with each other.

Figures 1 and 2 show the real and nominal data as well as the estimated driving processes under the baseline scenario. The model matches the nominal variables as well as output and employment extremely closely. It also matches the separation rate and accession rate fairly well, but it predicts too many job flows in 1932 and too few in 1941.

Even though these data are not of the best quality, they do seem to contain useful information about the economy of the 1920s and 1930s. The model matches the medium-run behavior of vacancies well, but the model predicts more short-run volatility than the data indicate. It also matches the high labor share during the contraction phase of the Depression; this is due to sticky nominal wages. The model matches the other variables very well.

V.B. Nominal and intertemporal shocks and their effects

Nominal factors appear to drive the cyclical behavior of labor markets during the early phases of the Depression. The long run price level was relatively stable during the 1920s, with some possible mild deflationary pressure throughout the decade. It then crashed and stayed persistently low after 1933. The data, narrative history, and model all agree that expectations of persistent price changes played a large role in the business cycle dynamics of the period. In contrast with Eggertsson (2008), this model indicates that the environment throughout the 1930s was still profoundly deflationary, primarily based on the low observed nominal interest rates. The intuition for this form of deflationary bias is simple: With persistently low nominal interest rates, households' intertemporal Euler Equation (4) demonstrates the Fisher Effect. Expected inflation tracks nominal interest rates, so as nominal interest rates decline in the long run, so does expected inflation. As Friedman (1963) noted, the low interest rates of this period appear to be a sign of deflationary, not inflationary, pressure.

Eggertsson (2008) emphasizes the effects of intertemporal shocks on real allocations and on inflation. Indeed, it appears that people acted more patiently and tried

to save more during the early 1930s, and this pushed down the efficient level of real interest rates. In the short run these shocks are deflationary. Holding long-run price level expectations and nominal interest rates constant, the willingness to consume less today causes today's output to fall in price relative to tomorrow's output. In the medium run these shocks are inflationary, as prices rise back toward their long run levels. Real interest rates fall and this sets the stage for a rebound.

Figures 4 and 5 show the cumulative effects of all the shocks in the model; the employment and output effects of the various shocks (save productivity) track each other closely. The estimated shocks from 1923 onward are fed into the model, and the effects after 1929 are shown in the charts (re-based to zero). The shocks to interest rates and to prices are taken together, since theory and measurement are silent as to their exact relationship. For both output and employment, these nominal shocks are the main drivers of the Depression. They contribute 13 points to the fall in output from trend and 16 points to the fall in employment from trend during the contraction phase. The intertemporal preference shocks analyzed by Eggertsson, by contrast, should have caused a small rise in output during the Depression as falling expected real interest rates should have stimulated production and employment by 7 and 8 percentage points.

Nominal shocks also account for half of the 1937-38 recession in terms of the fall in employment from trend, though the model does predict a longer recession than the one which actually occurred. Eggertsson and Pugsley (2006) argue that this recession was caused by the Fed's deliberate engineering of lower inflationary expectations, and the model and data are consistent with this interpretation of events. However, the model economy predicts a faster recovery from the initial onset of the Depression than the one

which in fact happened. Since very little happened with interest rates and with the long run price level after 1933, wage and price adjustment should have brought the economy back to trend by about 1937.

V.C. Evaluating the monetarist hypothesis

One might naturally ask the question, how well does money growth predict long-run nominal output? Friedman and Schwartz (1963) and many authors since then assign an important role to the money supply during the Depression period. A rough measure of this correlation is given by regressing the forecast error of long run nominal output on the forecast error of long run money. The coefficient obtained over the entire sample is 0.59, with that coefficient rising to 1.36 beginning in the second quarter of 1933. It is clear that the money supply was correlated with nominal output (but not long run prices); a simple inspection of Figure 2 shows this. This is the empirical basis for the monetarist claim that the money supply matters even in a liquidity trap.

To investigate the monetarist hypothesis, one can what happens when one takes the additional information from the M1 money supply into account when estimating shocks to nominal output. This is done by replacing equation (39) with the expression:

$$\ln(J_t) = \ln(J_{t-1}) - \ln\left(\frac{P_t}{P_{t-1}}\right) - \ln\left(\frac{Y_t}{Y_{t-1}}\right) + \frac{1}{1-\rho_M} \varepsilon_t^\Theta + \varepsilon_t^V, \quad (39M)$$

and reestimating the shock processes. This specification restricts nominal output in the long run to be governed solely by the money supply and by a structural shock to the long-run velocity of money. In this model, money supply need not feed through into nominal output in every period (that is, velocity can vary endogenously in the short run). In the long run, however, as conditions return to normal, one would expect velocity to revert to

its long-run value. If the money supply were effective at providing a nominal anchor, then this is equivalent to saying that the quantity theory holds in the medium to long run.

Figure 6 shows the results of this exercise. The effects of money supply shocks in this monetarist model mostly follow the underlying process of money growth. That is, money does exert a contractionary influence from 1929 through 1933. However, money supply growth shot up after 1933, and the model predicts that by early 1934, output should have reverted to trend. Indeed, the model counterfactually predicts a very large boom during the mid-1930s, and this is after allowing for generous measurement error in the money supply process. As a result of this anomalous behavior, the log likelihood of the monetarist model equals 2,048.2 versus 2,073.9 (to a constant) for the baseline model. The data reject a monetarist interpretation of events of the entire decade. Not only were low interest rates an unreliable indicator of the stance of long-run monetary policy; it seems that the *money supply* was an unreliable indicator of the stance of expected monetary policy.⁵ Nominal and real output growth did not reliably follow from money growth during the period of low interest rates.

V.D. The role of government spending and productivity shocks

A look at Figures 4 and 5 indicate a more moderate role for government spending and productivity shocks in comparison with nominal shocks. Contrary to popular wisdom, real government spending was mildly *stimulative* on average under the Hoover administration, adding about one percent each to employment and output between the beginning of 1929 and the beginning of 1933. It did dip slightly in 1932, however. It

⁵ Taking the monetary base as the driver of long-run nominal output would only strengthen this conclusion, since the monetary base grew even more quickly than broad money during the 1930s, beginning in 1930.

continued to exert a mildly stimulative influence throughout the rest of the Depression, adding about 3% each to employment and output in mid-1936, and it accounted for only a tiny part of the 1937 recession. In conjunction with a slight moderation in deflationary expectations, war spending helped to pull the economy out of the Depression toward the end of 1941. The changes in government spending before 1941 were simply too small to account for much, and this is in a model with a moderately large government multiplier.⁶

The model and data also indicate a moderate role for productivity, on the order of 7 percent of employment and 19 percent of output. The employment data used here are based on Kendrick (1961)'s quality-adjusted labor input measure which is cleansed of sectoral composition bias. In comparison with an unadjusted measure of employment, this measure of labor input shows smaller productivity fluctuations. During this period there was a massive shift in the labor force away from manufacturing and into less-productive agriculture. The role ascribed here for movements in productivity should still be considered an upper bound on the effects of productivity shocks because of the difficulties inherent in measuring hours of work, but it seems that unfavorable productivity shocks played a noticeable role in the behavior of output and employment.

V.E. Labor market shocks and the slow recovery

The estimated bargaining power and labor supply shifters shifted upwards, persistently, for the entire Depression period. This indicates that there were disturbances that kept labor demand persistently low, apart from productivity and nominal shocks. Labor's bargaining power shows slightly more cyclical than does the labor supply

⁶ The total cumulative multiplier (the output gain divided by the spending innovation in present value) equals 0.62.

shifter, while the latter made a one-time jump upward between 1933 and 1935. Figures 4 and 5 show that neither one matters much at a business cycle frequency. Their main contribution is to account for the persistent downward shift in the Beveridge Curve during the 1930s and especially for the poor labor market performance through 1935. Low vacancy creation precedes low employment, so while the shocks to labor's bargaining power hit during the contraction, it took until the mid-1930s until their effects were completely felt. By contrast, labor supply remained fairly healthy until the New Deal and exerted a minor drag on employment thereafter. Overall, the circumstances in the 1930s reflect unusually sclerotic labor markets, and this coincides with a high labor share of income as well as a depressed Beveridge curve.

V.F The importance of the model parameters

Figures 7 through 9 show the effects of the nominal shocks under different values of the labor market parameters, after reestimating the structural shocks and holding other parameters constant. This exercise tends to overexaggerate the importance of individual parameter choices, but it offers insight into how the model works. Figure 7 shows what happens when one raises the share of vacancy posting costs to 2.0% and the standard deviation of the idiosyncratic shocks to 1.20. In this case the model tracks the baseline model very well. Reducing vacancy posting costs to 1.0% and reducing the standard deviation of the idiosyncratic shocks to 0.30, by contrast, provides more amplification for nominal shocks during the contraction while predicting a faster recovery. Different values of the matching elasticity a show the same pattern, with high values showing a deeper depression and low values showing much smaller effects for nominal shocks. A

higher value of a is unlikely since that would imply a very large hiring rate provoked by high unemployment (and thus cheap vacancy posting) in 1932. Not shown is the habit persistence parameter h , which does not matter to the naked eye. Figure 8 shows the importance of the nominal parameters. The model is sensitive to these parameters since without them nominal expectations are almost neutral. The model with a value of ω of 0.1 has only small differences from the baseline value of 0.5, while a sticky price parameter of 0.67 interestingly shows somewhat fewer effects for nominal shocks. This parameter is quantitatively not too important. The wage stickiness parameter ν is absolutely crucial at explaining what happened during the Depression, with small variations making a large difference. Figure 9 shows the effects of the capital market parameters; the parameterization of depreciation and utilization do not matter while a higher capital share in production provides substantial amplification. Investment dynamics are simply an important part of business cycle dynamics.

One can draw a few general conclusions as to how the model works based on these robustness checks. Vacancy posting costs and individual-level volatility matter for the model; without them there would be no job flows and no unemployment. The nominal stickiness parameters also matter; they provide the initial transmission mechanism from nominal shocks into real aggregates. While the exact numerical results of the model depend on the parameter values and upon model specification, the qualitative results are robust. In most cases, shocks to long run expectations can account for large portions of the recessions of 1929-33 and 1937-38, while they cannot account for the slow recovery in between. In every case, some other wedge appears to have shifted the Beveridge Curve downward.

V.G The relationships among shocks

The above discussion assumes that the structural shocks are orthogonal to each other. In the data the shocks are not closely correlated with each other except for some of the nominal shocks. Still, it is worth exploring what happens when one allows these shocks to be related. Any imposed ordering of the shocks will be somewhat arbitrary, but a well chosen one can illuminate the lines along which these structural shocks might reflect deeper patterns. For instance, it allows for one to see how government spending feeds through to inflation expectations during the Depression, since this is a mechanism proposed by Eggertsson (2006) through which the New Deal brought recovery.

Figure 10 repeats the above decomposition exercise but after allowing for the shocks to government spending, productivity, labor's bargaining power, and labor supply to affect the long-run price level and interest rates in a linear manner. This involves taking the baseline model and estimating these eight additional coefficients through maximum likelihood. The results are striking. The only shocks that seem to matter are shocks to productivity and especially to bargaining. Government spending shocks, intertemporal shocks, and to some extent labor supply shocks appear to have very little effect, and there is no evidence that government spending shocks are expansionary once their effect on future inflation is taken into account. More government spending did not feed through into higher inflation during the Depression. Furthermore, comparing Figure 10 with Figure 4 reveals that the rise in labor's bargaining power and the rise of deflationary expectations were part of the same episode in terms of the timing of their effects. There seems to be a relationship in terms of timing between the collapse in nominal output and the rise in labor's bargaining power.

VI Conclusion

Recent experiences with low and persistent interest rates have forced researchers and policymakers to reevaluate what actually drove the Great Depression, with the hope of not repeating it. This paper has shown that a modern model of unemployment, when fed with a series of plausible shocks to long-run expectations, can replicate much of the cyclical behavior of real aggregates during that period. However the model still relies on labor supply and vacancy wedges to account for the slow recovery after 1933. This is consistent with the view that restrictive labor market policies caused unemployment to remain structurally high, and it coincides with a drastic downward shift in the Beveridge Curve. If the Depression had been caused by nominal shocks alone, the US economy should have recovered quite well by the mid to late 1930s.

The results of these estimations also cast a revisionist view on the importance of the money supply and of inflationary expectations during the Depression. The money supply does show a positive relationship with the long-run price level during this period, but the model also rejects the view that exogenous changes in the money supply or in real aggregate demand drove nominal output. Otherwise, 1934 through 1936 would have been years of great prosperity. This is consistent with New Keynesian thinking, whereby nominal spending is a purely forward-looking variable in conditions of slack money demand. Instead, the persistently low interest rates of the period indicate a profoundly deflationary environment, even after 1933.

The relative unimportance of monetary aggregates and the continued deflationary pressures indicated by low nominal interest rates are at odds with most traditional views of the 1930s, but they hold special relevance for policymakers faced with a low interest

rate environment. In this type of situation the usual indicators of monetary policy are no longer reliable guides as to the evolution of nominal output, and expectations of the long run become particularly important in determining current outcomes. Policymakers need to take this into account when designing policies to cope with low interest rates; in a liquidity trap one should not mistake low interest rates and an expanding money supply for inflationary pressure.

Appendix A: Numerical solution to the model

A.1 Deriving the steady state from calibrated parameters

The state-space approach requires a specification for the state equation which comes from the linearized model. The linearized model in turn contains coefficients which depend on the steady state of the model. Deriving the steady state from the calibrated parameters while taking growth rates into account is fairly straightforward. Given a nominal interest rate R , a balanced growth rate $\bar{\Gamma}$, a gross inflation rate Π , and a risk aversion parameter σ , it is possible to calibrate the rate of time preference β from equation (I.4) after noting that the costate variable λ grows at rate $\bar{\Gamma}$:

$$\beta = \frac{\bar{\Gamma}\Pi}{R}. \quad (\text{A1})$$

In a zero-inflation steady state with a driftless velocity, the money growth rate $\bar{\Theta}$ simply equals the economic growth rate $\bar{\Gamma}$. Given a markup μ , one can solve the equation

$$\mu = \frac{\theta}{\theta - 1},$$

to get θ .

Given a process for a_{it} and total and exogenous separation rates ρ and ρ^x , it is possible to derive the endogenous separation probability and the cutoff value for productivity:

$$F(\tilde{a}) = \rho^n = \frac{\rho - \rho^x}{(1 - \rho^x)}. \quad (\text{A2})$$

Given an observed unemployment rate u as well as a total separation rate ρ , and job and worker finding rates k^w and k^f , it is easy to find the number of employed (before separations):

$$N = \frac{1-u}{1-\rho}, \quad (\text{A3})$$

the number of vacancies from the homogeneous matching function,

$$k^f v = k^w u, \quad (\text{A4})$$

and the retention rate:

$$\varphi = (1-\rho^x)[1-F(\tilde{a})]. \quad (\text{A5})$$

The capital evolution equation, given a steady state investment ratio and depreciation rate, determines the steady-state capital-output ratio:

$$s_k = \frac{s_i}{(\bar{\Gamma}-1+\delta)}, \quad (\text{A6})$$

and the intertemporal investment equation determines ρ_k and the depreciation elasticity parameter:

$$\rho_k = R(R-1) + \delta, \quad (\text{A7})$$

and

$$\phi_k = \frac{\rho_k}{\delta}. \quad (\text{A8})$$

The demand for capital and the value of vacancy posting costs s_v determine the value of α :

$$\alpha = \frac{\rho_k s_k \mu}{1 + s_v} \quad (\text{A9})$$

Given the output equation, one can then find a value for gross output Q :

$$Q = \frac{(1-\rho)N \left[\int_{\tilde{a}_i}^{\infty} a_i dF(a_i) \right]}{1-F(\tilde{a})} \left[\frac{\alpha}{\mu_i \rho_i^K} \right]^{1-\alpha}. \quad (\text{A10})$$

This gives values for Y and γ based on the equation for value added:

$$Y = \frac{Q}{1 + s_v}, \quad (\text{A11})$$

and

$$\mathcal{P}^v = \frac{Q - Y}{v}. \quad (\text{A12})$$

The average surplus is taken from integrating over output in excess over the reservation value:

$$s = \frac{(1 - \alpha) \left[\int_{\tilde{a}_i}^{\infty} (a_i - \tilde{a}) dF(a_i) \right]}{(1 - F(\tilde{a})) \mu R} \left[\frac{\alpha}{\mu_i \rho_i^K} \right]^{\frac{\alpha}{1 - \alpha}}. \quad (\text{A13})$$

The surplus equation a closed-form expression for q :

$$q = \frac{\bar{\varphi} \bar{\Gamma} (1 - k^w) s}{R} + \frac{k^w \mathcal{P}^v}{k^f}, \quad (\text{A14})$$

and the vacancy posting condition yields the firm's share of the surplus:

$$s^f = \frac{\mathcal{P}^v}{k^f \bar{\varphi} \bar{\Gamma}}. \quad (\text{A15})$$

The real wage follows the form (in steady state):

$$W = R \left(\frac{(1 - \alpha) Q}{\varphi N \mu R} - s^f + \frac{\mathcal{P}^v}{k^f} \right) \quad (\text{A16})$$

and the rebargained wage is given by

$$W^* = W \frac{(1 - \nu / \bar{\Gamma})}{(1 - \nu)}. \quad (\text{A17})$$

The initial value of the costate variable in consumption is determined by the first-order condition of the household's optimization problem:

$$\frac{1}{C - hC / \bar{\Gamma}} - \frac{\beta h}{\bar{\Gamma} C - hC} - \lambda = 0, \quad (\text{A18})$$

and the surplus equation yields A :

$$A = \left(\frac{(1-\alpha)Q}{\varphi N \mu R} - s + q \right) \lambda. \quad (\text{A19})$$

The price of vacancies can be normalized (by extension determining γ):

$$p^v = 1. \quad (\text{A20})$$

The initial value of the velocity does not matter for the calibration of this model and can be set to one.

A.2 Linearization around the steady state

Linearizing the quantity equation in first differences obtains the stochastic money demand relation (which determines velocity implicitly):

$$\hat{\pi}_t + \hat{y}_t - \hat{\Theta}_t - \Delta \hat{V}_t = \hat{y}_{t-1} \quad . \quad (\text{A21})$$

The evolution of the number of matches comes from the accounting condition after substituting the relationship between matches and vacancy filling:

$$\hat{n}_{t+1} = \varphi \hat{n}_t + \varphi \hat{\phi}_t + \left(\frac{vk^f}{N} \right) \hat{v}_t + \left(\frac{vk^f}{N} \right) \hat{k}_t^f. \quad (\text{A22})$$

The endogenous job destruction margin comes next:

$$\begin{aligned} \hat{a}_t = \hat{r}_t + \frac{1}{1-\alpha} \hat{\mu}_t + \frac{\alpha}{1-\alpha} \hat{\rho}_t^k - \hat{z}_t - \left(\frac{q}{A/\lambda - q} \right) \hat{q}_t \\ + \left(\frac{A/\lambda}{A/\lambda - q} \right) (\hat{A}_t - \hat{\lambda}_t), \end{aligned} \quad (\text{A23})$$

followed by an expression for the job retention rate:

$$\hat{\phi}_t = - \left(\frac{\rho^n}{1-\rho^n} \right) e_{Fa} \hat{a}_t, \quad (\text{A24})$$

where e_{Fa} equals the elasticity of F with respect to \tilde{a} . The number of job seekers is approximated by the expression

$$\hat{u}_t = -\left(\frac{\phi N}{u}\right)\hat{\phi}_t - \left(\frac{\phi N}{u}\right)\hat{n}_t. \quad (\text{A25})$$

The parameterization for the matching function ensures that the vacancy filling probability relates to vacancies and job searchers:

$$\hat{k}_t^f = a\hat{u}_t - a\hat{v}_t, \quad (\text{A26})$$

and the job finding probability relates to the vacancy filling probability such that

$$\hat{k}_t^f + \hat{v}_t = \hat{k}_t^w + \hat{u}_t. \quad (\text{A27})$$

Linearizing the job posting condition yields:

$$\hat{p}_t^v = \hat{k}_t^f - \hat{r}_t + E_t\hat{\pi}_{t+1} + E_t\hat{s}_{t+1}^f + E_t\hat{\phi}_{t+1}. \quad (\text{A28})$$

Linearizing the output equation yields:

$$\begin{aligned} \hat{y}_t = & \left(\frac{Q}{Y}\right)(e_{Ha}\hat{a}_t + \hat{\phi}_t + \hat{n}_t + \hat{z}_t - \frac{\alpha}{1-\alpha}\hat{\mu}_t - \frac{\alpha}{1-\alpha}\hat{\rho}_t^k) \\ & - \left(\frac{\mathcal{W}p^v}{Y}\right)(\hat{v}_t + \hat{p}_t^v), \end{aligned} \quad (\text{A29})$$

where e_{Ha} equals the elasticity of $H(\tilde{a}) \equiv \frac{1}{1-F(\tilde{a})} \int_{\tilde{a}_t}^{\infty} a_i dF(a_i)$ with respect to \tilde{a} .

The asset pricing equation follows its typical form:

$$\hat{\lambda}_t = \hat{r}_t + E_t\hat{\lambda}_{t+1} - E_t\hat{\pi}_{t+1}, \quad (\text{A30})$$

and the first-order condition for consumption becomes:

$$\frac{\bar{\Gamma}^2 + \beta h^2}{(\bar{\Gamma} - h)^2 c} \hat{c}_t + \frac{\bar{\Gamma} \beta h}{(\bar{\Gamma} - h)^2 c} E_t \hat{c}_{t+1} - \frac{\bar{\Gamma} h}{(\bar{\Gamma} - h)^2 c} + \hat{\lambda}_t = 0. \quad (\text{A31})$$

The conditions for the retail sector give rise to a New Keynesian Phillips Curve linearized around a zero inflation steady state:

$$\frac{\omega}{R} E_t \hat{\pi}_{t+1} = \omega \hat{\pi}_t + (1 - \omega) \left(1 - \frac{\omega}{R} \right) \hat{\mu}_t. \quad (\text{A32})$$

The relationship between the continuation value of the surplus and future values of that surplus is approximated by the following:

$$\begin{aligned} q \hat{q}_t = & \frac{\phi \bar{\Gamma} s (1 - k^w)}{R} (E_t \hat{\phi}_{t+1} - \hat{r}_t + E_t \hat{\pi}_{t+1} + E_t \hat{s}_{t+1}) \\ & + \left(\frac{k^w \mathcal{P}^v}{k^f} - \frac{\phi \bar{\Gamma} s k^w}{R} \right) \hat{k}_t^w + \frac{k^w \mathcal{P}^v}{k^f} (\hat{p}_t^v - \hat{k}_t^f). \end{aligned} \quad (\text{A33})$$

To get the factor shares and the continuation value of the match, it is helpful to have a linearized equation for the average surplus:

$$\begin{aligned} s \hat{s}_t = & \frac{(1 - \alpha) Q}{\phi N \mu R} \left(\frac{Y}{Q} \hat{y}_t + \frac{\mathcal{W} p^v}{Q} (\hat{v}_t + \hat{p}_t^v) - \hat{\phi}_t - \hat{n}_t - \hat{\mu}_t - \hat{r}_t \right) \\ & - \frac{A}{\lambda} (\hat{A}_t - \hat{\lambda}_t) + q \hat{q}_t, \end{aligned} \quad (\text{A34})$$

The surplus imbalance is linearized as follows (in levels, not log levels):

$$\hat{L}_t = s^f \hat{s}_t^f - (1 - \eta) s \hat{s}_t + \eta s \hat{\eta}_t, \quad (\text{A35})$$

and the transition equation for this expected imbalance, which determines the wage bargain, is linearized as:

$$\begin{aligned} \hat{L}_t = & \frac{W^*}{R} \hat{w}_t^* - \frac{W}{R} \hat{w}_t - \left(\frac{W^* - W}{R} + \frac{\phi \bar{\Gamma} L}{R} \right) \hat{r}_t + \frac{\phi \bar{\Gamma} L}{R} (E_t \hat{\phi}_{t+1} + E_t \hat{\pi}_{t+1}) \\ & + \frac{\phi \bar{\Gamma}}{R} E_t \hat{L}_{t+1}. \end{aligned} \quad (\text{A36})$$

The sticky wage equation becomes

$$W\hat{w}_t + (W - (1-\nu)W^*)\hat{\pi}_t - (1-\nu)W^*\hat{w}_t^* = \frac{\nu W}{\Gamma}\hat{w}_{t-1}. \quad (\text{A37})$$

The firm's portion of the surplus, on average, is given as follows, after substituting in the job creation condition:

$$s_t^f = \frac{(1-\alpha)Q_t}{\varphi_t N_t \mu_t R_t} - \frac{W_t}{R_t} + \frac{\mathcal{P}_t^v}{k_t^f},$$

so

$$\begin{aligned} s_t^f \hat{s}_t^f &= \frac{(1-\alpha)Y}{\varphi N \mu R} \hat{y}_t + \frac{(1-\alpha)\mathcal{P}^v \nu}{\varphi N \mu R} \hat{v}_t - \frac{(1-\alpha)Q}{\varphi N \mu R} (\hat{\mu}_t + \hat{\varphi}_t + \hat{n}_t) \\ &\quad - \frac{W}{R} \hat{w}_t + \left(\frac{\mathcal{P}^v}{k^f} + \frac{(1-\alpha)\mathcal{P}^v \nu}{\varphi N \mu R} \right) \hat{p}_t^v - \frac{\mathcal{P}^v}{k^f} \hat{k}^f + \left(\frac{W}{R} - \frac{(1-\alpha)Q}{\varphi N \mu R} \right) \hat{r}_t. \end{aligned} \quad (\text{A38})$$

The resource constraint is linearized as

$$\hat{y}_t = s_c \hat{c}_t + s_i \hat{i}_t + s_g \hat{g}_t, \quad (\text{A39})$$

and the capital transition equation is linearized as

$$s_k \Gamma \hat{k}_{t+1} = s_k (1 - s_\delta) \hat{k}_t - s_\delta s_k \phi \hat{n}_t^k + s_i \hat{i}_t. \quad (\text{A40})$$

The return to capital is given by

$$\hat{\rho}_t^k = \frac{Q}{Y} \hat{y}_t + \frac{\mathcal{P}^v \nu}{Y} (\hat{v}_t + \hat{p}_t^v) - \hat{k}_t - \hat{n}_t^k - \hat{\mu}_t, \quad (\text{A41})$$

and the investment equation is given by

$$\begin{aligned} R(\hat{r}_t - E_t \hat{\pi}_{t+1}) &= \frac{\rho^k N^K}{R} E_t \hat{\rho}_{t+1}^k + \left(\frac{\rho^k N^K - s_\delta \phi}{R} \right) E_t \hat{n}_{t+1}^k \\ &\quad - \frac{\rho^k N^K - s_\delta}{R} E_t \hat{r}_{t+1}, \end{aligned} \quad (\text{A42})$$

while the utilization equation is given by

$$\hat{\rho}_t^k = (\phi - 1)\hat{n}_t^k. \quad (\text{A43})$$

Finally, it is necessary to include the eight linearized driving processes:

$$\hat{\Theta}_t = \rho_m \hat{\Theta}_{t-1} + \varepsilon_t^\Theta, \quad (\text{A44})$$

$$\hat{g}_t = \rho_g \hat{g}_{t-1} + (1 - \rho_g) \hat{z}_{t-1} + \varepsilon_t^g, \quad (\text{A45})$$

$$\hat{z}_t = \rho_{\bar{z}} \hat{z}_{t-1} + \varepsilon_t^{\bar{z}}, \quad (\text{A46})$$

$$\hat{r}_t = \rho_R \hat{r}_{t-1} + \varepsilon_t^R, \quad (\text{A47})$$

$$\hat{\eta}_t = \rho_\eta \hat{\eta}_{t-1} + \varepsilon_t^V, \quad (\text{A48})$$

$$\hat{A}_t = \rho_A \hat{A}_{t-1} + \varepsilon_t^A, \quad (\text{A49})$$

$$\hat{\beta}_t = \rho_\beta \hat{\beta}_{t-1} + \varepsilon_t^\beta, \quad (\text{A50})$$

and

$$\hat{J}_t = \hat{J}_{t-1} - \hat{\pi}_t - \hat{y}_t + \hat{y}_{t-1} + \varepsilon_t^{\bar{z}} + \varepsilon_t^P. \quad (\text{A51})$$

The end result of all of this is a reduced-rank VAR representation that provides the laws of motion for the underlying system for the state-observer setup.

Appendix B: Construction of the dataset

Constructing a consistent set of quarterly interwar labor market data required synthesizing a quarterly dataset from a number of different sources. This appendix contains details on the construction of these data elements and their sources:

1. The quarterly growth rate in the GNP deflator. The NIPA deflator post-1929 was used; the Kendrick (1961) deflator was used before that. They were interpolated using the growth rates of the price index for department store sales and of the BLS's index of wholesale prices, both available from the NBER database.

2. The level of real output. The NIPA data were used post-1929 and the Kendrick (1961) data before that. These were interpolated using the FRB industrial production index and real department store sales. The former is available from the St. Louis Fed and from the Federal Reserve Board; the latter is available from the NBER database. This is taken to be at trend relative to population in 1923, 1928, and 1948. One appealing feature of using the Kendrick data is that he adjusts for long-run sectoral changes, avoiding much of the spurious choppiness that older fixed-weight indexes imposed on the data.

3. A measure of labor input. The Kendrick (1961) quality-adjusted labor input data were used. They were interpolated using the BLS's series on employment for production workers. The main features of these data as opposed to quality-unadjusted data are that they scale down part-time workers to a full-time equivalent basis, and that they make some attempt to control for composition differences. During the mid-1930s, for instance, agricultural employment (particularly self-employment) did not significantly decrease while manufacturing employment stayed depressed. Not controlling for this

paints a misleading picture of productivity, since it is those less productive sectors which were less hit by the Depression. More historical work needs to be done in terms of measuring the hours of the self-employed and refining the quality adjustments for these labor series. It seems that adjusting for shorter workweeks and composition moves one in the right direction with regard to reconciling employment and output data. This is taken to be at trend, relative to population, in 1923, 1928, and 1948.

4. The growth rate in M1. The end-of-month data come from the appendices of Friedman and Schwartz (1963) via the NBER, with the money supply defined as currency plus adjusted demand deposits held by the public. These are then averaged throughout the quarter. These monthly averages, in turn, equal the average of the money supply at the end of the previous month and the money supply at the end of the current month.

5. A nominal interest rate. The banker's acceptance rate is used (from the NBER) since it tracks the risk-free interest rate closely and provides consistent data for the entire period. There is no comparable series of short-term treasury notes available from that time.

6. A measure of labor's share of output, corrected for changes in the sectoral composition of gross income, particularly the income of proprietors and government workers. Economywide compensation is first calculated as the labor share of corporate GDP less taxes on production and imports, times total GDP. To do this, an annual series is constructed for the corporate share of gross income originating from 1922 onward. Moroney (1964) and Osborne and Epstein (1956) report data on corporate net income originating, that is, income gross of direct corporate taxes but net of depreciation and indirect taxes (taxes on production and imports). Using data on corporate depreciation

allowances, investments treated as expenses, and inventory valuation adjustments published by Goldsmith (1955), an approximate capital consumption allowance is added back in to these series using the national income accounting rules prevalent at the time. This yields a measure of corporate gross income originating, net of taxes on production and imports. Data for the post-1929 period come directly from the NIPA. Using 1958-vintage NIPA (*U.S. Income and Output*, 1958) data as a reality check, it appears that the data constructed by this method from the 1958 and 2009 vintages show similar behavior after 1929, with the 1958-vintage data showing slightly larger changes in labor's share during the trough of the Contraction. In the interest of conservatism, the 2009-vintage series was used, ratio-spliced to the 1958-vintage series at 1929 where the 2009-vintage series begins. This composite series shows no clear trend in labor's share from 1922 through 2009. This lack of trend contrasts with the long-run rise in labor's share of economywide value added, reflecting the decline in proprietor's income from agriculture and the increase in labor income from government.

Economywide compensation is then interpolated by using the FRB's index of composite wages as well as manufacturing labor input. This way, compensation and income estimates are interpolated independently of each other. The labor share is calculated with compensation as the numerator and nominal GDP as the denominator.

7. A measure of vacancies. The Met Life help wanted series is used. It is seasonally adjusted at the source. The vacancy-employment ratio appears to be relatively stable, and it is taken to be at trend in 1948, with trend vacancies being determined by trend labor input. Zagorsky (1998) documents the long-run stability of this trend using data through the early 1990s. Most notably, vacancies remain above trend during the

1920s and then collapse right around the end of 1929. They fall below trend and remain there until the third quarter of 1942 when they shoot upward because of the effects of the war. Arithmetic percent deviations are taken from trend.

8. A measure of the separation rate of workers. These data come from the appendix to Woytinsky (1942) augmented by issues of *Employment and Earnings* from the 1970s. Woytinsky warns of a break in the methods used to compute the series between 1929 and 1930 but finds that these data, taken together, still provide a useful picture of interwar labor flows. The series behaves much as one would expect given the fact that recessions often come with a burst of job destruction and reductions in the accession rate. The pre-1930 series are also re-measured and amplitude adjusted in order to match the post-1930 series in terms of overall levels. As it is, the inclusion or exclusion of these data and the specification of the measurement errors on the job flow variables will not particularly affect the results of the estimates in this paper. These data should not be taken too literally, but they provide some information about the cyclical behavior of job flows during this period. As with the quality-adjusted labor input data, this situation cries out for more historical work to be done.

9. A measure of the rate of new hiring, from the same sources as above. Calculations proceed in much the same way, and the same caveats apply.

10. Nominal government spending is taken from Balke and Gordon (1986). These data are divided by trend nominal GDP and taken as arithmetic percent deviations from trend.

11. Nominal investment is taken from Balke and Gordon (1986) and treated the same way. Investment consists of investment in inventories, residential and

nonresidential structures, and equipment. These items show the greatest deviations from trend, with residential structures behaving mostly like investment and somewhat like consumption, and with the narrowest definitions of investment turning negative in levels. Durable goods behave more like consumption goods, so they are treated as such in the model and data.

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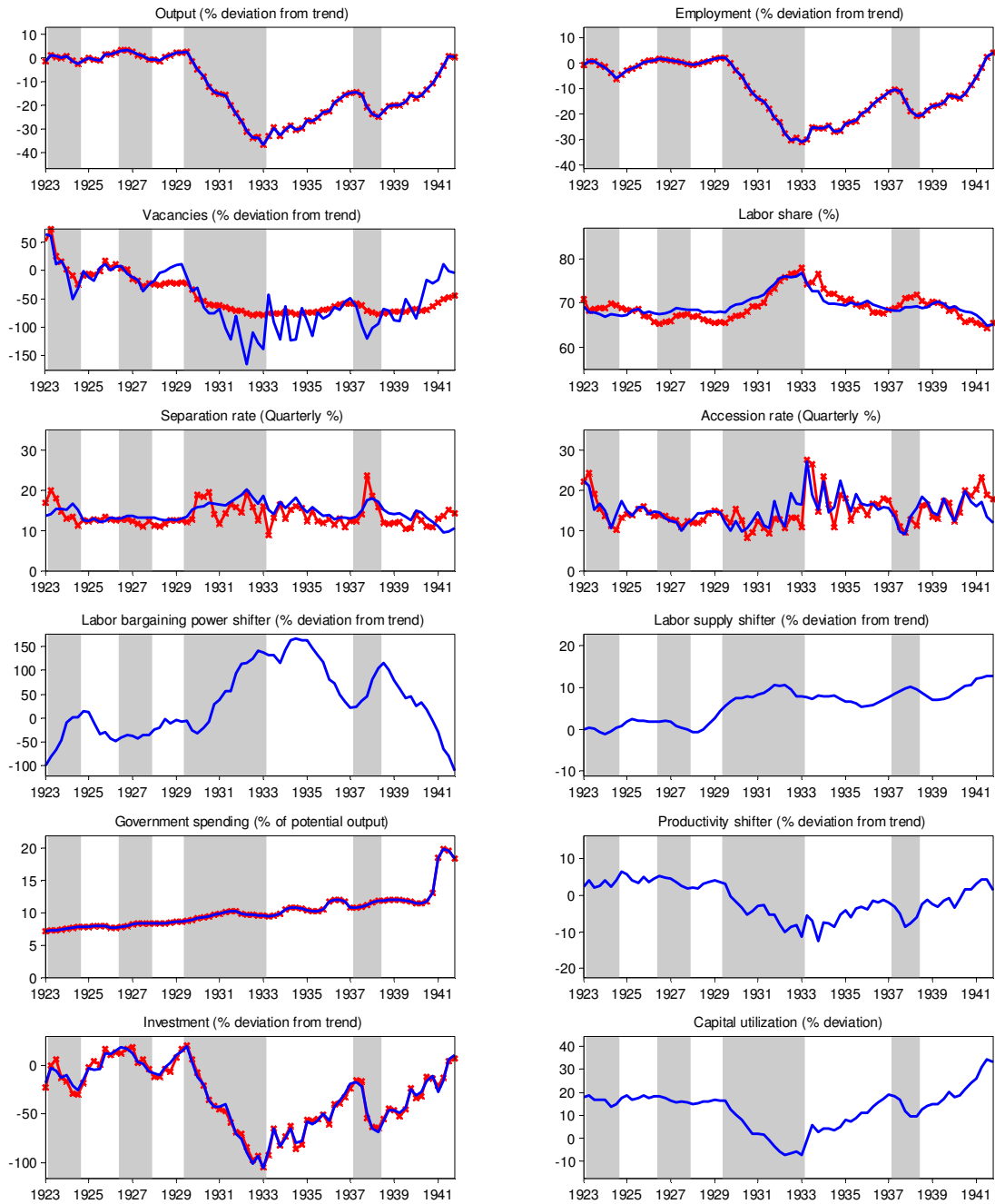
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Table 1 – Correlation matrix for the shock processes, baseline model

	Θ_t	G_t	z_t	P_∞	η_t	A_t	r_t	β_t
Θ_t	1	0.20	0.31	-0.11	-0.09	-0.17	-0.25	-0.08
G_t	0.20	1	0.15	-0.14	-0.19	0.23	-0.04	-0.31
z_t	0.31	0.15	1	0.05	0.23	-0.20	0.09	0.05
P_∞	-0.11	-0.14	0.05	1	-0.21	0.04	0.86	-0.03
η_t	-0.09	-0.19	0.23	-0.21	1	-0.17	0.10	0.23
A_t	-0.17	0.23	-0.20	0.04	-0.17	1	0.13	0.01
r_t	-0.25	-0.04	0.09	0.86	0.10	0.13	1	-0.06
β_t	-0.08	-0.31	0.05	-0.03	0.23	0.01	-0.06	1

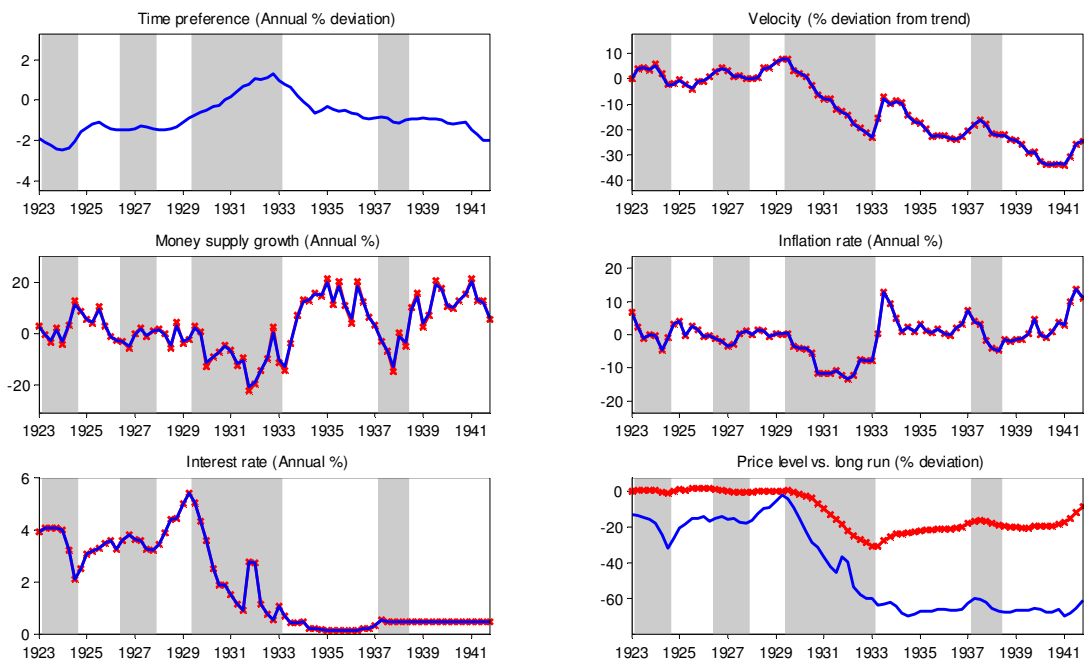
Source: Author's calculations.

Figure 1 – Real variables (observed and smoothed)



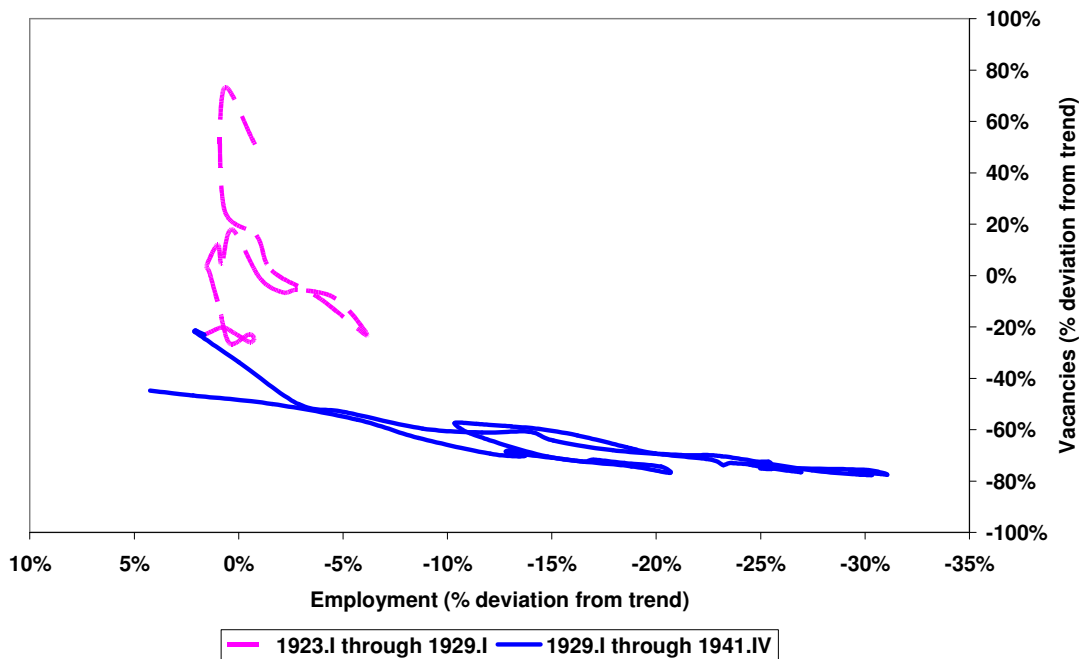
Red 'x' lines denote observed data; blue solid lines denote smoothed data as described in the text. For details on data sources and calculations, see text.

Figure 2 – Nominal variables and driving processes (observed and smoothed)



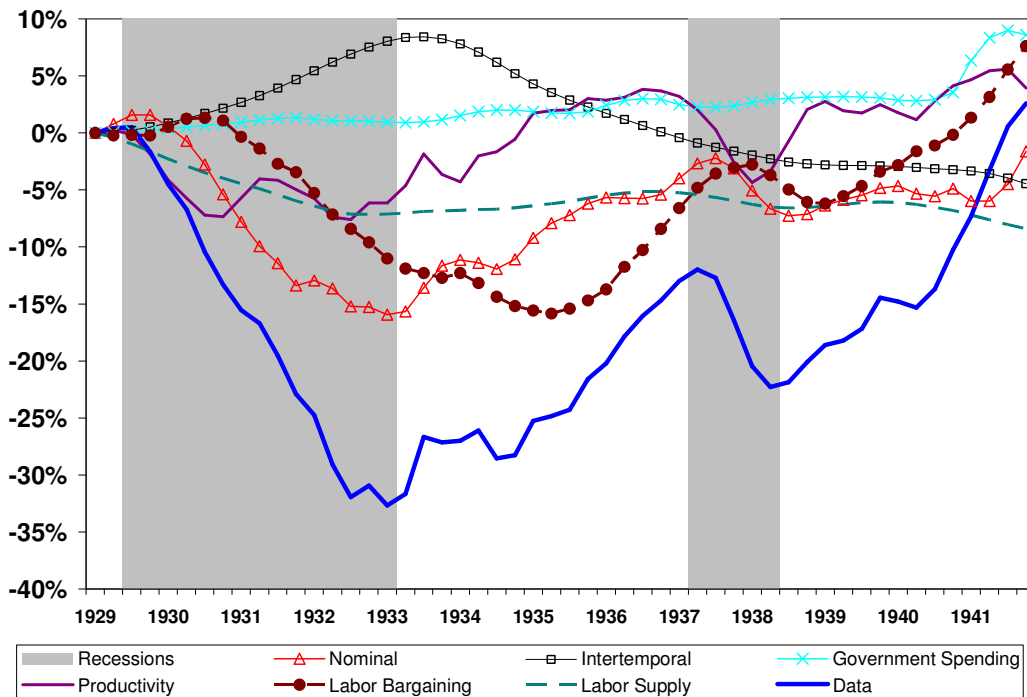
Red 'x' lines denote observed data; blue solid lines denote smoothed data as described in the text. For details on data sources and calculations, see text.

Figure 3 – Beveridge Curve, pre and post-1929 (% deviation from trend)



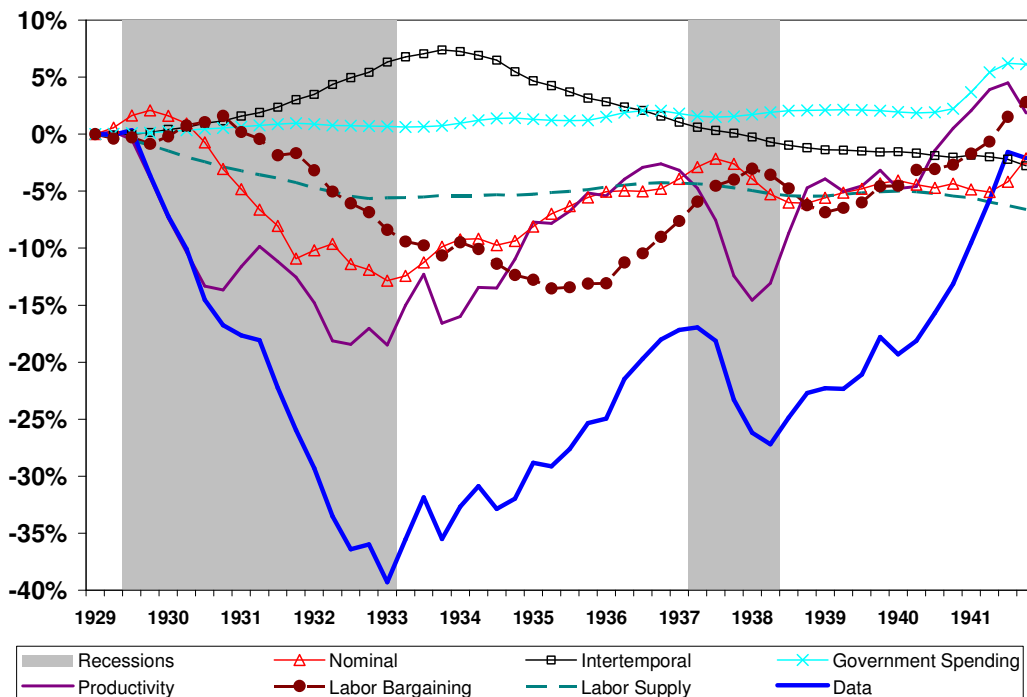
Source: Same data as used for Figure 1. See text for details.

Figure 4 – Estimated effects of shocks on employment, baseline model



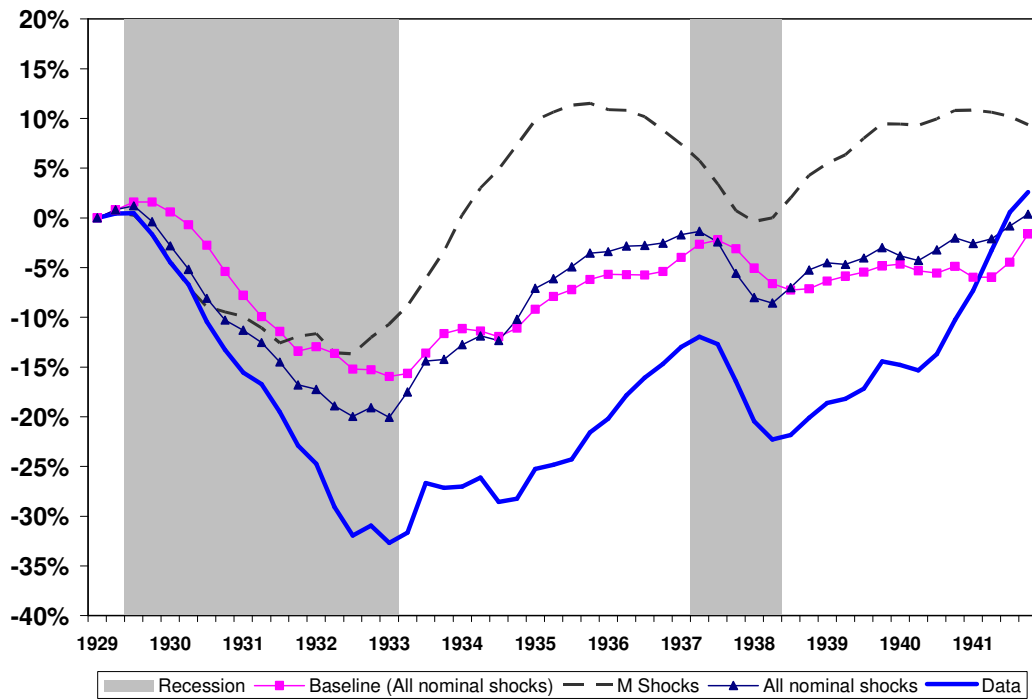
Source: Author's calculations, 1929.I set to 0.

Figure 5 – Estimated effects of shocks on output, baseline model



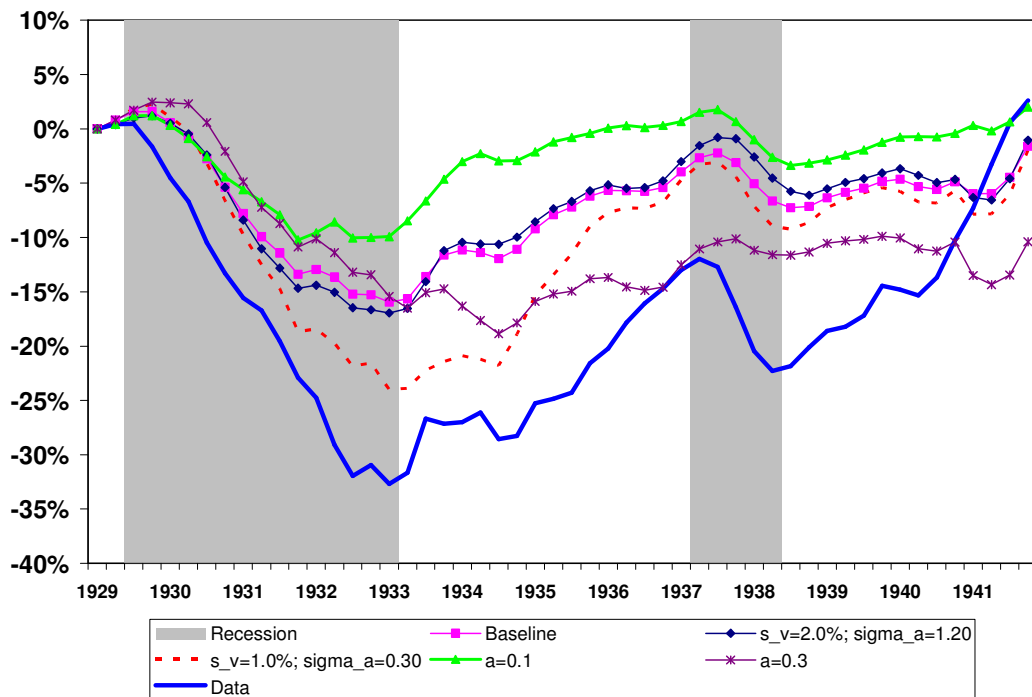
Source: Author's calculations, 1929.I set to 0.

Figure 6 – Estimated effects of nominal shocks on employment, monetarist model



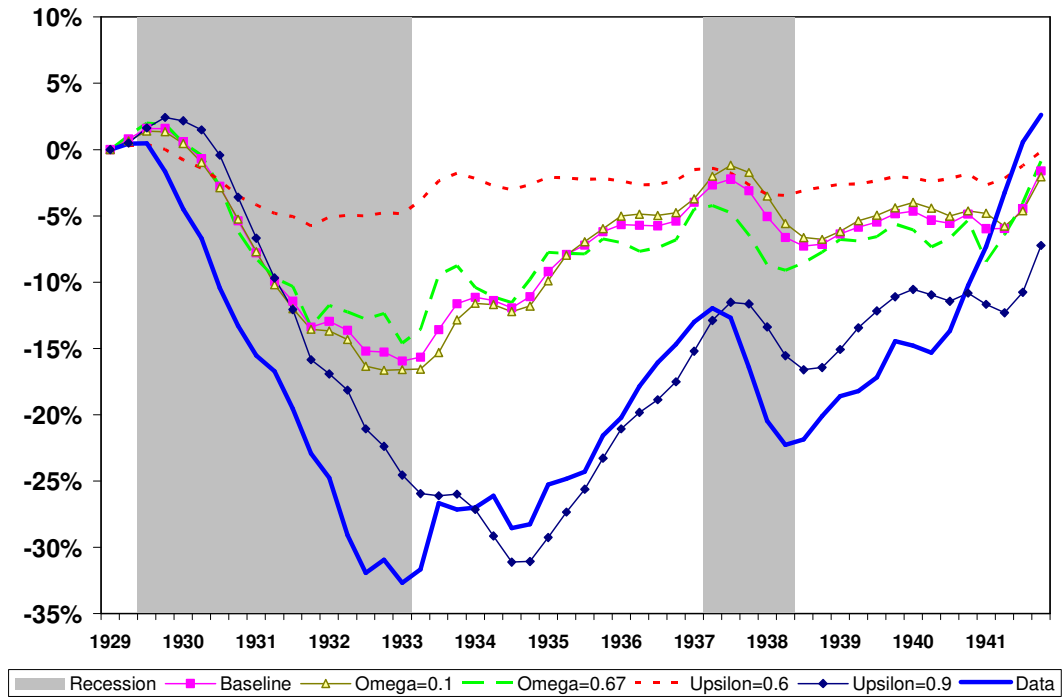
Source: Author's calculations. See text for explanation.

Figure 7 – Estimated effects of nominal shocks on employment, various scenarios



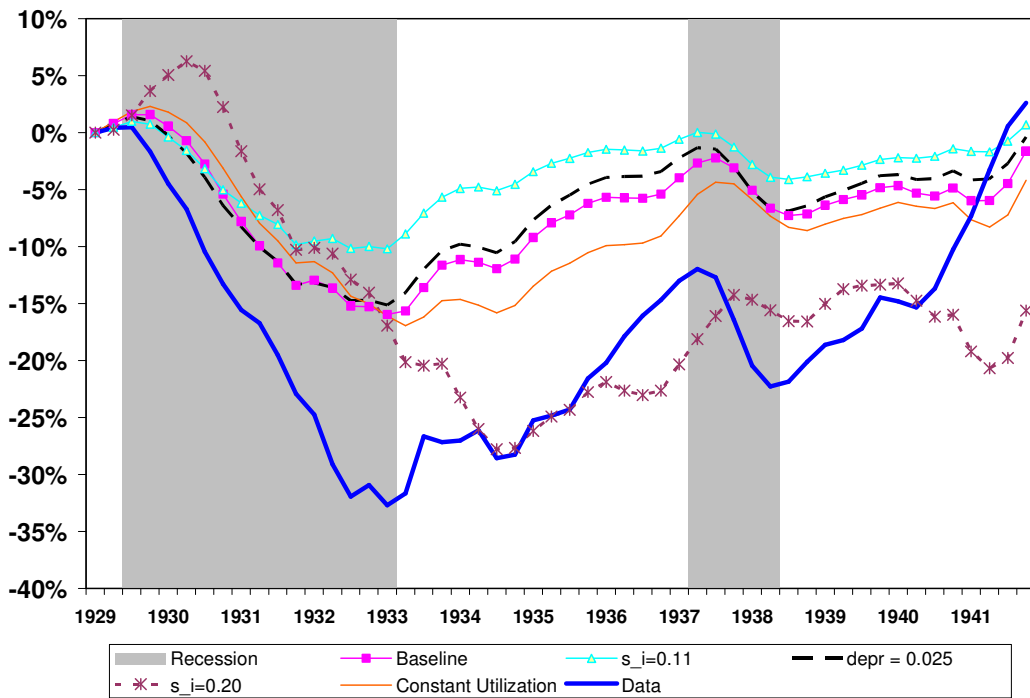
Source: Author's calculations. Baseline: $s_v = 1.68\%$; $h = 0.7$; $a = 0.2$; $\sigma_a = 0.70$.

Figure 8 – Estimated effects of nominal shocks on employment, various scenarios



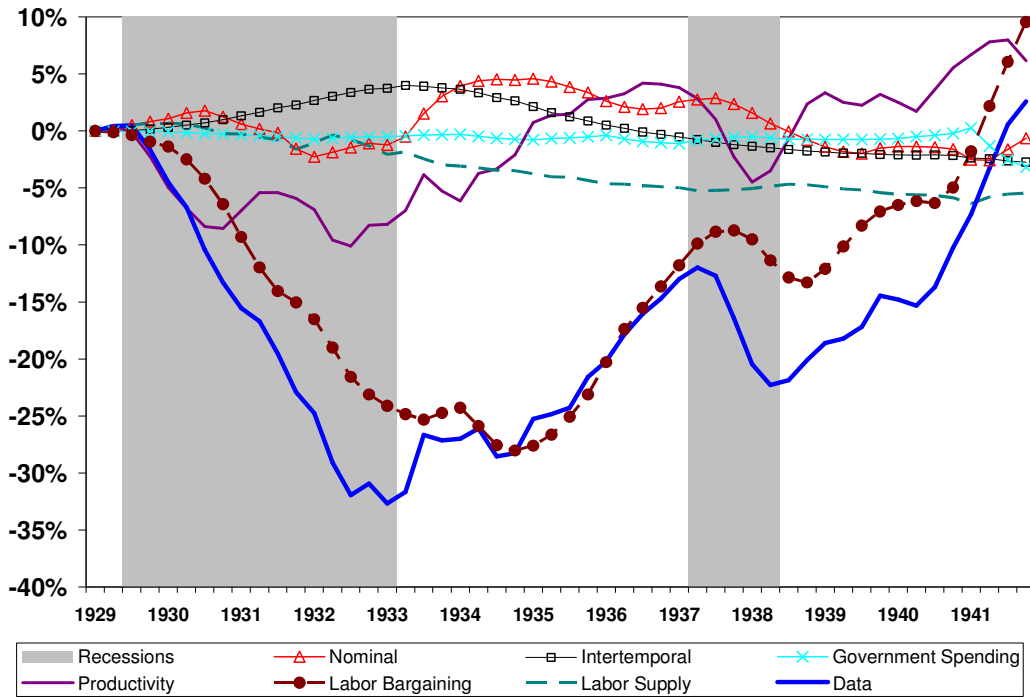
Source: Author's calculations. Baseline: $\omega = 0.5$; $\nu = 0.80$.

Figure 9 – Estimated effects of nominal shocks on employment, various scenarios



Source: Author's calculations. Baseline: $s_i = 15\%$; $\delta = 0.015$; variable utilization.

Figure 10 – Estimated effects of shocks on employment, correlated scenario



Source: Author's calculations. This chart shows what happens when one takes the baseline model and allows the government spending, productivity, bargaining power, labor supply, and intertemporal shocks to feed through into the nominal shocks.