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The International Great Depression: Productivity Shocks and the Stock Market*

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ABSTRACT

This paper presents a dynamic, stochastic general equilibrium (DSGE) study of the causes of the international Great Depression. We merge the empirical, cross-country literature that focuses on deflation with the single-country DSGE literature that focuses on productivity. We evaluate the relative contributions of deflation and productivity, and find that productivity accounts for about 70 percent of the Depression, with deflation accounting for about 30 percent. The main reason deflation doesn't account for more of the Depression is because there is no systematic relationship between deflation and output during this period. We evaluate the factors that might be driving these productivity shocks, and study the most promising classes of models for understanding the Depression. We find that contemporaneous and lagged real stock prices explain a high fraction of productivity, and conclude that models with financial market imperfections that either exacerbate agency problems, disrupt normal trading patterns, or in which net worth impacts firm performance, is the most promising class of models.

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1. Introduction

There are two very different literatures that have addressed the international Great Depression. One literature uses dynamic stochastic general equilibrium (DSGE) models with productivity (TFP) shocks to study individual countries.[1] The other literature uses panel data regressions to comparatively study many countries, and focuses on deflation, with sticky nominal wages, as the key shock.[2] This paper brings these two very different approaches together. We use the comparative, cross-country aspect of the empirical literature, we use the DSGE modeling approach of the neoclassical literature, and we quantify the contributions of both the deflation shocks emphasized in the empirical cross-country literature and of the productivity shocks emphasized in the single-country DSGE literature.

To conduct the analysis, we construct a DSGE model with TFP shocks and monetary shocks. A new and quantitatively important feature of the model is that the monetary nonneutrality is due to an information imperfection, as in Lucas (1972). We compile an international Depression dataset that includes the most recent data revisions. Despite these updated data, some challenging date issues require developing new quantitative procedures that differ from the standard procedures of the DSGE literature. These new methods include a procedure for identifying latent shocks, a new method for testing the empirical plausibility of a model economy, and a shock decomposition procedure that allocates output (or other endogenous variables) into orthogonal components in which the empirical shocks are both correlated and have non-zero means. Our main finding is that the component of productivity that is orthogonal to monetary shocks/deflation accounts for about 70 percent of the

[1] These studies include Cole and Ohanian (1999), Chari, Kehoe, and McGrattan (2006), and a number of studies in Kehoe and Prescott (2002, 2006). Other neoclassical studies of the Depression that omit monetary/deflation shocks include Cole and Ohanian (2004) and Harrison and Weder (2005).

[2] These include Bernanke (1995), Bernanke and Cary (1996), Bordo et al (2000), Choudri and Kochin (1980), and Eichengreen and Sachs (1985).

Depression.

Regarding the data, we construct a panel data set using data from 17 countries between 1929 and 1933. The data are compiled from a number of sources, including very recent measures for some of the countries. The dataset thus provides the most up-to-date measures of international macroeconomic data for the interwar period. We first statistically summarize the data, including the relationships between output and the two shocks. The key point from this summary is that productivity is strongly related to output, but deflation is only weakly related to output; deflation accounts for only about 25 percent of the Depression in a panel regression.

We develop a DSGE model that includes both the deflation/sticky wage channel featured in the empirical deflation literature, as well as productivity shocks that are featured in the neoclassical literature. The monetary nonneutrality in the model comes from an information imperfection that leads households to misperceive monetary shocks as real shocks, as in Lucas (1972). There is a range of values for the nonneutrality of money in our model, and this variable nonneutrality is important in conducting the quantitative analysis and evaluating the robustness of the results. Moreover, our model provides a very simple way of introducing the Lucas misperceptions feature into a fully-specified GE model. This type of monetary non-neutrality has otherwise been largely excluded from the DSGE literature.[3]

Data limitations require us to develop new procedures for constructing the shocks, for quantifying the relative contributions of the shocks, and for testing the model. Regarding the shocks, money shocks are always a latent variable, and we also treat total factor productivity (TFP) as a latent variable because we do not have capital stocks for some countries. We therefore construct the monetary and productivity shocks so that the model economy exactly

[3] To our knowledge, Cooley-Hansen's (1995) islands formulation is the only calibrated DSGE model that captures the Lucas misperceptions approach. Our model is considerably simpler than Cooley-Hansen.

reproduces output and deflation in each country and for each year of the Depression. We assess the empirical plausibility of model productivity by comparing the constructed productivity shocks to actual productivity (TFP for some countries, and labor productivity for some other countries). The constructed productivity shocks from the model are very similar to actual productivity, with a correlation of about 0.95.

To decompose output into orthogonal components, we develop a method that deals with shocks that have non-zero means and that are correlated. The method can be generically used to analyze changes in the time paths of endogenous variable in any log-linear model, which is useful because economists are increasingly conducting analyses of actual time paths of variables using DSGE models with multiple shocks, and empirical shock realizations over any time interval - particularly during periods of dramatic changes such as the Depression - will almost certainly have these complicating features. We are unaware of any other procedure in the DSGE literature that jointly deals with these two issues. The productivity shock is the major factor during the Depression, as the component of productivity that is orthogonal to deflation accounts for about 70 percent of output change. We test the empirical plausibility of this decomposition by comparing this model-generated component of output that is orthogonal to deflation to a statistical measure of output that is orthogonal to deflation. this statistical component is the residual from a regression of output on deflation. These two measures of orthogonal output are virtually identical. This means that accounting for the quantitatively large component of the Depression that is unrelated to deflation requires a model that is observationally equivalent to a stochastic growth model with productivity shocks that are orthogonal to deflation. .

Given the importance of productivity, we then conduct further analysis to identify classes of richer models that can potentially account for both the productivity shocks and the Depression. Specifically, some classes of models with financial shocks or with trade shocks are observationally equivalent to productivity shocks in a stochastic growth model. To identify whether financial and/or open economy models with these alternative shocks are promising for understanding productivity and the Depression, we test whether the productivity shocks can be explained by financial and trade-related variables, including deflation, nominal and real interest rates, real exchange rates, various monetary aggregates, a measure of banking panics, and the real value of the stock market. Real stock prices are the only one of these variables that explain a substantial fraction of the productivity shocks. Our model with the productivity component explained by the stock market, and with the monetary shock, accounts for 73 percent of real output change in the panel of countries. These findings indicate that the most promising factor for jointly understanding productivity change and the international Depression is a financial factor that affects real share prices and productivity, but that is largely unrelated to interest rates, exchange rates, deflation, and monetary aggregates.

2. The Data

Our analysis features a panel data set with annual data from 17 countries.[4] We selected the countries on the basis of consistent availability of real GNP data. We also have compiled a number of other variables, including the GNP deflator, a wage index, a labor index, the value of the stockmarket, industrial production, the exchange rate, nominal interest rates, measures of the money supply, and the consumer and producer price indexes for most countries. There are several primary sources for the data. We have used the most recently constructed data, which yields the most up-to-date measures of macroeconomic time series for the interwar period. The Appendix describes the data and presents the data sources. Here, we focus on deflation and productivity, the shocks that are emphasized in the two Depression literatures,

[4] The data used in this study are for 17 countries. 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.

and summarize the relationship between these shocks with output.

The empirical cross-country literature highlights deflation/contractionary monetary policy as the major shock that caused the Depression.[5] Temin (1989) argues, "This massive international deflationary movement — a 20 percent fall in 2 years — is a key part of the story of the Great Depression". Bernanke (2004) argues, "The collapse of the money supply...that in many ways had a bias toward deflation built into it, seems clearly to have been the major single cause of the Depression." The empirical deflation literature stresses sticky wages as the channel through which deflation reduced output. Specifically, the literature assumes that nominal wages were imperfectly flexible, and that deflation raised real wages, which then reduced employment and output (see Eichengreen and Sachs (1985), Bernanke (1995), Bernanke and Carey, (1996), Bordo et al (2000). In contrast, the recent neoclassical literature highlights productivity shocks as a key factor, including work by Cole and Ohanian (1999), Chari, Kehoe, and McGrattan (2001, 2006), Amaral and McGee (2002), Kehoe and Ruhl (2003), and Kehoe and Prescott (2002).

We begin with deflation. Figure 1 and Tables 1 and 2 summarize deflation and its relationship with output. The figure shows a cross-country scatter plot of log output deviations from 1929 and the annual percentage change in the price level for each year from 1930 through 1933. The main feature of these data is that there is no systematic relationship between output and deflation. Table 1 shows the correlation between the change in the log of the deflator and the log deviation of output in each year of the Depression; this correlation is negative or small in 3 of the 4 depression years. Table 2 shows the cumulative log output change and the cumulative log price change across the countries in our data set. Note that many countries had similar cumulative deflations, but had very different cumulative output

[5] Eichengreen (1992) and others cite the gold standard as the key mechanism that transmitted deflation across countries.

changes. For example, the United States and Italy both had 24 percent deflations between 1929 and 1932, but real GNP fell 33 percent in the United States, compared to only a 7 percent decline in Italy.

To assess the potential explanatory power of deflation, we estimate a series of regressions that approximate classes of log-linearized business cycle models in which deflation reduces output. To see this approximation, note that output change in any log-linearized DSGE model which (i) abstracts from capital, and (ii) in which contemporaneous deflation is a shock, can be written as $y_t = \alpha\pi_t$, where y_t is the log-deviation of output from its steady-state value, π_t is the log of the change in the GNP deflator between $t-1$ and t, and α is the parameter governing the impact of log price change on output. We therefore estimate the following equation using ordinary least squares (OLS), in which y_{it} is the log deviation of output in country i and in year t from its 1929 value: $y_{it} = \beta_1\pi_{it} + \varepsilon_{it}$.Deflation explains 23 percent of the sum of squared output deviations.[6] The second regression adds lagged deflation to the regression to account for possible delayed impact of price changes. This specification approximates a DSGE model in which deflation is the only shock and has contemporaneous and lagged effects.[7]

The addition of lagged log price change is quantitatively unimportant, as it increases the explanatory power from 23 percent to just 29 percent. We next add a constant term to the first two regressions to determine whether deflation may have higher explanatory power if it is not required to account for the mean change in output. We interpret the constant term as a very simple proxy for omitted state variables. All of the deflation regressors are statistically insignificant when a constant term is added to these first two regressions.

[6] The explanatory power of deflation in this equation is an upper bound because we place no economic restrictions on the size of the parameter α, and because we abstract from using instruments for deflation.

[7] We do not report additional lags of logged price change in the regression because for most countries price levels were very similar between 1927 and 1928, as well as between 1928 and 1929. Deflation typically began in 1929 or afterwards.

As a final check, we estimated a third regression with country-specific deflation coefficients, as opposed to the common coefficient in the first to regressions, to see if abandoning the discipline of the cross-country aspect of the Depression substantially raises the importance of deflation. We therefore estimated $y_{it} = \alpha_i + \beta_i \pi_{it} + \varepsilon_{it}$.This third regression also includes a country-specific constant term to allow for country fixed effects, and we interpret the fixed effect as a proxy for omitted state variables that differ across countries. The deflation coefficients were jointly insignificant in this regression.[8] Deflation thus has relatively low explanatory power within the class of log-linear business cycle models, and an additional shock is required to account for the Depression.

We now turn to productivity. Figure 2 shows the log changes in output and productivity between 1930-33 for the seven countries for which we can construct aggregate productivity. We have economy-wide total factor productivity (TFP) for five countries (Canada, France, Germany, the United Kingdom, and the United States) and economy-wide labor productivity for two other countries (Australia and Japan). The figure shows a systematic relationship between productivity and output: the countries with large depressions (Canada, France, Germany, and the United States) had large productivity declines, and the countries with mild depressions or expansions (Australia, Japan, and the United Kingdom) did not have these large productivity declines. We summarize the relationship between productivity and output in the remaining countries by constructing labor productivity in the industrial sector (industrial production divided by industrial labor), which is available for almost all of the countries. This productivity measure also is systematically to output, with a correlation of 0.64. For comparative purposes, this correlation is higher than the correlation between annual logged, HP-filtered postwar U.S. output and industrial productivity. [9]

[8] We also estimated a fourth regression with both contemporaneous and lagged deflation, with country-specific coefficients and fixed effects, and found that deflation was quantitatively unimportant.

[9] The U.S. data are annual, from **x to x**, and we filtered the log of these data using two values of the

Further evidence supporting productivity is the cross-country relationship between real wages and output. Figures 3 shows annual scatter plots between log output deviations from 1929 and real wage changes, and the second panel of Table 1 shows the correlation between real wages and output. The key feature of these data is that the correlation between real wages and output is positive in each year, ranging between .47 and .30. This positive correlation requires that one of the shocks in the model needs to be a *labor demand shifter,* and a productivity shock satisfies this requirement.

These data suggest that productivity will be a quantitatively important factor in the model economy. In anticipation of that finding, we note that we will move beyond the standard approach in the RBC literature that treats productivity shocks as an exogenous process, and instead we extend the analysis and interpret productivity shocks as the possible consequence of other economic factors. In particular, some classes of models with financial intermediation and/or international trade are observationally equivalent to a one-sector growth model with productivity shocks (for example, see Chari, Kehoe, and McGrattan (2006), Backus and Crucini (2000), and Crucini and Kahn (2006)). We therefore will test if the productivity shocks are significantly related to financial and trade variables. This analysis which relates productivity to other variables will be a first step towards identifying promising classes of deeper models for understanding the International Depression.

Our study analyzes the contributions of deflation and productivity shocks during 1929–33. We do not analyze the recovery period (post-1933) from the Depression. A recovery analysis is important and interesting in its own right, but is beyond the scope of this paper. This is because a recovery analysis would need to take into account the different types of government policies countries adopted in response to the Depression. For example, Cole and Ohanian (2004) present an analysis of these programs for the U.S. recovery and argue

smoothing parameter, 6.25 and 400. The results were not sensitive to this. **(Hal - source of these data)** that post-Depression labor market policies raised real wages and retarded the U.S. recovery, and Fischer and Hornstein (2002) present evidence that large changes in union power had important effects on the German recovery.

3. The Model

To develop our model, we follow the empirical depression literature that assumes the monetary nonneutrality operated through imperfectly flexible nominal wages. We introduce nominal wage inflexibility using an information imperfection in the spirit of Lucas (1972). In our model, households make their labor supply decisions without full information; they know the nominal wage when choosing their labor supply, but they don't know the price level; thus they face a signal extraction problem when choosing labor supply. Our model brings the Lucas misperceptions paradigm into the quantitative DSGE literature, which otherwise has ignored the Lucas model due to the computational difficulties associates with the islands formulation.[10] Our formulation is quite simple, as it does not use an islands environment.

With a log-linear approximation, our model is qualitatively identical to a standard predetermined wage model, but our model provides a stronger theoretical foundation for sticky wages, and also is a better quantitative tool for studying the Depression than a standard predetermined wage model.[11] Our model generates sticky wages through an information-theoretic mechanism, which is useful because there are no specific institutional features in place during the Depression that would strongly suggest substantial nominal wage stickiness. Quantitatively, our misperceptions model is preferable to a standard predetermined wage model because the nonneutrality of money is too large in the standard predetermined wage model. Specifically, the standard model generates way too large a depression for almost

[10] Cooley and Hansen (1995) develop a Lucas-type model with islands, but we are unaware of any other fully articulated DSGE models with the specific nonneutrality stressed by Lucas (1972).

[11] The sticky wage model we refer to is one in which workers are imperfect substitutes in production and set their nominal wages each period before knowing the monetary and productivity shocks. (See Cole and Ohanian (2001) or Chari, Kehoe, and McGrattan (2002)).

every country when the model is simulated with just monetary shocks that generate the observed deflation rate. This implies that the standard sticky wage model requires very large *positive* productivity shocks to account for output change in the Depression. Moreover, the standard predetermined wage model also generates grossly counterfactual labor productivity in response . For example, the sticky wage model misses U.S. labor productivity by 26 percentage points: actual labor productivity is 18 points below its 1929 level, while the sticky wage model generates an 8 percent increase in labor productivity.

We therefore need a model which has a smaller nonneutrality. Our misperceptions model satisfies this requirement, and moreover, the nonneutrality in our model takes on a range of values, just as it does in the Lucas (1972(model. This is important because it allows us to choose a nonneutrality value that is quantitatively plausible for the analysis, and also lets us assess whether the decomposition results are sensitive to different values of the nonneutrality.[12]

To conserve space, we present the main equations of the model. Cole, Ohanian, and Leung (2005) present details about the model. There is a large number of identical households who have preferences over sequences of a cash good, a credit good, and leisure. We normalize the size of the population to one. Preferences are given by

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

where c_1 is the cash good, c_2 is the credit good, and $1-n$ is non-market time. The household

[12] We could have reduced the size of the nonneutrality either by shortening the length of the period in which wages are fixed or by constructing a multisector model in which only some wages are fixed. Both of these approaches, however, are complicated. The first approach is complicated because the data are available on only an annual frequency. The second approach is complicated because it requires constructing an explict multisector model and dealing with a host of sectoral issues. Our misperceptions model is simpler to use than either of these alternatives, and also provides a deeper theoretical foundation for sticky wages.

maximizes (1) subject to a wealth constraint and a cash-in-advance (CIA) constraint:

$$m_t + w_t n_t + r_t k_t + (T_t - 1)M_t$$

$$\geq m_{t+1} + p_t \left[c_{1t} + c_{2t} + k_{t+1} - (1-\delta)k_t\right],$$

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

Nominal wealth is the sum of initial cash holdings m_t, labor income $w_t n_t$, capital income $r_t k_t$, and 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. The household finances cash carried forward, m_{t+1} and purchases of cash goods, credit goods, and investment $(p_t[c_{1t} + c_{2t} + k_{t+1} - (1-\delta)k_t])$. Output is given by:

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

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

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

The resource constraint is

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

The transition rule for capital is

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

Monetary policy is given by exogenous changes in the gross growth rate of money.[13] The money stock follows a first-order lognormal autoregressive process:

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

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

We now describe the timing of information and transactions. Define the state of the economy by $S_t = (K_t, \hat{z}_{t-1}, \hat{\tau}_{t-1}, \varepsilon_t^z, \varepsilon_t^\tau)$. The lagged values of the 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), knows a subset of the state vector which we denote by $\bar{S}_t = (K_t, \hat{\tau}_{t-1}, \hat{z}_{t-1})$, and knows the nominal wage. Note that households do not know the realizations of the money supply or technology innovations, while the representative firm knows the full state vector.[14] The labor market opens, and the household and firm make their labor market choices. Note that households choose labor supply without knowing the full state vector.

In the second sub-period, the full aggregate state (S_t) is revealed, households receive their monetary transfer from the government, workers rent capital to the firm, output is realized, and households acquire cash consumption goods, credit consumption goods, and

[13] 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)).

[14] We do not introduce imperfect information in the firms problem, because it is not required to generate the monetary nonneutrality and it would complicate the model considerably. See Cole, Ohanian and Leung (2005).

investment goods. The firm's maximization problem is standard:

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

To construct a recursive formulation, we denote the law of motion for aggregate capital by $H(S_t)$, and we divide all date t nominal variables by $M_{t-1}T_{t-1}$. This implies that the normalized beginning of period aggregate money stock is one ($m_t = 1$). This stationary-inducing transformation yields the following relationship between the quantity of money chosen by the household in period t ($\tilde{m}_{t+1}$) and the quantity of money that the household has at the start 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. We use this transition equation in the household's budget constraint below, substituting $T_t m_{t+1}$ for $\tilde{m}_{t+1}$.

The representative household has a two-stage maximization problem. The Bellman equation for the household is given by

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

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

subject to

$$m_t + w_t n_t + r_t k_t + (T_t - 1)M \geq m_{t+1} T_t + p_t \left[k_{t+1} - (1-\delta)k_t + c_{1t} + c_{2t}\right]$$

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

and subject to the stochastic processes for the shocks. In the first stage maximization, the household chooses its labor supply, 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:

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

The household equates the marginal utility of leisure to the *expected* marginal utility of nominal wealth (λ_t), scaled by the nominal wage. This expectational equation is solved using standard signal extraction methods. To conserve space, we omit the definition of equilibrium, and refer the reader to Cole, Ohanian, and Leung (2005).

A. The Nonneutrality of Money and Imperfect Information

We now show how the information imperfection generates the nonneutrality. These results are in the spirit of Lucas (1972), in that a standard signal extraction problem is used to infer the values of the shocks from a subset of prices. For simplicity, we consider an i.i.d. money shock. The key equation is the household's labor-leisure first-order condition. Log-linearizing this condition yields:

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

where capital letters are steady-state values, and the other variables are log-deviations from the steady state. With imperfect information, the household makes its labor supply decision by forecasting the marginal value of nominal wealth ($\hat{\lambda}_t$), conditioning on the nominal wage ($\hat{w}_t$) and the restricted state vector ($\bar{s}_t = (\hat{k}_t, \hat{z}_{t-1}, \hat{\tau}_{t-1})$).The log-linearized equation for $\hat{\lambda}_t$ is given by

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

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

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

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

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

where, the parameter η is given by

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

The parameter η depends on variances of the shock innovations and on linearization coefficients. This parameter lies between 0 (maximum nonneutrality) and -1 (minimum nonneutrality). 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 a single negative money shock 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, and this 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 shock, but the case in which is $\eta = 0$ ($\sigma_\tau = 0$) 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 the actual negative monetary shock. This misperception of a lower real wage leads households to reduce their labor supply. Consequently, the equilibrium nominal wage falls less than the price level, and employment and output fall.

The reason that this model has a smaller nonneutrality than the predetermined wage model is that the nominal wage in this model partially responds to shocks to clear the labor market. The extent of that response depends on the nonneutrality parameter η. In summary, a contractionary money shock works in this model just as in the standard international Depression story: a negative money shock drives up the real wage through deflation and imperfect nominal wage adjustment, generating lower employment and output.

4. Quantitative Methodology

This section describes our methodology, which includes: (1) a new method to identify the shocks, (2) a new method to test the empirical plausibility of the model, and (3) a method for decomposing output change (or changes in other endogenous variables) into orthogonal components due to multiple shocks that have the complications of non-zero means and non-zero covariances. All of these procedures described here can be used easily in any log-linear model.

A. Identifying the Shocks and Testing their Empirical Plausibility

Data limitations prevent us from using the standard approach to identifying productivity shocks. Specifically, TFP can be constructed for only 5 of the 17 countries. Identifying the money shock is also complicated because money shocks are latent variables, and there is no canonical method for estimating monetary shocks during this period, which is also further complicated by the possibility of money demand shocks Specifically, the possibility of money demand shocks (see Field (1984) and Christiano, Motto, and Rostagno (2004)). We therefore develop a new procedure for identifying the shocks. This procedure treats both the productivity and monetary shocks as latent variables, and solves for the values of the shocks in each year so that output and the price level in the model for each country and for each year matches the actual output and price data. The procedure is very simple to perform. Specifically, we take the linear equations for the log of the deflator and the log of output, and we use these two linear equations to solve for the values of the technology and monetary shocks that equate the model price and output variables to the actual data for these variables. Thus, we are solving two linear equations (the equations for price and output) in the two unknown values of the shocks.

Regarding the two variables we choose to match, it is necessary to match output to decompose the change in output into monetary and productivity components. We match the price level because of the view from the empirical Depression literature that accounting for the observed deflation across countries is central for accounting for the Depression. It would be trivial to match the money supply in the model to the actual money supply by adding a shock that shifts money demand, and adding a third equation to solve for the money demand shock. We do not add a money demand shock because our previous work (Cole and Ohanian (2001)) showed that money demand shocks have virtually no affect on equilibrium quantities in this class of monetary models. Thus, equating the model money supply to the actual money supply would not change the decomposition findings. Thus, While equating deflation in the model to actual deflation is important, equating the model money supply to the actual money supply is unimportant. It is important, however, to determine whether productivity in the model is similar to actual productivity change. To assess the empirical plausibility of productivity, we compare the model productivity to actual productivity.

B. The Decomposition Procedure

We measure the contribution of each shock as the percentage of the sum of squared output deviations explained individually by each shock:

$$1 - \frac{\sum_{i=1}^{17}\sum_{t=1930}^{1933}(y_{it}^{p} - y_{it})^2}{\sum_{i=1}^{17}\sum_{t=1930}^{1933} {y_{it}}^2}, \tag{3}$$

where y_{it} is the log-deviation of real output from its 1929 level in country i in period t, and y_{it}^{p} is the log-deviation of real output from its 1929 level generated in the model from each shock individually. Conducting this decomposition is complicated because the shocks have nonzero means and a nonzero covariance. Note that this complication will *invariably* affect any analysis that evaluates actual changes in variables during periods of large shocks. Consequently, the sum of the two fractions obtained from (3) may differ from one. We are unaware of any approach to dealing with both of these complications. We therefore develop a new accounting procedure that allocates the mean and covariance components of the shocks to construct maximum and minimum bounds on the contribution of each shock so that the sum of the bounds is one.

Our procedure is as follows. First, we write each shock as the sum of three components: (1) a mean component (m), (2) an uncorrelated zero-mean component (u), and (3) a correlated zero-mean component (v). Since the mean and covariance terms differ each year, we specify year-specific mean and covariance components for this decomposition:

$$\varepsilon_{zt} = m_{zt} + u_{zt} + v_t,$$

$$\varepsilon_{\tau t} = m_{\tau t} + u_{\tau t} + \gamma_t v_t.$$

This procedure extends the standard variance decomposition procedure for zero-mean random variables to non-zero-mean random variables. Recall that the standard variance decomposition problem decomposes the variance of a random variable that is the sum of two mean-zero correlated shocks. The standard resolution of this problem constructs bounds for the contribution of each variable by attributing the covariance term to one shock and then to the other shock. Our procedure allocates the covariance term between the shocks this same way. We also must allocate the mean components, because the means of the two shocks may be related. For example, the money shock mean may be a linear function of the productivity shock mean. Since we cannot separate the means into common and idiosyncratic components, we construct the bounds by attributing the correlated mean zero component and both mean components to one shock and then to the other shock.

The *minimum bound* for the productivity shock is the fraction of squared output deviations in (3), calculating y_{it}^{p} just from the zero-mean orthogonal component of the productivity shock, u_{zt}. It is the minimum bound because we are attributing the contribution from the correlated zero-mean common component (v_t) and the mean components ($m_{zt} + m_{\tau t}$) to the money shock. The *minimum bound* for the money shock is constructed in an analogous fashion using $u_{\tau t}$. We calculate $u_{\tau t}$ as the residual from a regression of $\varepsilon_{\tau t}$ on a constant and ε_{zt}. Since the mean and covariance terms differ each year, this regression is estimated each year. We calculate u_{zt} analogously. The *maximum bound* for the money shock is just one minus the lower bound for the productivity shock, and similarly the *maximum bound* for the productivity shock is one minus the lower bound for the money shock. In addition to these bounds, we will construct another orthogonalization in which we calculate the contribution of productivity that is orthogonal to deflation. This is an interesting decomposition because the orthogonalized component of productivity is corrected for deflation-related mis-measurement, such as deflation-driven changes in capacity utilization.

C. Testing The Decomposition Results

We test the decomposition based on productivity that is orthogonal to deflation by comparing output from the model generated only by the orthogonal component of productivity, to a statistical measure of output that is orthogonal to deflation. To form this statistical measure of output orthogonal to deflation, we take the residual from the regression of output on deflation. We then compare these two measures of output, one of which is a model-based measure of the component of output unrelated to deflation, and the other which is a statistical measure of output unrelated to deflation.

D. Parameter Values

Table 3 presents the parameter values. The discount rate to 0.95, the exponent on labor in the production function to 2/3, and the depreciation rate to 7 percent per year. We choose the preference parameters α and σ such that the steady state of the model matches two long-run money demand 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 choose the autocorrelation coefficient for the technology shock to be 0.9. We choose the autocorrelation coefficient for money growth 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 this parameter between -0.5 and 0.5 and found that the results were insensitive to this variation.

The innovation variances for the money supply and the technology shock determine the size of the impact of a money shock on output. We label this nonneutrality parameter η. We directly choose a value for η, rather than individually choose the innovation variances. Table 4 shows the impact of a contractionary money shock that reduces the price level by 10 percent for different values of η. The maximum nonneutrality decreases labor input by about 15 percent from a 10 percent decrease in the price level. The medium nonneutrality ($\eta = -.5$) decreases labor input by about 10 percent in response to a 10 percent deflation.[15]

We choose a benchmark value for η such that productivity changes in the model are similar to those in the data. This turns out to be the mid-range value, $\eta = -.5$. To understand the implications of η for labor productivity, note that for a money shock of a given size, a large nonneutrality drives down employment significantly. This increases labor productivity and the real wage. In contrast, in a neutral model, which is $\eta = -1$, employment and labor productivity will be driven entirely by a productivity shock. Thus, contractionary monetary shocks drive labor productivity higher, with the size of the impact depending on the value of η, while contractionary technology shocks drive labor productivity lower.

We assess the robustness of the results to different values of η. A surprising finding presented in the next section is that the relative contributions of productivity and money to output fluctuations are fairly insensitive to different values of the nonneutrality parameter η, although labor productivity is sensitive to this parameter.

5. Evaluating the Shocks

Before we turn to the decomposition results, we assess the empirical plausibility of the shocks. We evaluate the plausibility of the productivity shock model by comparing model productivity to various measures of actual productivity. The first analysis compares productivity from the model to actual productivity. We have aggregate productivity for 7 of the 17 countries (TFP for Canada, France, Germany, the United Kingdom, the United States, and economy-wide labor productivity for Australia and Japan) for each year. Figure 4 shows a strong and systematic relationship between actual productivity and model productivity for

[15] For comparative purposes, note that a model with our production technology, but in which wages are set in advance, drives down employment 30 percent from a 10 percent unanticipated deflation. This follows directly from equating the marginal product of labor to the real wage.

each country and each year (Appendix Table A4 shows these data.). The correlation between these variables is 0.89. The fact that the model generates productivity changes that are extremely similar to the data means that the model is accurately decomposing the fraction of output change into changes due to inputs and changes due to productivity. We can compare model productivity to actual productivity for more countries by examining labor productivity from the industrial sector. We have industrial labor productivity for 14 countries beginning in 1930 and for 11 countries beginning in 1929.[16] We therefore calculate the correlation between the change in industrial labor productivity between 1929 and 1932 and model TFP over for the set of 11 countries, and between 1930 and 1932 for the set of 14 countries. These correlations are 0.63 and 0.60 with model TFP, which are very similar to a benchmark comparison of the correlation between U.S. HP-filtered industrial labor productivity and HP-filtered aggregate TFP (0.72).[17] These comparisons show that productivity shocks derived from the model economy are very similar to actual productivity during the Depression.

6. The Relative Contributions of Money and Productivity Shocks

Table 5 presents the lower and upper bounds on the contribution of technology shocks and money shocks for different values of the nonneutrality parameter η. We report the average value of the bounds for the 1930–33 period. Our main finding is that the productivity shock is more important than the money shock. For the benchmark value of η, the bounds for productivity are a maximum of 89 percent and a minimum of 54 percent, and the bounds for money are a maximum of 46 percent and a minimum of 11 percent. Averaging the values at the two bounds shows that productivity accounts for about 70 percent of the Depression, and monetary shocks account for about 30 percent. The table also shows that these bounds

[16] All countries except for Czecholoslovakia, Denmark and Switzerland have industrial labor productivity beginning in 1930. Within this group of 11 countries, all expect for Austria, France, and Germany have industrial labor productivity beginning in 1929.

[17] The reported correlations are for HP-filtered data where the filtering parameter was set to 400. We also computed these correlations for a filtering parameter of 6.25, and the results were very similar.

are not very sensitive to changes in the value of the nonneutrality parameter. The maximum bound for productivity ranges between 82 and 94 percent, and its minimum bound ranges between 45 and 48 percent.[18]

The table also reports the orthogonal contribution of productivity from an alternative orthogonalization procedure that removes the component of the productivity shock that is related to deflation.[19] This orthogonal component is the residual from a regression of the productivity shock on deflation that is estimated separately each year. Note that this year-by-year estimation provides a conservative estimate of the contribution of this orthogonal component relative to estimating one regression over all four years. The contribution of productivity from this alternative orthogonalization procedure is also high, ranging between 70 and 81 percent for different values of η.

Table 9 reports statistics on the money and productivity shocks for our benchmark parameterization. Productivity shocks are positive in 1930 because there was a large deflation that year, but average output was roughly unchanged (see Table 1). The productivity shock is negative in every year after 1930, despite the residual effects of the 1930 positive productivity shock. Table 9 also shows that the shocks are not highly correlated for most of the Depression. This means that the difference between the minimum and maximum bounds is primarily due to the allocation of the nonzero means of the shocks, rather than the covariance between the shocks.

The reason deflation accounts for a relatively small fraction of output in the model economy is the same reason why the R^2 statistics in the log-linear output-deflation regressions were low: deflation is not systematically related to output. To see this in more detail, we

[18] We experimented with a pre-determined wage version of this model. Specifically, workers were imperfect substitutes in production and they set their nominal wage one period in advance. The bounds were similar to those reported here. See Cole, Ohanian, and Leung (2005) for details.

[19] For example, Bernanke and Parkinson (1991) interpret lower productivity in U.S. manufacturing productivity during the Depression as potentially reflecting capacity utilization and/or labor hoarding.

separate the log output fluctuations into 2 components for each year: a cross-country mean component and a country-specific component:

$$y_{it} = \bar{y}_t + \varepsilon_{it},$$

where y_{it} is the log deviation of output in country i in year t from its 1929 value, $\bar{y}_t$ is the cross-country mean log deviation in year t, and ε_{it} is the country-specific component.

Table 6 shows that the country-specific component accounts for most of the squared output fluctuations and it also shows that this country-specific component is not systematically related to deflation. The table shows that the correlation between output and deflation, which is the appropriate measure of the relationship between the country-specific component of output and deflation, is negative in 1930 and 1931 and is reasonably large and positive only in 1932. In the model, however, money shocks generate a correlation between output deviations and deflation that is nearly one. This large difference between the empirical correlation between output and deflation, and the model correlation between output and deflation,, is the reason why money/deflation does not account for more of the Depression.

This large difference between the relationship between deflation and output in the model, and deflation and output in the data, is also the reason why deflation will not be the dominant shock in other classes of log-linear business cycle models, such as models with monetary induced capacity utilization, labor hoarding, etc.. In particular, recall that the regressions from Section 2 show that the approximate upper bound on the explanatory power of deflation is less than 30 percent.[20] This means that the productivity shocks cannot be explained by deflation-induced capacity utilization/labor hoarding or other deflation-induced factors.

[20] Also recall that the positive correlation between output and real wages is inconsistent with the deflation-high real wage hypothesis and labor hoarding.

A. Assessing the Plausibility of the Orthogonalized Decomposition

We now evaluate the plausibility of the decomposition based on productivity that is orthogonal to deflation, we compare the component of output generated just from model TFP that is orthogonal to deflation to the residual from the regression of output on deflation in (1). Thus, we compare a model-based measure of output that is orthogonal to deflation to a statistical measure of output that is orthogonal to deflation. To see why this comparison is relevant note that in a log-linear framework (abstracting from capital) the regression residual from (1) can be written as the sum of the orthogonal components of the non-deflation shocks that are driving output, multiplied by linearization coefficients:

$$\varepsilon_{it}^{y} = \alpha_1 u_{i1t} + \alpha_2 u_{i2t} + ... + \alpha_n u_{int}, \tag{4}$$

where ε_{it}^{y} is the residual component of output from the output-deflation regression, and u_{ijt} is the "jth" shock in the "ith" country. If ε_{it}^{y} is largely due to productivity shocks that are orthogonal to deflation, then it should be similar to model output generated just from orthogonal productivity. In fact, we find that these two series are virtually identical. Figure 5 shows the two series. They lie nearly on the 45 degree line. The fact that these two series are the same means that accounting for the component of output that is statistically unrelated to deflation from (1) requires an economic model that is observationally equivalent to a growth model with productivity shocks that are orthogonal to deflation.

We now turn to comparing the other variables in the model to the data. First, we compare the real wage rate in the model and the real wage rate in the data. This comparison also shows a significant similarity between the model and the data. This comparison is more complicated, however, because of a number of measurement issues. These include (1) cyclical compositional changes among workers, (2) the wage rate in the model is for the aggregate economy, but the measured wage rate is just for the industrial sector, (3) the size and composition of the industrial sectors differ across countries, (4) wage survey methodologies differ across countries, and (5) data transcription errors may be large for some countries.[21] We are able to make some adjustments for the first two of these problems but unfortunately not for the others. Thus, this wage comparison is probably less informative than the productivity comparisons.

Regarding worker compositional change, the average quality of workers tends to rise during depressions because the least experienced and least productive employees are typically the first to be laid off. We have addressed this measurement problem by compositionally adjusting the wage rate in the model using the postwar U.S. estimates of cyclical labor composition bias produced by Solon, Barsky, and Parker (1994).[22] Regarding the issue that the measured wage is only for the industrial sector of the economy, we provide a benchmark for interpreting the relationship between the model wage and the actual industrial wage by calculating the relationship between the aggregate wage and the industrial wage during postwar U.S. business cycles. We therefore measured the cyclical correlation between industrial wages and the aggregate wage using postwar U.S. HP-filtered data and obtained a value that ranges between of 0.48 and 0.8, depending on the value of the smoothing parameter.[23] The correlation between the model wage and the actual wage for each of the four Depression ranges between 0.47 to 0.75. Considering the measurement issues described above, we consider these positive correlations between the model wage and the actual wage as evidence supporting the

[21] Regarding this latter measurement issue, we found that the nominal wage index in some countries is implausibly constant (up to a decimal point) for a sequence of years, which will tend to lead to positive real wage measurement error during deflationary periods.

[22] The log-deviations in model real wages, w, were generated according to $\hat{w} = w - 0.49 * n$, where n, the employment share, is serving as a proxy for unemployment. We compositionally adjust the model wages since we have measures of employment in the model for all of our countries.

[23] The correlation is 0.48 for a smoothing parameter of 400 and is 0.84 for a smoothing parameter of 6.25. The U.S. annual series are average hourly earnings for manufacturing and average hourly earnings for the private economy, from 1955 to 2003.

decomposition results.

The final comparison we make is between the money supply in our model and that in the data. This comparison is complicated because some authors argue that there were significant money demand shocks during the Depression (Christiano, Motto, and Rostagno (2004) and Field (1984). Since our model abstracts from money demand shocks, there will tend to be difference between the money supply in the model and in the data, even though our model matches the price level.[24] Despite abstracting from money demand shocks, we find a correlation between the model money supply and the actual money supply that is quite high, ranging between 0.5 and 0.7 for three of the four Depression years (1931-33). [25]

7. Understanding the Productivity Shock

To date, little progress has been made in understanding the factors that may be contributing to productivity shocks during the depression, or for that matter, more generally during postwar business cycles.[26] This section extends our analysis by evaluating possible economic factors that could be driving these productivity shocks. Specifically, there are a variety of models, including models with financial shocks, and models with trade shocks, which are observationally equivalent to a productivity shock in a closed economy stochastic growth model. To determine whether these classes of models are promising ones for understanding

[24] To see this, suppose there is a shock to money demand that lowers the price level. Note that our model without the money demand shock would generate this lower price level through a negative money supply shock. Thus, the money supply that our model requires will reflect both money supply and money demand shocks, and thus may differ from observed changes in the money supply. Note that we could add a money demand shifter in this model by making the cash goods preference parameter a random variable. We did not incorporate this complication, however, as our interest is in accounting for the importance of observed deflation.

[25] Recall that it would be straightforward to add a money demand shock to the model and match the actual money supply, and that this modification would not change the relative contributions of the two shocks.

[26] Ohanian (2001) suggests possible factors that contributed to productivity change during the Depression, but does not carry out any quantitative analysis of these factors. Regading postwar business cycles, Hansen and Prescott (1991) suggest productivity may be the consequence of changes in government policies and regulation, though we are unaware of any tests of this hypothesis. Recall that we are not pursuing capacity utilization/labor hoarding explanations since deflation explains a small fraction of the Depression.

the Depression, we test whether financial or trade-related variables can explain a significant fraction of the productivity shocks. To do this, we continue to use the framework of log-linear models, which implies that the log deviation of the productivity shock will be linearly related to the log deviations of these other factors:

$$\varepsilon_{zit} = X_{it}\beta,$$

where ε_{zit} is the productivity innovation, X_{it} is a vector of other factors and β is a vector of coefficients. We therefore regress the productivity shock innovations on a number of financial and trade variables. There are four financial variables (a nominal interest rate, an ex-post real interest rate, the Bernanke-James (need year) measure of banking panics, and the real value of the stock market), four monetary variables (deflation, M0, M1, M1-M0, which represents the endogenous component of M1)), and one international trade variable (the real exchange rate). All of these variables are described in detail in the Appendix. We first estimate regressions with one variable at a time to maximize the potential explanatory value of each of these variables. The regressions take the following form, where x represents the single explanatory factor:

$$\varepsilon_{zit} = \gamma x_{it} + u_{it}.$$

Table 10 shows the goodness of fit statistic for these regressions, which is the explain sum of squared productivity innovations divided by the total sum of squared productivity innovations. This is a pseudo R^2, as the regressions do not not include a constant term (which would be inappropriate in the log-linear framework). Our main finding is that the stock market is the only variable that is substantially related to the productivity innovation, accounting for 41 percent of its sum of squared deviations. Most of the other variables account for little of the productivity innovation. In particular, the monetary base, which is the monetary aggregate most closely controlled by Central Banks, explains none of the productivity shock. Deflation explains just 9 percent. M1 explains 21 percent, which is driven by the endogenous component of M1 (M1-M0) and the covariance between the base and the endogenous component of M1. Nominal interest rates and real interest rates are both unimportant, as is the real exchange rate. The Bernanke-James banking panic variable explains 19 percent.

For comparative purposes, the table also presents the explanatory power for each of these variables (except the banking panic variable) in the same regression estimated using annual U.S. post-World War II data. The most striking comparison is with the stock market. The R^2 is only .05 in postwar U.S. data, compared to .41 during the depression.

We also evaluated whether the non-stock market variables were jointly important for explaining the Depression productivity shocks. Specifically, we tested whether deflation, M1, the nominal interest rate and the banking panic variable add any significant explanatory power beyond the stock price variable. They do not - the F statistic for the joint significance of these variables is 1.43, compared to the 5 percent critical value of 2.09. We also evaluated the joint explanatory power of these other variables without the stock market in the regression. The R^2 from the regression from these four variables is significantly less than the R^2 from the regression with just the stock market. This indicates that the most promising channel for understanding TFP is through the stock market. We next test whether there is a significant relationship between lagged real stock prices and the productivity innovations. We do this for two reasons. First, this provides a test of whether the productivity shock was forecastable, and whether stock prices were reacting to anticipated low economic activity. This evaluation is important because the standard view is that the Depression was due to a long sequence of transitory and unforcastable shocks (e.g. the Robert Lucas interview in Klamer (1981)), which stands in sharp contrast to the predictable and persistent productivity shocks in our model economy. Second, this evaluates whether there is a significant relationship between the stock market and productivity after removing the contemporaneous endogenous component from stock prices.

We therefore regressed the productivity innovations on lagged real stock prices. The lagged stock market accounts for 33 percent of the productivity innovations. It is also interesting to note that lagged real stock prices account for 52 percent to the productivity shock level (as opposed to the innovation) during the Depression, compared to just 1 percent in postwar U.S. data. These findings show that there is a systematic and quantitatively important relationship between the stock market and productivity, and that there is a significant predictable component of productivity during the Depression.

We now quantify the importance of the stock market related-component of the productivity innovations. Specifically, we use our benchmark model to solve for output in each country between 1930-33 with monetary shocks to generate observed deflation as in our previous experiments and with the component of productivity explained by the contemporaneous stock price. Our model accounts for 73 percent of the Depression. This finding is very promising as it indicates that a financial factor that (i) depresses the efficiency and profitability of a firm, but (ii) that is largely unrelated to interest rates, monetary factors, or exchange rates, may account for a large fraction of the Depression. The next section summarizes microeconomic evidence relating these types of factors with firm performance and firm productivity, and summarizes financial models that are promising in this regard.

8. Financial Shocks, the Stockmarket and TFP

We first review classes of models that can be used to interpret the quantitative relationship between stock prices and productivity and that are promising candidates for further study of the Depression. The classes of models share the feature that a shock that depresses stock prices also depresses output and productivity through financial market imperfections. There are three basic mechanisms through which this occurs. The three mechanisms are limitations on input choices, exacerbation of internal informational frictions within the firm, and the disruption of normal trading relationships.

Regarding the limitations on input choices induced by changes in stock prices, models developed by Kyotaki and Moore 1997, Bernanke and Gertler 1989, and Carlstom and Fuerst 1997 have the feature that the level of inputs is constrained by the net worth of the entrepreneur, and thus decreases in net worth reduce inputs. Chari, Kehoe, and McGrattan (2006) modify this class of models such that some inputs are particularly sensitive to these types of financial factors, and this change in the composition of inputs reduces measured TFP.

There are two channels through which stock prices can exacerbate the internal frictions of the firm and reduce productivity. First, to the extent the stockmarket fall signaled a greater likelihood that the firm would cease to exist, this could make agency frictions within the firm more severe. This sort of channel is in keeping with the classic Folk theorem results in games of incomplete information (e.g. Fudenberg, Levine and Maskin). In addition, there is a class of models that consider how agency and other informational frictions within the firm evolve over time, including Albuquerque and Hopenhayn 1997, Cooley, Marimon and Quadrini (2003), and Atkeson and Cole 2006 (AC)). In all of these models, any factor that reduces the expected duration of the relationship between the principal and the agent, such as a decline in the share price, exacerbates the importance of the agency friction. The increases in these frictions lead to increases in monitoring costs, inefficient rent-seeking, diversion of investments to less efficient uses, and a an increased difficulty in generating optimal choices of privately observed actions like effort. All of these effects reduce measured TFP and output.

The third mechanism through which a stock price fall reduces output and measured TFP is by disrupting normal trading relationships. For example, in the model of Kyotaki and Moore (1997), changes in the probability of repayment will lead firms to reduce trade credit to their trading partners or spend additional resources on evaluating or monitoring their trading partners. These disruptions will lead to lower output and TFP. Similarly, Kobayashi (2006) studies the impact of financial factors on TFP in a model in which a financial disruption of normal trading relationships generates lower productivity through a reduction in specialization within the firm. All of these models have the feature that shocks that reduce the value of a firm also impact productivity and performance. We now examine microeconomic studies of these relationships.

Maksimovic and Phillips (1998) is perhaps the most comprehensive study that studies the impact of the financial distress associated with filing for bankruptcy (Chapter 11). They analyze 1195 manufacturing plants of 302 firms that filed for Chapter 11 between 1977 and 1990, and a control group of over 50,000 plants of non-bankrupt firms. They compared plant-level productivity in the financially distressed firms to TFP all firms, and also to TFP across industry groups that differ by varying levels of financial distress associated with demand shocks.[27] For these industry groups, the lowest industry grouping consisted of those that were significantly distressed (very negative long-run demand shocks associated with long-run declining industries), and the highest industry grouping consisted of those were not distressed (very positive demand shocks associated with rapidly expanding industries). They found that TFP was low in the financially distressed firms, and systematically higher in firms that were in expanding industries, indicating that financial distress is associated with low TFP.

[27] TFP is adjusted for variation in capacity utilization.

In particular, they found that TFP in distressed firms for the two years before filing for Chapter 11 was about 4.5 percent lower compared to all plants, and as much as 15 percent lower than plants in industries with the most positive demand shocks. During the first year of Chapter 11, the plants of distressed firms had productivity that was 9 percent below all firms, and almost 19 percent below those in industries with the most positive demand shocks. Three years after entering Chapter 11 the productivity of the plants of distressed firms was almost 37 percent below those in the industries with positive demand shocks. Productivity continued to be low after leaving Chapter 11. Relative to all firms, the plants of firms exiting Chapter 11 had productivity that was about 9-16 percent lower 1-3 years after Chapter 11. Moreover, productivity was also very low for plants in firms which were not bankrupt but were experiencing considerable financial distress. Specifically, the productivity in the lowest quartile of these shocks was not very different from the productivity in the plants of bankrupt firms.

The corporate finance literature has tried to evaluate both the direct and the indirect costs of financial distress. The direct costs include the administrative costs and legal fees associated with bankruptcy, which have been estimated to be around 4% of market value.[28] The indirect costs include misplaced managerial effort, costly reductions in capital and sales of assets at depressed prices. While not all of these costs will translated into falls in measure TFP, some of them, such as misplaced managerial effort and the potential misallocation of capital can.

Andrade and Kaplan (1998) examine highly leveraged firms in order to evaluate the impact of pure financial distress. They estimate that firms that experienced financial distress lost 10 to 20 percent of their market value. Opler and Titman (1994) looked at the differential response of firms within an industry to a common shock based upon their degree of leverage.

[28] See Altman (1984), Ang et al (1982), Warner (1977) and Weiss (1990).

They found that firms with high leverage ratios performed substantially worse with, firms in the highest decile of leverage having 25% lower sales growth. Finally Maksimovic and Phllips (1998) find that firms in chapter 11 for less than a year have TFP levels that are 9% below firms in the industry who did not file for bankruptcy.

9. Comparing Our Findings to the Literature

We now compare our findings to those in the single-country neoclassical literature and those in the cross-country empirical deflation literature. Regarding the neoclassical literature, these studies cover only 5 of the 17 countries studied here, and the literature typically does not measure the relative contributions of productivity versus money shocks. With these caveats in mind, we find that our results are largely consistent with the results from these single-country studies. This literature includes studies of the United States (Cole and Ohanian (1999, 2000), Chari, Kehoe, and McGrattan (CKM) (2001, 2004), and Bordo, Erceg, and Evans (2000), Christiano, Motto, Rostagno (2004), Harrison and Weder (2004)), Canada (Amaral and MacGee (2002)), Germany (Fisher and Hornstein (2002)), France (Beaudry and Portier (2002)), and Italy (Perri and Quadrini (2002)). Nine of these eleven papers are comparable to our framework, and of these nine, seven study productivity shocks and generally find a role for this shock, though only CKM measure the relative contribution of productivity.[29] Few of these papers study the role of monetary shocks. Cole and Ohanian (2001), Amaral and MacGee, and CKM suggest that money played some role but was not the major factor in the U.S. between 1929-33. The one paper that argues that deflation–sticky wages is the dominant factor for the United States is Bordo, Erceg, and Evans (2000). Their findings differ from ours and from CKM's findings because their one-shock model abstracts

[29] Christiano, Motto, and Rostagno (2004), and Harrison and Weder (2004) are not really comparable, as their environments and their focus are quite different from ours. In particular, the model in Christiano et al is very different from any of the others in the literature, and the focus of their paper is on money demand shocks. Harrison and Weder (2004) focus on sunspots as a cause of the Depression.

from productivity shocks. Consequently, their model counterfactualy predicts very high labor productivity during the Depression. It is likely that their findings would have been similar to ours and CKM's if they had included a productivity shock, as their model economy is qualitatively similar to the one used by us and by CKM.[30]

The goal of the second strand of the literature is to exploit the cross-sectional feature of the data by estimating cross-country regressions, including work by Bernanke (1995), Bernanke and Carey (1996), Eichengreen and Sachs (1985), and Choudhri and Kochin (1980). This literature is really not comparable, and in fact addresses a different issue than our study. In particular, this literature (1) uses a different methodology, (2) focuses on a different question, which is the recovery from the Depression rather than the causes of the Depression, (3) does not include productivity shocks, (4) uses different measures of output and prices, and (5) includes post-Depression (post-1933) data in the analysis. These papers argue that monetary forces operating through sticky wages are a key factor for recovery from the Depression, based on regressions that show a negative relationship between industrial production (IP) and a nominal wage rate deflated by a wholesale price index (WPI).[31]

To compare our findings to those in this literature, it is necessary to account for the difference between the positive wage-output correlation reported in this paper and the negative relationship reported in these other papers. There are two differences between our analysis and this literature that are relevant for this issue: the measurement of the real wage, and the years covered by the analysis. We address each of these in turn.

Regarding measurement of the real wage, this other literature uses the wholesale price index to deflate the nominal wage, but this is not the right price index to use because the sticky-wage theory requires that the wage be deflated by the price of *final* output. However,

[30] Capacity use here...

[31] Choudhri-Kochin do not focus on the relationship between output and real wages, but on the relationship between output and prices for a small group of countries. Our comments below about output and real wages also apply to output and prices in this paper.

the wholesale price index is based on a bundle of raw *input* prices.[32] Regarding the years of observation, our analysis focuses solely on the Depression years (1930-33). This other literature mixes data from part of the Depression and from the post-Depression period. (For example, Bernanke's study omits the first year of the Depression (1930), and includes two years of data after the Depression (1934–35).

We address these issues by calculating the correlation between our preferred measure of the real wage and output for two periods: during the Depression and then after the Depression. We make the same calculation for the measure of real wages and output used in the other literature for the Depression (1930-33).

First we consider the output-wage correlation during the Depression (1930-33). Recall that Table 1 showed that the correlation between real GNP and the wage deflated by the GNP deflator were positive each year between 1930-33, ranging between ..47 to .30. The correlation between IP and the wage deflated by the WPI for 1930-33 is similar. They are positive in 3 of the 4 Depression years, and range between .44 and -.03. The higher variability of these correlations relative to those computed from real GNP and the wage deflated by the deflator likely reflects measurement error due to the significant measurement issues involved with using the WPI, including both the conceptual problem of using the WPI to deflate the wage, as well as the fact that the components of the WPI vary widely across countries. We conclude from these comparisons that the real wage-output correlation is largely positive during the Depression (1930-33).

We now turn to data from the recovery period (post-1933), using our preferred measures of real GNP and the wage deflated by the GNP deflator. After 1933, the correlation between these variables becomes negative, ranging from -.22 to -.60 for the 1934-1937 period.

[32] Moreover, the composition of wholesale indexes differs substantially across countries, which further complicates cross-country comparisons.

This change in the correlation sign between real GNP and the wage deflated by the GNP deflator raises the possibility that monetary forces working through sticky wages may have been more important for fostering recovery after 1933, than as a cause of the Depression between 1929-1933. Moreover, it is *post-1933* data, rather than data from the Depression (1930-33), that drives the conclusions reached in the cross-country regression literature about reflation and recovery from the Depression. But this correlation evidence from post-1933 data presented here does not establish the importance of the monetary shock/sticky wage factor. One key reason is because these correlations do not control for other variables, including productivity, and in particular, the large government policy changes that were adopted in many countries at the end of the Depression. For example, Cole and Ohanian (2004) and Fisher and Hornstein (2002) argue that labor market policies - not monetary policies - significantly affected post-Depression real wages in the U.S. and Germany, respectively.[33] As discussed in Section 2, addressing the relative importance of monetary and other shocks for the post-Depression period requires a parameterized, multi-shock general equilibrium model and detailed historical analyses that are beyond the scope of this paper.

We conclude that the cross-country empirical International Depression literature doesn't have implications for our decomposition results for the 1930-33 period. The post-1933 data do raise interesting questions about the importance of monetary shocks for the recovery from the Depression. Our future work will address this issue by modifying the present framework to include the large government policy changes that occurred during this period.

[33] Cole and Ohanian (2004) present evidence that shows cartelization policies raised real wages and retarded the U.S. recovery. Fisher and Hornstein (2002) present evidence that shows anti-unionization policies reduced real wages and accelerated the German recovery.

10. Summary and Conclusion

This paper has blended the cross-country empirical Depression literature that focuses on deflation with the single-country DSGE literature that focuses on productivity. We developed a model that features both the deflation/high real wage channel of the empirical literature, and the productivity shock channel of the DSGE literature, constructed a panel data set of 17 countries, and quantified the relative contribution of the two shocks. In doing this, we developed a novel version of the misperceptions model that was easy to take to data, a new procedure for constructing monetary and productivity shocks, and a new decomposition procedure that constructs minimum and maximum bounds for the contribution of potentially correlated shocks that have non-zero means. Our main finding is that productivity is the dominant shock, accounting for about 70 percent of the Depression, with deflation accounting for about 30 percent. Similarly, regression analysis indicates that the maximum explanatory power of deflation in any log-linear model is about 30 percent. Deflation accounts for a small fraction of the depression because it is not systematically related to output. We tested the model by comparing the constructed productivity shocks in the model to actual productivity changes, and found that the constructed shocks and the actual productivity changes are extremely similar.

Our findings indicate that understanding the International Depression requires understanding these productivity shocks. To do this, we extended the analysis to assess whether the productivity shocks are the consequence of other deeper factors, as some models with financial shocks and trade shocks are observationally equivalent to a TFP shock in a closed economy stochastic growth model. We tested the relationship between productivity and a number of trade and financial variables, and found an extremely strong relationship between productivity and the stock market, but with no other variables. This strong relationship between stock prices and productivity suggests that the most plausible candidate factor for explaining the TFP shocks is a financial shock that depresses real stock prices, and that the most promising class of models for this type of shock are financial friction models with either agency problems, net worth imperfections, or the disruption of normal trading patterns. Future research on the Depression should focus on developing models with these features for understanding this important period.

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11. Appendix

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.*

12. Tables

Table 1: Cross-Country Statistics - Output, Real Wage, and Deflator Hatted Variables are Log Deviations from 1929, π is Log Difference of Deflator								
	Mean			**Correlation with $\hat{y}$**		**Standard Deviation**		
Year	$\hat{y}$	$\hat{w}-\hat{p}$	π	π	$\hat{w}-\hat{p}$	$\hat{y}$	$\hat{w}-\hat{p}$	π
1930	-0.01	0.05	-0.04	-0.22	0.35	0.04	0.03	0.04
1931	-0.06	0.08	-0.07	-0.28	0.47	0.08	0.05	0.03
1932	-0.10	0.09	-0.05	0.55	0.30	0.11	0.06	0.05
1933	-0.09	0.08	-0.02	0.36	0.37	0.14	0.08	0.03

Table 2: Output and Deflator in 1932 Cumulative Log Changes from 1929		
Country	**Output**	**Deflator**
Australia	-0.07	-0.28
Italy	-0.08	-0.24
U.S.	-0.33	-0.24
Hungary	-0.04	-0.23
Japan	0.05	-0.22
Netherlands	-0.08	-0.20
Germany	-0.28	-0.19
Canada	-0.29	-0.18
Denmark	0.04	-0.17
Finland	-0.04	-0.17
Switzerland	-0.04	-0.17
Sweden	-0.04	-0.15
Norway	0.01	-0.12
Czech.	-0.11	-0.08
U.K.	-0.06	-0.08
Austria	-0.22	-0.02
France	-0.11	-0.02
Mean	-0.08	-0.15

Table 3: Benchmark Parameters						
θ	$\boldsymbol{\beta}$	σ	$\boldsymbol{\delta}$	$\boldsymbol{\alpha}$	$\boldsymbol{\rho_z}$	$\boldsymbol{\rho_\tau}$
.33	.95	.92	.07	.5	.90	.00

Table 4: Impact of a 10 Percent Deflation on Labor ($\hat{n}$)

for Different Values of the Nonneutrality Parameter (η)

$\boldsymbol{\eta}$	$\hat{\mathbf{n}}$
0	-14.8%
-0.25	-12.7%
-0.50	-9.8%
-0.75	-5.9%
-1.00	-0.0%

Table 5: Output Decomposition Bounds

Percentage of Output Change Explained by

	Monetary Shock		**Productivity Shock**	
$\boldsymbol{\eta}$	**Lower**	**Upper**	**Lower**	**Upper**
-0.75	6	45	55	94
-0.50	11	46	54	89
-0.25	15	47	53	85
0.00	18	48	52	82

Table 6: Output Decomposition with Alternative Orthogonalization **Percentage of Output Change Explained by**		
	Money and Non-orthogonal Productivity	**Productivity Orthogonal to Deflation ($\varepsilon_z \perp \boldsymbol{\pi}$)**
1930	21	79
1931	24	76
1932	28	72
1933	30	70

Table 7: Log Output Change due to Country-Specific Component and the Correlation between Log Output and Log Price Change

Year	Country-Specific Component (%)	Correlation
1930	98	-0.22
1931	62	-0.28
1932	56	0.55
1933	70	0.36

Table 8: Output Decomposition Bounds

High and Low Non-Neutrality Experiment[34]

Percentage of Output Change Explained

Money Shocks		**Productivity Shocks**	
Lower	Upper	Lower	Upper
12	53	47	88

[34] The following countries were assigned an η of 0: Austria, Canada, Czechoslovakia, France, Germany, and the United States. The rest were assigned an η of -0.80.

Table 9: Characteristics of the Shocks $\eta = -0.50$					
Year	**Mean(**ε_z**)**	**Std(**ε_z**)**	**Mean(**ε_τ**)**	**Std(**ε_τ**)**	**Corr(**$\varepsilon_z, \varepsilon_\tau$**)**
1930	0.01	0.03	-0.04	0.04	-0.23
1931	-0.02	0.03	-0.09	0.03	0.18
1932	-0.03	0.03	-0.08	0.06	0.23
1933	-0.01	0.03	-0.03	0.05	0.56

Table 10: R^2 **- Productivity Innovation Regressions**

Cross-Country Depression Data and Postwar U.S. Data

Independent Variable	$R^2 - Depression$	$R^2 - Postwar\ US$
Change in Log Deflator	0.09	0.02
Nominal Interest Rate	0.04	0.11
Real Interest Rate	0.03	0.10
Real Exchange Rate	0.05	0.11
M0	0.00	0.01
M1	0.21	0.01
M1-M0	0.15	0.01
Bernanke-James Bank Variable	0.19	NA
Real Stock Price	**0.41**	**0.05**

13. Appendix Tables

Table A1 shows the data in Figure 2, and Table A2 shows the data used in Figure 4.

Table A1: Log Deviations from 1929 in Output and Productivity[35]

	Output				**Productivity**			
Country	**1930**	**1931**	**1932**	**1933**	**1930**	**1931**	**1932**	**1933**
Australia	0.01	-0.08	-0.07	-0.01	0.05*	0.01*	0.03*	0.04*
Canada	-0.05	-0.18	-0.29	-0.36	-0.03	-0.13	-0.18	-0.22
France	0.01	-0.06	-0.11	-0.09	0.00	-0.06	-0.10	-0.08
Germany	-0.07	-0.20	-0.28	-0.20	-0.03	-0.07	-0.07	-0.03
Japan	0.01	0.04	0.05	0.09	0.00*	0.06*	0.06*	0.08*
U.K	0.00	-0.05	-0.06	-0.04	0.01	-0.03	-0.03	-0.04
U.S.	-0.10	-0.19	-0.33	-0.35	-0.06	-0.09	-0.18	-0.20

[35] The productivity measure is labor productivity if the variable has an "*" and total factor productivity otherwise.

Table A2: Log Productivity Deviations from 1929[36]								
	Model ($\eta = -0.50$)				**Data**			
Country	**1930**	**1931**	**1932**	**1933**	**1930**	**1931**	**1932**	**1933**
Australia	0.07*	0.03*	0.01*	-0.01*	0.05*	0.01*	0.03*	0.04*
Canada	-0.02	-0.09	-0.14	-0.22	-0.03	-0.13	-0.18	-0.22
France	0.01	-0.03	-0.05	-0.04	0.00	-0.06	-0.10	-0.08
Germany	-0.04	-0.10	-0.12	-0.11	-0.03	-0.07	-0.07	-0.03
Japan	0.07*	0.10*	0.01*	0.02*	0.00*	0.06*	0.06*	0.08*
U.K.	0.00	-0.02	-0.02	-0.02	0.01	-0.03	-0.03	-0.04
U.S.	-0.05	-0.08	-0.15	-0.21	-0.06	-0.09	-0.18	-0.20

[36] We compare TFP in the model to TFP in the data for countries in which we can calculate TFP. Otherwise, we compare labor productivity in the model to labor productivity in the data . The productivity measure is labor productivity if the variable has an "*" and total factor productivity otherwise.

Figure 1: Output and Deflation 1930-33

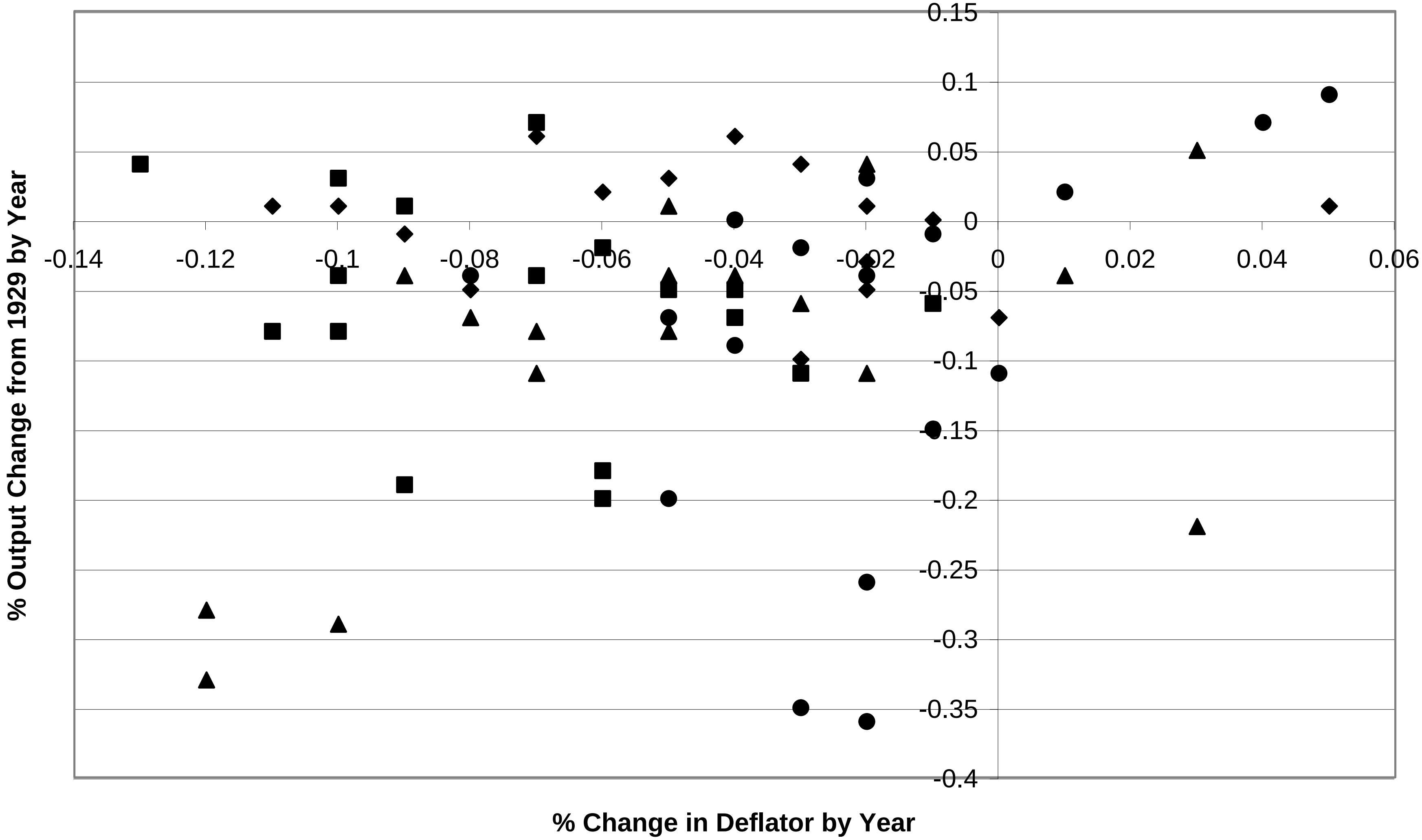

Figure 2: Output and Productivity

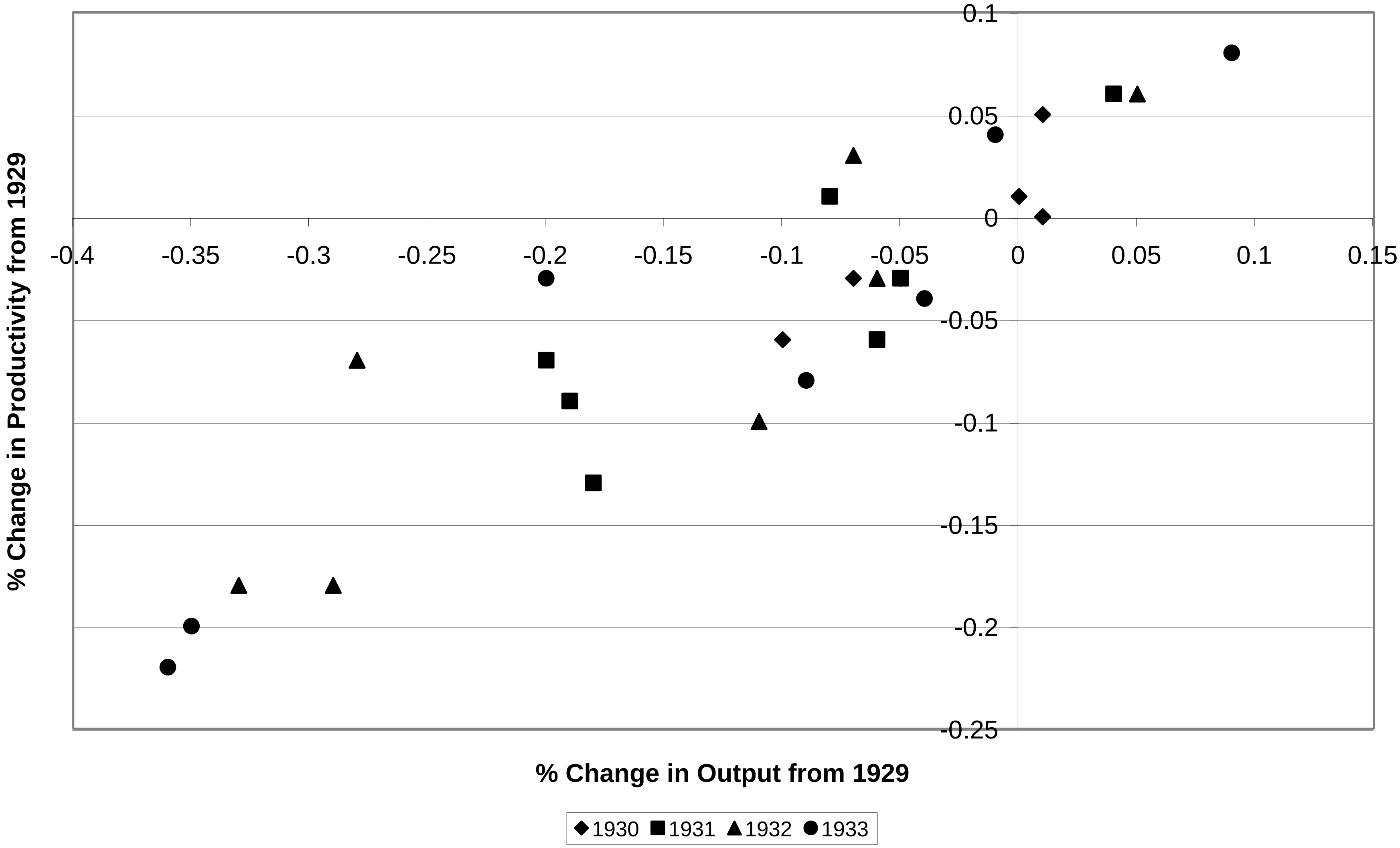

Figure 3: Output and Real Wages

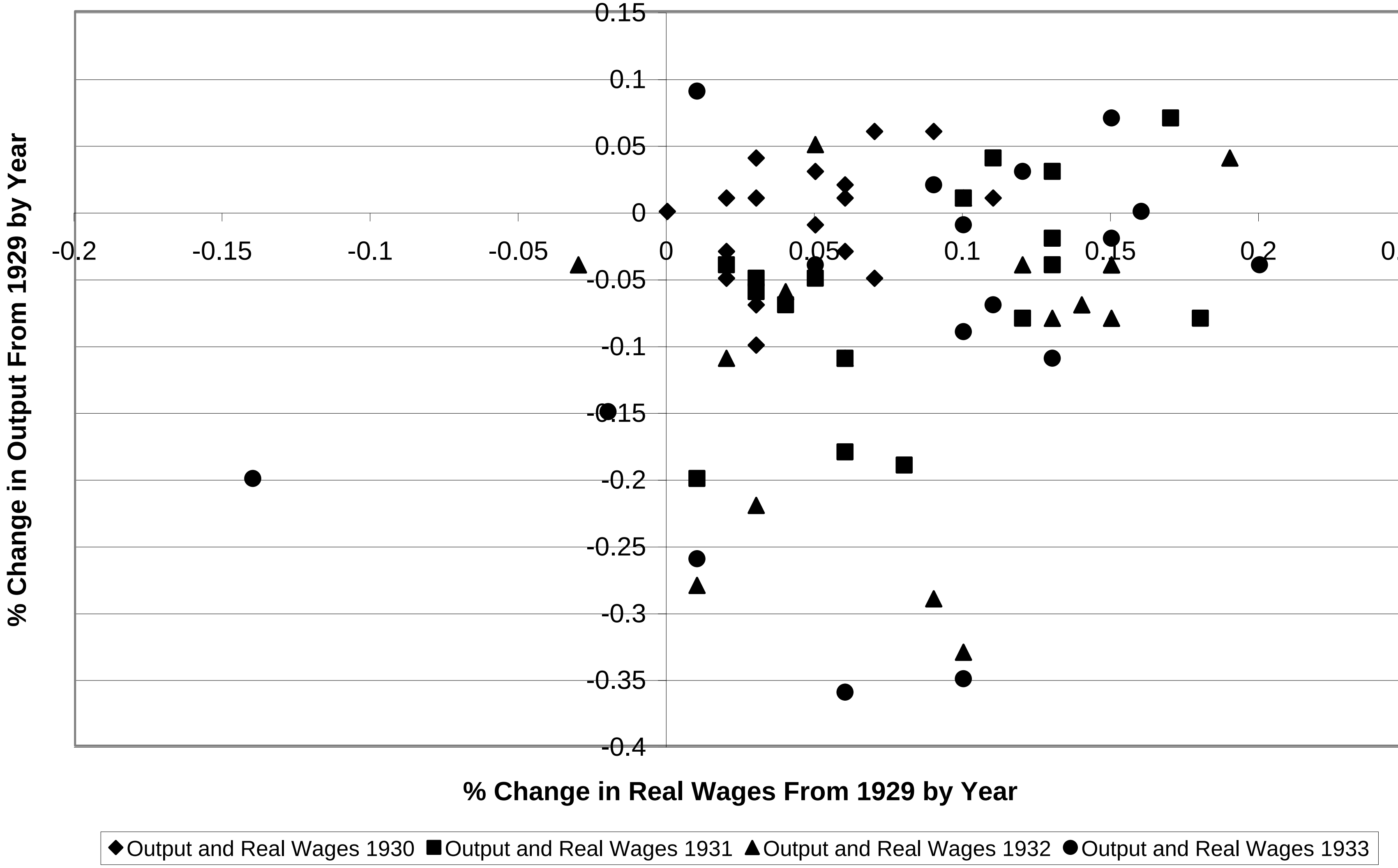

Figure 4: Productivity: Model vs. Data

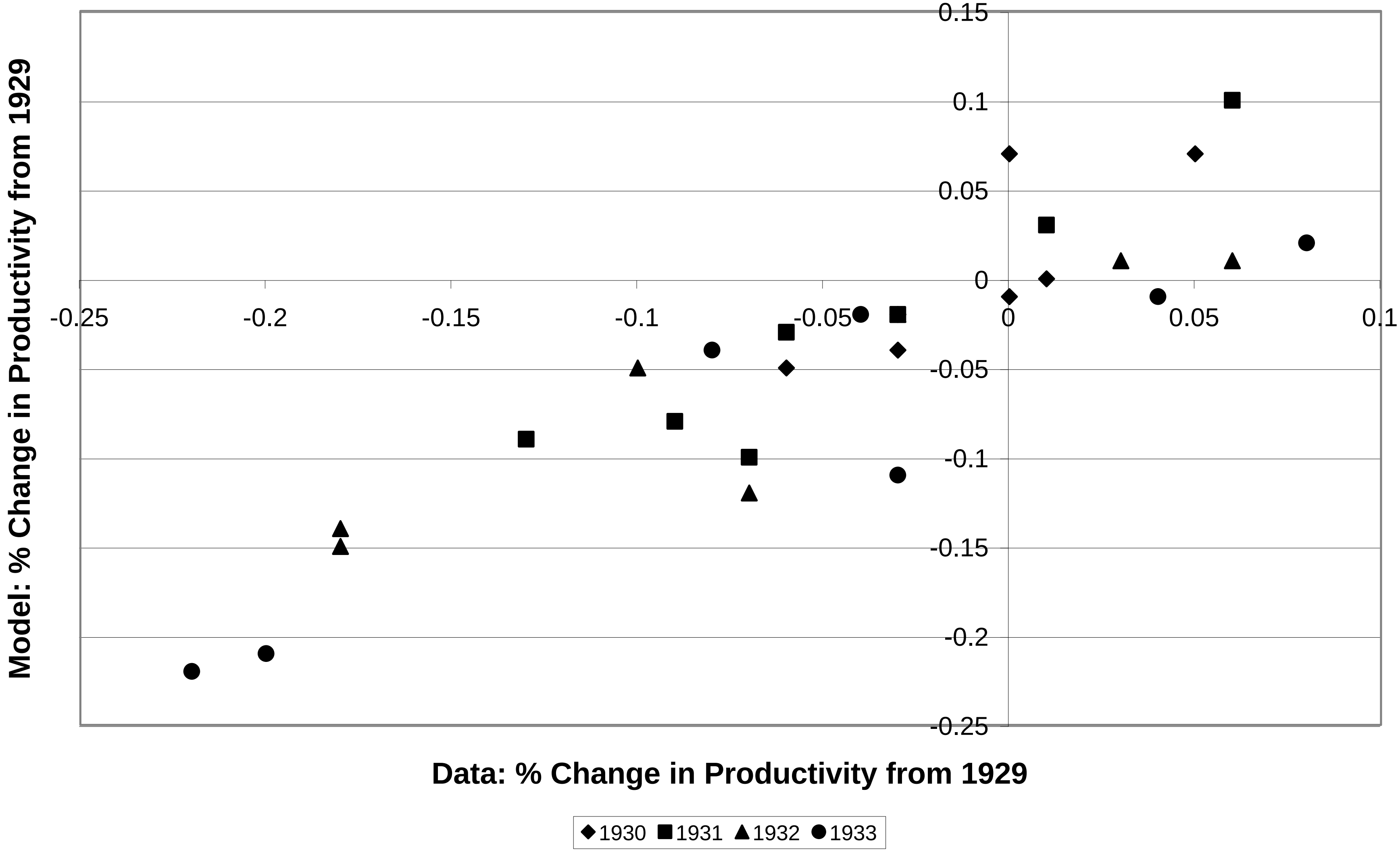

Figure 5: Comparing Output from Model & Data After Accounting for Deflation