working paper

09 11R

Re-Examining the Role of Sticky Wages in the U.S. Great Contraction: A Multisector Approach

Pedro S. Amaral and James C. MacGee

FEDERAL RESERVE BANK OF CLEVELAND

Working Paper 09-11R August 2012

Re-Examining the Role of Sticky Wages in the U.S. Great Contraction: A Multisector Approach

Pedro S. Amaral and James C. MacGee

We quantify the role of contractionary monetary shocks and wage rigidities in the U.S. Great Contraction. While the average economy-wide real wage varied little over 1929–33, real wages did rise signicantly in some industries. We calibrate a two-sector model with intermediates to the 1929 U.S. economy, where wages in one sector adjust slowly. We find that nominal wage rigidities can account for less than a fifth of the fall in GDP over 1929–33. Intermediate linkages play a key role, as the output decline in our benchmark is roughly half as large as in our two-sector model without intermediates.

JEL Classication: E20, E30, E50.

Keywords: Great Depression, Sectoral Models, Sticky Wages.

*The first version of this paper was posted in December 2009, under the title "A Multisectoral Approach to the U.S. Great Depression."

Pedro Amaral is at the Federal Reserve Bank of Cleveland and can be reached at pedro.amaral@clev.frb.org. James C. MacGee (corresponding author) is at Western University and can be reached at jmacgee@uwo.ca. The authors thank Berthold Herrendorf, Chris Telmer, and participants in seminars at the Federal Reserve Banks of Cleveland and Atlanta; seminar participants at the University of Guelph, Queen's University, Wilfrid Laurier University, and York University; and participants at the 2009 Macroeconomics Across Space and Time, the 2009 Latin American Meetings of the Econometric Society, the 2010 SED, the 2010 World Congress of the Econometric Society and the 2011 CEA meetings for comments. An antecedent of this paper was presented at the 2006 CMSG. This research was supported by the Social Science and Humanities Research Council of Canada grant "Trade, Relative Prices, and the Great Depression."

1 Introduction

The role of high real wages in the U.S. "Great Contraction" of 1929-33 remains much debated. On the one hand, a long-standing view is that deflationary monetary policy and rigid nominal wages led to high real wages that were a key contributor to the fall in employment and output over this period.[1] Recently, however, some have argued that the rise in real wages was too small to have played more than a minor role.[2]

In this paper, we re-examine the quantitative contribution of high real wages to the U.S. Great Contraction using a multi-sector model economy with intermediate goods. This approach is motivated by two observations. First, when we construct estimates of wages using data on compensation and hours for all workers we find that aggregate real wages increased little over 1929-33 (see Figure 1.A). More importantly, we find that while real wages rose significantly in some sectors, in others they fell markedly. Second, these large shifts in relative wages were accompanied by large shifts in relative prices. In particular, prices of intermediate goods experienced large declines relative to those of final goods. This is potentially important for assessing the impact of high sectoral real wages, as a fall in the price of intermediates may push up a firm's labor demand. We show, using data on several manufacturing industries, that lower input prices appear to have been passed through to final gross output prices. As a result, the real wage for manufacturing (using the value-added deflator we construct) closely resembles our economy-wide real wage, and rises little over the Great Contraction.

The large sectoral shifts in relative wages data lead us to construct a two-sector model with sector-specific nominal rigidities. In the *flexible* sector, wages adjust freely to equate labor demand and supply, while in the *sticky* sector nominal wages adjust slowly. To facilitate comparison with the literature, we follow Bordo, Erceg, and Evans (2000) and assume that sticky-sector wages are determined by Taylor nominal wage contracts so that hours worked depend on the firm's real product wage. Each of the sectoral goods is produced using capital, labor and a sector-specific intermediate good comprised of both sectoral goods. Including intermediates allows us to investigate how the relative price changes described above interact with sectoral wage rigidities. The output of the two sectors is used to produce the final good

[1] See Bernanke (1995), Bordo, Erceg, and Evans (2000), Eichengreen (1995), and Friedman and Schwartz (1963).

[2] See Cole and Ohanian (2001) and Christiano, Motto, and Rostagno (2003).

that can be used for consumption and/or investment.

To assess the quantitative role of wage rigidities, we input the estimated money supply growth shocks from 1929:4 to 1936:4 into our calibrated model economy. We find, contrary to the established view, that deflation and wage rigidity played a modest role as our benchmark economy can account for less than a fifth of the fall in output during the Great Contraction. It is worth emphasizing that our benchmark features both a large sticky-sector (roughly 60% of GDP) and a larger rise in the aggregate real wage than observed in the data over 1929-33. This suggests that our experiment overestimates the fall in output.

Our model environment introduces two mechanisms that could mitigate the impact of high sectoral real wages. First, the flexible wage sector offers final goods producers a way to substitute away from the more expensive sticky-sector good. Second, since the sectoral intermediate bundle is a mix of the flexible and inflexible goods, a contractionary monetary shock results in a fall in the price of intermediates relative to the sticky wage. This leads sticky-sector firms to substitute towards intermediates, raising their labor demand schedule, and mitigating the effect of higher real wages.

Our findings suggest that it is intermediate linkages rather than sectoral heterogeneity per se that mitigates the distortionary effects of high sectoral real wages. When we compare the two-sector model without intermediates to a one-sector version calibrated to match the same aggregate real wage, we find that both environments deliver similar predictions for aggregate output and employment. This is due to the fact that a two-sector model with sectoral wage rigidities introduces offsetting mechanisms. While the flexible sector provides a way to substitute away from the sticky good, this also lowers the real consumption wage in the flexible sector. As a result, a larger rise in the sticky sector real wage (i.e. a "larger" friction) is required to match the same aggregate real wage as in a one-sector environment.

In contrast, introducing intermediate linkages significantly changes the aggregate impact of sectoral high wages. Comparing our model with intermediates to a one-sector model (with both calibrated to the same aggregate real wage), we find that the fall in output is roughly half as large in the environment with intermediates. Similarly, we find that our benchmark intermediate economy generates roughly half as large a fall in output over 1929 to 1939 as the two-sector model without intermediates. This reflects the fact that intermediates impact both relative sectoral gross output prices and sectoral labor demand.

Incorporating intermediates also helps address the view that the multi-sector model with asymmetric wage rigidities is inconsistent with the data. In an insightful discussion, Bordo, Erceg, and Evans (2001) use manufacturing as a proxy for the sticky sector and point out that since the WPI of manufactures declined by more than the GNP deflator, the manufacturing real product wage increased by more than the real consumption wage over 1929-1933. In contrast, in a multi-sector model without intermediates, a contractionary monetary shock results in a smaller rise in the sticky real product wage than the real consumption wage, since the sticky sector price falls by less than that of final output. We show that intermediates help solve this apparent puzzle. In section 4.1, we construct an implied value added price deflator for manufacturing and find that it falls by less than the GNP deflator, similar to what happens in the model. This is due to the pass-through of lower intermediate goods prices into the manufacturing gross output price, highlighting the importance of accounting for input-output relationships during periods of large shifts in relative prices.

There is a large literature debating the contribution of deflation and wage rigidity to the Great Depression.[3] Most closely related to this paper are Bordo, Erceg, and Evans (2000) and Cole and Ohanian (2001), who reach different conclusions on the contribution of wage rigidity to the U.S. Great Contraction. Unlike the former, we adopt a multi-sectoral approach. While we share with Cole and Ohanian (2001) the view that sectoral heterogeneity in wage rigidity is an essential feature, we differ both in incorporating intermediate linkages and by explicitly modeling nominal rigidities in a two-sector general equilibrium model, "nesting" the Bordo, Erceg, and Evans (2000) framework as a limiting case. In addition, our calibration (based on our estimates of sectoral wages) features a much larger sticky-wage sector, roughly twice as large as their benchmark.[4]

Several recent papers also examine the contribution of high real wages to the Great Contraction. Dighe (1997) notes that real wages in manufacturing during the Great Depression resembled those observed in the shallower 1920-22 recession. In recent work, Cole, Ohanian, and Leung (2007) revisit the conclusions of Eichengreen and Sachs (1985) and Bernanke and Carey (1996) that different timing in abandoning the international gold standard can account for the observed cross-country deflations and output declines. They find evidence of the former, but not the latter causal relationship. Interestingly, Ohanian (2009) argues

[3]The use of quantitative DSGE models to examine Great Depressions is relatively recent. The papers in Kehoe and Prescott (2007) examine the experiences of a number of countries.

[4]Since our model also abstracts from any underlying productivity growth, these differences address the key criticisms of Gertler (2001) and Bordo, Erceg, and Evans (2001) of Cole and Ohanian (2001).

that the threat of unionization in manufacturing allowed President Hoover to convince manufacturing firms to keep their wages high while reducing the length of their workweek in exchange for protection from unions. Inputting the observed wages and workweek length in manufacturing and agriculture into a two-sector model, he is able to generate two-thirds of the fall in output by the end of 1931. Unlike these papers, we show that explicitly taking into account intermediates linkages significantly reduces the impact of high real product wages on the output decline during the Great Contraction.

Our work is also related to a large literature on cyclical movements in relative prices of different goods. Means (1966) highlighted the large shifts in relative prices across industries during the Great Depression, while Neal (1942) examined whether movements in relative prices across manufacturing industries could be accounted for by differences in input price movements. Our paper differs from these early studies both in its quantitative theory emphasis and focus on real wages. More recent work has found that prices of intermediates goods relative to both final goods and average wages moves procyclically in the post war period (e.g. Murphy, Shleifer, and Vishny (1989)), and that monetary contractions lower the relative price of less processed to more processed goods (e.g. Clark (1999)). While we find similar effects of monetary shocks over 1929-33, we differ in our focus on the quantitative contribution of wage rigidities to the Great Contraction.[5]

The remainder of this paper is organized as follows. Section 2 documents several key facts on aggregate and sectoral wages and hours. Section 3 examines the impact of contractionary monetary shocks in a two-sector environment without intermediates. Section 4 examines the role of intermediates on U.S. manufacturing wholesale prices and extends the model to include intermediate goods. The final section offers a brief conclusion.

2 Data

While the labor market figures prominently in many explanations of the Great Depression, surprisingly little attention has been paid to the considerable heterogeneity in both wages and hours worked across industries.[6] In this section, we construct aggregate and sectoral

[5] Bouakez, Cardia, and Ruge-Murcia (2009) find that sectoral hetereogenity in price rigidities and intermediate linkages can help account for the transmission of monetary shocks. Huang, Liu, and Phaneuf (2004) argue that shifts in the level of intermediate usage can account for changes in the cyclicality of real wages.

[6] A notable exception is Cole and Ohanian (2001), who document the fall in agricultural wages relative to manufacturing. Cole and Ohanian (2004) focus on New Deal policy induced heterogeneity over 1934-1939.

measures of nominal wages and hours worked during the Great Contraction.

We find little increase in the economy-wide real wage for all workers over 1929-1933. While one might be tempted to conclude that this is compelling evidence against high real wages being an important cause of the Great Contraction, the sectoral data suggests this conclusion is not warranted as there was considerable sectoral heterogeneity in real wages and hours worked. While real wages rose in some sectors over 1929-1933, workers in other industries experienced large declines. These shifts in relative wages coincide with large shifts in relative prices across industries. Consistent with a differential degrees of wage rigidity, hours worked tended to decline more in industries where real wages rose than where they fell. Altogether, the sectoral differences suggest that evaluating the role of real wage rigidities in the Great Contraction requires a multi-sector environment. We pursue this in section 3.

2.1 Aggregate Estimates of Wages and Hours

Since direct measures of hourly wages exist for only a few industries, we use estimates of hours worked and total labor income to construct hourly wage series. Our guide in this exercise, the neoclassical growth model, does not distinguish between hours worked by employees and the self-employed, therefore our measure of the workforce is persons engaged in production (full-time equivalent employees plus sole-proprietors). Total hours worked is the product of total workers and average hours worked per full-time equivalent worker.[7] Since hours worked includes sole-proprietors, we define total income as total employee compensation plus 60 percent of sole-proprietors income.[8] The nominal wage is total labor income divided by total hours. We use the Balke and Gordon (1986) GNP deflator to compute real wages, and all measures are per working-age person.[9]

Our measure of the average real wage (*All-workers* in figure 1.A) exhibits little increase during the Great Contraction, rising only after the introduction of New Deal policies. This contrasts with the conventional wisdom that real wages increased over 1929-33. The main reason for this difference is that our measure includes the self-employed, who comprised

[7] We use the Denison (1962) average hours estimates so as to be comparable with Bordo, Erceg, and Evans (2000). Our industry estimates of hours are based on Kendrick (1961). Both total hours series are similar over 1929-39.

[8] The change(s) in real wages are not very sensitive to reasonable (constant) values for the labor share of sole proprietors' income.

[9] As Hanes (2000) notes, this series likely overstates the decline in the average price level since it overweighs the prices of less processed goods, which fell more than processed goods during the Great Contraction.

nearly 25% of the work force in 1929. To illustrate this, we construct an average real wage for employed workers only (*Employees* in figure 1.A), where labor income is total compensation of employees while hours worked is the product of full time equivalent employees and the average hours worked reported in Denison (1962). This average real wage series increases significantly, rising roughly 12% between 1929 and 1932.

The finding that once one accounts for self-employment, aggregate real wages were basically flat until 1933 constitutes a challenge to any explanation of the Great Depression based on high real wage mechanisms in the context of a one-sector economy.

2.2 Industry Estimates of Wages and Hours

While the large decline in agricultural wages relative to manufacturing (over 40%) over 1929-33 is well known, the lack of direct measures of wages in other industries has led to debate over whether similar shifts in wages also occurred in other sectors. To address this, we construct estimates of real wages and hours worked for construction, wholesale trade, retail trade, transportation and public utilities, finance, insurance, and real estate (FIRE), services, and government, in addition to agriculture and manufacturing.

To compute industry wages, we divide labor compensation from NIPA by hours worked. The hours worked estimates are based on Kendrick (1961), who reports hours worked for agriculture, government, manufacturing, mining, and transportation plus public utilities.[10] For the remaining private non-farm industries, total hours are given by Kendrick's estimate of private non-farm hours less hours worked in the aforementioned non-farm industries. Lacking better information, we apportion these hours to each industry using the number of persons engaged in production. For each industry, total labor compensation is labor compensation plus 60% of sole proprietor's income with inventory and Capital Cost Allowance (CCA) adjustments. Again, all wages are deflated using the GNP deflator, and quantities are per working-age person.

We begin with agriculture and manufacturing. In 1929, these industries each accounted for roughly 20% of employment, although value added in agriculture was roughly 10% of GDP versus 25% in manufacturing. Panel B in figure 1 plots our imputed real wage series as

[10] If we construct hours worked using persons engaged in production and Denison's average hours series, we obtain similar hours worked (and hence wages) in agriculture, and slightly smaller declines in hours worked in manufacturing (and hence larger wage declines). This estimate of the manufacturing wage closely tracks the Bureau of Labor Statistics' series for entrance wages in manufacturing during the Great Contraction.

well as a commonly cited real wage series for each sector. Our estimate of the manufacturing wage tracks the National Industrial Conference Board's (NICB) average manufacturing wage series closely. Compared to the Alston and Hatton (1991) farm laborer wage series, our agricultural real wage initially declines faster, before rebounding over 1932-1935. This larger fall is not surprising, as most (roughly two-thirds) of the workforce in agriculture were sole-proprietors and there were large swings in farm income during the Depression. Overall, the imputed wage series implies a slightly larger decline in agricultural wages relative to manufacturing than direct estimates of average wages. Consistent with the shift in relative wages, while hours worked in agriculture declined very little over 1929-1932, hours worked in manufacturing declined by over 40% from their 1929 level (see table 1).

The real wages we estimate for the remaining industries reinforce the view that there were large shifts in relative wages across industries during the Great Contraction. They were flat or declined in agriculture, construction, retail trade and FIRE. These industries all had large shares of sole-proprietors, and together accounted for more than four-fifths of all self-employed workers. In the remaining sectors, real wages increased over 1929-33, with transportation and government showing even larger increases than manufacturing.

It is this divide, between industries where real wages increased and those where they did not, that constitutes the basis for our mapping from the data to a two-sector model where one sector is subject to real wage rigidities and the other is not. For simplicity we refer to these sectors as *sticky* and *flexible*, respectively. We classify manufacturing, transportation and communications, government, mining, services, and wholesale trade as sticky, and agriculture, construction, retail trade and FIRE as flexible. The flexible industries accounted for roughly 41% of GDP in 1929.

Figure 2 plots our sectoral estimates of real wages, computed using the GNP deflator, and hours per adult as log-deviations from their 3rd quarter of 1929 values. As weights in computing these series, we use the relative share of hours worked in each industry in 1929. Consistent with a story of sectoral heterogeneity in wage rigidities, real wages rose more and hours fell more in the sticky than in the flexible wage sector.

While we lack the data to construct industry specific price deflators, the available Cost of Living Allowances (COLA) data reveal large shifts in relative prices over 1929-33 as shown in table 2. Goods related to Agriculture (food) and FIRE (rent) showed the largest price declines, while Utilities (fuel) and Services (the better part of miscellaneous) had the smallest.

Overall, the shifts in relative prices largely coincide with the sectoral real wage movements.

3 A Two-sector Model

Motivated by our empirical observations, we examine a two-sector model where wage rigidities vary across sectors. In section 4, we extend the model to include intermediates, after establishing that gross output and value-added prices yield different implications for the shift in relative prices across sectors during the Great Contraction.

The model economy has two sectors that differ in their wage adjustment process. The flexible wage sector has competitive labor markets where wages adjust each period to equate labor demand and supply. The sticky wage sector is based on Bordo, Erceg, and Evans (2000) and features Taylor nominal wage contracting. The firm (the short side of the market) decides how much to hire given the real product wage it faces. Both sectors use capital and labor in production. The output of the two sectors is used to produce the final good that can be used for consumption and/or investment.

A key issue in any sectoral model is how to model sectoral reallocation. We assume that capital can be reallocated across sectors. In modeling the labor market, we assume that workers cannot switch sectors. Hours worked in the inflexible sector are determined by firms, and do not enter the household's utility function. This assumption acts to amplify the impact of wage rigidities in our framework, and thus gives the real wage story the best possible shot at accounting for the downturn. We return to this issue in section 3.3.

3.1 Environment

Households

The economy is populated by an infinitely-lived stand-in household with preferences defined over streams of consumption of the final good, $\{C_t\}_{t=0}^{\infty}$, hours of work in the flexible wage sector (sector 1), $\{L_{1,t}\}_{t=0}^{\infty}$ and real money balances, $\left\{\frac{M_t}{P_t}\right\}_{t=0}^{\infty}$, where P_t is the price level associated with one unit of the final good. The household chooses consumption, hours of work in the flexible sector, nominal bond holdings, B_t, money holdings, M_t, and capital in each sector, $K_{i,t+1}$, so as to solve:

$$\max \quad \sum_{t=0}^{\infty} \beta^t \left[\log C_t - \frac{\mu_L}{1-\sigma_L} L_{1,t}^{1-\sigma_L} + \mu_M \log \left(\frac{M_t}{P_t} \right) \right] \tag{1}$$

$$\begin{aligned} s.t. \quad & B_t = (1 + R_{t-1}) B_{t-1} + \sum_{i=1}^{2} (J_{i,t} K_{i,t} + W_{i,t} L_{i,t}) + \sum_{i=1}^{2} \pi_{i,t} + X_t \\ & - \left(M_t - M_{t-1} + P_t C_t + P_t \sum_{i=1}^{2} I_{i,t} \right), \qquad (2) \\ & K_{i,t+1} = (1 - \delta_i) K_{i,t} + I_{i,t}, \qquad i = 1, 2, \qquad (3) \end{aligned}$$

where R is the nominal interest rate on bonds, X is a lump-sum cash transfer from the government, and J_i, W_i, I_i, L_i, δ_i, and π_i are sectoral variables: the rental rate of capital, the nominal wage, investment, hours worked, the depreciation rate of capital and sectoral nominal profits, respectively.

Firms

Firms in both sectors seek to maximize static profits. They have access to a constant returns to scale production in capital and labor, $Y_{i,t} = K_{i,t}^{\theta_i} L_{i,t}^{1-\theta_i}$, which they rent from households, and take sectoral prices, $P_{i,t}$, and factor prices as given when making production decisions to solve:

$$\max P_{i,t} K_{i,t}^{\theta_i} L_{i,t}^{1-\theta_i} - W_{i,t} L_{i,t} - J_{i,t} K_{i,t}.$$

Final output producers buy sectoral goods, $Y_{i,t}$, and take sectoral prices and the final good price as given when maximizing profits:

$$\max P_t \left(\eta Y_{1,t}^{\rho} + (1 - \eta) Y_{2,t}^{\rho} \right)^{1/\rho} - \sum_{i=1}^{2} P_{i,t} Y_{i,t}, \tag{4}$$

where $\rho < 1$ and the elasticity of substitution is $\sigma = \frac{1}{1-\rho}$.

The final good, $Y_t = \left(\eta Y_{1,t}^{\rho} + (1 - \eta) Y_{2,t}^{\rho} \right)^{1/\rho}$, can be transformed into consumption or allocated to investment in either sector:

$$Y_t = C_t + I_{1,t} + I_{2,t}. \tag{5}$$

Wage Setting

While wages are perfectly flexible in sector 1, they are subject to Taylor-type contracts in sector 2.[11] Labor is divided into four equally-sized cohorts. Each period, the contract wages of one cohort are adjusted. The nominal wage the firm pays is a geometric average of the cohort contract wages:

$$W_{2,t} = x_t^{\phi_0} x_{t-1}^{\phi_1} x_{t-2}^{\phi_2} x_{t-3}^{\phi_3}, \tag{6}$$

where ϕ_i are cohort weights that sum to 1.

In turn, the contract wage, x_t, depends on the average wage, $W_{2,t}$, as well as on the difference between current hours and steady-state labor, $\bar{L}_2$, in the following way:

$$\begin{aligned} \log x_t &= \phi_0 \log W_{2,t} + \gamma(L_{2,t} - \bar{L}_2) + E_t\Big\{\phi_1 \log W_{2,t+1} + \gamma(L_{2,t+1} - \bar{L}_2) \\ &+ \phi_2 \log W_{2,t+2} + \gamma(L_{2,t+2} - \bar{L}_2) + \phi_3 \log W_{2,t+3} + \gamma(L_{2,t+3} - \bar{L}_2)\Big\}, \end{aligned} \tag{7}$$

where γ is a labor-gap adjustment parameter to be estimated.

Setting cohort weights to be the same, $\phi_i = 0.25$, repeated substitution of (6) into (7) yields the current contract wage as a function of past and expected contract wages and the current and expected labor gaps:

$$\begin{aligned} \log x_t &= E_t\Big\{\frac{1}{12}\log x_{t-3} + \frac{1}{6}\log x_{t-2} + \frac{1}{4}\log x_{t-1} + \frac{1}{4}\log x_{t+1} + \frac{1}{6}\log x_{t+2} \\ &+ \frac{1}{12}\log x_{t+3} + \sum_{k=0}^{3}\gamma\left(L_{2,t+k} - \bar{L}_2\right)\Big\}. \end{aligned} \tag{8}$$

Money

The stock of money is exogenously determined, and its growth rate follows an AR(1) process:

$$g_t = \log M_t - \log M_{t-1}, \tag{9}$$

$$g_{t+1} = g + \rho_m g_t + \epsilon_{t+1}, \tag{10}$$

where the innovation ϵ_{t+1} is iid $N(0, \sigma_g^2)$.

[11] The Taylor contract assumption makes our results comparable to Bordo, Erceg, and Evans (2000).

Equilibrium

Given the law of motion for the growth rate of money, the nominal variables are non-stationary, therefore we rescale them by the stock of money. Let $\tilde{P}_t = \frac{P_t}{M_t}$, $\tilde{B}_t = \frac{B_t}{M_t}$, $\tilde{P}_{it} = \frac{P_{it}}{M_t}$, $\tilde{J}_{it} = \frac{J_{it}}{M_t}$, $\tilde{W}_{it} = \frac{W_{it}}{M_t}$, $\tilde{X}_{it} = \frac{X_{it}}{M_t}$, and $\tilde{x}_t = \frac{x_t}{M_t}$.

Given g_0, M_0, $K_{i,0}$, and the laws of motion (9) and (10), an equilibrium is quantities $\left\{\tilde{B}_t, C_t, K_{i,t}, L_{i,t}, \tilde{X}_t, \pi_{i,t}\right\}_{t=0}^{\infty}$, and prices $\left\{\tilde{J}_t, \tilde{P}_t, \tilde{P}_{i,t}, R_t, \tilde{W}_{i,t}, \tilde{x}_t\right\}_{t=0}^{\infty}$, such that households, firms in each sector and final good producers all solve the problems described above subject to market clearing conditions. In particular, in any equilibrium for this model specification, $\tilde{B}_t = 0$, as there is one representative household; $\tilde{\pi}_{i,t} = 0$, as the sectoral technologies are CRS; and the government transfer has to equal the newly printed money: $X_t = M_t - M_{t-1}$.

The household's, the sectoral firms', and the final producer's first-order conditions, together with the wage setting equations (6), and (7) and the market clearing conditions for the final and sectoral goods constitute the set of necessary conditions. We solve the model by log-linearizing around the non-stochastic steady-state and applying the techniques described in Uhlig (1999).

3.2 Calibration

Each of the four contract periods lasts one quarter. We set $\beta = 0.99$, which implies an annual risk-free return of roughly 4%. The quarterly depreciation rate of capital for both sectors is 0.025. We choose μ_L so that steady-state total market time, $\bar{L}_1 + \bar{L}_2$, is one third. Since μ_M has no effect on the dynamics of the system we follow Bordo, Erceg, and Evans (2000) in setting it.

The elasticity of substitution between sectoral goods in the final good aggregator, $\frac{1}{1-\rho}$, and the share of flexible goods used in final good production, η, are jointly calibrated to match the flexible sector share of GDP in 1929 and to minimize the distance between the model's flexible sector share of GDP and its data counterpart over 1929-33. Similarly, in calibrating γ, the crucial parameter regulating nominal wage adjustment in the sticky sector, we minimize the squared distance between the sticky sector's real consumption wage, $\frac{W_2}{P}$, in the model and the data over 1929-33.

As discussed in Section 2, we allocate industries to the flexible or the inflexible sector based on whether the industry real wage increased or decreased during the Great Contraction. To compute the labor share in each sector, we follow the convention that ambiguous income sources (such as proprietors' income) breakdown between capital and labor income in the same proportion as unambiguous sources of income. Since our model abstracts from both a government sector and residential housing, we follow Gomme and Rupert (2007) in excluding income from these sources. Unambiguous labor income is total compensation of private employees less housing compensation of employees, while unambiguous capital income is rental income plus net interest income plus corporate profits plus capital consumption for private, nonresidential capital less housing rental income, housing net interest income and housing corporate profits.[12] The average labor share in 1929 is roughly 0.7 in both the sticky and flexible wage sectors. This leads us to set the capital share of value added to 30% in both sectors, so $\theta_1 = \theta_2 = 0.3$.

Finally, our raw money supply measure is M1 from Friedman and Schwartz (1963)(table A-1). To be consistent with our model, we look at M1 per adult. We estimate the parameters in the money growth rate's law of motion, equation (10), from the second quarter of 1922 to the last quarter of 1928. The estimates we obtain are $\hat{g} = 0.0015$ and $\hat{\rho_m} = 0.44$.

A summary of the parameter values appears in table 3.

3.3 Results

To illustrate the transmission of contractionary monetary shocks, we input the money supply growth shocks from the data from 1929:4 to 1936:4 into the model economy.[13]

With sectoral asymmetries in wage rigidity, a contractionary monetary shock shifts relative sectoral wages and prices. This in turn impacts the sectoral *real product wages* and the *real consumption wage*. In the sticky sector, labor demand is pinned down by the real product wage. In the flexible sector, hours worked are determined by labor supply and demand, and thus depend on both the real consumption wage and the real product wage.

These shifts in real wages play a key role in the sectoral responses to a contractionary monetary shock that appear in figure 3. While prices and wages decline in both sectors, they fall by more in the flexible sector, as staggered wage contracts in the sticky sector cause nominal wages to decline slower than prices after a contractionary monetary shock. This rise in the real product wage results in a decline in hours worked and output. The output decline pushes up the sticky good price relative to the flexible sector's. This results

[12] Our measure of private sector CCA excludes sole-proprietors' income. Although this is not significant for the economy-wide average, it does matter for the labor share at the industry level.

[13] We assume that the economy was at its steady-state in the third quarter of 1929.

in a relatively small decline in the inflexible sector's price, which partially offsets the slow decline in wages by lowering the real product wage. In the flexible sector, hours depends on both labor supply and demand. The decline in flexible hours reflects a decline in the real consumption wage (partially offset by a negative wealth effect), and a rise in the sectoral real product wage as the nominal wage declines by less than the flexible good price.[14] As a result, the real consumption wage in the inflexible sector rises more than the average real consumption wage for the economy and the sectoral real product wage.

In our simple two-sector economy, contractionary monetary shocks combined with wage rigidities can account for less than a third of the fall in aggregate output (see Figure 4.A). This is an upper bound estimate, as the aggregate real wage in the model (averaging across the flexible and inflexible sectors) is higher than our data estimate over 1929 to 1934. This is driven by our calibration strategy, which chooses the wage rigidity parameter, γ, to match the real consumption wage in the sticky sector during the contraction (see Figure 3.H). In turn, as Figure 3.D shows, our simulation also generates a larger decline in the sticky sector price than in the data, and thus a higher sticky real product wage relative to the real consumption wage than observed in the data. As a result, our calibration strategy is biased in favor of the contractionary monetary story.

One might think that the aggregate results are sensitive to how substitutable sectoral goods are in final good production. The top two panels in figure 5 show that varying the elasticity of substitution up ($\rho = 0$: Cobb-Douglas) or down ($\rho = -2$) has little effect on model aggregates. Indeed, making it harder to substitute away from the distorted sector actually leads to a smaller fall in output. This seemingly counter-intuitive effect is due to the larger shift in relative prices induced by a lower elasticity of substitution. This results in a smaller decline in the sticky-sector price, and thus a smaller rise in real product wages. This largely offsets the reduced ease with which the final good producer can substitute the (cheaper) flexible good for the inflexible sector good.

The distinction between real product and consumption wages is central to the debate over the importance of sectoral differences for the quantitative role of wage rigidities in the Great Contraction. Two heavily cited papers which represent opposite sides in this debate are Cole and Ohanian (2001) and Bordo, Erceg, and Evans (2000). Whereas Cole and Ohanian (2001)

[14]If hours worked in the sticky sector enter the utility function, but are not a decision variable for the household, flexible hours would fall by (slightly) less, and overall output would decline by roughly 16% instead of 18%.

conclude that, in the context of a two-sector model, imperfectly flexible wages can account for less than a sixth of the fall in output, Bordo, Erceg, and Evans (2000) find that, in a one-sector world, wage rigidities account for roughly 70% of the output decline over 1929 to 1933. These papers also take very different views on the importance of sectoral differences in wages, as Cole and Ohanian (2001) argue that nominal wages in most sectors were flexible during the Great Contraction.[15]

Our findings suggest that these different conclusions are largely due to the aggregate real wage series targeted in each paper. When we reproduce the one-sector model of Bordo, Erceg, and Evans (2000) but calibrate the wage rigidity parameter, (γ,) to match the economy-wide real wage in our two-sector model, we find a nearly identical decline in output as in the two sector model (compare "No-intermediates" to "One-Sector" in figure 6).[16] Our model generates a lower real economy-wide wage than that targeted by Bordo, Erceg, and Evans (2000), albeit above our estimate of the economy-wide real wage. Their larger decline in output thus results from targeting a real wage series that closely resembles our data estimate for the inflexible sector, rather than our estimate of the economy-wide real wage. In other words, the two-sector and one-sector models have similar aggregate predictions when the wage rigidity parameter is calibrated to match the same economy-wide average real wage.[17]

A key mechanism in the two-sector model is the rise in the relative price of the inflexible sector good pushing down the real product wage in the sticky sector. The question of whether this is consistent with the data is controversial. On the one hand, this relative price shift is consistent with the sectoral price estimates we construct using disaggregated components of the COLA. However, this contrasts with a common view, cogently outlined by Bordo, Erceg, and Evans (2001) that manufacturing real product wages (a proxy for the sticky sector) increased by more than real consumption wages during the Great Contraction. Since the wholesale price of manufactures declines more the GNP deflator (or the COLA), the manufacturing real product wage in the data seems to rise by more than the real consumption

[15] Our two-sector framework differs from Cole and Ohanian (2001) in several respects which address the key criticisms of Gertler (2001) and Bordo, Erceg, and Evans (2001). First, our calibration results in a sticky wage sector roughly twice as large as their benchmark. Second, we explicitly incorporate nominal rigidities in our sectoral model by "nesting" the one-sector framework of Bordo, Erceg, and Evans (2000). Finally, we abstract from productivity growth which offsets the impact of wage rigidities.

[16] The γ required to match the same economy-wide real wage varies significantly with model structure.

[17] Herrendorf, Rogerson, and Valentinyi (2012) come to a similar conclusion when they compare the implications of two-sector models with the one sector growth model when examining differences in cross-country growth.

wage. Thus, this interpretation suggests that the relative sectoral price movements implied by our model are wrong.

This raises the question of how to reconcile these views. One possible solution lies in recognizing the difference between sectoral gross output prices and the implied value-added deflators. Since a considerable share of manufacturing inputs were commodities and semi-processed goods, the manufacturing WPI is influenced by the relative price of commodities which declined significantly during the Great Contraction (figure 7.A). Thus, part of the observed decline in the manufacturing WPI (a gross output price deflator) could reflect lower intermediate prices rather than a decline in the implicit value added price of manufacturing output.[18] We examine the quantitative importance of intermediates in the next section.

4 The Importance of Intermediate Linkages

The prices of less processed goods used as intermediates in manufacturing declined in both absolute and relative terms during the Great Contraction (see Figure 7.A).[19] To evaluate how this impacted the WPI for manufactured goods (a gross output price) relative to the GNP deflator, we construct implicit value-added deflators for manufacturing and seven frequently studied manufacturing industries over 1929-33. We find the pass-through of lower intermediate prices leads to a smaller decline in the constructed value-added price deflators than in the manufacturing WPI or the GNP deflator. As a result, real product wages constructed using value-added price deflators increase by less than the real consumption wage.

This leads us to incorporate intermediate goods in our two sector model. When we calibrate this environment to the U.S. interwar economy, we find that the high real wage mechanism can account for less than a sixth of the decline in output during the Great Contraction. Importantly, we also find the sectoral structure plays an important role when one considers intermediate linkages. Unlike the environment without intermediate linkages, our calibrated two-sector framework with intermediates generates a much smaller decline in GDP than the one-sector model calibrated to the same economy-wide real wage.

[18] Recent work finds that factor prices changes are passed through into output prices (e.g. Bils and Chang (2000)).

[19] The large decline in the price of unprocessed goods is frequently cited as a reason to use the sub-component of the WPI for manufacturing goods rather than the WPI itself to construct real product wage in manufacturing (e.g. see Eichengreen and Hatton (1988)). However, we find that the pass-through of lower intermediate prices also biases this measure.

4.1 Data

To assess the quantitative importance of relative price movements, we assemble data on intermediate and gross output prices, intermediates, and gross output to construct value-added price deflators for manufacturing and seven manufacturing industries over 1929-33.

To guide our initial analysis, we extend the (value-added) Cobb-Douglas production function, $y_i = K_i^{\theta_i} L_i^{1-\theta_i}$, specification from Section 3 to a gross output production function:

$$Y_i = \left(K_i^{\theta_i} L_i^{1-\theta_i}\right)^{\alpha_i} Q_i^{1-\alpha_i}, \tag{11}$$

where Q_i denotes intermediate goods and Y_i is gross output in industry i. If firms are competitive price takers, then the value added, $p_{i,VA}$, and gross output prices, $p_{i,GO}$, satisfy:

$$p_{i,GO} = \left(\frac{r}{\alpha_i \theta_i}\right)^{\alpha_i \theta_i} \left(\frac{w}{(1-\theta_i)\alpha_i}\right)^{(1-\theta_i)\alpha_i} \left(\frac{p_Q}{1-\alpha_i}\right)^{1-\alpha_i} = \left(\frac{1}{\alpha_i}\right)^{\alpha_i} p_{i,VA}^{\alpha_i} \left(\frac{p_Q}{1-\alpha_i}\right)^{1-\alpha_i} \tag{12}$$

where p_Q denotes the price of intermediates.

For manufacturing, the intermediate expenditure share of gross output, $1 - \alpha$, during the interwar period was roughly 55 percent. Equation (12) thus implies that each percent decline in the price of intermediates lowers the gross output price deflator by 0.55 percent. Rearranging (12) the implicit value added price deflator can be expressed as:

$$WPI_{VA} = \alpha_i (1-\alpha_1)^{\frac{1-\alpha_i}{\alpha_1}} \left(\frac{WPI_{\text{finished}}}{WPI_{\text{intermediates}}^{1-\alpha_i}}\right)^{1/\alpha_i}. \tag{13}$$

Panel B in figure 7 compares three real product wages, each of which uses a different price index to deflate the average hourly earnings of all wage earners for manufacturing from the NICB. The first is the usual measure which uses the WPI for finished goods as the output price. In the other measures, we use equation (13) to construct a value-added price deflator so as to strip-out the pass-through of lower intermediate costs. As a proxy for the intermediate price, we use either raw materials prices or semi-manufactured prices and assume an intermediate share of 50 percent.

As figure 7 illustrates, the decline in the relative price of intermediates has a large impact on the real product wage during the Great Contraction. While the ratio of nominal wages to the WPI for manufactured goods increased over 1929 to 1933, the real product wages adjusted for intermediate prices were roughly constant over 1929-31, and declined by between 10 and 20 percent over 1931-33. Over 1929-31, the decline in the WPI for finished goods can largely be accounted for by the decline in the proxy for intermediate goods prices. As a result, the implied value added price deflator remained roughly constant – which combined with flat nominal wages implies little movements in the real product wage. After 1931, a number of manufacturing firms moved to reduce nominal wages, which combined with a decline in the relative price of intermediates to final manufacturing goods led to a reduction in the ratio of nominal wages to the implied value added deflator.

Industry Level Data: 7 Manufacturing Industries

To further explore the impact of intermediate prices on real product wages, we examine seven manufacturing industries for which data on average hourly wages and total hours worked (NICB), input and output prices (WPI) as well as an index of gross output (Federal Reserve Bulletin) are available.[20] The intermediate share varied considerably across these industries, from roughly 40 percent in lumber to over 80 percent in meat packing. As can be seen from table 4, industries with large declines in their wholesale output prices also had the largest decline in intermediate prices. Overall, industries with relatively less processing (meat packing, leather, and wool) had larger price declines than those producing relatively more processed goods.[21]

For each industry we compute a (Cobb-Douglas) value-added deflator using input and output prices and the average intermediate share over 1929-33. As table 5 illustrates, taking into account shifts in intermediate prices leads to very different real product wages. In five of the seven industries, real product wages measured using our implied VA deflator are significantly (10 to 80 percent) below the WPI measure, and actually *decline* through 1932. This industry-level pattern is consistent with the manufacturing average, which shows relatively small movements in real wages over 1929-1933.

This suggests that intermediate prices had a significant impact on real product wages during the Great Contraction. To quantify how intermediates interacted with the contractionary

[20] These industries were examined in Bernanke (1986), and largely overlap with those studied in Bernanke and Parkinson (1991) and Bordo and Evans (1995) who replace meat packing with petroleum and include the rubber industry. See the supplementary data appendix on the authors website for more details.

[21] The one industry which faced flat input prices was iron and steel, as iron ore and coke had very small price declines. Interestingly, iron and steel featured a significant degree of vertical integration, as a large fraction of iron ore production was owned by steel producers (Hines (1951)).

monetary shocks, the next section introduces intermediate into our two-sector model.

4.2 Environment with Intermediates

We extend the model outlined in Section 3 by assuming that both sectoral goods are used as intermediate inputs in their production. Our timing has the household purchasing period $t-1$ intermediate goods from both sectors, $Q_{i,t-1}$, at prices $P_{i,t-1}$. At the beginning of period t the household sells its holdings of intermediates to each sector at price $P^s_{i,t}$. Intermediate goods are akin to investment with this timing. The household budget constraint is:

$$B_t = (1+R_{t-1})B_{t-1} + \sum_{i=1}^{2}(J_{i,t}K_{i,t} + W_{i,t}L_{i,t}) + \sum_{i=1}^{2}\pi_{i,t} + X_t + \sum_{i=1}^{2}\sum_{j=1}^{2} P^s_{i,t}Q_{ij,t}$$

$$- \left(M_t - M_{t-1} + P_tC_t + P_t\sum_{i=1}^{2} I_{i,t} + \sum_{i=1}^{2} P_{i,t}Q_{i,t}\right), \tag{14}$$

$$K_{i,t+1} = (1-\delta_i)K_{i,t} + I_{i,t}, \qquad i = 1,2, \tag{15}$$

$$Q_{i,t-1} = Q_{ii,t} + Q_{ij,t}, \qquad i = 1,2, \tag{16}$$

where Q_{ij} denotes intermediates produced by sector i and used in sector j.

Firms in both sectors rent capital and labor services, and purchase intermediate goods from the household. We assume a CES production structure at the sectoral level, and begin by assuming intermediates are perfect complements (below we explore how sensitive the results are to this assumption). The problem of a firm in sector $i = 1,2$ is:

$$\max \pi_{i,t} = P_{i,t}\left[\alpha_i\left(K^{\theta_i}_{i,t}L^{1-\theta_i}_{i,t}\right)^{\rho_i} + (1-\alpha_i)\min\left\{Q_{1i,t}, \chi_i Q_{2i,t}\right\}^{\rho_i}\right]^{\frac{1}{\rho_i}} - \sum_{j=1}^{2} P^s_{j,t}Q_{ji,t} - K_{i,t}J_{i,t} - W_{i,t}L_{i,t}, \tag{17}$$

where Q_{ji} are intermediates produced in sector j and used in sector i.

Final output production and the wage setting process remain the same as in section 3, with perfectly flexible wages in sector 1 and Taylor-type wage contracts in sector 2.

4.3 Calibration

The (aggregate) calibration targets for the household and money supply process remain the same. Given the modified production structure, we construct additional calibration targets for sectoral production parameters (α_i, ρ_i, and χ_i): (i) the gross output share of intermediates in the flexible (sticky) sector is 32% (38%); (ii) the share of flexible intermediates in total intermediates is 39% (31%) in the flexible (sticky) sector; and (iii) the elasticity of substitution between value added and intermediates in both sectors is 0.69. The complete calibration is reported in table 3.

We maintain the same division of industries into flexible and sticky wage sectors, and use a variety of data sources to construct sectoral estimates of value added and the composition of intermediate bundles. Our sectoral estimates are based on the weighted average of industry level data. For manufacturing and transportation we use the 1929 input-output table of Leontief (1951) and the Statistical Abstract of the U.S. to estimate value added shares (0.45 and 0.66, respectively) and a share of intermediates coming from the flexible sector of 0.35 and 0.26, respectively.[22] In mining, our value added estimate is 0.83, which is the average value across 1919 and 1954 (table Db1-11, Historical Statistics of the United States). Given the limited input-output data for service sectors industries, we use Census data for 2002 on business expenses in trade, which lumps wholesale and retail together and imply a value added share of 77% and a share of flexible intermediates of 25%. We assume that the numbers for services, communications and government are the same as for trade. Turning to the flexible sector, the value added share in gross output in agriculture in 1929 was 0.49, with a share of flexible intermediates of $\frac{0.35}{0.35+0.16} = 0.69$ (Leontief (1951)). The 1930 Census data for construction implies a value added share of 0.57. Construction uses very little flexible sector inputs, so we make the educated guess that their share is 10% (we use the same number for mining). We assume that the numbers for FIRE are the same as those in trade.

To convert these values into sector averages, we weight each of these industry shares by their value-added share in their respective sector. This implies an intermediate share in the flexible sector of $1 - \alpha_1 = 0.316$, 39% of which is allocated to flexible intermediates. For the sticky sector, the intermediate share is $1 - \alpha_2 = 0.384$, with 31 % being allocated to flexible intermediates. The value of η is chosen so that the value-added share of the flexible sector in

[22]Since Leontief (1951) does not distinguish between investment and consumption goods, we assume that flows from iron and steel manufacturers to other industries are investment, which we assign to final output.

GDP is equal to 0.42. The elasticity of substitution between value-added and intermediates is set to 0.69, which is the mean value estimated by Rotemberg and Woodford (1996) for U.S. manufacturing industries. Finally, we assume intermediates are perfect complements.

4.4 Results

We follow our earlier approach, and feed the estimated money supply growth shocks for 1929:4 to 1936:4 into the calibrated model economy. To facilitate comparison, Figure 8 and 9 plots key aggregate and sectoral variables with and without intermediates.

Introducing intermediates significantly reduces the impact of high sectoral real wages, with GDP falling roughly half as much at the trough as in the no-intermediates case (see figure 8.A). The smaller decline in GDP reflects a similar smaller decline in total hours (figure 8.D). This occurs despite a larger increase in the average real wage for all workers (figure 8.C) in the economy with intermediates. As a result, with intermediate linkages, the multi-sector model now predicts a smaller decline in aggregate output than a one-sector model that delivers the same economy-wide real wage.

Intermediates introduce a meaningful distinction between sectoral gross output and value added prices. The sectoral gross output price is the weighted average of the sectoral value added deflator (the weighted average of the sectoral wage and rental rate) and the intermediate price. Since the cost of the intermediate bundle is a weighted average of the inflexible and flexible price, the price of the sticky intermediate bundle declines relative to the sticky good value added price (compare 9.F to G). Given that our calibration strategy targets $\frac{W_2}{P}$, the real product wage sticky-sector firms face, $\frac{W_2}{P_2}$, is higher than in the no-intermediates case (i.e. $\frac{P}{P_2}$ falls less.)

If the sticky real product wage is higher at the trough in the intermediate economy, and sticky hours are determined by the firms' labor demand schedule, how can hours fall by less? The key is that the intermediate bundle is a mix of sector 1 and 2 goods. This leads the sticky firm to substitute away from relatively more expensive labor into relatively cheaper intermediates. This substitution effect explains why intermediate usage falls by less in the sticky than in the flexible sector (figure 8.H). In the sticky sector, this fall in the relative price of itermediates acts like a positive shift in the marginal product of labor schedule. As a result, the sticky firm labour demand falls by 20%, versus 30% in the no-intermediates case, despite a higher real product wage.

There is a second, more subtle, reason why output decreases by less when we introduce intermediates. Holding the nominal wage distortion parameter, γ, fixed, the aggregate price level falls by more in the economy with intermediates. This follows from the fact that a quantity equation holds in this model, and since intermediates lead to a smaller fall in output the quantity equation implies prices must fall by more. However, this in turn implies that less sectoral wage rigidity (i.e. a higher value of γ, see table 3) is required to match the increase in sticky sector real consumption wages, $\frac{W_2}{P}$ (see figure 9.D). It is worth noting that the model also delivers a higher economy wide average real wage than the no-intermediate set-up, due to a smaller decline in the flexible sector real consumption wage.

Intermediates also lead to a smaller fall in flexible sector output (see 9.A). Intuitively, the larger fall in the price of the final good results in a smaller fall in the flexible sector real consumption wage, and thus a movement along the labor supply schedule. The flexible labor demand schedule is hit by two effects. On the one hand, intermediates become relatively more expensive compared to labor, which pushes up the labor demand schedule. However, more expensive intermediates also works like a negative productivity shock. In our intermediates benchmark, these forces result in a smaller fall in flexible hours and output.

The smaller output decline in the economy with intermediates, despite a larger increase in the real average wage, suggests that modeling intermediates is important for evaluating the high real wage story. In figure 10 we compare our economy with intermediates with a one-sector economy where the wage rigidity parameter, γ, is chosen to minimize the distance between the economy-wide real consumption wage in the two economies from 1929:3 to 1933:4 (panel C). As panel A shows, output declines substantially less in the economy with intermediates. This contrasts with our earlier finding in section 3.3 that the two-sector model without intermediates and the one-sector model generate similar output decreases.

The inclusion of intermediates also helps resolve the question of whether the real product and consumption wages generated by the model are consistent with the data. As discussed in section 4.1, there were important differences between gross-output and value-added measures of prices in manufacturing during the Great Contraction period. Panel F in figure 9 plots the model counterpart of these measures. As in the data, the availability of the cheaper flexible sector intermediates means the gross output price falls by more, at the trough, than the value-added price in the sticky-sector.

One dimension along which the two-sector model cannot match the data is the relationship between the sticky sector's gross output price and the GNP deflator. In the data, the WPI for manufactured goods declines by more than the GNP deflator due in part to the pass-through of large declines in intermediate prices. In the model, as we increase the flexible share of intermediate goods in the sticky sector, we find that the gross output price of the sticky-sector good declines more. However, the sticky sector's gross output price always declines less than the price of the final good. This follows from our model structure, as the price of final output is a weighted average of the two sectoral goods. It is worth noting that in an environment with three or more sectors, one would be able to construct input-output structures where the gross output price of at least one inflexible wage sector declined by more than the price of final output.

4.4.1 Sensitivity: Understanding the Role of Intermediates

Our sensitivity analysis illustrates the importance of taking the input-output structure into account. In the two bottom panels of figure 5, we compare our benchmark intermediates economy to two alternatives: one where the elasticity of substitution between value-added and intermediates is 1 (labeled "$\rho_i = 0$"), and another where the sectoral intermediate aggregator is Cobb-Douglas (labeled "CD") instead of Leontief. In these experiments we adjust the elasticity of substitution in final good production, ρ, the share of each sector in final production η, and the wage rigidity parameter, γ so as to match the same calibration targets (i.e. the real sticky sector consumption wage and the sector shares of GDP).

In both cases GDP falls by more than in the benchmark (see panel 5.C). To understand why, recall that in the absence of the nominal wage friction, a monetary shock would impact the price level, but not relative sectoral prices. Thus, the larger change in the relative price of sticky and flexible goods (see panel 5.D) indicates the sectoral wage rigidity is more distortionary than in the benchmark. Why does the sticky good become relatively more expensive compared to the benchmark? In the $\rho_i = 0$ case, flexible-sector firms substitute away from intermediates and into (cheaper) labor, while sticky sector firms substitute away from expensive labor and into intermediates. Since flexible labor is relatively cheaper than intermediates (in units of the final consumption good), the flexible good becomes relatively cheaper. In the "CD" case, firms in both sectors substitute away from sticky intermediates and into flexible ones. This causes a relative increase in the sticky sector price for 2 reasons: (i) sticky intermediates have a larger share in sticky production than in flexible production, and (ii) while the sticky sector real wage path is the same as the benchmark, in the flexible sector it is lower, so firms there substitute towards cheaper labor.

This leads to a larger output decline than in the benchmark for two reasons. First, the aggregate price level declines by less (recall the inflexible sector accounts for nearly 60 % of value added output). Since our calibration targets the same real sticky consumption wage, this results in a larger wage rigidity parameter. This parameter change accounts for nearly one-third of the larger output decline. Second, the shift in prices impacts sectoral labour demand and output. In the flexible sector, the larger fall in prices and lower intermediate usage pushes down labor demand and output. In the inflexible sector, the reduced use of intermediates acts like a negative productivity shock, which is only partially offset by the relatively higher price of the sticky good. As a result, output falls by more in both sectors than in the benchmark.

This sensitivity analysis has two implications. First, it highlights the importance of modeling intermediates during periods of large shifts in sectoral prices, as it shows that sectoral differences in nominal rigidities combined with intermediates can lead to different aggregate implications, even when calibrated to match the same targets. Second, while the two sensitivity analysis experiments seemingly open up the possibility for a larger role for wage rigidities during the Great Contraction, they carry important counterfactual implications. The $\rho_i = 0$ case, unlike our benchmark specification, is inconsistent with the fact that the intermediate share of gross output in manufacturing (agriculture) fell (rose) over 1929-33.[23] Regarding the elasticity of substitution between different types of intermediates, which we set to one in the "CD" case and assume its zero in the benchmark, it seems reasonable to think that the substitutability between fairly granular inputs (e.g. substituting steel for wood in automobiles) at such a short horizon should be low.

5 Conclusion

Our results yield two important messages for the debate over the quantitative role of wage rigidities during the Great Contraction. First, contractionary monetary shocks coupled with nominal wage rigidities played a modest role in the Great Contraction, as our model with

[23] An elasticity of one between between value-added and intermediates is well above our benchmark (0.69), which is already at the higher end of the estimates in the literature. Rotemberg and Woodford (1999) cite estimates roughly half as large as the one we use, which would lead to even smaller decreases in GDP.

intermediates can account for less than a fifth of the output decline. This is likely an upper bound, as the economy-wide real wage in the model exceeds our estimate for the U.S.

Second, we find that the input-output structure of the economy matters for the debate over real product wages during the Great Contraction. It is worth emphasizing that this finding differs from the prior debate over the role of sectoral heterogeneity in wage rigidity in the U.S. Great Contraction. Our comparison of the two-sector model (without intermediates) with a one-sector version suggests that the Bordo, Erceg, and Evans (2000) and Cole and Ohanian (2001) debate is largely about different views on aggregate real wages during the Great Contraction, as we find nearly identical declines in output when one targets the same aggregate real wage. Importantly, however, the introduction of intermediates breaks this link, as our model with intermediates delivers half as large an output decline compared with a one-sector model calibrated to match the same aggregate real wage.

This has important implications for the relationship between real consumption wages and real product wages in manufacturing. As Bordo, Erceg, and Evans (2001) point out, while a two-sector model with sectoral heterogeneity in wage rigidity is consistent with the divergence in relative wages across industries, it is seemingly at odds with the fact that manufacturing real product wages (deflated by the manufacturing WPI) increase by more than manufacturing's real consumption wages over 1929-33. Our work suggests that intermediates can largely resolve this puzzle. Our calculations for manufacturing in Section 4.1 show that when one uses the implied value-added deflator to compute manufacturing's real product wages, these go up by at most 4% (see table 5), while manufacturing's real consumption wages go up by over 10% (panel B in figure 1), which is consistent with the predictions of our two-sector model with intermediates.

While we focus on the U.S. experience, our environment also has implications for recent work by Cole, Ohanian, and Leung (2005). Building on Bernanke and Carey (1996) and Eichengreen and Sachs (1985), they use cross-country data on real wages and output to help identify the contribution of wage rigidities to the Great Contraction. Despite the fact that money enters differently in their model, through a Lucas (1972)-type misperception, they also conclude that contractionary monetary shocks are not the main cause of the decline in output over 1929 to 1933. Instead, they argue that real shocks are the driving force, as roughly two thirds of the fall in output can be accounted for by TFP. Similarly to Cole, Ohanian, and Leung (2005), when we introduce sectoral TFP shocks in our framework, we find that (with contractionary monetary shocks) our model can account for the decline in GDP and hours.[24] However, TFP shocks have trouble matching key features of shifts in relative prices and quantities observed in the sectoral data. This suggests that an increased focus on sectoral data across countries might be a useful direction for future research.

Finally, our findings suggest that while the multi-sectoral linkages we examine are important in accounting for the sectoral disparities observed during the Great Contraction, they must have interacted with some exogenous price shocks, as contractionary monetary shocks on their own fail to generate enough action in output. Here, we conjecture that modeling international trade, particularly in commodities, where price changes were very significant in this period, might be a fruitful avenue to pursue in future research.

References

ALSTON, L. J., AND T. HATTON (1991): "The Earnings Gap Between Agricultural and Manufacturing Laborers, 1925-1941," *Journal of Economic History*, pp. 83–99.

BALKE, N., AND R. J. GORDON (1986): "Appendix B, Historical Data," in *The American Business Cycle: Continuity and Change*, ed. by R. J. Gordon, pp. 781–850. Chicago University Press, Chicago, IL.

BERNANKE, B. S. (1986): "Employment, Hours and Earnings in the Depression: An Analysis of Eight Manfuacturing Industries," *American Economic Review*, 76, 82–109.

——— (1995): "The Macroeconomics of the Great Depression: A Comparative Approach," *Journal of Money, Credit and Banking*, 27(1), 1–28.

BERNANKE, B. S., AND K. CAREY (1996): "Nominal Wage Stickiness and Aggregate Suply in the Great Depression," *Quarterly Journal of Economics*, III(3), 853–858.

BERNANKE, B. S., AND M. PARKINSON (1991): "Procyclical Labor Productivity and Competing Theories of the Business Cycle: Some Evidence from Interwar U.S. Industries," *Journal of Political Economy*, 99(1).

[24] We choose the shocks to match the decline in aggregate measured TFP. These results are available upon request.

BILS, M., AND Y. CHANG (2000): "Understanding How Price Responds to Costs and Production," *Carnegie-Rochester Conference Series on Public Policy*, 52, 33–77.

BORDO, M. D., C. J. ERCEG, AND C. L. EVANS (2000): "Money, Sticky Wages, and the Great Depression," *The American Economic Review*, 90(5), 1447–1453.

——— (2001): "Comment: Re-examining the Contributions of Money and Banking Shocks to the U.S. Great Depression," *NBER Macroeconomics Annual 2000*, pp. 227–37.

BORDO, M. D., AND C. L. EVANS (1995): "Labor Productivity During the Great Depression," *Economics Letters*, 47, 41–45.

BOUAKEZ, H., E. CARDIA, AND F. RUGE-MURCIA (2009): "The Transmission of Monetary Policy in a Multisector Economy," *International Economic Review*, 50(4), 1243–1266.

CHRISTIANO, L., R. MOTTO, AND M. ROSTAGNO (2003): "The Great Depression and the Friedman-Schwartz Hypothesis," *Journal of Money, Credit, and Banking*, 35, 1121–97.

CLARK, T. (1999): "The Responses of Prices at Different Statges of Production to Monetary Policy Shocks," *Review of Economics and Statistics*, 81(3), 420–33.

COLE, H. L., AND L. E. OHANIAN (2001): "Re-examining the Contributions of Money and Banking Shocks to the U.S. Great Depression," in *NBER Macroeconomics Annual 2000*, ed. by B. Bernanke, and K. Rogoff, pp. 183–227. MIT Press, Cambridge, MA.

——— (2004): "New Deal Policies and the Persistence of the Great Depression: A General Equilibrium Analysis," *Journal of Political Economy.*

COLE, H. L., L. E. OHANIAN, AND R. LEUNG (2005): "Deflation and the International Great Depression: A Productivity Puzzle," *NBER Working Paper 11237.*

——— (2007): "The International Great Depression: Deflation, Productivity and the Great Depression," *mimeo.*

DENISON, E. F. (1962): *Sources of Economic Growth in the U.S.* Committe for Economic Development.

DIGHE, R. S. (1997): "Wage Rigidity in the Great Depression: Truth? Consequence?," *Research in Economic History*, 17, 85–134.

Eichengreen, B. (1995): *Golden Fetters: The Gold Standard and the Great Depression 1919-1939*. Oxford University Press, New York.

Eichengreen, B., and T. Hatton (1988): *Interwar Employment in International Perspective*chap. Interwar Employment in International Perspective: An Overview, pp. 1–59. Kluwer Academic Publishers.

Eichengreen, B., and J. Sachs (1985): "Exchange Rates and Economic Recovery in the 1930s," *Journal of Economic History*, XLV, 925–946.

Friedman, M., and A. Schwartz (1963): *A Monetary History of the United States 1867-1960*. Princeton University Press, Princeton, NJ.

Gertler, M. (2001): "Comment: Re-examining the Contributions of Money and Banking Shocks to the U.S. Great Depression," *NBER Macroeconomics Annual 2000*, pp. 237–58.

Gomme, P., and P. Rupert (2007): "Theory, Measurement and Calibration of Macroeconomic Models," *Journal of Monetary Economics*, 54, 460–497.

Hanes, C. (2000): "Nominal Wage Rigidity and Industry Characteristics in the Downturns of 1893, 1929, and 1981," *American Economc Review*, 90(5), 1432–1446.

Herrendorf, B., R. Rogerson, and A. Valentinyi (2012): "Growth and Structural Transformation," in *Handbook of Economic Growth, forthcoming*, ed. by R. Gregory, and N. Butlin. Elsevier.

Hines, L. G. (1951): "Price Determination in the Lake Erie Iron Ore Market," *American Economc Review*, 41(4), 650–661.

Huang, K. X., Z. Liu, and L. Phaneuf (2004): "Why Does the Cyclical Behavior of Real Wages Change over Time?," *American Economc Review*, 94(4), 836–856.

Kehoe, T., and E. Prescott (eds.) (2007): *Great Depressions of the Twentieth Century*. Federal Reserver Bank of Minneapolis.

Kendrick, J. W. (1961): *Productivity Trends in the United States*. Princeton University Press, Princeton.

Leontief, W. W. (1951): *The Structure of American Economy, 1919-1939: An Empirical Application of Equilibrium Analysis*. Oxford University Press, New York.

Lucas, R. E. (1972): "Expectations and the Neutrality of Money," *Journal of Economic Theory*, 4, 103–24.

Means, G. C. (1966): *The Structure of the American Economy: Part I. Basic Characteristics*. Augustus M. Kelley, New York.

Murphy, K. M., A. Shleifer, and R. W. Vishny (1989): "Building Blocks of Market Clearing Business Cycle Models," in *NBER Macroeconomics Annual 1989*, ed. by O. Blanchard, and S. Fischer, pp. 247–286. MIT Press, Cambridge, MA.

Neal, A. C. (1942): *Industrial Concentration and Price Inflexibility*. American Council on Public Affairs, Washington, D.C.

Ohanian, L. E. (2009): "What - or who - started the Great Depression?," *Journal of Economic Theory*, 144, 2310–2335.

Rotemberg, J. J., and M. Woodford (1996): "Imperfect Competition and the Effects of Energy Price Increases on Economic Activity," *Journal of Money, Credit and Banking*, 28, 549–577.

——— (1999): "The Cyclical Behaviour of Prices and Costs," in *Handbook of Macroconomics, Volume 1*, ed. by J. Taylor, and M. Woodford. Elsevier.

Uhlig, H. (1999): "A Toolkit for Analysing Nonlinear Dynamic Stochastic Models Easily," in *Computational Methods for the Study of Dynamic Economies*, ed. by R. Marimon, and A. Scott, pp. 30–61. Oxford University Press, Oxford, UK.

Table 1: **Sectoral labor market statistics (per adult, 1929=100)**

Hours Worked

Year	Agric.	Constr.	Retail	FIRE	Flex.	Manuf.	Transp.	Gov.	Min.	Serv.	Wholesale	Sticky	Total
1929	100	100	100	100	100	100	100	100	100	100	100	100	100
1930	97.6	91.3	92.6	94.9	95.0	83.5	89.9	101.3	83.3	93.9	93.1	89.6	91.9
1931	98.0	80.7	85.0	88.6	91.0	67.2	75.3	100.8	64.3	85.8	82.4	77.5	83.5
1932	93.4	64.5	75.3	81.8	83.1	53.0	60.8	96.6	49.0	76.0	72.4	65.5	73.4
1933	92.0	53.5	73.9	77.7	80.3	56.1	56.3	113.7	51.4	72.5	71.2	66.4	72.6

Real Wages

Year	Agric.	Constr.	Retail	FIRE	Flex.	Manuf.	Transp.	Gov.	Min.	Serv.	Wholesale	Sticky	Total
1929	100	100	100	100	100	100	100	100	100	100	100	100	100
1930	78.2	92.3	99.6	95.4	91.1	104.0	103.8	104.5	106.2	102.5	103.7	104.4	98.9
1931	65.4	80.6	99.9	97.4	84.2	109.1	112.4	116.3	109.0	106.6	107.4	111.1	99.6
1932	49.5	59.3	91.6	98.9	72.6	108.7	116.8	127.9	111.30	107.4	103.5	113.5	96.3
1933	55.7	53.3	85.1	98.0	70.5	106.0	115.2	113.3	106.3	101.8	92.7	111.5	94.2

Source: Hours data from Kendrick (1961).
Note: Transp. is Transportation, Communications and Public Utilities.

Table 2: **Price Indices (1929=100)**

		COLA						
Year	GNP Defl.	All	Food	Cloth	Rent	Fuel	H. Furn.	Misc.
1929	100	100	100	100	100	100	100	100
1930	96.9	97.5	95.1	97.7	97.2	99.0	97.5	100.5
1931	88.1	88.7	78.4	89.0	92.1	96.8	87.7	99.5
1932	78.4	79.7	65.3	78.8	82.7	91.9	76.5	97.2
1933	76.7	75.4	63.5	76.2	71.2	88.9	75.4	94.1
1934	83.3	78.1	70.7	83.3	66.8	90.1	83.1	93.6

Source: GNP deflator is from Balke and Gordon (1986). COLA data is from Table 5 in *Cost of Living in 1941*, BLS Bulletin No. 710..

Table 3: **Calibration**

Benchmark		
Parameter	Value	Target
β	0.99	Annual risk-free rate 4%
δ	0.025	Annual depreciation rate 10%
η	0.3398	Flexible sector's share of GDP in SS: 41%
g	0.0015	Estimated
γ	0.0328	Sticky sector's real consumption wage path (1929-1933)
μ_L	7.3345	Total market time of 1/3
μ_M	0.013	BEE (2000)
ϕ_i	0.25	Quarterly contracts
ρ_m	0.44	Estimated
ρ	-0.82	Path of Flex. sector's share of GDP (1929-1933)
θ_1	0.3	Capital income share of 30%
θ_2	0.3	Capital income share of 30%

Intermediates		
Parameter	Value	Target
α_1	0.8750	Intermediates' share (Flex. sector): 32%
α_2	0.8410	Intermediates' share (Sticky sector): 38%
η	0.3870	Flex. sector's share of GDP in SS: 41%
γ	0.0763	Sticky sector's real consumption wage path (1929-1933)
ρ	-1.1091	Path of Flex. sector's share of GDP (1929-1933)
ρ_1	-0.4493	Elast. of subst. between VA and intermediates: 0.69
ρ_2	-0.4493	Elast. of subst. between VA and intermediates: 0.69
χ_1	0.7888	Flex. intermediates' share (Flex. sector): 39%
χ_2	0.5545	Flex. intermediates' share (Sticky sector): 31%

Table 4: **Industry Wholesale Output and Main Input Price (1929=100)**

	WPI (GO)					*WPI (Main Input)*				
Industry	1929	1930	1931	1932	1933	1929	1930	1931	1932	1933
Automobile	100	94.2	89.2	88.9	87.9	100	93.9	87.8	83.7	82.8
Boots and Shoes	100	96.0	88.1	81.0	84.9	100	89.5	76.1	57.5	63.1
Iron and Steel	100	93.9	87.8	83.7	82.8	100	101.3	100.6	100.4	98.1
Meat Packing	100	90.2	69.1	53.3	45.8	100	84.1	60.2	45.4	40.9
Paper and Pulp	100	96.9	91.6	84.9	86.2	100	94.1	83.6	70.2	56.3
Leather	100	89.5	76.1	57.5	63.1	100	80.7	53.4	37.3	59.5
Wool Man	100	89.5	77.2	65.3	78.5	100	70.4	51.5	36.9	59.1
Manufacturing	100	93.1	81.5	74.4	74.6	100	86.5	67.3	56.5	57.9

Source: See the data appendix. The input price indices are based on the main input for each industry. For manufacturing, the input price index is for raw materials (the values for the index of semi-manufactured goods are 100, 87.1, 73.5, 63.2, 69.5).

Table 5: **Real Product Wages (1929=100)**

	VA Deflator (C-D)					*WPI Deflator*				
Industry	1929	1930	1931	1932	1933	1929	1930	1931	1932	1933
Automobile	100	105.8	107.0	88.8	90.1	100	106.5	109.9	98.5	99.8
Boots and Shoes	100	91.1	84.0	68.7	77.8	100	98.3	98.6	99.9	107.5
Iron and Steel	100	112.5	119.9	107.8	106.5	100	107.7	110.8	97.1	96.7
Meat Packing	100	78.9	69.7	68.1	101.3	100	113.7	142.5	156.7	182.8
Paper and Pulp	100	99.4	94.6	78.0	52.4	100	103.5	107.4	101.7	94.8
Leather	100	103.9	109.1	111.8	111.6	100	104.9	109.1	108.1	100.9
Wool Man	100	93.7	67.2	70.6	122.4	100	113.8	126.3	121.9	105.7
Manufacturing	100	99.1	103.9	93.5	102.8	100	107.3	117.4	113.4	111.5

Source: Wage data is from the NICB and the industry wholesale price deflators are from various issues of *Wholesale Prices*. The manufacturing input price series is semi-finished materials.

Figure 1: **Labor market estimates**

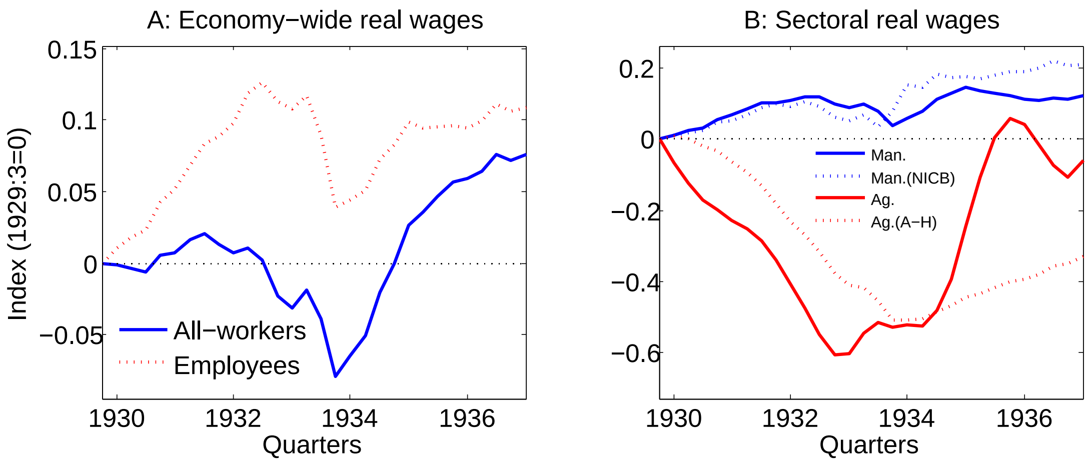

Figure 2: **Sectoral real wages and hours**

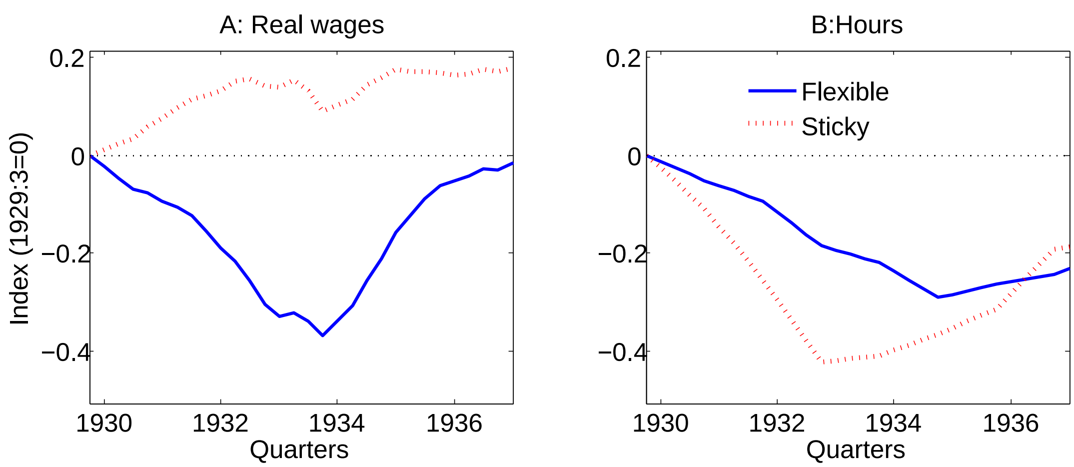

Figure 3: **No intermediates: sectoral variables**

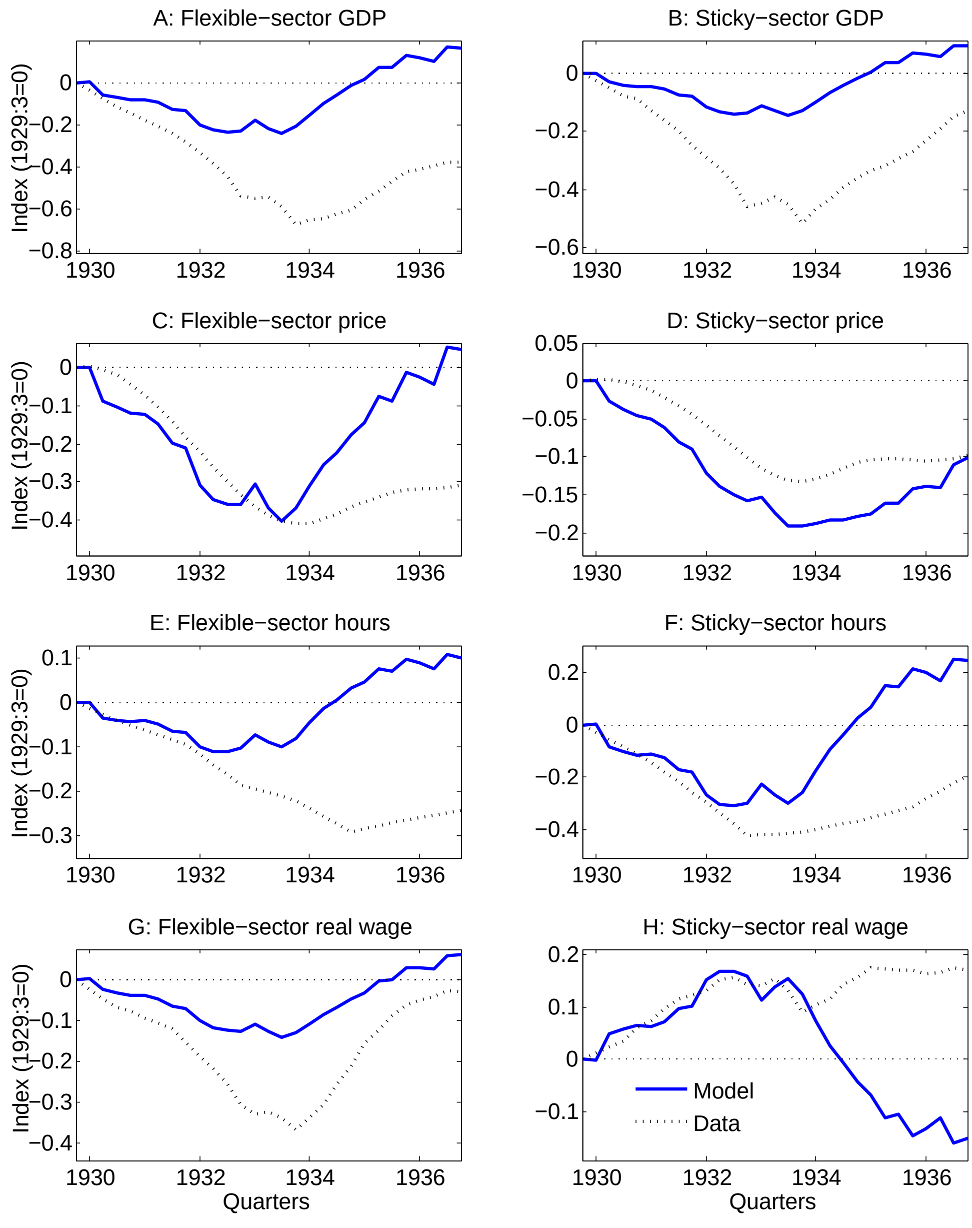

Figure 4: **No intermediates: aggregate variables**

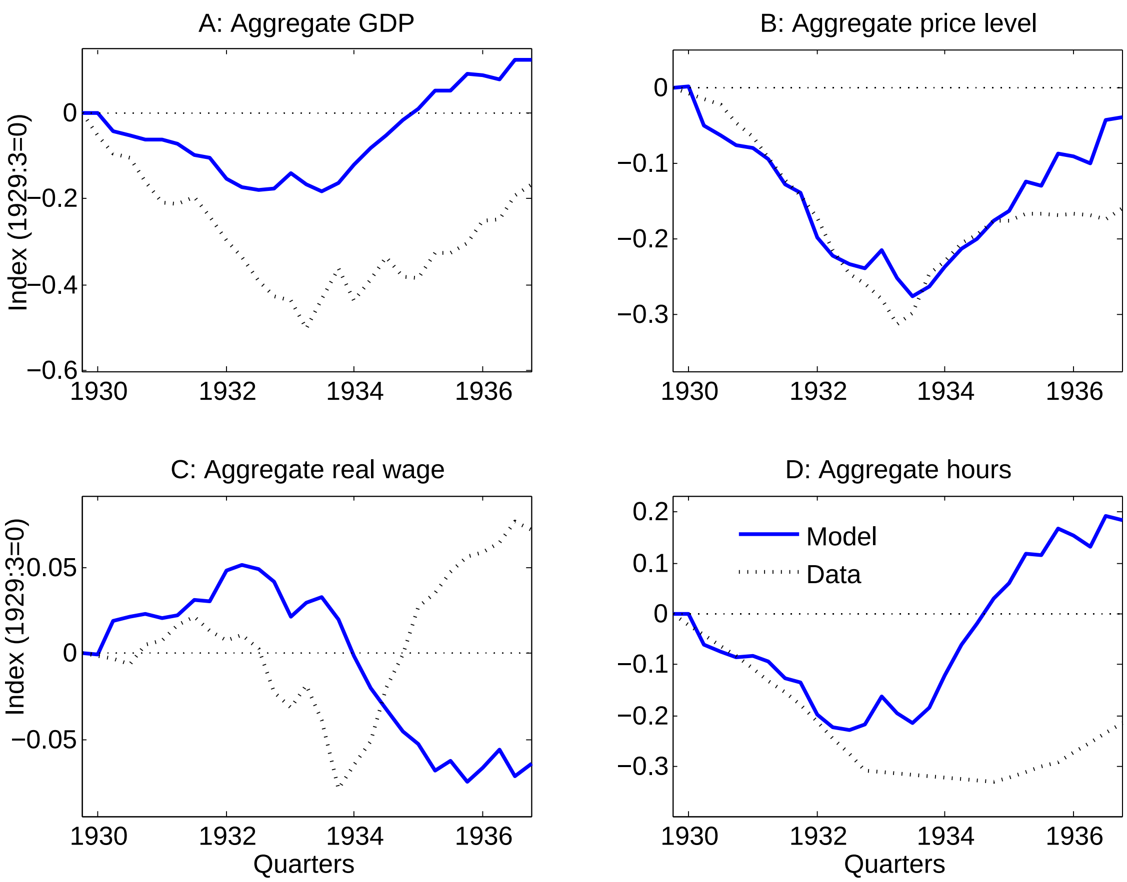

Figure 5: **Sensitivity analysis**

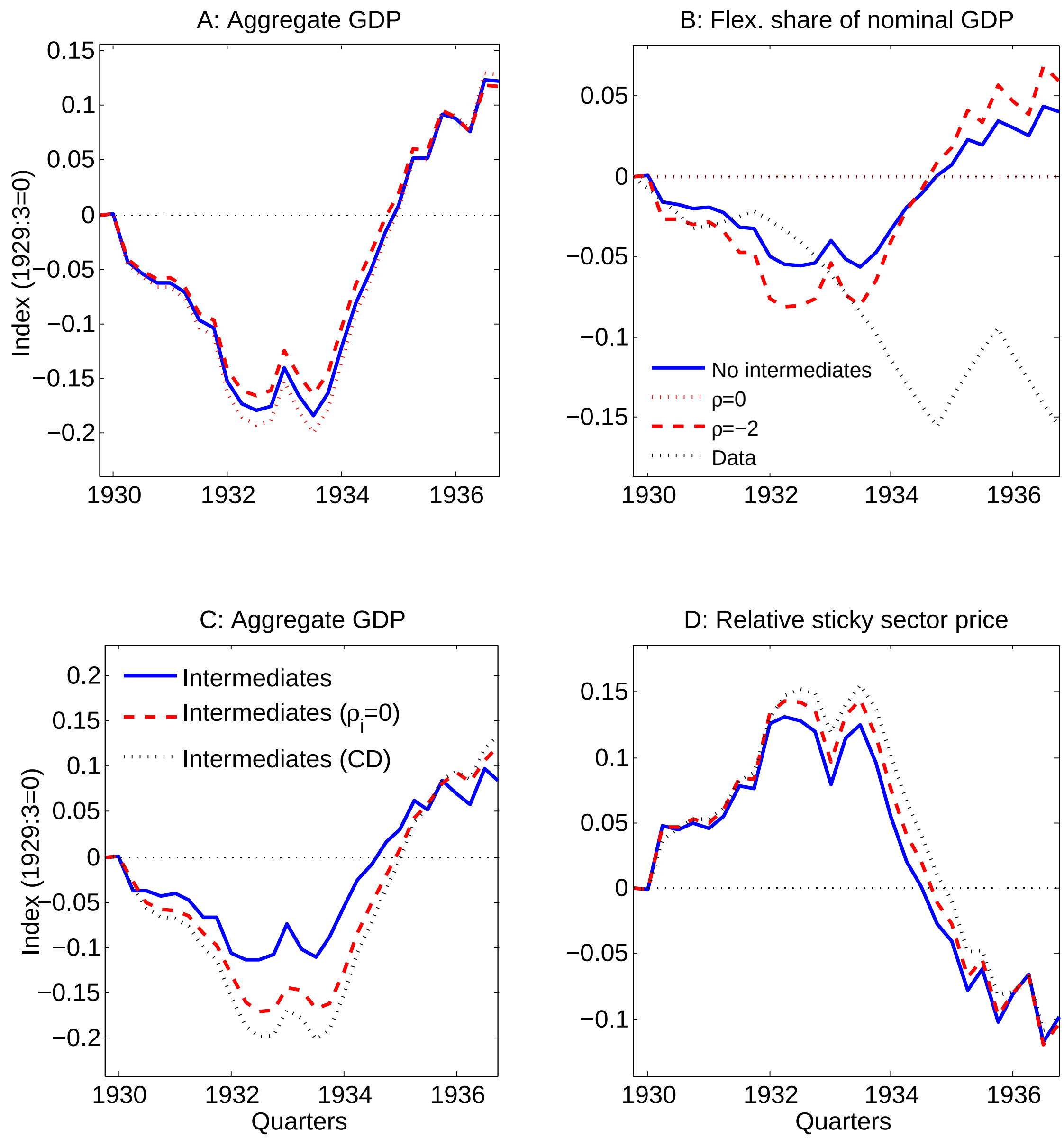

Figure 6: **Comparison: aggregate variables**

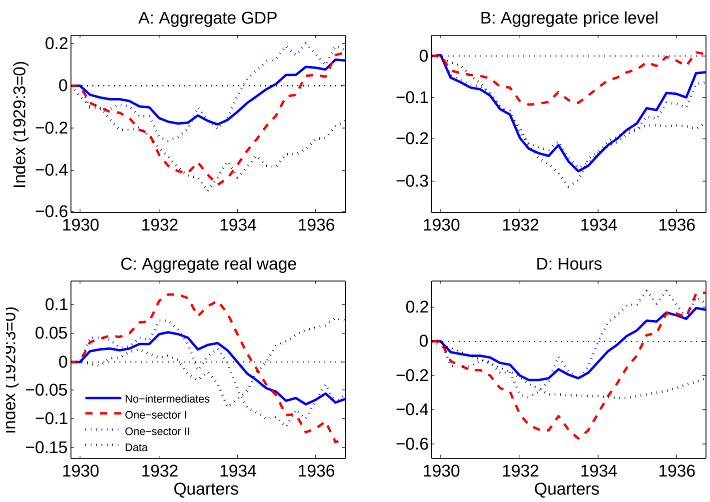

Figure 7: **Pass-through effect**

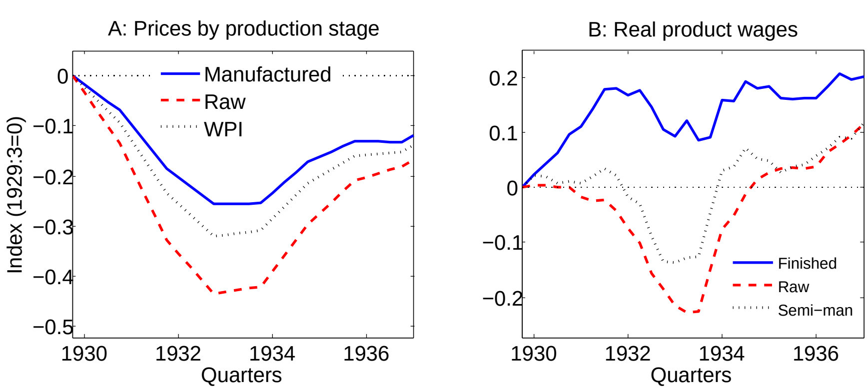

Figure 8: **Intermediates: aggregate variables**

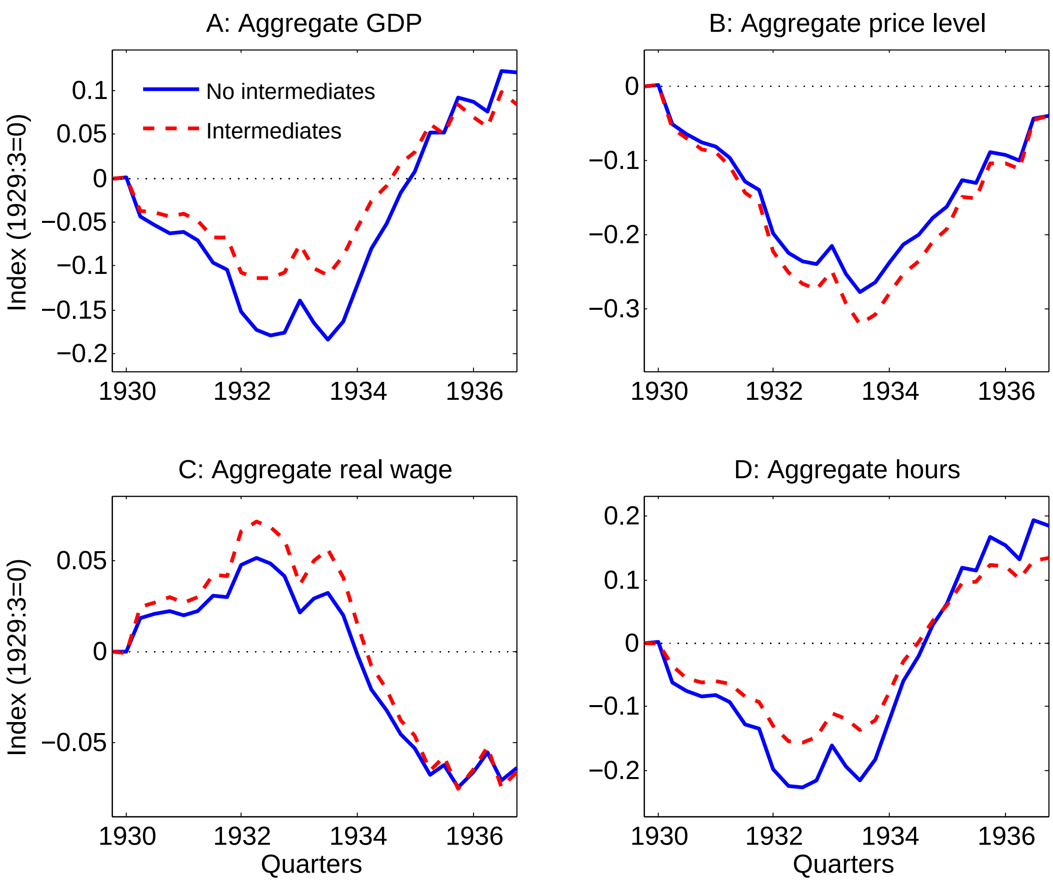

Figure 9: **Intermediates: sectoral variables**

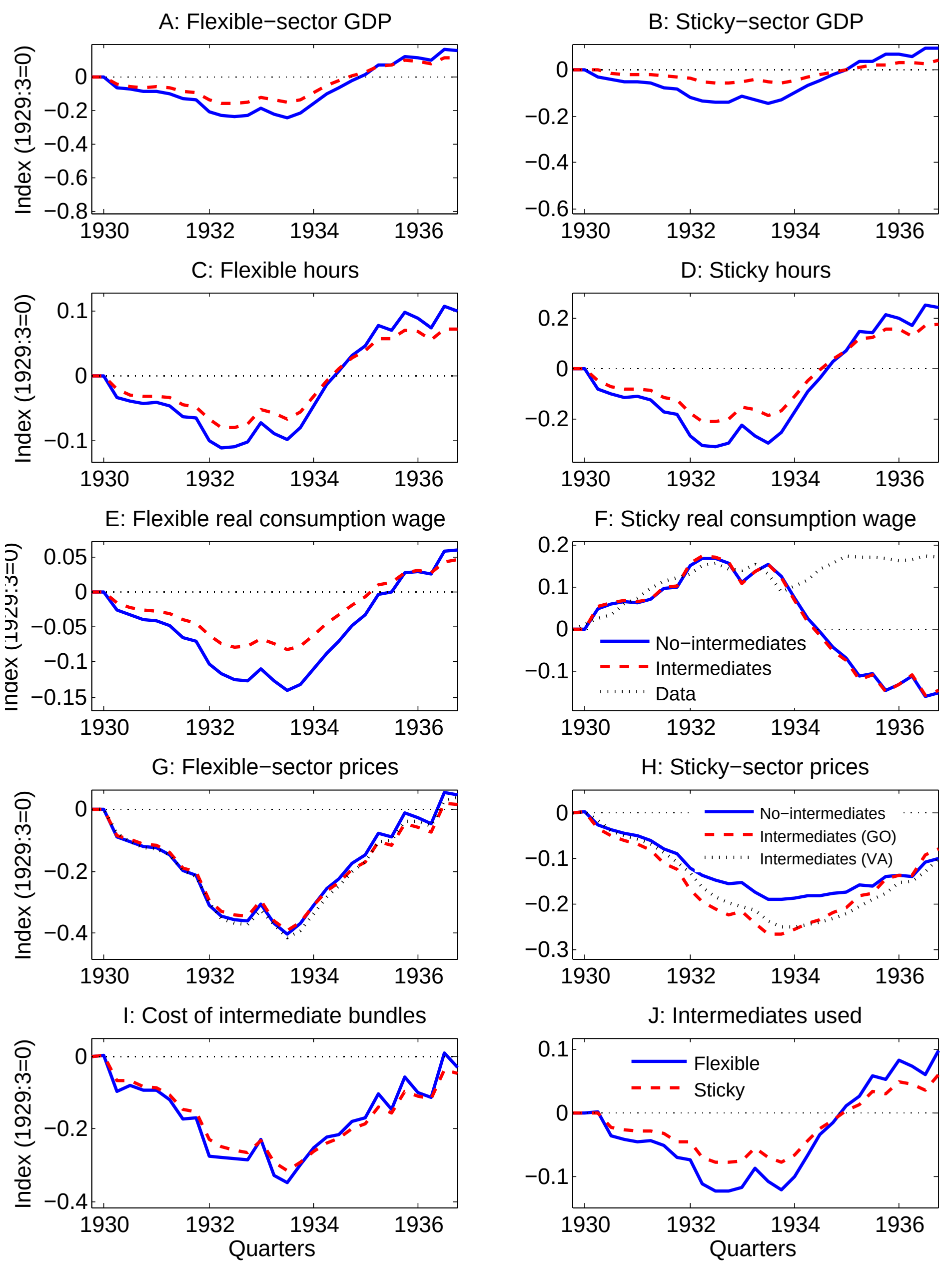

Figure 10: **Comparison: aggregate variables**