Federal Reserve Bank of Minneapolis
Research Department Staff Report ???

July 2003

Deflation, Real Wages, and the International Great Depression: A Productivity Puzzle

Harold L. Cole
U.C.L.A.

Lee E. Ohanian
U.C.L.A. and F.R.B. of Minneapolis

Ron Leung
University of Minnesota

ABSTRACT

The high real wage story is one of the leading hypotheses for how deflation caused the International Great Depression. The story is that world-wide deflation, combined with incomplete nominal wage adjustment, raised real wages in a number of countries, and these higher real wages reduced employment as firms moved up their labor demand curves. This paper studies the high real wage hypothesis in an international cross section of 17 countries between 1930-33 using dynamic, general equilibrium monetary models. We find that the high real wage story by itself does not account for output changes in the international cross section. The models make large errors predicting output in the international cross section, largely because the correlation between real wages and output in the models is -1, while this correlation is positive in the data. This means that the world-wide Depression was not just firms moving up their labor demand curves in response to high real wages. Instead, accounting for the Depression requires a shock that shifts labor demand curves differentially across countries. We add productivity shocks to the model as a candidate labor demand shifter. We find that the productivity shocks in the model are very similar to productivity changes in the data. We also find that productivity shocks account for about 2/3 of output changes, while monetary shocks account for about 1/3 of output changes.

1. Introduction

Since Kydland and Prescott, (1982), it has become common practice to measure the relative contributions of different shocks to business cycle fluctuations, and to evaluate how these shocks generate these fluctuations. This paper conducts this type of shock decomposition analysis for the international Great Depression of 1929-33. We measure the fraction of output fluctuations for 17 countries that are accounted for by monetary shocks and productivity shocks. It may seem surprising to conduct such a decomposition analysis, given the consensus view is that money is by far the dominant shock driving the international Great Depression. In particular, Bernanke (1995), Bernanke and Carey (1994), and Eichengreen and Sachs (1985), among others, argue that worldwide contractionary monetary shocks drove down price levels in many countries, which raised real wages through incomplete nominal wage adjustment. They further argue that these higher real wages reduced employment as firms moved up their labor demand schedules to equate the higher real wage to a higher marginal product of labor. Table 1 provides some support for this view. The table shows that, on average, output fell, prices fell, and real wages rose across these 17 countries.[1]

Figures 1 and 2 motivate why we conduct a productivity - money shock decomposition for the international Depression. Figure 1a-d show a scatterplot of the log deviations of real wages and real output for 1930-33 relative to 1929. If the International Depression was only due to the consensus story of deflation and high real wages, then we should see a strong negative cross-country relationship between real wage changes and output changes. That is, the countries with the biggest real wage increases should have had the biggest depressions.

[1] The countries are Australia, Austria, Canada, Czechoslovakia, Denmark, Finland, France, Germany, Hungary, Italy, Japan, the Netherlands, Norway, Sweden, Switzerland, the U.K. and the U.S. Output is real GNP, the price level is the GNP deflator, and the wage rate is for the industrial/manufacturing sector.

We instead see the opposite pattern; the cross-country correlation between real wages and real output is positive, instead of negative, ranging from 0.26 to 0.48 for these years.

Figures 2a-d show a scatterplot of the log deviations of the GDP deflator and real output for 1930-33 relative to 1929. If the depression was only due to deflation, then we should see a strong positive cross-country relationship between price changes and output changes. That is, the countries with the biggest deflations should have had the biggest depressions. We instead see the opposite relationship; the correlation between price changes and output changes is largely negative during these years, ranging from -0.47 to 0.06.

These data indicate that accounting for the international Depression requires an additional shock beyond a money shock. We treat this additional shock as a productivity shock. There are two reasons why we do this. The first reason is that the positive correlation between real wages and output in Figure 1a-d indicates that the second shock needs to be a labor demand shifter, and a productivity shock satisfies this requirement. The second reason is that countries with large depressions had large decreases in productivity, and countries with small depressions did not. Table 2 shows data for 4 countries for which we have aggregate labor data. These data show that countries with mild depressions had small changes in labor productivity, countries that had major depressions had large declines in labor productivity. The table shows labor productivity (real GNP per worker) and output for Australia, Canada, the U.K., and the U.S. Australia and the U.K. had mild depressions (-1 and -4 percent, respectively, in 1933) and little productivity change. In contrast, Canada and the U.S. had severe depressions (-36 and -31 percent, respectively in 1933) and substantial productivity decreases.

To conduct the shock decomposition analysis, we develop a dynamic, stochastic, general equilibrium model with both productivity shocks, and money shocks that operate through imperfectly flexible wages. Our main finding is that the productivity shock is quantitatively important. This shock accounts for between 44 and 78 percent of the sum of squared output deviations across our 17 country sample, depending on the orthogonalization of the two shocks. Our preferred orthogonalization decomposes productivity into two components, one of which is orthogonal to deflation. For this decomposition, we find that orthogonal productivity shocks account for about 2/3 percent of the sum of squared output deviations across countries.

Given this finding about the importance of the productivity factor, we then compare labor productivity in the model to actual labor productivity in the 4 countries for which we have economy-wide labor productivity. We find that labor productivity in the model is very similar to actual labor productivity in these 4 countries. We then go beyond the 4 countries for which we have economy-wide labor productivity data, and compare labor productivity in the model to manufacturing labor productivity in the data, which we have for 15 countries. We find that the correlation between labor productivity in the model and actual manufacturing labor productivity is around .65.

This suggests that accounting for the International Depression within this class of models requires a quantitatively important, country specific factor that shifts labor demand and that acts and looks a lot like a productivity shock. We then examine a number of factors that might be generating these productivity shocks, including capacity utilization, labor hoarding, international trade, real exchange rate changes, and gold devaluations. We find that none of these factors provide a plausible accounting of this productivity factor. We conclude that a productivity-like shock is key for understanding the Great Depression, and more research is required to understand what this factor might be.

The paper is organized as follows. Section 2 presents the model. Section 3 presents the parameterization. of the models. Section 4 presents the shock decomposition analysis. Section 5 analyzes what factors might be driving the productivity shocks. Section 6 concludes. The Appendix describes technical details about the model and presents additional tables.

A. The Model Economy

This section presents the model economy we use for the decomposition. We construct a model in which the nonneutrality of money works through imperfectly flexible wages, and this comes from an information imperfection as in Lucas (1972). Specifically, households must make their labor supply decisions knowing the nominal wage, but without knowing either the monetary shock or the productivity shock. Thus, they choose their labor supply knowing the nominal wage, but without knowing the real wage.

We chose the misperceptions model after we experimented with a standard wage-setting model in which wages are set in advance of the monetary and productivity shocks, and cannot be changed for one period (one year). We found that the pre-determined wage model is not a useful model for analyzing the Depression. This model makes enormous errors predicting both output and labor productivity in our sample of countries during the Depression because the impact of a money shock in this model is much too large. In particular, this model predicts way too large of a depression for most of the countries with money shocks alone, and also counterfactually predicts very large increases in labor productivity. (The Appendix presents the empirical problems with the standard pre-determined wage model in detail).

We therefore construct a misperceptions model with a smaller nonneutrality of money. An additional benefit of this misperceptions model is that the size of the nonneutrality can take on a range of values that is governed by the relative variances of the productivity and money shocks. This means that the robustness of the results can be easily assessed for different impacts of a money shock. We now turn to this model.

Preferences: There is a large number of identical households who have identical preferences over sequences of a cash good, a credit good, and leisure. We normalize the size of the population to one.

Preferences for the household are given by

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

where c_1 is the cash good, c_2 is the credit good, and $1-n$ is non-market time. The household maximizes (1) subject to the following wealth constraint and CIA constraints:

$$\begin{aligned} & m_t+w_tn_t+r_tk_t+(T_t-1)M_{t-1} \\ \geq \; & m_{t+1}/T_t+p_t\left[c_{1t}+c_{2t}+k_{t+1}-(1-\delta)k_t\right], \end{aligned}$$

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

The household's wealth is the sum of its beginning-of-period cash holdings m_t, its labor income w_tn_t, its capital income r_tk_t,and a lump-sum monetary transfer from the government $(T_t-1)M_{t-1}$,where T_t is the gross growth rate of the money stock. The household's wealth is used to finance the sum of the cash the household carries into the following period m_{t+1}/T_t, plus its purchases of cash goods, credit goods, and investment $p_t[c_{1t}+c_{2t}+k_{t+1}-(1-\delta)k_t]$.[2]

[2]Note that money balances that the household carries over to the following period are divided by the

The CIA constraint is standard, and requires that the stock of cash carried over by the household from the previous period, plus the lump-sum monetary transfer it receives from the government, is sufficient to pay for cash goods $p_t c_{1t}$.

Technology: Output is produced from a constant returns to scale Cobb-Douglas technology:

$$Y_t = Z_t K_t^{\theta} N_t^{1-\theta},$$

where Z is a technology shock that follows a first order lognormal autoregressive process:

$$Z_t = e^{z_t},\ z_t = \rho_z z_{t-1} + \varepsilon_{zt}, \varepsilon_{zt} \sim N(0, \sigma_z^2)$$

The resource constraint is given by:

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

The transition rule for capital is given by:

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

Monetary Policy: Monetary policy is given by changes in the gross growth rate of money, which follows a first-order lognormal autoregressive process:

$$T_t = \bar{\tau} e^{\tau_t},\ \text{where } \tau_t = \rho_\tau \tau_{t-1} + \varepsilon_{\tau t}, \varepsilon_{\tau t} \sim N(0, \sigma_\tau^2)$$

The change in the money stock at the beginning of the period is thus equal to $(T_t - 1)M_t$, and the total money stock at the beginning of the period is given by:

$$M_{t+1} = T_t M_t$$

gross growth rate of money, T_t. This formulation preserves stationarity in the model by keeping the aggregate money stock constant over time. This general approach of retaining stationarity is standard in monetary models (e.g. Cooley and Hansen, 1989).

Information and the Timing of Transactions: We now specify the timing of information and the timing of activities within a period. To do this, we first need to define the state of the economy, which we denote as $S_t = (K_t, z_{t-1}, \tau_{t-1}, \varepsilon_t^z, \varepsilon_t^\tau)$. Note that we include the lagged values of the shocks and their current innovations separately in the state vector, because the model requires that households make their labor market choices before they observe $(\varepsilon_t^z, \varepsilon_t^\tau)$.

At the start of a period, the households knows its own state (k_t, m_t), knows a subset of the state vector: $\bar{S}_t = (K_t, \tau_{t-1}, z_{t-1})$, and knows the nominal wage. We assume that the representative firm knows the full state vector, which means that they know the state of technology and the nominal price of their good.[3] At this stage, the labor market opens, and the household and firm make their labor market choices, given the nominal wage. After the labor market, the full aggregate state $S_t = (K_t, z_{t-1}, \tau_{t-1}, \varepsilon_t^z, \varepsilon_t^\tau)$ is revealed, and households receive their monetary transfer from the government. The household then supplies labor and capital in production, and acquires cash consumption goods, credit consumption goods, and investment goods. At the end of the period, firms and labor settle their remaining transactions, with firms paying households for their labor and capital services, and households

[3] 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 simply environment to stand in for a richer environment in a multi-sectors model producing heterogenous consumer goods. In such an environment, the firm only cares about 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 does. 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.

paying firms for credit consumption goods and investment goods.

We now specify a recursive formulation of the model. We denote the law of motion for aggregate capital by $H(S_t)$. We normalize the aggregate money stock to one.

A Recursive Formulation: The representative household has a two-stage maximization problem in this model. The Bellman equation for the household is given by:

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

subject to

$$\begin{aligned} & m_t + w_t n_t + r_t k_t + (T_t - 1) M_t \\ \geq \;\; & m_{t+1}/T_t + p_t \left[k_{t+1} - (1-\delta) k_t + c_{1t} + c_{2t} \right] \end{aligned}$$

$$m_t + (T_t - 1) M_t \geq p c_{1t}.$$

In the first stage maximization, the household chooses their labor supply, given $\bar{S}_t$ and given the nominal wage. Thus, they optimally forecast the technology and monetary shocks from the current state and the nominal wage. This can be seen in the household's first order condition (f.o.c.) for choosing labor:

$$-\phi/(1-n_t) + w_t E\{\Lambda_t | w_t, \bar{S}_t\} = 0.$$

In this equation, the household is equating the marginal utility of leisure to the *expected* marginal utility of nominal wealth (Λ_t), scaled by the nominal wage. The household solves this expectational equation using standard signal extraction formulae. The Appendix presents the details of this signal extraction problem.

After the household chooses its labor supply, S_t given its state and the nominal wage, the full state is revealed and the household chooses cash goods consumption, credit goods consumption, money holdings for next period, and investment during the second stage. The f.o.c.'s for the second stage maximization are given respectively by:

$$\left[\alpha {c_{1t}}^{\sigma} + (1-\alpha){c_{2t}}^{\sigma}\right]^{-1} \alpha {c_{1t}}^{\sigma-1} - (\Lambda_t + \Psi_t)p_t = 0$$

$$\left[\alpha {C_{c1t}}^{\sigma} + (1-\alpha){c_{2t}}^{\sigma}\right]^{-1} (1-\alpha) {c_{2t}}^{\sigma-1} - \Lambda_t p_t = 0,$$

$$\beta E_t V_1 / T_t - \Lambda_t = 0$$

$$\beta E_t V_2 - \Lambda_t p_t = 0$$

The envelope conditions for m_t and k_t are

$$V_1 = E\{\Lambda_t + \Psi_t | \bar{S}_t, w_t\}$$

and

$$V_{2,t} = E\left\{\Lambda_t \left(r_t + 1 - \delta\right) | \bar{S}_t, w_t\right\}$$

Producer's Problem: Given that the firm knows S_t, the firm's maximization problem is standard:

$$\max_{K_t, N_t} p_t Z_t (K_t)^{\theta} (N_t)^{1-\theta} - w_t N_t - r_t K_t$$

Market Clearing and Aggregate Consistency Conditions: The market clearing conditions are

$$M_t = m_t,$$

$$Y_t = C_{1t} + C_{2t} + K_{t+1} - (1-\delta)K_t,$$

$$N_t = n_t,$$

$$K_t = k_t,$$

The aggregate consistency condition is:

$$k_{t+1} = H(S_t),$$

where $H(S_t)$ is the law of motion for the aggregate capital stock.

B. The Role of Imperfect Information

We now illustrate how the information imperfection generates the monetary nonneutrality. We do this by analyzing the impact of an i.i.d. money shock in a version of the model without capital. In the absence of capital accumulation, the impact of a monetary shock on labor input boils down to two equations: the household's labor/leisure condition, and the firm's first order condition for hiring labor.

The household's labor/leisure first order condition is presented below, along with the equation in the model with full information for comparison. Log-linearizing, we obtain:

$$\text{Misperceptions Model:} \qquad \hat{w}_t - \frac{\hat{n}_t N}{1-N} = -E\{\hat{\lambda}_t | \hat{w}_t, \bar{s}_t\},$$

$$\text{Full Information Version} \quad : \qquad \hat{w}_t - \frac{\hat{n}_t N}{1-N} = -\hat{\lambda}_t,$$

where capital letters are steady state objects and, the other variables are log-deviations from the steady state. With imperfect information, the household forecasts the marginal value of nominal wealth ($\hat{\lambda}_t$), conditioning on the nominal wage ($\hat{w}_t$) and the restricted state vector

($\bar{s}_t$), to make their labor supply decision.Thus, the household forecasts this object without knowing the productivity shock or the monetary shock.

The forecasting rule comes from standard signal extraction formulae that are given in the Appendix, and are the same as in Lucas (1972). The nonneutrality of money is thus a consequence of the household imperfectly forecasting the nominal marginal value of wealth, and the size of the nonneutrality depends on how badly they forecast this object; large forecast errors will lead to a large nonneutrality, and small forecast errors will lead to a small nonneutrality.

The size of the forecast error of $\hat{\lambda}_t$ depends on the relative variances of the productivity and monetary shocks. To see this, consider two polar cases. First consider the case in which the variance of the technology shock approaches zero. In this case, money will be neutral. This is because with a negative money shock, the household correctly attributes the lower nominal wage to the monetary contraction. Thus, they correctly forecast that the marginal value of wealth falls by the same percentage as the nominal wage, which leads to no change in hours worked. Next, consider the case in which the variance of the money shock approaches zero. In this case, money is nonneutral. Here, a negative money shock drives down the nominal wage, but the household incorrectly attributes the lower wage entirely to a negative productivity shock, rather than to a negative money shock. This means they incorrectly forecast the nominal marginal value of wealth, and consequently choose to work less at the lower nominal wage. As the variance of the money shock rises, the size of the nonneutrality falls.

The second equation that determines the impact of a money shock is the firm's first order condition for hiring labor. This shows the equilibrium relationship between the real wage and hours worked:

$$(2) \qquad \hat{n}_t = -\frac{1}{\theta}(\hat{w}_t - \hat{p}_t),$$

where θ is the exponent on capital in the production function. A contractionary money shock thus works in this model just as in the standard Depression story: a negative money shock drives down the nominal wage, but less than the price level, resulting in a higher real wage. This higher real wage results in lower employment and output, as firms move up their labor demand curve.

2. Parameter Values

Table 3 presents the parameter values. A number of these choices are standard and do not affect the decomposition results. We set the discount rate to 0.95, the exponent on labor in the production function to 2/3, and the depreciation rate to about 9 percent per year, which yields a steady-state capital/output ratio of 2.5. We choose the preference parameters α and σ such that the steady state of the model matches two long-run observations: an interest semi-elasticity of money demand of -.08, and an average velocity level of 3.2. We choose the leisure parameter ϕ so that households spend about 1/3 of their time working in the deterministic steady state.

We chose the autocorrelation coefficient for the technology shock to be 0.9. We chose the autocorrelation coefficient for money growth (ρ_τ) to be zero, which is consistent with the average serial correlation of money growth during the Gold Standard period. We conducted a sensitivity analysis for values of the money growth serial correlation parameter between -0.5 and 0.5, and found that our results were insensitive to values in this range.

The innovation variances for the money supply and the technology shock determine the size of the nonneutrality - that is, the impact of an unanticipated money shock on output. We label this nonneutrality parameter as η. We conduct the analysis for three values of η : the maximum size of the nonneutrality parameter ($\eta = 0$, which is the case in which the variance of the money shocks is zero), a very small value of the nonneutrality ($\eta = -0.8$), in which the variance of the money shock is much bigger, and consequently money has only a very small effect on output, and a middle range for the nonneutrality ($\eta = -0.5$). The shock decomposition results are insensitive to these different values of the nonneutrality parameter.

Table 4 displays the impact of a contractionary money shock that reduces the price level by 10 percent for these values of η, and also for some other values. The maximum nonneutrality produces a 15 percent decrease in hours worked from a 10 percent decrease in the price level, the medium nonneutrality produces an 10.7 percent decrease in hours, and the low nonneutrality produces a 5.4 percent decrease in hours. For comparative purposes, we note that a standard predetermined wage model drives down employment 30 percent from a 10 percent unanticipated deflation.

3. Accounting for the Great Depression

We now conduct the shock decomposition analysis. Ideally, we would conduct this two shock analysis by feeding in measured productivity shocks and money shocks. Unfortunately, TFP is available only for the U.S. and Canada in our 17 country sample, and money shocks by definition are latent variables. We therefore conduct an alternative decomposition analysis as follows.

For a given value of the nonneutrality parameter η, we construct country-specific productivity shocks and country-specific monetary shocks in the model so that output and the price level in the model for each country and for each year matches the data. We match the price level because the consensus view is that deflation is the key driving force behind the Depression. We match output so that we can conduct the shock decomposition. We focus on the results for $\eta = -0.5$, because this value produces labor productivity in the model that is close to that in the data, and because the shock decomposition results are insensitive to the choice of η. The Appendix presents the results for the other two extreme values of η.

Mechanically, this procedure boils down to solving 2 linear equations in the 2 shocks for each year and each country. To conduct the shock decomposition accounting analysis, however, we need to orthogonalize the shocks. We follow the standard practice of calculating the two bounds on the orthogonalizations; the first orthogonalization attributes all of the non-orthogonal movements in the two shocks to productivity, and the second orthogonalization attributes all of the non-orthogonal movements in the two shocks to money.

Table 5A reports characteristics about the constructed raw productivity shocks. The mean productivity shock across countries is very negative around the trough of the Depression (-4 percent in both 1932 and 1933), and is also highly correlated with output in these years. Table 5B shows statistics about the orthogonalized components of the productivity shock. Each row of the table indexed by a year shows the fraction of the squared output deviation in that year from 1929 accounted for by a specific orthogonalization of the productivity shock. The bottom row of the table labeled as "total" is the weighted average of these yearly fractions, where the weight for a specific year is the fraction of the sum of squared output deviations from 1930-33 accounted for the sum of squared output deviations in that specific year.

The first column in this table is the fraction of output variation accounted for by the productivity shock that is orthogonal to the money shock. This orthogonalization attributes all of the covariance between the money shock and the productivity shock to money. Despite this conservative orthogonalization, orthogonal productivity is quantiatively important, explaining between 40-97 percent of output variation during the 1930-33. The second column is the fraction of output variation accounted for by the productivity shock that is orthogonal to deflation, which is our preferred orthogonalization. This is our preferred orthogonalization because the consensus view is that deflation caused the Great Depression, and this decomposition lets us control for productivity shocks that may be proxying for the effects of deflation. In particular, this orthogonalization allows us to correct for deflation-induced changes in capital utilization or other deflation-related measurement issues. We calculate the orthogonal component by projecting the vector of country-specific productivity shocks onto the deflation rates for each country. We calculate this orthogonal component separately for each year. The fraction of output variations explained by this orthogonal component of productivity ranges from 52 to 98 percent, with a weighted average across years of 69 percent.

A key reason why productivity shocks are such a large factor is because deflation and output are *negatively* correlated during this period. For example, the correlation between deflation and the log-deviation of output from 1929 is -0.34 for 1930 and -0.25 for 1931. Note that productivity orthogonal to deflation accounts for 96 percent and 72 percent of squared output fluctuations for these years, respectively. The only year in which there is a sizeable positive correlation is in 1932, when the correlation is 0.47. This is the year in which orthogonal productivity accounts for the smallest fraction of output: 50 percent.

Taken together, these results indicate that productivity shocks are playing a quantitatively important role in the model. We now check to see if the constructed productivity shocks from the model are similar to the available productivity data. We do this two ways. We first compare labor productivity from the model to labor productivity in the data for the 4 countries for which we have economy-wide labor productivity: Australia, Canada, the U.K., and the U.S. Table 5C shows that the labor productivity in the model is very similar to labor productivity in the data for each year and for each country. For 1933, labor productivity in the actual data vs. the model is: U.S., -16% (actual) vs. -15% (model), U.K., -2% vs. -2%, Australia, 4% vs. 1%, and Canada, -25% vs. -15%. (The Appendix shows labor productivity for the other values of the nonneutrality parameter, and for the pre-determined wage model.)

We now go beyond the 4 countries for which we have economy-wide labor productivity data, and compare the constructed productivity shocks in the model to manufacturing labor productivity in the data. We have this measure for 15 countries, which is all the countries except Czechoslovakia and Denmark.[4] We take an average of the TFP shock in the model between 1930-32, and calculate the correlation between the time-averaged TFP and averaged orthogonalized TFP in the model (orthogonal to deflation) to the 1930-32 average of manufacturing labor productivity in the data. These correlations are reasonably high, between 0.58 and 0.77.[5]

We also analyze the relationship between measured real wages in the data, and real wages in the model. Before proceeding, it is important to note that measurement error is likely a quantiatively important issue for the measured wages. One source of measurement error is

[4] For Austria, France and Germany, data limitations allowed us to only use deviations from their 1930 levels.

[5] We chose to compare correlations between the model TFP shocks and industrial labor productivitity, rather than compare the labor productivites in the model to the manufacturing labor productivies because there may have been a level difference between the manufacturing sector and the overall economy. For example, the shocks may differ because the manufacturing sector tends to get hit harder during downturns than the overall economy.

compositional changes in the labor force. That is, the average quality of workers tends to rise during depressions, as the least experienced and productive employees are typically the first to be laid off. We have addressed this compositional bias by compositionally adjusting the wage rate in the model, using the postwar U.S. estimates of cyclical labor composition bias produced by Barsky, Solon, and Parker. Table 5D shows statistics about these compositionally adjusted wages. The average wage in the model tends to be above normal during the first years of the Depression, but is close to its normal level in 1931 and 1932. Given measurement error, perhaps the most interesting comparison between the model wage and the actual wage is the correlation between these two variables. This correlation is quite high, particularly considering the possibility of significant measurement error in the actual wage data, and ranges between 0.54 to 0.67.

We evaluated the robustness of these decompositions two ways. First, we calculated the decompositions for the maximum nonneutrality ($\eta = 0$) and a very low nonneutrality ($\eta = -0.8$). Appendix tables X.B and XX.B shows that these differences in the size of the nonneutrality did not change the results significantly. The fraction accounted for by productivity orthogonal to deflation is 64 percent for the maximum nonneutrality, and 66 percent for the small nonneutrality. Our second robustness check is to test our assumption that all countries had the same nonneutrality of money. We did this by splitting the 17 countries into two groups, with each group having a different value for the nonneutrality parameter. The first group includes the six countries that had very large depressions: Canada, U.S., France, Germany, Austria, and Czechoslovakia, and the second group is the remaining eleven countries that had small output changes: Finland, Sweden, Switzerland, Japan, Australia, Denmark, Hungary, Italy, the Netherlands, and the UK.

We assigned the maximum nonneutrality value of $\eta = 0$ to the six large depression countries, and we assigned the small nonneutrality value ($\eta = -0.8$) to the remaining 11 countries with small output changes. Table 6A shows the results. Splitting the countries into these two separate groups did not change the shock decomposition results significantly; orthogonal productivity still explains 62 percent of the sum of squared output deviations, compared to 66 percent with the common nonneutrality parameter. (Table 6B shows the labor productivity in the model - note that this version of the model generates labor productivity numbers that are too high relative to the data). We also experimented with other values of the nonneutrality parameter for the two groups, and this did not change the results.

Taken together, these assessments suggest that the model is producing a plausible decomposition of output fluctuations due to productivity, and fluctuations due to changes in labor input. We conclude from this section of the analysis that a shock that (1) works like a productivity shock, (2) that is largely orthogonal to deflation, and (3) looks a lot like productivity in the data, is a quantitatively important factor in accounting for the International Depression.

4. What is Generating the Productivity Shocks?

We now analyze what might be generating these productivity shocks. We first consider the "usual suspects" for procyclical productivity: capacity utilization and labor hoarding. There are two reasons why these large productivity shocks are not just due to capacity utilization brought about by a monetary contraction. If this was the explanation, then the productivity shock would be strongly related to deflation. It is not; about 2/3 percent of the international depression is due to a productivity shock that is *orthogonal* to deflation. The second reason is that labor productivity fell significantly in a number of countries, including the U.S. and Canada. If the productivity shocks were just due to capacity changes, then labor productivity would be higher, not lower.[6]

There are also two reasons why the productivity shocks are not just due to labor hoarding brought about by a monetary contraction. The first is the previously mentioned factor that the bulk of the depression is accounted for by productivity orthogonal to deflation. The second is that labor hoarding cannot account for the positive cross-country relationship between real wages and output in the data. This is because if the international Depression was just labor hoarding and deflation, there should be a strong negative cross-country relationship between real wages and output.

Given that the usual suspects don't provide a plausible explanation for these productivity shocks, we now explore other factors that might be generating these shocks. We do this by calculating the correlation between the values of productivity and the orthogonal component of productivity across countries with 5 country-specific factors - differences in the share of international trade, differences in the size of the agricultural sector, and differences in the real effects of deflation, differences in the real exchange rate, and differences in gold devaluation. Table 7 presents these results.

The first factor we consider is the size of a country's trade sector in 1929. The idea here is that more open economies would be more vulnerable to foreign shocks. We measure the size of the trade sector as the sum of exports and imports divided by output. We have data for all the countries in the sample except Czechoslovakia and Germany. The correlation

[6] This follows from the fact that the capital labor ratio rises in response to higher real wages as long as there is non-zero substiutability between capital and labor.

is low (.04 and .15), and the sign is the opposite of what we would have expected. Thus, productivity does not seem to be proxying for trade, at least as measured by the share of output in exports and imports.

We now consider whether productivity is proxying for country-specific differences in the real effects of deflation that were not picked up in our analysis that split the nonneutrality between two groups of countries that we previously considered. We measure these country-specific differences using data from the 1920s, when many countries in our sample experienced large deflations. For each country for which we have data, we measure the country-specific 1920s response to deflation as the ratio of the log-deviation in output to the log-deviation in prices over the two years of the deflation. We then multiply this ratio by the log-deviation in prices during the 1930-32 period. This yields an estimate of the country-specific decrease in output during the 1930s, given each country's 1920s deflation response. This measure proxies for country-specific deflation effects if country-specific effects in the 1930s were similar to those in the 1920s. We find that the correlation between the country-specific output decrease from deflation and the constructed productivity shock across countries is also low (.07 to .22). Thus, if productivity is just proxying for country-specific differences in the real effects of deflation, then these country-specific effects must have fundamentally changed from the previous decade.

We next assess whether productivity is proxying for more general, country-specific policy differences. We do this by calculating the correlation between the productivity shocks and the percentage change in the country's currency value of gold. Some economists argue that countries that devalued their currency relative to gold were able to escape serious depressions. The correlation between this factor and the raw productivity shock is -.47, and is

-.24 between the orthogonal productivity shock and this factor. This suggests that there may be some connection between the raw productivity shock and the gold devaluation, but not much of a connection between the orthogonal component and the gold devaluation. Further evidence against this factor is seen in the correlation between the productivity shock and the real exchange rate, which is about 0 for both the raw productivity shock and the orthogonal productivity shock. Eichengreen and Sachs, among others, argue that low real exchange rates were key for recovery from the Depression, but it appears that productivity shocks are not proxying for the exchange rate factor.

The final country-specific factor we consider is the composition of output as measured by the share of output accounted for by agriculture in 1929. We have data for 12 countries out of the 17 for the agricultural share - we do not have data on this factor for France, Japan, the Netherlands, Norway, and Switzerland. The correlations of this factor with both productivity and orthogonalized productivity are higher, (.44 and .49). This indicates that countries with larger agricultural shares did have lower output decreases, but this seems unrelated to deflation, since the correlation is the same for both the raw shock and the orthogonalized shock. We suspect that this correlation may partially reflect the stage of development in these countries. This is because the high agricultural share countries tend to be low income countries that are catching up to the leaders, and thus are growing faster.

Finally, we explore the relationship between the productivity shocks and two measures of money, the log difference of M1 and the log difference of the monetary base. Table 8 shows the results. There is very little relationship between the productivity shocks and M1 in the first two years of the Depression. Perhaps more surprisingly, there is very little relationship between M1 and output in these years. There is a relationship between M1 and the base in the later years of the Depression, and also between money and output. More work is needed to assess whether productivity is proxying for monetary changes in the later years.

5. Summary and Conclusion

This paper presented evidence that a labor demand shifter - productivity shocks - is a key addition to the standard high wage story for the International Great Depression. We evaluated the relative contributions of productivity shocks, and of money shocks operating through high real wages, to output changes for 17 countries between 1930-33. We estimate that about 2/3 of output changes in the international cross section is accounted for by a productivity or productivity-like shock which is orthogonal to deflation, and about 1/3 of output changes is accounted for by money shocks.

This finding about the importance of productivity shocks is reminiscent of our findings about why the U.S. Great Depression was so much worse than the 1920-22 recession, despite the fact both episodes had very similar deflations. We argued that a key reason why the U.S. Great Depression of 1930-33 was so severe was because productivity fell substantially between 1930-33, and that a key reason why the 1920-22 recession was comparatively mild was because productivity rose between 1920-22. (See Cole and Ohanian 2001.)

This analysis has followed the standard practice in general equilibrium model of decomposing output changes into changes in inputs and changes in productivity. Since we have restricted the analysis to two shocks, it remains an open question whether the relative importance of productivity is an artifact of abstracting from other shocks that could move around the inputs. If this was the case, there would probably be a mismatch between labor productivity in the model and labor productivity in the data. The fact that labor productivity in the model lines up with labor productivity suggests that our decomposition is not an artifact of just considering two shocks. However, more work is required to systematically address this interesting question.

Our findings suggest a key puzzle: what economic factors are causing these productivity-like shocks? It is of course unlikely that these negative productivity shocks are technological regress. Thus, future research should develop and analyze theories that can shed light on what these productivity-like shocks might be standing in for in our simple growth model. Some possibilities for these productivity-like shocks might include breakdowns in borrowing/lending relationships and credit (see Bernanke (1983)), large decreases in organization/information capital (see Ohanian (2001)), or government policy interventions that affected efficiency, such as Herbert Hoover's jawboning of U.S. firms to practice work sharing rather than use layoffs during the downturn (see Cole and Ohanian (2001)). A key point is that any candidate factor cannot be a shock that affects only inputs. Rather, a candidate factor must work so that it looks like a productivity shock in a simple neoclassical production function.

6. References

(To Be Added)

7. Appendix
A. 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. $-B/(1-N_t) + W_t E\{\Lambda_t | W_t, \hat{S}_t\} = 0.$

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

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. $\beta E_t\{\lambda_{t+1} + \Psi_{t+1}\}/T_t - \Lambda_t = 0$

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. Note that Λ's log deviation is given λ and Ψ's log-deviation is given by ψ. We denote by the untime-subscripted capitals the values around which we're taking our approximation.

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. $-B/(1-N) + \Lambda W = 0$

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

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

6. $\beta(\Lambda + \Psi)/T - \Lambda = 0$

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

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

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

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

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

$-p - \dfrac{\Lambda P\lambda + \Psi P\psi}{\Lambda P + \Psi P}$

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

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

$-(\lambda + p)$

6. $\beta E\{\Lambda\lambda_{t+1} + \Psi\psi_{t+1}\} - \bar{\tau}\Lambda(\lambda_t + \tau_t) = 0.$

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

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

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

B. Solving the Model via the Method of Undetermined Coefficients

In this case we define the state vector to be $s_t = (k_t, z_{t-1}, \tau_{t-1}, \varepsilon_t^z, \varepsilon_t^\tau)$ and assume that our controls can all be written as a linear function of the state. Thus we define our controls to be $d_t = (k_{t+1}, n_t, c_t, p_t, w_t, r_t, \lambda_t, \psi_t)$, 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 :

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

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

$$
H = \begin{bmatrix} D_k \\ I_z \\ I_\tau \\ 0_5 \\ 0_5 \end{bmatrix}
$$

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

$$E\{D_{\lambda 4}\varepsilon_t^z + D_{\lambda 5}\varepsilon_t^\tau | D_{w4}\varepsilon_t^z + D_{w5}\varepsilon_t^\tau\} = \eta\left(D_{w4}\varepsilon_t^z + D_{w5}\varepsilon_t^\tau\right)$$

$$\text{where } \eta = \frac{E([D_{\lambda 4}\varepsilon_t^z + D_{\lambda 5}\varepsilon_t^\tau][D_{w4}\varepsilon_t^z + D_{w5}\varepsilon_t^\tau])}{E([D_{w4}\varepsilon_t^z + D_{w5}\varepsilon_t^\tau]^2)} = \frac{D_{\lambda 4}D_{w4}\sigma_z^2 + D_{\lambda 5}D_{w5}\sigma_\tau^2}{(D_{w4})^2\sigma_z^2 + (D_{w5})^2\sigma_\tau^2}. \quad (3)$$

Hence,

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

C. Characterizing the Equilibrium of the Sticky Wage Model

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

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

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

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

and deviation equation

$$E_{\hat{S}_t}\left\{\frac{N}{(1-N)}n_t - \theta\Lambda(\lambda_t + n_t)\right\} = 0,$$

which, becomes

$$\begin{pmatrix} \left\{\left[\frac{N}{(1-N)}\right] D_n - \theta\Lambda(D_\lambda + D_n)\right\}\hat{S} \\ +Dw * (1-\hat{S}) \end{pmatrix} s_t = 0,$$

where $\hat{S} = [1\ 1\ 1\ 0\ 0\ ]$.

D. 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 $s_{t+1,1:4}$.

8. Tables

Table 1: Cross-Country Means

(Log Deviation From 1929)

Year	**y**	**w − p**	**dp**
1930	-0.01	0.05	-0.04
1931	-0.06	0.09	-0.07
1932	-0.10	0.09	-0.05
1933	-0.09	0.09	-0.02

Table 2: Deviations in Output and Labor Productivity in 4 Countries

	Output				**Labor Productivity**			
Country	**1930**	**1931**	**1932**	**1933**	**1930**	**1931**	**1932**	**1933**
Australia	.01	-.08	-.07	-.01	0.05	0.01	0.03	0.04
Canada	-.05	-.18	-.29	-.36	-0.01	-0.14	-0.19	-0.25
U.K	.00	-.05	-.06	-.04	0.02	-0.01	-0.02	-0.02
U.S.	-.09	-.16	-.30	-.31	-0.04	-0.05	-0.09	-0.16

Table 3: Benchmark Parameters Values

γ	β	θ	δ	α	ω	ρ_z	ρ_τ
.33	.95	.9	.023	.5	.92	.90	.00

Table 4: Impact of a 10 Percent Deflation on Labor (n)

for different values of the noneutrality parameter (η)

η	dn/dp
0	-15.0%
-0.25	-13.5%
-0.50	-10.7%
-0.75	-6.4%
-0.80	-5.4%
-0.90	-3.0%
-1.00	-0.0%

Table 5: Misperceptions Model $\boldsymbol{\eta} = -0.5$

5.A Characteristics of Productivity Shocks z		
Year	**Mean(z)**	**Corr(z, y)**
1930	0.01	0.03
1931	-0.01	0.20
1932	-0.04	0.74
1933	-0.04	0.64

5.B. Contribution Breakdown of shock to output movements		
Year	$\mathbf{z} \perp \boldsymbol{\varepsilon}_{\tau}$	$\mathbf{z} \perp \mathbf{dp}$
1930	0.97	0.95
1931	0.59	0.76
1932	0.30	0.47
1933	0.46	0.78
Total	0.44	0.66

5.C.	**Labor Productivity**			
Country	**1930**	**1931**	**1932**	**1933**
Australia	0.07	0.03	0.02	-0.01
Canada	0.00	-0.04	-0.08	-0.15
U.K	0.01	0.00	-0.01	-0.02
U.S.	-0.02	-0.03	-0.08	-0.15

5.D Manufacturing Real Wages (w) vs. Compositionally Adjusted Model Real Wages (w^*)			
Year	**mean($\mathbf{w}^*$)**	**mean($\mathbf{w} - \mathbf{w}^*$)**	**corr($\mathbf{w}, \mathbf{w}^*$)**
1930	0.03	0.02	0.67
1931	0.05	0.04	0.54
1932	0.01	0.07	0.64
1933	-0.02	0.10	0.60

Table 6: Two η Experiment

$\boldsymbol{\eta = \{0, -0.8\}}$[7]

6.A Deflation Shock Only		
Year	**Error Share**	**Mean Error**
1930	1.11	0.01
1931	0.50	-0.02
1932	0.50	-0.06
1933	0.81	-0.07
Total	0.65	

6.B Deflation and Productivity Shocks Contribution Breakdown of shock to output movements		
Year	$\mathbf{z} \perp \varepsilon_\tau$	$\mathbf{z} \perp \mathbf{dp}$
1930	0.92	0.91
1931	0.53	0.68
1932	0.23	0.42
1933	0.41	0.75
Total	0.38	0.62

[7] **The following countries were assign an η of 0: Austria, Canada, Czechoslovakia, France, Germany, U.S..**

Table 6.C	**Labor Productivity**			
Country	**1930**	**1931**	**1932**	**1933**
Australia	0.05	-0.02	-0.01	-0.01
Canada	0.01	0.00	0.03	-0.18
U.K	0.00	-0.02	0.02	-0.02
U.S.	0.00	0.01	-0.02	-0.18

Table 7. Cross-Country Correlation of 1932

Productivity Shocks with Other Factors[8]

$\boldsymbol{\eta = -0.5}$

Factors	**z**	**z ⊥dp**
1920s Response to Deflation	0.07	0.22
Trade Share 1929	0.16	0.04
Agricultural Share pre 1930	0.49	0.44
ch. Industrial Productivity 1929-32	0.82	0.66
ch. Industrial. Productivity.1930-32	0.77	0.58
ch. Real Exchange Rate	0.07	0.03
ch. Gold Parity	-0.47	-0.24

[8] All variables, with the execption of the trade and agriculature shares are in terms of their log-deviation from 1929.

Table 8. Correlations of Money Change Measures

with Model Shocks and Output[9]

$\boldsymbol{\eta = -0.5}$

	$dM1$				$dM0$			
Year	**z**	**z ⊥dp**	ε_{τ}	**y**	**z**	**z ⊥dp**	ε_{τ}	**y**
1930	-0.07	-0.02	0.21	0.01	-0.26	-0.20	0.27	-0.17
1931	0.11	0.14	0.06	0.14	-0.48	-0.47	0.09	-0.46
1932	0.61	0.60	-0.16	0.59	0.46	0.49	0.09	0.50
1933	0.59	0.54	-0.28	0.52	0.22	0.21	-0.04	0.21

[9] All variables are measured as log-deviations. Hence, for example, the change in $M1$ is the change in the log-deviation.

9. Appendix Tables

Table A: Cross-Country Correlations with y

(Log Deviation From 1929)

Year	w − p	dp	p	dp_{-1}
1930	0.44	-0.43	-0.43	-
1931	0.48	-0.34	-0.47	-0.51
1932	0.26	0.52	-0.08	-0.36
1933	0.32	0.27	0.06	0.49

Table B: Cross-Country Standard Deviations

(Log Deviation From 1929)

Year	y	w − p	dp
1930	0.05	0.03	0.03
1931	0.08	0.06	0.03
1932	0.12	0.07	0.05
1933	0.14	0.08	0.05

Table D: Impulse Response to

One Percent Negative Money Shock:

Table D.A: Sticky Wage Model

Period	$\mathbf{y}$	$\mathbf{w-p}$	$\mathbf{p}$
1	-1.55	0.78	-0.78

Table D.B: Misperceptions Model

$(\boldsymbol{\eta} = -\mathbf{0.5})$

Period	$\mathbf{y}$	$\mathbf{w-p}$	$\mathbf{p}$
1	-0.65	0.32	-0.92

Table E: Constructed Productivity Shocks in the Model

(Shocks: Money and Productivity, $\eta = -0.5$)

Country	**1930**	**1931**	**1932**	**1933**	**Country Avg.**
Australia	0.05	-0.01	-0.01	0.00	0.01
Austria	-0.01	-0.06	-0.14	-0.15	-0.09
Canada	-0.02	-0.08	-0.13	-0.21	-0.11
Czech.	-0.01	-0.02	-0.06	-0.09	-0.04
Denmark	0.07	0.07	0.04	0.03	0.05
Finland	0.03	0.02	-0.03	0.01	0.01
France	-0.01	-0.03	-0.07	0.00	-0.03
Germany	-0.04	-0.09	-0.11	-0.10	-0.09
Hungary	0.04	0.04	0.02	-0.02	0.02
Italy	-0.02	0.01	0.02	0.01	0.00
Japan	0.05	0.08	0.02	0.03	0.05
Netherlands	0.04	0.01	-0.01	-0.06	-0.01
Norway	0.04	-0.01	0.02	0.03	0.02
Sweden	0.05	0.02	-0.01	0.00	0.02
Switzerland	0.01	0.06	0.00	0.02	0.02
U.K	0.00	-0.02	-0.02	-0.02	-0.01
U.S.	-0.05	-0.08	-0.15	-0.20	-0.12
Year Avg.	0.02	0.00	-0.04	-0.04	-0.02

Table F: Comparing the Implications of the Models[10]

F.A. Sticky Wage Model				
	Deflation Shock Only		**Deflation and Productivity Shocks**	
Year	**Error Share**	**Mean Error**	**Mean z**	**Contribution of z $\perp$dp**
1930	7.62	0.08	0.03	0.82
1931	2.03	0.09	0.04	0.67
1932	0.46	0.00	0.02	0.30
1933	0.80	-0.04	-0.01	0.66
Total	1.10			0.53

F.B. Misperceptions Model $\eta = 0$				
	Deflation Shock Only		**Deflation and Productivity Shocks**	
Year	**Error Share**	**Mean Error**	**Mean z**	**Contribution of z $\perp$dp**
1930	2.89	0.04	0.02	0.93
1931	0.89	0.02	0.01	0.74
1932	0.51	-0.04	-0.02	0.43
1933	0.80	-0.06	-0.03	0.76
Total	0.77			0.64

[10]The error share is defined as the sum of sqared prediction errors relative to the sum of squared values of the actual value of the variable, and the mean error is simply the mean of the prediction errors. The contribution of $z \perp dp$ denotes the contribution of the orthogonal (to deflation) component in z to accounting for the overall variation in y.

F.C. Misperceptions Model $\eta = -0.5$				
	Deflation Shock Only		Deflation and Productivity Shocks	
Year	**Error Share**	**Mean Error**	**Mean z**	**Contribution of z $\perp$dp**
1930	1.92	0.02	0.01	0.95
1931	0.77	-0.01	-0.01	0.76
1932	0.62	-0.06	-0.04	0.47
1933	0.84	-0.07	-0.04	0.78
Total	0.78			0.66

F.D. Misperceptions Model $\eta = -0.8$				
	Deflation Shock Only		Deflation and Productivity Shocks	
Year	**Error Share**	**Mean Error**	**Mean z**	**Contribution of z $\perp$dp**
1930	1.28	0.01	0.01	0.98
1931	0.80	-0.04	-0.03	0.78
1932	0.78	-0.08	-0.06	0.52
1933	0.91	-0.08	-0.05	0.79
Total	0.85			0.69

Table G:Aggregate Labor Productivity in the Models

(Shocks: Money and Productivity)

Table G.A.	**Sticky Wage**			
Country	**1930**	**1931**	**1932**	**1933**
Australia	0.10	0.14	0.11	-0.04
Canada	0.02	0.06	0.06	-0.24
U.K	0.01	0.04	0.03	-0.04
U.S.	0.03	0.07	0.09	-0.24

Table G.B.	**Misperceptions** $\eta = 0.0$			
Country	**1930**	**1931**	**1932**	**1933**
Australia	0.08	0.07	0.04	-0.02
Canada	0.00	0.00	-0.03	-0.18
U.K	0.01	0.02	0.01	-0.03
U.S.	0.00	0.01	-0.02	-0.18

Table G.C.	**Misperceptions** $\eta = -0.8$			
Country	**1930**	**1931**	**1932**	**1933**
Australia	0.05	-0.02	-0.01	-0.01
Canada	-0.02	-0.08	-0.13	-0.11
U.K	0.00	-0.02	-0.02	-0.01
U.S.	-0.05	-0.07	-0.15	-0.13

Table H: Misperceptions Model $\eta = 0.0$

H.A Characteristics of Productivity Shocks z		
Year	**Mean(z)**	**Corr(z, y)**
1930	0.02	0.00
1931	0.01	0.19
1932	-0.02	0.74
1933	-0.03	0.65

H.B. Contribution Breakdown of shock to output movements		
Year	$\mathbf{z} \perp \varepsilon_\tau$	$\mathbf{z} \perp \mathbf{dp}$
1930	0.97	0.93
1931	0.59	0.74
1932	0.22	0.43
1933	0.43	0.76
Total	0.41	0.64

H.C Cross-Country Correlation of 1932

Productivity Shocks with Other Factors

$\boldsymbol{\eta = 0.0}$

Factors	**z**	**z $\perp$dp**
1920s Response to Deflation	0.11	0.22
Trade Share 1929	0.13	0.05
Agricultural Share pre 1930	0.49	0.46
ch. Industrial Productivity 1929-32	0.80	0.69
ch. Industrial. Productivity.1930-32	0.74	0.61
ch. Real Exchange Rate	0.07	0.04
ch. Gold Parity	-0.43	-0.28

Table H.D Correlations of Money Measures

with Shocks and Output

$\boldsymbol{\eta = 0.0}$

	$dM1$				$dM0$			
Year	**z**	**z $\perp$dp**	ε_τ	**y**	**z**	**z $\perp$dp**	ε_τ	**y**
1930	-0.09	-0.01	0.21	0.01	-0.29	-0.20	0.28	-0.17
1931	0.11	0.14	0.06	0.14	-0.48	-0.47	0.11	-0.46
1932	0.60	0.60	-0.18	0.59	0.43	0.50	0.07	0.50
1933	0.60	0.54	-0.29	0.52	0.22	0.21	0.05	0.21

Table I: Misperceptions Model $\eta = -0.80$

I.A Characteristics of Productivity Shocks z		
Year	**Mean(z)**	**Corr(z, y)**
1930	0.01	0.08
1931	-0.03	0.21
1932	-0.06	0.75
1933	-0.05	0.62

I.B. Contribution Breakdown of shock to output movements		
Year	$\mathbf{z} \perp \varepsilon_\tau$	$\mathbf{z} \perp \mathbf{dp}$
1930	0.96	0.98
1931	0.59	0.78
1932	0.23	0.52
1933	0.50	0.79
Total	0.46	0.69

I.C Cross-Country Correlation of 1932

Productivity Shocks with Other Factors

$\eta = -0.80$

Factors	**z**	**z ⊥dp**
1920s Response to Deflation	0.05	0.23
Trade Share 1929	0.18	0.03
Agricultural Share pre 1930	0.48	0.43
ch. Industrial Productivity 1929-32	0.82	0.62
ch. Industrial. Productivity.1930-32	0.78	0.55
ch. Real Exchange Rate	0.08	0.02
ch. Gold Parity	-0.52	-0.19

Table I.D Correlations of Money Measures

with Shocks and Output

$\eta = -0.80$

	$dM1$				$dM0$			
Year	**z**	**z ⊥dp**	ε_τ	**y**	**z**	**z ⊥dp**	ε_τ	**y**
1930	-0.0	-0.02	0.21	0.01	-0.23	-0.20	0.26	-0.17
1931	0.13	0.14	0.07	0.14	-0.48	-0.47	0.07	-0.46
1932	0.61	0.60	-0.13	0.59	0.48	0.49	0.12	0.50
1933	0.67	0.55	-0.25	0.52	0.22	0.21	-0.03	0.21

Table J: Implications of the Wage Shock[11]

Sticky Wage Model			
Year	**Error Share**	**Mean Error**	**Corr($\mathbf{y}, \hat{\mathbf{y}}$)**
1930	7.79	0.09	-0.46
1931	4.68	0.14	-0.41
1932	2.79	0.14	-0.25
1933	4.76	0.19	-0.36
Total	4.10		

[11] **The money sequence of money shocks were choosen so as to reproduce the path of real wages in the data for each country. Only the results for the sticky wage are reported since all of the models have essentially identical implications for these values.**

Table K: Two Model Experiment

Sticky Wage and $\boldsymbol{\eta} = -\mathbf{0.8}$[12]

K.A Deflation Shock Only		
Year	**Error Share**	**Mean Error**
1930	0.97	0.02
1931	0.26	0.00
1932	0.30	-0.04
1933	0.77	-0.05
Total	0.52	

K.B Deflation and Productivity Shocks Contribution Breakdown of shock to output movements		
Year	$\mathbf{z} \perp \varepsilon_\tau$	$\mathbf{z} \perp \mathbf{dp}$
1930	0.76	0.77
1931	0.30	0.42
1932	0.09	0.22
1933	0.27	0.64
Total	0.22	0.45

[12] The following countries were assign the sticky wage model: Austria, Canada, Czechoslovakia, France, Germany, U.S..

Aggregate Labor Productivity in the Models

(Shocks: Money and Productivity)

K.C	**St.Wage & $\boldsymbol{\eta = -0.8}$**			
Country	**1930**	**1931**	**1932**	**1933**
Australia	0.05	-0.02	-0.01	-0.01
Canada	0.02	0.06	0.06	-0.24
U.K	0.00	-0.02	0.02	-0.02
U.S.	0.03	0.07	0.09	-0.24

Figure 1a: Real Ouput vs. Wages 1929-30

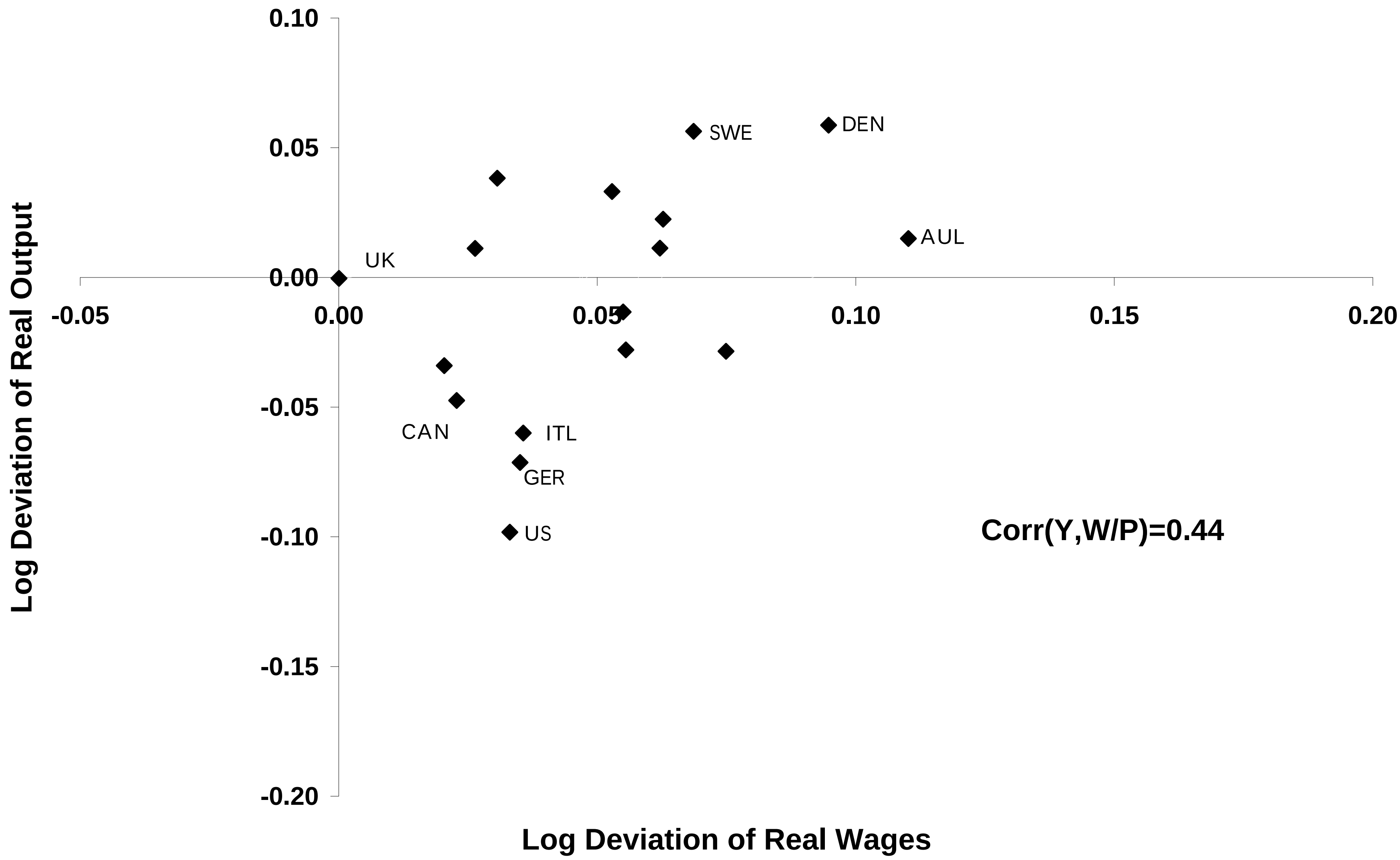

Figure 1b: Real Output vs Wages 1929-31

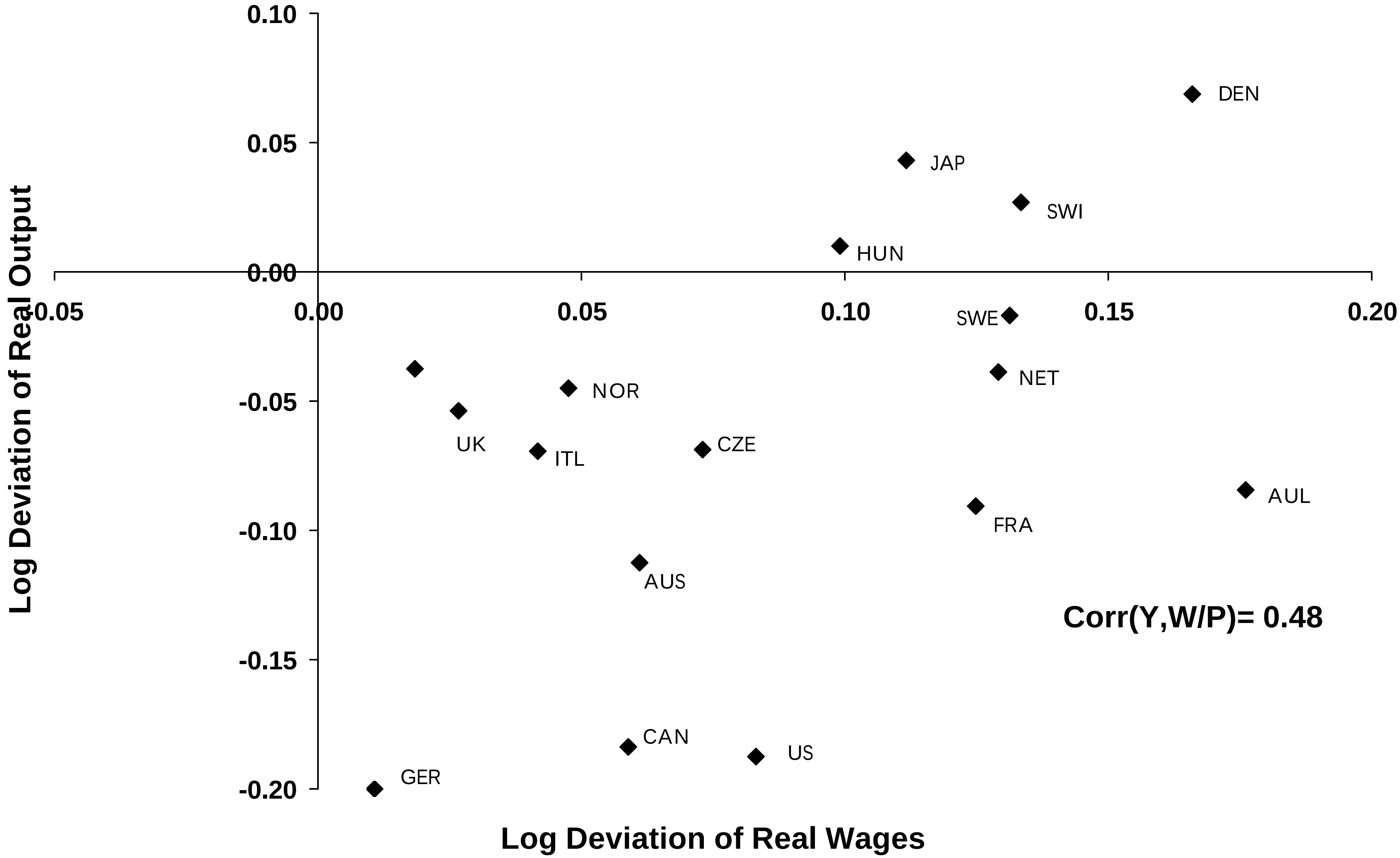

Figure 1c: Output vs Real Wages 1929-32

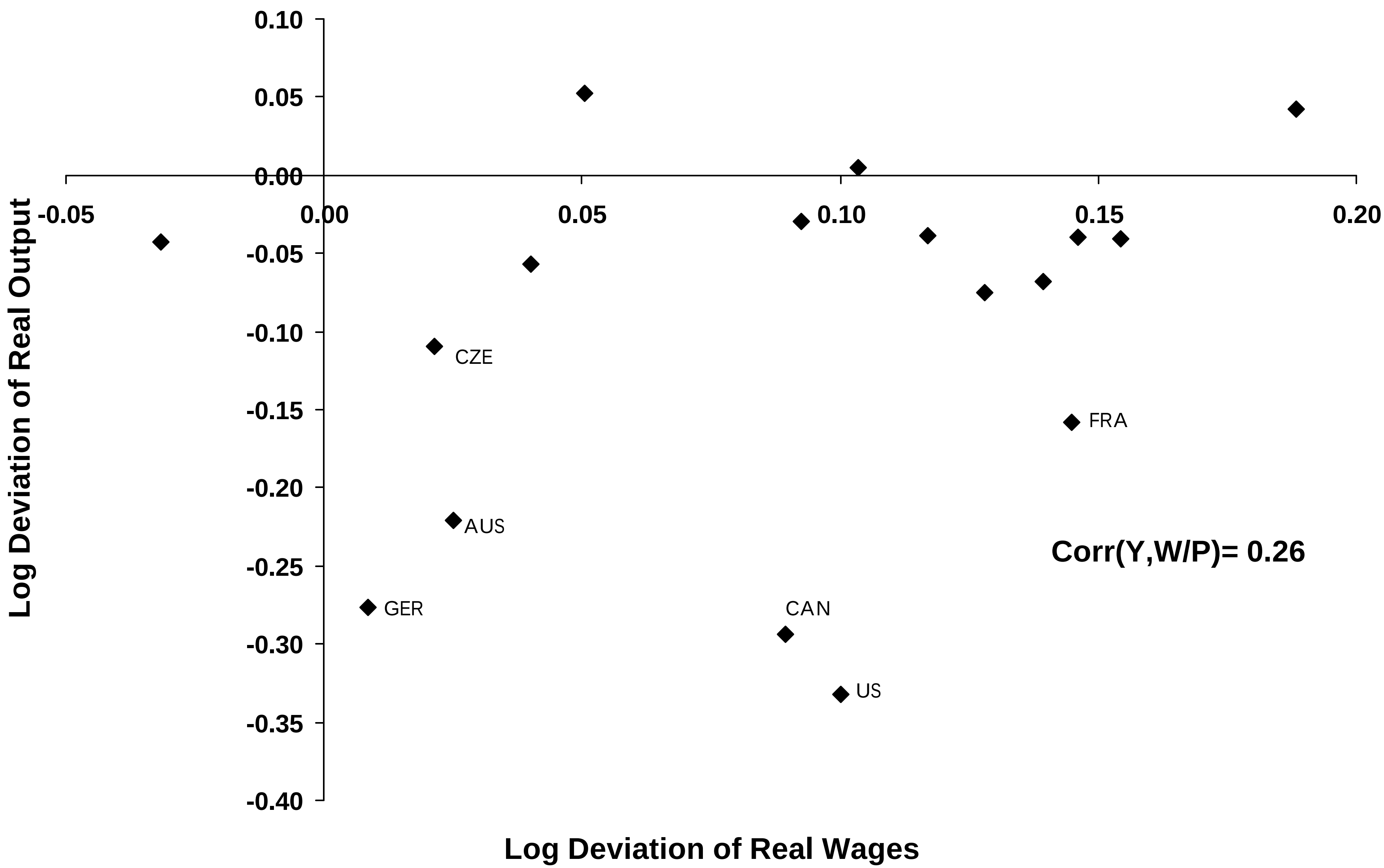

Figure 1d: Output vs Real Wages 1933-29

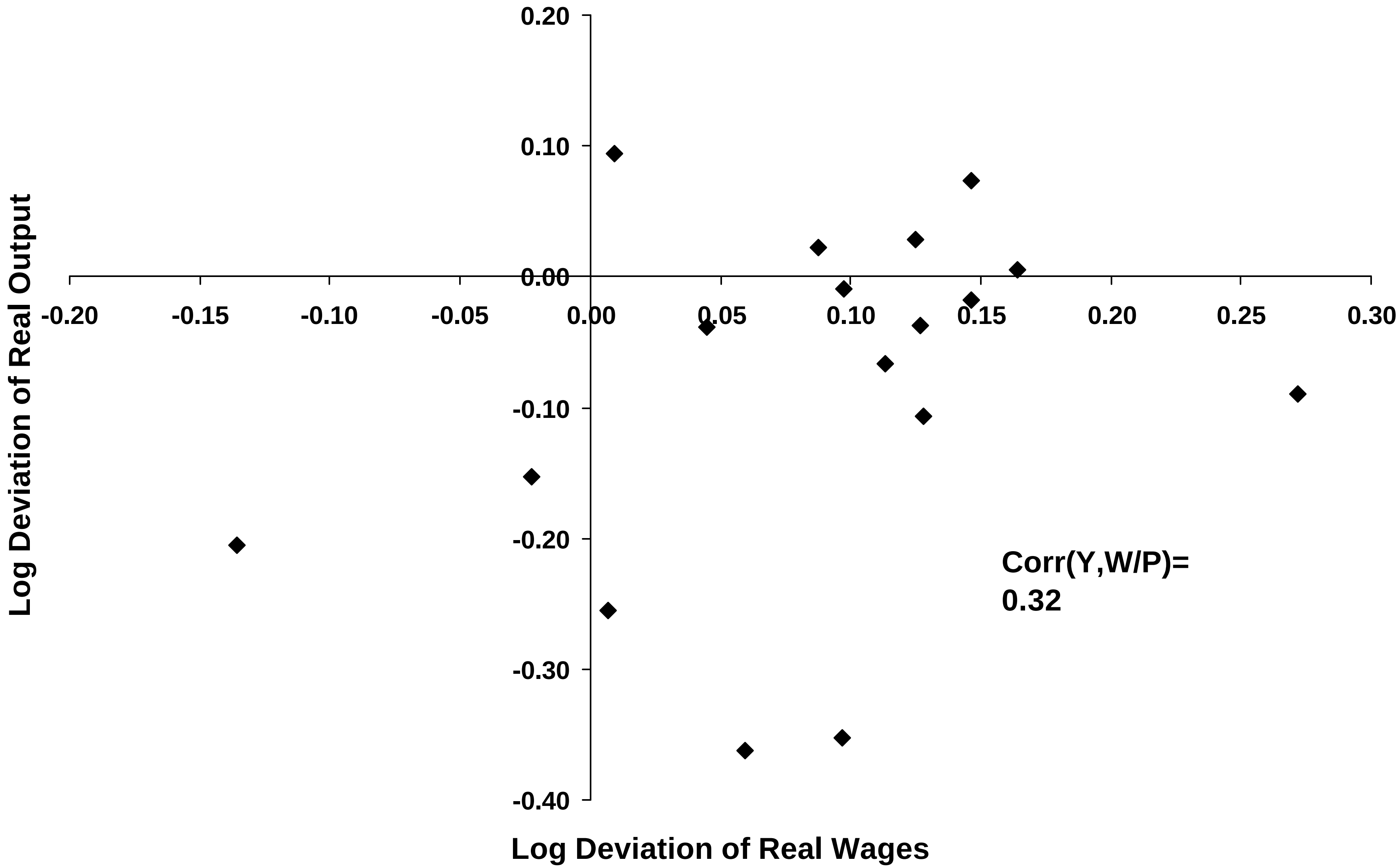

Figure 2a: Output vs Prices 1929-30

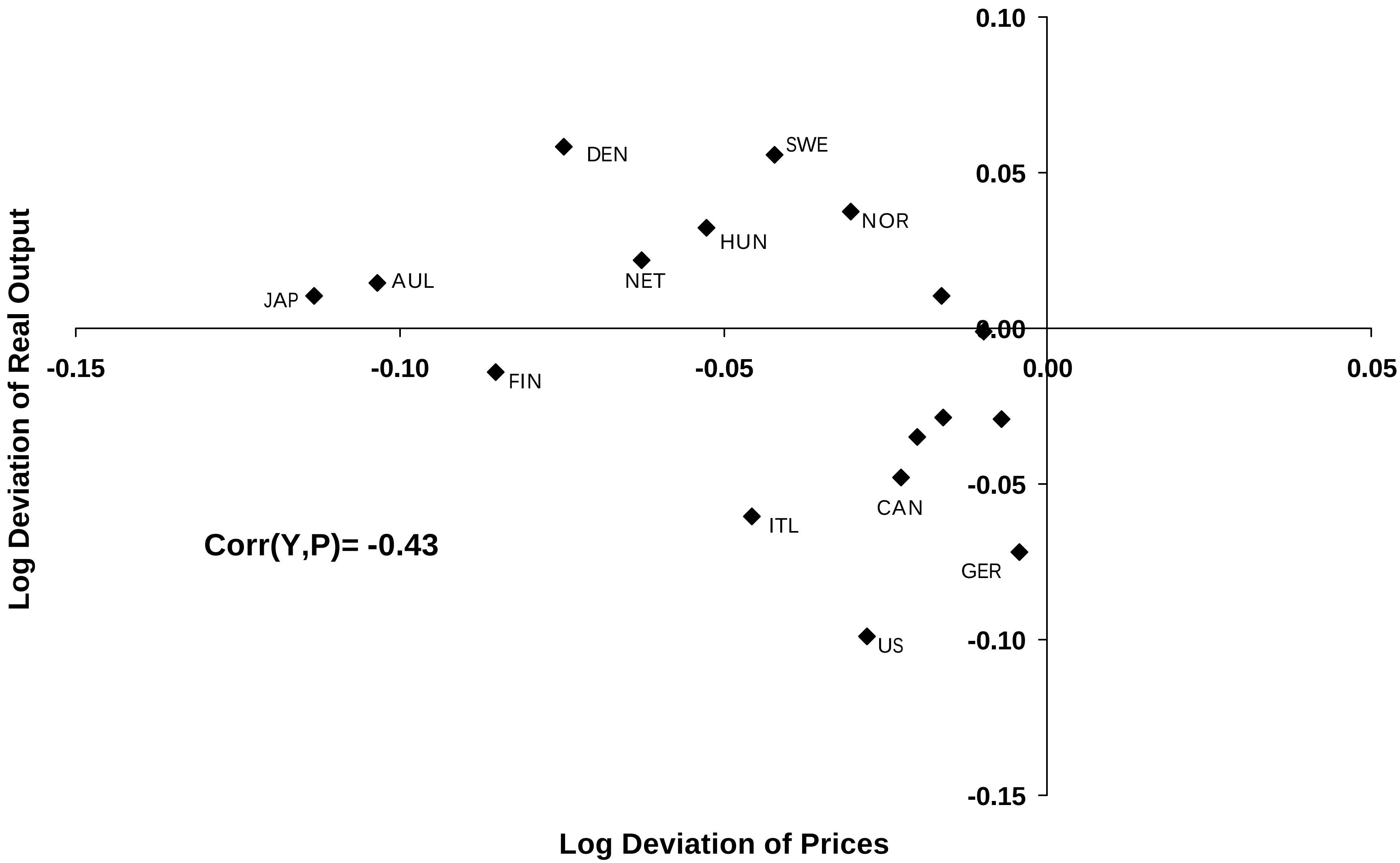

Figure 2b: Real Output vs. Prices 1929-31

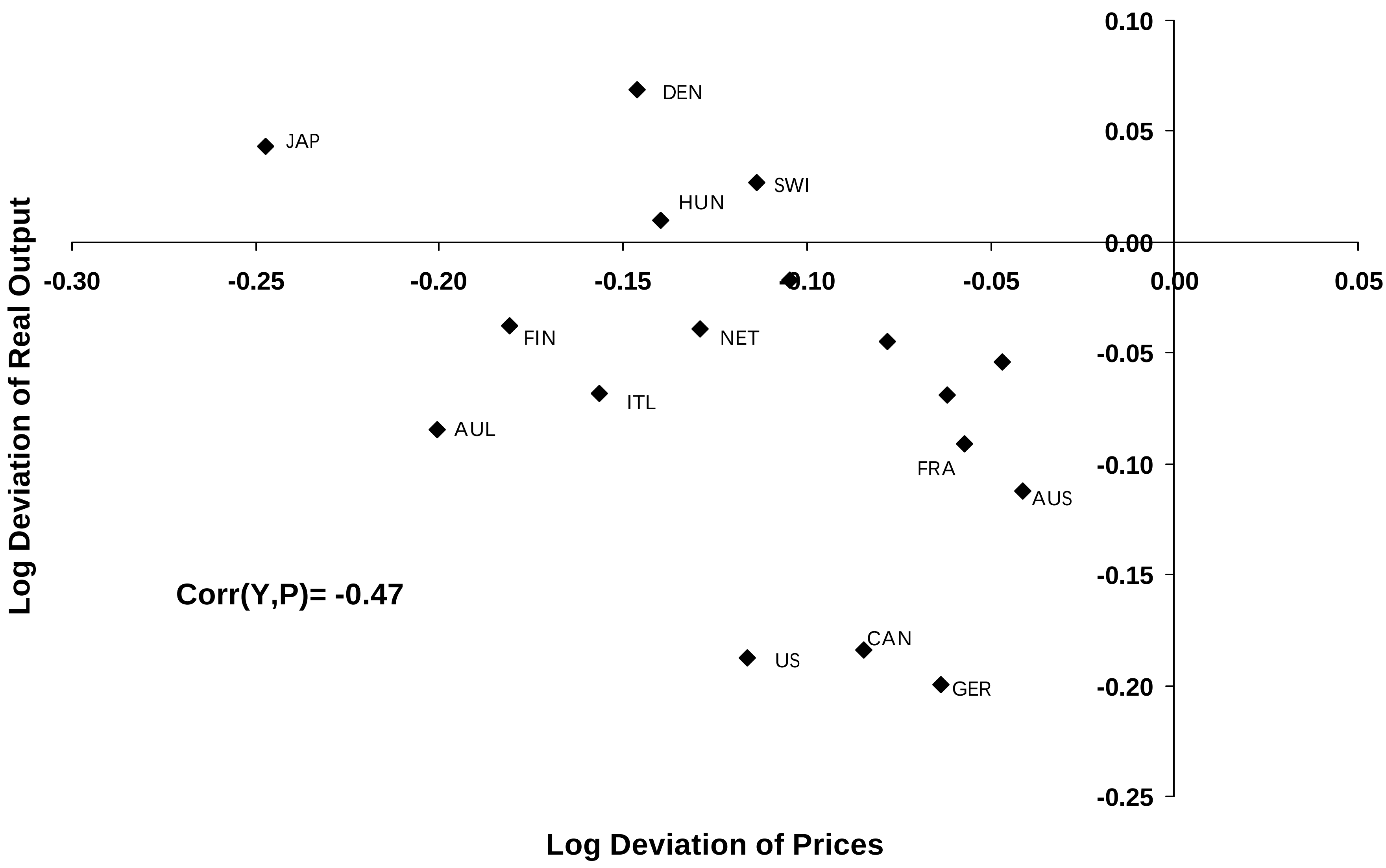

Figure 2c: Real Output vs. Prices 1929-32

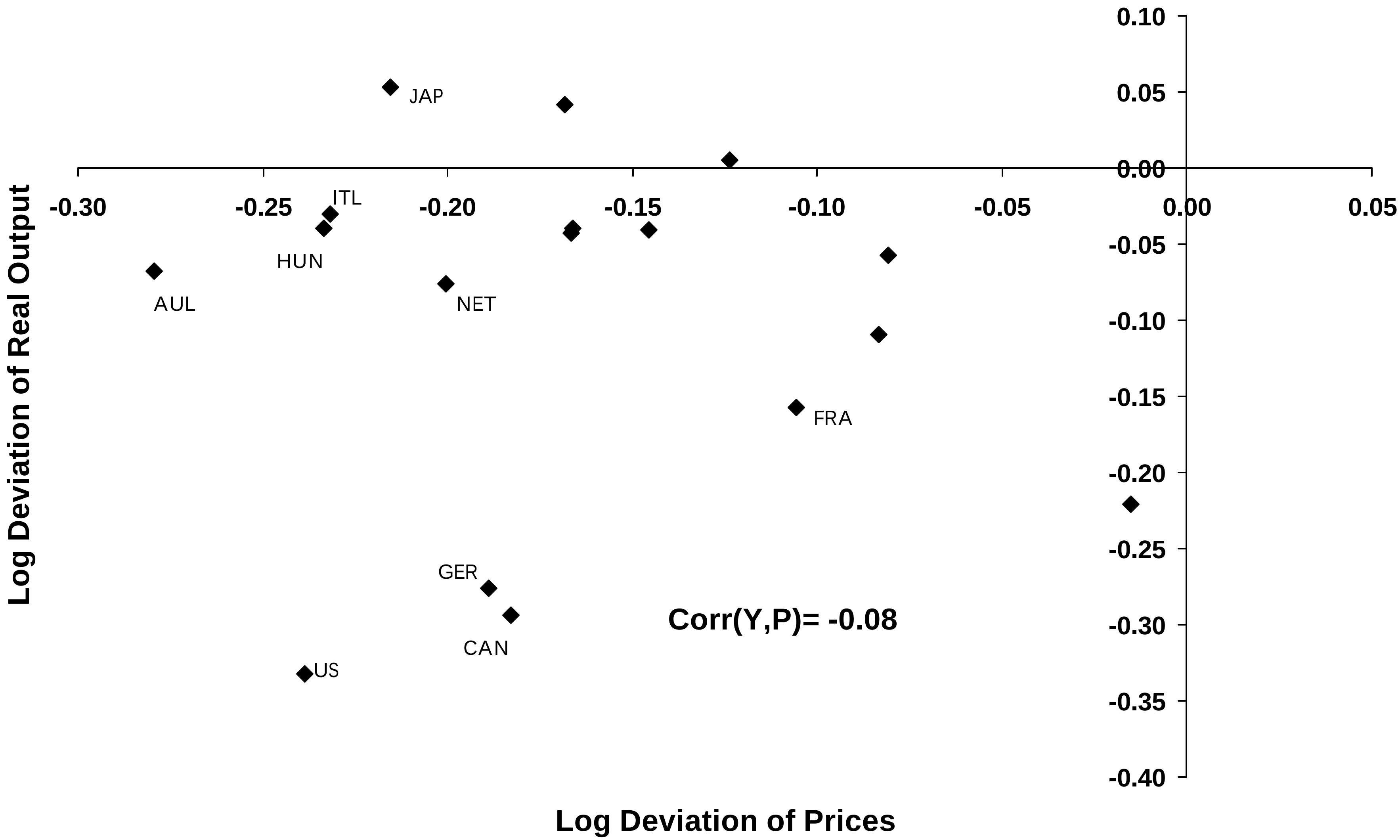

Figure 2d: Real Output vs. Prices 1929-33