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Three Essays on Estimation of Policy Disturbances

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in

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by

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The dissertation of Christopher Phillip Reicher is approved, and it is acceptable in quality and form for publication on microfilm:

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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ABSTRACT OF THE DISSERTATION

Three Essays on Estimation of Policy Disturbances

by

Christopher Phillip Reicher

Doctor of Philosophy in Economics

University of California, San Diego, 2008

Professor Garey Ramey, Chair

Chapter I estimates a series of shocks to a labor matching model with money and sticky prices, using U.S. data from the Great Depression. These shocks consist of shocks to the supply and demand for money, to short-run and long-run productivity, to labor supply, and to labor's share of bargaining surpluses. The estimates, based on a persistent downward shift in the Beveridge curve combined with persistently high wages, suggest that a rise in labor's share of bargaining surpluses accounts for a large

part of the contraction and most of the slow recovery during the Depression. Shocks to labor supply explain some the slow recovery and monetary shocks explain some of the contraction. Shocks to productivity do not seem to have been important during this period.

Chapter II shows that the same model can match labor's share of income rather well using postwar data. However, it cannot explain much of the behavior of employment and vacancies without resorting to additional shocks beyond monetary and productivity shocks. As with other New Keynesian models, the model suggests that monetary policy shocks can account for only a small portion of postwar fluctuations apart from the Volcker episode. Productivity shocks can account for some of the behavior of labor's share and employment during the late 1960s and the early 1980s. Most recessions, however, appear driven by other shocks.

Chapter III estimates a fiscal policy rule using postwar U.S. data in order to understand how governments set fiscal policy in order to stabilize the debt-GDP ratio. This chapter synthesizes the literature on fiscal Taylor rules and error correction models, treating the former as a special case of the latter. The estimated rule suggests that the government sector has stabilized deficits through adjustments to purchases and taxes, in that order. It has appeared extremely reluctant to adjust transfers in response to fiscal imbalances. Cyclically, government spending and transfers as a share of output rise strongly with unemployment while taxes fall strongly. Furthermore, since 1981, the government sector has stabilized deficits much less aggressively, while the cyclical behavior of fiscal variables has not changed.

I Wage Bargaining, Job Matching, and the Great Depression

I.A Introduction

In the macroeconomic history of the twentieth century, the Great Depression stands out as one of the most important and puzzling episodes. From 1929 to 1933, real output fell by over fifty percent relative to trend, in log terms, and employment fell by over thirty-five percent. Banks failed in several large waves and the money supply contracted by nearly forty percent from trend. Output and employment did not return to trend until after the onset of the Second World War; the failure of the economy to recover more quickly represents one of the great puzzles of macroeconomics. Attempting to explain the slow recovery, a number of authors have recently 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 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 (2007), Cole and Ohanian (2004), and Ebell and Ritschl (2007), in addition to previous historians, present narrative and quantitative evidence that the policies of Presidents Hoover and Roosevelt intended to promote higher wages may have played a large role in dampening the demand for labor. Using a bargaining model with clearing labor markets, Ohanian claims that Hoover's high-wage policy could account for up to ten percentage points of the decline in output from 1929 through 1931. In separate work, Cole and Ohanian contend that Roosevelt's attempts to promote industrial cartelization and unionization may have retarded the recovery after 1933. Ebell and Ritschl further explore this issue in a theoretical setting with a stripped-down labor matching model. Based on a comparison between steady states, they find that an economywide shift toward unionization can possibly contribute to high rates of unemployment in the long run. By looking at a labor matching framework rather than a flexible RBC-style labor market, Ebell and Ritschl avoid the failure, noted by Cole and Ohanian (1999, 2004), Mulligan (2002), Chari, Kehoe, and McGrattan (2007), and many others, for hours worked to lie on a stable labor supply curve. Based on all of this evidence, it appears that shocks to workers' bargaining power might belong to the array of shocks which deepened and lengthened the Depression.

This paper uses a standard labor matching model with money and sticky prices to estimate these bargaining shocks and a number of other shocks which appear to have hit the U.S. economy during the 1920s and 1930s. It uses quarterly data on GNP, employment, labor's share of output, the money supply, prices, interest rates, job vacancies, job accession rates, and job separation rates. In spirit, it resembles the business cycle accounting approaches of Chari, Kehoe, and McGrattan (2007) and Christiano, Motto, and Rostagno (2004), but in a labor matching framework. Using a standard Kalman filter, the paper delivers estimates of shocks to six driving processes—shocks to labor's bargaining power, shocks to the disutility from work, shocks to the supply and demand for money, and short-run and long-run shocks to productivity.

The estimates suggest that an unexplained rise in labor's share of bargaining surpluses can explain a large part of the Great Depression. For a set of baseline parameter values, the unexplained rise in labor's share of bargaining surpluses explains a 17% decline in output relative to trend between 1929 and 1933, and it explains a 22% decline in employment relative to trend. An apparent increase in workers' disutility from work accounts for a similar portion of the slow recovery in output but relatively little of the contraction. Together these disturbances to the labor market explain a substantial portion of the decline in employment during the contraction phase of the Depression, and they completely account for the slow recovery. An increase in labor's share of income coincided with a persistent downward shift in the Beveridge Curve—for a given level of employment, firms appeared much more reluctant to post vacancies and hire during the entire 1930s than they had during the 1920s, as wages remained stubbornly high.

In contrast with the findings of Chari, Kehoe, and McGrattan, productivity shocks had little effect on employment throughout the period. Shocks to money supply and demand, taken together, appear to have played a large role in the contraction but not in the slow recovery.[1] By contrast, the unexplained rise in labor's share of surpluses persists well into the recovery phase of the Depression, and it matches the low rates of employment and vacancy creation.

I.B The data

This paper makes use of linearly detrended quarterly observations on nine variables related to real activity, job flows, and nominal variables from the first quarter of 1923 through the fourth quarter of 1941. An appendix to this section discusses the details of the construction and ultimate sources of the dataset. Figure I.1 shows the behavior of linearly detrended quarterly real GNP and nonfarm employment from 1923 through 1941. The GNP series comes from the National Income and Product Accounts and from Kendrick (1961), interpolated to a quarterly frequency using the Balke and Gordon (1986) series. Nonfarm employment comes from Kendrick (1961), interpolated to a quarterly frequency by an index of the employment of production workers in manufacturing. Both series tell a standard story of the Depression. Between 1929 and 1933, employment fell by nearly 31% relative to trend and output by 41% relative to trend, in absolute terms. They both began to recover erratically, ultimately taking until the onset of World War II to recover to trend, after a deep recession in 1937 and 1938.

[1] With respect to the slow recovery, Bordo, Erceg, and Evans (2000) note the complete failure of a New Keynesian model with sticky wages to explain the persistently low levels of output and employment after 1933 given the large rise in the money supply after that date. Bernanke and Carey (1996) suggest that this might result from an extreme amount of nominal stickiness.

Figure I.2 shows the behavior of manufacturing separation and accession rates. The manufacturing separation and accession rates reported by Metropolitan Life and the BLS (Woytinsky, 1942, and the December 1942 *Monthly Labor Review*) both fell during the recessions of 1924 and 1927 and rose during the subsequent expansions. By contrast, both series looked like mirror images of each other during the Depression, with separations and accessions both playing an important role in job flows during the 1930s. Figure I.3 shows the relationship between employment and vacancies known as the Beveridge curve.[2] The detrended Metropolitan Life help wanted index (a proxy for vacancies) showed higher than usual vacancy rates all throughout the 1920s. By contrast, beginning in 1929, the Beveridge curve shifted downward as vacancy rates remained unusually low all throughout the Depression.

Figure I.4 shows the behavior of labor's share of corporate and national gross income, interpolated to a quarterly frequency from annual data. The portion of the corporate series before 1929 was constructed on the basis of annual data provided by Moroney (1964), Osborne and Epstein (1956), and Goldsmith (1955). The portion after 1929 is available in the NIPA. Information on economywide labor compensation comes from Kuznets (1941) and the NIPA. Both labor share series rose sharply during the contraction from 1929 through 1933. The corporate labor share began to stabilize near postwar levels by late 1936. It spiked upward again during the recession in 1937 and again late in 1938 but then fell well below trend during the early war years, where it remained during the war. Throughout the 1930s, labor's share seemed particularly

[2] Normally the Beveridge Curve shows unemployment instead of employment. Due to the unavailability of a continuous unemployment series, Figure I.3 uses detrended employment instead, graphed from higher to lower values.

high and volatile, a fact noted by Johnson (1954) and Solow (1958) as well.[3] Looking at the long-run behavior of the corporate labor share in Figure I.5 using annual data, it shows that labor's share was indeed unusually low during the late 1920s and high during the 1930s; the late 1920s show the lowest labor share during peacetime throughout the entire series.

Figure I.6 shows the behavior of inflation rates, money growth, and interest rates. The rates of detrended money supply growth and of price inflation showed considerable volatility during the interwar period. The data on the price level and interest rates on commercial paper were taken from Balke and Gordon (1986) while the data on the money supply came from Friedman and Schwartz (1963). They tell a familiar story. From 1929 to 1933, the money supply crashed and so did prices. After 1933, the money supply grew rapidly but, after an initial burst of inflation, prices rose much less. Nominal interest rates started off at normal levels in 1929, fell during the contraction, and remained extremely low throughout the 1930s even as prices and output began to recover.

Taken together, the data suggest that labor's share of income was far from constant during the Depression era and that this high labor share accompanied unusually low rates of vacancy creation and employment, expressed as a downward shift in the Beveridge Curve. The data on the corporate labor share and on vacancies suggest that during the mid to late 1920s, labor's share of gross income was a little bit below its normal historical levels and that vacancies were if anything slightly above

[3] Boldrin and Ruiz (undated abstract) and Gomme and Rupert (2004) find that labor's share has tended to rise at the beginning of postwar recessions as well, using quarterly data.

normal. The extremely high and volatile labor share and the unusually low rates of vacancies represent two of the salient features of the labor market in the 1930s. Notably, labor's share of gross income remained high and vacancies remained low even after the recovery began in 1933. Any description of the Depression has to explain a persistently high labor share, low vacancies, and low employment. It also has to address the persistent behavior of these series in the face of volatile money growth and inflation.

I.C The model

Walsh (2002, 2005) and Cooley and Quadrini (1999) present different models of labor matching in the presence of nominal rigidities. They find that labor matching models show much more persistence and amplification of shocks than their counterparts which feature clearing labor markets. Since involuntary unemployment and labor search introduce major frictions into the economy, it makes sense to include these features of the labor market, especially when discussing episodes such as the Depression.[4] This paper adapts the model of Walsh (2002) to allow for disturbances to labor's market power, to the disutility from work, and to the demand for money. On the household side, it consists of a standard cash-in-advance model with infinitely lived consumers. Production and hiring take place in a firm-worker match, as in Mortensen and Pissarides (1994). A retail sector aggregates output from the wholesale

[4] Christiano, Eichenbaum, and Evans (2005), for example, document the intimate relationship between real and nominal rigidities in propagating nominal shocks. Walsh finds that hiring costs provide a particularly important source of persistence.

sector and resets retail prices in a staggered manner. This allows for a straightforward treatment of sticky prices. The monetary authority allows the stock of money to evolve randomly, as Friedman and Schwartz characterize the Fed's behavior in the late 1920s and early 1930s. The model contains no government or fixed capital although one might think of vacancy posting costs as proxying for a form of intangible investment.

I.C.1 The household sector

Sticking closely with Walsh's notation, individual 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

$$E_t \sum_{i=0}^{\infty} \beta^i \left[\frac{C_{t+i}^{1-\sigma}}{1-\sigma} - \chi_{t+i} A_{t+i} \bar{z}_{t+i} \right], \qquad \text{(I.1)}$$

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.

Put this way, $A_{t+i}\bar{z}_{t+i}$ is the net disutility from having to go to work instead of staying home to produce and consume a home production good. It represents the worker's one-period outside option from refusing a job offer which includes time devoted to leisure and home production in addition to unemployment benefits. The long-run productivity shifter $\bar{z}_{t+i}$ appears for balanced-growth reasons; one can think of it as applying symmetrically to market output, home production, and vacancy posting costs.[5]

Markets operate in three stages per period. In the first stage, after shocks are realized and known to those concerned, financial markets open. People trade bonds and withdraw money in order to make their consumption purchases. In the second stage, the goods market opens. Production and consumption occur. In the third stage, workers and shareholders take home their paychecks which clear by the beginning of the following period. Households cannot consume out of current income and must spend money in an exogenous proportion to their consumption purchases. Households are large and members pool their earnings and their household production in an insurance scheme.

In terms of economic activity, households face two constraints: a cash-in-advance constraint and a budget constraint. Households cannot spend their income on current consumption because they have not yet received their factor payments. The cash-in-advance constraint, modified by the inclusion of an exogenous time-varying velocity shifter, implies that intermediate cash holdings must go toward a proportion of consumption expenditures:

$$P_t C_t = V_t M_{t+1} . \qquad \text{(I.2)}$$

After consumption purchases are made, money spent on consumption flows back to the households at the end of the period in the form of factor payments, thus

[5] It appears for much the same reasons that one might place restrictions on preferences in a Hansen (1985)-Rogerson (1988) model, to keep employment rates relatively stable in response to long-run technology.

completing the circular flow. In this setup, V_t equals an exogenous money demand shifter.[6]

The household's budget constraint relates household money holdings, total income, bond purchases, money transfers, 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 cash transfers received by the household from monetary authorities.

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

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

$$\lambda_t = E_t \beta R_t \frac{P_t}{P_{t+1}} \lambda_{t+1} , \qquad \text{(I.4)}$$

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

$$C_t^{-\sigma} - \lambda_t = 0 . \qquad \text{(I.5)}$$

Because of market clearing, output equals consumption:

$$Y_t = C_t , \qquad \text{(I.6)}$$

and the quantity equation therefore holds:

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

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[6] In typical cash-in-advance models, transactions technologies do not vary and, without loss of generality, velocity is set to one. In the case of the Depression, Christiano et al. (2004) and Warburton (1945) present strong evidence that a depressed velocity of money played an important role in the Depression. Christiano et al. attribute much of the fall in velocity to the drastic substitution of currency for deposits, particularly as a result of bank runs.

Equations (I.4) through (I.7) characterize the behavior of the household sector in this fairly standard setup, apart from the money demand shifter in the cash-in-advance constraint.

I.C.2 The retail sector and sticky prices

Monopolistically competitive retailers buy output competitively from the wholesale sector and resell it to households at a markup. Households aggregate it according to a Dixit-Stiglitz aggregator. The aggregator stands in for a richer set of preferences over variety that consumers have; the product differentiation implicit in the aggregator allows for retailers to exercise some monopoly power. Retailers buy their products y_{jt} competitively from wholesale producers who produce homogeneous intermediate goods. The aggregate level of output is given by

$$Y_t = \left[\int_0^1 y_{jt}^{\frac{\theta-1}{\theta}} dj \right]^{\frac{\theta}{\theta-1}}, \tag{I.8}$$

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

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

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

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

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-ω*. Based on these random intervals between price changes, prices will show a considerable degree of persistence. This will allow nominal shocks to have substantial real effects—since prices cannot adjust instantaneously, the quantity of output must rise in response to an increase in the money supply or in the velocity of money.

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 $D_{i,t+1}$ equal the discount factor $\beta^i(\lambda_{t+i}/\lambda_{t+1})$, the objective function for the price-changers equals

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

Long-run profit maximization results in the first order condition

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

with the aggregate retail price index given by

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

Current prices are a weighted function of lagged prices and the prices set by those firms that could adjust. Conditions (I.12) and (I.13) describe a New Keynesian

Phillips Curve relationship which relates current retail markups to current and expected future inflation.

I.C.3 The wholesale sector and labor matching

The wholesale sector distinguishes this model from typical sticky-price models. This model follows the lead of Mortensen and Pissarides (1994) and the modern literature on labor matching in treating employment as a long-term relationship. The labor market in this model is a special case of that of den Haan, Ramey, and Watson (2000), without fixed capital. In order for workers and firms to produce, they must do so in a matched relationship. Workers and firms separate for both exogenous and endogenous reasons, and firms search for workers based on expectations of future profitability. Such a framework allows for a better treatment of unemployment than the typical RBC-style approach. Walsh goes through the basic model in much more detail.

Using standard notation, $U_t = 1 - N_t$ 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), a systematic temporary productivity shock z_t, 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 $y_{it} = a_{it}\bar{z}_t z_t$ 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 three shock processes have an unconditional mean of one and are independent from each other. The idiosyncratic shocks are also independent and identically distributed over time and across agents, while the other productivity shocks are common to every agent.

Firms seeking workers post vacancies at a fixed cost. Workers without jobs who would rather work must first find a job and therefore cannot freely supply labor on the spot. As a result of matching frictions, matches earn an economic surplus, and in a well-functioning bargaining environment, workers and firms will want to remain matched so long as that surplus exceeds zero. Because of the cash-in-advance constraint and the slight delay in making factor payments, this period's money income only becomes available the following period to consume. As a result, sales (and factor payments) are discounted at the rate R_t. This serves to introduce a simple cost channel into the model.

Noting that the retailer's gross markup μ_t equals 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, less the instantaneous disutility of work, plus the expected discounted continuation value of the match (denoted by q_{it}), all in product terms:

$$s_{it} = \frac{a_{it} z_t \bar{z}_t}{\mu_t R_t} - A_t \bar{z}_t + q_{it} . \tag{I.14}$$

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 (II.14) to zero gives the value of this cutoff:

$$\tilde{a}_t = \frac{\mu_t R_t (A_t \bar{z}_t - q_t)}{z_t \bar{z}_t} . \tag{I.15}$$

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:

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

and

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

In a match, workers and firms engage in Nash bargaining. The worker receives a time-varying exogenous share of the surplus η_t; the firm receives the share $(1 - \eta_t)$. The worker's share of the surplus summarizes the state of the bargaining environment; a higher share means that the bargaining environment is more explicitly favorable to workers. 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:

$$q_t = (1-\rho^x)\beta E_t \frac{\lambda_{t+1}}{\lambda_t}(1-\eta_{t+1}k_t^w)\int_{\tilde{a}_{t+1}}^{\infty} s_{it+1} dF(a_{it+1}) . \tag{I.18}$$

Firms can post vacancies at a fixed cost $\gamma\bar{z}_t$ but face no other barriers to entry.[7] Vacancies get filled at a gross rate k_t^f. This results in a free-entry condition equating the present value of a firm's vacancy posting with the cost of posting that vacancy:

$$\gamma\bar{z}_t = (1-\rho^x)k_t^f \beta E_t \frac{\lambda_{t+1}}{\lambda_t}(1-\eta_{t+1})\int_{\tilde{a}_{t+1}}^{\infty} s_{it+1} dF(a_{it+1}) . \tag{I.19}$$

To a first-order approximation, (I.18) and (I.19) yield the continuation value:

$$q_t \approx E_t \frac{\gamma\bar{z}_t(1-\eta_{t+1}k_t^w)}{(1-\eta_{t+1})k_t^f} . \tag{I.20}$$

Increasing either the job finding rate or the vacancy filling rate will tend to reduce the value of an existing match by making it easier for firms and workers to go elsewhere. Similarly, decreasing γ will reduce the value of the existing match; as γ goes to zero, firms can search costlessly and will post an infinite number of vacancies. An increase in labor's bargaining power will actually increase the continuation value of the surplus. This happens because workers lose out on a greater share of output when unemployed, so the gain from remaining employed is higher. It unambiguously reduces the firm's share of that surplus, and at least in the parameterization used in this paper, a rise in labor's bargaining power results in a dramatic and persistent fall in vacancy creation.

Aggregating these things is rather simple. The total number of job searchers 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

[7] The term $\bar{z}_t$ appears here to keep vacancy posting costs from vanishing in a growing economy in the same way that it appears in the utility function.

$$u_t \equiv U_t + \rho_t N_t = 1 - (1-\rho_t) N_t . \tag{I.21}$$

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

$$k_t^f = \frac{m(u_t, v_t)}{v_t}, \tag{I.22}$$

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

$$k_t^w = \frac{m(u_t, v_t)}{u_t}. \tag{I.23}$$

Abstracting from exit and entry into the labor force, the number of matches evolves according to the accounting identity

$$N_{t+1} = (1-\rho_t) N_t + m(u_t, v_t), \tag{I.24}$$

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

$$Q_t = \frac{(1-\rho_t) N_t z_t \bar{z}_t \left[\int_{\tilde{a}_t}^{\infty} a_{it} \, dF(a_{it}) \right]}{1 - F(\tilde{a}_t)}. \tag{I.25}$$

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

$$Y_t = Q_t - \gamma \bar{z}_t v_t . \tag{I.26}$$

Taken together, these conditions describe an equilibrium in the labor market. The inability of workers to instantaneously find jobs and of firms to instantaneously find workers result in quasi-rents that both sides must split through a bargaining mechanism. The bargaining environment expected to prevail in the future feeds back into firms' decisions to post vacancies today and into workers' decisions as to whether or not to separate. In particular, one might expect increases in labor's bargaining power to increase the total surplus and decrease firms' portion of the surplus, driving down the rates of job creation and destruction and resulting in lower levels of employment.

I.C.4 The monetary authority

During the interwar period, the Fed wished to stabilize nominal exchange rates, targeting either the nominal price of gold or the sterling exchange rate. Other branches of government such as the Treasury directed a large portion of monetary policy as well. As a result, the Fed had little discretion in choosing an operating target—it could not target nominal interest rates or money supply growth directly but had to let them evolve more or less in response to other developments. Furthermore, an unstable banking sector may have caused the ratio of inside money to outside money to fluctuate wildly, especially before the introduction of deposit insurance. With interest rates throughout the 1930s remaining extremely low and with the dollar fixed against the sterling, it seems accurate to treat the Fed as letting M1 evolve exogenously rather than the to treat it as following an interest rate rule.

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

$$\ln(\Theta_t) = (1-\rho_m)\ln(\overline{\Theta}) + \rho_m \ln(\Theta_{t-1}) + \varepsilon_t^{\Theta}. \qquad (I.27)$$

This follows Walsh (2002), Cooley and Quadrini (1999), and Christiano, Eichenbaum, and Evans (2005). The money demand shifter V_t is assumed to be exogenous to the decisions of households. Christiano et al. (2004) find a role for the currency-deposit ratio in determining the velocity of M1, and it seems reasonable to conjecture that a more vigorous effort to establish deposit insurance or otherwise maintain the integrity of the banking system would have had a stabilizing effect on velocity. One might appropriately think of V_t as a composite residual reflecting any factor that caused nominal output to fall by more than the change in the money supply. It seems reasonable to treat it as a highly persistent AR(1) process:

$$\ln(V_t) = (1-\rho_V)\ln(V) + \rho_V \ln(V_{t-1}) + \varepsilon_t^V . \qquad \text{(I.28)}$$

I.C.5 Productivity and real factors

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

$$\ln(\bar{z}_t) - \overline{\Gamma}t = \rho_{\bar{z}}\left[\ln(\bar{z}_{t-1}) - \overline{\Gamma}(t-1)\right] + \varepsilon_t^{\bar{z}} . \qquad \text{(I.29)}$$

The temporary productivity shifter z_t follows an exogenous stationary AR(1):

$$\ln(z_t) = \rho_z \ln(z_{t-1}) + \varepsilon_t^z . \qquad \text{(I.30)}$$

This way, it is possible to model the effects of both temporary and permanent productivity shocks assuming that unemployment acts in a well-behaved manner in the long run. The shocks will exhibit very different impulse responses from each other; a positive permanent productivity shock results in a proportionate increase in each of the terms in the surplus equation. It will therefore have no direct effect on separations or vacancy creations; it may have indirect effects as prices take time to adjust. By contrast, a positive temporary productivity shock boosts labor demand and has its usual effects.

The labor bargaining parameter η_t also follows an AR(1) as does the labor supply parameter A_t:

$$\ln(\eta_t) = (1-\rho_\eta)\ln(\eta) + \rho_\eta \ln(\eta_{t-1}) + \varepsilon_t^\eta , \tag{I.31}$$

and

$$\ln(A_t) = (1-\rho_A)\ln(A) + \rho_A \ln(A_{t-1}) + \varepsilon_t^A . \tag{I.32}$$

Positive shocks to either process would increase labor's share of total income, but they would have different effects on job turnover and vacancies. Shocks to bargaining power result in dramatic falls in both vacancy creation and turnover as surpluses rise but it becomes unprofitable to post vacancies. Shocks to labor supply result in negligible changes in vacancies, but turnover rates rise as surpluses shrink.

I.C.6 Equilibrium and solution method

The aggregate household conditions (I.4) through (I.7), the New Keynesian retail conditions (I.12) and (I.13), the aggregated versions of (I.14) through (I.26) from the wholesale sector, and the shock processes (I.27) through (I.32) constitute a rational expectations equilibrium for this economy, should one exist. The method used to estimate the shocks hitting this economy 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). An appendix derives the system of equations describing the steady state and the linearization of the model around that steady state. In this particular situation, the equilibrium exists and is unique in the neighborhood around the steady state.

I.D Estimation strategy

I.D.1 State space approach

The linearized model conveniently lends itself to a state space representation. Given a set of feedback rules and quarterly data on nine variables, it is fairly simple to use the Kalman Filter to estimate the underlying unobservable states.[8] Based on observable data (e.g. output or employment) and a set of unobservable states (e.g. bargaining power or labor supply) governing the evolution of the data, the filter estimates the most likely state of the economy at each date in the sample. Based on these estimates and the laws of motion of the system, it is then possible to simulate the effects of the realized shocks. The filter also delivers the Gaussian likelihood of the model and makes it possible to compute the maximum likelihood estimates for those parameters such as the shock variances for which it is not possible to impose a sensible external calibration.

The first half of the state space approach consists of the reduced-rank VAR representation of the linearized model. The VAR representation relates the current

[8] Hamilton (1994, 2005) shows how to straightforwardly implement the Kalman Filter. Christiano et al. (2004), in another application, use the Kalman Filter to estimate the underlying shocks and responses in a rather different model of the Depression. Their model focuses on the role of various shocks to financial markets; they model the labor market as continuously clearing but with sticky wages.

values of each of the exogenous and endogenous variables to their own lags and to the contemporaneous shocks. The transition equation follows the form

$$x_t = A_1 x_{t-1} + B_1 \varepsilon_t , \tag{I.33}$$

where the values of the coefficients come directly from the solution to the linearized model. In general, x_t exhibits a fairly high dimension and reduced rank; it contains a complete characterization of the economy's underlying laws of motion as contained in the calibrated model. Since the conclusions of the model are sensitive to the variances of ε_t, and little prior information exists on most of these parameters, these variances are estimated by maximum likelihood.

The second half of the state space approach consists of the observation equation relating the variables in the model to the nine observed data series. One can label these nine observed series as x_t^*. Based on the linearized model, one can represent the data as some linear combination of the true underlying economic variables. Algebraically, this idea can be represented by the observation equation:

$$x_t^* = D_1 x_t + \varepsilon_t^* . \tag{I.34}$$

The iid (across time and variables) observation shocks ε_t^* consist of a combination of model misspecification and true observation errors, especially in the case of the vacancy and job flow data. They consist of those aspects of the data that the model has a difficult time explaining. In general, attaching a greater variance to the observation error processes will lead the model to explain less of the observed data. The variances of the observation errors are calibrated manually based on the likelihood function.

I.D.2 Calibrated parameter values

Most of the parameter values follow the calibrations used in Walsh (2002), and they are used in order to set up the transition equation (I.33) based on the linearized model. The values used for household preferences are within the range of standard values from the literature on postwar business cycles. Households have a coefficient of relative risk aversion σ of 2, implying greater risk aversion than log preferences but less risk aversion than equity prices might imply. The nominal interest rate R equals 4.5 percent per year. Output and consumption per capita grow at 1.7 percent per year. The net rate of inflation is approximately zero on average.

Also taken from Walsh's calibration, the gross retail markup μ equals 1.1, for a value of θ of 11. Retail firms change their prices on average once every nine months for a value of ω of 0.67. This remains higher than Bils and Klenow's (2004) estimates of about 0.5 but is in line with the value of 0.67 typically used in the literature. This parameter has little effect on the actual results. 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 0.9974 in order to keep the consumer's intertemporal Euler equation in balance.

Data on total job flows from the interwar period seem to indicate that the long-run behavior of hiring and firing in manufacturing have not changed much over the long run.[9] 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 a dispersion parameter σ_a of 0.13, for a central location parameter μ_a of -0.0085. This delivers a value for $\tilde{a}$ of 0.7826.

Hairault (2002) and Walsh calibrate vacancy posting costs to one percent of value added. According to Andolfatto (1996), the share of output taken by vacancy costs does not greatly affect the results of the model, and others have followed him out of custom. However, the estimated effects of shock to labor's bargaining power in the 1930s do appear sensitive to this. The likelihood of the model in the baseline setup in fact does favor a share for vacancy posting costs of about one percent of output. Not much solid evidence exists on this parameter, and in this model it also proxies for fixed investment.

The unemployment share a of the matching function, in the baseline calibration, equals 0.4. Walsh cites Blanchard and Diamond (1989, 1991) who use postwar CPS data to derive such an estimate. A sensitivity analysis reveals this parameter as unimportant in explaining the effects of fluctuations in labor's bargaining share.[10] The steady-state unemployment rate U equals 0.05, in line with the relatively

[9] The available job flow data are restricted to manufacturing, which is somewhat more volatile than the economy at large. They indicate similar behavior between the interwar period and the postwar period as far as labor turnover is concerned. For more information, see Utter (1982) and Woytinsky (1942). Woytinsky's data suggest average quarterly turnover rates in the 11-13% range for manufacturing.

[10] Based on the interwar sample, it appears that a lower matching elasticity around 0.25 and a vacancy cost share of 1.2% match the behavior of the vacancy series much better. Bleakley and Fuhrer (1997) note unusually slow matching behavior during the 1970s and early 1980s as well.

low unemployment of the late 1920s. 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 0.145 job searchers u and 0.124 vacancies v in the steady state. Based on the steady state of the bargaining model, the baseline calibration implies initial values of 0.461 for labor's bargaining power η, 0.835 for the disutility of work A, and 0.132 for the continuation value q.

To capture the persistence of the driving processes while keeping the filtering process simple, the autoregressive parameters for the shocks to money demand, long-run productivity, labor's bargaining power, and labor supply equal 0.999. The resulting endogenous variables become nearly cointegrated. To identify the different productivity sequences, the autoregressive parameter on z_t equals 0.4 based on information provided by the likelihood function. The results do not change much even with parameters in the 0.9 range. Money growth has a persistence ρ_m of 0.75, in line with the first-order autocorrelation of money growth during that period. Altogether, this calibration yields a unique rational expectations equilibrium near the steady state.

Based on the likelihood function, it is also possible to calibrate the variances of the shock processes and to obtain further insight about the other parameters (e.g. vacancy posting costs) on which there is little prior information. The standard deviations of the nine observation error processes in the baseline case are set to 1.5% for quarterly inflation, 1.5% for the level of output, 1.0% for employment, 2.5% for quarterly money growth, 0.1% for the quarterly nominal interest rate, 5.5% for labor's share, 40% for vacancies, 17% for the separation rate, and 17% for the accession rate.

They are based upon the likelihood function with some allowance for additional measurement error in nominal interest rates and in some of the real variables. The estimates presented below for the real shocks are not sensitive to these parameters, and this parameterization represents a conservative approach to fitting the model to the data. The likelihood function indicates that the model does a poor job at accounting for the joint behavior of the nominal variables, particularly in response to changes in the money supply.[11]

I.E Estimation results

I.E.1 The driving processes

The standard deviations of the six driving processes must be estimated by maximum likelihood using the linearized model and observation error processes. The estimated standard deviations equal 0.0009 for the money supply shocks, 0.0124 for the temporary productivity shocks, 0.0136 for the long-run productivity shocks, 0.0336 for the money demand shocks, 0.1365 for the labor bargaining power shocks, and 0.0063 for the labor supply shocks. The actual series on money supply growth shows much more volatility than this; most of the volatility in that series is accounted for by the measurement error process, with the actual effects of these shocks lumped in with money demand. Shocks to labor's share of bargaining surpluses also show an

[11] This is a common feature of New Keynesian models. Galí (2003) and many others note the difficulty in getting New Keynesian models such as this one to generate a liquidity effect. Serially correlated money supply shocks should beget expectations of future inflation and *higher* nominal interest rates by way of the intertemporal Euler equation. As a result, the likelihood function encourages a close match for either interest rates or money growth, but not both.

enormous degree of volatility as none of the other shock processes can account for the high and volatile labor share combined with the low level of vacancies during the 1930s.

The top two panels in Figure I.7 show the estimated bargaining power and labor supply shifters, expressed as percent deviations from steady state. The data seem to indicate that from the perspective of the labor matching model, large increases in labor's bargaining power η occurred during each of the four NBER recessions in the sample. The estimated bargaining power shifter rose particularly sharply during the Great Contraction, when Hoover intervened to keep wages above their market-clearing levels. As labor's share, employment, and vacancies showed an incomplete recovery during the mid-1930s, the estimated bargaining power shifter fell again, only to rise during the 1937-38 recession. As labor's share of income fell back below its long run level heading into the war, the bargaining power shifter returned toward more normal levels. Interestingly, the bargaining power shifter does not track annual union membership rates shown in Figure I.9; union membership rates actually fell during the early 1930s before rising substantially in the later part of that decade.

The labor supply shifter (the disutility from work A_t) shows fewer systematic cyclical movements, except for a gradual rise during the 1929-33 contraction. From the perspective of the labor matching model, workers appeared less willing to work during the Depression. Like the bargaining power shifter, the rise in the labor supply shifter increased labor's share of gross income and reduced employment. The labor supply shifter accounts for the rise in the separation rate, as a greater percentage of existing matches developed a negative surplus and found it unprofitable to continue. Both the labor supply and bargaining power shifters appear to have moved in a strongly positive direction during the early 1930s.

Figure I.7 also depicts the behavior of the short-run and long-run productivity shifters. These two productivity shifters show very different behavior from each other. The short-run productivity shifter does not fluctuate much. The long-run productivity shifter shows a large, persistent decline during the 1930s, to a large extent reflecting the fact that the model and the data do not include variable hours worked per employed worker or other variable input margins. These shifters capture the fact that output per worker declined in the mid-1930s for reasons extrinsic to the model and that they did so in a persistent way.

Figure I.8 shows the money supply and demand shifters as estimated from the Kalman filter (the blue solid lines) versus how they appear in the underlying raw data (the red 'x' lines). The filter, with its large observation error associated with money growth, indicates that the behavior of both the nominal and real sides of the economy do not match the theoretical effects money supply growth at all. The level of the money demand shifter as estimated by the Kalman filter follows the data quite a bit more. It essentially tracks the behavior of nominal output. Both series show substantial volatility in real life, but the model indicates that the economy did not behave as if it had experienced persistent money supply shocks.

I.E.2 Effects of the individual shocks

Tables I.1 and I.2 decompose the effects of each of the six estimated shocks on output and employment during the Depression. They represent the cumulative effects of the estimated residuals from 1923 onward, normalized to zero at the beginning of 1929. Between 1929 and the middle of 1933, labor bargaining shocks account for a 17% fall in output and a 22% fall in employment, and they account for much of the massive decline in vacancies that happened during that period.[12] During the same period, labor supply shocks account for an approximate 11% fall in output and an approximate 6% fall in employment, and they account for the high rate of separations. The labor supply shocks play a much bigger role in the slow recovery. They correspond conceptually with Chari, Kehoe, and McGrattan's (2007) labor wedge in their business cycle accounting framework. They find that their labor wedge explains the vast majority of the fall in employment during the Depression. It is interesting to note that labor supply shocks still account for much of the slow recovery in the labor matching framework. Together, the two sets of labor market shocks account for more than the entire slow recovery in employment and for almost all of the slow recovery in output.

Both the short-run and long-run productivity shocks account for negligible portions of the fall in employment, and only the long run productivity shock accounts for a substantial portion of low output (topping out at 14% of output in 1935). A bit of caution is in order since good data on variable hours worked and capital utilization do

[12] Bargaining shocks account for a 9% fall in output through the end of 1931. This is in line with Ohanian's figure of a 10% fall in output over the same period.

not exist for the entire period; the estimated productivity shifters therefore capture much of the fall in these inputs. Chari, Kehoe, and McGrattan find a larger role for productivity shocks since they model their productivity shocks as short-run, output-specific shocks. Based on the labor matching model with separate productivity shocks, by contrast, it appears that productivity did not affect employment all that much during the 1930s.

The estimated money supply shocks have almost no effect upon either output or employment. The filter gives up on matching the money supply shocks to the Friedman-Schwartz data, so the estimated effects of these shocks similarly disappear. Money demand shocks appear to play a substantial role in the contraction, explaining an 18% fall in output and a 12% fall in employment from 1929 through 1932. Their estimated effects disappear, however, by early to mid 1934, as money and velocity quickly recover in the data. Assigning an important role to nominal shocks does not match the slow recovery; the model simply cannot match the joint behavior of nominal and real variables during the entire Depression.[13] Bordo, Erceg, and Evans (2000) also document the failure for nominal shocks to explain the slow recovery using a standard New-Keynesian model with sticky wages. Altogether, the two sets of labor market shocks explain the vast majority of the behavior of vacancies, employment, and output throughout the 1930s.

[13]This role for nominal shocks holds even under an aggressively "Monetarist" calibration where the money supply shocks and inflation are forced to fit the data more tightly and given no persistence. Under that calibration, money supply shocks can account for an 8% drop in employment and a 12% drop in output from 1929 through 1933. Money demand shocks become less important. Cecchetti (1992), however, documents people's expectations of further declines in money and prices once the monetary contraction had begun. Based on these shocks alone, the model predicts a full recovery by mid-1934.

Tables I.3 and I.4 report the contribution of shocks to labor's bargaining power under different parameter choices. The vacancy cost parameter matters substantially. A larger vacancy posting cost of 1.5% will imply that the increase in labor's bargaining power accounts for much more of the Depression than under the baseline case. A low vacancy posting cost of 0.2% would imply that changes in labor's bargaining power can explain very little of the Depression. It appears that the matching elasticity a has relatively little effect on these results after letting the vacancy posting cost vary according to the likelihood function. A value of a of 0.25 (the most likely scenario) will result in a marginally smaller output loss attributable to changes in labor's bargaining power, while a value of a of 0.6 will result in a marginally larger output loss. Under the monetarist calibration, the conclusions regarding the bargaining power shocks also match the baseline case extremely well. Most mainstream calibrations seem to assign similar roles to changes in labor's bargaining power during the Depression.

I.F Conclusion

Given a standard labor matching model with monetary frictions and using much-overlooked data on labor markets from the 1920s and 1930s, it is possible to estimate the effects of a variety of shocks on vacancy creation, output, and employment during the Depression. For a baseline set of parameters, it appears that large increases in labor's share of bargaining surpluses caused firms to post fewer vacancies and hire fewer workers in the 1930s than they had in the 1920s. These shocks appear to have reduced employment by about 22% and output by about 17% during the contraction phase of the Depression. Shocks to labor supply play little role in the contraction, but both sets of labor market shocks more than account for the slow recovery of employment throughout the 1930s. The estimates, especially with regards to employment, are reasonably robust to a range of parameter selections, although more data on the vacancy creation and hiring processes, as well as the inclusion of other factors of production, might improve the accuracy of the estimates.

Productivity shocks do not appear to have had any serious effects on employment but account for some of the depressed output during the mid-1930s. Money supply shocks in the New Keynesian framework do a poor job at explaining the behavior of the economy during the Depression period. Evidence does exist, in line with Christiano et al. and Warburton, that unexpected changes in the velocity of money are an important feature of the contraction. But none of these classes of shocks can explain the persistence of low employment and vacancies during the Depression. It appears that disturbances which greatly increased labor's share of surpluses played an important role in lengthening and deepening the Depression, keeping economic activity depressed until the outbreak of the Second World War. The persistent downward shift in the Beveridge curve suggests that artificially high wages may have played an important role throughout the entire Depression period.

I.G Appendix: Numerical solution to the model

I.G.1 Deriving the steady state from calibrated parameters

The state-space approach requires a specification for the state equation (I.33) 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 $\overline{\Gamma}$, 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 $\overline{\Gamma}^{-\sigma}$:

$$\beta = \frac{\overline{\Gamma}^{\sigma}\Pi}{R}. \tag{I.A1}$$

In a zero-inflation steady state with a driftless velocity, the money growth rate $\overline{\Theta}$ simply equals the economic growth rate $\overline{\Gamma}$. 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:

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

Given an unemployment rate U and an employment rate $N = 1 - U$ 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 job searchers, the sum of beginning-of-period unemployed plus separations:

$$u = U + \rho N, \qquad \text{(I.A3)}$$

the number of vacancies from the homogeneous matching function,

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

and the retention rate:

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

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

$$Q = \frac{(1-\rho)N\left[\int_{\tilde{a}_t}^{\infty} a_i dF(a_i)\right]}{1 - F(\tilde{a})}. \qquad \text{(I.A6)}$$

If vacancy posting costs as a share of output are given as s_v, this gives values for Y and γ based on the equation for value added:

$$Y = \frac{Q}{1 + s_v}, \qquad \text{(I.A7)}$$

and

$$\gamma = \frac{Q - Y}{v}. \qquad \text{(I.A8)}$$

The vacancy posting and continuation value expressions pin down labor's bargaining power at its initial state, solved from the expression:

$$\gamma = \frac{\Theta(1-\rho^x)k^f(1-\eta)}{\mu R^2}\int_{\tilde{a}_i}^{\infty}(a_i - \tilde{a})dF(a_i)\,. \tag{I.A9}$$

This all yields a closed-form expression for q:

$$q = \frac{\gamma(1-\eta k^w)}{(1-\eta)k^f}\,, \tag{I.A10}$$

and for A:

$$A = q + \frac{\tilde{a}}{\mu R}\,. \tag{I.A11}$$

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

$$Y^{-\sigma} - \lambda = 0\,. \tag{I.A12}$$

The initial value of the velocity does not matter for the calibration of this model.

It is also helpful to have expressions for labor's portion of income W. It equals wholesale production marked down, minus the wholesale firms' accounting profits. Those profits in turn equal the firm's share of the surplus minus the discounted value of a filled vacancy, since the value of the firm merely equals the present discounted value of profits. To a first order approximation this gives the level of real labor compensation:

$$W_t \approx \frac{Q_t}{\mu_t} - R_t\varphi_t N_t\left((1-\eta_t)s_t - \frac{\gamma\bar{z}_t}{k_t^f}\right), \tag{I.A13}$$

which in steady state yields

$$W = \frac{Q}{\mu} - \varphi NR\left((1-\eta)s - \frac{\gamma}{k^f}\right). \tag{I.A14}$$

Equations (I.A1) through (I.A14) describe the relationships among the different parameters and steady state ratios in this model. The model is then linearized around this steady state using the numerical values obtained from the calibration.

I.G.2 Linearization around the steady state

Given a calibration and its implied steady state, it is possible to linearize the system around that steady state. This approximates the laws of motion of the system in the region of the initial conditions. In general, because of the driving processes, the system will exhibit a considerable degree of persistence and volatility. The particular model, calibration, and linearization used here rule out transitions between steady states, sunspots, or other forms of indeterminacy. These individual equations are assembled into a matrix of difference equations which yield a reduced-rank stable VAR.

Linearizing the cash-in-advance constraint in first differences obtains the stochastic money demand relation:

$$\hat{\pi}_t + \hat{y}_t - \hat{\Theta}_t - \hat{V}_t = \hat{y}_{t-1} - \hat{V}_{t-1} \ . \qquad \text{(I.A15)}$$

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

$$\hat{n}_{t+1} = \varphi \hat{n}_t + \varphi \hat{\varphi}_t + \left(\frac{vk^f}{N} \right) \hat{v}_t + \left(\frac{vk^f}{N} \right) \hat{k}_t^f \ . \qquad \text{(I.A16)}$$

The endogenous job destruction margin comes next:

$$\hat{a}_t = \hat{r}_t + \hat{\mu}_t - \hat{z}_t - \left(1 - \frac{A\mu R}{\tilde{a}}\right)\hat{\hat{z}}_t - \left(\frac{\mu R q}{\tilde{a}}\right)\hat{q}_t + \left(\frac{A\mu R}{\tilde{a}}\right)\hat{A}_t, \qquad \text{(I.A17)}$$

followed by an expression for the job retention rate:

$$\hat{\varphi}_t = -\left(\frac{\rho^n}{1-\rho^n}\right)e_{Fa}\hat{a}_t, \qquad \text{(I.A18)}$$

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

$$\hat{u}_t = -\left(\frac{\varphi N}{u}\right)\hat{\varphi}_t - \left(\frac{\varphi N}{u}\right)\hat{n}_t. \qquad \text{(I.A19)}$$

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

$$\hat{k}_t^f = a\hat{u}_t - a\hat{v}_t, \qquad \text{(I.A20)}$$

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

$$\hat{k}_t^f + \hat{v}_t = \hat{k}_t^w + \hat{u}_t. \qquad \text{(I.A21)}$$

Linearizing the job posting condition yields:

$$\hat{k}_t^f + \hat{q}_t = \hat{\hat{z}}_t - \frac{\eta k^w}{1-\eta k^w}\hat{k}_t^w + \left(\frac{\eta}{1-\eta} - \frac{\eta k^w}{1-\eta k^w}\right)E_t\hat{\eta}_{t+1}. \qquad \text{(I.A22)}$$

Linearizing the output equation yields:

$$\hat{y}_t = \left(\frac{Q}{Y}\right)(e_{Ha}\hat{a}_t + \hat{\varphi}_t + \hat{n}_t + \hat{z}_t + \hat{\hat{z}}_t) - \left(\frac{\gamma v}{Y}\right)(\hat{v}_t + \hat{\hat{z}}_t), \qquad \text{(I.A23)}$$

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:

$$\hat{\lambda}_t = \hat{r}_t + E_t\hat{\lambda}_{t+1} - E_t\hat{\pi}_{t+1}, \tag{I.A24}$$

and the first-order condition for consumption yields the usual marginal utility expression:

$$-\sigma Y^{-\sigma}\hat{y}_t - \lambda\hat{\lambda}_t = 0. \tag{I.A25}$$

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

$$\frac{\omega}{R}E_t\hat{\pi}_{t+1} = \omega\hat{\pi}_t + (1-\omega)\left(1-\frac{\omega}{R}\right)\hat{\mu}_t. \tag{I.A26}$$

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

$$\hat{q}_t = E_t\hat{\varphi}_{t+1} - \hat{r}_t + E_t\hat{\pi}_{t+1} - \frac{\eta k^w}{1-\eta k^w}\left(\hat{k}_t^w + E_t\hat{\eta}_{t+1}\right) + E_t\hat{s}_{t+1}. \tag{I.A27}$$

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

$$s\hat{s}_t = \frac{Q}{\varphi N\mu R}\left(\frac{Y}{Q}\hat{y}_t + \frac{\gamma v}{Q}\left(\hat{v}_t + \hat{\bar{z}}_t\right) - \hat{\varphi}_t - \hat{n}_t - \hat{\mu}_t - \hat{r}_t\right) - A(\hat{A}_t + \hat{\bar{z}}_t) + q\hat{q}_t,$$

or

$$\begin{aligned} s\hat{s}_t &= -\frac{Q}{\varphi N\mu R}(\hat{\varphi}_t + \hat{n}_t + \hat{\mu}_t + \hat{r}_t) + \frac{Y}{\varphi N\mu R}\hat{y}_t \\ &+ \frac{\gamma v}{\varphi N\mu R}\hat{v}_t + \left(\frac{\gamma v}{\varphi N\mu R} - A\right)\hat{\bar{z}}_t - A\hat{A}_t + q\hat{q}_t \quad , \end{aligned} \tag{I.A28}$$

and of labor's earnings:

$$W\hat{w}_t = \frac{Y}{\mu}\hat{y}_t + \frac{\gamma v}{\mu}\hat{v}_t - \frac{Q}{\mu}\hat{\mu}_t - \varphi NR(1-\eta)s\hat{s}_t$$
$$-\varphi NR\left((1-\eta)s - \frac{\gamma}{k^f}\right)(\hat{\varphi}_t + \hat{n}_t + \hat{r}_t) + \varphi NRs\eta\hat{\eta}_t$$
$$+\left(\frac{\varphi NR\gamma}{k^f} + \frac{\gamma v}{\mu}\right)\hat{\bar{z}}_t - \frac{\varphi NR\gamma}{k^f}\hat{k}_t^f \,. \qquad \text{(I.A29)}$$

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

$$\hat{\Theta}_t = \rho_m\hat{\Theta}_{t-1} + \varepsilon_t^{\Theta}, \qquad \text{(I.A30)}$$

$$\hat{z}_t = \rho_z\hat{z}_{t-1} + \varepsilon_t^{z}, \qquad \text{(I.A31)}$$

$$\hat{\bar{z}}_t = \rho_{\bar{z}}\hat{\bar{z}}_{t-1} + \varepsilon_t^{\bar{z}}, \qquad \text{(I.A32)}$$

$$\hat{V}_t = \rho_V\hat{V}_{t-1} + \varepsilon_t^{V}, \qquad \text{(I.A33)}$$

$$\hat{\eta}_t = \rho_\eta\hat{\eta}_{t-1} + \varepsilon_t^{V}, \qquad \text{(I.A34)}$$

and

$$\hat{A}_t = \rho_A\hat{A}_{t-1} + \varepsilon_t^{A}. \qquad \text{(I.A35)}$$

These twenty-one linearized equations in twenty-one unknowns uniquely determine the dynamics of the system in the vicinity of the steady state for the calibrated parameter values chosen. It is possible to solve for the rational expectations equilibrium of this system using the methodology and code provided by Sims (2002), who implements a robust version of the Blanchard-Kahn (1980) solution method. The end result is a reduced-rank VAR representation that provides the laws of motion for the underlying system in the form of equation (I.33) in the state-observer setup.

I.H Appendix: 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, taken directly from the appendix of Balke and Gordon (1986). They base their deflator on wholesale prices and interpolate from annual GNP deflators using the Chow-Lin method.

2. The level of real output, taken from the quarterly nominal GNP series of Balke and Gordon (1986). To avoid spurious movements in labor's share of output based on different data sources, the quarterly nominal GNP observations were adjusted to match the annual NIPA from 1929 onward and the data of Kendrick (1961) for the 1923-28 period, as explained in the following appendix. Output was assumed to be approximately at trend in the first quarter of 1923, the fourth quarter of 1929, and the first quarter of 1942. Piecewise loglinear trends were interpolated using those quarters as anchors. Romer (1989) suggests that these particular income and product estimates become less reliable before 1923, so the analysis begins in that year. One effect of this decision is to exclude the depression of 1920-21 and the builddown from the First World War from the analysis. Good higher-frequency data from those periods might shed some light on this extremely interesting and often-neglected period of macroeconomic history.

3. A measure of employment. At a monthly frequency, a BLS nonfarm establishment employment series is available from 1929 onward from the NBER

Macrohistory Database, Series m08268a and m08268b, ratio-spliced at 1939. For the pre-1929 period, an index of manufacturing production worker employment is contained in NBER Series m08010b. These two series were independently seasonally adjusted, made quarterly, and used to interpolate the annual nonfarm employment data from Kendrick (1961, Table A-VI), with one minor exception in late 1941. The large discrepancy which appears in 1942 is not allocated across the years 1941 and 1942. Given the large shocks to government employment during the fourth quarter of 1941 and thereafter, total employment rose at the beginning of 1942 but production worker employment fell as workers shifted from manufacturing into the military. The data for 1942 were extrapolated using the comprehensive BLS establishment series, ratio-spliced onto the interpolated series. This only affects the calculation of the trend since the time-series analysis ends in 1941, and it matches Balke and Gordon's (1986) estimates of potential employment fairly well.

The more comprehensive post-1929 BLS establishment data provide an independent check of the quality of the manufacturing data as an interpolator for the period after 1929. The series share a common stochastic trend, by construction, and the standard deviation of the quarterly discrepancy is less than 0.8 percent. Based on impressions from the studies of unemployment in that period, employment appeared to be approximately at trend in the first quarter of 1923, the fourth quarter of 1929, and the second quarter of 1942, and a piecewise linear employment trend was drawn based on those periods. No higher-frequency agricultural employment series exists, but it does show considerably less cyclical variation than the manufacturing employment series. The lack of good high-frequency agricultural employment data represents a serious limitation of the data currently available. The extremely good quality of the interpolations encourages the use of the series based on manufacturing workers throughout the entire sample.

4. The growth rate in M1. The end-of-month data come from the appendices of Friedman and Schwartz (1963), with the money supply defined as currency plus demand deposits held by the public. Approximate quarterly data on transaction services come from taking an average of transaction services in each month in 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. This sidesteps some of the time-aggregation biases inherent in the analysis of models where stocks and flows interact instantaneously but the data come as aggregates over discrete chunks of time. The measure of money here, therefore, is meant to capture money's role as a provider of transaction services throughout a period rather than as a major component of wealth at the end of a period.

5. A nominal interest rate. This is simply the three-month commercial paper rate taken from Balke and Gordon (1986). This is an approximate yield for short-term, high-quality debt on the open market. The commercial paper rate tracks the three-month treasury rate fairly well and it does not appear to contain much in the way of default risk.

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. Post-1929 monthly data on total nonfarm labor compensation are available from NBER Series m08273a and m08274a, which originate in the *Survey of Current Business*. These are independently seasonally adjusted, made quarterly, and summed. Pre-1929 monthly data on composite wages come from the FRB index of composite wages (NBER Series m08061c), seasonally adjusted and made quarterly. The composite wage data are multiplied by the employment series (3) above to obtain an approximate index of labor compensation, abstracting from variable effort and hours worked per employee and the important difference between actual and paid hours worked. Sporadic monthly data do exist on hours worked per worker throughout the period, but the existing series on manufacturing hours shows a strong secular downward trend and does not distinguish between paid and actual hours worked. No satisfactory economywide measure of labor input exists for the entire period at anything but an annual frequency. Both quarterly compensation series are adjusted to add up to the annual NIPA data (post-1929) and the Kuznets (1941) data (pre-1929, NBER Series a08181a, ratio-spliced to the NIPA data). In the post-1929 period, the two series behave in a similar manner with the NIPA treating supplements to wages and salaries somewhat differently, especially beginning in the mid-1930s. The data, so treated, yield a fairly reliable quarterly estimate of labor's share of economywide gross value added.

To bring this series in line with the concept of labor income relevant to private sector hiring, 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 2007 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 2007-vintage series was used, ratio-spliced to the 1958-vintage series at 1929 where the 2007-vintage series begins. This composite series shows no clear trend in labor's share from 1922 through 2006. 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.

The quarterly economywide labor share is then used to interpolate the corporate labor share to a quarterly frequency. The long-run corporate labor share in the annual version of this series equals 0.6874, so trend labor compensation equals that ratio times trend output.

7. A measure of vacancies. The NBER Macrohistory Database contains a help wanted index constructed by the Metropolitan Life Insurance Company (Series m08082a) from 1919 onward. It is seasonally adjusted and made quarterly. Vacancies and employment over the long run appear to share the same trend, and that is true of this series. The trend level of the vacancy index is taken to be a constant times the trend level of employment. Based on particular series at hand, spanning four decades, that constant appears to approximately equal 1.615. 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.

8. A measure of the separation rate of workers. NBER Series m08254a and m08254b contain information on the monthly separation rate of manufacturing workers gathered by the BLS and Met Life, as does the appendix to Woytinsky (1942) augmented by the December 1942 *Monthly Labor Review*. The version used in Woytinsky is used here since later versions of the BLS data appear to have undergone substantial conceptual and compositional revisions and do not match the data from before 1929. 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 composite series is seasonally adjusted, made quarterly, and de-meaned. 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 data are particularly unreliable before 1923, further encouraging the use of that date as a cut-off. 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.

9. A measure of the rate of new hiring. NBER Series m08256a and m08256b contain measures of the gross accession rate in manufacturing, from the same sources as the job destruction data. As with the destruction data, however, the data from Woytinsky (1942) and the December 1942 *Monthly Labor Review* are used instead. Calculations proceed in much the same way, and the same caveats apply. New hiring in manufacturing shows its usual cyclical behavior as well, and a glance at Figures I.1 and I.2 shows a much stronger relationship between output growth and job creation.

10. The annual union membership data from 1914 through 1941 are not part of the state-space model because no suitable monthly or quarterly interpolator exists. They still provide a useful reality check, and they indicate a substantial divergence between the estimated shocks to labor's bargaining power and union membership rates. Union membership is given as a percentage of the labor force and of workers engaged. The numerator, union membership, is reported in the *Historical Statistics of the United States* (2006) series Ba4783 (Union Members) from the BLS. The labor force equals the civilian labor force, series Ba470, which comes from Weir (1992). The number of civilian workers engaged equals the value given by Kendrick (1961, Table A-VI). Both series show gradual declines from the early 1920s through the trough of the Depression and then a permanent surge from 1936-37 onward. They

continue rising and remain higher for some time after the war. The particular BLS series reported in the *Historical Statistics* ends in the 1970s so it is not possible to track union membership rates to the present day using that particular series.

I.I Appendix: Interpolation of quarterly data

The interpolation of quarterly interwar series from annual ones requires the usage of conceptually related series that, for whatever reason, cannot completely proxy for the annual series. For instance, industrial production and manufacturing employment tend to track the behavior of the broader economy rather well. Unfortunately, they show much larger cyclical fluctuations than broader measures of income such as GNP and nonfarm employment, and they also seem to have different trends. Nonetheless, if industrial production falls, then GNP most likely falls as well. Balke and Gordon (1986), for instance, interpolate their GNP figures using the Chow-Lin (1971) method using industrial production. Fernández (1981) and Litterman (1983) extend the Chow-Lin procedure to deal with the relationships between nonstationary time series under different time-series assumptions. The method used here approximates Fernandez and Chow-Lin in a simple manner, and as discussed above, it does an excellent job at interpolating the employment series for which there exist good high-frequency data after 1929.

To interpolate the series x^* from the nonstationary but related series z^*, one must specify a statistical relationship for the two. A simple relationship might be the linear regression relationship

$$x^* = b_0 + b_1 t + b_2 z^* + u_t^*,$$

where the behavior of the residual determines how to proceed. In the event that the residual follows a random walk, one can estimate the coefficients b_1 and b_2 optimally using OLS on annualized first-differences of the relevant data. By restricting the intercept b_0 such that the average residual in a base year such as 1922 equals zero, one can estimate the projected value of the variable x^* and the associated residuals.

In this particular implementation, the annual residuals get distributed in a smooth manner over the quarterly observations based on the very persistent nature of these residuals. This prevents sharp discontinuities between years where the residuals change dramatically. In this procedure, each quarter's residual is a weighted average of the two annual residuals surrounding it, under the assumption that the annual residuals equal the approximate value of the residual in the middle of that year. The third quarter of 1923, for instance, gets a residual equal to 7/8 of the residual for 1923 plus 1/8 of the residual for 1924 since it lies, on average, that much closer to the middle of 1922. The fourth quarter of 1923 gets a residual equal to 5/8 of the residual for 1923 and 3/8 of the residual for 1924, and so on. In essence, this results from drawing a straight line between annual midpoints and taking the integral of the implied residual throughout each quarter. Finally, the endpoints have their first two (or last two) quarterly residuals set in a straight line such that the average residual for the period equals the average interpolated residual and that both quarters show equal changes in that residual.

This procedure, in the context of this paper, generates a series that respects the movements of the annual series while generally matching the patterns of the higher-frequency series and avoiding arbitrary discontinuities. It also avoids a problem that using the raw interpolated series might cause. Since manufacturing employment is about twice as volatile as total employment, a naive interpolation would create spurious movements in employment within years, an example being the short but sharp drop during the 1924 recession. There is no foolproof way to interpolate time series using other series, but this method appears to give good results in this particular context. In particular, the employment and output series respect the NBER's chronology of business cycle turning points and match the behavior of other series where these series are available. They also reflect contemporary accounts of business conditions quite well.

I.J Tables and figures

The following pages contain the tables and figures, respectively, from this chapter.

Table I.1: Percent response of output by shock – Baseline (1929.I = 0).

Quarter	Money Supply	Money Demand	Short-Run Prod.	Long-Run Prod.	Labor Barg.	Labor Supply	Data
1929.I	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
1929.II	0.0	0.3	0.3	0.3	0.2	0.4	**3.2**
1929.III	0.0	-1.1	0.3	0.4	0.3	0.8	**3.1**
1929.IV	0.0	-3.8	-0.2	0.1	0.1	1.1	**-2.4**
1930.I	0.0	-6.7	-0.3	-0.3	-0.3	1.1	**-6.8**
1930.II	0.0	-8.3	-0.4	-0.6	-1.0	0.9	**-8.0**
1930.III	0.0	-10.8	-0.7	-1.1	-2.0	0.6	**-13.8**
1930.IV	0.0	-12.3	-1.0	-1.7	-3.2	0.2	**-19.3**
1931.I	0.0	-11.4	-1.0	-2.1	-4.5	-0.3	**-19.9**
1931.II	-0.1	-10.8	-1.0	-2.3	-5.9	-0.7	**-18.9**
1931.III	-0.1	-12.3	-1.1	-2.6	-7.3	-1.4	**-23.6**
1931.IV	-0.1	-14.9	-1.3	-3.1	-8.9	-2.1	**-29.6**
1932.I	-0.1	-16.7	-1.6	-3.6	-10.4	-2.9	**-34.0**
1932.II	-0.1	-18.2	-1.8	-4.3	-11.9	-4.0	**-39.7**
1932.III	-0.1	-17.4	-1.9	-5.4	-13.5	-5.3	**-44.0**
1932.IV	-0.1	-16.2	-1.9	-6.5	-14.9	-6.7	**-45.3**
1933.I	-0.2	-15.4	-2.0	-7.8	-15.9	-8.2	**-52.0**
1933.II	-0.2	-8.5	-1.5	-8.9	-16.6	-9.6	**-45.8**
1933.III	-0.2	-3.9	-1.1	-9.8	-16.4	-10.8	**-38.9**
1933.IV	-0.1	-3.8	-1.6	-11.0	-16.0	-11.9	**-46.9**
1934.I	-0.1	-0.3	-1.5	-11.8	-15.6	-12.7	**-42.3**
1934.II	-0.1	1.7	-1.3	-12.2	-15.1	-13.2	**-37.4**
1934.III	-0.1	1.1	-1.5	-13.0	-14.9	-13.7	**-42.5**
1934.IV	-0.1	2.1	-1.2	-13.7	-14.7	-14.0	**-43.2**
1935.I	-0.1	4.6	-0.9	-14.0	-14.5	-14.1	**-37.8**
1935.II	-0.1	5.4	-0.8	-14.2	-14.2	-14.1	**-38.3**
1935.III	-0.1	7.2	-0.5	-14.4	-14.0	-14.0	**-36.3**
1935.IV	-0.1	9.1	-0.1	-14.3	-13.7	-13.8	**-31.7**
1936.I	-0.1	9.9	0.0	-14.2	-13.4	-13.5	**-31.9**
1936.II	-0.1	12.0	0.4	-13.8	-12.9	-13.1	**-26.6**
1936.III	-0.1	12.4	0.8	-13.4	-12.3	-12.7	**-24.6**
1936.IV	-0.1	12.7	1.0	-13.0	-11.7	-12.3	**-22.1**
1937.I	-0.1	11.8	1.0	-12.7	-11.2	-11.9	**-23.1**
1937.II	-0.1	10.9	0.8	-12.3	-10.7	-11.4	**-21.4**
1937.III	-0.1	8.2	0.4	-12.0	-10.4	-11.0	**-22.5**
1937.IV	-0.1	2.8	-0.2	-12.0	-10.4	-10.8	**-30.6**
1938.I	-0.1	0.4	-0.5	-12.1	-10.9	-10.9	**-35.6**
1938.II	-0.1	1.3	-0.4	-12.1	-11.3	-11.0	**-34.7**
1938.III	-0.1	4.1	0.0	-11.9	-11.7	-11.1	**-29.8**
1938.IV	-0.1	5.7	0.4	-11.6	-11.9	-11.0	**-26.6**
1939.I	-0.1	5.4	0.4	-11.6	-12.0	-11.0	**-28.3**
1939.II	-0.1	5.2	0.2	-11.6	-12.0	-11.0	**-30.6**
1939.III	-0.1	7.0	0.3	-11.4	-11.9	-10.9	**-27.6**
1939.IV	-0.1	8.5	0.5	-11.0	-11.7	-10.9	**-22.1**

Table I.2: Percent response of employment by shock - Baseline (1929.I = 0).

Quarter	Money Supply	Money Demand	Short-Run Prod.	Long-Run Prod.	Labor Barg.	Labor Supply	Data
1929.I	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
1929.II	0.0	0.2	0.1	-0.4	0.3	0.2	**0.5**
1929.III	0.0	0.4	0.2	-0.9	0.2	0.4	**0.8**
1929.IV	0.0	-0.6	0.4	-0.9	-0.4	0.7	**-1.0**
1930.I	0.0	-2.3	0.6	-0.3	-1.5	0.9	**-3.5**
1930.II	0.0	-4.3	0.3	0.1	-2.9	0.8	**-5.4**
1930.III	0.0	-5.2	0.2	0.3	-4.8	0.7	**-9.4**
1930.IV	0.0	-6.9	0.3	0.7	-6.9	0.5	**-12.4**
1931.I	0.0	-7.8	0.2	1.0	-8.8	0.1	**-15.1**
1931.II	0.0	-7.2	-0.1	0.9	-10.2	-0.2	**-16.6**
1931.III	0.0	-6.8	-0.2	0.4	-12.3	-0.5	**-19.7**
1931.IV	0.0	-7.9	-0.1	0.4	-14.4	-1.0	**-23.7**
1932.I	-0.1	-9.5	-0.1	0.6	-15.8	-1.5	**-26.0**
1932.II	-0.1	-10.7	-0.1	0.8	-18.0	-2.1	**-31.4**
1932.III	-0.1	-11.7	-0.3	1.3	-20.1	-2.9	**-35.3**
1932.IV	-0.1	-11.1	-0.5	2.1	-21.0	-3.8	**-34.1**
1933.I	-0.1	-10.3	-0.5	2.4	-21.8	-4.8	**-36.6**
1933.II	-0.1	-9.8	-0.5	2.9	-21.7	-5.9	**-35.3**
1933.III	-0.1	-5.2	-0.8	3.0	-19.3	-6.8	**-27.9**
1933.IV	-0.1	-2.2	-0.5	2.5	-18.2	-7.6	**-27.0**
1934.I	-0.1	-2.3	-0.1	2.8	-17.7	-8.3	**-25.2**
1934.II	-0.1	0.1	-0.4	2.4	-16.8	-8.8	**-22.4**
1934.III	-0.1	1.3	-0.4	1.6	-17.2	-9.1	**-25.1**
1934.IV	-0.1	0.9	-0.3	1.7	-17.4	-9.3	**-25.4**
1935.I	-0.1	1.6	-0.4	1.6	-16.8	-9.5	**-22.5**
1935.II	-0.1	3.2	-0.4	1.0	-16.5	-9.6	**-22.7**
1935.III	-0.1	3.7	-0.2	0.6	-16.4	-9.5	**-22.5**
1935.IV	-0.1	4.9	-0.2	0.2	-15.8	-9.4	**-19.9**
1936.I	-0.1	6.2	-0.1	-0.3	-15.2	-9.2	**-19.2**
1936.II	-0.1	6.6	0.2	-0.6	-14.5	-9.0	**-17.0**
1936.III	-0.1	8.0	0.2	-1.1	-13.5	-8.8	**-15.5**
1936.IV	-0.1	8.2	0.4	-1.5	-12.8	-8.5	**-14.2**
1937.I	0.0	8.4	0.6	-1.6	-12.1	-8.2	**-13.0**
1937.II	0.0	7.8	0.8	-1.5	-11.6	-7.9	**-12.3**
1937.III	0.0	7.2	0.8	-1.6	-11.7	-7.6	**-13.0**
1937.IV	0.0	5.4	0.9	-1.6	-12.6	-7.3	**-16.2**
1938.I	0.0	1.8	0.8	-1.1	-14.1	-7.2	**-20.7**
1938.II	0.0	0.4	0.4	-0.6	-14.8	-7.4	**-22.2**
1938.III	-0.1	1.1	0.2	-0.6	-15.0	-7.5	**-21.8**
1938.IV	-0.1	2.9	0.0	-0.9	-14.8	-7.5	**-20.1**
1939.I	-0.1	3.9	0.2	-1.1	-14.6	-7.4	**-19.1**
1939.II	-0.1	3.7	0.5	-0.9	-14.6	-7.4	**-19.1**
1939.III	-0.1	3.5	0.5	-0.7	-14.3	-7.4	**-18.5**
1939.IV	-0.1	4.7	0.4	-0.9	-13.6	-7.4	**-16.0**

Table I.3: Percent response of output to bargaining shocks (1929.I = 0).

Quarter	Baseline	s_v = 1.5%	s_v = 0.2%	s_v = 1.2% a = 0.25	s_v = 0.7% a = 0.6	Mone-tarist	Data
1929.I	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
1929.II	0.2	-0.4	0.1	0.0	0.2	0.3	**3.2**
1929.III	0.3	-1.1	0.3	0.0	0.4	0.5	**3.1**
1929.IV	0.1	-2.2	0.6	-0.2	0.3	0.2	**-2.4**
1930.I	-0.3	-3.7	0.6	-0.6	-0.2	-0.4	**-6.8**
1930.II	-1.0	-5.9	1.0	-1.2	-1.0	-1.1	**-8.0**
1930.III	-2.0	-8.6	1.3	-2.0	-2.1	-2.2	**-13.8**
1930.IV	-3.2	-11.8	1.5	-3.0	-3.5	-3.5	**-19.3**
1931.I	-4.5	-15.2	1.6	-4.1	-5.0	-4.9	**-19.9**
1931.II	-5.9	-18.9	1.9	-5.2	-6.4	-6.3	**-18.9**
1931.III	-7.3	-22.9	2.1	-6.4	-8.0	-8.0	**-23.6**
1931.IV	-8.9	-27.0	2.2	-7.7	-9.7	-9.7	**-29.6**
1932.I	-10.4	-31.1	2.5	-8.8	-11.4	-11.3	**-34.0**
1932.II	-11.9	-35.3	2.7	-10.0	-13.2	-13.1	**-39.7**
1932.III	-13.5	-39.2	2.5	-11.2	-15.0	-14.9	**-44.0**
1932.IV	-14.9	-42.7	2.5	-12.2	-16.5	-16.2	**-45.3**
1933.I	-15.9	-45.6	2.3	-13.1	-17.7	-17.2	**-52.0**
1933.II	-16.6	-47.4	1.6	-13.5	-18.4	-17.7	**-45.8**
1933.III	-16.4	-48.3	1.5	-13.4	-18.1	-17.2	**-38.9**
1933.IV	-16.0	-48.7	1.4	-13.1	-17.7	-16.7	**-46.9**
1934.I	-15.6	-48.8	1.3	-12.8	-17.2	-16.1	**-42.3**
1934.II	-15.1	-48.8	1.7	-12.4	-16.6	-15.4	**-37.4**
1934.III	-14.9	-49.0	1.7	-12.3	-16.4	-15.3	**-42.5**
1934.IV	-14.7	-49.1	1.5	-12.2	-16.2	-15.2	**-43.2**
1935.I	-14.5	-49.0	1.6	-12.0	-15.9	-14.8	**-37.8**
1935.II	-14.2	-48.9	1.6	-11.9	-15.6	-14.6	**-38.3**
1935.III	-14.0	-48.6	1.4	-11.8	-15.3	-14.4	**-36.3**
1935.IV	-13.7	-48.2	1.4	-11.6	-14.8	-14.0	**-31.7**
1936.I	-13.4	-47.6	1.3	-11.4	-14.3	-13.6	**-31.9**
1936.II	-12.9	-46.8	1.1	-11.2	-13.7	-13.1	**-26.6**
1936.III	-12.3	-45.8	1.1	-10.8	-12.9	-12.4	**-24.6**
1936.IV	-11.7	-44.9	1.0	-10.4	-12.2	-11.7	**-22.1**
1937.I	-11.2	-43.9	0.9	-10.0	-11.5	-11.1	**-23.1**
1937.II	-10.7	-43.1	1.1	-9.7	-10.9	-10.5	**-21.4**
1937.III	-10.4	-42.7	1.4	-9.5	-10.6	-10.3	**-22.5**
1937.IV	-10.4	-42.8	1.7	-9.6	-10.7	-10.6	**-30.6**
1938.I	-10.9	-43.3	1.6	-9.9	-11.3	-11.3	**-35.6**
1938.II	-11.3	-43.8	1.6	-10.2	-11.9	-11.7	**-34.7**
1938.III	-11.7	-44.2	1.5	-10.5	-12.3	-12.0	**-29.8**
1938.IV	-11.9	-44.4	1.6	-10.7	-12.5	-12.1	**-26.6**
1939.I	-12.0	-44.5	1.5	-10.8	-12.6	-12.2	**-28.3**
1939.II	-12.0	-44.5	1.4	-10.9	-12.6	-12.3	**-30.6**
1939.III	-11.9	-44.2	1.3	-10.9	-12.5	-12.2	**-27.6**
1939.IV	-11.7	-43.7	1.3	-10.7	-12.3	-11.9	**-22.1**

Table I.4: Percent response of employment to bargaining shocks (1929.I = 0).

Quarter	**Baseline**	s_v **= 1.5%**	s_v **= 0.2%**	s_v **= 1.2%** a **= 0.25**	s_v **= 0.7%** a **= 0.6**	**Mone-tarist**	**Data**
1929.I	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
1929.II	0.3	-0.3	0.2	0.1	0.3	0.6	**0.5**
1929.III	0.2	-0.9	-0.1	0.0	0.4	0.3	**0.8**
1929.IV	-0.4	-2.0	-0.8	-0.6	-0.3	-0.9	**-1.0**
1930.I	-1.5	-3.7	-1.7	-1.5	-1.5	-2.6	**-3.5**
1930.II	-2.9	-5.9	-1.9	-2.8	-3.1	-3.3	**-5.4**
1930.III	-4.8	-8.7	-3.1	-4.4	-5.1	-5.7	**-9.4**
1930.IV	-6.9	-11.9	-4.1	-6.2	-7.4	-7.9	**-12.4**
1931.I	-8.8	-15.1	-4.7	-7.7	-9.3	-9.8	**-15.1**
1931.II	-10.2	-18.3	-5.1	-9.0	-10.8	-11.2	**-16.6**
1931.III	-12.3	-21.9	-6.2	-10.7	-12.9	-13.8	**-19.7**
1931.IV	-14.4	-25.7	-6.9	-12.4	-15.2	-16.1	**-23.7**
1932.I	-15.8	-28.8	-7.2	-13.5	-16.9	-17.6	**-26.0**
1932.II	-18.0	-32.5	-8.2	-15.1	-19.3	-20.2	**-31.4**
1932.III	-20.1	-36.0	-8.9	-16.6	-21.6	-22.5	**-35.3**
1932.IV	-21.0	-38.5	-8.5	-17.3	-22.7	-22.8	**-34.1**
1933.I	-21.8	-40.5	-8.6	-17.9	-23.6	-23.6	**-36.6**
1933.II	-21.7	-41.6	-7.9	-17.8	-23.6	-23.2	**-35.3**
1933.III	-19.3	-40.8	-5.6	-15.9	-20.9	-19.8	**-27.9**
1933.IV	-18.2	-40.5	-5.2	-15.1	-19.8	-19.1	**-27.0**
1934.I	-17.7	-40.3	-5.0	-14.6	-19.3	-18.3	**-25.2**
1934.II	-16.8	-39.8	-4.5	-13.9	-18.1	-17.0	**-22.4**
1934.III	-17.2	-40.2	-5.7	-14.4	-18.5	-18.3	**-25.1**
1934.IV	-17.4	-40.4	-5.8	-14.5	-18.7	-18.5	**-25.4**
1935.I	-16.8	-40.1	-5.0	-14.1	-18.0	-17.0	**-22.5**
1935.II	-16.5	-39.9	-5.3	-14.0	-17.6	-17.3	**-22.7**
1935.III	-16.4	-39.8	-5.4	-14.1	-17.4	-17.3	**-22.5**
1935.IV	-15.8	-39.2	-4.9	-13.6	-16.6	-16.3	**-19.9**
1936.I	-15.2	-38.5	-4.8	-13.3	-15.8	-15.9	**-19.2**
1936.II	-14.5	-37.7	-4.4	-12.8	-14.9	-14.9	**-17.0**
1936.III	-13.5	-36.7	-3.9	-12.1	-13.7	-13.7	**-15.5**
1936.IV	-12.8	-35.8	-3.6	-11.7	-12.9	-13.0	**-14.2**
1937.I	-12.1	-34.9	-3.4	-11.2	-12.1	-12.2	**-13.0**
1937.II	-11.6	-34.2	-3.2	-10.8	-11.6	-11.6	**-12.3**
1937.III	-11.7	-34.1	-3.7	-10.9	-11.6	-12.1	**-13.0**
1937.IV	-12.6	-34.6	-4.7	-11.6	-12.7	-13.7	**-16.2**
1938.I	-14.1	-35.7	-5.6	-12.7	-14.6	-15.4	**-20.7**
1938.II	-14.8	-36.3	-5.3	-13.2	-15.5	-15.5	**-22.2**
1938.III	-15.0	-36.6	-5.4	-13.5	-15.7	-15.6	**-21.8**
1938.IV	-14.8	-36.7	-5.2	-13.4	-15.4	-15.2	**-20.1**
1939.I	-14.6	-36.6	-5.2	-13.3	-15.1	-15.3	**-19.1**
1939.II	-14.6	-36.5	-5.1	-13.3	-15.1	-15.4	**-19.1**
1939.III	-14.3	-36.0	-4.7	-13.1	-14.7	-14.8	**-18.5**
1939.IV	-13.6	-35.3	-4.3	-12.6	-14.0	-14.0	**-16.0**

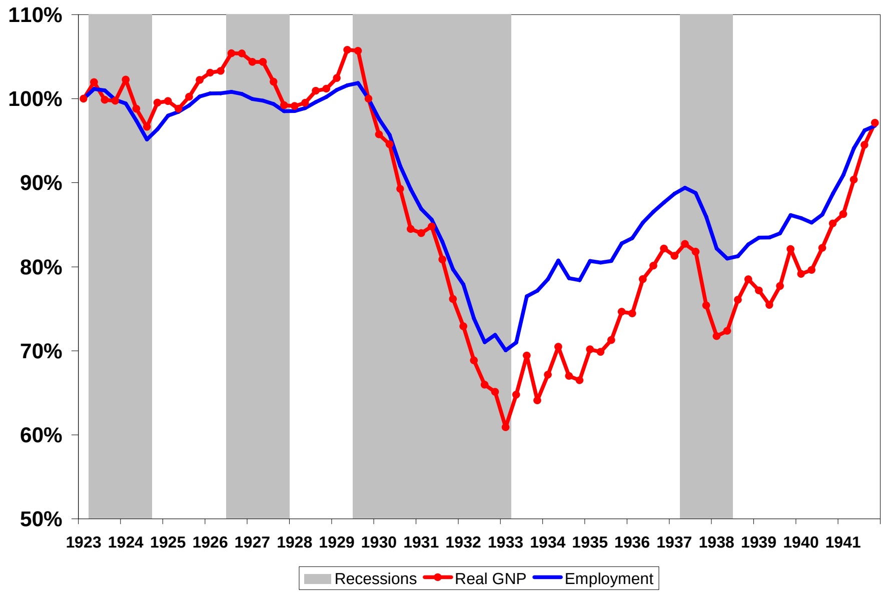

Figure I.1: Real GNP and nonfarm employment (% of trend).
Source: See Appendix I.H.

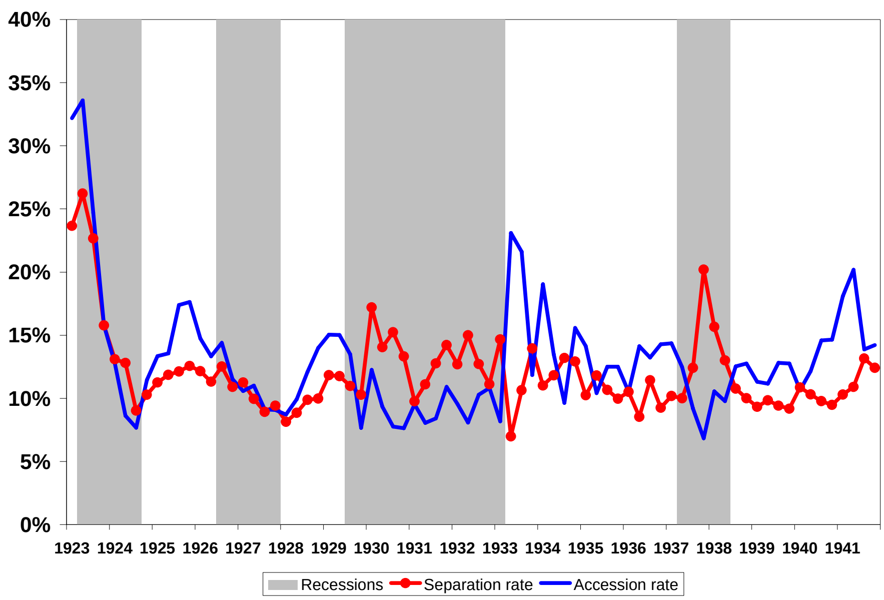

Figure I.2: Gross job flow rates (% quarterly).
Source: See Appendix I.H.

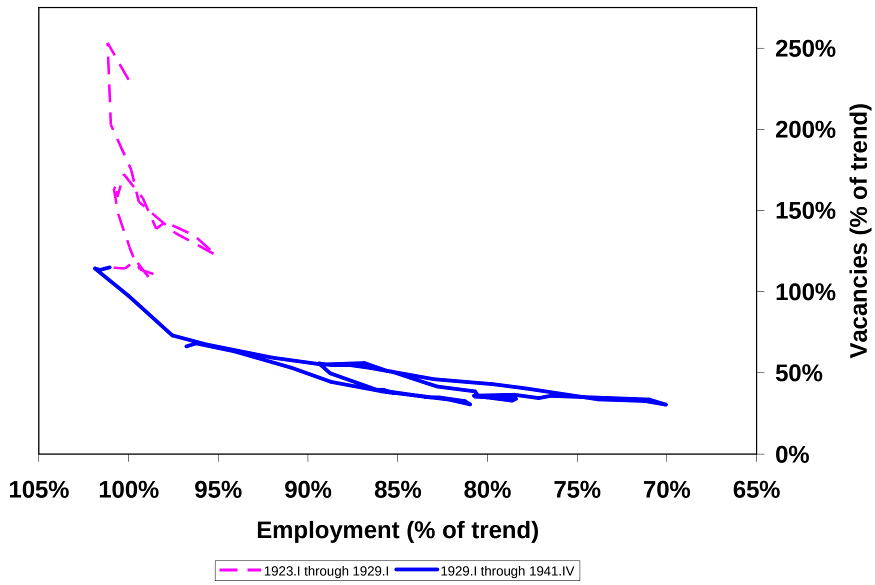

Figure I.3: Beveridge curve, pre and post-1929 (% of trend).
Source: See Appendix I.H.

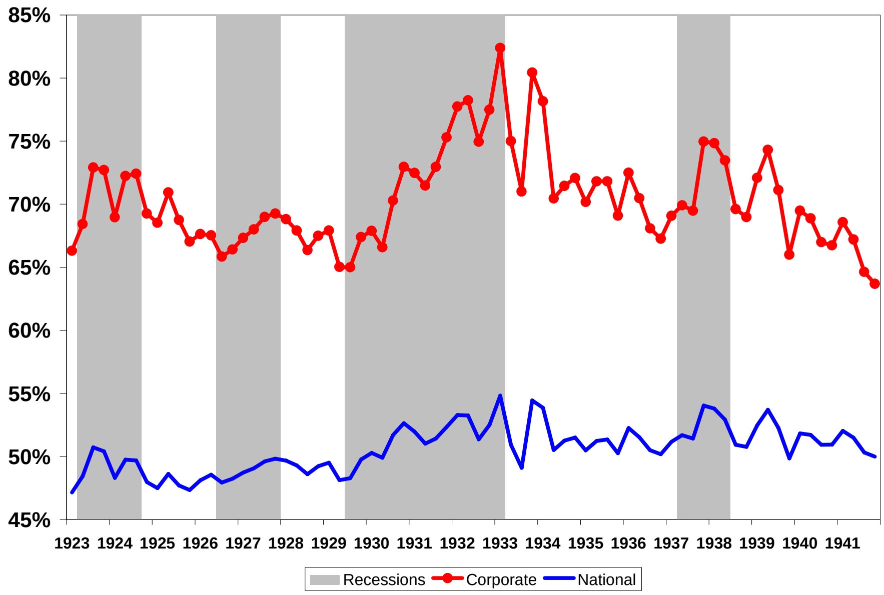

Figure I.4: Labor's share of corporate and national gross income (%).
Source: See Appendix I.H.

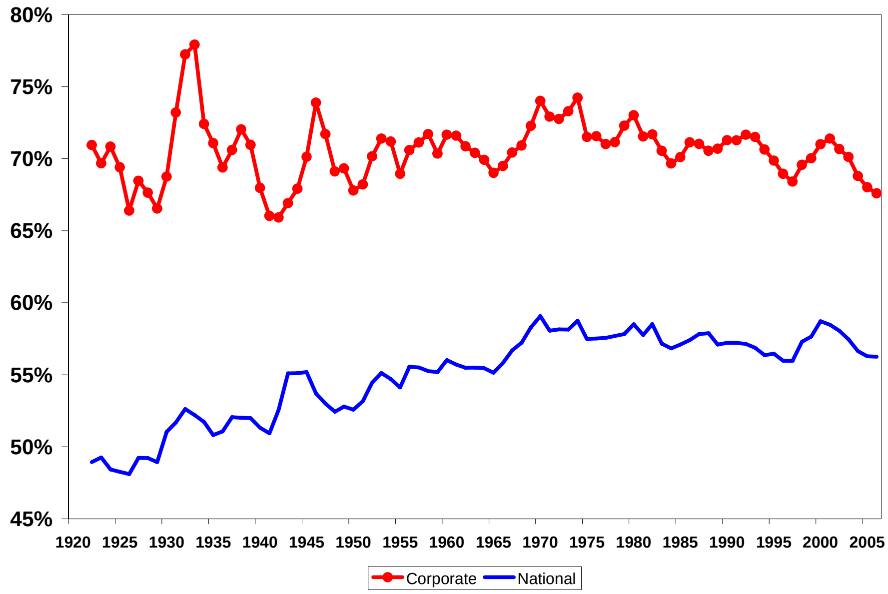

Figure I.5: Labor's share of corporate and national gross income, 1922-2006 (%). Source: See Appendix I.H.

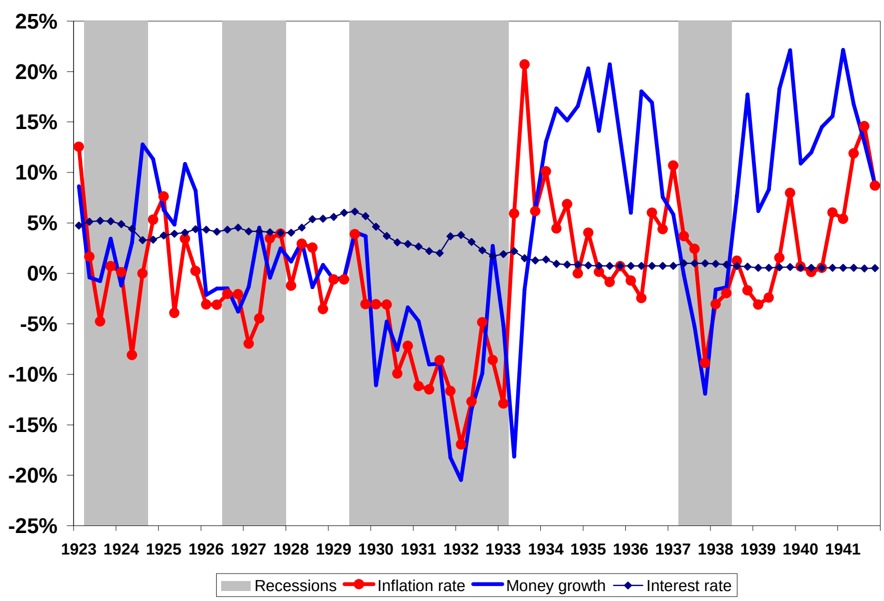

Figure I.6: Inflation, money growth, and interest rates (% annual). Source: See Appendix I.H.

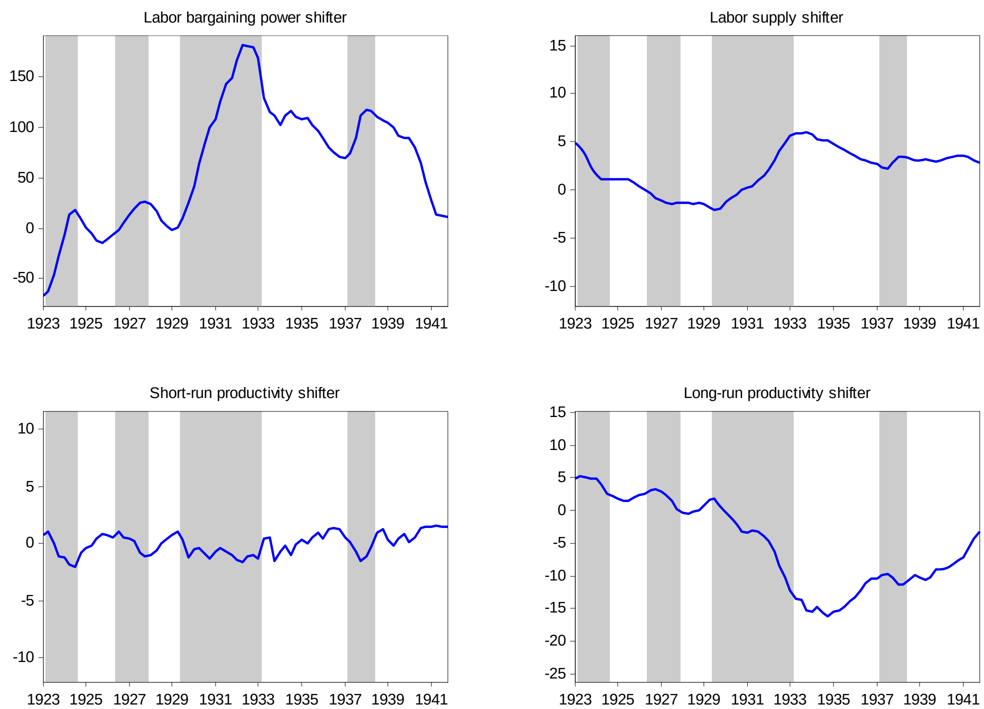

Figure I.7: Estimated real driving processes (% deviation).
The solid blue line shows the filtered estimates. Gray bars indicate recessions.

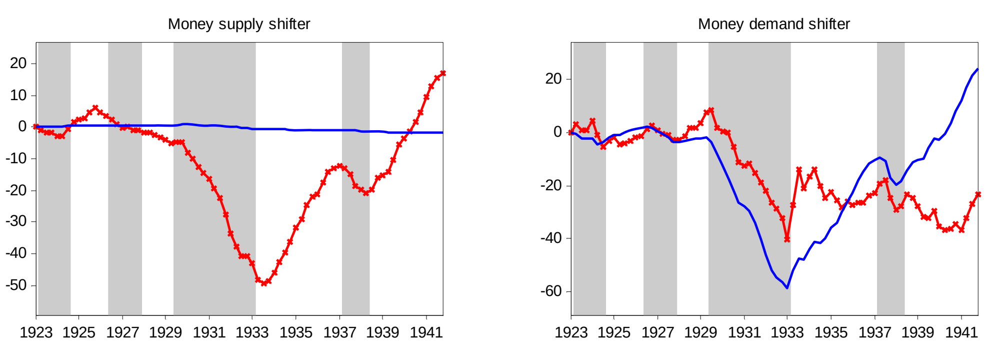

Figure I.8: Estimated nominal driving processes (% deviation).
The red ‘x’ lines show the observed values; the solid blue lines show the filtered estimates. Gray bars indicate recessions.

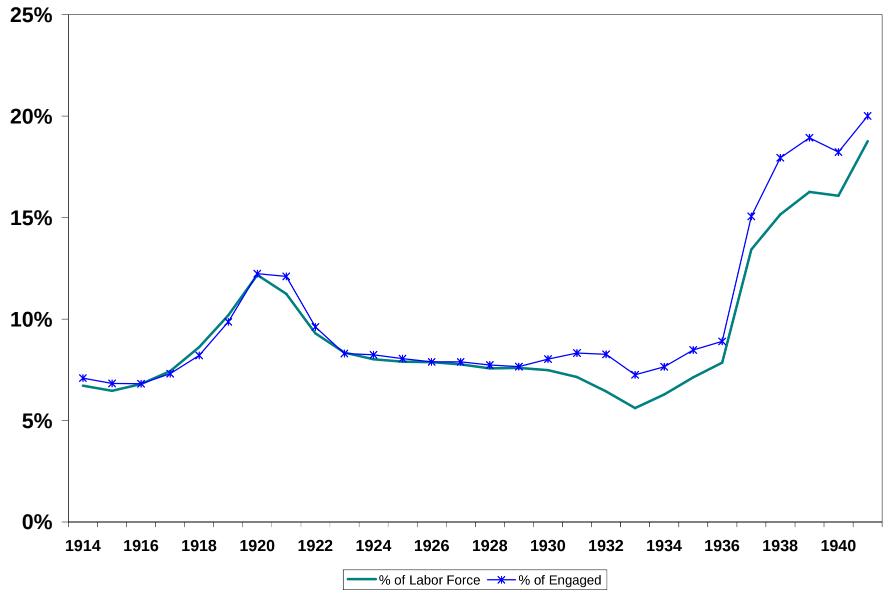

Figure I.9: Approximate labor union membership rates, 1914-1941 (%).
Source: See Appendix I.H.

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II Can a Labor Matching Model Match Labor's Share?

II.A Introduction

The RBC and New Keynesian revolutions have reached a point where scholars and policymakers have begun to use DSGE models to make forecasts and set policy. Analysis has typically centered on a canonical New Keynesian model, in which an RBC model is modified to include a number of nominal and real rigidities. Smets and Wouters (2004, 2007); Christiano, Eichenbaum, and Evans (2005); Altig, Christiano, Eichenbaum, and Lindé (2005); Del Negro, Schorfheide, Smets, and Wouters (2005); Dib, Gammoudi, and Moran (2008); and others give examples of DSGE models which actually perform as well as or better than unrestricted VARs in terms of fit and forecast performance in postwar data. As a result of these developments, attention has shifted away from calibrating models by matching impulse responses or unconditional second moments and toward more formal methods of model evaluation. Smets and Wouters (2007), for instance show that the canonical New Keynesian model, when estimated using postwar data, requires shocks outside of the usual productivity and monetary policy shocks to explain the majority of the variation of output apart from the Volcker episode.[14]

[14] One might be able to think of this as a more structural version of Chari, Kehoe, and McGrattan's (2007) business cycle accounting exercise.

One unattractive feature of these canonical New Keynesian models consists of their limited treatment of labor markets. Instead of embodying the old Keynesian idea of unemployment as an essential feature of business cycles, these models simply ignore unemployment and act as though labor inputs adjust purely on the intensive margin. Cooley and Quadrini (1999), Walsh (2002, 2005), Trigari (2004), and Blanchard and Galí (2007) show how labor search frictions and wage bargaining can amplify and propagate nominal shocks in New Keynesian models. Particularly when combined with sticky prices and inertial monetary policy rules, these models can produce fluctuations that look much like monetary-driven business cycles with a more appealing theoretical structure and fewer additional assumptions about real rigidities. Fout (2006); Yashiv (2006); Beauchemin and Tasci (2007); and Christoffel, Küstel, and Linzert (2007) have investigated different aspects of labor matching models using real-world data.

This paper seeks to extend this latter literature in the direction of the comprehensive New Keynesian model evaluation literature by estimating a series of structural shocks in the context of a New Keynesian labor matching model during the postwar period. As it turns out, the model delivers similar performance to other New Keynesian models with respect to monetary policy. In this model, shocks to monetary policy play a predominant role during the Volcker episode and some role during the late-1940s recession but much smaller roles otherwise. Productivity shocks, depending on the way one wishes to treat the data, can explain the late 1960s boom and some of the economic weaknesses of the 1970s and early 1980s. Neither set of shocks can explain any of the movements in employment since the early 1980s.

Perhaps more surprisingly, the labor matching model with Nash bargaining and endogenous separation but otherwise flexible real wages goes a long way toward matching the behavior of labor's share of income over the business cycle.[15] It does not do quite so well at matching the behavior of manufacturing job flows, both in the long run and at business-cycle frequencies. The model can produce a positive correlation between predicted job separation and accession rates and the data. The model also has a hard time combining nonstationary productivity with stationary employment. The most important failure of the New Keynesian labor matching model, however, comes from the fact that it simply lacks a credible source of impulses. These findings suggest that labor matching models say something useful about the relationship between labor market frictions and wage-setting but share serious limitations with other New Keynesian models.

II.B The data

This paper makes use of detrended quarterly observations on nine variables related to real activity, job flows, and nominal variables from the second quarter of 1947 through the first quarter of 2007. Quarterly statistics on real GDP, GDP prices, and labor's share of corporate gross income come from the National Income and

[15] Boldrin and Ruiz (undated abstract), Gomme and Rupert (2004), Hansen and Prescott (2005), Choi and Ríos-Rull (2008), and others also discuss the systematic behavior of labor's share over the cycle.

Product Accounts. Raw data on employment levels and unemployment rates (used to detrend employment) come from the CES and CPS, respectively. Secondary market rates on three-month treasury bills come from the St. Louis Fed's FRED database. The Conference Board's Help Wanted Index is used as a proxy for vacancies from 1957 through 2007, with corrections applied to the post-1993 data to account for online vacancy postings. For the period before 1957, the Met Life Help Wanted Index is ratio-spliced to the Conference Board's index.[16] Finally, quarterly data on job flows from manufacturing come from Faberman (2006), updated to reflect revisions to the BED data released in 2006 and 2007. The post-1992 revised data are spliced onto the earlier data using the average ratio between the revised and original data from 1992 to 2007. The series is then led a period to reflect the fact that the data reflect lagged job flows.

Detrended employment is calculated based on unemployment rates, assuming that employment is at two percent above trend at the beginning of 1947 and at trend in the second quarter of 1964, the third quarter of 1979, the fourth quarter of 1996, and the fourth quarter of 2005. These dates are chosen based on a historical average of about 5.3 percent unemployment. A piecewise log-linear trend is drawn through these points. Vacancies share the same underlying trend. Log output per worker is linearly detrended, and detrended log output is taken to equal detrended employment plus detrended output per worker.

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[16] Valletta (2005) describes how to adjust the post-1993 data using the Job Openings and Labor Turnover Survey (JOLTS). Zagorsky (1998) discusses the long-run stability and accuracy of this composite series.

Figure II.1 depicts the resulting series on detrended real GDP, vacancies (divided by 10) and employment. Figure II.2 shows detrended output per worker. Detrended employment follows the CBO's own employment and output gaps very closely and shows more low-frequency variation than an employment gap derived from a high-pass filter. Employment tends to lag vacancies by about a quarter, and vacancies are just over eight times as volatile as employment.[17] The output and productivity series also retain some of their lower-frequency variation. Productivity grows at an unusually high rate until 1966, experiences a slowdown until the early 1980s, and shows another pickup from the mid-1990s into the mid-2000s, and movements in employment lag productivity by about four to seven quarters.

Figure II.3 shows the behavior of the manufacturing separation and accession rates throughout the sample. In manufacturing, most of the volatility during recessions is with separations, while a smaller wave of accessions typically accompanies the early stages of an expansion. This has become less noticeable in recent years. Figure II.4 shows the behavior of labor's share of corporate gross income. It shows an inverted U-shape at low frequencies, with a particularly high labor share during the 1970s. It tends to negatively lead filtered employment and positively lag it, with no contemporaneous correlation. Figure II.5 shows the behavior of inflation along with the return to three-month treasury bills. These data show the usual story of rising inflation and interest rates until 1980 and falling inflation and interest rates thereafter. Inflation is positively correlated with output at high

[17] All cross-correlations are reported using HP-filtered (λ=100,000) data in order to remove very low-frequency movements.

frequencies, while at very low frequencies, inflation and interest rates both correlate negatively with employment. Berentsen, Menzio, and Wright (2007) take the latter fact as evidence of a cost channel in an economy where money is essential. Finally, data on the money supply (demand deposits plus currency) come from the St. Louis Fed for the period after 1959 and Friedman and Schwartz (1970) for the period before 1959.

II.C The model

Walsh (2002, 2005), Trigari (2004), and Cooley and Quadrini (1999) present different models of labor matching in the presence of sticky prices. They find that labor matching models show much more persistence and amplification of shocks than their counterparts which feature clearing labor markets.[18] This paper adapts the basic model of Walsh (2002) to allow for disturbances to labor's market power, to the disutility from work, and to the demand for money. On the household side, it consists of infinitely lived consumers who face a monetary friction. Production and hiring take place in a firm-worker match, as in Mortensen and Pissarides (1994). A retail sector aggregates output from the wholesale sector and resets retail prices in a staggered manner. This allows for a straightforward treatment of sticky prices. The monetary authority adjusts interest rates according to a Taylor rule with one important

[18] Christiano, Eichenbaum, and Evans (2005) discuss the role of real rigidities in a more standard New Keynesian model.

qualification—sometimes it adjusts its long-run inflation target without immediately changing interest rates.

II.C.1 The household sector

Sticking closely with Walsh's notation, individual 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 in order to consume later. They each seek to maximize the objective function

$$E_t \sum_{i=0}^{\infty} \beta^i \left[\frac{C_{t+i}^{1-\sigma}}{1-\sigma} - \chi_{t+i} A_{t+i} \bar{z}_{t+i} \right], \qquad \text{(II.1)}$$

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.

Put this way, $A_{t+i}\bar{z}_{t+i}$ is the net disutility from having to go to work instead of staying home to produce and consume a home production good. It represents the worker's one-period outside option from refusing a job offer which may include leisure and home production in addition to unemployment benefits. The long-run productivity shifter $\bar{z}_{t+i}$ appears for empirical balanced-growth reasons; one can think of it as applying symmetrically to market output, home production, and vacancy posting costs.[19]

[19] It appears for much the same reasons that one might place restrictions on preferences in a Hansen (1985)-Rogerson (1988) model, that is, to keep employment from wandering off with productivity in the long run.

Markets operate in three stages per period. In the first stage, after shocks are realized and known to those concerned, financial markets open. People trade bonds and withdraw money in order to make their consumption purchases. In the second stage, the goods market opens. Production and consumption occur. In the third stage, workers and shareholders take home their paychecks which clear by the beginning of the following period. Households cannot consume out of current income and must spend money in an exogenous proportion to their consumption purchases. Households are large and members pool their earnings and household production in an informal insurance scheme.

In terms of economic activity, households face two constraints: a transactions constraint and a budget constraint. Households cannot spend their income on current consumption because they have not yet received their factor payments. The transaction friction, which contains an exogenous time-varying velocity shifter, implies that intermediate cash holdings must go toward a proportion of consumption expenditures:

$$P_t C_t = V_t M_{t+1} . \tag{II.2}$$

After consumption purchases are made, money spent on consumption flows back to the households at the end of the period in the form of factor payments, thus completing the circular flow. In this setup, V_t equals an exogenous money demand shifter. In typical cash-in-advance models, transactions technologies do not vary and velocity is set to one. In situations such as the postwar U.S. where monetary authorities target interest rates, the monetary authority automatically engages in open market operations to offset any shock to *V*. The result of all of this is simply to allow data on the money supply to be used as it contains useful information about nominal output.

The household's budget constraint relates household money holdings, total income, bond purchases, money transfers, 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 cash transfers received by the household from monetary authorities.

$$M_{t+1} + B_{t+1} + P_t C_t = P_t Y_t + R_{t-1} B_t + M_t + T_t \,. \qquad \text{(II.3)}$$

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

$$\lambda_t = E_t \beta R_t \frac{P_t}{P_{t+1}} \lambda_{t+1} \,, \qquad \text{(II.4)}$$

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

$$C_t^{-\sigma} - \lambda_t = 0 \,. \qquad \text{(II.5)}$$

Because of market clearing, output equals consumption:

$$Y_t = C_t \,, \qquad \text{(II.6)}$$

and the quantity equation therefore holds:

$$P_t Y_t = V_t M_{t+1} \,. \qquad \text{(II.7)}$$

Equations (II.4) through (II.7) characterize the behavior of the household sector in this fairly standard setup, apart from the money demand shifter in the transactions technology equation.

II.C.2 The retail sector and sticky prices

Monopolistically competitive retailers buy output competitively from the wholesale sector and resell it to households at a markup. Households aggregate it according to a Dixit-Stiglitz aggregator. The aggregator stands in for a richer set of preferences over variety that consumers have; the product differentiation implicit in the aggregator allows for retailers to exercise some monopoly power. Retailers buy their products y_{jt} competitively from wholesale producers who produce homogeneous intermediate goods. The aggregate level of output is given by

$$Y_t = \left[\int_0^1 y_{jt}^{\frac{\theta-1}{\theta}} dj \right]^{\frac{\theta}{\theta-1}}, \tag{II.8}$$

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

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

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

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

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-ω*. Based on these random intervals between price changes, prices will show a considerable degree of persistence. This will allow nominal shocks to have substantial real effects—since prices cannot adjust instantaneously, the quantity of output must rise in response to nominal shocks.

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 $D_{i,t+1}$ equal the discount factor $\beta^i(\lambda_{t+i}/\lambda_{t+1})$, the objective function for the price-changers equals

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

Long-run profit maximization results in the first order condition

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

with the aggregate retail price index given by

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

Current prices are a weighted function of lagged prices and the prices set by those firms that could adjust. Conditions (II.12) and (II.13) describe a New Keynesian

Phillips Curve relationship which relates current retail markups to current and expected future inflation.

II.C.3 The wholesale sector and labor matching

The wholesale sector distinguishes this model from most typical sticky-price models. This model follows the lead of Mortensen and Pissarides (1994) and the modern literature on labor matching in treating employment as a long-term relationship. The labor market in this model is a special case of that of den Haan, Ramey, and Watson (2000), without fixed capital. In order for workers and firms to produce, they must do so in a matched relationship. Workers and firms separate for both exogenous and endogenous reasons, and firms search for workers based on expectations of future profitability. Such a framework allows for a better treatment of unemployment than the typical RBC-style approach. Walsh goes through the basic model in much more detail.

Using standard notation, $U_t = 1 - N_t$ 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), a systematic temporary productivity shock z_t, 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 $y_{it} = a_{it}\bar{z}_t z_t$ 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 three shock processes have an unconditional mean of one and are independent from each other. The idiosyncratic shocks are also independent and identically distributed over time and across agents, while the other productivity shocks are common to every agent.

Firms seeking workers post vacancies at a fixed cost. Workers without jobs who would rather work must first find a job and therefore cannot freely supply labor on the spot. As a result of matching frictions, matches earn an economic surplus, and in a well-functioning bargaining environment, workers and firms will want to remain matched so long as that surplus exceeds zero. Because of the transactions friction and the slight delay in making factor payments, this period's money income only becomes available the following period to consume. As a result, sales (and factor payments) are discounted at the rate R_t. This serves to introduce a simple cost channel into the model.

Noting that the retailer's gross markup μ_t equals 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*, less the instantaneous disutility of work, plus the expected discounted continuation value of the match (denoted by q_{it}), all in product terms:

$$s_{it} = \frac{a_{it} z_t \bar{z}_t}{\mu_t R_t} - A_t \bar{z}_t + q_{it} . \qquad \text{(II.14)}$$

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 (II.14) to zero gives the value of this cutoff:

$$\tilde{a}_t = \frac{\mu_t R_t (A_t \bar{z}_t - q_t)}{z_t \bar{z}_t}. \tag{II.15}$$

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:

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

and

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

In a match, workers and firms engage in Nash bargaining. The worker receives a time-varying exogenous share of the surplus η_t; the firm receives the share (1 - η_t). The worker's share of the surplus summarizes the state of the bargaining environment; a higher share means that the bargaining environment is more explicitly favorable to workers. 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:

$$q_t = (1 - \rho^x) \beta E_t \frac{\lambda_{t+1}}{\lambda_t} (1 - \eta_{t+1} k_t^w) \int_{\tilde{a}_{t+1}}^{\infty} s_{it+1} dF(a_{it+1}). \tag{II.18}$$

Firms can post vacancies at a fixed cost $\gamma\bar{z}_t$ but face no other barriers to entry.[20] Vacancies get filled at a gross rate k_t^f. This results in a free-entry condition equating the present value of a firm's vacancy posting with the cost of posting that vacancy:

$$\gamma\bar{z}_t = (1-\rho^x)k_t^f \beta E_t \frac{\lambda_{t+1}}{\lambda_t}(1-\eta_{t+1})\int_{\tilde{a}_{t+1}}^{\infty} s_{it+1} dF(a_{it+1}). \qquad \text{(II.19)}$$

To a first-order approximation, (II.18) and (II.19) yield the continuation value:

$$q_t \approx E_t \frac{\gamma\bar{z}_t(1-\eta_{t+1}k_t^w)}{(1-\eta_{t+1})k_t^f}. \qquad \text{(II.20)}$$

Increasing either the job finding rate or the vacancy filling rate will tend to reduce the value of an existing match by making it easier for firms and workers to go elsewhere. Similarly, decreasing γ will reduce the value of the existing match; as γ goes to zero, firms can search costlessly and will post an infinite number of vacancies. An increase in labor's bargaining power will actually increase the continuation value of the surplus but feed through into much lower vacancy rates and falling employment. An increase in the disutility from work will result in a wave of separations and higher wages.

Aggregating these things is rather simple. The total number of job searchers 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

$$u_t \equiv U_t + \rho_t N_t = 1-(1-\rho_t)N_t. \qquad \text{(II.21)}$$

[20] The term $\bar{z}_t$ appears here to keep vacancy posting costs from vanishing in a growing economy in the same way that it appears in the utility function.

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

$$k_t^f = \frac{m(u_t, v_t)}{v_t}, \tag{II.22}$$

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

$$k_t^w = \frac{m(u_t, v_t)}{u_t}. \tag{II.23}$$

Abstracting from exit and entry into the labor force, the number of matches evolves according to the accounting identity

$$N_{t+1} = (1-\rho_t)N_t + m(u_t, v_t), \tag{II.24}$$

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

$$Q_t = \frac{(1-\rho_t)N_t z_t \bar{z}_t \left[\int_{\tilde{a}_t}^{\infty} a_{it} dF(a_{it})\right]}{1-F(\tilde{a}_t)}. \tag{II.25}$$

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

$$Y_t = Q_t - \gamma \bar{z}_t v_t. \tag{II.26}$$

Taken together, these conditions describe an equilibrium in the labor market. The inability of workers to instantaneously find jobs and of firms to instantaneously find workers result in quasi-rents that both sides must split through a bargaining mechanism. The main effects of using the bargaining mechanism to move away from perfectly competitive labor markets are twofold. First of all, the economy responds much more slowly to shocks since it is difficult to adjust labor inputs. Secondly, the bargaining mechanism ensures that productivity shocks result in a less than one-for-one change in wages since workers are not paid their marginal product. During periods of low productivity, therefore, one might expect labor's share of income to be unusually high.[21] As it turns out, this allows the labor matching model to go a long way toward matching the behavior of labor's share without having to resort to extreme wage rigidities.

II.C.4 The monetary authority

It has become common practice to model monetary policymakers as adjusting interest rates in response to inflation and output, an approach popularized by Taylor (1993) and Woodford (2003). This paper continues in that tradition, with a few modifications. First of all, Walsh (2005) shows how sluggish interest rate adjustment feeds back into inflation and output dynamics; in the presence of a cost channel, it seems reasonable to include lagged interest rates on the right hand side of a Taylor rule. Additionally, Bordo, Erceg, Levin, and Michaels (2007) investigate the behavior of interest rates and output in the presence of a changing inflation target, with an application to the Volcker disinflation. They modify their Taylor rule to include changes in a long-run inflation target, in addition to adding lagged interest rate terms. The basic form of the Taylor rule used in this paper closely resembles their specification.

Expressed as deviations from the steady state, the Taylor rule follows the form

[21] Merz (1995) and others point this out. Ordinary New Keynesian labor matching models completely miss out on the attenuated relationship between productivity and wages due to the bargaining process.

$$\hat{r}_t - \hat{\pi}_t^* = \rho_r(\hat{r}_{t-1} - \hat{\pi}_t^*) + \rho_\pi(\hat{\pi}_t - \hat{\pi}_t^*)$$
$$+ \rho_{EMPL}(\hat{n}_t - \hat{n}_{t-1}) + \varepsilon_t^r . \quad \text{(II.27)}$$

An increase in the inflation target $\hat{\pi}_t^*$ eventually results in a one-for-one increase in nominal interest rates, but nominal interest rates adjust extremely slowly. As a result, a rising inflation target results in a period of unusually low real interest rates. Such behavior of interest rates matches the experience of the US relatively well, with low real interest rates during the inflationary 1960s and 1970s and high real interest rates during the disinflationary 1980s and 1990s. This specification of the Taylor rule also allows for monetary policymakers to adjust interest rates in response to *changes* in macroeconomic conditions, as captured in the coefficient ρ_{EMPL}. Since there are endogenous variables on the right-hand side of the Taylor rule, its coefficients must be estimated by maximum likelihood since OLS behaves badly in such a situation.

The inflation target itself evolves according to a persistent AR(1) process:

$$\hat{\pi}_t^* = \rho_{\pi^*} \hat{\pi}_t^* + \varepsilon_t^{\pi^*} . \quad \text{(II.28)}$$

It seems reasonable to treat the money demand shifter V_t as a highly persistent AR(1) process:

$$\ln(V_t) = (1 - \rho_V)\ln(V) + \rho_V \ln(V_{t-1}) + \varepsilon_t^V . \quad \text{(II.29)}$$

Fluctuations in the money demand shifter have no real effects because the Fed follows an interest rate rule, and most monetized RBC models quietly drop this set of shocks or they ignore money entirely. These variables are included here in order to reconcile the behavior of money with the behavior of real output and inflation—data on the money supply will contain useful information about these variables in a situation when prices and output are measured with error.

II.C.5 Productivity and real factors

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

$$\ln(\bar{z}_t) - \overline{\Gamma}t = \rho_{\bar{z}}\left[\ln(\bar{z}_{t-1}) - \overline{\Gamma}(t-1)\right] + \varepsilon_t^{\bar{z}} . \tag{II.30}$$

The temporary productivity shifter z_t follows an exogenous stationary AR(1) process:

$$\ln(z_t) = \rho_z \ln(z_{t-1}) + \varepsilon_t^z . \tag{II.31}$$

This way, it is possible to model the effects of both temporary and permanent productivity shocks with unemployment acting in a well-behaved manner in the long run. The shocks will exhibit very different impulse responses from each other; a positive permanent productivity shock results in a proportionate increase in each of the terms in the surplus equation. It will therefore have no direct effect on separations or vacancy creation. By contrast, a positive temporary productivity shock boosts labor demand and has its usual effects. The allocation of movements in productivity between these shocks is particularly important in evaluating the effects of these movements.

The bargaining weight η_t also follows an AR(1) process as does the labor disutility A_t:

$$\ln(\eta_t) = (1-\rho_\eta)\ln(\eta) + \rho_\eta \ln(\eta_{t-1}) + \varepsilon_t^\eta , \tag{II.32}$$

and

$$\ln(A_t) = (1-\rho_A)\ln(A) + \rho_A \ln(A_{t-1}) + \varepsilon_t^A . \tag{II.33}$$

Positive shocks to either process would somewhat increase labor's share of total income, but they would have different effects on job turnover and vacancies. Shocks to bargaining power result in dramatic falls in both vacancy creation and turnover as surpluses rise but it becomes unprofitable to post vacancies. Shocks to labor supply result in negligible changes in vacancies, but turnover rates rise as surpluses shrink.

II.C.6 Equilibrium and solution method

The aggregate household conditions (II.4) through (II.7), the New Keynesian retail conditions (II.12) and (II.13), the aggregated versions of (II.14) through (II.26) from the wholesale sector, and the shock processes (II.27) through (II.33) constitute a rational expectations equilibrium for this economy, should one exist. The method used to estimate the shocks hitting this economy 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). An appendix derives the system of equations describing the steady state and the linearization of the model around that steady state. In this particular situation, the equilibrium exists and is unique in the neighborhood around the steady state.

II.D Estimation strategy and calibration

II.D.1 State space approach

The linearized model conveniently lends itself to a state space representation. Given a set of feedback rules and quarterly data on nine variables, it is fairly simple to use the Kalman Filter to estimate the underlying unobservable states.[22] Based on observable data (such as output or employment) and a set of unobservable states (such as bargaining power or labor supply) governing the evolution of the data, the filter estimates the most likely state of the economy at each date in the sample. Based on these estimates and the laws of motion of the system, it is then possible to simulate the effects of the realized shocks. The filter also delivers the Gaussian likelihood of the model and makes it possible to compute the maximum likelihood estimates for those parameters such as the shock variances for which it is not possible to impose a sensible external calibration.

The first half of the state space approach consists of the reduced-rank VAR representation of the linearized model. The VAR representation relates the current values of each of the exogenous and endogenous variables to their own lags and to the contemporaneous shocks. The transition equation follows the form

$$x_t = A_1 x_{t-1} + B_1 \varepsilon_t , \qquad \text{(II.34)}$$

where the values of the coefficients come directly from the solution to the linearized model. In general, x_t exhibits a fairly high dimension and reduced rank; it contains a

[22] Hamilton (1994, 2005) shows how to straightforwardly implement the Kalman Filter in such a setting.

complete characterization of the economy's underlying laws of motion as contained in the calibrated model. Since the conclusions of the model are sensitive to the variances of ε_t, and little prior information exists on most of these parameters, these variances must be estimated by maximum likelihood.

The second half of the state space approach consists of the observation equation relating the variables in the model to the nine observed data series. One can label these nine observed series as x_t^*. Based on the linearized model, one can represent the data as some linear combination of the true underlying economic variables. Algebraically, this idea can be represented by the observation equation:

$$x_t^* = D_1 x_t + \varepsilon_t^* . \tag{II.35}$$

The iid (across time and variables) observation shocks ε_t^* consist of a combination of model misspecification and true observation errors, especially in the case of the vacancy and job flow data. They consist of those aspects of the data that the model has a difficult time explaining. In general, attaching a greater variance to the observation error processes will lead the model to explain less of the observed data. The variances of the observation errors are calibrated manually based on the likelihood function.

II.D.2 Calibrated parameter values

Most of the parameter values follow the calibrations used in Walsh (2002), and they are used in order to set up the transition equation (II.34) based on the linearized model. The values used for household preferences are within the range of standard values from the literature. Households have a coefficient of relative risk aversion σ of 2, implying greater risk aversion than log preferences but less risk aversion than equity prices might imply. The nominal interest rate R is based on net 4.5 percent real return on assets per year, implying a value of β of 0.9974. Output and consumption per capita grow at 1.7 percent per year. The model is linearized around a zero-inflation steady state.

Also taken from Walsh's calibration, the gross retail markup μ equals 1.1, for a value of θ of 11. The likelihood function encourages a massive amount of price stickiness—retail firms change their prices on average once every two years for a value of ω of 0.875. This is much higher than Bils and Klenow's (2004) estimates of about 0.5 but is in line with the higher values typically used in the literature. Christiano, Eichenbaum, and Evans (2005) find that, in the absence of explicit nominal wage rigidity, a monetized RBC model favors an extreme degree of price rigidity. In this particular implementation, the high degree of price rigidity allows one to better match labor's share and trend inflation while leaving the real effects of the other shocks intact. As it happens, nominal shocks do not appear to drive most of the postwar business cycles no matter what one is willing to assume about nominal rigidities.

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 a dispersion parameter σ_a of 0.13, for a central location parameter μ_a of

-0.0085. This delivers a value for $\tilde{a}$ of 0.7826. Hairault (2002) and Walsh calibrate vacancy posting costs to one percent of value added. According to Andolfatto (1996), the share of output taken by vacancy costs does not greatly affect the results of the model, and others have followed him out of custom. However, the estimated effects of different shocks do appear sensitive to this. The likelihood function of the model in the baseline setup in fact does favor a share for vacancy posting costs of about one percent of output.

The unemployment share a of the matching function, in the baseline calibration, equals 0.4. Walsh cites Blanchard and Diamond (1989, 1991) who use postwar CPS data to derive such an estimate. A sensitivity analysis reveals that the likelihood function encourages a higher unemployment share.[23] The steady-state unemployment rate U equals 0.05. 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 0.145 job searchers u and 0.124 vacancies v in the steady state. Based on the steady state of the contracting model, the baseline calibration implies initial values of 0.461 for labor's bargaining power η, 0.835 for the disutility of work A, and 0.132 for the continuation value q.

To capture the persistence of the driving processes while keeping the filtering process simple, the autoregressive parameters for the shocks to target inflation, to money demand, long-run productivity, labor's bargaining power, and labor supply all equal 0.999. The resulting endogenous variables become nearly cointegrated. To

[23] The likelihood of the model encourages an unemployment share on the order of 0.5.

identify the different productivity sequences, the autoregressive parameter on z_t equals 0.9 based on information provided by the likelihood function. The results are not particularly sensitive to this parameter. Altogether, this calibration yields a unique rational expectations equilibrium near the steady state. The likelihood of the model when shocks to trend inflation are not taken into account would put the model into an indeterminacy region.

Based on the likelihood function, it is also possible to calibrate the variances of the shock processes. The standard deviations of the nine observation error processes in the baseline case are set to 0.45% for quarterly inflation, 0.16% for the level of output, 0.13% for employment, zero for quarterly money growth, 0.04% for the quarterly nominal interest rate, 0.3% for labor's share of output, zero for vacancies, 21.2% for the log separation rate, and 23.1% for the log accession rate. The baseline model matches everything except the job flows well. The data on job flows simply do not match the behavior of employment at low frequencies, and since the job flow data are restricted to manufacturing, they may not mirror the behavior of the economy as a whole.

The baseline model features shocks to long-run productivity which have no other effects, in addition to standard RBC-style shocks to short-run productivity. As it turns out, the data on labor compensation end up identifying the different types of productivity shocks in the baseline setup. An alternative calibration, the "RBC calibration", relaxes this identifying assumption. In this calibration, the standard deviation of the observation error on labor's share is set to 1.3% and of the errors on separations and accessions to 15% and 11%, respectively. The variance of the long-run productivity shocks is set to zero; and the persistence of short-run productivity rises to 0.98. To reflect these changes, all of the data in the RBC calibration are detrended using an HP filter with a smoothing parameter of 100,000 in order to remove much of the very low-frequency variation in the data. This calibration is more in line with the canonical RBC-style labor matching model; it gives the RBC hypothesis its best chance at explaining postwar economic fluctuations. Results for both calibrations are reported below.

II.E Estimation results

II.E.1 The driving processes

The standard deviations of the six driving processes must be estimated by maximum likelihood using the linearized model and calibrated observation error processes. The estimated standard deviations under the baseline calibration equal 0.0017 for the interest rate shocks, 0.0010 for shocks to trend inflation, 0.0070 for the temporary productivity shocks, 0.0083 for the long-run productivity shocks, 0.0114 for the money demand shocks, 0.0574 for the labor bargaining power shocks, and 0.0040 for the labor supply shocks. The estimated standard deviations under the RBC calibration equal 0.0017 for the interest rate shocks, 0.0013 for shocks to trend inflation, 0.0077 for the temporary productivity shocks, 0.0105 for the money demand shocks, 0.0553 for the labor bargaining power shocks, and 0.0058 for the labor supply shocks.

II.E.2 Monetary policy and its effects

Under the baseline calibration, monetary policy shows a clear split between those portions of inflation which the Fed accommodates and those portions of inflation which it acts to reverse. The coefficients ρ_r, ρ_π, and ρ_{EMPL} have reasonable values after taking this into account (0.85, 0.42, and 0.29, respectively). Interest rates, conditional on trend inflation, show a strong degree of persistence—the Fed appears reluctant to adjust interest rates too quickly, and this in fact helps to ensure determinacy in the presence of a cost channel. The Fed tends to raise interest rates during periods of rising employment or above-trend inflation. Interest rates respond strongly to above-trend inflation (with a long-run response of 0.42/0.15, or 2.8 times), while the Fed only slowly adjusts interest rates one-for-one to match changes in inflation which it wishes to accommodate. This results in low real interest rates during periods of rising trend inflation and explains the behavior of real interest rates during the 1970s and 1980s.

Figure II.6 depicts the behavior of the nominal variables. The upper left hand panel compares the filtered inflation rate with the unfiltered data. The model manages to capture most of the variation in inflation over the postwar period, the notable exceptions being the Korean War period and much of the very short-run variation in measured inflation. The upper right-hand panel of Figure II.6 shows the filtered inflation series (blue line) and the estimated trend π^* (green dashed line). Interestingly, it shows a number of local peaks. These peaks occur in the third quarter of 1947, the first quarter of 1951, the fourth quarter of 1955 or the third quarter of

1956, the second quarter of 1968, the fourth quarter of 1974, the first quarters of 1980 and 1981, and the first quarter of 1989, with rising trend inflation near the end of the sample. All but the 1951 peak fall within one to two quarters of dates identified by Romer and Romer (1989, 1994) as representing the beginning of tightening actions by the Fed. The narrative evidence seems to support the contention that this is an economically meaningful trend inflation series.

Figure II.8 depicts the cumulative effects of shocks to monetary policy on employment since 1947 under the baseline calibration. The green dashed line depicts the effects of changes in the inflation target. The rising inflation target provided a slight stimulus during the 1960s. By the late 1970s, interest rates had gradually risen to reflect the rise in trend inflation, and this exerted a minor but noticeable drag on employment. The black dotted line depicts the effects of interest rate shocks on employment. For the most part, exogenous monetary policy shocks appear not to have generated postwar recessions. The exceptions consist of the fall in employment surrounding the Volcker disinflation and, debatably, a portion of the recession at the end of the 1940s. Even in a model with a very large degree of nominal rigidity, it is very difficult to attribute business cycles to real-world fluctuations in monetary policy.

Under the RBC calibration, the coefficients ρ_r, ρ_π, and ρ_{EMPL} are similar to those under the baseline calibration, with a lower response to inflation. These coefficients equal 0.85, 0.195, and 0.29, respectively, for a long-run response of interest rates to above-trend inflation of 1.3. Looking at the simulation results in Figure II.9, the RBC calibration shows similar employment responses to monetary shocks as under the baseline calibration. Monetary policy now accounts for larger portions of the late-1940s and Volcker recessions as well as a small portion of other cycles during the 1950s and 1970s. In general, though, both calibrations imply that exogenous shocks to monetary policy have not played a large role in most postwar recessions, with no role for monetary policy shocks since the mid-1980s. Smets and Wouters (2007) find a similarly small role for monetary policy shocks in postwar fluctuations, again with the exception of the Volcker episode. This appears to be a robust feature of New Keynesian models when confronted with the data.

II.E.3 The role of productivity shocks

Figure II.7 depicts the behavior of the short-run and long-run productivity shifters under the baseline calibration. These two productivity shifters show very different behavior from each other. The short-run productivity shifter does not fluctuate that much, showing some weakness during the 1970s. The long-run productivity shifter shows a large, persistent rise up until about 1973. After that period, it falls gradually, picking up again beginning in the mid to late 1990s. Figure II.10 shows the cumulative effects of productivity shocks. Under the baseline calibration, the data do not favor the RBC hypothesis as an explanation for short-run fluctuations. Productivity shocks can explain some of the economic weaknesses of the 1970s but they do not appear to generate recessions at business-cycle frequencies.

To further investigate this issue, Figure II.11 shows the results from the RBC calibration. Here, productivity shocks can do a somewhat better job of explaining the behavior of employment at business-cycle frequencies. Shocks to productivity can explain the behavior of employment from the early 1960s through the early 1970s, and they can also contribute somewhat to the poor economic performance of the early 1980s. Apart from these few episodes, observed productivity fluctuations simply cannot match the real-world behavior of employment, and even getting RBC-style shocks to match the behavior of employment during the 1960s and early 1970s requires ignoring the lower-frequency components of the data. It appears that Shimer (2005), Hall (2005), and others might be correct—based on the timing of real-world shocks, it appears that productivity does not drive the majority of postwar business cycles in a labor matching model.

II.E.4 The role of labor market disturbances

The top two panels in Figure II.7 shows the estimated bargaining power and labor supply shifters under the baseline parameterization, expressed as percent deviations from steady state. The data seem to indicate that from the perspective of the labor matching model, large increases in labor's bargaining power η_t occurred during each of the NBER recessions in the sample. The bargaining power shifter does not seem to track the gradual fall in union membership since the 1960s; instead, the estimation procedure treats it more as a generic shock which results in a fall in vacancy creation and somewhat higher wages. The labor supply shifter (the disutility from work A_t) shows far fewer systematic cyclical movements, with most of its movements happening at lower frequencies.

Figure II.12 shows the effects of these shocks. From the perspective of the labor matching model, most of the fluctuations in vacancies and employment appear to come from the labor market shocks. This reflects the fact that exogenous shocks to productivity and monetary policy, when confronted with actual data on employment and output, simply cannot account for most of the employment fluctuations in the postwar period. Figure II.13 shows the effects on employment of these labor market shocks under the RBC calibration. As under the baseline calibration, these shocks basically capture those fluctuations in employment which shocks to productivity and monetary policy cannot explain. That is, shocks which resemble shocks to labor supply and demand drive most postwar cycles.

II.E.5 Fitting the data on job flows and labor's share

Figures II.14 and II.15 depict the performance of the model at matching job flows and labor's share under the baseline and RBC calibrations, respectively. The model matches the other variables, except for inflation, almost exactly, and under the baseline parameterization the labor share is used to identify short-run productivity. The baseline parameterization cannot match the behavior of job flows at all. It gets the low-frequency components of job creation and destruction rates completely wrong. At higher frequencies, fitted separation rates have a correlation of +0.24 with the data, and fitted accession rates have a +0.08 correlation with the data. Under the RBC calibration which ignores lower-frequency movements, these correlations rise to +0.35 and +0.22. In particular, the fitted separation rate is not volatile enough, and it does not track the data well after the early 1980s. The fitted accession rate completely misses the behavior of employment during the 1980s (when manufacturing and the rest of the economy became decoupled), but it shows a more reasonable amount of volatility.

The baseline calibration matches labor's share almost by construction; it uses labor's share to identify the short-run versus long-run productivity shocks. The RBC calibration still does a reasonable job at matching labor's share at high frequencies. The correlation between the fitted and actual data is +0.64, with the fitted series *lagging* the actual series by one quarter with a correlation of +0.70. The data have a standard deviation 1.6 times as large as the fitted series, indicating that the model does not quite deliver enough volatility for labor's share. Nonetheless, it appears that the model goes a long way toward matching the behavior of labor's share in comparison with its frictionless counterparts. It does noticeably worse at matching the timing and magnitude of job flows. The data seem to informally support Krause and Lubik's (2007) contention that real wage rigidity is neither necessary nor particularly useful in explaining the behavior of the real economy since unmeasured wage rigidity would result in the fitted series on labor's share *leading* the actual series.

II.F Conclusion

A recent literature has sprung up devoted to evaluating New Keynesian models using techniques which involve estimating deep parameters and analyzing the types of shocks that these models imply when confronted with data. A New Keynesian model which features labor matching frictions shows mixed results when subjected to a detailed model evaluation. As with much of the New Keynesian paradigm, it appears that monetary policy shocks are not an important component of postwar economic fluctuations, except for the Volcker episode and some possible fluctuations early in the postwar period. Productivity shocks appear to drive the boom of the late 1960s and part of the early-1980s bust, if one is willing to concede that the model cannot match the joint behavior of productivity and employment in the very long run. Neither set of shocks can account for most postwar business cycles. It appears that other shocks to the demand for labor account for the majority of postwar economic fluctuations.

More encouragingly, the model does somewhat well at predicting the behavior of labor's share of output without having to resort to more complicated forms of wage rigidity. The bargaining model seems to tell an economically meaningful story of how productivity shocks may feed through into an attenuated change in wages. The challenge going forward is twofold. First of all, it is necessary to think harder about the relationship between vacancy posting costs and productivity in the long run. Secondly, it seems that the entire family of New Keynesian models suffers from a lack of credible impulses and propagation mechanisms, sticky prices or not. The RBC and New Keynesian revolutions have not yet resulted in a theory which can adequately explain the greater portion of postwar economic fluctuations.

II.G Appendix: Numerical solution to the model

II.G.1 Deriving the steady state from calibrated parameters

The state-space approach requires a specification for the state equation (II.33) 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, taking growth rates into account, is fairly straightforward. Given a nominal interest rate R, a balanced growth rate $\overline{\Gamma}$, a gross inflation rate Π, and a risk aversion parameter σ, it is possible to calibrate the rate of time preference β from equation (II.4) after noting that the costate variable λ grows at rate $\overline{\Gamma}^{-\sigma}$:

$$\beta = \frac{\overline{\Gamma}^{\sigma}\Pi}{R}. \tag{II.A1}$$

In a zero-inflation steady state with a driftless velocity, the money growth rate $\overline{\Theta}$ simply equals the economic growth rate $\overline{\Gamma}$. 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:

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

Given an unemployment rate U and an employment rate $N = 1 - U$ 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 job searchers, the sum of beginning-of-period unemployed plus separations:

$$u = U + \rho N , \tag{II.A3}$$

the number of vacancies from the homogeneous matching function,

$$k^f v = k^w u , \tag{II.A4}$$

and the retention rate:

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

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

$$Q = \frac{(1-\rho)N\left[\int_{\tilde{a}_t}^{\infty} a_i dF(a_i)\right]}{1 - F(\tilde{a})} . \tag{II.A6}$$

If vacancy posting costs as a share of output are given as s_v, this gives values for Y and γ based on the equation for value added:

$$Y = \frac{Q}{1 + s_v} , \tag{II.A7}$$

and

$$\gamma = \frac{Q - Y}{v} . \tag{II.A8}$$

The vacancy posting and continuation value expressions pin down labor's bargaining power at its initial state, solved from the expression:

$$\gamma = \frac{\Theta(1-\rho^x)k^f(1-\eta)}{\mu R^2}\int_{\tilde{a}_i}^{\infty}(a_i - \tilde{a})dF(a_i)\,. \tag{II.A9}$$

This all yields a closed-form expression for q:

$$q = \frac{\gamma(1-\eta k^w)}{(1-\eta)k^f}, \tag{II.A10}$$

and for A:

$$A = q + \frac{\tilde{a}}{\mu R}\,. \tag{II.A11}$$

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

$$Y^{-\sigma} - \lambda = 0\,. \tag{II.A12}$$

The initial value of the velocity does not matter for the calibration of this model.

It is also helpful to have expressions for the wage bill W. It equals wholesale production marked down, minus the wholesale firms' accounting profits. Those profits in turn equal the firm's share of the surplus minus the discounted value of a filled vacancy, since the value of the firm merely equals the present discounted value of profits. To a first order approximation this gives the level of real labor compensation:

$$W_t \approx \frac{Q_t}{\mu_t} - R_t\varphi_t N_t\left((1-\eta_t)s_t - \frac{\gamma\bar{z}_t}{k_t^f}\right), \tag{II.A13}$$

which in steady state yields

$$W = \frac{Q}{\mu} - \varphi NR\left((1-\eta)s - \frac{\gamma}{k^f}\right). \tag{II.A14}$$

Equations (II.A1) through (II.A14) describe the relationships among the different parameters and steady state ratios in this model. The model is then linearized around this steady state using the numerical values obtained from the calibration.

II.G.2 Linearization around the steady state

Given a calibration and its implied steady state, it is possible to linearize the system around that steady state. This approximates the laws of motion of the system in the region of the initial conditions. In general, because of the driving processes, the system will exhibit a considerable degree of persistence and volatility. The particular model, calibration, and linearization used here rule out transitions between steady states, sunspots, or other forms of indeterminacy. These individual equations are assembled into a matrix of difference equations which yield a reduced-rank stable VAR.

Linearizing the cash-in-advance constraint in first differences obtains the stochastic money demand relation:

$$\hat{\pi}_t + \hat{y}_t - \hat{\Theta}_t - \hat{V}_t = \hat{y}_{t-1} - \hat{V}_{t-1} \ . \qquad \text{(II.A15)}$$

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

$$\hat{n}_{t+1} = \varphi\hat{n}_t + \varphi\hat{\varphi}_t + \left(\frac{vk^f}{N}\right)\hat{v}_t + \left(\frac{vk^f}{N}\right)\hat{k}_t^f \ . \qquad \text{(II.A16)}$$

The endogenous job destruction margin comes next:

$$\hat{a}_t = \hat{r}_t + \hat{\mu}_t - \hat{z}_t - \left(1 - \frac{A\mu R}{\tilde{a}}\right)\hat{\hat{z}}_t - \left(\frac{\mu Rq}{\tilde{a}}\right)\hat{q}_t + \left(\frac{A\mu R}{\tilde{a}}\right)\hat{A}_t, \qquad \text{(II.A17)}$$

followed by an expression for the job retention rate:

$$\hat{\varphi}_t = -\left(\frac{\rho^n}{1-\rho^n}\right)e_{Fa}\hat{a}_t, \qquad \text{(II.A18)}$$

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

$$\hat{u}_t = -\left(\frac{\varphi N}{u}\right)\hat{\varphi}_t - \left(\frac{\varphi N}{u}\right)\hat{n}_t. \qquad \text{(II.A19)}$$

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

$$\hat{k}_t^f = a\hat{u}_t - a\hat{v}_t, \qquad \text{(II.A20)}$$

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

$$\hat{k}_t^f + \hat{v}_t = \hat{k}_t^w + \hat{u}_t. \qquad \text{(II.A21)}$$

Linearizing the job posting condition yields:

$$\hat{k}_t^f + \hat{q}_t = \hat{\hat{z}}_t - \frac{\eta k^w}{1-\eta k^w}\hat{k}_t^w + \left(\frac{\eta}{1-\eta} - \frac{\eta k^w}{1-\eta k^w}\right)E_t\hat{\eta}_{t+1}. \qquad \text{(II.A22)}$$

Linearizing the output equation yields:

$$\hat{y}_t = \left(\frac{Q}{Y}\right)(e_{Ha}\hat{a}_t + \hat{\varphi}_t + \hat{n}_t + \hat{z}_t + \hat{\hat{z}}_t) - \left(\frac{\gamma v}{Y}\right)(\hat{v}_t + \hat{\hat{z}}_t), \qquad \text{(II.A23)}$$

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:

$$\hat{\lambda}_t = \hat{r}_t + E_t\hat{\lambda}_{t+1} - E_t\hat{\pi}_{t+1}, \qquad \text{(II.A24)}$$

and the first-order condition for consumption yields the usual marginal utility expression:

$$-\sigma Y^{-\sigma}\hat{y}_t - \lambda\hat{\lambda}_t = 0. \qquad \text{(II.A25)}$$

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

$$\frac{\omega}{R}E_t\hat{\pi}_{t+1} = \omega\hat{\pi}_t + (1-\omega)\left(1-\frac{\omega}{R}\right)\hat{\mu}_t. \qquad \text{(II.A26)}$$

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

$$\hat{q}_t = E_t\hat{\varphi}_{t+1} - \hat{r}_t + E_t\hat{\pi}_{t+1} - \frac{\eta k^w}{1-\eta k^w}\left(\hat{k}_t^w + E_t\hat{\eta}_{t+1}\right) + E_t\hat{s}_{t+1}. \qquad \text{(II.A27)}$$

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

$$s\hat{s}_t = \frac{Q}{\varphi N\mu R}\left(\frac{Y}{Q}\hat{y}_t + \frac{\gamma v}{Q}\left(\hat{v}_t + \hat{\bar{z}}_t\right) - \hat{\varphi}_t - \hat{n}_t - \hat{\mu}_t - \hat{r}_t\right) - A(\hat{A}_t + \hat{\bar{z}}_t) + q\hat{q}_t,$$

or

$$s\hat{s}_t = -\frac{Q}{\varphi N\mu R}(\hat{\varphi}_t + \hat{n}_t + \hat{\mu}_t + \hat{r}_t) + \frac{Y}{\varphi N\mu R}\hat{y}_t$$
$$+\frac{\gamma v}{\varphi N\mu R}\hat{v}_t + \left(\frac{\gamma v}{\varphi N\mu R} - A\right)\hat{\bar{z}}_t - A\hat{A}_t + q\hat{q}_t \quad , \qquad \text{(II.A28)}$$

and of labor's earnings:

$$W\hat{w}_t = \frac{Y}{\mu}\hat{y}_t + \frac{\gamma v}{\mu}\hat{v}_t - \frac{Q}{\mu}\hat{\mu}_t - \varphi NR(1-\eta)s\hat{s}_t$$
$$-\varphi NR\left((1-\eta)s - \frac{\gamma}{k^f}\right)(\hat{\varphi}_t + \hat{n}_t + \hat{r}_t) + \varphi NRs\eta\hat{\eta}_t$$
$$+\left(\frac{\varphi NR\gamma}{k^f} + \frac{\gamma v}{\mu}\right)\hat{\bar{z}}_t - \frac{\varphi NR\gamma}{k^f}\hat{k}_t^f . \quad \text{(II.A29)}$$

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

$$\hat{\pi}_t^* = \rho_{\pi^*}\hat{\pi}_t^* + \varepsilon_t^{\pi^*} , \quad \text{(II.A30)}$$

$$\hat{z}_t = \rho_z \hat{z}_{t-1} + \varepsilon_t^z , \quad \text{(II.A31)}$$

$$\hat{\bar{z}}_t = \rho_{\bar{z}} \hat{\bar{z}}_{t-1} + \varepsilon_t^{\bar{z}} , \quad \text{(II.A32)}$$

$$\hat{V}_t = \rho_V \hat{V}_{t-1} + \varepsilon_t^V , \quad \text{(II.A33)}$$

$$\hat{\eta}_t = \rho_\eta \hat{\eta}_{t-1} + \varepsilon_t^V , \quad \text{(II.A34)}$$

$$\hat{A}_t = \rho_A \hat{A}_{t-1} + \varepsilon_t^A , \quad \text{(II.A35)}$$

and the Taylor rule:

$$\hat{r}_t - \hat{\pi}_t^* = \rho_r(\hat{r}_{t-1} - \hat{\pi}_t^*) + \rho_\pi(\hat{\pi}_t - \hat{\pi}_t^*)$$
$$+ \rho_{EMPL}(\hat{n}_t - \hat{n}_{t-1}) + \varepsilon_t^r . \quad \text{(II.A36)}$$

These twenty-two linearized equations in twenty-two unknowns uniquely determine the dynamics of the system in the vicinity of the steady state for the calibrated parameter values chosen. It is possible to solve for the rational expectations equilibrium of this system using the methodology and code provided by Sims (2002), who implements a robust version of the Blanchard-Kahn (1980) solution method. The end result is a reduced-rank VAR representation that provides the laws of motion for the underlying system in the form of equation (II.34) in the state-observer setup.

II.H Tables and figures

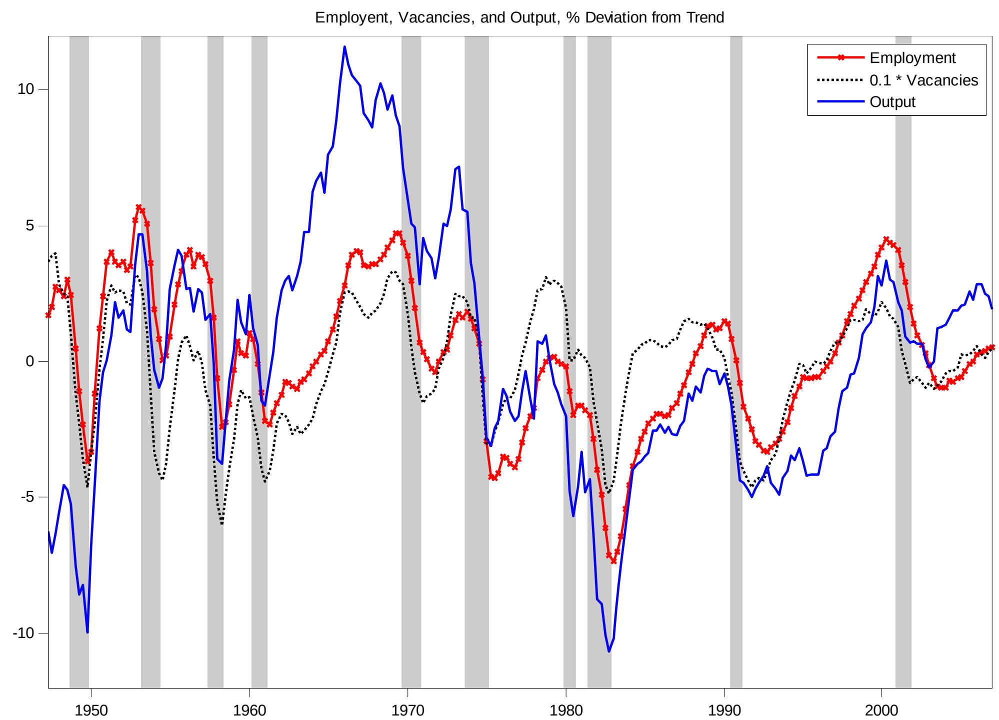

Figure II.1: Real GDP, vacancies, and nonfarm employment (% deviation from trend). Source: NIPA, CES, and adjusted Conference Board / Met Life Help Wanted Index.

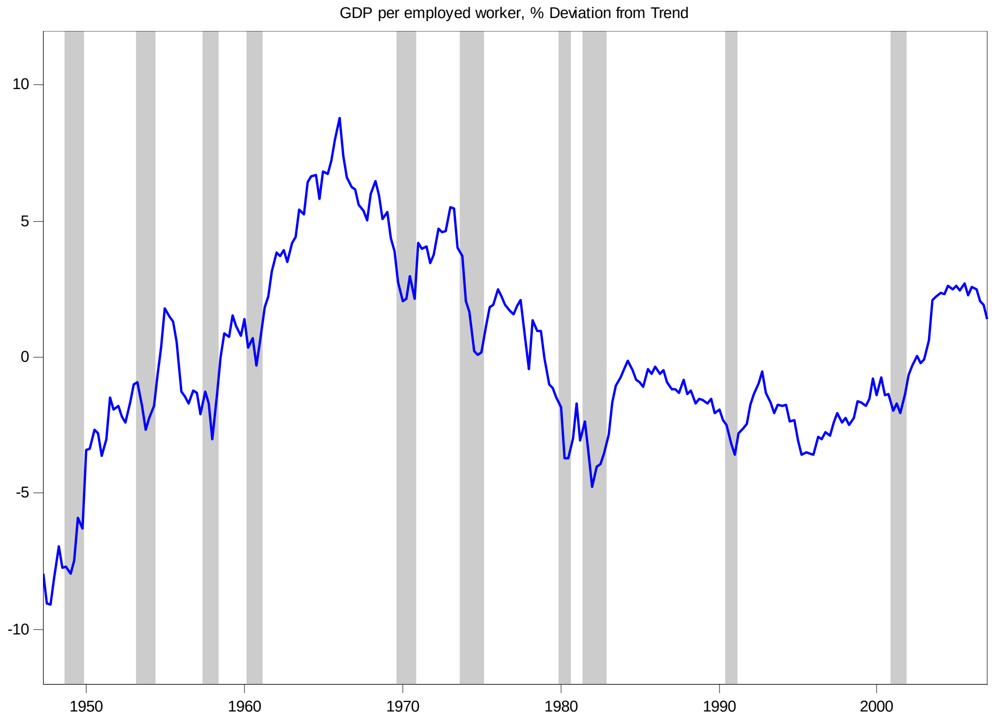

Figure II.2: Real GDP per worker (% deviation from trend).
Source: NIPA and CES. This series is the difference of the two series in Figure II.1.

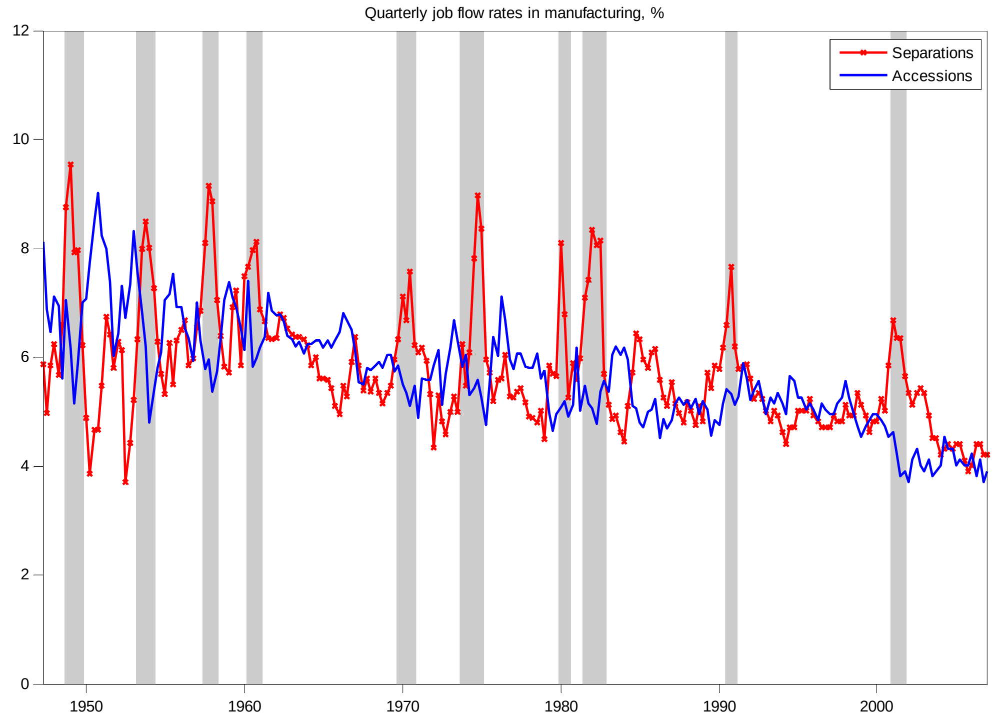

Figure II.3: Job flow rates in manufacturing (% quarterly).
Source: Faberman (2006), supplemented with revised BED data.

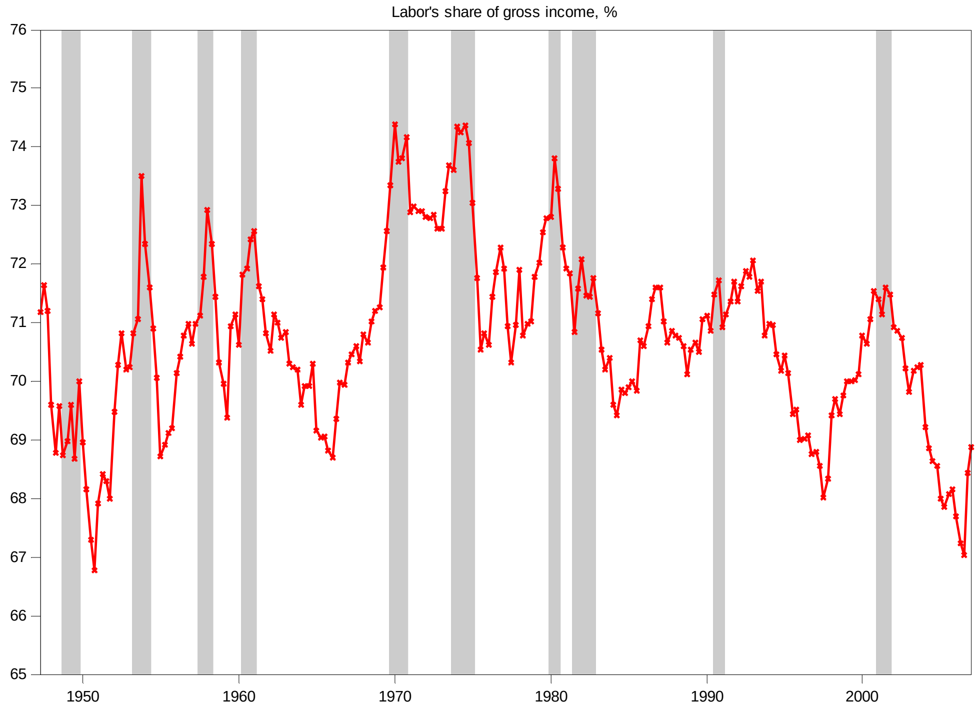

Figure II.4: Labor's share of corporate gross income (%).
Source: NIPA.

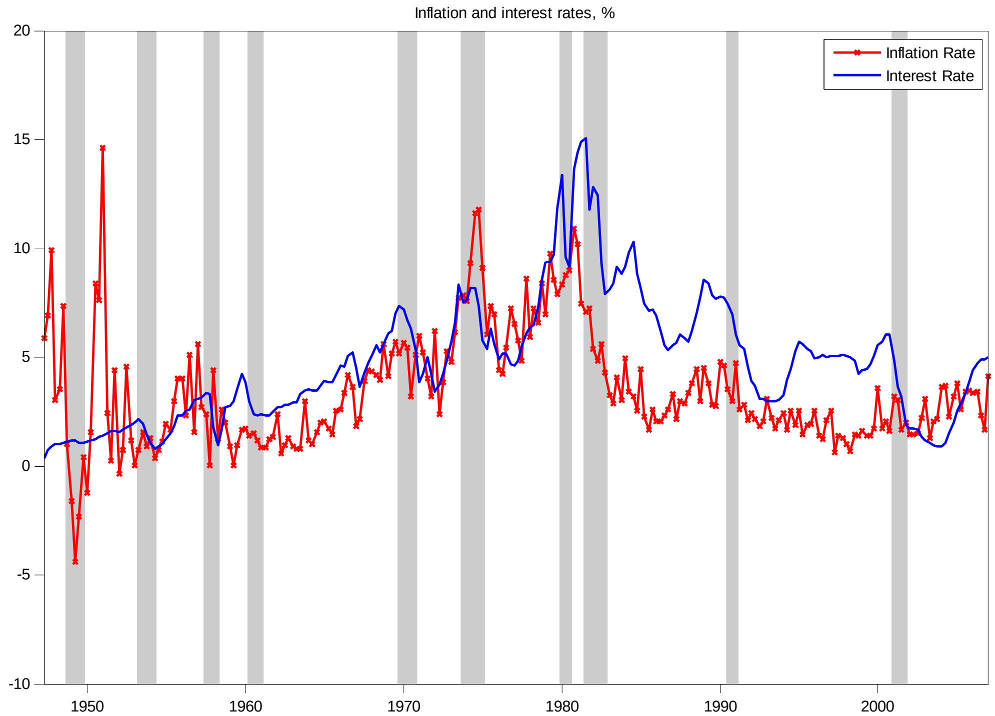

Figure II.5: Inflation and nominal interest rates (% annual).
Source: NIPA and St. Louis Fed (FRED).

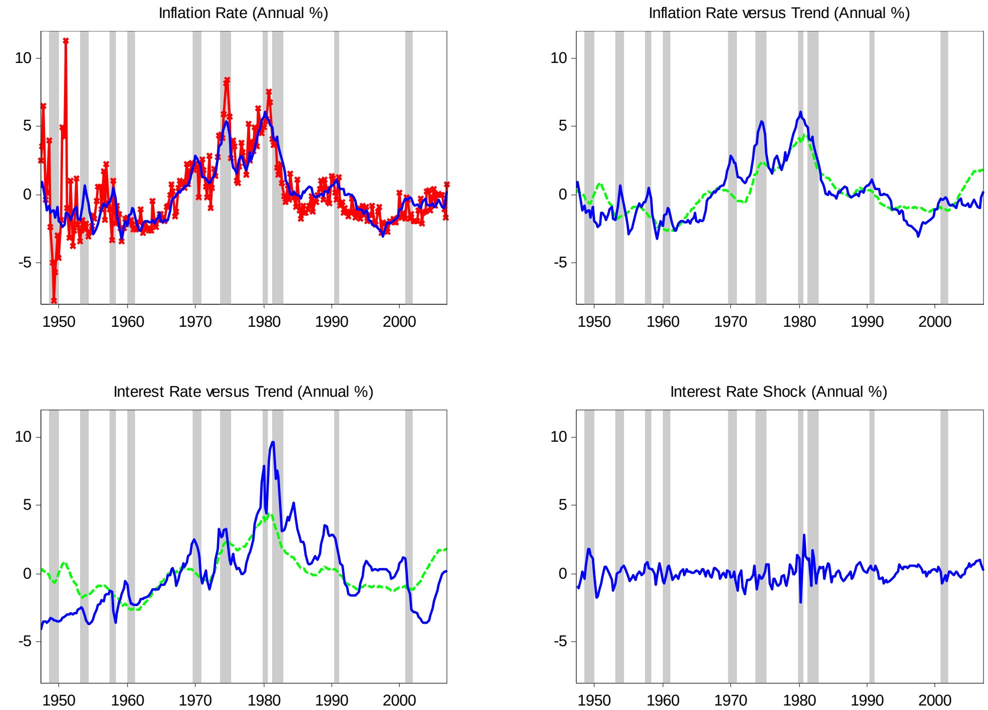

Figure II.6: Estimated nominal driving processes (% deviation) – Baseline. Observed inflation is shown in red; trend inflation is shown in green. Gray bars indicate recessions.

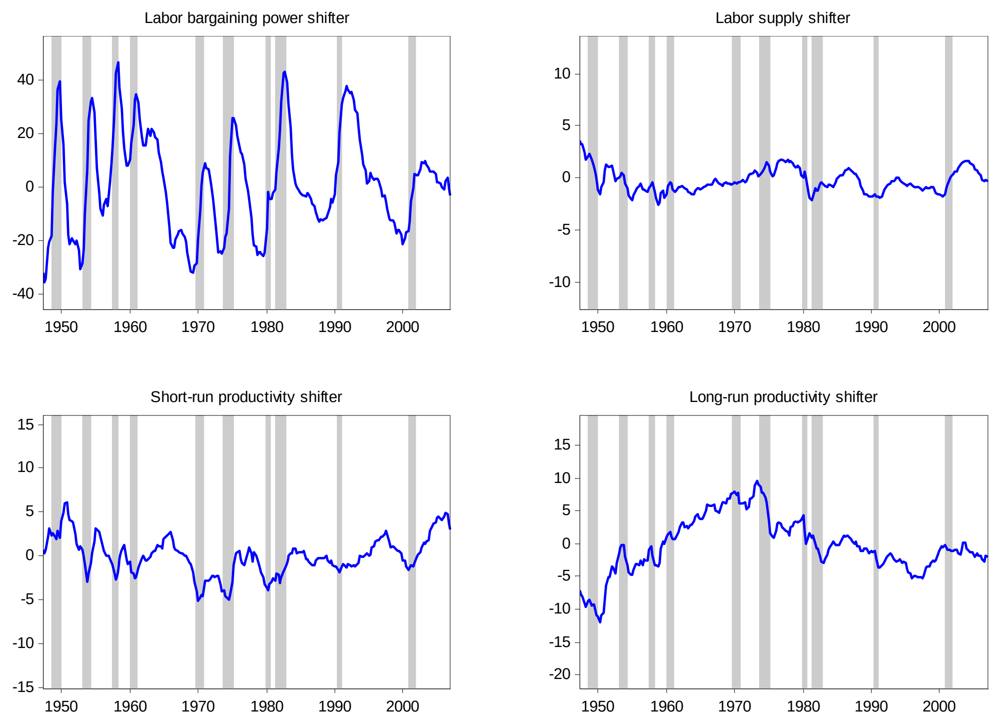

Figure II.7: Estimated real driving processes (% deviation) – Baseline. The solid blue lines show the filtered estimates. Gray bars indicate recessions.

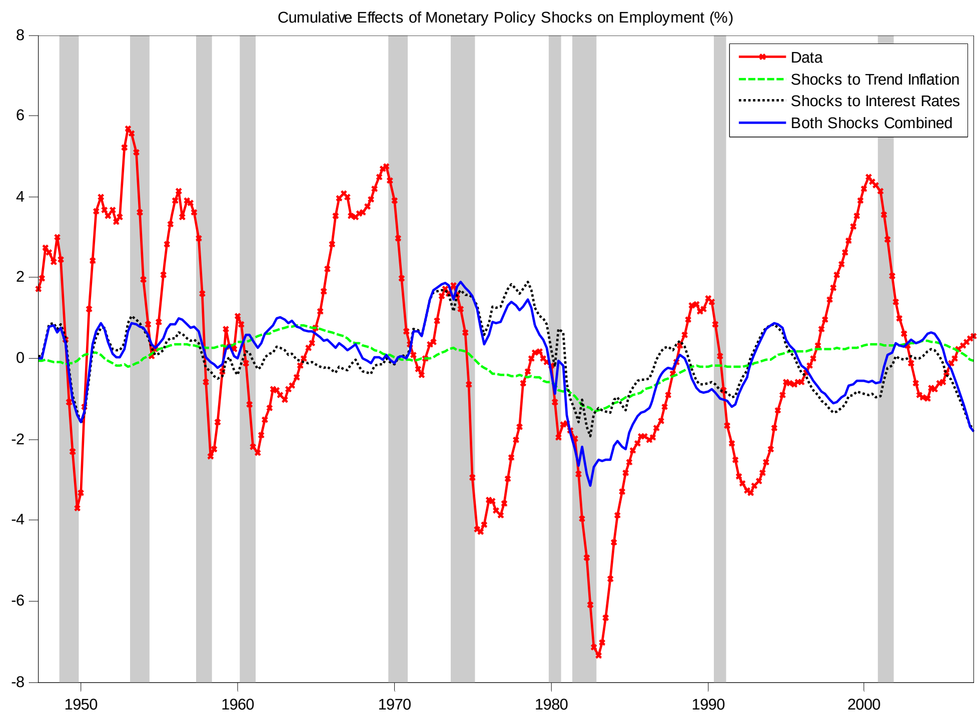

Figure II.8: Estimated real effects of monetary policy shocks – Baseline. The red line depicts detrended employment (not HP filtered). Gray bars indicate recessions.

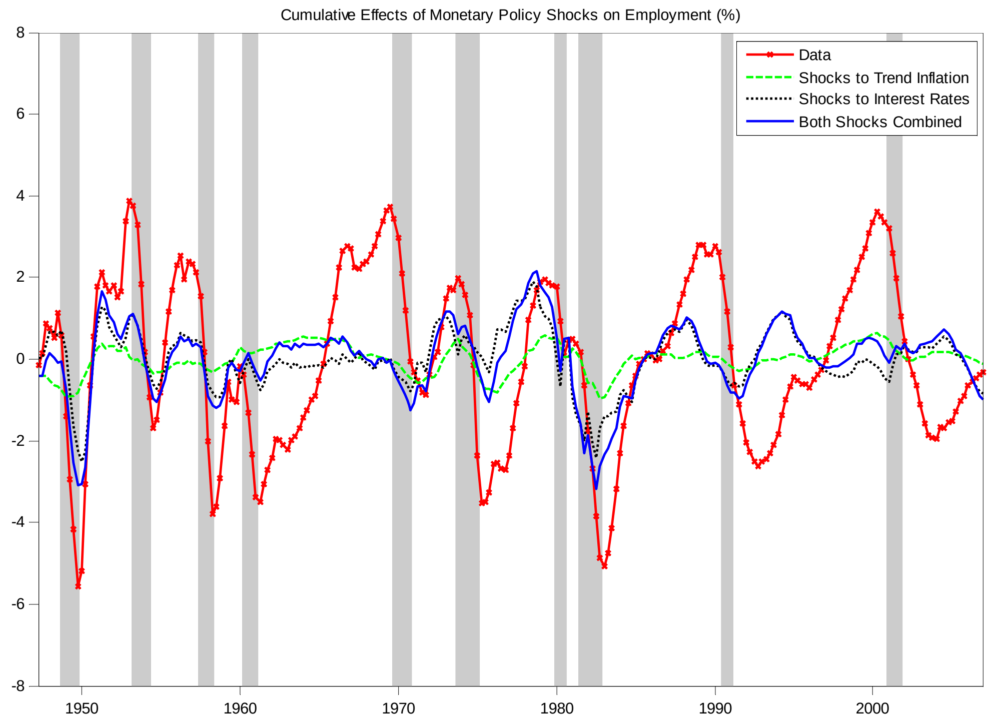

Figure II.9: Estimated real effects of monetary policy shocks – RBC calibration. The red line depicts detrended employment (HP filtered, λ = 100,000). Gray bars indicate recessions.

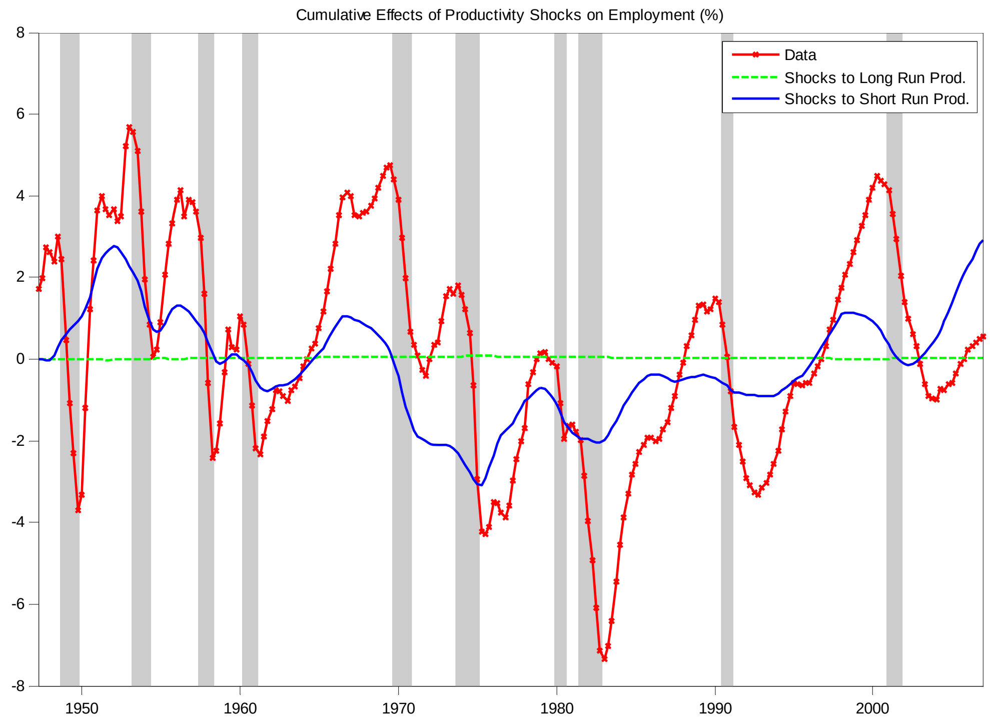

Figure II.10: Estimated real effects of productivity shocks – Baseline. The red line depicts detrended employment (not HP filtered). Gray bars indicate recessions.

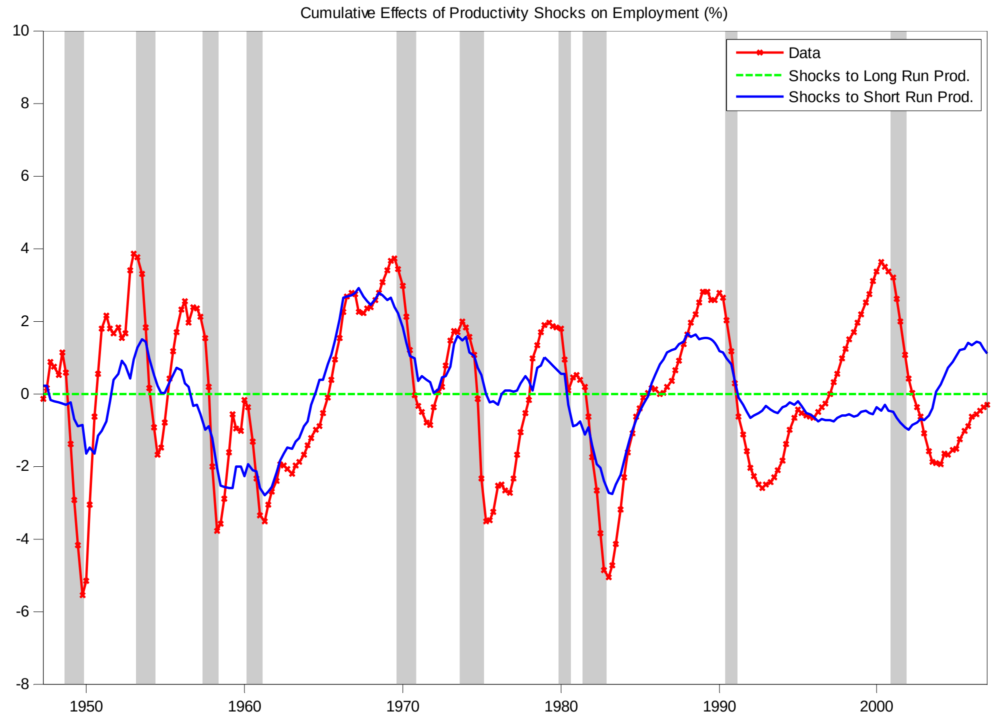

Figure II.11: Estimated real effects of productivity shocks – RBC calibration. The red line depicts detrended employment (HP filtered, λ = 100,000). Gray bars indicate recessions.

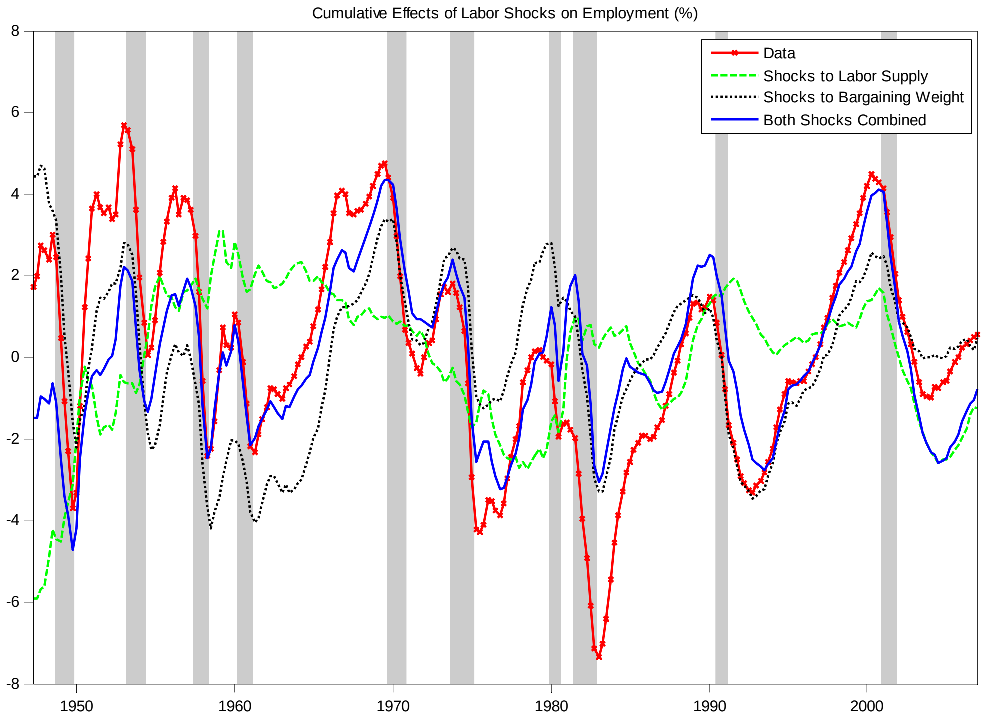

Figure II.12: Estimated real effects of labor market shocks – Baseline. The red line depicts detrended employment (not HP filtered). Gray bars indicate recessions.

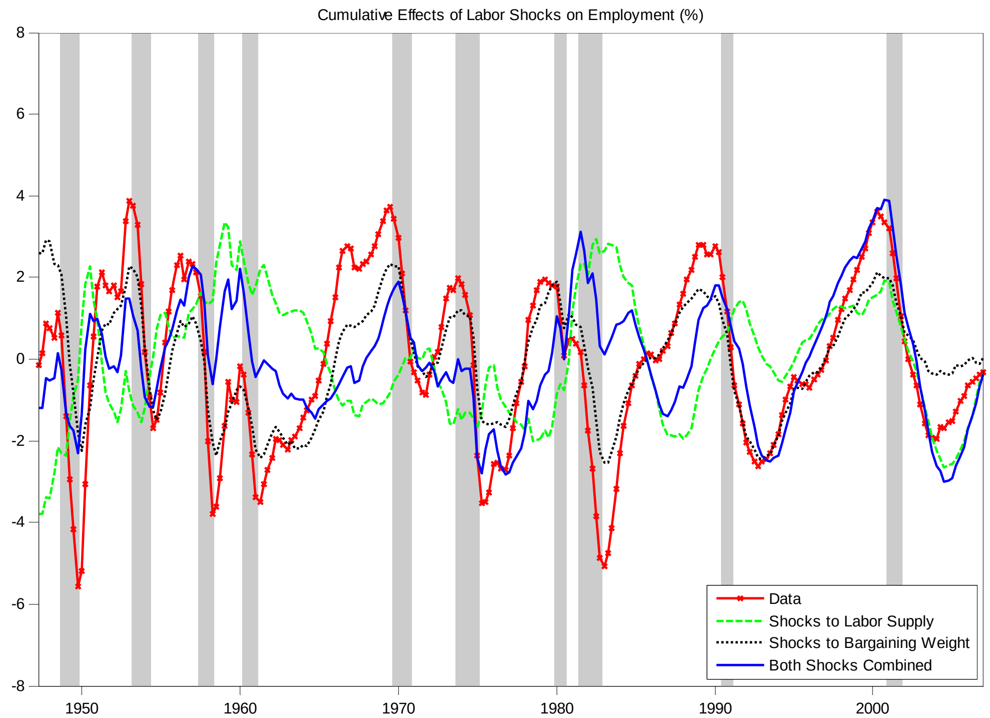

Figure II.13: Estimated real effects of labor market shocks – RBC calibration. The red line depicts detrended employment (HP filtered, $\lambda = 100{,}000$). Gray bars indicate recessions.

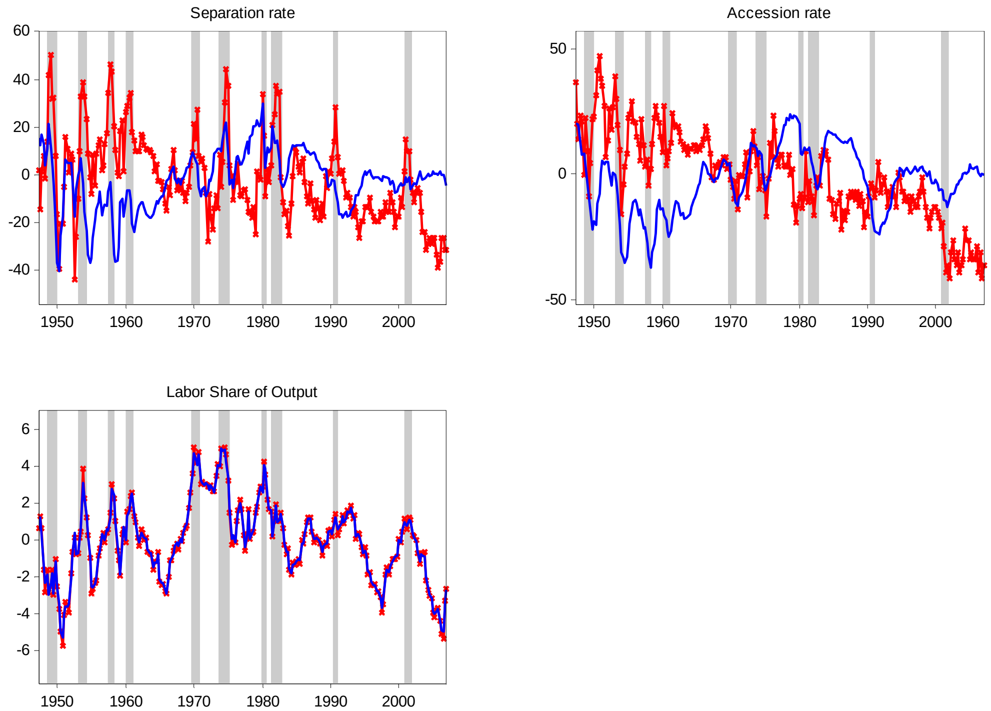

Figure II.14: Filtered versus actual job flows and labor share (% deviation) – Baseline. The red lines depict detrended raw data (not filtered), and blue lines show filtered data. Gray bars indicate recessions.

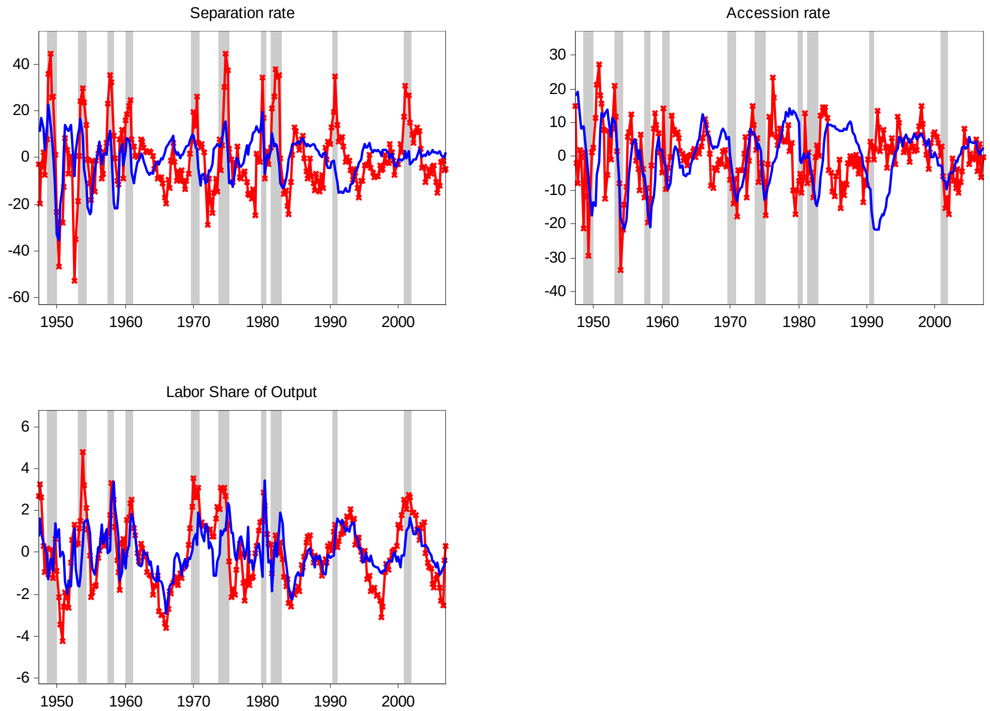

Figure II.15: Filtered versus actual job flows and labor share (% deviation) – RBC calibration. The red lines depict detrended raw data (HP filtered, λ = 100,000), and blue lines show filtered data. Gray bars indicate recessions.

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III Fiscal Policy Rules in the Postwar United States

III.A Introduction

In the period since Taylor (1993) formulated a reduced-form rule relating the Fed's interest rate target to output and inflation, the relationship between systematic monetary policy and economic performance has fueled a large amount of discussion. Much less discussion has gone into evaluating the effects of systematic fiscal policy for a number of reasons. For one thing, fiscal policymakers do not have a single instrument like the Fed Funds Rate or the growth rate of outside money to target. They can adjust purchases, transfer payments, and tax rates, or they can issue money in response to short-run conditions. In this sense, deficits are an accounting identity, not a control variable. Secondly, fiscal authorities must take their intertemporal budget constraint into account, in a way that monetary authorities do not have to.[24] Fiscal authorities must fashion their policy so that the debt-GDP ratio does not explode while attempting to smooth out transitory fluctuations in the economy. A satisfactory analysis of reduced-form fiscal feedback functions will therefore necessarily account for long-run fiscal imbalances in addition to short-run cyclical conditions.

[24] Sargent and Wallace (1981) and Leeper (1991) show the potential importance of fiscal responses to debt in determining the interactions between monetary and fiscal policy. Woodford (2001) and Benigno and Woodford (2006) provide good discussions of current thinking on the subject. Bohn (1992) shows how an optimizing government might reduce spending in response to fiscal imbalances, and how this might induce violations of Ricardian equivalence among consumers and investors.

The analysis proceeds in two parts. The first part lays out a general fiscal response function in a nonstationary context, relating fiscal Taylor rules to the more general fiscal response function. The second part presents estimates of this multivariate fiscal Taylor rule using quarterly data covering the entire government sector of the United States from 1952 through 2006. These estimates quantify the degree to which fiscal authorities have adjusted their behavior in order to stabilize the debt-GDP ratio, using a growth-adjusted deficit measure derived from the government's balance sheet. The estimation strategy takes the nonstationarity of the individual fiscal variables into account. In doing so, the results mostly confirm conventional wisdom, with the added finding that the government sector appears reluctant to stabilize the deficit by adjusting transfer payments.

First of all, the major instruments of fiscal policy have responded exactly as expected in response to cyclical conditions. Government purchases rise slightly as a share of GDP when unemployment rises. Transfers as a share of GDP increase strongly with increases in unemployment. Taxes as a share of GDP fall strongly. By contrast, the major instruments of fiscal policy have responded sluggishly to fiscal imbalances. When fiscal adjustment has finally occurred, government purchases have played a surprisingly large role in that adjustment, with taxes playing a somewhat smaller role. Transfers have performed little if any role in fiscal adjustment. The findings regarding taxes and government spending reflect previous findings from the literature on vector error correction models (VECMs), but the finding regarding transfers is a new result.

The sample at hand also indicates that fiscal authorities have not behaved in a consistent manner over time, as Crowder (1997) has suggested. For the full sample, counterfactually holding unemployment and growth-adjusted interest constant, the fiscal Taylor rule suggests that primary *deficits* have had a quarterly persistence of about 96.2 percent. That is, structural fiscal imbalances have appeared, on average, to have a half life of a little bit less than five years. Since the 1981 tax cuts, however, this quarterly persistence has increased to over 99 percent, and it is in fact statistically impossible to distinguish the observed fiscal policy since that date from one that does not directly seek to stabilize the debt-GDP ratio at all. Fiscal policy has apparently become much more active and much less responsive to debt, so that a chart of the debt-GDP ratio since 1981 even looks dramatically different from its predecessor to the naked eye.

In short, a proper estimation of fiscal response functions for the United States shows a conventional fiscal response to cyclical and fiscal imbalances, with two important qualifications. Adjustments to government purchases perform a large role alongside taxes in fiscal stabilization, while transfer payments perform a tiny role in stabilization. Models that rely purely on taxes to perform fiscal adjustment therefore miss out on an important feedback mechanism from fiscal conditions into the real economy. Also in accordance with views commonly held by the public, fiscal policy has become much less focused on fiscal stabilization since the late 1970s and early 1980s. Interestingly, fiscal policy has appeared to move away from debt stabilization at about the same time that the Federal Reserve moved toward inflation stabilization.

III.B Previous literature

Previous estimates of fiscal responses for the United States have taken two main forms—simple fiscal Taylor rules and vector error correction models (or VECMs). Taylor (2000), in applying his name to fiscal rules, models fiscal deficits as a structural component plus a systematic response to cyclical conditions. He estimates a response of the federal deficit-GDP ratio to a measure of an output gap, as a percent of GDP, of about 0.5. He does not include a response of fiscal variables to fiscal imbalances in his estimates. Galí and Perotti (2003) and Claeys (2006) estimate univariate fiscal policy rules for the United States—they find evidence of sluggish fiscal adjustment and of lower responses of deficits to output than Taylor. Favero and Monacelli (2005) estimate a fiscal rule in a regime-switching framework, relating U.S. federal deficits to an output gap and the *level* of the debt-GDP ratio. They find little evidence of deliberate debt stabilization at most times by fiscal authorities. Their only estimated episodes of fiscal stabilization appear in 1975 during the Ford tax cuts and from 1995 through 2001. They do not find evidence of a sustained change in fiscal policy throughout their sample. They use a strong notion of fiscal sustainability under which fiscal stabilization implies a stationary debt-GDP ratio.

Another take on the issue of fiscal responses, which allows for nonstationarity, involves the formulation and estimation of vector error correction models (VECMs). Fiscal VECMs are basically vector autoregressions of nonstationary fiscal and economic variables, in first differences, with an additional term on the right hand side reflecting a stationary deficit-GDP ratio (but a nonstationary debt-GDP ratio).[25] Unlike reduced form fiscal rules, VECMs take the nonstationary time-series behavior of individual deficit components and of the debt into account. Using this approach, Bohn (1991, 1998, and 2005) documents continual fiscal stabilization efforts throughout the history of the United States. Crowder (1997) estimates a small-scale error correction model for the United States federal government using postwar data and finds evidence of a regime shift sometime late in the 1970s or early in the 1980s.

Bohn and Crowder both find that broad categories of government expenditures perform much of the adjustment necessary to keep the public debt-GDP ratio from exploding, with taxes doing less of the adjustment. Crowder also documents a change in fiscal policy away from fiscal stabilization toward the late 1970s or early 1980s. More recently, Favero and Giavazzi (2007) set up and estimate something like a vector error correction model augmented by output in response to Blanchard and Perotti (2002) and Perotti's (2005) use of vector autoregressions to estimate the dynamic effects of innovations to government spending and taxes. Favero and Giavazzi recommend using a model with explicit responses to *levels* of the debt-GDP ratio instead—their model is basically a VAR with an extra debt variable on the right-hand side. That is, Favero and Giavazzi assume the debt-GDP ratio to be stationary in levels rather than difference-stationary. They get the exact opposite results from Crowder. As it happens, a fiscal Taylor rule which takes proper account of

[25] In the language of time series econometrics, this is appropriate when individual deficit components such as taxes and spending as a share of GDP are nonstationary but cointegrated.

nonstationarity delivers conclusions more like those of Bohn and Crowder and less like those of Favero et al.

III.C The data: Debt, revenues, and expenditures

The National Income and Product Accounts contain quarterly data, dating from 1947, on revenues and expenditures by category for the entire government sector of the United States. This allows one to properly construct series for government consumption and investment purchases, net transfer payments, and revenues. The Flow of Funds Accounts contain seasonally adjusted quarterly information on the financial assets and liabilities for the entire government sector plus the stock of outside money, dating from 1952 at a quarterly frequency and 1945 at an annual frequency. The analysis will cover the behavior of five aggregate fiscal variables as a share of GDP: Growth-adjusted interest on the net public debt, government purchases (net of consumption of fixed capital), net transfer payments, net revenues, and the creation of outside money.[26] The series on the five fiscal variables, debt, and outside money are constructed in such a way that the change in net liabilities equals implicit interest plus purchases and transfers, minus tax revenues and seigniorage. Quarterly net liabilities data are constructed using end-of-year balances adjusted for intervening flows.

[26] The Flow of Funds Accounts contain the data on the par value of the government's financial assets and liabilities used here. The Dallas Fed publishes figures for the market value of the federal debt. They track each other closely, with deviations primarily reflecting swings in long-run nominal interest rates. Hamilton and Flavin (1986), for instance, use the market value of the federal debt in their analysis. For coverage reasons, the estimates in this paper use par values.

Figure III.1 displays the resulting end-of-period quarterly net liabilities-GDP ratio from the first quarter of 1947 through the fourth quarter of 2006. It also displays the ratio of the stock of outside money to GDP and the resulting net debt-GDP ratio from the first quarter of 1952 through the fourth quarter of 2006. The fiscal picture for the government sector of the United States primarily follows the conventional story of the federal debt. First of all, the net liabilities and debt of the government sector as a share of GDP decreased rather steadily from the end of World War II through the 1970s, with notable exceptions during the Korean War and most recessions. Both ratios then rose fairly strongly from the early 1980s through the early 1990s, with the debt-GDP ratio reaching a peak of about 48% at the end of 1993. It fell to just under 29% by the third quarter of 2001. By the end of the sample at the end of 2006, the debt-GDP ratio appeared to stabilize at about 36%.

Figure III.2 shows the values of the implicit interest expense, government purchases, transfer payments, revenue, and seigniorage scaled by GDP at a quarterly frequency. The implicit interest expense equals the residual change in the net debt-GDP ratio after taking the other non-interest expenditure and revenue items into account. Implicit interest has averaged about -0.03% of GDP throughout the sample, indicating that economic growth has equaled or slightly exceeded the interest payments on government debt. Government purchases spiked upward during the Korean War and have shown a downward trend since then as defense spending has gradually shrunken as a share of GDP. A rise in transfers has more than made up for the fall in government consumption and investment purchases, with notably large fluctuations during recessions and during the welfare state expansions of the late 1960s and early 1970s.

Figure III.3 shows the effect of adjusting government deficits for growth—that is, taking the first difference of the debt-GDP ratio rather than taking the first difference of nominal debt and then scaling it by GDP as done conventionally. The growth-adjusted deficit measure lies well below the growth-unadjusted measure. The difference primarily reflects the treatment of interest payments. The conventional measure uses nominal interest payments to measure the interest expense paid by the government sector on its debt. The adjusted measure subtracts a "growth dividend" which, on average, cancels out the nominal interest expense. Bohn (2005) finds a similar result throughout the entire history of the United States at the federal level. Properly adjusting for nominal growth removes the illusory "deficit bias" from most of the post-World-War-II data.

With respect to time series properties, it appears that the series for government purchases, transfers, and revenues are not individually stationary—purchases seem to have drifted downward throughout the sample, while transfers and taxes have both drifted upward. Bohn (1998, 2005) shows that standard time-series methods cannot reject a unit root in the debt-GDP ratio. He finds substantial evidence of deliberate fiscal stabilization when this nonstationarity is properly taken into account. That is, he finds that *changes* in the debt-GDP ratio, or growth-adjusted deficits, appear to be stationary and well-behaved. Nonstationary deficit components and debt, accompanied by stationary deficits, imply cointegration and error correction. If deficits become too large or small, fiscal authorities will slowly adjust fiscal variables to bring the growth-adjusted budget back into balance. In essence, one can think of fiscal responses as the systematic actions taken by the government sector, in the aggregate, to maintain a nonexplosive debt-GDP ratio in the presence of ongoing changes in fiscal and economic conditions.

III.D Sustainability, error correction, and Taylor Rules

III.D.1 Fiscal responses and sustainability

The definition of sustainability used here is a fairly loose one. Much of the original time-series literature on fiscal sustainability, such as Hamilton and Flavin (1986), formulates and develops tests for the stationarity of the federal debt-GDP ratio ("strong sustainability"). Trehan and Walsh (1991) show that a *difference*-stationary debt-GDP ratio satisfies a form of sustainability ("weak sustainability") that still respects the government's budget constraint. Bohn (2007) extends this line of thought to its logical conclusion and shows that a debt-GDP ratio integrated of any finite order satisfies the budget constraint, and that revenues and spending do not even need to be cointegrated ("absurdly weak sustainability"). As a result, given a finite-length sample, one cannot ever truly test for fiscal sustainability. In practice, Bohn's result simply means that one must not confuse sufficient conditions for sustainability with necessary ones, and that the time-series properties of the underlying processes for spending and revenues matter when estimating feedback functions. Keeping Bohn's critique in mind, this paper will assume weak sustainability since there is not much evidence that the debt-GDP ratio is integrated of any order greater than one.

To put the notion of systematic fiscal policy into a concrete context, one might model fiscal policy and economic feedbacks as a fiscal response function embodying a systematic response of fiscal and other economic variables to debt and to cyclical conditions. A general fiscal response function might involve responses to lags of debt and cyclical conditions as well, since it takes Congress and state legislatures time to issue legislation or to respond to fiscal imbalances. In such a case, the fiscal response might take the form

$$x_t = \alpha_b(L)b_t + \alpha_u(L)u_t + \varepsilon_t, \qquad \text{(III.1)}$$

where x_t represents the fiscal variables stacked into a vector; u_t equals the unemployment rate; and b_t equals the debt-GDP ratio. The exogenous process ε_t is integrated of a finite order and may have some dynamics associated with it. The response coefficients $\alpha_b(L)$ and $\alpha_u(L)$ take the form of lag polynomials and represent the explicit structural response of fiscal policymakers to current and previous values of the debt-GDP ratio and unemployment rate. In general, if the exogenous process governing fiscal policy has dynamics associated with it, it is not possible to estimate these objects without making further restrictions. The entire system has a reduced-form VECM representation and it is possible to estimate impulse responses.[27]

[27] Hamilton (1994) goes through the algebra which follows after taking the fiscal rule in first differences and substituting the budget constraint in the form $\Delta b_t = mx_t$.

Without further restrictions on the dynamics, though, it is not possible to estimate the structural feedback coefficients.

In the absence of explicit feedback rules, fiscal policy would follow the process ε_t which is exogenous to the system. For instance, changes in demographics affect the politics of transfer payments—with rising numbers of elderly voters, expansions of Social Security and Medicare tend to follow. International events such as the Soviet invasion of Afghanistan in 1979 or the Vietnam escalation in 1965 initiated long periods of relatively high levels of government purchases. Political events such as the California property tax revolt or the divisions between the executive branch and Congress in the late 1990s (or the end of that situation in early 2001) represent independent shocks to taxes.[28] These shocks have dynamics of their own—the post-1979 military buildup did not fully play out until the mid-1980s but much of it was forecastable. Demographic and political considerations regarding transfer payments and taxes—the percentage of the population over 65 or with children in school, for instance—may show some dynamics as well.

Formulated this way, statements about fiscal stability are actually statements about the joint behavior of fiscal and economic variables as expressed by the budget constraint and fiscal response function. Debt is nothing more or less than the sum of past deficits, properly scaled. What determines the stability or instability of debt is precisely the total feedback effect that debt has upon the individual elements of x_t. Insofar as the fiscal variables themselves are concerned, if policy acts in such a

[28] Romer and Romer (2007), for instance, document a number of large, discontinuous changes in the tax code that correspond with well-known political events.

manner as to reduce deficits in response to a rise in debt, then this satisfies weak sustainability. In this sense, fiscal response functions capture the government's deliberate response to fiscal conditions undertaken in order to keep the debt-GDP ratio from exploding.

III.D.2 Fiscal Taylor Rules

Assuming no dynamics for ε_t and no delays in fiscal responses to debt or unemployment, it is possible to estimate a fiscal response function such as (III.1) rather easily. It is necessary to take the possible endogeneity of current-period unemployment into account, but apart from that, it means that taking first differences of (III.1) will yield a simple estimation problem. Since levels of debt and their lags are predetermined at time *t*, past deficits can instrument for themselves. Since unemployment may be stationary, past levels and changes in unemployment provide additional valid and relevant instruments for current-period changes in unemployment.

As a result, for each fiscal variable of interest, estimating a fiscal Taylor rule boils down to estimating individual rows of the expression

$$\Delta x_{it} = \mu + \alpha_{bi}\Delta b_t + \alpha_{ui}\Delta u_t + \eta_{it}\,. \qquad \text{(III.2)}$$

Estimates of the fiscal Taylor rule deliver a rough idea of the response of individual fiscal variables to fiscal and cyclical conditions. To the extent that budget deficits are highly autocorrelated, it does not matter much whether the government responds to current debt or debt with a slight lag. If the government makes fiscal projections and preemptively adjusts spending or taxes to take possible imbalances into account, using current debt might even yield better estimates than using lagged debt.

Taking a fiscal Taylor rule in first differences, so long as the omitted dynamics do not cause much of a problem, can therefore provide consistent estimates of the response of different fiscal variables to fiscal and economic conditions. Because of the inclusion of both a fiscal and a cyclical indicator, the coefficient on changes in debt will capture the response of individual policy categories to long-term fiscal imbalances, while the coefficient on unemployment will capture those short-term imbalances attributable to business cycle conditions. A fiscal Taylor rule does not represent a complete model of debt and deficit dynamics with which to estimate impulse responses—for this, a larger-scale model like a VECM is necessary. Nonetheless, it gives a good indication about how fiscal authorities adjust fiscal variables in response to fiscal imbalances and cyclical conditions.

III.E Results

III.E.1 Coefficients on unemployment

The estimates for the fiscal Taylor rule for the full sample suggest a strong, Keynesian-style response of fiscal variables to the business cycle. Table III.1 contains OLS and two-stage least squares estimates for the simplified fiscal Taylor rule over the entire 1952-2006 sample. For the most part, they appear rather similar to each other. The first stage OLS regression, which predicts changes in unemployment using lagged levels and first differences in unemployment and the change in the debt-GDP ratio, has an R-squared of 0.42. An F-test overwhelmingly rejects the null hypothesis of no relationship between changes in unemployment and its own lagged levels and first differences. Such a fit indicates the likely relevance of these instruments in predicting unemployment. As a result, the small-sample bias of the two-stage estimator is exceedingly small, and its variance does not much exceed that of the OLS estimator.

Based on the coefficients on unemployment from the two-stage estimates, government purchases as a share of GDP tend to fall by 0.162 points in response to a one percentage point increase in unemployment. A coefficient of this magnitude, given a 0.183 share of GDP for government purchases and an Okun's Law coefficient greater than one, implies that the level of government purchases actually falls slightly in response to a rise in unemployment.[29] It seems that, since state and local governments appear reluctant to issue debt, they prefer to defer purchases until an economic recovery when tax revenues recover. The statistically and economically significant positive coefficient on unemployment provides strong evidence that the government sector attempts to smooth purchases relative to economic fluctuations.

Both levels of transfers and their share of GDP, on the other hand, rise vigorously in response to unemployment, with a response coefficient of 0.408. Unemployment insurance and welfare payments naturally respond in a strong way when unemployment rises. A glance at Figure III.3 shows large increases in transfers as a share of GDP during every major recession from the early 1970s onward,

[29] Conventional estimates of Okun's Law find, statistically, a two percent increase in output for a one percentage point decrease in the unemployment rate. The data on hand confirm that estimate.

followed by decreases during recoveries. The other major portions of transfer payments, namely Social Security payments and medical programs, do not typically see cuts during a recession either. Politicians seem to increase transfers during bad economic times, waiting until periods of low unemployment to bring them back toward more normal levels.

Tax revenues as a share of GDP also respond strongly to business cycles, varying positively with unemployment and negatively with output. Average tax rates fall by about 0.51 percentage points for every percentage point increase in unemployment. This is about the same under both the OLS and two-stage estimates. Much of this is due to the nonlinear, complicated, nature of the tax code and its interactions with asset prices; Romer and Romer (2007) identify only a handful of deliberate large policy changes in the postwar period. A few such deliberate changes coincide with rising unemployment, particularly the tax cuts of Ford, Reagan, and George W. Bush. Average tax rates move rather strongly with the business cycle through some combination of automatic and discretionary responses to cyclical conditions.

All in all, the responses of deficits and their individual components to unemployment follow their conventional storyline. The government sector in the United States does not cut purchases by nearly the amount that GDP falls during recessions; it attempts to smooth its purchases to a large degree. It increases transfer payments, especially to the unemployed. It adjusts average tax rates over the business cycle, using the progressivity of the tax code to automatically raise taxes during good times and reduce them during bad times. For every one percent increase in unemployment above its average long-run rate, the government sector runs an average primary deficit of about 1.08 percent of GDP.

III.E.2 Coefficients on debt

The coefficient estimates on debt for the full sample suggest that adjustments to government purchases perform about half of all primary deficit stabilization, with adjustments to taxes performing most of the rest. Transfers do not appear to adjust much in response to fiscal imbalances. Counterfactually holding unemployment, seigniorage, and growth-adjusted interest constant, the deliberate portion of fiscal adjustment seems like a sluggish process, with 96.2% (100% minus 3.81%) of primary deficits persisting from one quarter to the next and 85.6% of primary deficits persisting from one year to the next.

Adjustments to government purchases perform about 49% (0.0186% divided by 0.0381%) of deficit stabilization. This suggests that any fiscal reaction function that fails to have government purchases respond to debt suffers from a specification error. Bohn (1991) finds similar results in a VECM using annual federal data which combines government purchases with transfers—there, he finds that adjustments to total government spending together make up the majority of fiscal adjustments undertaken by the federal government. The coefficient of government purchases on debt of -0.0186 is in fact the only coefficient on debt which is statistically significant at conventional levels.

By contrast, the government sector does not adjust transfers much, if at all, in response to fiscal imbalances, with a coefficient of transfers on debt of -0.0055. Transfers only perform a statistically and economically insignificant 14% of fiscal adjustment in spite of comprising nearly a third of total government spending throughout the sample and more in recent years. By and large, transfers seem to respond mostly to business cycle conditions and to exogenous factors such as demographics. Given past history, this suggests that if demographic imbalances in the United States ever bring about large fiscal imbalances, the government sector as a whole would tend to respond by cutting purchases and raising taxes to roughly equal degrees.

Tax rates appear to respond to debt in an economically significant but statistically insignificant way. The estimates suggest that they perform the remaining 37% of deliberate fiscal stabilization. It seems interesting that politicians in the United States would rather cut government spending than raise taxes to stabilize the fiscal situation in the long run. The full-sample coefficient of taxes on debt of 0.0140 indicates that taxes adjust extremely slowly to fiscal imbalances. In the aggregate, the estimates from the Taylor rule confirm Bohn's analysis of federal spending, with the additional qualification that most fiscal adjustment in response to long-run fiscal imbalances comes through government purchases, then taxes, then transfers.

III.E.3 Properties of residuals

Table III.2 contains the standard deviations of the residuals from the OLS and IV regressions. Innovations to government purchases as a share of GDP have a standard deviation of about 0.28 points per quarter; innovations to transfers as a share of GDP have a standard deviation of 0.21 percent per quarter; and innovations to revenues as a share of GDP have a standard deviation of 0.45 percent per quarter. As a whole, innovations to primary deficits have a standard deviation of 0.55 percent per quarter, driven primarily by the relatively large amount of variation in taxes.

The contemporaneous residuals are not closely correlated. The residuals for government purchases and transfers have a -0.14 correlation coefficient, and none of the other combinations has a correlation greater than 0.1 in absolute value. The residuals for government purchases, transfers, and revenues have a first-order autocorrelation of -0.01, -0.20, and -0.30, respectively. To correct for this by including own-lags of each fiscal variable does not change the results much, with one important qualification. The direct responses of taxes and transfers to debt shrink even more, and they respond somewhat negatively to their own lags instead—this might happen, for instance, if taxes and transfers have a significant transitory component. Tables III.3 and III.4 report these results for the two-stage least squares estimates. As expected, the estimates for the response of government purchases do not change much, while transfers and taxes respond negatively to their previous changes. In particular, nearly a third of a surprise tax change gets reversed by the following quarter. The disproportionate role of government purchases in long-run fiscal stabilization remains after accounting for lagged values of the individual fiscal variables.[30]

III.E.4 Results from a split sample at the fourth quarter of 1981

Favero and Monacelli (2005) estimate a simple deficit feedback rule, where the level of the debt-GDP ratio feeds back to deficit decisions. They find evidence of regime instability, with regimes of debt stabilization punctuating an otherwise nonstabilizing policy rule. From the VECM literature, Crowder (1997) finds evidence of a possible regime switch in fiscal policy during the late 1970s or early 1980s, with particularly strong evidence of a break in late 1981 toward less fiscal stabilization. A visual examination of the debt-GDP ratio in Figure III.1 and of the various measures of deficits in Figure III.3 suggests this as a distinct possibility. Favero et al. and Crowder get different results because they assume different orders of integration for debt and different notions of sustainability. It is interesting to ask, under the notion of weak sustainability, if an estimated fiscal Taylor rule can corroborate Crowder's results.

Table III.5 contains the estimates for the response coefficients for the simple fiscal Taylor rule from the first quarter of 1952 through the third quarter of 1981, followed by estimates from the fourth quarter of 1981 through the fourth quarter of 2006. Indeed, fiscal policy appears to have changed dramatically surrounding the passage and enactment of the Economic Recovery Tax Act. Before 1981,

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[30] A full VECM with one lag delivers strikingly similar results to this specification.

policymakers acted swiftly to undo any possible fiscal imbalances. As in the full sample, government purchases bore the largest role in fiscal stabilization, followed by taxes and transfers, respectively. All bore a statistically and economically significant role in stabilization. The government sector would close fiscal imbalances at the rate of 12% per quarter or at the rate of 40% per year, for rates of persistence of 88% quarterly and 60% annually.

By contrast, none of the fiscal variables in the post-1981 sample shows a statistically or economically significant effect of fiscal imbalances on policymaking. The point estimate shows weak and approximately equal responses of taxes and government purchases to imbalances, and it even shows a weak positive effect of fiscal imbalances on transfers. It shows a statistically insignificant response of total primary deficits to debt of about 0.89 percent per quarter, meaning that fiscal imbalances have a persistence of 99.1% per quarter or a persistence of 96.5% per year. This is statistically indistinguishable from no deliberate fiscal stabilization whatsoever. It confirms Crowder's findings, to a stunning degree, that the government sector has not responded aggressively to close fiscal imbalances since the late 1970s or early 1980s.

The coefficients on unemployment show much more stability between subsamples. They are slightly stronger than those estimated for the full sample, but the differences between subsamples are not statistically or economically significant. Their interpretation remains unchanged from their interpretation in the full sample.

The aggressiveness of fiscal policy in pursuing long-run fiscal stabilization has disappeared, but the cyclical behavior of fiscal policy has apparently not changed.

Table III.6 shows the contemporaneous properties of the residuals. Innovations to government purchases show much more volatility in the earlier subsample while taxes show slightly more volatility in the latter subsample. Contemporaneous residuals in primary deficits show similar properties between subsamples. The residuals from the regressions also indicate that fiscal variables, particularly taxes, have become much more difficult to forecast given cyclical conditions and lagged fiscal imbalances. Part of this is because of the much less volatile business cycle since the 1980s—the large response of deficits to unemployment means that less variation in unemployment will make it more difficult to forecast deficits.

In general, these estimates indicate a disappearing role for fiscal stabilization in setting fiscal policy but also indicate that fiscal responses to business cycle conditions have not changed much. Changes to government purchases have also become less volatile and changes to taxes more volatile, hence one possible explanation for the declining role of shocks to government purchases in driving output fluctuations noted by Perotti (2005) and confirmed by Favero and Giavazzi (2007). It appears that fiscal policy has in fact changed radically during the postwar period.

III.F Conclusion

Carefully taking the pitfalls of nonstationarity and the multiplicity of fiscal instruments into account, it is possible to estimate reduced-form fiscal feedback functions relating fiscal policy decisions to fiscal and economic imbalances. An estimate of a multivariate fiscal Taylor rule as a special case of an error correction model for the entire U.S. government, using postwar data, suggests that adjustments to government purchases have performed a large role in fiscal stabilization, with adjustments to tax rates accounting for most of the rest. Transfers have performed very little role in fiscal adjustment—policymakers seem to prefer to adjust government purchases and taxes before they adjust transfers. All three major components of fiscal policy appear to have responded in expected ways to cyclical conditions. During periods of high unemployment, deficits as a share of GDP have risen by a little more than one percentage point for each one percentage point increase in unemployment, with taxes and transfers accounting for most of that increase. Notably, these estimates imply quantitatively important feedback from fiscal imbalances to government purchases. Structural models that do not allow for such a feedback miss out on a potentially important source of real effects for fiscal shocks.

The postwar period also shows important evidence of structural instability in fiscal feedback mechanisms, as estimated by a fiscal Taylor rule. This break is even visible to the naked eye when presented with a deficit series. Up through the late 1970s or early 1980s, fiscal policymakers had responded aggressively to close fiscal imbalances. Since that time, fiscal policymakers have responded in a statistically and economically insignificant way to fiscal imbalances. Innovations to government purchases have also become less volatile while innovations to taxes have become more volatile. Interestingly, a fiscal policy change in 1981 also corresponds with a period with a radical shift in monetary policy toward inflation stabilization. The persistent change toward a less stabilizing fiscal policy combined with greater inflation stabilization poses a potential challenge to the fiscal theory of the price level. The fiscal policy change also corresponds with evidence of reduced Keynesian effects of government purchases in the U.S. Both of these issues deserve further investigation.

III.G Tables and figures

Table III.1: Estimates of response coefficients from Fiscal Taylor Rule, full sample.

Dependent Variable	OLS		2SLS	
	Coeff. on u	***Coeff. on b***	***Coeff. on u***	***Coeff. on b***
Govt. Purchases / GDP	**0.2959**	**-0.0226**	**0.1622**	**-0.0186**
(Std. Err.)	0.0526	0.0076	0.0854	0.0079
Transfers / GDP	**0.3191**	**-0.0028**	**0.4084**	**-0.0055**
(Std. Err.)	0.0402	0.0058	0.0650	0.0060
Revenues / GDP	**-0.4509**	**0.0121**	**-0.5118**	**0.0140**
(Std. Err.)	0.0845	0.0122	0.1354	0.0126
Primary Deficit / GDP	**1.0659**	**-0.0376**	**1.0824**	**-0.0381**
(Std. Err.)	0.1038	0.0149	0.1661	0.0154

Table III.2: Properties of residuals from Fiscal Taylor Rule, full sample.

Dependent Variable	OLS		2SLS	
	Std (η_{it})	R^2	***Std*** (η_{it})	R^2
Govt. Purchases / GDP	0.0028	0.1393	0.0028	0.1136
Transfers / GDP	0.0021	0.2290	0.0021	0.2115
Revenues / GDP	0.0045	0.1159	0.0045	0.1138
Primary Deficit / GDP	**0.0055**	**0.3272**	**0.0055**	**0.3271**

Table III.3: Estimates of response coefficients from Fiscal Taylor Rule with own lags, full sample.

Dependent Variable	2SLS, 1952-2006		
	Coeff. on u	***Coeff. on b***	***Coeff. on x_{it-1}***
Govt. Purchases / GDP	**0.1627**	**-0.0186**	**-0.0006**
(Std. Err.)	0.0955	0.0079	0.0730
Transfers / GDP	**0.4898**	**-0.0036**	**-0.1847**
(Std. Err.)	0.0697	0.0062	0.0669
Revenues / GDP	**-0.6590**	**0.0059**	**-0.2875**
(Std. Err.)	0.1377	0.0123	0.0669

Table III.4: Properties of residuals from Fiscal Taylor Rule with own lags, full sample.

Dependent Variable	2SLS, 1952-2006	
	Std (η_{it})	***R^2***
Govt. Purchases / GDP	0.0028	0.1138
Transfers / GDP	0.0022	0.1969
Revenues / GDP	0.0043	0.1694

Table III.5: Estimates of response coefficients from Fiscal Taylor Rule, split sample at 1981.IV.

Dependent Variable	**2SLS, 1952 – 1981.III**		**2SLS, 1981.IV – 2006**	
	Coeff. on u	***Coeff. on b***	***Coeff. on u***	***Coeff. on b***
Govt. Purchases / GDP	**0.2882**	**-0.0528**	**0.3928**	**-0.0061**
(Std. Err.)	0.1374	0.0169	0.1119	0.0073
Transfers / GDP	**0.4910**	**-0.0254**	**0.4252**	**0.0056**
(Std. Err.)	0.0984	0.0121	0.1160	0.0076
Revenues / GDP	**-0.6701**	**0.0420**	**-0.5817**	**0.0084**
(Std. Err.)	0.1737	0.0214	0.2895	0.0190
Primary Deficit / GDP	**1.4493**	**-0.1203**	**1.3997**	**-0.0089**
(Std. Err.)	0.2232	0.0275	0.3312	0.0217

Table III.6: Properties of residuals from Fiscal Taylor Rule, split sample at 1981.IV.

Dependent Variable	**2SLS, 1952 – 1981.III**		**2SLS, 1981.IV – 2006**	
	***Std* (η_{it})**	**R^2**	***Std* (η_{it})**	**R^2**
Govt. Purchases / GDP	0.0032	0.1956	0.0019	0.0880
Transfers / GDP	0.0023	0.2293	0.0020	0.1657
Revenues / GDP	0.0041	0.2055	0.0050	0.0207
Primary Deficit / GDP	**0.0052**	**0.4661**	**0.0057**	**0.1314**

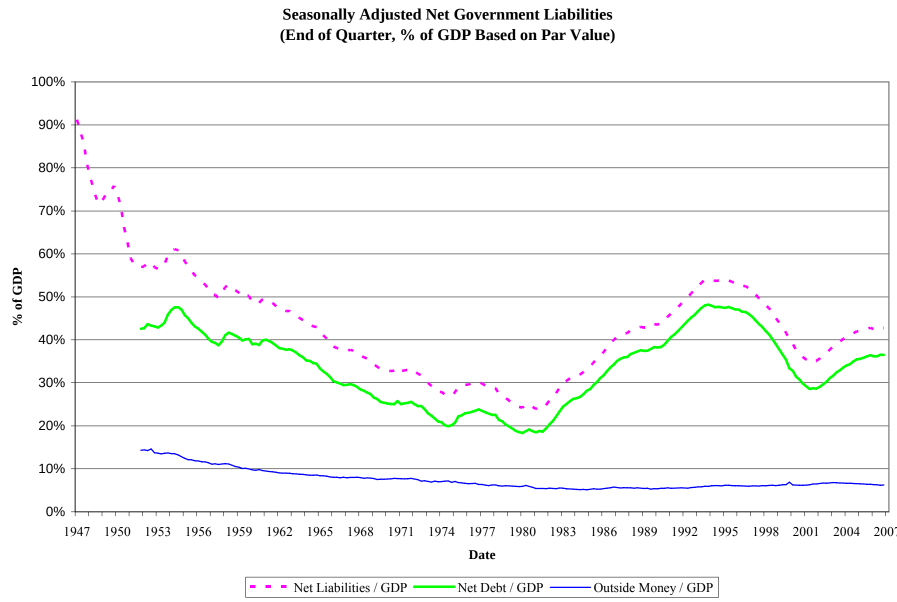

Figure III.1: Net liabilities for the government sector.

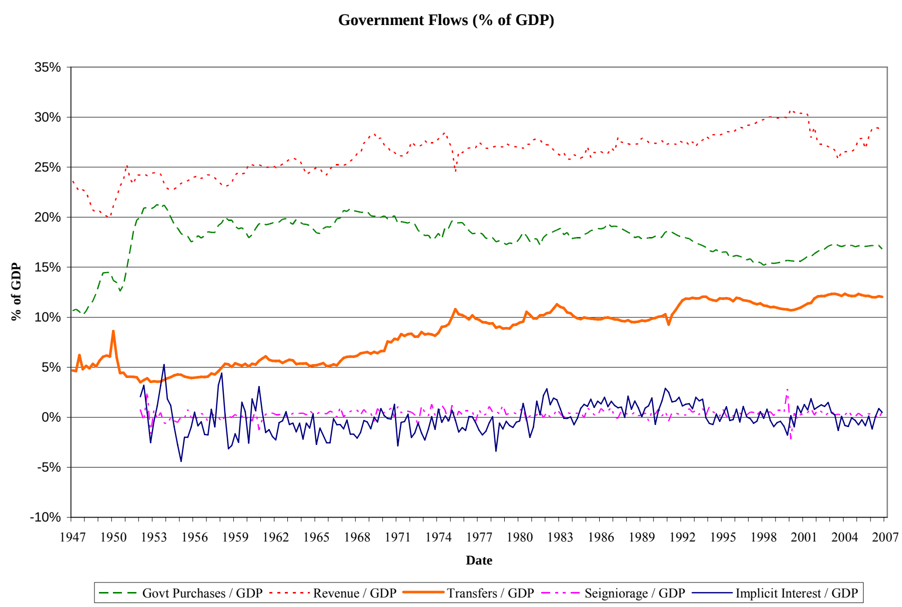

Figure III.2: Deficit items as a percent of GDP.

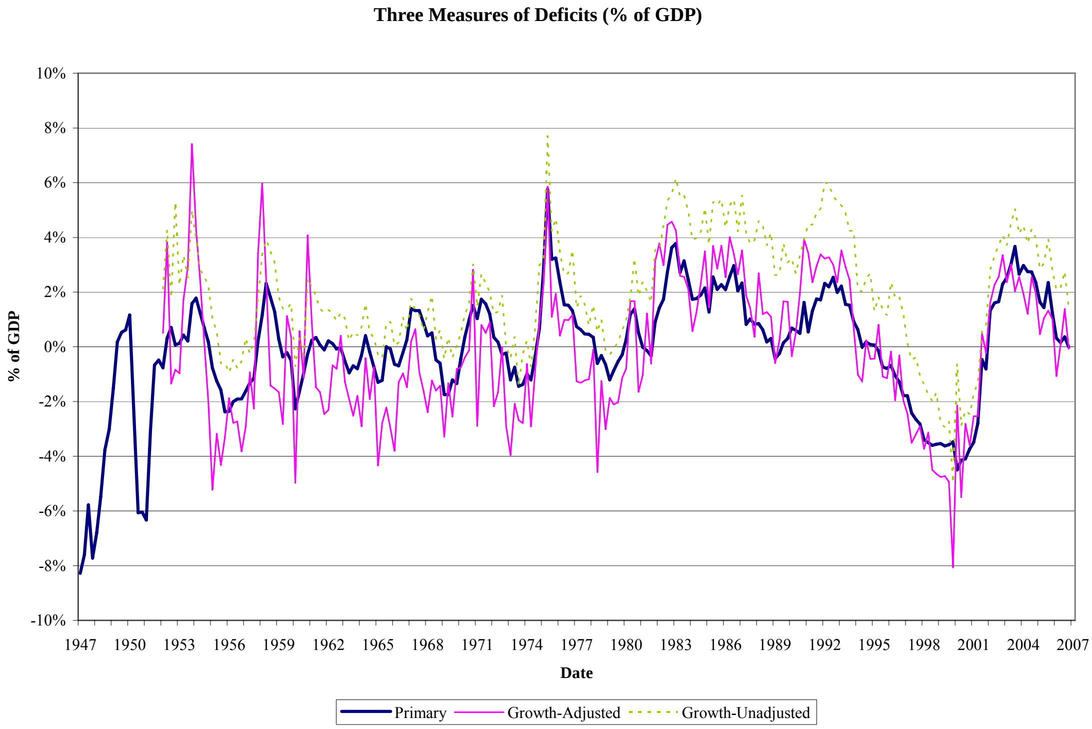

Figure III.3: Deficits as a percent of GDP.

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