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Monetary shocks and sticky wages in the U.S. great contraction: A multi-sector approach

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ABSTRACT

We quantify the role of contractionary monetary shocks and nominal wage rigidities in the U.S. Great Contraction. In contrast to conventional wisdom, we find little increase in the economy-wide real wage over 1929–33, although real wages rose significantly in some industries. In the context of a two-sector model with intermediates and nominal wage rigidities in one sector, contractionary monetary shocks account for only a third of the fall in GDP. Intermediate linkages play an important role, as the output decline without intermediates is almost a third larger at the trough. The role of nominal wage rigidities beyond their interaction with monetary shocks is limited.

1. Introduction

A long-standing view is that the interaction of deflationary monetary policy and rigid nominal wages led to high real wages that were a key factor in the fall in employment and output in the U.S. "Great Contraction" of 1929–33 (e.g., Bernanke, 1995; Bordo et al., 2000). Despite the conclusions of Cole and Ohanian (2001) and Christiano et al. (2003) that the rise in real wages was a minor contributor to the contraction, recent work by Hatton and Thomas (2010) and Ohanian (2009) continues to point to high real product wages (i.e., wages divided by sectoral output price) as a key contributor.

This leads us to re-examine the quantitative contribution of nominal wage rigidities and deflationary monetary shocks to the U.S. Great Contraction. Our analysis relies on two key elements: sectoral (industry) differences in the degree of wage rigidity and intermediate inputs. When these features are incorporated into a standard two-sector model calibrated to the interwar U.S. economy, contractionary monetary shocks can account for only a third of the decline in output during this period. Intermediate linkages play an important role, as the predicted decline in output increases by a third in a version of the model where intermediates are absent.

Our focus on sectoral heterogeneity in wage rigidity and intermediates is motivated by two observations. First, real wages rose significantly in some sectors while falling rapidly in others over 1929–33 (see Table 1). Moreover, in contrast to the conventional view, we find that the economy-wide real wage, constructed using compensation and hours for all workers,

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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	89.8	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	75.1	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	60.6	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	56.1	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	78.4	92.1	99.6	94.9	91.0	104.0	104.8	104.5	105.9	102.4	103.6	103.8	98.9
1931	65.7	80.3	99.8	97.0	83.9	109.0	116.5	116.3	108.6	106.4	107.3	110.4	99.6
1932	49.9	58.8	91.7	99.7	72.6	108.6	125.7	127.9	110.9	107.3	103.6	113.8	96.3
1933	56.0	53.0	85.3	99.1	70.5	105.9	125.7	113.3	106.3	101.7	92.8	109.8	94.2

% Self-employed

Year	Agric.	Constr.	Retail	FIRE	Flex.	Manuf.	Transp.	Gov.	Min.	Serv.	Wholesale	Sticky	Total
1929	66	36	31	10	41	1	4	0	2	21	6	5	23

Source: Hours data from Kendrick (1961). Hours are per working-age person.
Note: Transp. is Transportation, Communications and Public Utilities.

was relatively flat over 1929-33. Key to this finding is the inclusion of the earnings and hours worked of self-employed (see Fig. 1.A), who accounted for roughly a quarter of the workforce and were concentrated in industries (especially agriculture) where wages fell dramatically.

The second observation is that the shifts in relative wages were accompanied by shifts in relative prices, with large declines in the price of less processed goods used as intermediate inputs. This is important, since many papers point to a rise in the real product wage (the nominal wage deflated by the industry output price) in manufacturing as evidence of high real wages over 1929–33 (e.g., see Bernanke (1995)). Focusing on manufacturing industries for which data on gross output and intermediates are available reveals that the pass-through of lower intermediate prices accounts for a significant share of the fall in output prices. As a result, the value-added product wage for manufacturing (using the implied value-added deflator) resembles our economy-wide real wage, remaining roughly constant over the downturn.

These facts lead us to develop a two-sector model where sectors differ in the degree of wage rigidity and their use of intermediates. In the *flexible* sector, wages adjust to equate labor demand and supply, while in the *sticky* sector, nominal wages adjust slowly. To facilitate comparison with Bordo et al. (2000), sticky-sector wages are determined by Taylor nominal wage contracts. Each sectoral good is produced using capital, labor, and an intermediate good comprised of both sectoral goods. The consumption/investment good is produced using the sectoral goods.

To quantify the impact of monetary shocks and wage rigidities, this model economy is calibrated to match key moments of the interwar U.S. economy. To enable the model to match the fall in output and the price level during the early 1930s, our benchmark experiment includes sectoral TFP, liquidity preference, and money supply growth shocks from 1929:3 to 1936:2. To decompose the contribution of monetary shocks and wage rigidities, the model economy is also simulated using monetary shocks only. We find that monetary shocks account for only a third of the fall in output during the Great Contraction. Our decomposition also yields a modest role for the interaction between nominal wage rigidities and the TFP and liquidity shocks, as these channels account for roughly 15% of the Great Contraction.

The model features two mechanisms that mitigate the impact of high sectoral real wages. First, the flexible-wage sector offers final goods producers a channel to substitute away from the relatively more expensive sticky-sector good. Second, since the sectoral intermediate bundle includes both flexible and sticky goods, a contractionary monetary shock results in a lower price of intermediates relative to the sticky-sector wage. This allows sticky-sector firms to substitute intermediates for relatively more expensive labor. As a result, changes in relative prices drive a wedge between real product wages and real value-added wages.

The intermediates channel is quantitatively significant. Our model without intermediates, subject to the same degree of wage rigidity, generates a fall in output roughly a third larger than our benchmark. The key reason for this is that the fall in the (relative) price of flexible-sector intermediates partially offsets the effect of higher sticky wages, and leads to a smaller rise in the price of the sticky good.

In contrast, sectoral heterogeneity in wage rigidity alone does not significantly mitigate the effects of high sectoral real wages. The two-sector model without intermediates and a one-sector version calibrated to match the same economy-wide real wage have similar predictions for GDP. While the flexible sector provides a channel to substitute away from the sticky good, this lowers the flexible sector real consumption wage. 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 the one-sector environment.

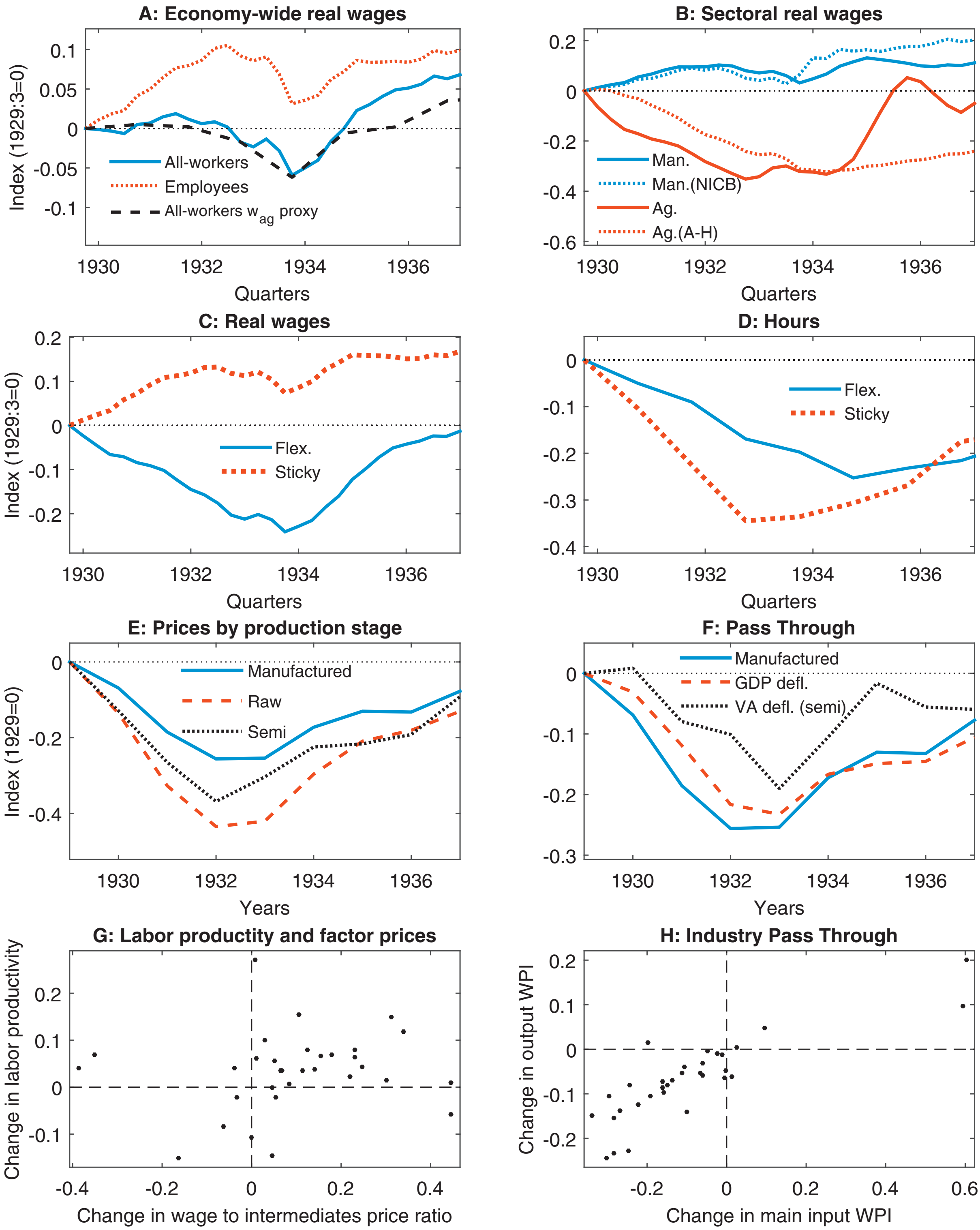

Fig. 1. Data estimates.

Our paper is most closely related to Bordo et al. (2000) and Cole and Ohanian (2001), who offer different estimates of the contribution of deflation and wage rigidity to the Great Contraction. While it shares with Cole and Ohanian (2001) the view that sectoral heterogeneity in wages is important, it differs in incorporating intermediate linkages and nominal rigidities. In contrast to Bordo et al. (2000) – whose one-sector framework is nested as a limiting case of our model – our results imply high real wages were not the predominant factor in the large fall in output during the Great Contraction. We also show that the key reason Cole and Ohanian (2001) find a smaller role for high real wages than Bordo et al. (2000) is not the multi-sector structure of their model, but rather their calibration to a smaller increase in the real wage. Unlike the conclusion of Christiano et al. (2003), however, our findings indicate that while wage rigidities were not the main factor, they were a significant contributor to the output decline in the Great Contraction,

Motivated by President Hoover's efforts to jawbone manufacturing firms into not cutting wages or employment in 1930, Ohanian (2009) examines a two-sector model where real wages in one sector exceed their steady-state level. Unlike our paper, Ohanian (2009) concludes high manufacturing wages and a fall in hours per worker can account for a large fraction of the 1929–33 fall in output. We show that intermediate linkages reduce the impact of high real product wages in manufacturing on output.

In recent work, Cole et al. (2005) find a link between the gold standard and deflation experiences, but conclude that deflation accounts for a small share of output declines. While our work has similar implications for the contribution of contractionary monetary shocks to the fall in prices and output during the Great Contraction, the focus is on the U.S. and on showing that intermediate linkages mitigate the high real wages in some sectors. Crucini and Kahn (1996) argue that higher tariffs on intermediate goods may have been a contributing factor to the Great Depression. Although our work shares an interest in the impact of intermediate prices, it highlights the implications of the fall in raw material prices for the impact of high real wages in manufacturing.

Early work by Means (1966) highlighted the large shifts in relative prices across industries during the Great Depression, while Neal (1942) examined whether shifts in input prices could account for movements in relative prices across manufacturing industries. Our paper differs in its focus on quantitative theory and real wages.

The remainder of this paper is organized as follows. Section 2 documents several key facts on aggregate and sectoral wages and hours and on the impact of shifts in the price of manufacturing intermediates. Section 3 outlines the model, while Section 4 quantifies the impact of contractionary monetary shocks and nominal wage frictions, and the importance of intermediates. The final section offers a brief conclusion.

2. Data

While the labor market figures prominently in discussions of the Great Contraction, the literature typically uses the average manufacturing wage as a proxy for the economy wide wage.[1] In this section, we argue this provides a misleading picture due to large shifts in relative wages and prices across industries in the early 1930s.

Since measures of hourly wages exist for few industries, estimates of hours worked and total labor income are used to construct aggregate and sectoral wages. According to these measures there were substantial shifts in relative wages across industries, which coincided with large shifts in relative prices over 1929–1933. In contrast to conventional wisdom, our average real wage for all workers over 1929–1933 barely rises. This is mainly due to our inclusion of the self-employed, whose income fell dramatically and were concentrated in sectors where real wages declined. Consistent with differential degrees of wage rigidity, hours worked tended to decline more in industries where relative wages rose.

2.1. Average real (consumption) wage

To construct an average wage series, total labor income is divided by total hours worked. Our measure of total hours worked is the product of persons engaged in production (full-time equivalent (FTE) employees plus sole-proprietors) and average hours worked per FTE worker.[2] Since this measure includes sole-proprietors, total labor income is defined as total employee compensation plus 60% of sole-proprietors' income.[3] The real *consumption* wage is computed by deflating our nominal wage estimate using the Balke and Gordon (1986) GNP deflator.

Our estimate of average real consumption wages (*All-workers* in Fig. 1.A) exhibits little increase during the downturn, rising only after the New Deal policies of the mid-1930s. However, as discussed in Section 2.2, there were large shifts in relative wages across industries. Since self-employed workers were concentrated in agriculture and retail trade (where wages fell), their inclusion has a large impact on wages. Indeed, unlike our estimate, the real wage of employees rises by roughly 12% over 1929 to 1932 (see *Employees* in Fig. 1.A).[4]

Other papers that construct real wages have taken different approaches to self-employed workers. Bordo et al. (2000) ignore the self-employed, and use the average real wage of employees. Christiano et al. (2003) follow Bordo et al. (2000) in using total compensation of employees as their estimate of earnings, but include hours worked by sole-proprietors. Since hours fell by less in industries with a large share of self-employed workers (as discussed below), this approach yields an aggregate real wage series that declines during the Great Contraction.

[1] See, for example, Margo (1993) and Bernanke (1995). Cole and Ohanian (2001) document the fall in agricultural wages relative to manufacturing.

[2] We use the Denison (1962) economy-wide average hours estimates for comparability with Bordo et al. (2000). This series is similar to that of Kendrick (1961) over 1929-39. The labor income data is from the BEA's NIPA accounts, Table 6.2A: Compensation of Employees by Industry.

[3] Changes in real wages are not very sensitive to reasonable (constant) values for the labor share.

[4] The average real wage for employed workers is total compensation of employees per hour, where hours are the product of FTE employees and average hours worked.

Are our findings robust to alternative estimates of self-employed hourly earnings? One check is to replace our measure with the hourly earnings of (employed) agricultural workers. This is a reasonable proxy since over half of self-employed workers were in agriculture. As Fig. 1.A illustrates, this exercise yields an economy-wide real wage estimate (*All-workers* w_{ag} *proxy*) similar to our benchmark. This suggests that excluding the self-employed from the calculation of average wages effectively under-weights industries where wages fell during the Great Contraction.

Should the self-employed be included in average wages? Theory suggests they should, as the standard growth model treats hours worked by employees and self-employed symmetrically. A more practical argument is that the self-employed accounted for over a fifth of the 1929 workforce. Moreover, contemporaneous observers reported that the self-employed resembled comparable wage workers.[5]

A possible concern is the effect of composition bias due to the lower average wage in industries where real wages fell. Since the share of total hours in these industries rose from roughly 44% in 1929 to 50% in 1933, this shift biases the average wage downwards. To approximate the magnitude of this bias, we compute an average wage series where the average wage of the two types of industries (according to whether real wages fell or rose) are weighted by their share of total hours in 1929. This implies a slightly higher real wage series then our benchmark, roughly 3% points higher over 1931 to 1933.

Working in the opposite direction is a shift towards more productive workers within each industry. Margo (1993) cites Lebergott's finding that manufacturing firms reduced the hours of their least productive workers, resulting in a 10% increase in average worker quality. Since Lebergott's estimate of the within-industry compositional shift more than offsets the cross-industry shift in worker composition, this suggests our estimate is an upper bound on the real consumption wage.

Overall, the data provides little evidence of a rise in the average real wage. However, measurement issues suggest our average wage estimate should be viewed with caution. Consequently, in our numerical exercises in Section 4, we target the path of real wages in the sector composed of industries that experienced increases in this measure, which had few self-employed workers.

2.2. Industry level estimates of wages and hours

While the decline in agricultural wages relative to manufacturing (over 40%) over 1929–33 is well known, the limited data on wages in other industries has left open the direction and size of wage changes in other sectors. To address this, we use estimates of hours worked and NIPA data on labor compensation to construct wages for construction, wholesale, retail, transportation and public utilities, finance, insurance, and real estate (FIRE), services, government, agriculture and manufacturing.

Industry wages are given by labor income divided by hours worked. Our measure of labor income is labor compensation plus 60% of sole-proprietors' income with inventory and Capital Cost Allowance (CCA) adjustments.[6] Hours worked in agriculture, government, manufacturing, mining, and transportation plus public utilities are from Kendrick (1961). For the remaining industries, the number of persons engaged in production is used to apportion Kendrick's estimate of private non-farm hours less hours worked in the aforementioned non-farm industries. All wages are deflated using the GNP deflator, and quantities are per working-age person.

Panel B in Fig. 1 plots our estimates of agriculture and manufacturing wages and commonly cited estimates. Our manufacturing wage closely tracks the NICB average manufacturing wage series. Compared to the Alston and Hatton (1991) farm laborer wages, our agricultural real wage initially declines faster, before rebounding over 1932–1935. This is not surprising, as most (roughly two-thirds) of the agriculture workforce were sole-proprietors and the Depression saw large swings in farm income. Consistent with the shift in relative wages, manufacturing hours declined by over 40%, while hours worked in agriculture declined little over 1929–32 (see Table 1).[7]

The other industries provide further evidence of large shifts in relative wages during the downturn. They were flat or declined in agriculture, construction, retail trade and FIRE. These industries included a significant number of sole-proprietors, and together accounted for more than four-fifths of the self-employed (see the last row of Table 1). In the remaining sectors, real wages increased over 1929–33, with larger increases in transportation and government than in manufacturing.

The Cost of Living Index (COLI) data in Table 2 shows that shifts in relative prices largely coincided with those in sectoral wages. Agriculture (Food) and FIRE (Rent), where real wages fell, experienced the largest price declines, while Utilities (Fuel) and Services (Miscellaneous), where real wages rose, had the smallest.[8]

This heterogeneity in wages motivates the two-sector model in Section 3, where the degree of wage rigidity varies by sector, referred to as *sticky* and *flexible*. To map the data into the model, industries where real wages rose compose the sticky

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[5] For example: "...there is a basis in the economic status of many farm operators for classifying them with wage earners." (pg. 66, Bureau of Labor Statistics (1939)). See the Web Appendix for further discussion.

[6] This data is from NIPA Tables 6.2, 6.14a, and 7.6. See Section 3.2 of the Web Appendix.

[7] We abstract from distinguishing between investment and consumption goods. The collapse in investment over 1929-33 is one explanation for the fall in hours worked in Construction in Table 1.

[8] Breaking out the distribution margin strengthens this conclusion (see the Web Appendix).

Table 2
Price indices (1929=100).

Year	GNP Defl.	WPI (Man.)	VA Defl. (Man.)	COLI						
				All	Food	Cloth	Rent	Fuel	H. Furn.	Misc.
1929	100	100	100	100	100	100	100	100	100	100
1930	96.9	93.1	100.8	97.5	95.1	97.7	97.2	99.0	97.5	100.5
1931	88.1	81.5	92.1	88.7	78.4	89.0	92.1	96.8	87.7	99.5
1932	78.4	74.4	89.9	79.7	65.3	78.8	82.7	91.9	76.5	97.2
1933	76.7	74.6	81.2	75.4	63.5	76.2	71.2	88.9	75.4	94.1

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

sector (manufacturing, transportation, government, mining, services, and wholesale) and those where wages fell (agriculture, construction, retail trade and FIRE) belong to the flexible one (roughly 41% of GDP in 1929).[9]

Panels C and D in Fig. 1 plot our sectoral estimates of real wages (computed using the GNP deflator) and hours per adult as log-deviations from their third quarter of 1929 values. The relative share of hours worked in each industry in 1929 serve as weights in computing these series. Consistent with a story of sectoral heterogeneity in wage rigidities, real wages rose more, and hours fell more, in the sticky sector.

2.3. Real product wages, intermediates and sectoral prices

Arguably the most cited evidence that deflation and slowly adjusting nominal wages were a key contributor to the Great Contraction is the rise in manufacturing real product wages. Starting from the smaller decline in manufacturing wages than wholesale prices over 1929-33, several authors have noted that the fall in employment and rise in labor productivity is consistent with a movement along the firm's labor demand curve (e.g., Bernanke, 1995; Margo, 1993).

Our critique of this interpretation is motivated by the large fall in the relative price of less processed goods used as intermediates during the early 1930s (see Fig. 1.E). Since the intermediate share of manufacturing costs exceeded 50%, the pass-through of lower intermediate prices could account for a large part of the fall in wholesale prices.[10] Moreover, standard theory implies that large shifts in the relative price of intermediates should impact labor productivity.

Formally, consider a competitive firm that produces output Y using labor L and intermediate goods Q using the technology $Y = [\alpha L^\rho + (1-\alpha)Q^\rho]^{\frac{1}{\rho}}$. Rearranging the first-order conditions yields the optimal input ratio as a function of relative factor prices: $\frac{Q}{L} = (\frac{1-\alpha}{\alpha}\frac{w}{p_Q})^{\frac{1}{1-\rho}}$. Using this together with the production function, labor productivity can be written as a function of the wage rate w and intermediate price p_Q: $\frac{Y}{L} = [\alpha + (1-\alpha)(\frac{1-\alpha}{\alpha}\frac{w}{p_Q})^{\frac{\rho}{1-\rho}}]^{\frac{1}{\rho}}$. Thus, a fall in the (relative) price of intermediates implies a rise in the gross output labor productivity, and a decrease in the output price, which is given by $p = [(\frac{w}{a})^r + (\frac{p_Q}{1-a})^r]^{\frac{1}{r}}$, where $r = \frac{\rho}{\rho_i}$, and $a = \alpha^{\frac{1}{\rho}}$.

To evaluate these implications, we assemble data on input and output prices (WPI), intermediate shares, average wages and real output for the manufacturing sector and seven large manufacturing industries over 1929–33.[11] The intermediate share of gross output for these industries in 1929 varied from roughly 53% in Boots & Shoes to nearly 87% in Meat-packing. The industry input prices are based on the prices of the main goods used as intermediates.

Shifts in relative industry output prices tracked shifts in the prices of intermediate inputs. Generally, the prices of primary good (especially agricultural commodities) fell more than more processed commodities, with the largest declines in Meat Packing, Leather, and Wool. Fig. 1.F plots our constructed manufacturing valued-added deflator (using the WPI for semi-manufactured as the intermediate price), the manufacturing WPI and the GNP deflator. Taking the pass-through of lower intermediate prices into account, the implied manufacturing value-added deflator falls by less than the GNP deflator. This suggests the pass-through of intermediate prices were a significant factor in the fall in manufacturing prices over 1929–33. A similar pattern holds at the industry level. Fig. 1.H plots the change in an industry's output WPI and the change in its main intermediate input WPI from one year to another from 1929 to 1933. Most of the dots fall in the lower left quadrant, implying that output prices fell concurrently with intermediate prices.

Data on real gross output and total hours yields (gross output) labor productivity estimates.[12] In five of the seven industries, the fall in the price of intermediates was accompanied by a rise in (gross output) labor productivity. The two industries where labor productivity fell (Automobiles and Iron and Steel) experienced the smallest declines in input prices.

[9] We include Wholesale in the sticky sector since real wages rose over 1929–32. This is a conservative approach, as it results in the sticky sector accounting for a larger fraction of the economy.

[10] Bils and Chang (2000) find that factor prices changes pass through into output prices.

[11] These industries have been studied in several papers, including Bernanke (1986). Meat-packing, iron and steel and automotive each accounted for over 5% of manufacturing gross output.

[12] The web appendix contains tables with our industry data.

Fig. 1.G shows this relationship graphically. Each dot in the scatter plot represents the change in an industry's wage to intermediate price ratio (x-axis) compared to the change in labor productivity from one year to another from 1929 to 1933. Most dots fall in the upper right quadrant, indicating that in most industries the decrease in the relative price of intermediates coincided with a rise in gross output labor productivity.

Theory implies the rise in labor productivity should be accompanied by a fall in intermediate productivity. Combining data on intermediate expenditures as a share of gross output with price and gross output data allows us to back-out intermediate productivity.[13] We find a similar (inverted) pattern, with the ratio of intermediates to gross output rising in most industries where input prices fell (see the Web Appendix). This implies a rise in the ratio of intermediates relative to labor in these industries, consistent with a substitution of intermediates for labor.

3. A two-sector model with intermediates

Motivated by the empirical observations in the previous section, we incorporate intermediates into a two-sector economy. Both sectors use capital, labor, and intermediate goods as inputs. Since most industries are an important source of their own intermediates, the sectoral intermediate bundle is modelled as an aggregate of the two sectoral goods.

Given our interest in quantifying the impact of heterogeneity in real wages across industries, sectors differ in how wages adjust. The flexible wage sector has a competitive labor market where wages adjust each period to equate labor demand and supply. The sticky wage sector builds on Bordo et al. (2000) and features Taylor nominal wage contracting. In this sector, the firm (the short side of the market) chooses hours given the (real) product wage. The two sectoral goods are used to produce the final consumption and/or investment good. To facilitate comparability with Bordo et al. (2000), real money balances appear as an argument in the utility function.

Capital can move freely across sectors, but workers cannot do so. Hours worked in the sticky sector are determined by firms and do not enter the household's utility function. This amplifies the effect of wage rigidities, and thus biases our analysis in favour of finding a significant role for high real wages.

To account for the possibility that the economic impact of high real wages were amplified by their interaction with other shocks, there is a liquidity shock to preferences, following Ireland (2004), and neutral sectoral TFP shocks. In our numerical experiments, these shocks are calibrated to quantitatively match the fall in output and the price level over 1929–1933. This allows us to back out the quantitative contribution of contractionary monetary shocks and nominal wage rigidities to the Great Contraction while matching the fall in output and prices in this period.

3.1. Environment

The economy is populated by an infinitely-lived household with preferences defined over streams of consumption, $\{C_t\}_{t=0}^{\infty}$, hours of flexible sector work, $\{L_{1,t}\}_{t=0}^{\infty}$ and real money balances, $\left\{\frac{M_t}{P_t}\right\}_{t=0}^{\infty}$, where P_t is the price of the final good. The household chooses consumption, hours in the flexible sector, nominal bond holdings, B_t, money holdings, M_t, capital in each sector, $K_{i,t+1}$, intermediate goods $Q_{i,\,t}$, and sales of intermediate goods (bought last period) to firms, $Q_{ij,\,t}$, to solve:

$$\max \sum_{t=0}^{\infty} \beta^t \left[\log C_t + \frac{\mu_L}{1-\sigma_L}(N_1 - L_{1,t})^{1-\sigma_L} + \nu_t \mu_M \log\left(\frac{M_t}{P_t}\right)\right] \tag{1}$$

$$\begin{aligned} s.t.\ \ B_t = {} & (1+R_{t-1})B_{t-1} + \sum_{i=1}^{2}(J_{i,t}K_{i,t} + W_{i,t}L_{i,t}) + \sum_{i=1}^{2}\pi_{i,t} + X_t \\ & + \sum_{i=1}^{2}\sum_{j=1}^{2} P^s_{i,t}Q_{ij,t} - \left(M_t - M_{t-1} + P_tC_t + P_t\sum_{i=1}^{2} I_{i,t} + \sum_{i=1}^{2} P_{i,t}Q_{i,t}\right), \end{aligned} \tag{2}$$

$$K_{i,t+1} = (1-\delta_i)K_{i,t} + I_{i,t}, \qquad i = 1, 2, \tag{3}$$

$$Q_{i,t-1} = Q_{ii,t} + Q_{ij,t}, \qquad i = 1, 2;\ j = 1, 2, \tag{4}$$

where R is the nominal interest rate on bonds, X is a lump-sum cash transfer from the government, N_1 is the total time endowment for sector 1 labor, 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. Q_{ij} denotes intermediates produced by sector i and used in sector j. The household purchases intermediate goods from both sectors, $Q_{i,t-1}$, at prices $P_{i,t-1}$ which they sell at the beginning of period t at price $P^s_{i,t}$. Finally, the household faces a liquidity shock, ν_t, that follows an AR(1): $\nu_{t+1} = (1-\rho_\nu) + \rho_\nu \nu_t + \varepsilon_{\nu,t+1}$, where $0 < \rho_\nu < 1$ and the innovation $\varepsilon_{\nu,t+1}$ is iid $N(0, \sigma^2_\nu)$.

[13] We use the identity Int. share $\equiv \frac{P_Q Q}{PY}$. Since the intermediate share is from the Census of Manufactures, this index of intermediate (gross output) productivity is only available bi-annually: for 1929, 1931 and 1933.

Firms

Sectoral output is produced using a CES production function:

$$Y_{i,t} = z_{i,t}\left[\alpha_i\left(K_{i,t}^{\theta_i}L_{i,t}^{1-\theta_i}\right)^{\rho_i} + (1-\alpha_i)\min\{Q_{1i,t}, \chi_i Q_{2i,t}\}^{\rho_i}\right]^{\frac{1}{\rho_i}}, \qquad i = 1, 2 \tag{5}$$

where the two intermediates inputs are perfect complements and $0 < \theta_i < 1$, $\rho_i < 1$, $\chi_i > 0$. Firms take sectoral output prices, factor prices and intermediates prices as given when making production decisions to maximize static profits. Sectoral productivity is stochastic and evolves according to $z_{i,t+1} = (1-\rho_{z_i}) + \rho_{z_i} z_{i,t} + \varepsilon_{z_i,t+1}$, where $0 < \rho_{z_i} < 1$ and the innovations $\varepsilon_{z_i,t+1}$ are iid $N(0, \sigma_{z_i}^2)$.

Final output producers buy sectoral goods, $Y_{i,t}^n$, and take prices as given when maximizing profits. The sum of intermediate goods bought by households and final good producers equals total sectoral output: $Y_{i,t} = Y_{i,t}^n + Q_{i,t}$, $i = 1, 2$. The final good, Y_t, can be allocated to consumption or investment in either sector:

$$Y_t = \left(\eta\left(Y_{1,t}^n\right)^{\psi} + (1-\eta)\left(Y_{2,t}^n\right)^{\psi}\right)^{1/\psi} = C_t + \sum_{i=1}^{2} I_{i,t}, \tag{6}$$

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

Wage setting

While wages adjust freely in sector 1, they are subject to Taylor-type contracts in sector 2. Each period, the contract wages of one of four equally-sized cohorts adjusts. The nominal wage the firm pays is a geometric average of the cohort contract wages:

$$W_{2,t} = x_t^{\phi_0} x_{t-1}^{\phi_1} x_{t-2}^{\phi_2} x_{t-3}^{\phi_3}, \tag{7}$$

where ϕ_i are cohort weights that sum to 1.

The contract wage in period t, x_t, depends on the current and future expected nominal wages and labor gaps relative to steady-state, so that:

$$\begin{aligned}\log x_t = {} & \phi_0 \log W_{2,t} + \gamma(L_{2,t} - L_2) + E_t\Big\{\phi_1 \log W_{2,t+1} + \gamma(L_{2,t+1} - L_2) \\ & + \phi_2 \log W_{2,t+2} + \gamma(L_{2,t+2} - L_2) + \phi_3 \log W_{2,t+3} + \gamma(L_{2,t+3} - L_2)\Big\},\end{aligned} \tag{8}$$

where γ is a labor-gap adjustment parameter. Repeated substitution of (7) into (8) (using $\phi_i = 0.25$) yields the current contract wage as a function of past and expected future contract wages and the current and expected labor gaps:

$$\begin{aligned}\log x_t = {} & \frac{1}{12}\log x_{t-3} + \frac{1}{6}\log x_{t-2} + \frac{1}{4}\log x_{t-1} + \gamma(L_{2,t} - L_2) \\ & + E_t\left\{\frac{1}{4}\log x_{t+1} + \frac{1}{6}\log x_{t+2}\frac{1}{12}\log x_{t+3} + \sum_{k=1}^{3}\gamma\left(L_{2,t+k} - L_2\right)\right\}.\end{aligned} \tag{9}$$

Money

The growth rate of the stock of money, $g_t = \log M_t - \log M_{t-1}$, follows an exogenous process:

$$g_{t+1} = g_0 + \rho_m g_t + \varepsilon_{m,t+1}, \tag{10}$$

where $0 < \rho_m < 1$ and the innovation $\varepsilon_{m,t+1}$ is iid $N(0, \sigma_m^2)$.

Equilibrium

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

The household's and firms' first-order conditions, the wage setting Eqs. (7) and (8), and the goods market clearing conditions constitute the set of necessary conditions. The model is solved using a perturbation method to generate a second-order approximation to policies, as in Schmitt-Grohe and Uribe (2004).

3.2. Parameterization and calibration

Most parameters are calibrated to match selected moments from the data. A summary of parameter values and targets appears in Table 3. The Web Appendix contains a discussion of the sensitivity of our results to alternative values of several key parameters.

Each period lasts one quarter, and $\beta = 0.99$, consistent with an annual risk-free return of 4%. The quarterly depreciation rate of capital is 0.025. Total hours available for work are normalized to $N_1 + N_2 = 1$ and set total hours available for flexible sector work equal to its share of GDP in 1929, implying $N_1 = 0.41$. Workers are equally productive across sectors in steady-state, and μ_L is set so that steady-state total market time $L_1 + L_2$ is one third of total available time. $\sigma_L = 4$ is set so that the Frisch elasticity, $\frac{N_1 - L_1}{\sigma_L L_1}$, is 0.5.

Table 3
Calibration.

Benchmark		
Parameter	Value	Target
β	0.99	Annual risk-free rate 4%
δ	0.025	Annual depreciation rate of approximately 10%
σ_L	4	Frisch elasticity of 0.5
μ_L	0.0149	Total market time of 1/3
N_1	0.41	Flexible sector's share of GDP in 1929: 41%
ϕ_i	0.25	Quarterly contracts
ψ	−1.23	Path of Flexible 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%
η	0.3867	Flexible sector's share of GDP in 1929: 41%
α_1	0.8723	Intermediates' share (Flexible sector): 32%
α_2	0.8378	Intermediates' share (Sticky sector): 38%
ρ_1	−0.4493	Elasticity of substitution between value-added and intermediates: 0.69
ρ_2	−0.4493	Manufacturing elast. of subst. between v.-a. and interm. (1929-33) of 0.775
χ_1	0.8021	Flexible intermediates' share (flexible sector): 39%
χ_2	0.5647	Flexible intermediates' share (sticky sector): 31%
μ_M	0.0051	Average M1 to PCE ratio (1921–1939) of 0.395
γ	0.210	Sticky sector's real consumption wage path (1929–1933)
g_0	0.0025	Estimated from M1 data (see text)
ρ_m	0.44	Estimated from M1 data (see text)
σ_m	0.0104	Estimated from M1 data (see text)
ρ_v	0.38	Estimated from M1 and PCE data (see text)
σ_v	0.3	Estimated from M1 and PCE data (see text)
ρ_{z_1}	0.99	Estimated from sectoral output data (see text)
σ_{z_1}	0.0132	Estimated from sectoral output data (see text)
ρ_{z_2}	0.64	Estimated from sectoral output data (see text)
σ_{z_2}	0.0284	Estimated from sectoral output data (see text)
$\varepsilon_{z_1,D}$	−0.011	Estimated to fit sectoral output 1929:33 (see text)
$\varepsilon_{z_1,R}$	0.009	Estimated to fit sectoral output 1933:36 (see text)
$\varepsilon_{z_2,D}$	−0.019	Estimated to fit sectoral output 1929:33 (see text)
$\varepsilon_{z_2,R}$	−0.023	Estimated to fit sectoral output 1933:36 (see text)
$\varepsilon_{v,D}$	1.55	Estimated to fit aggregate prices 1929:33 (see text)
$\varepsilon_{v,R}$	5.55	Estimated to fit aggregate output 1933:36 (see text)
No-intermediates version		
Parameter	Value	Target
η	0.3402	Flexible sector's share of GDP in steady-state: 41%
ψ	−0.82	Path of Flexible sector's share of GDP (1929–1933)
μ_L	0.0154	Total market time of 1/3

We allocate industries to the flexible or sticky sector based on whether the industry real wage increased between 1929 and 1933. To compute the labor share, ambiguous income sources (such as proprietors' income) are allocated between capital and labor income in the same proportion as unambiguous income. Since our model abstracts from a government sector and residential housing, income from these sources is excluded. Unambiguous labor income is total compensation of private employees less housing compensation, 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.[14] The average labor share in 1929 is roughly 0.7 in both sectors, so $\theta_1 = \theta_2 = 0.3$ (i.e. the capital share of value-added is 30%).

The targets for sectoral production parameters (α_i, ρ_i, and χ_i) are: (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. These targets are compiled from multiple sources. For manufacturing and transportation, the 1929 input-output table of Leontief (1951) and the Statistical Abstract of the U.S. yield value-added shares (0.45 and 0.66, respectively) and a share of flexible intermediates of 0.35 and 0.26, respectively. In mining, our value-added estimate is 0.83, the average for 1919 and 1954. Given limited available input-output data, the 2002 Census data on business expenses is used for wholesale and retail trade. This implies a value-added share of 77% and a flexible intermediates share of 25%, which is also used for services, communications, government and FIRE. The value-added share in agriculture in 1929 was 0.49, with a flexible intermedi-

[14] 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.

ate share of 0.69 (Leontief, 1951). The 1930 Census for construction implies a value-added share of 0.57. Construction and mining use little flexible-sector inputs, so their share is set to 10% in these sectors.

To convert these values into sector averages, each of these industry shares are weighted by their value-added share. This implies an intermediate share in the flexible sector of 0.32, 39% of which is allocated to flexible intermediates. For the sticky sector, the intermediate share is 0.38, with 31% allocated to flexible intermediates. The elasticity of substitution between value-added and intermediates is set to 0.69, the mean value estimated by Rotemberg and Woodford (1996) for U.S. manufacturing.

The elasticity of substitution between sectoral goods in the final good aggregator, $\frac{1}{1-\psi}$, and the share of flexible goods in final good production, η, are jointly calibrated to match the flexible-sector share of GDP in 1929 (0.41) and to minimize the squared distance between model and data (in this share) over 1929:3–1933:2.

There are four exogenous shock processes to calibrate. The parameters associated with the money growth rate's law of motion in Eq. (10) are estimated using M1 (from Friedman and Schwartz, 1963, Table A-1) per working-age person, from 1922.Q2 to 1928.Q4.

Calibrating the liquidity shock's law of motion parameters, first involves estimating μ_M. For this, construct a time series for the liquidity shock using the household's first order condition with respect to money balances:

$$\nu_t \mu_M = \frac{M_t}{P_t C_t} - \beta E_t\left[\frac{M_t}{P_{t+1} C_{t+1}}\right].$$

The same M1 data is used, along with nominal personal consumption expenditures (PCE) from Barger (1942) from 1922:4 to 1928:4. Assume households expect nominal PCE to grow at the same rate as money: that is $\nu_t \mu_M = \frac{M_t}{P_t C_t}(1 - \frac{\beta}{1+E_t g_{mt+1}})$, and use the law of motion for the growth rate of money to compute $E_t g_{mt+1}$. Although this is an ad-hoc approximation, as the expectation is a function of the full set of shocks, it allows us to calibrate the value of μ_M, without a full model estimation. In steady-state $\nu_t = 1$, so use the average of $\frac{M_t}{P_t C_t} - \beta E_t[\frac{M_t}{P_{t+1} C_{t+1}}]$ over 1922:4 to 1928:4 to back-out μ_M. Finally, given this value, use the time series for ν_t to estimate ρ_ν and σ_ν.

The sectoral TFPs' laws of motion parameters (ρ_{z_i} and σ_{z_i}) are calibrated so that the model simulated moments replicate the first order auto-correlation and the standard deviations of the (HP filtered) quarterly sectoral income from Barger (1942) and deflated using the GNP deflator over 1922:4 to 1928:4.

The parameters governing the laws of motion of the stochastic variables are used to construct the innovations $\{\varepsilon_{m,t}, \varepsilon_{z_1,t}, \varepsilon_{z_2,t}, \varepsilon_{\nu,t}\}_{t=1929:3}^{1936:2}$ that are fed into our benchmark experiment. While the series for $\varepsilon_{m,\,t}$ is directly computed from the adjusted M1 data, this strategy does not work for the liquidity shock since it is unobservable. Similarly, the lack of sectoral data on capital and intermediates means TFP and its realized innovations cannot be directly computed. Instead, we assume that each of these innovations are constant throughout the downturn (D), change at the trough and remain constant throughout the recovery (R). This leaves six unknowns, one for each of the three shocks in the downturn and recovery: $\{\varepsilon_{z_1,D}, \varepsilon_{z_1,R}, \varepsilon_{z_2,D}, \varepsilon_{z_2,R}, \varepsilon_{\nu,D}, \varepsilon_{\nu,R}\}$. These six unknowns are set so as to minimize the distance between the simulated model and data of the path of real sectoral output in each sector and the aggregate price level, in the downturn and the recovery. Jointly, the value for γ, which regulates the rigidity of nominal wages in the sticky sector, is set so that the model's simulated path of real sticky consumption wages matches its data counterpart over 1929–33. The reason for avoiding the 1934–36 period when calibrating γ is that the New Deal-related labor market policies introduced post-1933 are not consistent with the sticky-wage mechanism, as discussed in Section 4.1.[15]

4. Results

We use our calibrated model to quantify the impact of monetary shocks and wage rigidities in the Great Contraction. Our simulation strategy is in the spirit of Bordo et al. (2000), as the benchmark experiment inputs the path of innovations $\{\varepsilon_{m,t}, \varepsilon_{z_1,t}, \varepsilon_{z_2,t}, \varepsilon_{\nu,t}\}_{t=1929:3}^{1936:2}$. To quantify the contribution of contractionary monetary shocks, this experiment is compared to one without the sectoral TFP and liquidity shocks, so that the only shocks hitting the economy are the money supply growth innovations.[16]

Our modelling approach helps us address two critiques of past attempts (e.g., Bordo et al., 2000; Cole and Ohanian, 2001) to quantify the contribution of monetary shocks and wage rigidities to the Great Contraction. The first is that estimates of the impact of monetary shocks and nominal wage rigidities may not be robust to incorporating additional shocks that allow the model to match the fall in output and prices (Gertler, 2001). The second critique is related, and argues that an approach relying exclusively on monetary shocks will underestimate the role of nominal wage rigidities due to their interaction with other shocks. This leads us to our benchmark specification with four exogenous shocks that allows us to match the fall in output and the deflation of the early 1930s.

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[15] The sectoral output paths used as targets are constructed using quarterly industry nominal GDP from Barger (1942), deflated by the GNP deflator, as is our measure of real sticky wages.

[16] We assume the economy was at its steady-state in the third quarter of 1929. The Web Appendix shows that assuming the economy was above steady-state in 1929 yields similar results.

The cumulative output loss between the third quarter of 1929 and the second quarter of 1933 is our metric for the fraction of the fall in output during the Great Contraction accounted for by each experiment. This measure is consistent with our model framework which implies that output would be constant in the absence of shocks to the exogenous variables. By this measure, the cumulative fall in the data was nearly 80% of steady-state output.

Our experiments yield three insights. First, contrary to the established view, we find that contractionary monetary shocks, working through a wage rigidity channel, account for only about a third of the fall in output during the Great Contraction. Second, accounting for intermediate linkages is important, as the fall in output in our model without intermediates is roughly a third larger than in our benchmark. Finally, the interaction of nominal wage frictions with non-monetary shocks is modest.

4.1. Monetary shocks and the great contraction

Figs. 2 and 3 plot the key aggregate and sectoral variables (along with their data counterparts) from our simulation.[17] The benchmark model closely matches the fall in output and prices over 1929–36 (Figs. 2 and 3 panels A and B, *All shocks*). This is by construction, as the calibration of sectoral TFP and liquidity shocks effectively targets these series. The dashed line (*M shocks only*) shows the economy's performance when only monetary shocks are active.

The benchmark calibration results in large TFP and liquidity shocks.[18] The negative TFP shocks are key to matching the fall in sectoral output. However, the negative TFP shocks push prices up. To offset this effect, large positive liquidity shocks are needed for the model to match the deflation of the early 1930s.[19]

The benchmark does a good job of matching the fall in hours until 1934 (Fig. 2.D, *All shocks*). However, the average real wage (for workers in both sectors) in the benchmark (Fig. 2.C, *All shocks*) tracks well below the data. This is driven by wages in the flexible sector, as the calibration targets the sticky sector real wage (compare Fig. 3.G,H *All shocks*). This is largely due to the calibration of TFP needed to generate the fall in flexible sector output. Mechanically, the fall in TFP drives down the marginal product of labor, and thus the wage.

We find that monetary shocks account for just a third of the cumulative fall in output during the contraction.[20] This is less than half as much as the contribution reported by Bordo et al. (2000). For the calibrated γ, the monetary shocks experiment matches the drop in the aggregate price level and the increase in the sticky real wage (see the dashed line in Figs. 2 and 3).

The model introduces two margins of substitution relative to the one-sector model of Bordo et al. (2000) that lessen the impact of contractionary monetary shocks. The first is the introduction of a sector with flexible labor markets, which allows final goods producers to substitute away from the relatively more expensive good produced in the sticky wage sector. The second, and novel, margin is intermediates linkages.

To illustrate how intermediate linkages can mitigate high wages in the sticky sector, consider the monetary shocks experiment. In this experiment, contractionary monetary shocks results in the price of the sticky intermediate bundle falling relative to the cost of labor, as it is a weighted average of the sectoral prices (see Fig. 3.I). This induces a substitution of intermediates for sticky-sector labor (notice how intermediates, the thin dashed line in Fig. 3.J, fall less than hours, the dashed line in Fig. 3.F), which enables the substitution of flexible-sector labor embodied in intermediates for more expensive sticky labor. Indirectly, this offsets the impact of high sticky wages by pushing up the marginal product of labor. Since hours fall by more than output in the sticky sector, labor (intermediate) productivity rises (falls).

During the post 1933 recovery the calibrated monetary shocks are expansionary. As a result, the model cannot match the rise in real wages. This finding is not new, as Bordo et al. (2000) point out that the rise in real wages during a period of expansionary monetary policy is inconsistent with the sticky wage mechanism. One explanation is that the introduction of the National Industrial Recovery Act (NIRA) in 1933, and the National Labor Relations Act in 1935, pushed up nominal wages in parts of the economy. In addition, Cole and Ohanian (2004) argue that the NIRA suspended anti-trust law in sectors where wages were raised above market clearing levels. These considerations are why we focus on the 1929–1933 period when calibrating γ.

To assess the sensitivity of our quantitative conclusions, in the Web Appendix our main experiment is repeated for alternative values of the elasticity of substitution in sectoral, ρ_i, and final good production,ψ; the importance of real money balances in utility, μ_M; and the relative share of the sticky sector in GDP. The fall in aggregate output in our benchmark is not sensitive to changes in the elasticity of substitution in ψ or μ_M. Although large changes in ρ_i and in the sticky sector share can lead to declines in output that are up to 4 percentage points below or above the benchmark experiment, this does not change the relative importance of monetary shocks, intermediates, or nominal wage frictions.

[17] The simulations are pruned according to Kim et al. (2008) to guarantee non-explosive solutions.

[18] The web appendix discusses the size of the TFP and liquidity shocks (shown in Table 3) needed to fit the data.

[19] Christiano et al. (2003) also find a large role for liquidity shocks, although their model includes additional channels via which these shocks can impact the real economy.

[20] This is the ratio of the areas above the full and dashed lines up to 1933:2. Earlier versions of the paper focused on the output fall at the trough, which gives similar results.

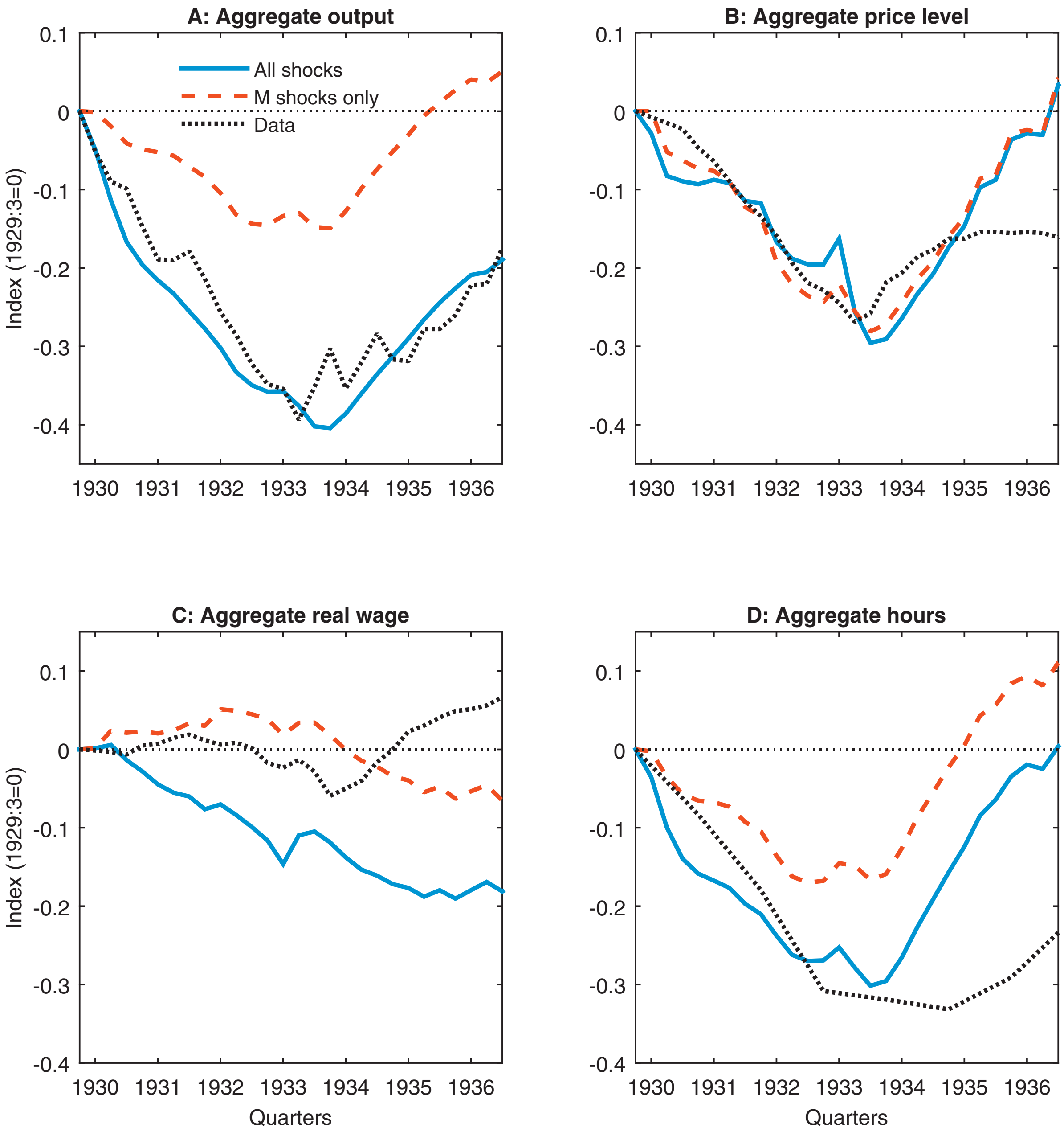

Fig. 2. The importance of monetary shocks: aggregates.

4.2. Are intermediates quantitatively important?

To quantify the effect of intermediates, we drop them from the model economy and repeat the experiment feeding in only the monetary shocks.[21]

While the aggregate outcomes are qualitatively similar to those of the benchmark economy, intermediates reduce the quantitative impact of monetary shocks. In the economy without intermediates, the fall in output from 1929 to 1933 is roughly 30% larger than in our benchmark (Fig. 4.A) as given by the ratio of the area between the solid blue and red dotted lines to the area between zero and the solid blue line up until 1933:2. This is driven by a larger decline in hours worked

[21] The only parameter values that change are those necessary to hit the steady-state targets (see Table 3). To isolate the impact of intermediates, the wage rigidity parameter, γ, is held fixed.

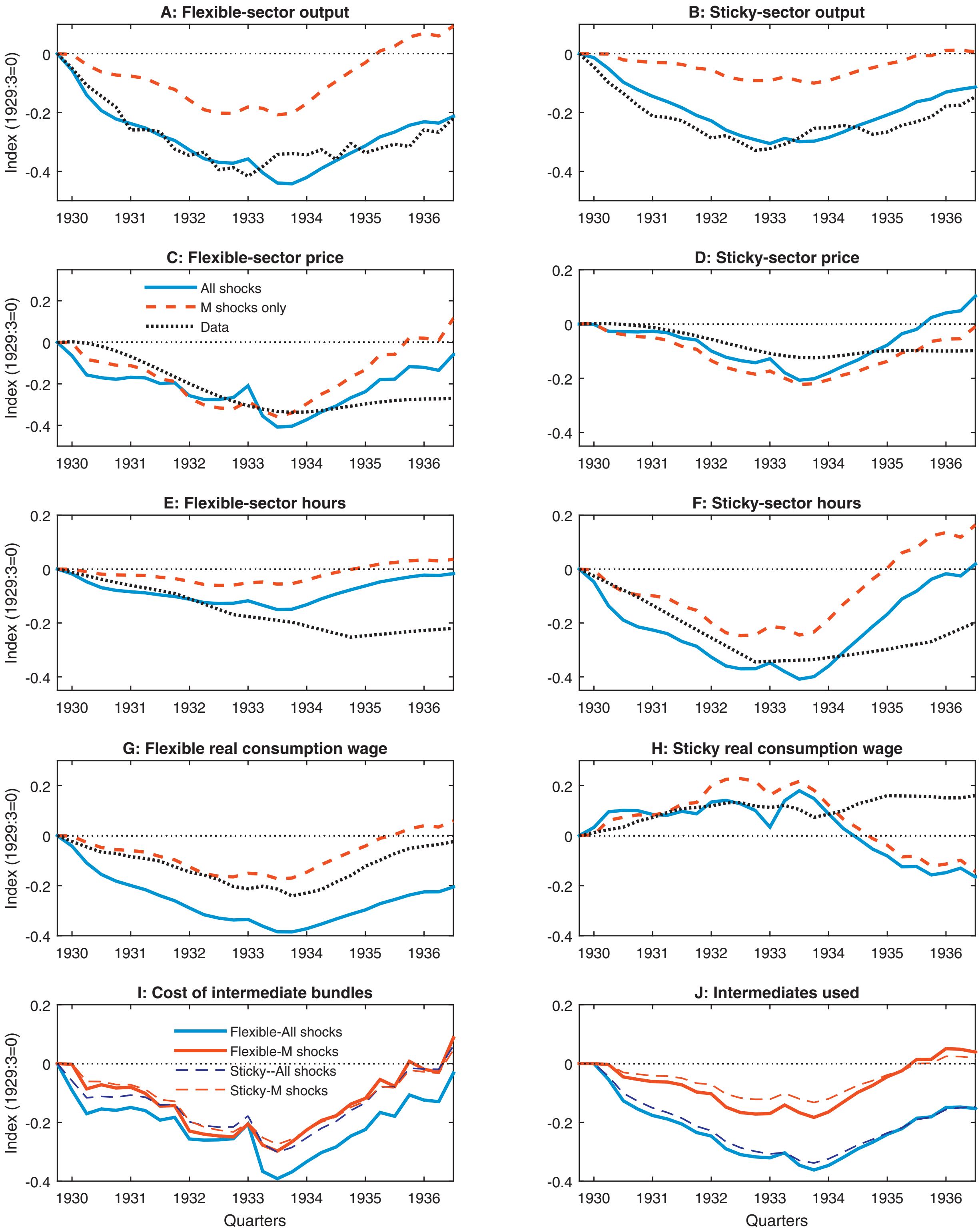

Fig. 3. The importance of monetary shocks: sectoral.

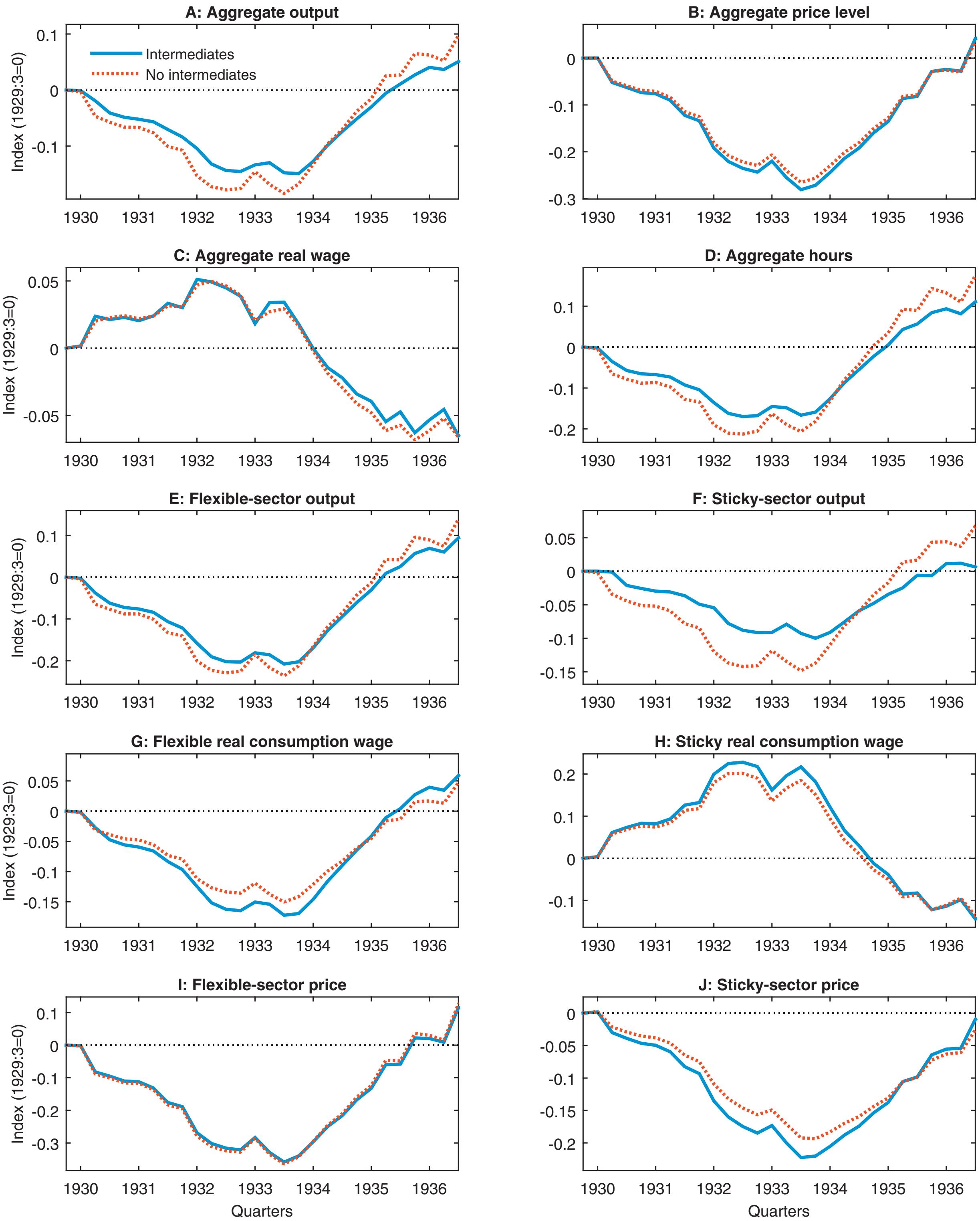

Fig. 4. The importance of intermediates.

(Fig. 4.D), despite a similar increase in the average real wage for all workers (Fig. 4.C), when compared to the economy with intermediates.

The sectoral variables follow a similar pattern, with sticky output and hours falling by more in the model without intermediates, despite a lower sectoral real product wage compared to the economy with intermediates. If the sticky real product wage is higher and sticky hours are determined by the firms' labor demand schedule, how can hours fall by less in the economy with intermediates? The key reason is that intermediate bundles use both goods. Since the flexible price falls relative to the sticky, the price of the intermediate bundle sticky-sector firms buy falls relative to their wage. This relative price drop acts as a positive shift in the marginal product of labor schedule by increasing the ratio of intermediates to labor, partially offsetting the higher real wages. This pass-through from the cheaper (relative to sticky labor) intermediates drives a larger decline in the sticky price (Fig. 4.J) than in the economy without intermediates.[22]

This experiment arguably underestimates the importance of intermediates. Holding the wage adjustment parameter, γ, fixed, the aggregate price level falls by more in the economy with intermediates. This follows from the quantity equation: since output falls by less with intermediates, the price level must fall by more when the money supply declines. This results in a smaller increase in the sticky real consumption wage (Fig. 4.H). If instead γ was recalibrated to match the same increase in the sticky real consumption wage, the output decline in the no-intermediates economy would would be even larger.

An alternative way to illustrate the quantitative importance of intermediates is by comparing our two-sector environments to a one-sector version based on the sticky sector.[23] For consistency, the wage rigidity parameter in the one-sector model is re-calibrated to generate the same economy-wide real wage from 1929 to 1933 as that of each of the two-sector economies (with and without intermediates). We find that the one-sector economy and the two-sector economy without intermediates generate similar output declines. However, output declines less in the economy with intermediates than in its one-sector counterpart.

These experiments regarding the quantitative importance of the substitution margins present in our model yield two main messages. First, sectoral heterogeneity in wage rigidity (alone) implies similar predictions for the impact of a contractionary monetary shock as an appropriately calibrated one-sector model. Second, intermediate linkages, combined with sectoral heterogeneity in wage rigidity, significantly reduce the contribution of monetary shocks to the Great Contraction.

4.3. Isolating the contribution of nominal wage rigidities

In the absence of nominal wage rigidities, monetary shocks do not impact real variables in the model. Nonetheless, nominal wage frictions could affect real variables through their interaction with other shocks. To isolate these channels from the interaction with contractionary monetary shocks, we feed in the calibrated shocks from the benchmark experiments into a version of the model where wages adjust to clear the labor markets in both sectors. While in steady-state real consumption wage rates are the same in the two sectors, the assumption that workers cannot move between sectors is maintained.[24]

The results are plotted in Fig. 5, with the dashed lines labeled *Competitive*, whereas the original experiment with the nominal wage friction is represented by the lines labeled *Benchmark*. Since the values of the monetary shocks are the same, the flexible wage version generates a larger decline in the price level than the benchmark. However, since there are no wage rigidities, this implies a larger fall in real wages, particularly in the (hitherto) sticky sector (see Fig. 5.C and D).

In the absence of nominal wage frictions, TFP shocks and liquidity shocks account for 52% of the fall in output over 1929:3 to 1933:2 (see Fig. 5.A). Since the benchmark accounts for the entire fall in output, this implies that nominal wage frictions, through their interactions with all the shocks (including monetary ones), account for 48% of the fall. The experiment with monetary shocks and nominal wage frictions in Section 4.1 found this interaction accounted for 33% of the fall in output. This leaves 15% (= 48−33)of the output contraction that can be attributed to the interaction between nominal wage frictions and TFP and liquidity shocks. This indicates that quantitative contribution of nominal wage rigidities via their interaction with other shocks is less than half as large as their interaction with monetary shocks.

4.4. Discussion: wage rigidity, intermediates and the great contraction

While our work's focus on intermediates is novel, it contributes to a larger debate over the quantitative importance of the interaction between monetary shocks and nominal wage rigidity in the U.S. Great Contraction. In a well-cited paper, Bordo et al. (2000) conclude this interaction accounts for roughly 70% of the output decline over 1929 to 1933. In contrast, Cole and Ohanian (2001), using a two-sector model, find these shocks account for roughly a sixth of the fall in output. Our analysis in Section 4.2 indicates these conclusions result primarily from the targeting of different real wage series. By reproducing the one-sector model of Bordo et al. (2000) while calibrating the wage rigidity parameter, γ, to match the economy-wide real wage in our two-sector model without intermediates, we find both environments imply a similar output decline.[25] However, targeting a real wage series similar to that used by Bordo et al. (2000) (close to our sticky-sector estimate) implies a much larger decline in output.

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[22] This mechanism is consistent with the discussion in Section 2.3.

[23] See theweb appendix for this experiment.

[24] Since the wage rigidity parameter does not impact our steady-state, our calibrated parameters continue to match the same targets as our benchmark.

[25] Herrendorf et al. (2014) reach a similar conclusion when they compare one- and two-sector models.

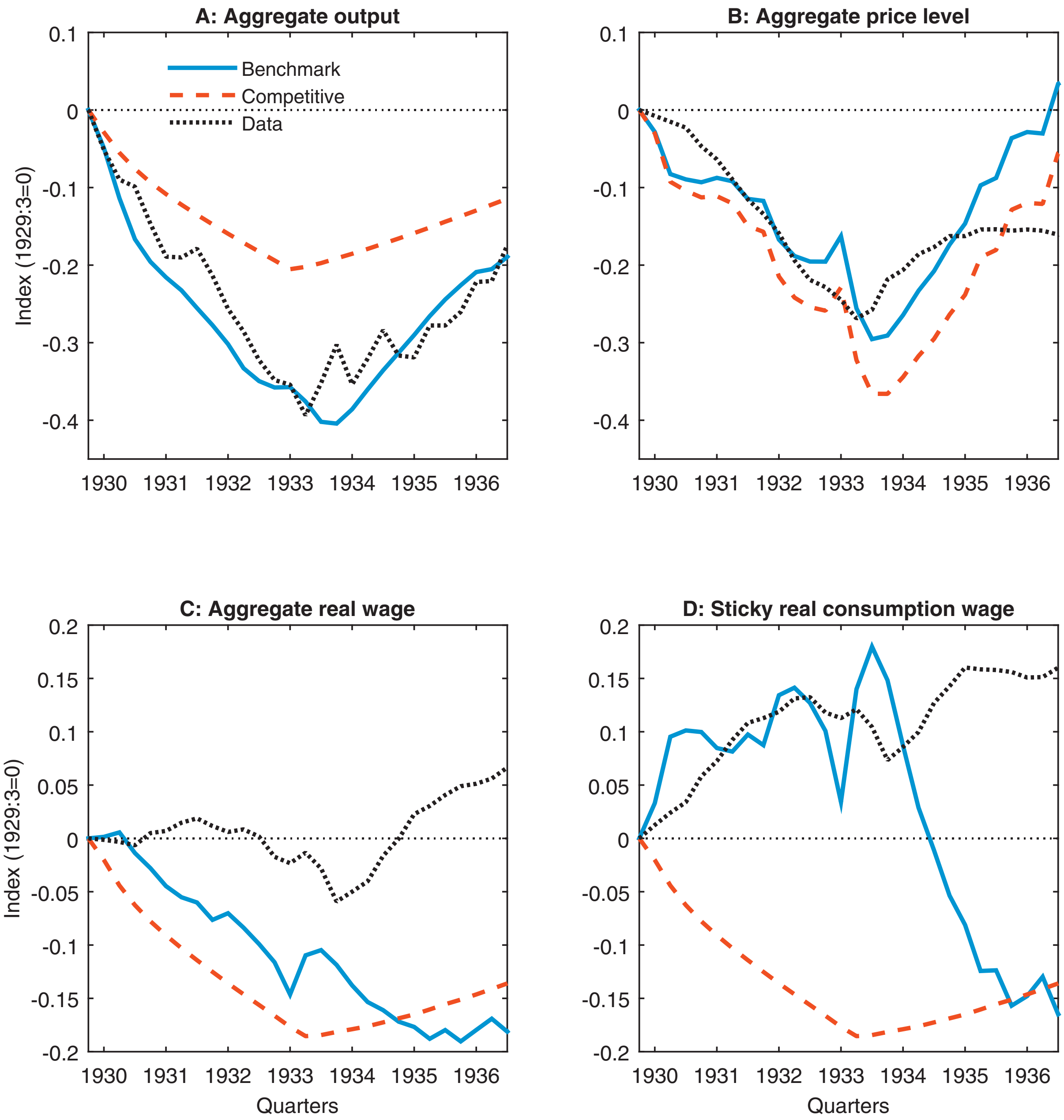

Fig. 5. The importance of nominal wage rigidities.

Although our benchmark experiment yields a similar quantitative result as that of Cole and Ohanian (2001), it addresses the key criticisms raised by Gertler (2001) and Bordo et al. (2001). First, our calibration results in a sticky-wage sector roughly twice as large as in Cole and Ohanian (2001). Second, nominal rigidities are incorporated in the sectoral model by "nesting" the one-sector framework of Bordo et al. (2000). Finally, the model abstracts from productivity growth which offsets the impact of wage rigidities.

Bordo et al. (2001) claim the two-sector model's prediction that a contractionary monetary shock implies a larger rise in the sticky-sector real consumption wage than in the real product wage is inconsistent with the data. They argue that since the wholesale price of manufactures fell by more than the GNP deflator, manufacturing real product wages (a proxy for the sticky sector) increased relative to real consumption wages over 1929–33. Hence, while sectoral heterogeneity in wage rigidities is consistent with the divergence in relative wages, it does not match relative prices.

Our work suggests that modeling intermediates largely resolves this critique. Using the implied value-added deflator plotted in Fig. 1.F to compute manufacturing's real product wages yields a rise of at most 4%, while real consumption wages (shown in Fig. 1.B) increase over 10%. This highlights the importance of accounting for intermediates during periods of large relative price shifts.

One dimension along which the two-sector model with intermediates cannot match the data is the sticky-sector's gross output price relative to the GNP deflator. In the data, the WPI for manufactured goods declines by more than the GNP deflator due, in large part, to the pass-through of intermediate prices. In the model, as the flexible share of intermediate goods in the sticky sector increases, this results in larger declines in the sticky gross output price. However, since the price of final output is a weighted average of the sectoral goods, the sticky sector's gross output price must decline by less than the price of the final good. With three or more sectors, one can construct input-output structures where the gross output price of at least one sticky-wage sector declines by more than the price of final output.

5. Conclusion

Contrary to conventional wisdom, we find that contractionary monetary shocks coupled with nominal wage rigidities were not a key factor in the Great Contraction. In our benchmark model with intermediates this mechanism can account for only a third of the output decline.

Our findings indicate the input-output structure of the economy is quantitatively important in reaching this conclusion. Comparing the two-sector model (without intermediates) with a one-sector version suggests that the Bordo et al. (2000) and Cole and Ohanian (2001) debate is largely about different views on the path of aggregate real wages, as our experiments yield 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 a smaller output decline than a one-sector model. However, TFP shocks have trouble matching key features of shifts in relative prices and quantities observed in sectoral data.

Finally, our work suggests that sectoral linkages interacted with other shocks, as contractionary monetary shocks fail to generate enough action in output and relative prices. We conjecture that modeling international trade, particularly in commodities which saw large price falls in this period, might be a fruitful avenue to pursue in future research regarding the cross-country spread of the Great Depression.

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Supplementary material

Supplementary material associated with this article can be found, in the online version, at 10.1016/j.jmoneco.2017.08.003

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