

Cartelization Policies and the International Great  
Depression  
(Preliminary and Incomplete)

Harold L. Cole and Lee E. Ohanian  
Penn, UCLA, Minneapolis Fed

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# 1 Introduction

Cole and Ohanian (1999, 2004) and Ohanian (2009) present theory and evidence that *cartelization policies* that distort incentives and reduce competition in product and labor markets contributed to both the severity and the duration of the U.S. Great Depression. This paper analyzes how much cartelization policies depressed economic activity in other countries during the 1930s. We pursue this analysis for two reasons. One is that other countries, including Italy under Mussolini, and Germany under Hitler, adopted cartel policies during the 1930s. Another is that analyzing panel data allows us to exploit cross-country differences in both cartel policies and in the severity and length of the Depression to provide new tests of the cartelization hypothesis by comparing the experiences of countries that adopted these policies to those that did not.

The paper also presents the first analysis of the world depression using a general equilibrium framework. The model, which is estimated using maximum likelihood with panel data from 18 countries, provides estimates of the contributions of not only cartelization policies, but also of money shocks and productivity shocks.

Our main findings are as follows. The estimated model fits the data well, accounting for about 80 percent or more of the observed changes in real output, consumption, investment, labor, GNP deflator, money stock, and productivity. Cartelization policies account for much of the change in labor, particularly after 1933 when these policies become more severe in several countries. Monetary shocks are somewhat important in accounting for real variables early in the 1930s, as deflation accelerates during this period, but money accounts for very little of the change in real variables after 1933. We also find that employment and output loss was much larger in countries with severe cartelization policies than in countries that did not have severe policies.

Conducting this cross-country analysis requires a common model framework. We develop such a framework by exploiting the fact that many types of cartel policies, including those of the U.S. Germany, and Italy, map into a standard neoclassical growth model featuring a wedge between the marginal rate of substitution between consumption and leisure and the marginal product of labor. Thus, differences in the severity of these policies across countries will show up in the model as country-specific differences in this marginal rate of substitution wedge.

To quantify the contributions of cartel policies, we construct a model economy that includes three driving factors: (1) cartel policies, (2) monetary shocks, and (3) productivity shocks. We include these latter two shocks because both of these factors have attracted considerable attention. There is a very large literature on the contribution of deflation to the international Depression, including Eichengreen and Sachs (1985), and Bernanke (1995), who suggest that deflation depressed real activity by raising real wage rates. We include productivity shocks, as there is a recent and growing literature on the contribution of this factor to the Depression (see Cole and Ohanian (1999), and Kehoe and Prescott (2007)). Our analysis thus conditions estimating the contribution of cartelization policies on these other two factors.

Our cross-country analysis of the international depression is novel in a number of ways. One is that this is the first general equilibrium-based analysis exploiting cross country data, as

previous general equilibrium models of the Depression typically study just a single country, while cross-country studies, such as Eichengreen and Sachs (1985), are largely empirical. Another is that we present a new model of monetary nonneutrality, in which the size of the nonneutrality takes on a range of values, ranging from a very large nonneutrality, in which nominal wages adjust very little in response to a monetary shock, to a purely neutral model, in which nominal wages adjust fully to monetary shocks. We estimate the nonneutrality using maximum likelihood. We develop an information-based model of monetary nonneutrality, which is similar in spirit to Lucas (1972), in which the nonneutrality is a result of imperfect information that prevents households from inferring changes in wages resulting from changes in the money supply or changes in productivity. This source of nonneutrality results in imperfectly flexible nominal wages, and presents an alternative to standard sticky wages models that is historically more plausible, as there is little evidence of long term nominal wage contracts during this period. We estimate the model using MLE and use Kalman smoothing to measure the fit of the model, including comparing actual measures of shocks to the model inferred shocks.

Since some economists have suggested that productivity shocks during periods of depression may reflect imperfect input measurement, we analyze two versions of the model, one with fixed capacity, and one with variable capacity. The variable capacity has two important features. First, monetary and policy shocks have the potential to account for some of the Solow residual operating through changes in capital utilization. Second, the response to a productivity shock is larger since capacity also adjusts, and as a result the magnitude of the shocks is diminished. The resulting model inferred TFP shocks are much smaller than the measured Solow residual.

## 2 Cartelization Policies as Marginal Rate of Substitution Distortions

A number of countries adopted *cartelization policies* that restricted competition and impeded the operation of normal market forces in product and labor markets. This section summarizes the most extreme versions of those policies that were present in the United States, Germany, and Italy, and describes how they can be generically modelled within a simple and common quantitative framework. Specifically, we discuss three different features of such policies: expanding industrial cartels, government nominal wage and price fixing, and increasing worker bargaining power that raises real wages.

Ohanian (2009) and Cole and Ohanian (2004) describe how all three of these features were present in U.S. policies under Hoover, and Roosevelt, respectively. Both Presidents promoted monopoly and helped raise real wages above the levels that would have prevailed under competition. Hoover oversaw a high level of industrial cartelization, and developed a nominal wage maintenance policy that required that firms maintain nominal wages, even with declining prices, in order to receive protection from union organization. FDR continued cartelization policies once deflation ended with the National Industrial Recovery Act (NIRA), which provided industry with explicit monopoly power if firms immediately and substantially raised wages and agreed to collective bargaining. After the NIRA was declared

unconstitutional in 1935, these policies continued with the Wagner Act, which led to large increases in unionization. Real wages rose significantly during this period, as did relative prices of output from cartelized sectors.

Wage fixing and monopoly were also in force in Germany, under Hitler's *New Plan*, and in Italy, under Mussolini's *Corporateist Plan*. Regarding Italy, Giordano, Piga and Trovato (2009) documents Fascist government intervention in Italian labor and product markets and the impact of those interventions on prices and wages. Italian policies fostered substantial cartelization, including laws that forbid expanding plants or creating new plants, and created obligatory labor unions that set wages by region. Tooze () describes substantial intervention in German labor and product markets. Hitler froze wages and salaries at Summer, 1933 levels, and regional labor trustees decided on future wage increases. Hitler also broke unions that year and fostered industry cartels.

To see how these different cartel policies in the U.S., Germany, and Italy, can be mapped into a common framework of marginal rate of substitution distortions, first note that in many competitive models, efficient time allocation between market and non-market activities results in equating the marginal rate of substitution between consumption and leisure to the marginal product of labor, which in turn is equated to the real wage and which in turn equates labor supply ( $L^s$ ) and labor demand ( $L^d$ ):

$$\begin{aligned} MRS &= MPL = W \\ L &= L^s = L^d \end{aligned}$$

First, consider the impact of product market cartelization. By definition, any deviation from perfect competition in product markets breaks this equality, since the relevant firm efficiency condition with imperfect competition equates the marginal revenue product to the wage, and not the marginal product, and thus depresses employment relative to that under competition. Thus, expanding product market monopoly increases this wedge, with  $MRS < MPL$ .

Next, consider the union-cartel policies adopted by FDR which increase worker bargaining power, as in Cole and Ohanian (2004). Expanding unionization also drives a wedge into this equation as higher worker bargaining power raises the wage and lowers employment. This means that labor is demand-determined, as households are rationed in employment as they would choose to work more at the high wage if this was feasible, thus  $MRS < MPL$ , and  $L = L^d < L^s$ .

Finally, consider the case of nominal wage fixing. If the nominal wage is fixed such that the real wage is above the competitive level, then the result is the same as in the case of expanding unionization, with labor being demand-determined, and households are at a corner in terms of labor supply. If the nominal wage is fixed such that the real wage is below its market clearing level, then labor demand exceeds labor supply, and employment is supply-determined. This also generates a wedge as employment is low relative to the marginal product of labor, thus  $MRS < MPL$  and  $L = L^s < L^d$ .

Each of these distortions creates a wedge between the MRS and the MPL. Thus, time variation in the severity of a variety of cartelization policies will generate country-specific time variation in this wedge

### 3 Data

We analyze data from 18 countries. We focus on countries from North America and Europe, as they are two regions that are widely studied. We include the U.S. and Canada from North America. In terms of European countries, we began with roughly the same countries as in Bernanke and Carey (1996) and Bernanke (1995), and we then selected those countries that have consistent time series on real GNP, the GNP deflator, the money stock (M1), and at least one of the following other standard macroeconomic variables: labor, consumption, investment, and TFP. This yielded 14 European countries. The dataset also includes Australia and Japan, both of which have a number of data series available.<sup>1</sup>

All data are available for seven countries: Australia, Canada, France, Germany, Italy, UK, and the US. We hereafter call this group the main seven countries, which includes four countries with particularly large depressions: Canada, France, Germany, and the U.S. For the other 11 countries (Austria, Czechoslovakia, Denmark, Finland, Hungary, Japan, Netherlands, Norway, Spain, Sweden, Switzerland) most data are available: consumption is available for 15 of 18 countries, investment is available for 17 of 18 countries, M1 is available for all of our countries, except for Austria in 1931 and 1936.

We will focus the analysis on the seven main countries with all data series available, because this provides the most discipline in fitting the model to the data. We will assess the robustness of the results by comparing the results from the seven main countries to those with all 18 countries.<sup>2</sup>

The data begin in 1929, which is around the start of the depression for most countries, and extend through 1936, which is the start of the Spanish civil war and which is also when anticipations of possible World War begin<sup>3</sup>. For this 1929-36 period, all countries experienced a decline in economic activity and all experience at least some economic recovery. All of the output series are measured in per capita terms and are detrended using a 2 percent annual growth rate.

Figure 1 shows the cross-country averages by year for output, TFP, labor, and prices between 1929 and 1936, and show significant declines in all these variables. Figures 2 - 4 summarize the dispersion in these variables by plotting cross-country data for output, the deflator, and labor. The most striking feature of these data is the enormous cross-country dispersion in these variables. Real output change ranges from a cumulative decline of less than four percent (Denamark), to a 50 percent decline (Canada), price changes ranges from modest inflation (Spain) to a 40 percent cumulative price decline (France), and labor

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<sup>1</sup>We do not include Latin American countries as they differ along a number of dimensions, including very different long-run growth paths and differences in the composition of output. Moreover, there is not as much availability for the data we require from Latin American countries. If it was the case that the findings from this type of analysis for Latin American countries were systematically different, that would be of interest in its own right and merit a separate paper.

<sup>2</sup>We do not include asset prices, such as nominal interest rates, in fitting the model. One reason is because the period length in the model is a year to match the frequency of the data, but the relevant interest rate for money demand is typically considered to be that of a very short maturity asset. Moreover, it is challenging to fit asset prices well, which means that including interest rates in the model would distort the estimated parameters along a dimension that the model is not informative about.

<sup>3</sup>cite here notes that war insurance for shipping began being cancelled in 1936. (other evidence)?

ranges from around a five percent cumulative decline (UK) to a 30 percent cumulative decline (U.S.). The other variables also feature large cross-country dispersion, and are presented in the online appendix to conserve space. We next assess how well a common model framework can account for the very large cross-country dispersion in the data.

## 4 The Model

This section develops a model with three types of shocks, each of which follows from a theme within the literature: a monetary/deflation shock (operating through inflexible nominal wages, as in Bernanke and Carey (1996), among others), time varying TFP, as in Cole and Ohanian (1999) and Kehoe and Prescott (2007), among others, and a labor policy/cartelization shock, as in Cole and Ohanian (2004), and Ohanian (2009), among others.

Before presenting details, we summarize the elements in the model as they relate to these three themes. We introduce money using a cash-credit good formulation that delivers a standard money demand function, and we introduce nominal wage inflexibility with an information imperfection in the spirit of Lucas (1972). This provides an information-theoretic foundation for monetary nonneutrality and yields a parameter that governs the size of the nonneutrality of money in the model. This parameter can take values ranging from a purely neutral model to a model with a very large nonneutrality. A key innovation of the analysis will be estimating the size of this parameter when we fit the model to the data. To our knowledge, estimating the size of the monetary nonneutrality has not been done either in the depression or the business cycle literature.

As described previously, cartelization policies are modelled as a marginal rate of substitution distortion, which specifically is represented as a time varying tax on labor income. TFP is modeled as a standard production function shifter, and we consider two variants of the model, one with standard fixed capacity, and one with variable capacity. We include the variable capacity model since it will allow for monetary shocks to account for some of the measured Solow Residual and thus increase the explanatory power of money/deflation.

We now turn to model details. There is a large number of identical households who have preferences over sequences of a cash good, a credit good, and leisure. The size of the population ( $N_t$ ) grows deterministically at rate  $\gamma_N$ . Preferences are given by

$$E \sum_{t=0}^{\infty} \beta^t \left\{ \log([\alpha c_{1t}^\sigma + (1 - \alpha)c_{2t}^\sigma]^{1/\sigma}) + \phi \log(1 - h_t) \right\} N_t, \quad (1)$$

where  $c_1$  is the cash good,  $c_2$  is the credit good, and  $1 - h$  is non-market time. The money available to the household to acquire cash goods is the sum of its initial money holdings  $m_t$  and the transfer that it receives from the government. The household maximizes (1) subject to a wealth constraint and a cash-in-advance (CIA) constraint:

$$m_t + w_t X_t h_t + r_t k_t + (T_t - 1)M_t + (1 - X_t)w_t H_t \geq m_{t+1} + p_t [c_{1t} + c_{2t} + k_{t+1} - k_t],$$

$$p_t c_{1t} \leq m_t + (T_t - 1)M_t.$$

The household's labor income  $w_t n_t$  is subject to a labor policy shock  $X_t$ , which is discussed above modeled a labor tax, and in which  $X_t < 1$  denotes a negative labor tax shock. The proceeds of the labor tax shock are rebated to the household lump sum, denoted as  $(1 - X_t)w_t \bar{H}_t$ , where  $\bar{H}_t$  denotes per capita labor, which in equilibrium coincides with the representative individual's labor choice  $h_t$ . Nominal wealth is the sum of initial cash holdings  $m_t$ , labor income  $w_t X_t h_t$ , capital income  $r_t k_t$ , a lump-sum monetary transfer from the government  $(T_t - 1)M_t$  where  $T_t$  is the gross growth rate of the money stock, and the rebate  $(1 - X_t)w_t \bar{H}_t$ . The rental price of capital,  $r_t$ , is measured net of depreciation. The household finances cash carried forward,  $m_{t+1}$  and purchases of cash goods, credit goods, and investment ( $p_t[c_{1t} + c_{2t} + k_{t+1} - k_t]$ ).

Output is given by:

$$Y_t = Z_t (U_t K_t)^\gamma H_t^{1-\gamma},$$

where  $U_t$  denotes utilization,  $K_t$  the capital stock,  $N_t$  labor input, and  $Z$  is a technology shock that follows a first-order lognormal autoregressive process:

$$Z_t = e^{\hat{z}_t}, \quad \hat{z}_t = \rho_z \hat{z}_{t-1} + \varepsilon_t^z, \quad \varepsilon_t^z \sim N(0, \sigma_z^2).$$

The resource constraint is

$$C_{1t} + C_{2t} + X_t \leq Y_t.$$

The transition rule for capital is

$$K_{t+1} = (1 - \delta(U_t))K_t + X_t,$$

where  $\delta(U_t)$  is the depreciation function, and it is assumed that  $\delta(U)$ ,  $\delta'(U)$  and  $\delta''(U)$  are all positive (for the variable capacity model, otherwise  $\delta$  is constant). Monetary policy is given by exogenous changes in the gross growth rate of money.<sup>4</sup> The money stock follows a first-order lognormal autoregressive process:

$$T_t = \bar{\tau} e^{\hat{\tau}_t}, \quad \text{where } \hat{\tau}_t = \rho_\tau \hat{\tau}_{t-1} + \varepsilon_t^\tau, \quad \varepsilon_t^\tau \sim N(0, \sigma_\tau^2).$$

The change in the money stock at the beginning of the period is  $(T_t - 1)M_t$ , and the total money stock at the beginning of the period is:  $M_{t+1} = T_t M_t$ .

The labor policy shock also follows a first-order lognormal autoregressive process:

$$X_t = e^{\hat{x}_t}, \quad \text{where } \hat{x}_t = \rho_x \hat{x}_{t-1} + \varepsilon_t^x, \quad \varepsilon_t^x \sim N(0, \sigma_x^2).$$

Households choose their labor supply at the beginning of the period without full information of the state. They observe the nominal wage and all of the aggregate state variables except the current realization of the innovations to the monetary and productivity shocks. Thus, they don't know the price level at the time they choose labor supply decisions, and thus face a signal extraction problem.

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<sup>4</sup>Our specification of exogenous, contractionary monetary shocks is consistent with the view stressed in the International Depression literature that deflation was caused by exogenous monetary shocks resulting from the gold standard (see Bernanke (1995) and Eichengreen (1992)).

We now describe the timing of information and transactions. The state of the economy is  $S_t = (K_t, \hat{z}_{t-1}, \hat{\tau}_{t-1}, \varepsilon_t^z, \varepsilon_t^\tau, \hat{x}_t)$ . The lagged shocks and their current innovations are included separately because the model requires that households choose labor supply before they observe  $(\varepsilon_t^z, \varepsilon_t^\tau)$ . There are two sub-periods. In the initial sub-period, the household knows its own state  $(k_t, m_t)$ , observes a subset of the state vector,  $\bar{S}_t = (K_t, \hat{\tau}_{t-1}, \hat{z}_{t-1}, x_t)$ , and observes the nominal wage. However, households do not know the realizations of the money supply or technology innovations. The representative firm knows the full state vector.<sup>5</sup> The labor market opens, and households and firms make their labor market choices. In the second sub-period, the full state ( $S_t$ ) is revealed, households receive monetary transfer from the government, output is produced, and households acquire consumption and investment goods.

The firm's maximization problem includes the choice of utilization, where the rental payment for capital is net of depreciation. The static optimization problem is:

$$\max_{K_t, N_t} p_t Z_t (U_t K_t)^\gamma (H_t)^{1-\gamma} - w_t H_t - r_t K_t - p_t \delta (U_t) K_t.$$

The conditions for labor and capital are standard, and the first condition for utilization is

$$p_t Z_t \gamma \left( \frac{H_t}{U_t K_t} \right)^{1-\gamma} - p_t \delta'(U_t) = 0,$$

which implies that utilization will be decreasing in the capital-to-labor ratio and increasing in productivity,  $Z_t$ . All of the shocks will lead to changes in utilization, and thus will change the Solow Residual, which is  $Z_t U_t^\gamma$ .

To construct a recursive formulation, we denote the law of motion for aggregate capital denoted by  $G(S_t)$ , and we divide all date  $t$  nominal variables by  $M_{t-1} T_{t-1}$ , which means that the normalized beginning of period money stock is one ( $m_t = 1$ ), and implies the following relationship between the household's money choice in period  $t$  ( $\tilde{m}_{t+1}$ ) and the quantity of money they have at the beginning of period  $t + 1$  ( $m_{t+1}$ ):

$$m_{t+1} = \tilde{m}_{t+1} / T_t.$$

This transition rule implies that the money stock is constant over time, and we denote this constant stock as  $M$ .<sup>6</sup>

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<sup>5</sup>These assumptions about the household's information set and the firm's information set are natural to make in this environment, given that we are using this simple environment to stand in for a richer environment in a multisector model producing heterogeneous consumer goods. In such an environment, firms only care about only four variables in the model: their product price, the state of their technology, and the rental prices of labor and capital. It seems plausible that the firm would know a lot about these variables just prior to production. The households in such an environment would care about many more variables than a firm would. In particular, the household would care about the entire distribution of prices in the economy. It seems plausible that households would have only imperfect information about the entire distribution at the start of the period. To match the larger informational frictions faced by households within our simple model, we assume that firms know the full state vector, which implies they know their technology and the prices, while households do not know the current shocks.

<sup>6</sup>We use this transition equation in the household's budget constraint, substituting  $T_t m_{t+1}$  for  $\tilde{m}_{t+1}$ . This is equivalent to quoting all prices relative to money.



The Bellman equation for the household is:

$$V(m_t, k_t, \bar{S}_t, w_t) = \max_{n_t} E_{(\bar{S}_t, w_t)} \left\{ \max_{c_{1t}, c_{2t}, m_{t+1}, k_{t+1}} \log([\alpha c_{1t}^\sigma + (1 - \alpha)c_{2t}^\sigma]^{1/\sigma}) + \phi \log(1 - h_t) \right\} + \beta E_{S_t} V(m_{t+1}, k_{t+1}, \bar{S}_{t+1}, w_{t+1})$$

subject to

$$m_t + w_t h_t X_t + r_t k_t + (T_t - 1)M + (1 - X_t)w_t \bar{H}_t \geq m_{t+1} T_t + p_t [k_{t+1} - k_t + c_{1t} + c_{2t}]$$

$$m_t + (T_t - 1)M \geq p_t c_{1t} \quad (2)$$

and subject to the stochastic processes for the shocks. In the first stage, households choose labor, given  $\bar{S}_t$  and given the nominal wage. Thus, they optimally forecast the technology and monetary shocks from their information set  $(\bar{S}_t, w_t)$ . Their labor choice satisfies:

$$-\phi/(1 - h_t) + w_t X_t E\{\lambda_t | w_t, \bar{S}_t\} = 0$$

The household equates the marginal utility of leisure to the *expected* marginal utility of nominal wealth ( $\lambda_t$ ), scaled by the nominal wage and the labor policy shock. This expectational equation is solved using standard signal extraction methods. To conserve space, we omit the definition of equilibrium, and refer the reader to the online appendix.

To assess the robustness of our findings, we also consider a standard predetermined wage version of the model, in which each household supplies a specialized labor input  $H_t(i)$ , where  $i$  indexes households, and that total labor input is given by

$$H_t = \left[ \int_0^1 H_t(i)^\theta di \right]^{1/\theta}.$$

each household sets their wage at the beginning of the period before observing the shocks, and the firm chooses how much of each labor-type to hire. The remainder of the model is the same as above. The details of the predetermined wage model are in the online appendix.

## 4.1 The Nonneutrality of Money

We now show how the information imperfection generates monetary nonneutrality. For heuristic purposes, we consider an i.i.d. money shock. There are four equations that are key, which we present in log-linearized form. The first equation is the household's labor-leisure first-order condition:

$$\hat{w}_t + \hat{x}_t - \frac{\hat{h}_t H}{1 - H} = -E\{\hat{\lambda}_t | \hat{w}_t, \bar{s}_t\}, \quad (3)$$

where capital letters are steady-state values, and lower-case letters are log-deviations from the steady state. With imperfect information, the household makes its labor supply decision by forecasting the log-deviation in the marginal value of nominal wealth ( $\hat{\lambda}_t$ ), conditioning on the log deviation in the nominal wage ( $\hat{w}_t$ ) and the restricted state vector ( $\bar{s}_t = (\hat{k}_t, \hat{z}_{t-1}, \hat{\tau}_{t-1})$ ). The second equation is the firm's first-order condition for hiring labor,

$$\hat{z}_t + \gamma(\hat{u}_t + \hat{k}_t - \hat{h}_t) = \hat{w}_t - \hat{p}_t. \quad (4)$$

third equation is the production function:

$$\hat{y}_t = \hat{z}_t + \gamma (\hat{u}_t + \hat{k}_t) + (1 - \gamma)\hat{h}_t. \quad (5)$$

The fourth equation is the optimal capital utilization level:

$$\hat{u}_t = \frac{1}{v - \gamma} \hat{z}_t + \frac{1 - \gamma}{v - \gamma} (\hat{h}_t - \hat{k}_t), \quad (6)$$

where  $v$  is the elasticity of depreciation with respect to utilization.

To understand the household's inference problem, note that the log-linearized equation for  $\hat{\lambda}_t$  is given by

$$\hat{\lambda}_t = D_{\lambda k} \hat{k}_t + D_{\lambda z} \hat{z}_{t-1} + D_{\lambda \tau} \hat{\tau}_{t-1} + D_{\lambda \varepsilon^z} \varepsilon_t^z + D_{\lambda \varepsilon^\tau} \varepsilon_t^\tau + D_{\lambda x} \hat{x}_t,$$

where  $D_{\lambda j}$  is the linearized coefficient for state variable  $j$ . Similarly, the log-linearized wage equation is given by

$$\hat{w}_t = D_{wk} \hat{k}_t + D_{wz} \hat{z}_{t-1} + D_{w\tau} \hat{\tau}_{t-1} + D_{w\varepsilon^z} \varepsilon_t^z + D_{w\varepsilon^\tau} \varepsilon_t^\tau + D_{wx} \hat{x}_t.$$

Given  $\bar{s}_t$  and  $\hat{w}_t$ , the workers forecast

$$\hat{\lambda}_t - E\{\hat{\lambda}_t | \bar{s}_t\} = D_{\lambda \varepsilon^z} \varepsilon_t^z + D_{\lambda \varepsilon^\tau} \varepsilon_t^\tau$$

from observing

$$\hat{w}_t - E\{\hat{w}_t | \bar{s}_t\} = D_{w\varepsilon^z} \varepsilon_t^z + D_{w\varepsilon^\tau} \varepsilon_t^\tau.$$

The solution to this standard signal extraction problem is

$$E\{\hat{\lambda}_t | \hat{w}_t, \bar{s}_t\} - E\{\hat{\lambda}_t | \bar{s}_t\} = \eta [\hat{w}_t - E\{\hat{w}_t | \bar{s}_t\}],$$

where  $\eta$  is the signal extraction parameter to be defined. Rewriting this equation yields

$$E\{(D_{\lambda \varepsilon^z} \varepsilon_t^z + D_{\lambda \varepsilon^\tau} \varepsilon_t^\tau) | (D_{w\varepsilon^z} \varepsilon_t^z + D_{w\varepsilon^\tau} \varepsilon_t^\tau)\} = \eta (D_{w\varepsilon^z} \varepsilon_t^z + D_{w\varepsilon^\tau} \varepsilon_t^\tau).$$

The optimal forecast of  $\hat{\lambda}_t$  is given by

$$E\{\hat{\lambda}_t | \hat{w}_t, \bar{s}_t\} = [D_{\lambda k}, D_{\lambda z}, D_{\lambda \tau}, \eta D_{w\varepsilon^z}, \eta D_{w\varepsilon^\tau}, D_{\lambda x}] * s_t, \quad (7)$$

where, the parameter  $\eta$  is given by

$$\eta = \frac{D_{\lambda \varepsilon^z} D_{w\varepsilon^z} \sigma_{\varepsilon_z}^2 + D_{\lambda \varepsilon^\tau} D_{w\varepsilon^\tau} \sigma_{\varepsilon_\tau}^2}{(D_{w\varepsilon^z})^2 \sigma_{\varepsilon_z}^2 + (D_{w\varepsilon^\tau})^2 \sigma_{\varepsilon_\tau}^2}. \quad (8)$$

The parameter  $\eta$  is the nonneutrality parameter, and depends on the variances of the shock innovations and on linearization coefficients. This parameter lies between 0 (maximum nonneutrality) and  $-1$ , in which money is neutral. It is 0 when the variance of money shocks is 0. This is because with log utility, a productivity shock has no effect on the marginal value of nominal wealth, and thus  $D_{\lambda \varepsilon^z} = 0$ . It is  $-1$  when the variance of productivity shocks is 0.

This is because in this case money shocks raise the nominal wage one-for-one, *ceteris parabus*, and reduce the marginal value of nominal wealth one-for-one ( $D_{w\varepsilon^\tau} = 1$ , and  $D_{\lambda\varepsilon^z} = -1$ ).

Consider an unanticipated decline in the money stock that ultimately lowers the price level by 10 percent. This implies that the nominal wage must immediately fall to clear the labor market. If  $\eta = -1$  ( $\sigma_z = 0$ ) then money is neutral, as the nominal wage also falls 10 percent, which leads workers to raise their forecast of  $\hat{\lambda}_t$  by 10 percent. Consequently, there is no change in any real variable.

Next, consider the same decline in money, but with  $\eta = 0$  ( $\sigma_\tau = 0$ ), which is the highest nonneutrality. The nominal wage must fall to clear the labor market, but in this case the household infers that the lower nominal wage is entirely due to a negative real shock, rather than a lower money supply. This misperception that the real wage has declined leads households to reduce labor. Consequently, the equilibrium nominal wage falls less than the price level, the real wage rises, and employment, utilization, and output all decline.<sup>7</sup>

#### 4.1.1 Distinguishing between MRS wedges created by cartel policies or deflationary money shocks

Both cartel policies and deflationary monetary shocks will impact real variables by driving a wedge between the marginal rate of substitution and the marginal product of labor. These two distinct sources of MRS distortions are in principal separately identified, as the monetary channel creates this distortion through money shocks, while cartel policies will be identified as the component of the wedge that cannot be accounted for by money shocks.

To see this, we first use the above equations to show that a MRS wedge from a money shock operates through the household's forecast error for the marginal value of nominal wealth. First, note that the difference between the marginal rate of substitution and the wage depends on the error in forecasting the marginal value of wealth, which depends on the size of the productivity and money shock innovations and the linearization coefficients. Equations **x** and **y** imply:

$$\begin{aligned}\hat{\lambda}_t - E\{\hat{\lambda}_t | \hat{w}_t, \bar{s}_t\} &= D_{\lambda\varepsilon^z} \varepsilon_t^z + D_{\lambda\varepsilon^\tau} \varepsilon_t^\tau - \eta [D_{w\varepsilon^z} \varepsilon_t^z + D_{w\varepsilon^\tau} \varepsilon_t^\tau] \\ &= \varepsilon_t^z [D_{\lambda\varepsilon^z} - \eta D_{w\varepsilon^z}] + \varepsilon_t^\tau [D_{\lambda\varepsilon^\tau} - \eta D_{w\varepsilon^\tau}]\end{aligned}$$

Substituting, noting that  $D_{\lambda\varepsilon^z} = 0$  and noting that  $D_{\lambda\varepsilon^\tau} = -1$  yields

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<sup>7</sup>By comparison, in the predetermined wage model, households forecast the marginal value of nominal wealth given only the restricted state vector,  $\bar{s}_t$ , and the analog of (3) in the predetermined wage model is given by:

$$\hat{w}_t + \hat{x}_t - \frac{\hat{n}_t N}{1 - N} = -E\{\hat{\lambda}_t | \bar{s}_t\}.$$

In the predetermined wage model, the difference is that households forecast the marginal value of nominal wealth given only the restricted state vector,  $\bar{s}_t$ . However, the other equations governing the impact of a monetary shock, (4-6) are unchanged. The steady state version of 4) is changed to include the mark-up which is governed by  $\theta$ . This means that a contractionary money shock qualitatively works the same way in the two models.

$$\varepsilon_t^z[0 - \eta D_{w\varepsilon^z}] + \varepsilon_t^\tau[-1 - \eta D_{w\varepsilon^\tau}]$$

Consider the case of the maximum nonneutrality,  $\eta = 0$ . In this case, there is a MRS wedge, which is equal to the money shock  $\varepsilon_t^\tau$ . More generally, since the forecast error in the marginal value of wealth is due to a forecast error in predicting inflation, then the impact of a money shock on this wedge depends on the size of the forecast error the household makes in forecasting the log change of the price level.

This means that identifying the source of MRS distortions as either money shocks or cartel policies will depend on the statistical relationship between deflation and the MRS/MPL wedge. If the correlation between the wedge and deflation forecast errors is 1, then the wedge will be attributed entirely to monetary surprises and not cartelization policies. In contrast, if the wedge and deflation forecast errors are unrelated, then the wedge will be attributed to cartel policies.

It is important to note, however that some cartel policies fixed the values of nominal variables, such as Hoover's nominal wage fixing policy (Ohanian, 2009). These cartel policies will thus be identified as nonneutral monetary shocks, rather than cartelization shocks. This fact will tend to understate the importance of cartel policies and overstate the importance of monetary shocks.

We close this section by discussing why money demand shocks are not included in the model. We did consider adding money demand shocks, as they tend to be related to banking and financial shocks, and money demand shocks have been included in an analysis of the U.S. Depression by Christiano et al (2003). We did not add them because our analysis suggests that they were fairly small. We explain this as follows. First, note that including money demand shocks simply requires modifying the CIA constraint with a stochastic shifter,  $\xi_t$ , that affects the extent that cash is required to purchase goods:

$$\xi_t p_t c_{1t} \leq m_t + (T_t - 1)M_t,$$

We call the term  $T_t M_t / \xi_t$  the *effective money supply*, and fluctuations in the effective money supply work just like fluctuations in the money supply in the model without this term. Specifically, increases in  $\xi_t$  increase money demand and reduce prices because it lowers the effective money supply. Thus, positive money demand shocks have exactly the same effect as negative money supply shocks. This means that the relevant money object in the model is the effective money supply, which will in turn will be well approximated by the actual money supply if money demand shocks are negligible.

We can therefore infer the relative size of money demand shocks as follows. If money demand shocks are large, then the Kalman-smoothed money supply in the model *without money demand shocks* will not fit the actual money supply very well, as the model money supply shock will combine both money supply and money demand components. But, we will see later that the model money supply fits the actual money supply quite well, accounting for about 80 percent of the squared change in money in the panel, in the absence of money demand shocks. This led us to not include money demand shocks in the analysis.<sup>8</sup>

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<sup>8</sup>Aside from the channel of money and deflation, we note that our model does not explicitly include other financial shock variables. We abstracted from other financial shocks for the following reasons. One reason is

## 5 Quantitative Methodology

Our quantitative methodology consists of choosing parameter values and evaluating the fit of the model by measuring the percentage of squared change in each variable from 1929 values. We choose parameters by using standard values where possible. Other parameters are estimated using maximum likelihood. The model has a standard state space representation::

$$\zeta_{t+1} = F\zeta_t + \varepsilon_t, \varepsilon_t \sim i.i.d.N(0, \Omega)$$

$$a_t = \nu\zeta_t + u_t, u_t \sim i.i.d.N(0, \Sigma)$$

$$\zeta_t = [k_t, z_{t-1}, \tau_{t-1}, \varepsilon_t^z, \varepsilon_t^\tau, x_t, m_t]'$$

$$\varepsilon_t = [\varepsilon_t^z, \varepsilon_t^\tau, \varepsilon_t^x]'$$

$$a_t = [y_t, p_t, c_t, i_t, n_t, z_t, m_t],$$

in which  $\zeta$  are the states,  $a$  is the observation vector,  $\varepsilon$  are white noise innovations to the states, and  $u$  are measurement errors. We use Kalman smoothing to assess model fit in which the values of the states at each date are inferred given the estimated model and the full history of data. Kalman smoothing allows us to assess the fit of the model more broadly by evaluating the fit of the state variables and the endogenous variables, and thus provides a more comprehensive test of the model. To our knowledge this approach has not been exploited in analyses of depressions and crises.

Table 1 shows the values for the parameters which we choose a priori. Of these, the choices for the parameters that govern capital's share in production,  $\theta$ , the discount factor,  $\beta$ , market time allocation,  $\phi$ , autocorrelation of the productivity shock,  $\rho_z$ , the elasticity of money demand,  $\sigma$  are common in the business cycle literature and are used in both the fixed and variable capacity versions of the model.

For the fixed capacity version of the model, the depreciation rate,  $\delta$ , is seven percent. For the variable capacity model, the *depreciation rate schedule* is given by:

$$\delta(U) = BU^v, v > 1$$

The parameter  $v$ , which governs the elasticity of capital utilization is set to 1.1, which is recommended by King and Rebelo (**cite**). We highlight this choice for  $v$  because it yields a very high elasticity for capital utilization in response to shocks. This means that monetary shocks may account for a substantial fraction of the Solow residual in the variable capacity model, and thus may increase money's explanatory power. Given the value for  $v$ , the scale parameter  $B$  is set so that the steady state depreciaton rate is also seven percent.

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that most countries in our dataset have no financial crises during this period, based on Bernanke and James (xxxx) measures. Moreover, there are no crises after 1933. Before that, Bernanke and James measure that 6 out of 18 countries in our dataset have crises for more than 3 months during 1931 and 1932, but for no other years. This fact, combined with the fact that there is no generally accepted framework for analyzing crises, led us to abstract from this factor. However, we do analyze the performance of those countries with 1931-1932 crises to see if there are substantive differences from the other countries. **We find that**

**Table 1**

$\theta$	$\beta$	$\alpha$	$\nu$	$\sigma$	$\phi$	$\rho_z$
.33	.95	.50	1.1	.92	2	.80

We estimate the remaining parameters for both versions of the model. These parameters are the autoregressive parameters for the money and labor policy process,  $\rho_\tau, \rho_x$ , the standard deviations of the three shock processes,  $\sigma_z, \sigma_\tau$ , and  $\sigma_x$ , and the standard deviations of the measurement errors. This is a standard Kalman filtering problem. Shumway and Stouffer's (1982) algorithm is used, which allows us to accommodate the fact that countries outside of the main seven do not have data on all of the variables.<sup>9</sup>

We note here that the state shock innovations are specified as independently distributed random variables. The estimated money innovations will be correlated, however, reflecting the tail event of worldwide deflation. This is unimportant for our analysis, however, because the model with the i.i.d. shock specification is observationally equivalent to the model with shocks that are correlated across countries, in which the innovations are the sum of a common shock and a country specific shock. The Appendix shows this equivalence.

Before turning to the results, we note that the variable capacity model can fit output and labor perfectly, which partially reflects the fact that the depreciation schedule is nearly linear. We retain the near linearity of depreciation to provide money with the best possible chance to explain real variables, and we address the perfect fit of labor and output by following the literature and pre-specifying the measurement error variances for these two variables. This approach of pre-specifying measurement error variance is recommended by Anderson, Hansen, McGrattan and Sargent (1996), and has been used by Villaverde (xxxx), and Sargent (1989), among others. Specifically, we estimate the model using both small and large measurement error variances to assess whether any of the other results are sensitive to the size of these pre-specified measurement error variances. We find that they are not.<sup>10</sup>

## 6 Findings

This section presents the quantitative findings, which are (1) the fit of the model, the estimated parameters, with a focus on the estimated nonneutrality of money and the labor policy shock process, (2) the relative importance of each of the shocks for understanding the evolution of both real variables and deflation, and (3) the implications of the model for going off the gold standard and subsequent economic recovery.

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<sup>9</sup>The EM algorithm was used to estimate the model with one modification that was required because of occasional numerical problems in inverting the covariance matrix during some EM iterations. To address this issue, we placed the autoregressive parameters for the money and the labor policy shock and for the standard deviations of the shock innovations on a fine grid, and for each grid point. EM was used to estimate the measurement error variances of the states and the endogenous variables. We then chose the parameter combination with the highest likelihood.

<sup>10</sup>To specify the large noise variance, we estimate a two-shock version of our model with just money and productivity shocks, and which does not fit any of the data perfectly. We then specify the high measurement error variances cases by choosing values that exceed the output and labor measurement error variances from the two shock model. We choose the low measurement error variance to be 0.5 percent, which follows from....

To summarize this findings, we note here that both the fixed and variable capacity versions of the model fit the data well, that the estimated nonneutrality is in the small (fixed capacity) to medium (variable capacity) range, that monetary shocks account for virtually all of the change in deflation, a modest amount of changes in real variables during the early stages of depression, but very little of the change in real variables after 1933, and that the labor policy variable, rather than productivity or deflation, is central in accounting for changes in employment.

## 6.1 Model Fit

Table 2 summarizes the fit of both models by showing the percentage of the cumulative squared change of each variable from its 1929 value explained by each model for the low measurement error variance case. The appendix shows this table for the high noise variance case. This measure of fit is equivalent to an R-square,, but without a constant term. Hereafter we call this measure of fit "pseudo-R square".

Both models fit the data well, with the model accounting for between 70 percent to 99 percent of the squared change across most variables. Note that the Kalman-smoothed productivity and money shocks fit the actual money and productivity data well. This means that the model infers money and productivity shocks that are very similar to actual money and productivity <sup>11</sup>

**Table 2 - Cumulative Share of Variable Change Explained**

	Variable Capacity				Fixed Capacity			
	Main 7		18 Countries		Main 7		18 Countries	
	1932	1936	1932	1936	1932	1936	1932	1936
Output	0.97	0.98	0.95	0.97	0.99	0.99	0.98	0.99
Prices	0.94	0.95	0.93	0.95	0.92	0.94	0.92	0.95
Cons.	0.78	0.88	0.74	0.82	0.84	0.92	0.82	0.87
Inv.	0.62	0.71	0.65	0.71	0.67	0.74	0.67	0.69
Labor	0.95	0.97	0.95	0.97	0.96	0.97	0.96	0.97
TFP	0.99	0.99	0.99	0.99	0.96	0.96	0.96	0.96
Money	0.82	0.81	0.74	0.78	0.82	0.78	0.75	0.77

The close fit of the model is noteworthy because the model and its parameter values are common across countries, but recall from figures 2-4 that there is enormous cross-country dispersion in all the variables.<sup>12</sup> To further assess the model's conformity, we compare the fit across different partiions of the data. We first partition the data between the downturn and recovery phases. Table 2 shows that the model fits these two phases about equally well. We next partition the data across differen sets of countries. The first partiion compares the fit between the main 7 countries and all of the countries. Table 2 shows that these fits are very similar. The next partition separates countries with large downturns (countries with

<sup>11</sup>Note that we do not fit the labor policy shock. This is because it is the deviation from a linear combination of output, consumption, and labor, which are already being fit.

<sup>12</sup>Moreover, there are other large cross-country differences, including large differences in per-capita income, the relative importance of sectoral output, large differences in trade shares, etc.

cumulative output decline above the median in 1932) from those with smaller downturns. Both models fit both sets of countries equally well. We also partitioned countries into two other groups, one with countries that remained on gold until at least mid-1932 and the other with countries that left gold before that. Both models also fit these two groups equally well.

These findings indicate that the model provides a simple and empirically accurate common framework for analyzing the substantial differences in the depression across countries, in which almost all of the cross-country differences in Depression reflect differences in the state variables, rather than country-specific differences in model parameters.

## 6.2 Parameter Estimates

Table 3 reports the autoregressive parameter values and the associated standard errors for the innovations of the three shocks. There are three particularly interesting parameter estimates. One is the nonneutrality parameter,  $\eta$ , which is a function of the innovation variances of the money and productivity shocks. It is estimated at -0.93 for the fixed utilization model, which is quite nonneutral, as at this value a 10 percent deflation reduces output by about 1.5 percent, compared to the maximum possible impact of about 11 percent lower output.

In the variable capacity model, a 10 percent deflation reduces output by 7 percent, compared to the maximum possible impact of about 20 percent lower output when this parameter is at its highest nonneutrality. It is surprising that the estimated nonneutrality is not larger because there is an implicit presumption in the literature that the nonneutrality of money was very high in the 1930s.

The other two key parameter estimates are those that govern the labor policy shock. Specifically, the standard deviation of this shock is as large as those of money and productivity shocks, and the shock is also very persistent with an autoregressive parameter of 0.8. Finally, note that money growth is serially uncorrelated ( $\hat{\rho}_\tau = 0$ ). This means that changes in money growth are unperceived, which generates larger money shocks compared to those with  $\rho_\tau > 0$ .

**Table 3 - Estimated Autoregressive Shock Parameters ( $\rho$ ) and Innovation Standard Deviations ( $\sigma_\varepsilon$ )**

	Variable Capacity		Fixed Capacity	
	$\rho$	$\sigma_\varepsilon$	$\rho$	$\sigma_\varepsilon$
$\hat{z}$	0.80 (prespecified)	0.03	0.8 (prespecified)	0.04
$\hat{\tau}$	0.00	0.05	0.00	0.05
$\hat{x}$	0.80	0.05	0.80	0.05

We now discuss the estimated nonneutrality parameter and the estimated labor policy shocks in more detail.

### 6.2.1 Understanding the Estimated Nonneutrality

Figure 5 shows the likelihoods for both the fixed and variable capacity models over the range of possible nonneutralities. The fixed capacity likelihood is steep around its optimum, as the



model fit deteriorates substantially as the nonneutrality gets large. The variable capacity model likelihood is somewhat flatter, but it also deteriorates at higher nonneutrality values.<sup>13</sup>

One reason that maximum likelihood chooses a fairly small nonneutrality, and that the likelihood deteriorates at large nonneutrality values, is because there is only a weak relationship between deflation and real variables in the data. To see this, table 4 shows some cross-country correlations between deflation and output, and cumulated price change and output. The cross-country correlation between output and deflation is close to zero or negative in four of the seven years, and is above 0.5 only in 1932. The correlation between output and cumulated deflation ( $p$ ), which captures lagged values of deflation, is close to zero or negative in most years.

This lack of a systematic pattern between deflation and real variables means that a high nonneutrality - which imposes a very strong relationship between these variables - is at variance with the data. However, we will use higher values of the nonneutrality parameter, in addition to the MLE values, when we use the model to address the implications of countries going off gold for fostering recovery.

**Table 4 - Correlation Between Output, Deflation, and Cumulated Price Change (All Countries)**

	1930	1931	1932	1933	1934	1935	1936
Correlation ( $y, \pi$ )	-0.33	-0.23	0.51	0.21	-0.03	0.38	-0.07
Correlation ( $y, p$ )	-0.33	-0.33	0.04	0.04	-0.02	0.07	0.18

### 6.3 Cartel Policies in the Model and Their Relationship with Actual Policies

The other striking feature of the estimation is that it yields a volatile stochastic process for the labor policy shock that generates large realizations of this shock for a number of countries. Figures 6 and 7 show plots of the Kalman-smoothed realizations of the labor shocks for the 7 main countries (for which we have labor data) for both models. Given that we have modelled these shocks as a labor tax, the fact that these shocks are negative means that the labor tax in the model is increasing and thus depressing labor.

One reason that the estimated labor policy shock is quantitatively important is because money and TFP shocks are not strongly correlated with labor, and thus these latter two shocks cannot account for the bulk of labor fluctuations over the period. Note there is a sizeable correlation between labor and deflation only in 1931 and 1932, and between labor and TFP only in 1930. We will see in the next subsection that the labor policy shock is the primary driver of labor fluctuations.

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<sup>13</sup>To assess the role of the elasticity of variable capacity utilization, the figure also reports the likelihood when we estimate the elasticity of capital services by estimating the curvature parameter,  $v$ . To preserve a reasonably high elasticity, we restrict  $v$  to be less than or equal to 1.6, as at higher values capacity does not fluctuate very much in response to the shocks. The estimation goes to the corner in choosing 1.6, and note that the likelihood tends to be at least as high or higher in this case. This suggests that the high elasticity we use is somewhat at variance with the data. However, we continue to use this value to give monetary shocks the best possible chance to account for the Solow residual.

**Table 5 - Correlation Between Labor, Deflation, and TFP (Main 7 Countries)**

	1930	1931	1932	1933	1934	1935	1936
Correlation ( $l, \pi$ )	0.17	0.48	0.86	-0.17	-0.49	0.13	-0.14
Correlation ( $l, tfp$ )	0.76	0.00	0.22	0.38	0.24	0.00	-0.04
Correlation( $tfp, \pi$ )	-0,48	-0.37	0.50	-0.18	0.17	0.57	-0.55

The labor policy shocks are particularly large and persistent for countries with the largest and most persistent depressions, including the U.S., Germany, and Italy. Moreover, the labor policy shock pattern for these countries differs sharply from the average pattern observed during postwar U.S. business cycles, which is a modest increase in the labor wedge during a recession, but with a reversal of the labor wedge immediately following (see Ohanian (2010)).

The patterns noted above in the U.S., Germany, and Italy are consistent with distortionary cartel/labor market policies that were implemented in these countries. We now discuss how the estimated labor policy shocks from this model relate to actual market policies in the 7 main countries for which we have labor data.

**United States.** Cole and Ohanian (2004) and Ohanian (2009) document wage setting and cartelization policies under both Hoover and Roosevelt. These papers describe that the goal of those policies was to raise prices and wages, and they show how those policies are observationally equivalent to the wage tax in this model. Hoover asked employers to either maintain nominal wages or raise nominal wages and that in return, Hoover would protect firms from union wage demands<sup>14</sup>. Roosevelt explicitly pursued cartelization policies with the National Industrial Recovery Act, which allowed industry to collude provided that they immediately raises wages. Moreover, this research describes how wage and cartelization policies became more distorting under Roosevelt. This pattern of actual policy shifts dovetails with the model results, as figures 6 and 7 shows that the model's labor policy shock became significantly more negative after 1933, which coincides with Roosevelt's New Deal labor and industrial policies, such as the National Industrial Recovery Act and the Wagner Act. They find that these policies raised relative prices and real wages in the cartelized sectors by 25 percent by the late 1930s.

**Germany.** In Germany, cartels and unions were entrenched prior to Hitler, and during the early 1930s, real wages rose, as nominal wages were inflexible. The rising real wage during the early years of the Depression thus dovetails with an increase in estimated labor distortions in the model. German policies are also consistent with an increase in this wedge after 1933. Specifically, labor policies changed substantially after Hitler took power, and these policies depressed wages relative to market clearing levels and also significantly impeded the market forces that would determine the allocation of labor. Unions were dissolved on May 2 1933. Post-1933 wages were set by a political board known as the "Trustees of Labor, and real wages fell substantially and likely were well below market-clearing levels. For example, James (1986) notes "savage" nominal wage cuts after Hitler took power, and Bry (1960) reports that real wages under Hitler would ultimately fall to 1913 levels, despite the fact that productivity had increased considerably since 1913.

<sup>14</sup>Ohanian (2009) documents that many large employers kept nominal wages fixed until late 1931. He also notes that Ford Motor Company raised nominal wages following Hoover's meeting.

James (1986) describes that the trustees used non-market approaches to deal with labor scarcity and labor allocation. For example, laws were passed in 1934 that prohibited hiring non-local labor in areas of high unemployment. Married women were officially discouraged from working and many were fired, which reflected the broad goal of sharply limiting double-income households. Unmarried women were offered marriage loans, which became outright grants if she became a "prolific mother". Workers who were dismissed from their jobs in the political and racial purge of 1933 could not register as unemployed. Workers under 25 were dismissed and replaced by men who were family fathers, and 130,000 jobs were impacted by this policy in 1935 alone. Unemployed young workers were drafted in work corps and emergency work. In 1934, this included about 870,000 workers. In February, 1935 a Work Book was introduced to be retained by the employer to make it difficult for a worker to move to a new job in search of higher wages. In November, 1936 a decree prevented newspaper advertising for building and metal workers to limit competition.

Germany thus placed many significant restrictions on labor markets through the 1930s, and which is consistent with the very large and persistent labor distortion in the model.

**Italy.** Italy's Fascist government under Mussolini adopted many cartel interventions in Italian labor and product markets that significantly impacted those markets, and that were qualitatively similar to those in Germany. Giordano, Piga, and Trovato (2009) document Italian cartelization and labor policies, which we summarize here. As in Germany, policies promoted higher real wages through inflexible nominal wages and deflation, and then policies substantially reduced wages. Giordano et al note that Italian industry cartels flourished after 1932. In 1933, law was passed forbidding plant expansion or creating new plants, which de facto restricted entry. Giordano et al shows that cartel prices rose during the early 1930s. Labor was organized under obligatory Fascist unions whose leaders were selected by the government. Wages were set across regions and industries, and wages relative to productivity declined substantially through the mid and late 1930s.

As in Germany, the fascist government also distorted labor and product markets significantly through the 1930s, which is consistent with large and growing labor policy distortion estimated by the model.

**Australia.** The labor wedge in Australia displays an interesting pattern with a growing distortion in the early 1930s, but a narrowing distortion afterwards, and policy changes are also consistent with this pattern. Before the Depression, Prime Minister Stanley Bruce wanted to eliminate Australia's collective bargaining and arbitration system so that wages could respond more quickly to changes in labor market conditions. Since 1907, Australian wages had been set with a principle of paying "fair and reasonable" wages, at first to qualify for tariff protection, and later government tribunals set wages across regions, industries and occupations.

Bruce was easily defeated in the 1929 election by Labor Party candidate James Scullin, who had portrayed Bruce as an enemy of high wages and decent working conditions, as about half of the Australian workforce belonged to a union at that time. The growing labor wedge in the early 1930s is thus consistent with the incumbent system of wage setting, which generated rigid nominal wages, along with deflation.

But rising unemployment and the rigidity of wage setting created the Federal Wage

Judgement of 1931, which called for a 10 percent nominal wage cut. The Attorney General called for the judgement to be delayed, and de facto, a number of tribunals were very slow to implement the cut (Shedvin, 1970). Shevdivin describes that over time, these nominal wage cuts were implemented. This fact, together with rising productivity, is clearly consistent with the decline in Australia's labor wedge in the mid and late 1930s. Thus, the estimated pattern of labor distortions in the model is consistent with actual Australian labor market policies in the 1930s.

**United Kingdom.** The estimated model finds very little change in the labor wedge in the U.K. relative to its 1929 value. This is consistent with the fact that there were no major new cartel/labor policies in the U.K. after 1929. Specifically, Cole and Ohanian (2002) discuss significant labor market distortions in the U.K. economy reflecting a poorly designed unemployment benefits system, but this system was adopted in the early 1920s.

**Canada.** The estimated model finds no large labor distortion in Canada. This is consistent with the fact that there were no major cartel/labor policies adopted in Canada during the Depression. Specifically, Amaral and Macgee (2007) report that Canada did try to adopt cartel policies similar to those in the U.S., but these Canadian policies were declared unconstitutional before they took affect. Amaral and McGee also note that real wages declined modestly over the course of the Depression, which stands in sharp contrast to the very large increase in wages in the U.S. The fact that labor deviations change little in Canada is consistent with the fact that they did not adopt significant cartel/labor policies.

**France.** The estimation finds only modest deviations in France through 1936, and we are unaware of any significant cartel/labor policies through this period. However, the Popular Front, which was allied with the French Communist Party and the Radical and Socialist Party, among other political groups, was elected in May, 1936, and this led to large changes in labor policy, including legislated higher wages, restriction on the workweek length, and collective bargaining rights. However, these factors primarily impacted France after the period which we analyze. Bridji (2009) studies the impact of the Popular Front.

Thus, we find a strong empirical relationship between actual cartel/labor policy changes and the estimates of such distortions in the model. For the seven countries for which we have economy-wide measures of labor input, the U.S., Germany, and Italy all adopted very significant cartel/labor policies during this period, and we estimate large distortions in the labor first order condition in these countries. Canada, France, and the U.K. did not adopt significant policies, at least through the period we consider, and we estimate only minor distortions in the labor first order condition in these countries. Australia had widespread union polices in place in the early 1930s, but these policies were weakened afterwards. In line with this, we estimate a significant labor distortion in the model in the early 1930s, but a reversal of that distortion afterwards.

## 6.4 Contributions of Individual Shocks

This section reports the contributions of each shock individually. The main findings are as follows: Monetary shocks account for virtually all of nominal price change, but are less important in accounting for real variables. They account for about 30 percent of output fluctuations in the early stages of the depression (1930-32), but have little explanatory power

for real variables during the recovery (after 1933). TFP shocks are particularly important in accounting for output and consumption, but are much less important in accounting for labor. Labor policy shocks are central in accounting for labor, explaining more than half of labor fluctuations in the latter stages of the Depression, .

We measure the individual contributions by feeding in each single shock into the estimated model and then calculate the percentage of squared change in the variables relative to their 1929 values. Tables 6a - 6b show the pseudo-R square for each year and for each of the three individual shocks. Money is quantitatively less important for real variables, particularly for the recovery period.

One hypothesis for why money is more important for the early Depression years is because cartel/labor policies in the U.S., Germany, Australia, and Italy in the early 1930s prevented nominal wages from declining in the face of deflation, which means that some of this factor is accounted for by deflation shocks, rather than labor policy shocks. We test this by comparing the correlation between output and deflation in two sets of countries, the U.S., Germany, Italy, and Australia, and all other countries for 1930-32. If deflation was primarily affecting output through nominal wage fixing policies, then this correlation should be higher in the U.S. et al group than the other group. We find that it is - the correlation between log output change and log price change is .36 in Germany, Italy, Australia, and the U.S. for 1930-32, but is -.04 for the other countries. This suggests that cartel policies may be the key driving factor behind monetary nonneutrality early in the Depression.

**Table 6a - Fraction of Variation Accounted for by Individual Shocks for Seven Main Countries - Variable Capacity**

	Money		TFP		Wedge	
	1932	1936	1932	1936	1932	1936
Output	0.25	0.08	0.69	0.75	0.42	0.32
Price Level	0.63	0.73	-0.96	-0.93	-0.32	-0.33
Consumption	0.09	0.08	0.62	0.70	0.23	0.25
Investment	0.13	0.06	0.35	0.43	0.20	0.24
Labor	0.38	0.15	0.08	0.17	0.71	0.67
TFP	0.09	0.00	0.96	0.96	0.10	0.05
Money (M1)	0.82	0.81	0.00	0.00	0.00	0.00

**Table 6b - Fraction of Variation Accounted for by Individual Shocks for Seven Main Countries - Fixed Capacity**

	Money		TFP		Wedge	
	1932	1936	1932	1936	1932	1936
Output	0.09	0.05	0.80	0.84	0.49	0.41
Price Level	0.59	0.63	-0.66	-0.96	-0.54	-0.50
Consumption	0.04	0.04	0.49	0.66	0.36	0.38
Investment	0.06	0.04	0.51	0.60	0.23	0.26
Labor	0.17	0.08	0.38	0.37	0.83	0.81
TFP	0.00	0.00	0.96	0.96	0.00	0.00
Money (M1)	0.82	0.78	0.00	0.00	0.00	0.00

## 7 The Impact of Two Policies: Leaving Gold Versus Eliminating Cartel Policies

This section uses the model to address the impact of two different economic policy shifts: leaving gold and eliminating cartel policies. We conduct two counterfactuals: (1) What would have happened to output and labor in the countries that left gold early had they instead stayed on gold and followed the monetary policies of the Gold Bloc countries? (2) What would have happened to output and labor in the three major cartel policy countries (US, Germany, Italy) had they not adopted cartel policies? Our findings are that leaving gold early fostered an earlier recovery, with moderately higher output and labor through 1933, but with very little difference after that, as price changes for the gold bloc countries were similar to the non-gold bloc countries by the mid-1930s. This finding suggests that the continuing large cross-country differences in output reflect factors other than monetary policy differences. Our cartel counterfactual experiment addresses this point, as we find a very large and persistent impact of cartel policies on economic activity, particularly by the mid-1930s when almost all countries are reflating significantly.

There are a number of empirical analyses regarding the timing of leaving gold, including Choudrhi and Kochin (1980), Eichengreen and Sachs (1985), and Bernanke (1995), that document that countries that left gold earlier recovered faster and had less deflation than countries that stayed on gold. Not surprisingly, the countries we analyze also have this feature. **(numbers here on recovery from gold for our countries, or just say they have the same feature?)**. However, it is difficult to empirically quantify the impact of leaving gold per se, because the timing of when to leave gold is endogenous, countries may, or may not, choose substantially different monetary policies than if they stayed on gold, and the decision to leave versus stay may significantly impact policies other than monetary policy. **Figure x** presents some evidence on the importance of how other policies may have changed when leaving gold. The figure shows for each country the recovery in output from 1933, measured as log output change from 1933 to 1936, on the vertical axis, and the average rate of inflation between 1933 to 1936 on the horizontal axis. The data show a negative relationship between recovery and reflation (correlation is -0.36), rather than the positive correlation that would be expected. One interpretation of these data is that other policies and/or factors changed significantly to distort the relationship between recovery and reflation predicted by nonneutral monetary policy.

Therefore, to address the impact of leaving gold, we use the variable capacity model to construct a counterfactual by asking what would have happened to output and labor in each country that left gold relatively early (by 1933 or before) had they instead followed the monetary policies of the gold bloc countries that did not leave gold until later?

We split the countries into two groups, those that left gold late (France, Netherland, Switzerland), and those that left gold earlier (all others). For each of the early countries, we define the year that they left gold as the year in which they were off gold for at least 20 percent of that year. Between the initial off-gold year and 1936, we construct the counterfactual money supply by year so that each of the earlier leaving countries has the same rate of log price change by year as the average for France, Netherlands, and Switzerland. We then

compare output and labor each year under the counterfactual gold-bloc monetary policy to that under their observed price path. We hold fixed the time path of productivity and labor policy shocks.

We find that leaving gold early did foster an earlier recovery, with differences in the size of the recovery across early-leaving countries that are due to difference between their rate of price change compared to that of the gold bloc. For example, the country with the smallest difference in price change relative to the gold bloc was Germany. Germany's deflation rate was only about 1.5 percentage points less per year than the gold bloc, as Germany did not change their gold parity and instead had to adopt other policies, including foreign exchange controls. Because German deflation was fairly similar to that of the gold-bloc, there is only a small difference in output under the counterfactual. In contrast, the UK had about five percentage points less deflation per year than the gold bloc, which translates into about a four percent difference in output between their observed price path and the counterfactual path.

**Table x shows the average change in output, cumulative price change, and labor between x and y.** On average, the early leavers had about 2.5 percentage points lower deflation per year, which generates a peak output and labor difference of about two percent by 1933 compared to the counterfactual. But these differences in output and labor quickly disappear after 1933, because the differences in prices across the two sets of countries are on average fairly similar between 1934-36.

These findings, together with the data from Figure x, which shows a negative relationship between recovery and reflation between 1933-36, suggests that the continuing large cross-country output differences reflect other factors, including cartel policies. **(Do we put in numbers here about the size of labor policy shocks and tfp shocks here?)**

To assess the impact of cartel policies, we construct a counterfactual which sets the labor policy shock to zero each period, with a focus on the countries with the most severe cartel policies, the US, Germany, and Italy. Note that by setting this shock to zero, we may be also eliminating other factors that are impacting the MRS/MPL distortion, which could overstate the importance of eliminating cartel policies. However, the fact that there is no MRS/MPL distortion in any of the countries for which we have labor and that do not adopt cartel policies suggests the possibility that much of these deviations in Australia, Germany, Italy, and the US may indeed be due to cartel policies.

We therefore calculate output and labor in the variable capacity model under the counterfactual that the labor policy shock is zero for each year. **Table x** shows the average output and labor change by year for an average over the US, Germany, and Italy. The analysis indicates that these three countries would have had much faster and stronger recoveries had they not adopted these policies. Specifically, removing the MRS/MPL distortion leads to large increases in output and labor that peak around 1935 with both variables rising more than 17 percent above their baseline levels, which is nearly an order of magnitude larger than the impact of staying on gold. The policy has a particularly large impact in the U.S., with output and labor rising more than twenty percent above their baseline levels. The predicted difference in output and labor in the US in the absence of these policies is similar to that reported by Cole and Ohanian's (2004) study of the New Deal cartel policies, correcting for the fact that Cole and Ohanian (2004) did not include a variable capacity margin in their

model.

## 7.1 The Importance of Money/Deflation in Alternative Models

The model indicates that money is important for only a few years in the Depression, and accounts for little of the changes in real variables, particularly in the recovery period. We next assess whether money might have a larger explanatory role in alternative models. To address this, we note that any log-linear model in which changes in the price level impact output will have the form (abstracting from other variables):

$$y_{it} = \alpha\pi_{it} + \varepsilon_{it}$$

in which  $y$  is the log-deviation of output from steady state, and  $\pi$  is the (unanticipated) log change in the price level. We estimate this model using OLS to obtain the maximum explanatory power for deflation. We find that deflation does not account for much output change in this regression, and is largely unrelated to output once country fixed effects are included.

Table x shows the regression coefficients and R-square. The R-square from this first regression was just .08. We next included lagged deflation to allow for longer-lived non-neutralities, which raised the R-square to 0.23. We next included a country fixed effect as a crude proxy for omitted state variables, such as labor market policies, and tested that against a regression with just the country fixed effects:

$$y_{it} = \alpha\pi_{it} + \beta_i + \varepsilon_{it}$$

and

$$y_{it} = \beta_i + \varepsilon_{it}$$

Note that deflation and lagged deflation are irrelevant when country fixed effects are included. Specifically the R-square is unchanged when deflation and lagged deflation are omitted from the regression. This evidence suggests that

**Table 10 - Regressions of Output on Deflation and Country Fixed Effects**

Regression	$\beta_\pi$	$\beta_{\pi-1}$	$R^2$
No Country Effects	0.98		.08
No Country Effects	1.79	0.10	.24
Country Effects	-.13		.846
Country Effects	.81	-.39	.847
Country Effects Alone			.845

## 8 Conclusions

What started the depression? What ended it? This analysis indicates that neither the monetary/deflation/gold standard view, nor the productivity view answer these questions,



particularly for understanding the recovery from the Depression. We find that labor fluctuations in the Depression are primarily due to distortions in the marginal rate of substitution - marginal product relationship. Economic policies that distorted labor and product markets are the best candidate for explaining these distortions. Several countries, including the U.S., Italy, and Germany, adopted non-market policies that significantly impacted this condition. Future work should focus on understanding these distortions in other countries.

## **9 References**

## 10 Appendix

Measurement Error Estimates

	Variable Capacity	Fixed Capacity
Output	0.0006	0.0078
Price Level	0.0051	0.0035
Consumption	0.0044	0.0028
Investment	0.1828	0.1349
Labor	(0.0100)	(0.0100)
TFP	0.0009	0.0027
Money (M1)	0.0207	0.0277

### 10.1 Characterizing the Equilibrium of the Misperceptions Model

We have the following set of equations:

1.  $Z_t K_t^\gamma N_t^{1-\gamma} = C_t + K_{t+1} - (1 - \delta)K_t$
2.  $\bar{\tau} e^{\tau t} = P_t \tilde{C}_t$
3.  $-B/(1 - N_t) + W_t X_t E\{\lambda_t | W_t, \hat{S}_t\} = 0.$
4.  $[\kappa \tilde{C}_t^\omega + (1 - \kappa) \hat{C}_t^\omega]^{-1} \kappa \tilde{C}_t^{\omega-1} - (\lambda_t + \mu_t) P_t = 0$
5.  $[\kappa \tilde{C}_t^\omega + (1 - \kappa) \hat{C}_t^\omega]^{-1} (1 - \kappa) \hat{C}_t^{\omega-1} - \lambda_t P_t = 0$
6.  $\beta E_t\{\lambda_{t+1} + \mu_{t+1}\} / T_t - \lambda_t = 0$
7.  $\beta E_t\{\lambda_{t+1} (R_{t+1} + P_{t+1}(1 - \delta))\} - \lambda_t P_t = 0$
8.  $P_t Z_t \gamma (N_t / K_t)^{1-\gamma} = R_t$
9.  $P_t Z_t (1 - \gamma) (K_t / N_t)^\gamma = W_t$
10.  $\tilde{C}_t + \hat{C}_t = C_t.$

The next step is to log-linearize the set of equations we're solving. We denote the log deviations in lower case, except for the multipliers, which in a slight abuse of notation we use bars to denote their levels and  $\lambda$  and  $\mu$  to denote the log deviations. We denote by the untime-subscripted capitals the values around which we're taking our approximation.

1.  $Z e^{z_t} (K e^{k_t})^\gamma (N e^{n_t})^{1-\gamma} = C e^{c_t} + K e^{k_{t+1}} - (1 - \delta) K e^{k_t}$
2.  $\bar{\tau} e^{\tau t} = P e^{p_t} \tilde{C} e^{\tilde{c}_t}$
3.  $-B/(1 - N e^{n_t}) + X W e^{x_t w_t} E\{\bar{\lambda} e^{\lambda_t} | e^{w_t}, \hat{S}_t\} = 0.$
4.  $[\kappa \tilde{C}^\omega e^{\omega \tilde{c}_t} + (1 - \kappa) \hat{C}^\omega e^{\omega \hat{c}_t}]^{-1} \kappa \tilde{C}^{\omega-1} e^{(\omega-1)\tilde{c}_t} - \bar{\lambda} \bar{P} e^{\lambda_t + p_t} - \bar{\mu} \bar{P} e^{\mu_t + p_t} = 0$

5.  $\left[ \kappa \tilde{C}^\omega e^{\omega \tilde{c}_t} + (1 - \kappa) \hat{C}^\omega e^{\omega \hat{c}_t} \right]^{-1} (1 - \kappa) \hat{C}^{\omega-1} e^{(\omega-1)\hat{c}_t} - \bar{\lambda} \bar{P} e^{\lambda_t + p_t} = 0$
6.  $\beta E_t \{ \bar{\lambda} e^{\lambda_{t+1}} + \bar{\mu} e^{\mu_{t+1}} \} / \bar{\tau} e^{\tau_t} - \bar{\lambda} e^{\lambda_t} = 0$
7.  $\beta E \{ \bar{\lambda} e^{\lambda_{t+1}} (\bar{R} e^{\bar{R}_{t+1}} + P e^{p_{t+1}} (1 - \delta)) | S_t \} - \bar{\lambda} e^{\lambda_t} P e^{p_t} = 0$
8.  $P e^{p_t} Z e^{z_t} \gamma (N e^{n_t} / K e^{k_t})^{1-\gamma} = \bar{R} e^{r_t}$
9.  $P e^{p_t} Z e^{z_t} (1 - \gamma) (K e^{k_t} / N e^{n_t})^\gamma = W e^{w_t}$
10.  $\tilde{C} e^{\tilde{c}_t} + \hat{C} e^{\hat{c}_t} = C e^{c_t}$ .

The steady state of our model is therefore determined by

1.  $Z K^\gamma N^{1-\gamma} = C + \delta K$
2.  $\bar{\tau} = P \tilde{C}$
3.  $-B / (1 - N) + \bar{\lambda} W = 0$
4.  $\left[ \kappa \tilde{C}^\omega + (1 - \kappa) \hat{C}^\omega \right]^{1/\omega-1} \kappa \tilde{C}^{\omega-1} - \bar{\lambda} \bar{P} - \bar{\mu} \bar{P} = 0$
5.  $\left[ \kappa \tilde{C}^\omega + (1 - \kappa) \hat{C}^\omega \right]^{-1} (1 - \kappa) \hat{C}^{\omega-1} - \bar{\lambda} \bar{P} = 0,$
6.  $\beta (\bar{\lambda} + \bar{\mu}) / T - \bar{\lambda} = 0$
7.  $\beta (\bar{R} + P(1 - \delta)) - P = 0$
8.  $P Z \gamma (N / K)^{1-\gamma} = \bar{R}$
9.  $P Z (1 - \gamma) (K / N)^\gamma = W$
10.  $C = \tilde{C} + \hat{C}$
11.  $Z = 1$
12.  $T = 1$

The deviations of our model around this steady state is determined by the following system of equations, where in an abuse of notation we denote the deviations of the shocks to technology and money growth from their means by  $z_t$  and  $\tau_t$  respectively:

1.  $z_t + \gamma k_t + (1 - \gamma) n_t = \frac{C}{Y} c_t + \frac{K}{Y} (k_{t+1} - (1 - \delta) k_t)$
2.  $\tau_t = p_t + \tilde{c}_t.$
3.  $-n_t N / (1 - N) + w_t + x_t + E \{ \lambda_t | w_t, x_t \} = 0.$
4.  $0 = \left\{ (\omega - 1) - \left[ \kappa \tilde{C}^\omega + (1 - \kappa) \hat{C}^\omega \right]^{-1} \kappa \tilde{C}^\omega \right\} \tilde{c}$   
 $- \left\{ \left[ \kappa \tilde{C}^\omega + (1 - \kappa) \hat{C}^\omega \right]^{-1} (1 - \kappa) \hat{C}^\omega \right\} \hat{c}$   
 $- p - \frac{\bar{\lambda} P \lambda + \bar{\mu} P \mu}{\bar{\lambda} P + \bar{\mu} P}$

$$\begin{aligned}
5.0 &= - \left\{ \left[ \kappa \tilde{C}^\omega + (1 - \kappa) \hat{C}^\omega \right]^{-1} \kappa \tilde{C}^\omega \omega \right\} \tilde{c} \\
&\quad + \left\{ (\omega - 1) - \left[ \kappa \tilde{C}^\omega + (1 - \kappa) \hat{C}^\omega \right]^{-1} (1 - \kappa) \hat{C}^\omega \omega \right\} \hat{c} \\
&\quad - (\lambda + p) \\
6. &\beta E \{ \bar{\lambda} \lambda_{t+1} + \bar{\mu} \mu_{t+1} \} - \bar{\tau} \bar{\lambda} (\lambda_t + \tau_t) = 0. \\
7. &E \{ (\beta R/P) r_{t+1} + \lambda_{t+1} + \beta (1 - \delta) p_{t+1} \} - (\lambda_t + p_t) = 0. \\
8. &p_t + z_t + (1 - \gamma)(n_t - k_t) = r_t. \\
9. &p_t + z_t + \gamma(k_t - n_t) = w_t \\
10. &\tilde{C} \tilde{c}_t + \hat{C} \hat{c}_t = C c_t. \\
11. &z_t = \rho_z z_{t-1} + \varepsilon_t^z, \\
12. &\tau_t = \rho_\tau \tau_{t-1} + \varepsilon_t^\tau.
\end{aligned}$$

#### Deriving Equations 4 & 5:

When we log-linearize (4) we get.

$$\begin{aligned}
4.0 &= \left\{ \begin{aligned} &\left[ \kappa \tilde{C}^\omega + (1 - \kappa) \hat{C}^\omega \right]^{-1} \kappa \tilde{C}^{\omega-1} (\omega - 1) \\ &- \kappa \tilde{C}^{\omega-1} \left[ \kappa \tilde{C}^\omega + (1 - \kappa) \hat{C}^\omega \right]^{-2} \kappa \tilde{C}^\omega \omega \end{aligned} \right\} \tilde{c} \\
&\quad - \left\{ \kappa \tilde{C}^{\omega-1} \left[ \kappa \tilde{C}^\omega + (1 - \kappa) \hat{C}^\omega \right]^{-2} (1 - \kappa) \hat{C}^\omega \omega \right\} \hat{c} \\
&\quad - \bar{\lambda} P (\lambda + p) - \bar{\mu} P (\mu + p)
\end{aligned}$$

If we then make use of our steady state result in (4) and divide through by  $(\bar{\lambda} P + \bar{\mu} P)$ , this becomes

$$\begin{aligned}
4.0 &= \left\{ (\omega - 1) - \left[ \kappa \tilde{C}^\omega + (1 - \kappa) \hat{C}^\omega \right]^{-1} \kappa \tilde{C}^\omega \omega \right\} \tilde{c} \\
&\quad - \left\{ \left[ \kappa \tilde{C}^\omega + (1 - \kappa) \hat{C}^\omega \right]^{-1} (1 - \kappa) \hat{C}^\omega \omega \right\} \hat{c} \\
&\quad - p - \frac{\bar{\lambda} P \lambda + \bar{\mu} P \mu}{\bar{\lambda} P + \bar{\mu} P}
\end{aligned}$$

When we log-linearize equation (5) we get

$$\begin{aligned}
5.0 &= - \left\{ \left[ \kappa \tilde{C}^\omega + (1 - \kappa) \hat{C}^\omega \right]^{-2} (1 - \kappa) \hat{C}^{\omega-1} \kappa \tilde{C}^\omega \omega \right\} \tilde{c} \\
&\quad \left\{ \begin{aligned} &\left[ \kappa \tilde{C}^\omega + (1 - \kappa) \hat{C}^\omega \right]^{-1} (1 - \kappa) \hat{C}^{\omega-1} (\omega - 1) \\ &- \left[ \kappa \tilde{C}^\omega + (1 - \kappa) \hat{C}^\omega \right]^{-2} (1 - \kappa) \hat{C}^{\omega-1} (1 - \kappa) \hat{C}^\omega \omega \end{aligned} \right\} \hat{c} \\
&\quad - \bar{\lambda} \bar{P} (\lambda + p)
\end{aligned}$$

Dividing through by  $\lambda P$  yields

$$5.0 = - \left\{ \left[ \kappa \tilde{C}^\omega + (1 - \kappa) \hat{C}^\omega \right]^{-1} \kappa \tilde{C}^\omega \omega \right\} \tilde{c} \\ \left\{ (\omega - 1) - \left[ \kappa \tilde{C}^\omega + (1 - \kappa) \hat{C}^\omega \right]^{-1} (1 - \kappa) \hat{C}^\omega \omega \right\} \hat{c} \\ - (\lambda + p)$$

## 10.2 Solving the Model via the Method of Undetermined Coefficients

In this case we define the state vector to be  $s_t = (k_t, z_{t-1}, \tau_{t-1}, \varepsilon_t^z, \varepsilon_t^\tau, x_t)$  and assume that our controls can all be written as a linear function of the state. Thus we define our controls to be  $d_t = (k_{t+1}, n_t, c_t, p_t, w_t, r_t, \lambda_t, \mu_t)$ , and our system has the form  $d_t = D_s s_t$ . For example,  $c_t = D_c s_t$ , and  $k_{t+1} = D_k s_t$ . We will also want to define the selector matrices for  $k_t$ ,  $z_t$  and  $\tau_t$ : We will also want to define the selector matrices for  $k_t$ ,  $z_t$ ,  $\tau_t$ , and  $x_t$ :

$$I_k = [1 \ 0 \ 0 \ 0 \ 0 \ 0] \\ I_z = [0 \ \rho_z \ 0 \ 1 \ 0 \ 0] \\ I_\tau = [0 \ 0 \ \rho_\tau \ 0 \ 1 \ 0] \\ I_x = [0 \ 0 \ 0 \ 0 \ 0 \ 1]$$

and the forecasting matrix  $H$  for  $s_{t+1}$ :

$$H = \begin{bmatrix} D_k \\ I_z \\ I_\tau \\ 0_6 \\ 0_6 \\ [0_5, \rho_x] \end{bmatrix}$$

### 10.2.1 Handling the expectational equation:

Equation (4) involves an expectational term. Given that  $\lambda_t = D_\lambda s_t$  and  $w_t = D_w s_t$ , and that all but the last two terms of the state vector are common knowledge at the beginning of the period, the inference problem for the workers to extract a forecast of

$$D_{\lambda 4} \varepsilon_t^z + D_{\lambda 5} \varepsilon_t^\tau$$

from observing

$$D_{w 4} \varepsilon_t^z + D_{w 5} \varepsilon_t^\tau.$$

This is a standard signal extraction problem, and the solution is given by

$$\text{where } \eta = \frac{E\{D_{\lambda 4} \varepsilon_t^z + D_{\lambda 5} \varepsilon_t^\tau | D_{w 4} \varepsilon_t^z + D_{w 5} \varepsilon_t^\tau\}}{E([D_{\lambda 4} \varepsilon_t^z + D_{\lambda 5} \varepsilon_t^\tau] [D_{w 4} \varepsilon_t^z + D_{w 5} \varepsilon_t^\tau])} = \frac{D_{\lambda 4} D_{w 4} \sigma_z^2 + D_{\lambda 5} D_{w 5} \sigma_\tau^2}{(D_{w 4})^2 \sigma_z^2 + (D_{w 5})^2 \sigma_\tau^2}.$$

Hence,

$$E\{\lambda_t|w_t\} = [D_{\lambda 1}, D_{\lambda 2}, D_{\lambda 3}, \eta D_{w 4}, \eta D_{w 5}, D_{\lambda 6}] * s_t,$$

and equation 3 becomes

$$3. -D_n s_t N / (1 - N) + D_w s_t + I_t s_t + [D_{\lambda 1}, D_{\lambda 2}, D_{\lambda 3}, \eta D_{w 4}, \eta D_{w 5}, D_{\lambda 6}] * s_t = 0.$$

### 10.2.2 Final Set of Equations

The equations we are picking  $D$  to satisfy are given by:

$$1. I_z s_t + \gamma I_k s_t + (1 - \gamma) D_n s_t + (1 - \delta) \frac{K}{Y} I_k s_t - \frac{C}{Y} D_c s_t - \frac{K}{Y} D_k s_t = 0$$

$$2. I_r s_t = D_p s_t + D_{\bar{c}} s_t.$$

$$3. -D_n s_t N / (1 - N) + D_w s_t + [D_{\lambda 1}, D_{\lambda 2}, D_{\lambda 3}, \eta D_{w 4}, \eta D_{w 5}] * s_t = 0.$$

$$4. 0 = \kappa \tilde{C}^{\omega-1} (\omega - 1) D_{\bar{c}} s_t - \left[ \begin{array}{l} \bar{\lambda} \bar{P} \kappa \tilde{C}^\omega (D_\lambda s_t + D_p s_t + \omega D_{\bar{c}} s_t) + \\ \bar{\lambda} \bar{P} (1 - \kappa) \hat{C}^\omega (D_\lambda s_t + D_p s_t + \omega D_{\bar{c}} s_t) \end{array} \right] \\ - \left[ \begin{array}{l} \bar{\mu} \bar{P} \kappa \tilde{C}^\omega (D_\mu s_t + D_p s_t + \omega D_{\bar{c}} s_t) + \\ \bar{\mu} \bar{P} (1 - \kappa) \hat{C}^\omega (D_\mu s_t + D_p s_t + \omega D_{\bar{c}} s_t) \end{array} \right]$$

$$5. 0 = (1 - \kappa) \hat{C}^{\omega-1} ((\omega - 1) D_{\bar{c}} s_t) - \kappa \tilde{C}^\omega \bar{\lambda} \bar{P} (\omega D_{\bar{c}} s_t + D_\lambda s_t + D_p s_t) \\ - (1 - \kappa) \hat{C}^\omega \bar{\lambda} \bar{P} (\omega D_{\bar{c}} s_t + D_\lambda s_t + D_p s_t)$$

$$6. \beta \{ \bar{\lambda} D_\lambda H s_t + \bar{\mu} D_\mu H s_t \} - \bar{\lambda} \bar{r} (D_\lambda s_t + I_r s_t) = 0.$$

$$7. (\beta R / P) D_r H s_t + D_\lambda H s_t + \beta (1 - \delta) D_p H s_t - (D_\lambda s_t + D_p s_t) = 0.$$

$$8. D_p s_t + I_z s_t + (1 - \gamma) (D_n s_t - I_k s_t) = D_r s_t.$$

$$9. D_p s_t + I_z s_t + \gamma (I_k s_t - D_n s_t) = D_w s_t$$

$$10. \tilde{C} D_{\bar{c}} s_t + \hat{C} D_{\bar{c}} s_t = C D_c s_t.$$

## 10.3 Characterizing the Equilibrium of the Sticky Wage Model

**Producer's Problem:** Because households are setting their wage, we include the CES labor aggregate in the firms problem to derive the firm's labor demand schedule for each type of labor. The profit maximization problem is given by:

$$\max_{K_t^d, N_t^d} P_t Z_t (K_t^d)^\gamma \left( \left[ \int_0^1 N_t^d(i)^\theta di \right]^{1/\theta} \right)^{1-\gamma} - \int_0^1 W_t(i) N_t(i) di - R_t K_t$$

The f.o.c.'s for this problem are

$$\begin{aligned} P_t Z_t \gamma (N_t / K_t)^{1-\gamma} &= R_t \\ P_t Z_t (1-\gamma) (K_t / N_t)^\gamma \left[ \int_0^1 N_t(i)^\theta di \right]^{(1-\theta)/\theta} \frac{1}{\theta} N_t(i)^{\theta-1} &= W_t(i), \end{aligned}$$

where

$$N_t = \left[ \int_0^1 N_t^d(i)^\theta di \right]^{1/\theta}.$$

This second equation yields the following labor demand function for labor of type  $i$  :

$$N_t^d(W_t(i)) \equiv \left[ \frac{P_t Z_t (1-\gamma) (K_t / N_t)^\gamma (N_t)^{1-\theta}}{W_t(i)} \right]^{\frac{1}{1-\theta}}$$

### Consumer's problem:

The consumer's two stage problem is given by

$$\begin{aligned} &V(M_t(i), K_t(i), \bar{S}_t) = \\ &\max_{W_t(i)} E_{\bar{S}_t} \left\{ \begin{aligned} &\max_{C_{1t}(i), C_{2t}(i), M_{t+1}(i), K_{t+1}(i)} \log([\alpha C_{1t}(i)^\sigma + (1-\alpha)C_{2t}(i)^\sigma]^{1/\sigma}) \\ &\quad + \phi \log(1 - N_t^d(W_t(i))) \\ &\quad + \beta E_{S_t} V(M_{t+1}(i)/T_t, K_{t+1}(i), H(S_t), z_t, \tau_t) \end{aligned} \right\} \end{aligned}$$

subject to

$$M_t + W_t X_t N_t + R_t K_t + (T_t - 1)M_t + (1 - X_t)W_t \bar{N}_t \geq M_{t+1} + p_t [C_{1t} + C_{2t} + K_{t+1} - (1 - \delta)K_t],$$

$$M_t(i) + (T_t - 1) \geq P_t C_{1t}(i).$$

The f.o.c. for choosing  $W_t(i)$  is

$$E_{\bar{S}_t} \left\{ \frac{-\phi N_t^d}{1 - N_t^d} + \lambda_t X_t (N_t + W_t(i) N_t^d) \right\} = 0.$$

This implies that

$$0 = E_{\bar{S}_t} \left\{ \left( \frac{-\phi}{1 - N_t^d} + \lambda_t X_t W_t(i) \right) N_t^d + \lambda_t X_t N_t^d \right\}$$

Note that in equilibrium,

$$\begin{aligned} \Rightarrow N_t^d &= - \left( \frac{1}{1-\theta} \right) \left[ \frac{P_t Z_t (1-\gamma) (K_t / N_t)^\gamma (N_t)^{1-\theta}}{W_t(i)} \right]^{\frac{1}{1-\theta}} W_t(i)^{-1} \\ &= - \left( \frac{1}{1-\theta} \right) \frac{N_t}{W_t}, \end{aligned}$$

and hence the wage equation becomes

$$\begin{aligned} 0 &= E_{\hat{S}_t} \left\{ \left( \frac{-\phi}{1-N_t} + \lambda_t X_t W_t \right) \left[ - \left( \frac{1}{1-\theta} \right) \frac{N_t}{W_t} \right] + \lambda_t X_t N_t \right\} \\ &= E_{\hat{S}_t} \left\{ \left[ \left( \frac{1}{W_t} \frac{\phi}{1-N_t} \right) - \theta \lambda_t X_t \right] N_t \right\} \end{aligned}$$

In addition to this condition we have the firm's first order condition for hiring labor, which determines labor demand given the wage. This condition simplifies to the same profit maximization condition that characterized the misperceptions model:

$$\begin{aligned} P_t Z_t (1-\gamma) (K_t^d / N_t^d)^\gamma (N_t^d)^{1-\theta} N_t^d(i)^{\theta-1} &= W_t(i) \\ \Rightarrow P_t Z_t (1-\gamma) (K_t / N_t)^\gamma &= W_t. \end{aligned}$$

The system of equations characterizing the sticky wage model is the same as the misperceptions model with exception of the third equation in our system which is now given by

$$3. E_{\hat{S}_t} \left\{ \left[ \left( \frac{1}{W_t X_t} \frac{B}{1-N_t} \right) - \theta \lambda_t X_t \right] N_t \right\} = 0$$

When we linearize equations (3), we derive the following steady state

$$\left( \frac{B}{(1-N)} \right) - \theta \bar{\lambda} W = 0,$$

and deviation equation

$$E_{\hat{S}_t} \left\{ \frac{N}{(1-N)} n_t - \theta \bar{\lambda} (\lambda_t + x_t + n_t) \right\} = 0.$$

## 10.4 Variable Capital Utilization Extension

Assume that capital utilization is now a choice variable with the utilization level denoted by  $U_t$ . Assume that output is given by  $Z_t [AU_t K_t]^\gamma N_t^{1-\gamma}$  and undepreciated capital is given by  $(1 - \delta(U_t))K_t$ , where  $\delta'(U_t) > 0$  and  $\delta''(U_t) > 0$ . We will assume that

$$\delta(U) = BU^v,$$

and calibrate  $v$  to match the elasticity assumed in the literature, and calibrate  $B$  so that in the steady state  $\delta(U) = \delta$  (our standard depreciation rate). The elasticity of depreciation is given by

$$\frac{d\delta}{dU} \frac{U}{\delta} = vBU^{v-1} \frac{U}{BU^v} = v.$$

In this case final equations 1, 7, 8, and 9 are changed to the following:

$$1. Z_t [U_t K_t]^\gamma N_t^{1-\gamma} = C_t + K_{t+1} - (1 - BU_t^v) K_t.$$



$$7. \beta E_t \{ \lambda_{t+1} (R_{t+1} + P_{t+1}(1 - BU_t^v)) \} - \lambda_t P_t = 0$$

$$8. P_t Z_t \gamma U_t^\gamma (N_t/K_t)^{1-\gamma} = R_t$$

$$9. P_t Z_t (1 - \gamma) (U_t K_t / N_t)^\gamma = W_t$$

In addition, since the optimal choice of utilization is aimed at maximizing the sum of output and undepreciated capital, and this yields the static optimality condition

$$\gamma Z_t K_t^\gamma N_t^{1-\gamma} U_t^{\gamma-1} - Bv U_t^{v-1} K_t = 0,$$

hence

$$U_t = \left[ \frac{\gamma}{Bv} Z_t \left( \frac{N_t}{K_t} \right)^{1-\gamma} \right].$$

Log-linearizing we get that

$$u_t = \frac{1}{v - \gamma} z_t + \frac{1 - \gamma}{v - \gamma} (n_t - k_t).$$

If we log-linearize our expressions for our modified equations we get

$$1. z_t + \gamma (u_t + k_t) + (1 - \gamma)n_t = \frac{C}{Y} c_t + \frac{K}{Y} (k_{t+1} - (1 - BU^v)k_t) + (\delta/A)v u_{t+1}$$

$$7. E \{ (\beta R/P)r_{t+1} + \lambda_{t+1} + \beta(1 - \delta)p_{t+1} - (\beta\delta/A)v u_{t+1} \} - (\lambda_t + p_t) = 0$$

$$8. p_t + z_t + \gamma u_t + (1 - \gamma)(n_t - k_t) = r_t.$$

$$9. p_t + z_t + \gamma(u_t + k_t - n_t) = w_t$$

We then plug in for  $u_t$  to get our final expressions. Note however, that when we linearize, we can just add in  $D_u s_t$  in the appropriate places to get our final expressions. So,

$$D_u = \frac{1}{v - \gamma} I_z + \frac{1 - \gamma}{v - \gamma} (D_n - I_k).$$

And, we just add  $D_u$  into the above expressions in the appropriate ways. Note that this doesn't expand the set of guess values because we have a closed form solution for  $U_t$ .

## 10.5 Deriving the Shock from Prices

In our computations, we have chosen to treat the price sequence as the fundamental object from which we derive our shocks to money. Assume that we're starting with some price sequence  $\{\bar{p}_t\}_{t=0}^T$ , where  $\bar{p}_t$  denotes the log of the price index in period  $t$  in the data, and  $t = 0$  is taken to be the starting point.

The initial deviation in the price level is therefore given by  $\bar{p}_1 - \bar{p}_0$ , and hence, we can infer our shock directly from

$$s_{1,5} = \frac{\bar{p}_1 - \bar{p}_0 - D_{p,1:4} s_{1,1:4}}{D_{p,5}}.$$

Now, because of our normalization, the price level in the second period in our model has been adjusted upwards by the negative of the money growth rate this period, hence  $p_2 - \tau_1$  corresponds to the price level in the model. Therefore,

$$s_{2,5} = \frac{\bar{p}_2 - \tau_1 - \bar{p}_0 - D_{p,1:4}s_{2,1:4}}{D_{p,5}}.$$

Hence,

$$s_{t,5} = \frac{\bar{p}_t - \sum_{r=1}^{t-1} \tau_r - \bar{p}_0 - D_{p,1:4}s_{t,1:4}}{D_{p,5}}$$

is the formula that we should use in computing the implied innovation to our money supply sequence in the model.

This result indicates that we can compute the implied outcomes of our model, given that we are requiring it to reproduce the normalized price sequence, or

$$\bar{p}_t = p_t + \sum_{r=1}^{t-1} \tau_r,$$

by iteratively computing the innovation to money  $s_{t,5}$ , given  $\{\bar{p}_t\}$  and  $s_{t,1:4}$ , then computing the outcomes implied by this innovation in period  $t$ , which in turn implies  $s_{t+1,1:4}$ .

## 10.6 Data

The primary data source of the data is B.R. Mitchell's *International Historical Statistics*. This includes most of the data on real and nominal GDP, industrial wages, production and prices, as well as the agricultural and industrial shares of GDP. Data on the stock market and gold parities come from the League of Nations Statistical Yearbooks from 1933 to 1940. Where available, we have used the latest official publications of historical data. This includes the data for Australia, Canada, Japan, the United Kingdom, and the United States. We have also endeavored to use the latest revisions of data where available. This includes the data for France, Germany, Italy, and Sweden. Listed below are the data sources by country. Unless otherwise indicated, the data used are from B.R. Mitchell and the League of Nations.

### Australia

Nominal and real GDP, GDP deflator: Butlin, M.W., 1977, A Preliminary Annual Database 1900/01 to 1973/74, Research Discussion Paper 7701, Reserve Bank of Australia.

Industrial production, price and wage indices: *Australian Historical Statistics* (Wray Vamplew, ed.), New York: Cambridge University Press, 1987.

### Canada

Nominal and real GDP, GDP deflator, industrial production and wages: Statistics Canada, Historical Statistics (SC-HS).

(<http://www.statcan.ca/english/freepub/11-516-XIE/sectiona/toc.htm>)

### **France**

Nominal and real GDP, GDP deflator, industrial production: Beaudry, P., and Portier, F., 2002, The French Depression in the 1930s. *Review of Economic Dynamics* 5 (January): 73–99

Note that the data provided by Beaudry and Portier were derived from data in Villa, P., 1993, *Une Analyse macro-Economique de la France au XXIeme Siecle*. Paris: Presses du CNRS.

### **Germany**

Nominal and real GDP, GDP deflator, industrial wages: Fisher, J., and Hornstein, A., 2002, The Role of Real Wages, Productivity, and Fiscal Policy in Germany's Great Depression, 1928–1937, *Review of Economic Dynamics* 5 (January): 100–127

### **Italy**

Nominal and real GDP, GDP deflator, industrial wages, production, and prices: Perri, F., and Quadrini, V., 2002, The Great Depression in Italy: Trade Restrictions and Real Wage Rigidities, *Review of Economic Dynamics* 5 (January) 128–151.

Note that the data provided by Perri and Quadrini were based on data in (i) Ercolani, P., 1978, Documentazione Statistica di Base in (G. Fua), *Lo sviluppo Economico in Italia*, 3: 388–472, and (ii) Rey, G., 1991, *I Conti Economici dell'Italia*, Bari: Laterza.

### **Japan**

Industrial prices and wages: (i) Hundred-Year Statistics (100 Years) of the Japanese Economy, 1966, Statistic Department, Bank of Japan, and (ii) Supplement to Hundred-Year Statistics of the Japanese Economy (English translation of footnotes).

### **Sweden**

Real GDP, GDP deflator, industrial production, prices, and wages: John Hassler's data set at (<http://hassler-j.iies.su.se/SWEDATA/>).

Note that the data used from Hassler's data set were derived from Krantz, O., and Nilsson, C-A., 1975, *Swedish National Product, 1861–1970*, Lund.

### **United Kingdom**

Nominal and real GDP, GDP deflator, industrial production, prices, and wages: Feinstein, C.H., 1972, *National Income, Expenditure and Output of the United Kingdom, 1855–1965*, Cambridge University Press.

### **United States**

Nominal and real GDP, GDP deflator for 1919–29: Romer, C., 1989, *The Prewar Business Cycle Reconsidered: New Estimates of Gross National Product, 1869–1908*.

Nominal and real GDP, GDP deflator for 1929–40: Bureau of Economic Analysis, *National Income and Product Accounts, Table 1.2B and Fixed Asset Tables, Table 1.2*.

Industrial production: Board of Governors of the Federal Reserve Bank, series FRB B50001.

Industrial prices: *Historical Statistics of the United States: Colonial Times to 1970*, part 1, (HSUS), U.S. Bureau of the Census.

Industrial wages: Hanes, C., 1996, Changes in the Cyclical Behavior of Real Wage Rates, 1870–1990, *Journal of Economic History*.

## 10.7 Choice of Price Index

We use the GNP deflator as a price index in our modelling and in our calculations because it is a measure of final goods prices. The empirical literature, which focuses on sticky wage models, including (Eichengreen and Sachs (1985), Bernanke and Carey (1996)) use the WPI, which is inappropriate because this index is not the price of final output, which is required for the sticky wage model, but rather the WPI is a bundle of input prices. Tables A3 and A4 report the composition of the wholesale price index and the industrial production index for a number of countries. Two things stand out. First, the wholesale price index is largely based on a bundle of raw *input* prices, and second, the correspondence between the composition of the wholesale price index and the industrial production index is very poor. For example, in Czechoslovakia the WPI puts a weight of 78% on agricultural, mining and energy products, while the industrial production index puts a weight of 73% on manufacturing products. In France the WPI puts a weight of 44% on food and agricultural products while the industrial production index puts a weight of 0% on these same products.