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

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1 Introduction

Cole and Ohanian (1999, 2004) and Ohanian (2009) present theory and evidence that *cartelization policies* that distorted incentives and 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 policies and in the severity and length of the Depression. These cross-country differences 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. Cartelization policies are the main driver of employment fluctuations in a number of countries, particularly after 1933. Monetary shocks are important early in the 1930s, as deflation accelerates during this period, but account for little of the continuation of depression after 1933, as almost all countries reflate after this date. We also find large and systematic differences in the pattern of output, employment, and other real variables across countries with these policies compared to those without, that are consistent with the cartelization theory.

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 that includes 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 and assess their relative importance, 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). 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. Moreover, the analysis also presents the quantitative contribution of monetary and productivity shocks, which is of interest in its own right. Monetary shocks impact real variables through imperfectly flexible nominal wages, as suggested by Bernanke (1995) and Eichengreen and Sachs (1985).

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 exploting cross country data, as previous general equilibrium models of the Depression typically study just a single country, while cross-country analyses, such as Eichengreen and Sachs (1985), is 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 an 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 nonneutraltiy, which is similar in spirit to Lucas (1972), in which the nonneutrality is a result of imperfect information that prevents households from infering 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 alterantive to standard sticky wages models that is historically more plausible, as there is little evidence of long term nominal wage contracts during this period.

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 greatly diminished. This can largely remove the need for productivity falls as opposed to productivity slowdowns.

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 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 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 union-cartel 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, Piga and xxxx (2009) documents Fascist government intervention in Italian labor and product markets and the impact of those interventions on prices and wages. These policies first raised real wages substantially, and then resulted in lower wages, both of which will be consistent with a marginal rate of substitution wedge. They 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. Piga shows that cartel prices rose during the early 1930s. Labor was organized under obligatory Fascist unions, and union leaders were not elected but selected by the government. Wages were set across regions and industries with goal of keeping wages fixed in real terms. Deflation initially raised wages, and then wages were cut substantially to restore firm profitability and this resulted in even lower real wages relative to productivity in late 1930s.

Tooze () describes substantial intervention in 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 industy 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 in 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-detemined. 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 $L = L^s < L^{d.}$

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.[1]

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, Czechoslovokia, 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.[2]

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 at the cusp of anticipations of World War[3]. 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

[1] 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 availablility 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.

[2] 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.

[3] 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 disperson, 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 a 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 explantory 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 γ_N. Preferences are given by

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

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 it's initial money holdings m_t and the transfer that it recives from the government. The household maximizes (1) subject to a wealth constraint and a cash-in-advance (CIA) constraint:

$$m_t+w_tX_th_t+r_tk_t+(T_t-1)M_t+(1-X_t)w_tH_t\geq m_{t+1}+p_t\left[c_{1t}+c_{2t}+k_{t+1}-k_t\right],$$

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

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 lum 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 represenatative 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:

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

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:

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

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 δ is constant). Monetary policy is given by exogenous changes in the gross growth rate of money.[4] The money stock follows a first-order lognormal autoregressive process:

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

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 autogressive process:

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

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.

[4] 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.[5] 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 optimiation 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

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

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.[6]

[5] 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.

[6] 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:

$$V(m_t, k_t, \bar{S}_t, w_t) =$$

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

subject to

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

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

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 (λ_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 abor 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:

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

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,

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

third equation is the production function:

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

The fourth equation is the optimal capittal utilization level:

$$\hat{u}_t = \frac{1}{\upsilon - \gamma}\hat{z}_t + \frac{1-\gamma}{\upsilon-\gamma}\left(\hat{h}_t - \hat{k}_t\right), \tag{6}$$

where υ 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

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

where η is the signal extraction parameter to be defined. Rewriting this equation yields

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

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

$$E\{\hat{\lambda}_t|\hat{w}_t,\bar{s}_t\} = [D_{\lambda k}, D_{\lambda z}, D_{\lambda\tau}, \eta D_{w\varepsilon_z}, \eta D_{w\varepsilon_\tau}] * s_t, \tag{7}$$

where, the parameter η is given by

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

The parameter η is the nonneutrality parmameter, 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.[7]

We close this section by discussing why money demand shocks are not included. 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 ultimately 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, ξ_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 ξ_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

[7]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:

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

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 θ. This means that a contractionary money shock qualitatively works the same way in the two models.

for about 80 percent of the squared change in money for our set of countries during the Great Depression. This suggests that money supply shocks are significantly more important than money demand shocks, which led us to not include money demand shocks in the analysis.[8]

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::

$$\zeta_{t+1} = F\zeta_t + \varepsilon_t, \varepsilon_t \tilde{} i.i.d.N(0, \Omega)$$
$$a_t = \nu\zeta_t + u_t, u_t \tilde{} i.i.d.N(0, \Sigma)$$

$$\begin{aligned} \zeta_t &= [k_t, z_{t-1}, \tau_{t-1}, \varepsilon_t^z, \varepsilon_t^\tau, x_t, m_t]' \\ \varepsilon_t &= [\varepsilon_t^z, \varepsilon_t^\tau, \varepsilon_t^x]' \\ a_t &= [y_t, p_t, c_t, i_t, n_t, z_t, m_t], \end{aligned}$$

in which ζ are the states, a is the observation vector, ε 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, θ, the discount factor, β, market time allocation,ϕ, autocorrelation of the productivity shock, ρ_z, the elasticity of money demand, σ are common in the business cycle literature and are used in both the fixed and variable capcity versions of the model.

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

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

[8] 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 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**

The parameter υ, 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 υ 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 υ, the scale parameter B is set so that the steady state depreciaton rate is also seven percent.

Table 1

$\boldsymbol{\theta}$	$\boldsymbol{\beta}$	$\boldsymbol{\alpha}$	υ	$\boldsymbol{\sigma}$	$\boldsymbol{\phi}$	$\boldsymbol{\rho_z}$
.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, ρ_τ, ρ_x, the standard deviations of the three shock processes, σ_z, σ_τ, and σ_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 accomodate the fact that countries outside of the main seven do not have data on all of the variables.[9]

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 observatonally 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 equivalnece

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.[10]

[9] The EM algorithm was used to estimate the model with one modfication 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 find 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

[10] 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 measurmeent error variances from the two shock model. We choose the low measurement error variance to be 0.5 percent, which follows from....

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 noneutrality 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.

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 productvitiy [11]

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

[11] 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.

dispersion in all the variables.[12] To further assess the model's conformity, we compare the fit acorss 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 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 fingings indicate that the model provides a simple and empirically accurate model framework for analyzing the substantial differences in the depression across countries.

6.2 Parameter Estimates

Table 3 reports the autoregressive parameter values and the associated standard errors for the the innovations of the three shocks. There are two particularly interesting parameter estimates. One is the nonneutrality of money, η, 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 when this parameter is at its highest nonneutrality in this model.

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 noneutrality of money was very high in the 1930s.

Table 3 - Estimated Autoregressive Shock Parameters and Innovation Standard Deviations

	Variable Capacity		Fixed Capacity	
	ρ	$s.e.$	ρ	$s.e.$
$\hat{z}$	0.80	0.03	0.8	0.04
$\hat{\tau}$	0.00	0.05	0.00	0.05
$\hat{x}$	0.8	0.05	0.8	0.05

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

[12] 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.

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.[13]

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 Ouput,Deflation, and Cumulated Price Change (All Countries)

	1930	1931	1932	1933	1934	1935	1936
Correlation (y, π)	-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 Labor Policy Shocks

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 and TFP data) for both models. These shocks are negative, which means that the labor tax in the model is increasing and thus depressing labor. The reason that the estimation finds the labor policy shock to be quantitatively important is because money and TFP shocks are not strongly correlated with labor, and thus cannot account for the bulk of labor fluctuations over the period. For example, there is a sizeable correlation between labor and deflation only in 1931 and 1932, and TFP only has a sizeable correlation with labor in 1930. We will see in the following subsection that the labor policy shock is the primary driver of labor fluctuations.

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

[13] 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, υ. To preserve a reasonably high elasticity, we restrict υ 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.

	1930	1931	1932	1933	1934	1935	1936
Correlation (l, π)	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, π)	-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 some of the largest and most persistent depressions, including the U.S., Germany, and Italy. The labor policy shock pattern for these countries differs sharply from the standard pattern observed during postwar U.S. business cycles, which is a moderately negative tax during a recession, but with a reversal of the negative shock immediately following (see Chari, Kehoe, and McGrattan,).

The patterns noted above, however, are consistent with distortionary labor market policies that were implemented in these countries. We now discuss how the estimated labor policy shocks from this model relate to actual labor market policies in the 7 main countries for which we have labor data. In terms of the 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. 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.

In sharp contrast, the estimation finds no large negative labor policy shocks for the UK. If anything, the estimation finds labor policies may have improved slightly diuring the 1930s. This finding is consistent with the fact that the UK adopted distorting labor policies in the *early* 1920s, and that these policies became somewhat less distorting over time. Specifically, Cole and Ohanian (2002) present evidence that very high UK unemployment benefits led to low employment during the early and mid-1920s, and then stabilized around that time.

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 fluctutations 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..

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 Implications for Going Off the Gold Standard

This section uses the estimated model to address the gold standard. There is considerable research analyzing how monetary relfation associated with leaving the gold standard was a central factor in promoting economic recovery, Choudry () and Kochin (), Eichengreen and Sachs (), and Bernanke () document that countries that left gold earlier tended to recover faster, and had less deflation, than countries that stayed on gold. These studies have concluded from these patterns that reflation through monetary expansion was the key factor in recovering from the Depression, and that nominal wage inflexibility was an important channel through which relfation led to recovery.

Table 7 shows outptut and prices for two sets of countries: those that left gold early (before June, 1932) and those that left gold after. This shows the same pattern is present in our dataset. Specifically, countries that left gold early had less deflation and less severe depressions than those left gold later We now use the model to understand these on-off gold differences, explain why they are important in the early 1930s, explain why they change later, and show that in contrast to the conclusions drawn from the previous literature, that the on-off gold distinction does not answer answer why off gold countries recovered much less by 1936.

To see how the model explains the on and off gold differences in the table, we first note that the very strong differences between on and off gold countries are just for a fairly short period of time - 1931-1933. During this period, on gold countries had money contraction of -17 percent, deflation of 12 percent, and output loss of 11 percent, compared to those from off gold countries of -6 percent, 5 percent, and 7 percent, respectively. And the estimated model is consistent with this fact, as it indicates that money had its maximum impact during this period, accounting for nearly 40 percent of the change in labor. Money is important in this period in the model because the cross-sectional correlation between money and real variables is relatively high.

The model also explains why these on-off gold patterns change so much for the recovery period (1933-36, panel 3, Table 7). This panel shows that both on and off gold countries had about the same inflation rate, but off gold countries had much higher output growth than on gold countries. Since inflation is about the same between on and off gold countries in 1933-36, then the theory implies that the difference in output between on and off gold is due to some other factor, which is presented in Table 8. The table shows that on-off gold differences between 1933-36 are largely due to TFP and labor policy shock differences. Specifically, on-gold TFP is one percent lower in these years than in off-gold countries, and the labor policy shock is two percent higher in on-gold countries relative to off gold countries. Moreover, note that this TFP measure takes into account capacity utilization arising from other shocks.

The key implication of this analysis is that despite the fact that off gold countries recovered faster than on gold countries, higher inflation is not the central factor during the recovery period (1933-36), as inflation is nearly identical in both sets of countries after 1933. The reason why off gold countries recovered more after 1933 than on-gold countries is because off gold had higher productivity growth and smaller labor policy shocks. Understanding the recovery patterns in on and off gold countries after 1933 requires accounting for non-inflation factors. This conclusion differs considerably from the empirical gold standard literature.

Table 7 On and Off Gold Differences

(on gold = countries on gold through atl least mid 1932

Years	1929-31	1931-33	1933-36
	On Gold		
Output	-0.12	-0.11	-0.01
Inflation	-0.12	-0.12	0.03
Money	-0.09	-0.17	0.01
	Off Gold		
Output	-0.11	-0.07	0.07
Inflation	-0.10	-0.05	0.04
Money	-0.14	-0.06	0.09

Table 8 - Fixed Capacity Model

The Difference in the Shocks: On vs. Off Gold

(on gold = on through mid 1932

Years	1929-31	1931-33	1933-36
	On Gold		
TFP	-0.05	-0.04	0.01
Money	-0.03	-0.14	-0.12
Wedge	-0.01	-0.03	-0.00
	Off Gold		
TFP	-0.05	-0.03	0.03
Money	-0.04	-0.10	-0.03
Wedge	-0.01	-0.01	0.02

Table 9 - Variable Capacity Model
The Difference in the Shocks: On vs. Off Gold
(on gold = on through mid 1932

Years	1929-31	1931-33	1933-36
	On Gold		
Prod	-0.02	-0.03	0.00
Money	-0.06	-0.12	-0.10
Wedge	-0.01	-0.02	-0.02
	Off Gold		
Prod	-0.02	-0.02	0.01
Money	-0.05	-0.08	-0.03
Wedge	-0.01	-0.02	0.00

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 on average, accounts for very little of the changes in real variables over the 1930-36 period, 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 state variables):

$$y_{it} = \alpha \pi i_t + \varepsilon_{it}$$

in which y is the log-deviation of output from steady state, and π is the (unanticipated) log change in the price level. We estimated 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 unchaged 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	β_π	$\beta_{\pi-1}$	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 substituion - 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 signficantly 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:

$$1.\ Z_t K_t^{\gamma} N_t^{1-\gamma} = C_t + K_{t+1} - (1-\delta)K_t$$

$$2.\ \bar{\tau}e^{\tau_t} = P_t\tilde{C}_t$$

$$3.\ -B/(1-N_t) + W_t X_t E\{\lambda_t | W_t, \hat{S}_t\} = 0.$$

$$4.\ \left[\kappa\tilde{C}_t^{\omega} + (1-\kappa)\hat{C}_t^{\omega}\right]^{-1}\kappa\tilde{C}_t^{\omega-1} - (\lambda_t + \mu_t)P_t = 0$$

$$5.\ \left[\kappa\tilde{C}_t^{\omega} + (1-\kappa)\hat{C}_t^{\omega}\right]^{-1}(1-\kappa)\hat{C}_t^{\omega-1} - \lambda_t P_t = 0$$

$$6.\ \beta E_t\{\lambda_{t+1} + \mu_{t+1}\}/T_t - \lambda_t = 0$$

$$7.\ \beta E_t\left\{\lambda_{t+1}\left(R_{t+1} + P_{t+1}(1-\delta)\right)\right\} - \lambda_t P_t = 0$$

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

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

$$10.\ \tilde{C}_t + \hat{C}_t = C_t.$$

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 λ and μ to denote the log deviations. We denote by the untime-subscripted capitals the values around which we're taking our approximation.

$$1.\ Ze^{z_t}(Ke^{k_t})^{\gamma}(Ne^{n_t})^{1-\gamma} = Ce^{c_t} + Ke^{k_{t+1}} - (1-\delta)Ke^{k_t}$$

$$2.\ \bar{\tau}e^{\tau_t} = Pe^{p_t}\tilde{C}e^{\tilde{c}_t}$$

$$3. -B/(1-Ne^{n_t}) + XWe^{x_t w_t}E\{\bar{\lambda}e^{\lambda_t}|e^{w_t}, \hat{S}_t\} = 0.$$

$$4.\ \left[\kappa\tilde{C}^{\omega}e^{\omega\tilde{c}_t} + (1-\kappa)\hat{C}^{\omega}e^{\omega\hat{c}_t}\right]^{-1}\kappa\tilde{C}^{\omega-1}e^{(\omega-1)\tilde{c}_t} - \bar{\lambda}\bar{P}e^{\lambda_t+p_t} - \bar{\mu}\bar{P}e^{\mu_t+p_t} = 0$$

$$5.\ \left[\kappa\tilde{C}^{\omega}e^{\omega\tilde{c}_t}+(1-\kappa)\hat{C}^{\omega}e^{\omega\hat{c}_t}\right]^{-1}(1-\kappa)\hat{C}^{\omega-1}e^{(\omega-1)\hat{c}_t}-\bar{\lambda}\bar{P}e^{\lambda_t+p_t}=0$$

$$6.\ \beta E_t\{\bar{\lambda}e^{\lambda_{t+1}}+\bar{\mu}e^{\mu_{t+1}}\}/\bar{\tau}e^{\tau_t}-\bar{\lambda}e^{\lambda_t}=0$$

$$7.\ \beta E\left\{\bar{\lambda}e^{\lambda_{t+1}}\left(\bar{R}e^{R_{t+1}}+Pe^{p_{t+1}}(1-\delta)\right)|S_t\right\}-\bar{\lambda}e^{\lambda_t}Pe^{p_t}=0$$

$$8.\ Pe^{p_t}Ze^{z_t}\gamma(Ne^{n_t}/Ke^{k_t})^{1-\gamma}=\bar{R}e^{r_t}$$

$$9.\ Pe^{p_t}Ze^{z_t}(1-\gamma)(Ke^{k_t}/Ne^{n_t})^{\gamma}=We^{w_t}$$

$$10.\ \tilde{C}e^{\tilde{c}_t}+\hat{C}e^{\hat{c}_t}=Ce^{c_t}.$$

The steady state of our model is therefore determined by

$$1.\ ZK^{\gamma}N^{1-\gamma}=C+\delta K$$

$$2.\ \bar{\tau}=P\tilde{C}$$

$$3.\ -B/(1-N)+\bar{\lambda}W=0$$

$$4.\ \left[\kappa\tilde{C}^{\omega}+(1-\kappa)\hat{C}^{\omega}\right]^{1/\omega-1}\kappa\tilde{C}^{\omega-1}-\bar{\lambda}\bar{P}-\bar{\mu}\bar{P}=0$$

$$5.\ \left[\kappa\tilde{C}^{\omega}+(1-\kappa)\hat{C}^{\omega}\right]^{-1}(1-\kappa)\hat{C}^{\omega-1}-\bar{\lambda}\bar{P}=0,$$

$$6.\ \beta(\bar{\lambda}+\bar{\mu})/T-\bar{\lambda}=0$$

$$7.\ \beta(\bar{R}+P(1-\delta))-P=0$$

$$8.\ PZ\gamma(N/K)^{1-\gamma}=\bar{R}$$

$$9.\ PZ(1-\gamma)(K/N)^{\gamma}=W$$

$$10.\ C=\tilde{C}+\hat{C}$$

$$11.\ Z=1$$

$$12.\ T=1$$

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 τ_t respectively:

$$1.\ z_t+\gamma k_t+(1-\gamma)n_t=\frac{C}{Y}c_t+\frac{K}{Y}(k_{t+1}-(1-\delta)k_t)$$

$$2.\ \tau_t=p_t+\tilde{c}_t.$$

$$3.\ -n_tN/(1-N)+w_t+x_t+E\{\lambda_t|w_t,x_t\}=0.$$

$$\begin{aligned}4.\ 0 \ &= \left\{(\omega-1)-\left[\kappa\tilde{C}^{\omega}+(1-\kappa)\hat{C}^{\omega}\right]^{-1}\kappa\tilde{C}^{\omega}\omega\right\}\tilde{c}\\ &-\left\{\left[\kappa\tilde{C}^{\omega}+(1-\kappa)\hat{C}^{\omega}\right]^{-1}(1-\kappa)\hat{C}^{\omega}\omega\right\}\hat{c}\\ &-p-\frac{\bar{\lambda}P\lambda+\bar{\mu}P\mu}{\bar{\lambda}P+\bar{\mu}P}\end{aligned}$$

$$
\begin{aligned}
5.\ 0 \quad = \quad & -\left\{\left[\kappa\tilde{C}^{\omega}+(1-\kappa)\hat{C}^{\omega}\right]^{-1}\kappa\tilde{C}^{\omega}\omega\right\}\tilde{c} \\
& +\left\{(\omega-1)-\left[\kappa\tilde{C}^{\omega}+(1-\kappa)\hat{C}^{\omega}\right]^{-1}(1-\kappa)\hat{C}^{\omega}\omega\right\}\hat{c} \\
& -(\lambda+p)
\end{aligned}
$$

$$6.\ \beta E\{\bar{\lambda}\lambda_{t+1}+\bar{\mu}\mu_{t+1}\}-\bar{\tau}\bar{\lambda}(\lambda_t+\tau_t)=0.$$

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

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

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

$$10.\ \tilde{C}\tilde{c}_t+\hat{C}\hat{c}_t=Cc_t.$$

$$11.\ z_t=\rho_z z_{t-1}+\varepsilon_t^z,$$

$$12.\ \tau_t=\rho_\tau \tau_{t-1}+\varepsilon_t^\tau.$$

Deriving Equations 4 & 5:
When we log-linearize (4) we get.

$$
\begin{aligned}
4.\ 0 \quad = \quad & \left\{\begin{array}{c}\left[\kappa\tilde{C}^{\omega}+(1-\kappa)\hat{C}^{\omega}\right]^{-1}\kappa\tilde{C}^{\omega-1}(\omega-1) \\ -\kappa\tilde{C}^{\omega-1}\left[\kappa\tilde{C}^{\omega}+(1-\kappa)\hat{C}^{\omega}\right]^{-2}\kappa\tilde{C}^{\omega}\omega\end{array}\right\}\tilde{c} \\
& -\left\{\kappa\tilde{C}^{\omega-1}\left[\kappa\tilde{C}^{\omega}+(1-\kappa)\hat{C}^{\omega}\right]^{-2}(1-\kappa)\hat{C}^{\omega}\omega\right\}\hat{c} \\
& -\bar{\lambda}P(\lambda+p)-\bar{\mu}P(\mu+p)
\end{aligned}
$$

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

$$
\begin{aligned}
4.\ 0 \quad = \quad & \left\{(\omega-1)-\left[\kappa\tilde{C}^{\omega}+(1-\kappa)\hat{C}^{\omega}\right]^{-1}\kappa\tilde{C}^{\omega}\omega\right\}\tilde{c} \\
& -\left\{\left[\kappa\tilde{C}^{\omega}+(1-\kappa)\hat{C}^{\omega}\right]^{-1}(1-\kappa)\hat{C}^{\omega}\omega\right\}\hat{c} \\
& -p-\frac{\bar{\lambda}P\lambda+\bar{\mu}P\mu}{\bar{\lambda}P+\bar{\mu}P}
\end{aligned}
$$

When we log-linearize equation (5) we get

$$
\begin{aligned}
5.\ 0 \quad = \quad & -\left\{\left[\kappa\tilde{C}^{\omega}+(1-\kappa)\hat{C}^{\omega}\right]^{-2}(1-\kappa)\hat{C}^{\omega-1}\kappa\tilde{C}^{\omega}\omega\right\}\tilde{c} \\
& \left\{\begin{array}{c}\left[\kappa\tilde{C}^{\omega}+(1-\kappa)\hat{C}^{\omega}\right]^{-1}(1-\kappa)\hat{C}^{\omega-1}(\omega-1) \\ -\left[\kappa\tilde{C}^{\omega}+(1-\kappa)\hat{C}^{\omega}\right]^{-2}(1-\kappa)\hat{C}^{\omega-1}(1-\kappa)\hat{C}^{\omega}\omega\end{array}\right\}\hat{c} \\
& -\bar{\lambda}\bar{P}(\lambda+p)
\end{aligned}
$$

Dividing through by λP yields

$$\begin{aligned}5.\ 0 &= -\left\{\left[\kappa\tilde{C}^{\omega} + (1-\kappa)\hat{C}^{\omega}\right]^{-1}\kappa\tilde{C}^{\omega}\omega\right\}\tilde{c} \\ &\left\{(\omega-1) - \left[\kappa\tilde{C}^{\omega} + (1-\kappa)\hat{C}^{\omega}\right]^{-1}(1-\kappa)\hat{C}^{\omega}\omega\right\}\hat{c} \\ &-(\lambda+p)\end{aligned}$$

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 $d_t = Ds_t$. 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 τ_t :We will also want to define the selector matrices for k_t, z_t, τ_t, and x_t :

$$\begin{aligned}I_k &= [1\ 0\ 0\ 0\ 0\ 0] \\ I_z &= [0\ \rho_z\ 0\ 1\ 0\ 0] \\ I_\tau &= [0\ 0\ \rho_\tau\ 0\ 1\ 0] \\ I_x &= [0\ 0\ 0\ 0\ 0\ 1]\end{aligned}$$

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

$$D_{w4}\varepsilon_t^z + D_{w5}\varepsilon_t^\tau.$$

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

$$\begin{aligned}E\{D_{\lambda 4}\varepsilon_t^z + D_{\lambda 5}\varepsilon_t^\tau | D_{w4}\varepsilon_t^z + D_{w5}\varepsilon_t^\tau\} &= \eta\left(D_{w4}\varepsilon_t^z + D_{w5}\varepsilon_t^\tau\right) \\ \text{where } \eta = \frac{E([D_{\lambda 4}\varepsilon_t^z + D_{\lambda 5}\varepsilon_t^\tau]\,[D_{w4}\varepsilon_t^z + D_{w5}\varepsilon_t^\tau])}{E([D_{w4}\varepsilon_t^z + D_{w5}\varepsilon_t^\tau]^2)} &= \frac{D_{\lambda 4}D_{w4}\sigma_z^2 + D_{\lambda 5}D_{w5}\sigma_\tau^2}{(D_{w4})^2\sigma_z^2 + (D_{w5})^2\sigma_\tau^2}.\end{aligned}$$

Hence,

$$E\{\lambda_t|w_t\} = [D_{\lambda 1}, D_{\lambda 2}, D_{\lambda 3}, \eta D_{w4}, \eta D_{w5}, D_{\lambda 6}] * s_t,$$

and equation 3 becomes

$$3.\ -D_n s_t N/(1-N) + D_w s_t + I_t s_t + [D_{\lambda 1}, D_{\lambda 2}, D_{\lambda 3}, \eta D_{w4}, \eta D_{w5}, D_{\lambda 6}] * s_t = 0.$$

10.2.2 Final Set of Equations

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

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

$$2.\ I_\tau s_t = D_p s_t + D_{\tilde{c}} s_t.$$

$$3.\ -D_n s_t N/(1-N) + D_w s_t + [D_{\lambda 1}, D_{\lambda 2}, D_{\lambda 3}, \eta D_{w4}, \eta D_{w5}] * s_t = 0.$$

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

$$\begin{aligned} 5.\ 0 &= (1-\kappa)\hat{C}^{\omega-1}\left((\omega-1) D_{\hat{c}} s_t\right) - \kappa\tilde{C}^{\omega}\bar{\lambda}\bar{P}\left(\omega D_{\tilde{c}} s_t + D_\lambda s_t + D_p s_t\right) \\ &\quad -(1-\kappa)\hat{C}^{\omega}\bar{\lambda}\bar{P}\left(\omega D_{\hat{c}} s_t + D_\lambda s_t + D_p s_t\right) \end{aligned}$$

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

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

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

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

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

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

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

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

$$V(M_t(i), K_t(i), \bar{S}_t) =$$

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

subject to

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

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

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

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

This implies that

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

Note that in equilibrium,

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

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:

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

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 $Z_t\left[AU_tK_t\right]^\gamma N_t^{1-\gamma}$ 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

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

and calibrate υ 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

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

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

$$1.\ Z_t\left[U_tK_t\right]^\gamma N_t^{1-\gamma}=C_t+K_{t+1}-(1-BU_t^\upsilon)K_t.$$

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

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

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

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

$$\gamma Z_t K_t^{\gamma} N_t^{1-\gamma} U_t^{\gamma-1} - B\upsilon U_t^{\upsilon-1} K_t = 0,$$

hence

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

Log-linearizing we get that

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

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

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

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

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

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

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,

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

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 be 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 results 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 bellow 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, Statistis 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.

Figure 1: Mean Output, Prices, Labor and Productivity
Main 7 countries

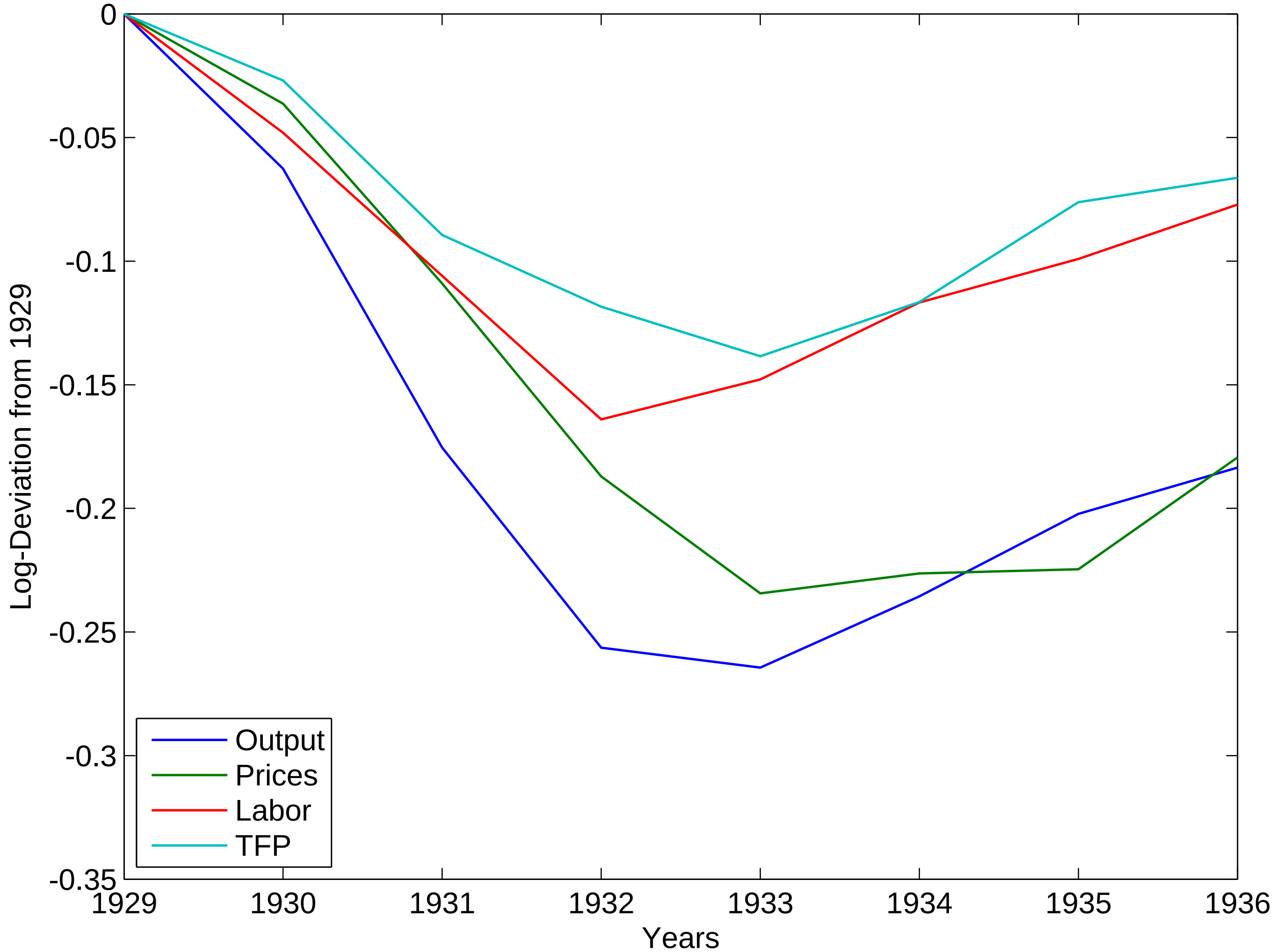


Figure 2: Outputs

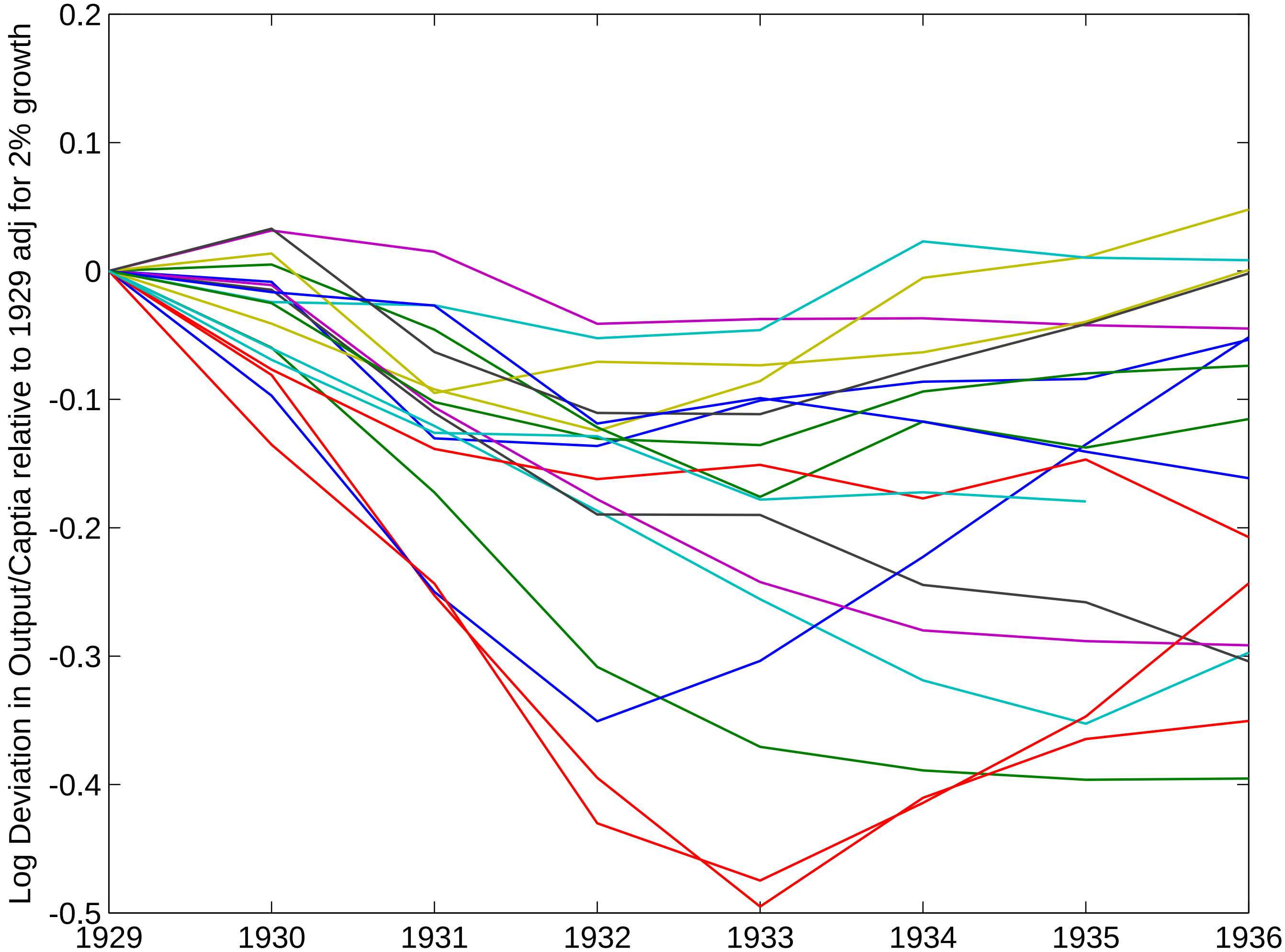


Figure 3: Prices

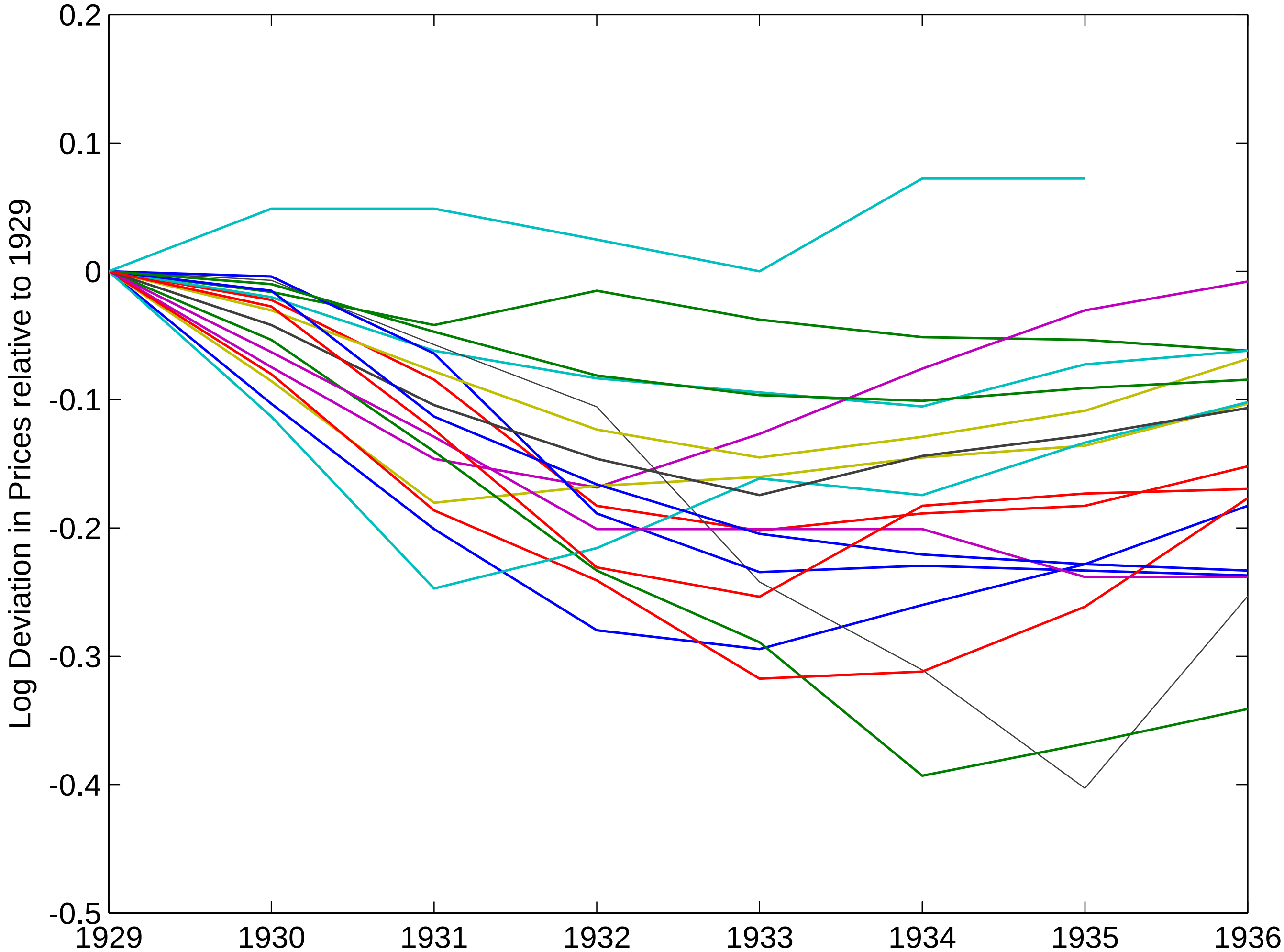


Figure 4: Labor Input

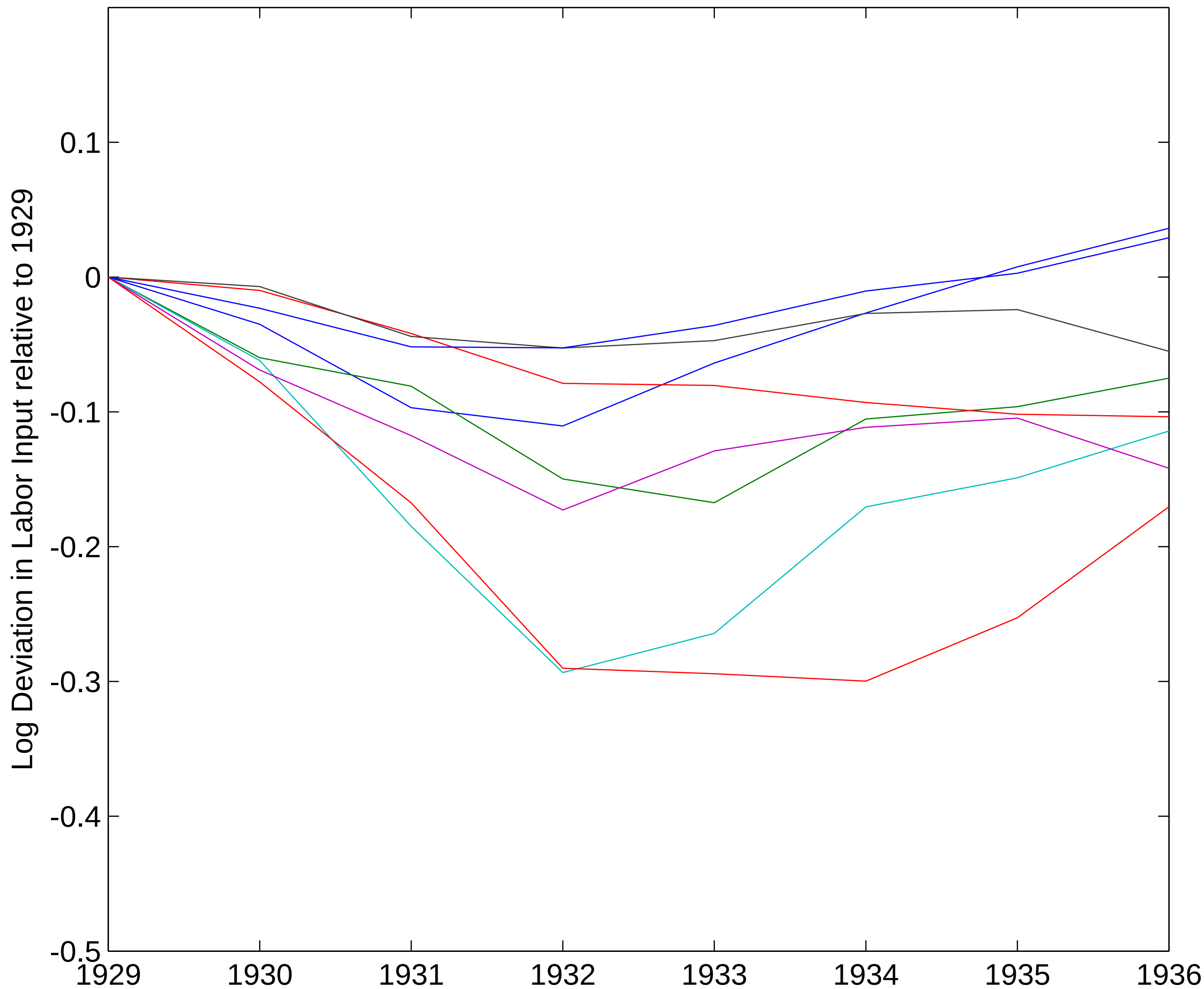
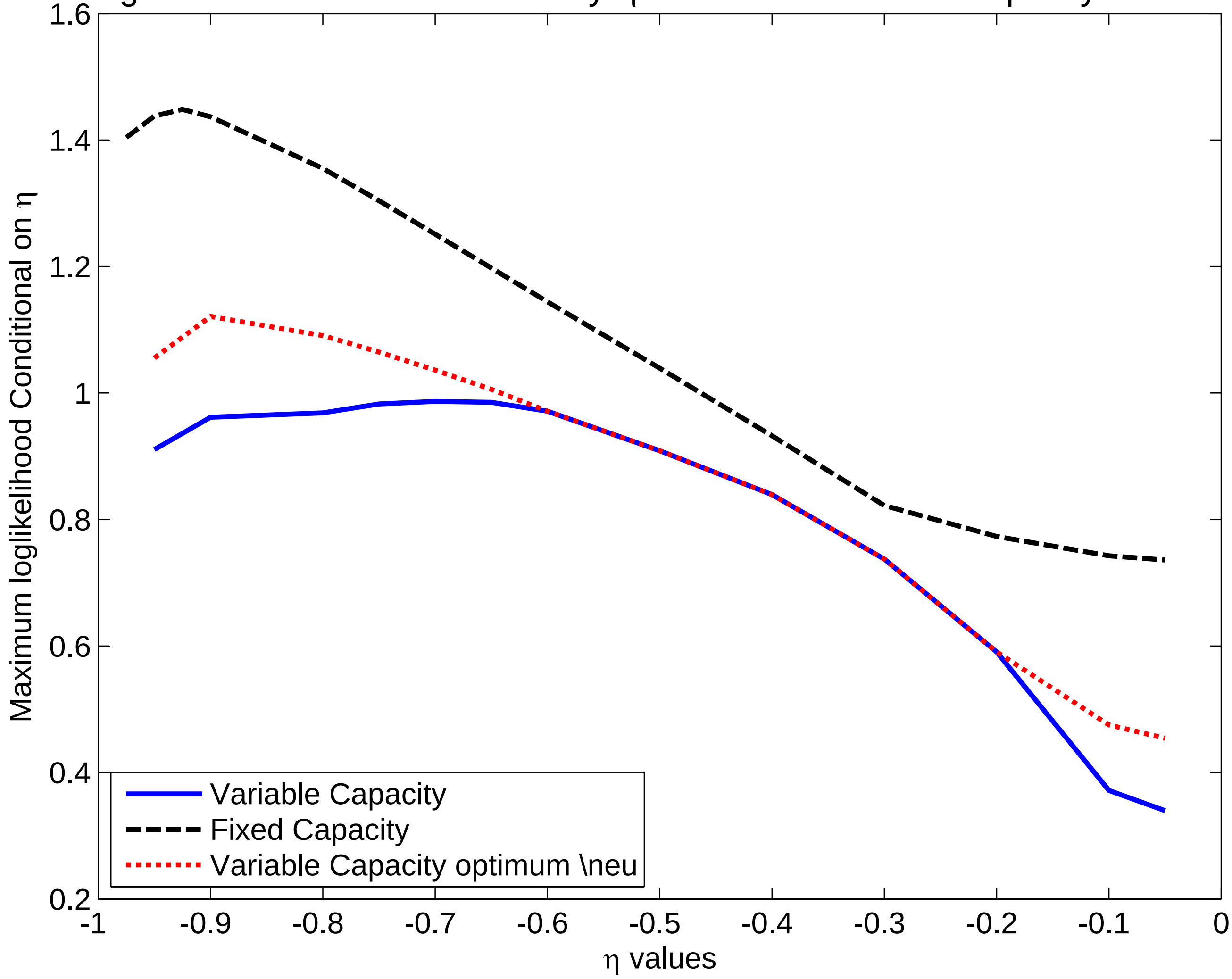
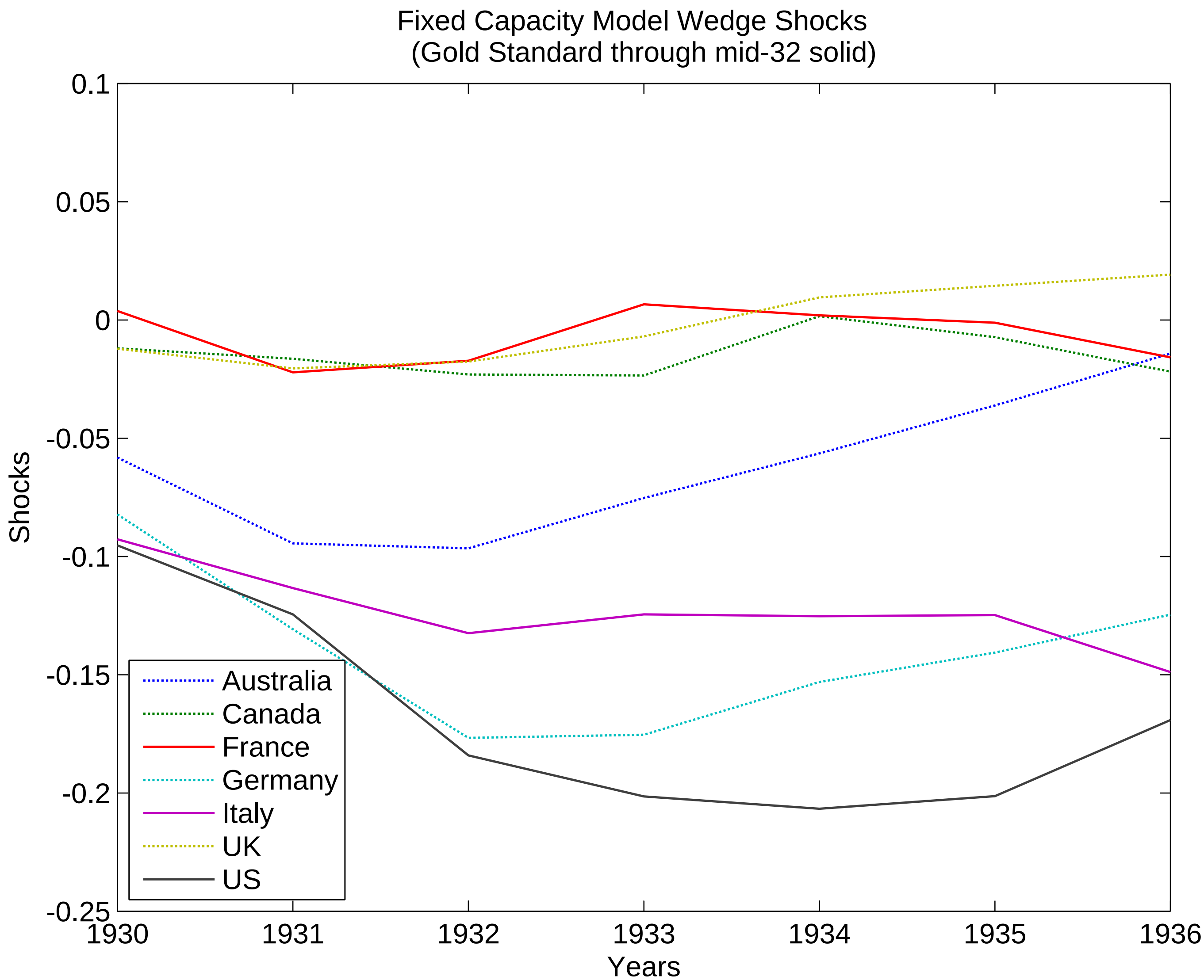
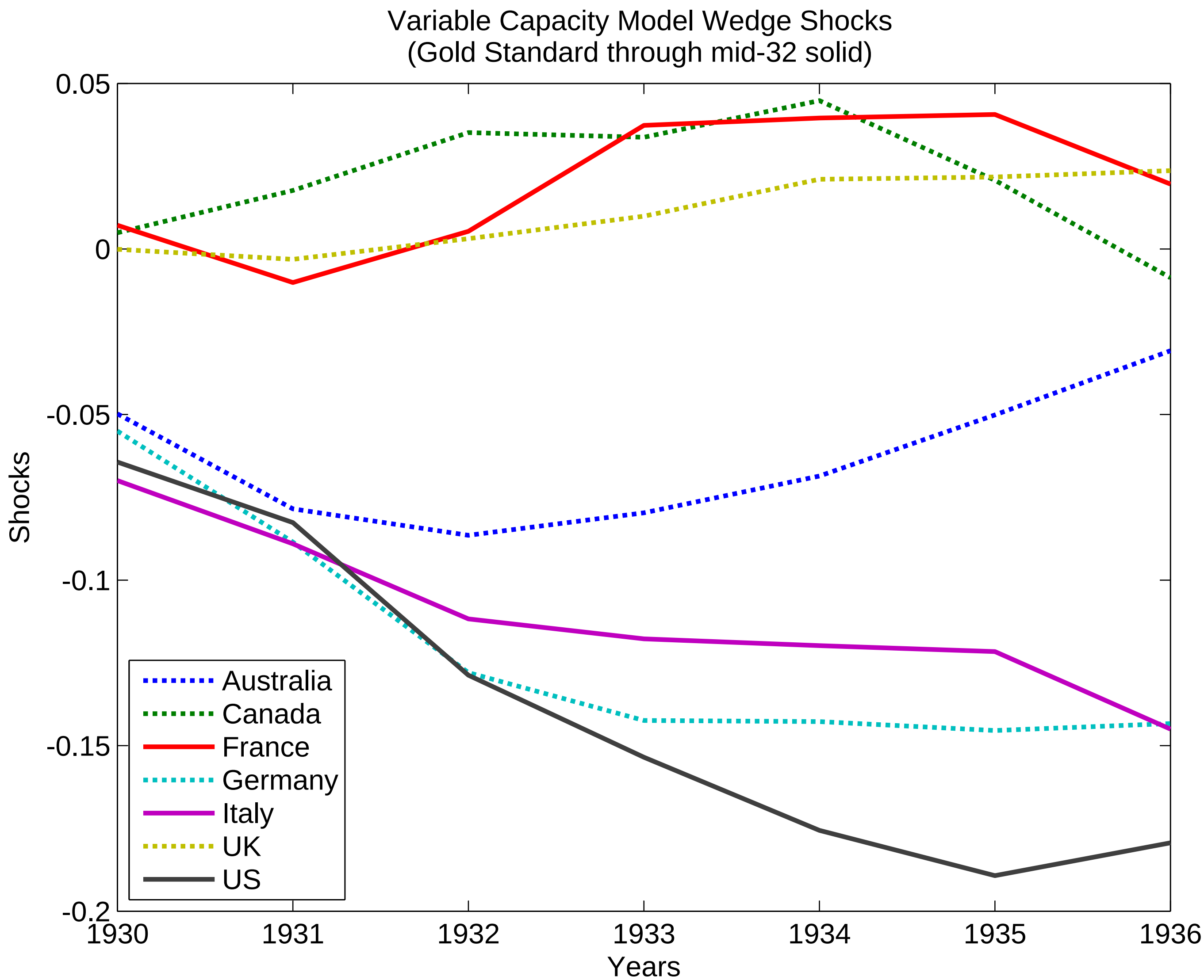


Figure 5: Maximum Likelihood by η: Variable and Fixed Capacity Models

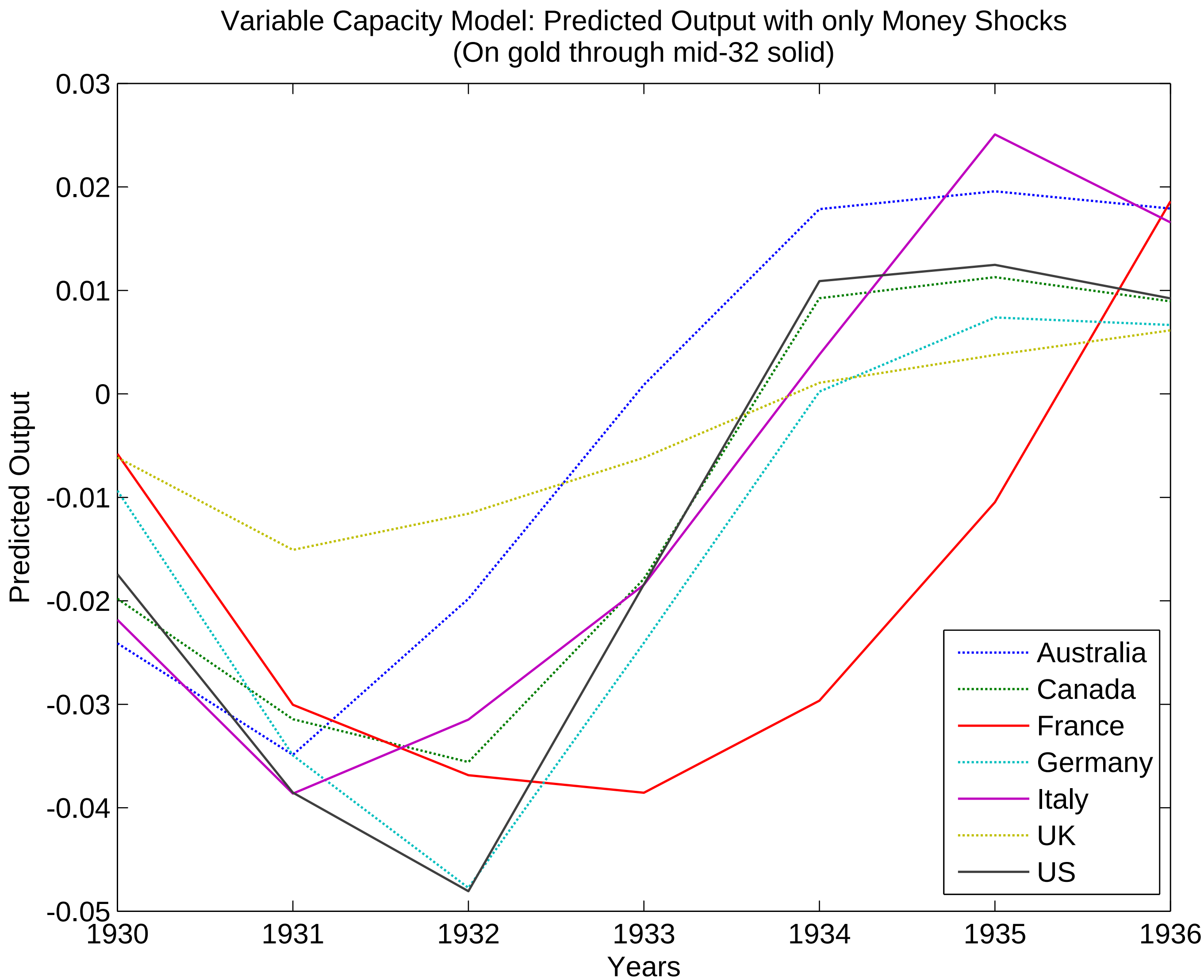




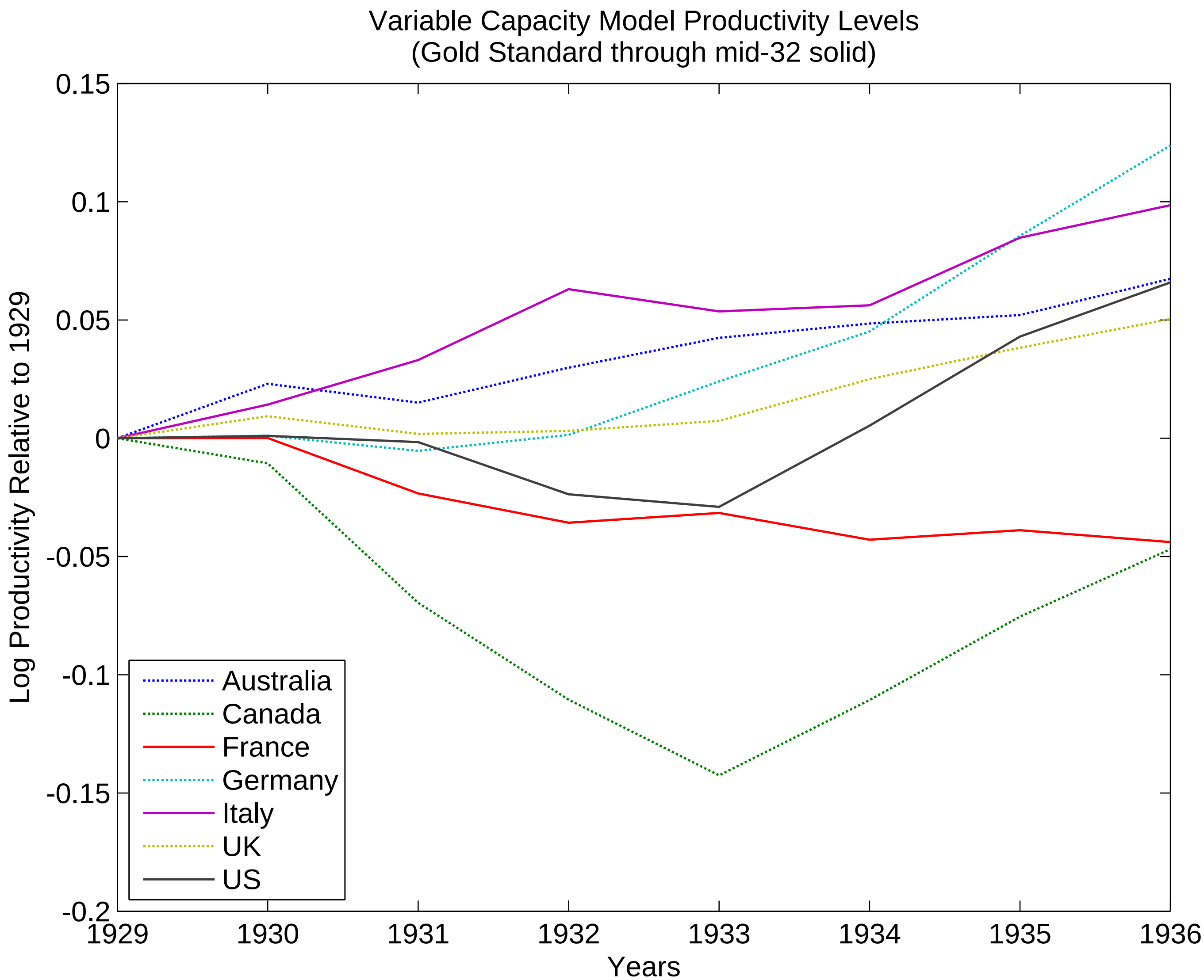
Fixed Capacity Model Wedge Shocks
(Gold Standard through mid-32 solid)
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
Shocks
1930
1931
1932
1933
1934
1935
1936
Years
Australia
Canada
France
Germany
Italy
UK
US

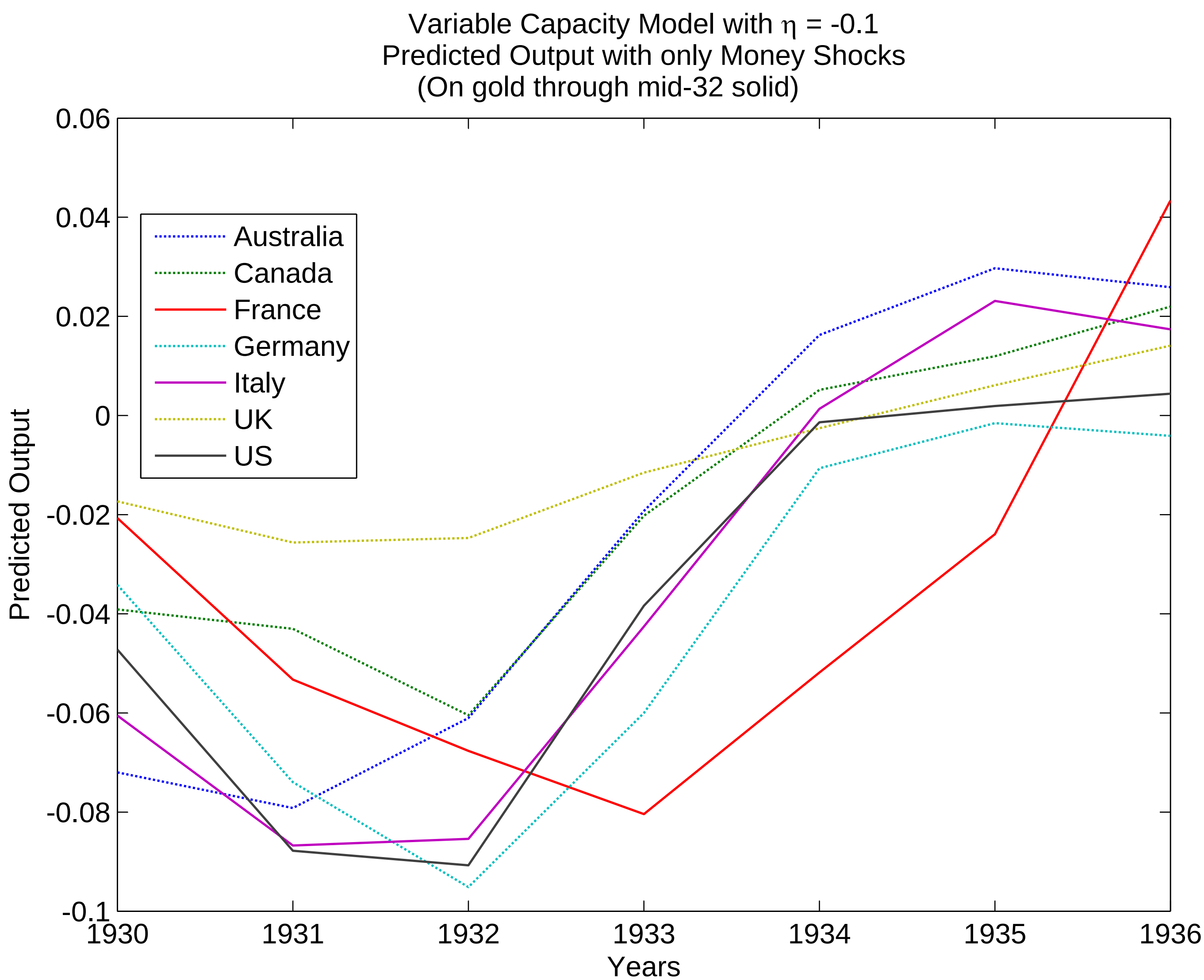


Variable Capacity Model Wedge Shocks
(Gold Standard through mid-32 solid)
0.05
0
-0.05
-0.1
-0.15
-0.2
Shocks
1930
1931
1932
1933
1934
1935
1936
Years
Australia
Canada
France
Germany
Italy
UK
US

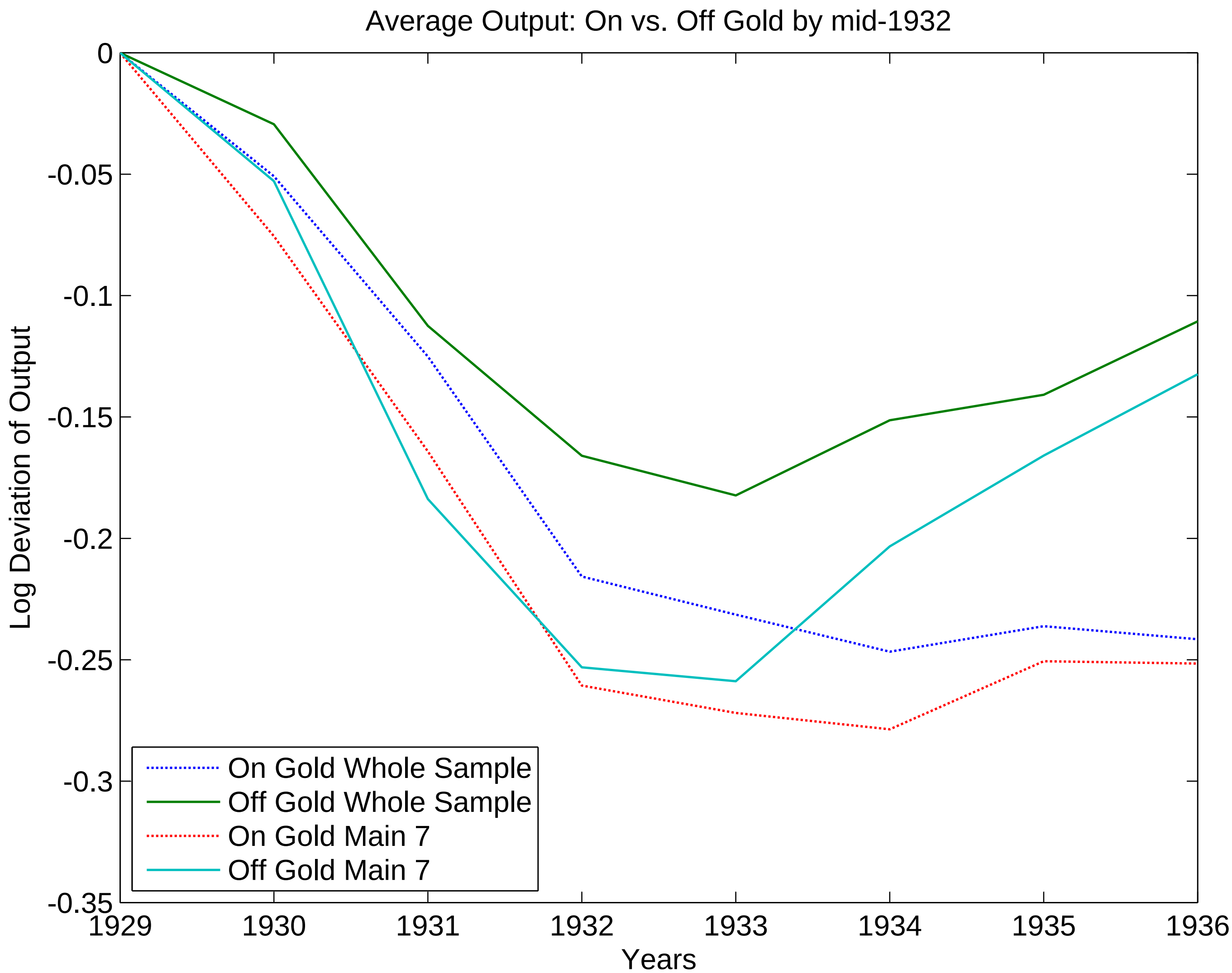


Variable Capacity Model: Predicted Output with only Money Shocks
(On gold through mid-32 solid)
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
Predicted Output
1930
1931
1932
1933
1934
1935
1936
Years
Australia
Canada
France
Germany
Italy
UK
US

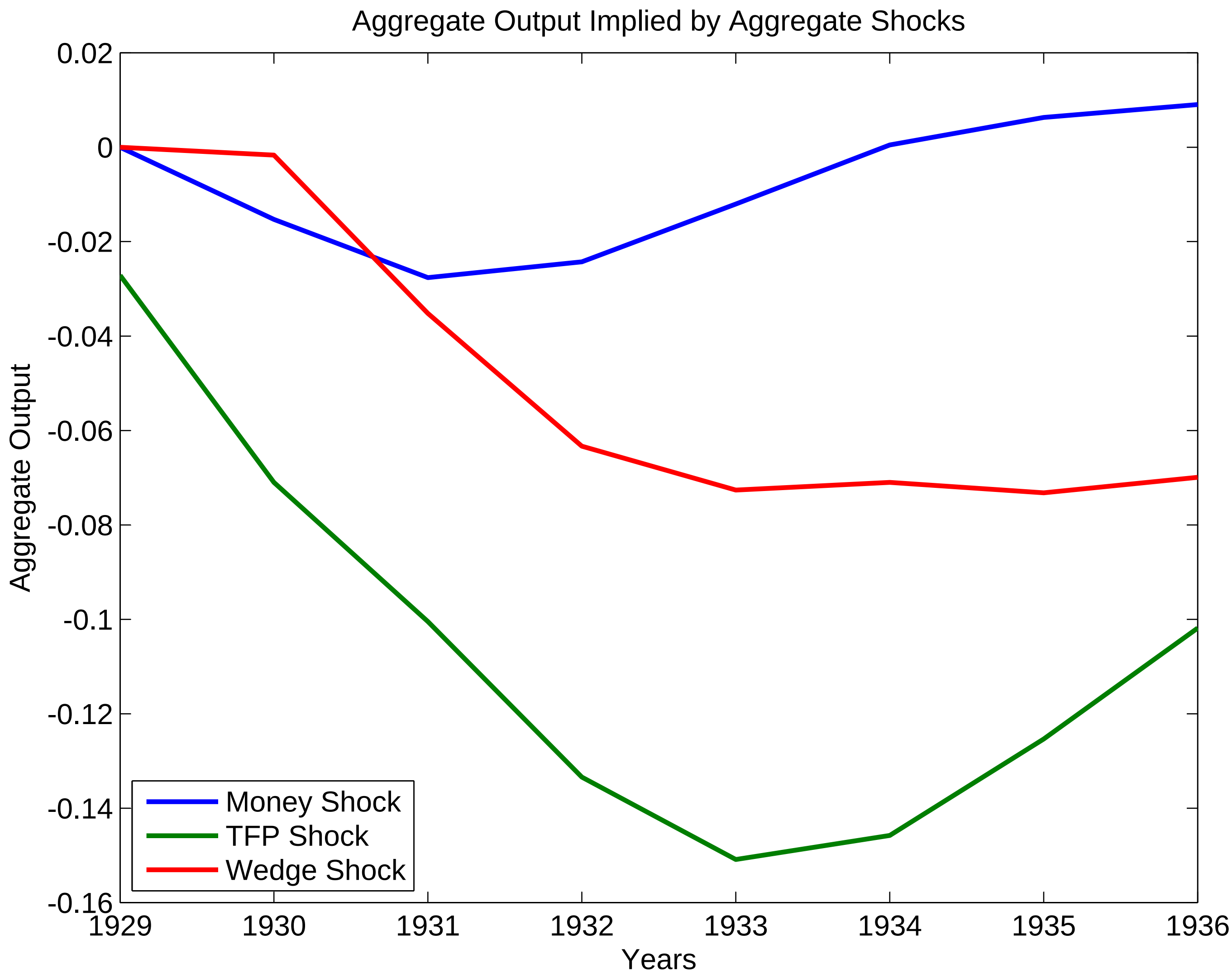

Variable Capacity Model Productivity Levels
(Gold Standard through mid-32 solid)
Log Productivity Relative to 1929
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
1929
1930
1931
1932
1933
1934
1935
1936
Years
Australia
Canada
France
Germany
Italy
UK
US



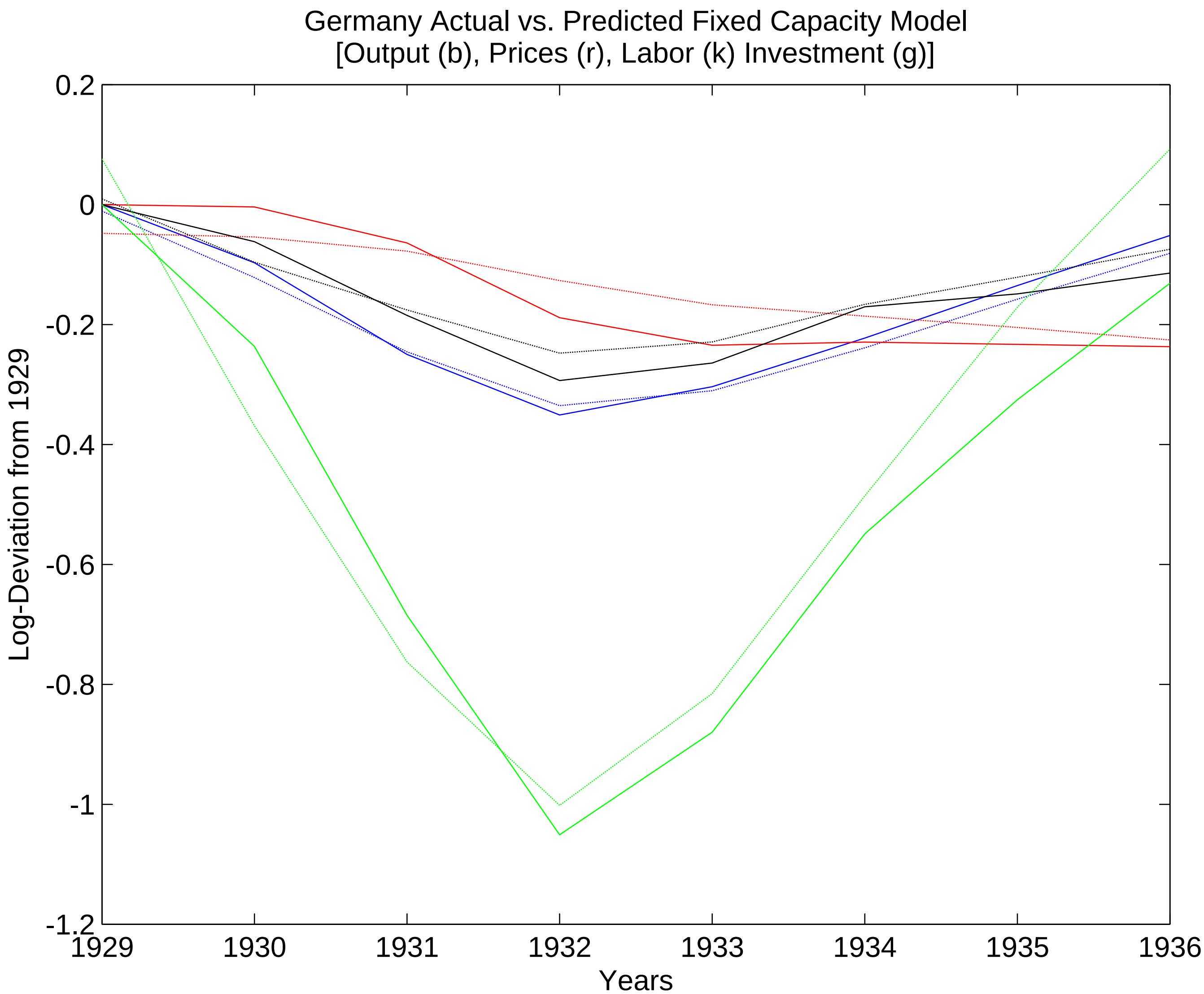
Variable Capacity Model with η = -0.1
Predicted Output with only Money Shocks
(On gold through mid-32 solid)
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
Predicted Output
1930
1931
1932
1933
1934
1935
1936
Years
Australia
Canada
France
Germany
Italy
UK
US

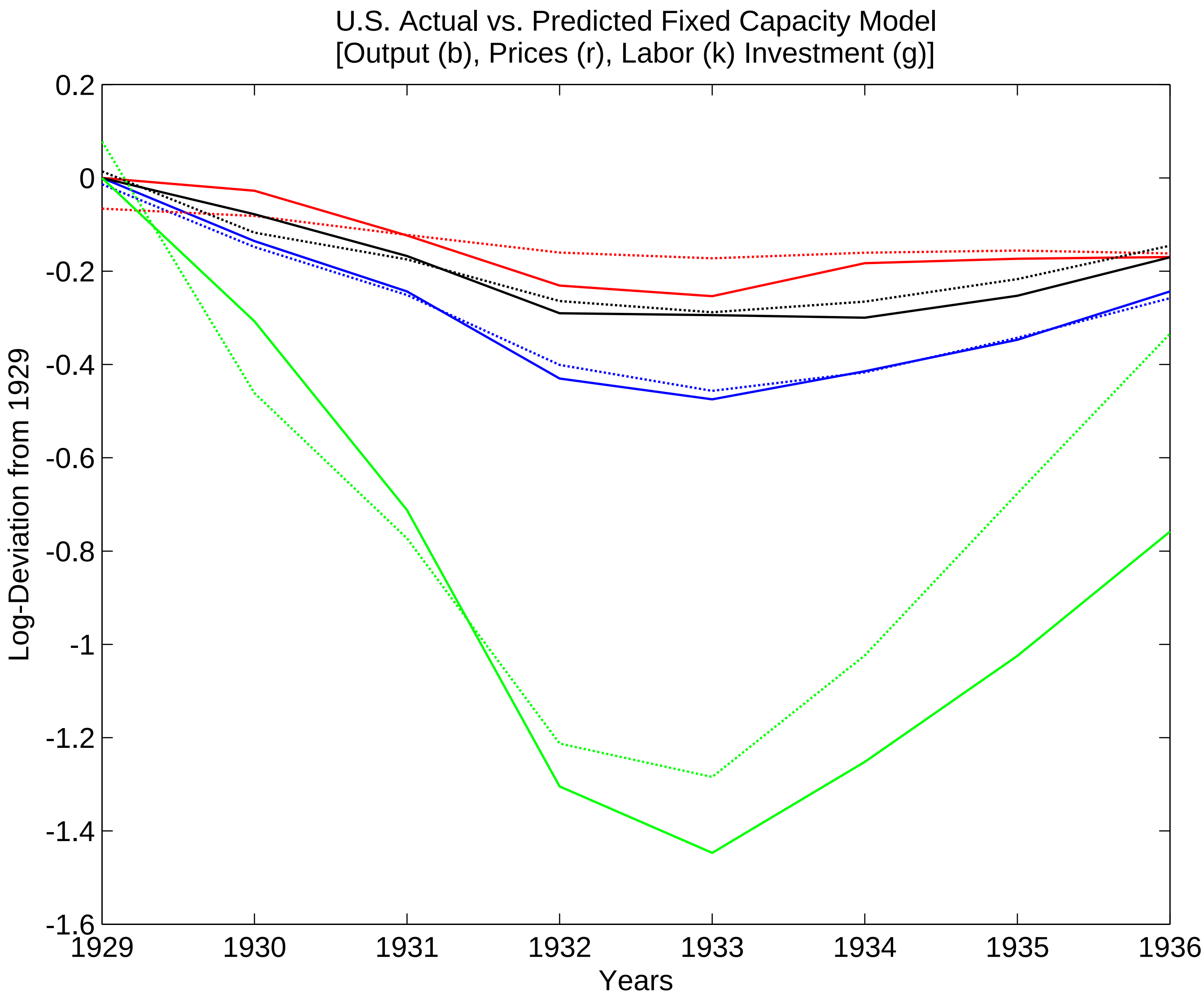


Average Output: On vs. Off Gold by mid-1932
0
-0.05
-0.1
-0.15
-0.2
-0.25
-0.3
-0.35
Log Deviation of Output
1929
1930
1931
1932
1933
1934
1935
1936
Years
On Gold Whole Sample
Off Gold Whole Sample
On Gold Main 7
Off Gold Main 7



Aggregate Output Implied by Aggregate Shocks
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
-0.12
-0.14
-0.16
Aggregate Output
1929
1930
1931
1932
1933
1934
1935
1936
Years
Money Shock
TFP Shock
Wedge Shock


Germany Actual vs. Predicted Fixed Capacity Model
[Output (b), Prices (r), Labor (k) Investment (g)]
Log-Deviation from 1929
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
1929
1930
1931
1932
1933
1934
1935
1936
Years


U.S. Actual vs. Predicted Fixed Capacity Model
[Output (b), Prices (r), Labor (k) Investment (g)]
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
-1.6
Log-Deviation from 1929
1929
1930
1931
1932
1933
1934
1935
1936
Years