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AND

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Abstract

The standard two-sector New Keynesian model with durable goods is at odds with conventional wisdom and VAR evidence: Following a monetary shock, the model generates (i) either negative or no comovement across sectoral outputs, and (ii) aggregate neutrality of money when durable goods' prices are flexible. We reconcile theory with evidence by incorporating real wage rigidities into the standard model: As long as durable goods' prices are more flexible than nondurable goods' prices, we obtain positive sectoral comovement and, thus, aggregate non-neutrality of money.

JEL classification: E32; E51; E52.
Keywords: Durable Goods; Real Wage Rigidities; Comovement; Money.

1.   Introduction

Using the standard two-sector New Keynesian model, Barsky, House, and Kimball (BHK) (2007) eloquently demonstrate that the degree of price flexibility in the durable goods sector dictates the response of aggregate output to a monetary shock. When non-durable goods' prices are sticky but durable goods' prices are flexible, the outputs of the two sectors move in opposite directions, leaving aggregate output unchanged. Aggregate output, however, reacts significantly when nondurable and durable goods' prices are sticky. But then nondurables output remains virtually unchanged. In other words, the standard New Keynesian model generates either negative sectoral comovement and aggregate neutrality or no sectoral comovement.

Yet, vector autoregression (VAR) evidence overwhelmingly suggests positive comovement in the aftermath of a monetary shock. Two stylized facts we read from several VAR studies are that (i) aggregate output and sectoral outputs move together and that (ii) the price and output of the durable sector react more strongly than those of the nondurable sector.[1] Moreover, the distinctive feature of a business cycle is that the outputs of many sectors of the economy move together. Therefore, the New Keynesian model, the workhorse in analysis of monetary business cycles, needs to be reconciled with these facts. We do so by simply introducing real wage rigidities into an otherwise standard two-sector New Keynesian model.

One supporting argument for the existence of real wage rigidities flows from the Dunlop-Tarshis observation – that hours worked and real wages are uncorrelated (Dunlop 1938 and Tarshis 1939). Regarding the dynamic effects of monetary shocks on the real wage, we report VAR evidence that the reaction of the real wage is rather muted, confirming the findings of Altig, Christiano, Eichenbaum, and Lindé (2011), Amato and Laubach (2003), and Christiano, Eichenbaum, and Evans (2005).[2] As a modeling fea-

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[1]See, for example, Erceg and Levin (2006), and Monacelli (2009). BHK (2003), using Romer dates, confirm the same evidence. In Section 2., we report VAR evidence of sectoral comovement.

[2]In their thorough survey of wage rigidities and cyclical wage adjustment, Basu and House (2016) distinguish among different measures of the real wage using longitudinal microdata. In particular, they analyze the average real wage, the average real wage adjusted by labor force composition (as in Elsby, Shin, and Solon 2016 and Solon, Barsky, and Parker 1994), the real wage of new hires (as in Haefke, Sonntag, and van Rens 2013), and the user cost of labor (as in Kudlyak 2014). Basu and House document that, unlike the average real wage, the other three measures are cyclical and respond significantly to monetary shocks. Nevertheless, the standard two-sector new Keynesian model, analyzed in BHK (2007) and that we augment in this paper, assumes a simple spot labor market with homogeneous workers and full employment. The model abstracts from nontrivial hiring decisions, implicit labor contracts, and changes in the labor force composition. Thus, the average real wage is the empirical counterpart of the real wage in the model.

ture, the crucial role of real wage rigidities in propagating shocks has also long been recognized. In his review of business cycle theory, Lucas (1981) argues that models relying on systematic real wage movements are *doomed to failure*. Ball and Romer (1990) show that real wage rigidities amplify the effects of nominal rigidities. Hall (2005) shows that real wage rigidities generate volatile unemployment and vacancies in the context of search and matching models. Blanchard and Gali (2007) show that real wage rigidities generate a trade-off between output and inflation stabilization. More recently, Shimer (2012) shows that real wage rigidities can account for jobless recoveries.

To model real wage rigidities, we follow Blanchard and Gali (2007): We modify the labor supply equation of the standard New Keynesian model by assuming that the real wage is a weighted sum of the lagged real wage and the marginal rate of substitution between consumption and leisure. Without any other change to the standard model, this simple modification removes the above-mentioned puzzling theoretical results, i.e., it obtains non-neutral money and positive comovement between sectoral outputs. Using our modification, we first show that when durable goods' prices are *perfectly flexible*, (i) durables output reacts sharply to monetary shocks; (ii) aggregate output and non-durables output react similarly and less dramatically than durables output; and (iii) the durable price index reacts more strongly than the nondurable price index. Using our modification we show that these three results also hold as long as durable goods' prices are (slightly) *more flexible* than nondurable goods' prices.[3] We then contrast the implications of real wage rigidities with those of nominal wage rigidities a la Calvo (1983). Both types of rigidities are alternative forms of labor market frictions. Both are based on ad hoc assumptions, and both solve the comovement problem. Yet, their implications differ in the response of the real wage. In the model with nominal wage rigidities, the real wage *decreases* in response to a monetary *expansion*, contrasting with the aforementioned evidence and conventional wisdom. The model with real wage rigidities, however, guarantees a data-consistent response of the real wage.

The economic intuition behind our results is also simple: Real wage rigidities decrease the elasticity of marginal costs, suppressing the reaction of prices in both sectors. This, in turn, renders positive comovement and aggregate non-neutrality possible.

Our reconciliation of the two-sector New Keynesian model is not the first. Bouakez, Cardia, and Ruge-Murcia (2011) and Sudo (2012) argue that input–output inter-

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[3]The condition that durable goods' prices are more flexible than nondurable goods' prices is in line with the empirical evidence documented in the literature on micro-price data (for a survey, see Klenow and Malin 2010).

actions help solve the comovement problem. In the models employed in both papers, because the production of nondurable goods requires durable goods as inputs, and vice versa, and because nondurable goods' prices are sticky, the pass-through of the monetary impulse into durable goods' prices is limited. Accordingly, durables output can move in the same direction as the change in aggregate demand. Carlstrom and Fuerst (2010) document that adding three features – nominal wage rigidities, adjustment costs in housing construction, and habit formation in consumption – into a New Keynesian model without capital brings it closer to reality. In their model, nominal wage rigidities are enough to generate sectoral comovement in the first quarter.[4] But adjustment costs in housing construction are required to generate sectoral comovement for more than one quarter. Monacelli (2009) suggests credit market frictions to account for positive sectoral comovement, but Sterk (2010) shows that the type of friction Monacelli employs exacerbates the comovement problem. Tsai (2016) emphasizes the cost channel of monetary policy. He shows that once firms require working capital – through which monetary policy directly affects marginal costs – and households form habit in nondurables consumption, sectoral outputs comove.

We believe that our approach has the advantages of parsimony and robustness. The way we modify the standard model is very simple: We replace only one equation to obtain our model with real wage rigidities. Our results are robust to all reasonable parameter values.

In the next section, we start by documenting VAR evidence for the US economy. To make our paper self-contained and our model easy to compare to that analyzed in BHK (2007), in Section 3., we briefly present their benchmark model, which, hereafter, we call *the standard model.* In Section 4., we incorporate real wage rigidities by simply modifying the labor supply equation of the standard model. In the same section, we also analytically assess the role of real wage rigidities in the neutrality and comovement problems. In Section 5., using the results of our numerical simulations, we evaluate the role of real wage rigidities and the role of sectoral price stickiness, and compare the model with real wage rigidities to a model with nominal wage rigidities. In Section 6., we offer some concluding remarks.

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[4]In Carlstrom and Fuerst (2010), when nominal wages are reset, on average, every three quarters, the response of durables output to monetary shocks is a thousand times larger than that of nondurables output. The main reason for this outcome is that their model abstracts from capital, implying that marginal costs solely depend on rigid labor costs. Thus, monetary shocks affect marginal costs vaguely and sectoral outputs strongly. If their model included capital like the model of BHK, nominal wage rigidities would generate a realistic response of sectoral outputs and sectoral comovement for more than one quarter. In that case, however, as we show in Section 5.2.4., the response of the real wage opposes the evidence.

2. VAR Evidence

We employ a seven-variable VAR to assess the dynamic effects of monetary shocks on the outputs and prices of durables and nondurables, and on the real wage in the US economy.[5] Figure 1 presents the impulse responses obtained from our VAR. After a negative monetary shock, (i) the outputs of durables and nondurables decrease; (ii) the decrease in durables output far exceeds that in nondurables; (iii) durable goods' prices decrease more than nondurable goods' prices; and (iv) the real wage decreases, but its response is statistically insignificant. These results are in line with previous studies. The first three results confirm the findings of BHK (2003), Erceg and Levin (2006), and Monacelli (2009). The fourth result confirms findings of Altig, Christiano, Eichenbaum, and Lindé (2011), Amato and Laubach (2003), and Christiano, Eichenbaum, and Evans (2005).

All this evidence suggests that a monetary model with durables and nondurables has to generate comovement across sectoral outputs. It further has to guarantee that the real wage either slightly comoves with output or does not move in response to monetary policy shocks. To reconcile theory with these facts, in Section 4., we incorporate real wage rigidities into the standard model.

3. The Model

3.1. The Household

The household supplies labor, n_t, and capital, k, to the firms in the durable and nondurable sectors. The stock of capital is fixed. Because production factors are perfectly mobile, the prices of these factors do not differ across sectors. The household chooses the consumption of nondurable goods, c_t, the stock of durable goods, d_t, labor supply, and purchases of durable goods, x_t, to maximize utility

$$\mathbb{E}_t \left[\sum_{i=0}^{\infty} \beta \left(\psi_c \ln c_{t+i} + \psi_d \ln d_{t+i} - \frac{\phi}{2} n_{t+i}^2 \right) \right],$$

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[5]The data, retrieved from the US Bureau of Economic Analysis, FRED, and Thomson Reuters Datastream, are quarterly from 1965:3 to 2016:2. We specify (i) durables output as the Törnqvist index of the sum of personal consumption expenditure on durable goods and investment housing; (ii) nondurables output as the Törnqvist index of the sum of personal consumption expenditures on nondurable goods and services; (iii) sectoral prices as the corresponding Törnqvist indices; and (iv) the real wage as real compensation per hour in the nonfarm business sector. Our VAR also includes the CRB commodity spot price index (to address the 'price puzzle') and the federal funds rate. All variables, except for the federal funds rate, are in logs. We estimate the VAR in levels with a constant and four lags.

We thank two anonymous referees for suggesting that we employ a VAR that includes the real wage.

subject to the budget constraint

$$\frac{p_{c,t}c_t}{p_t} + \frac{p_{x,t}x_t}{p_t} + \frac{m_t}{p_t} \leq w_t n_t + \Pi_t + t_t + \frac{m_{t-1}}{p_t} + r_t k,$$

and the law of motion for the stock of durable goods

$$d_t = x_t + (1-\delta)d_{t-1}, \tag{1}$$

where w_t, Π_t, t_t, and r_t are the real wage, the real dividend income from owning intermediate firms, real lump-sum transfers, and the real rental price of capital, respectively; m_t is nominal money balances; p_t is the GDP deflator; and $p_{c,t}$ ($p_{x,t}$) is the price index of the composite nondurable (durable) good. Regarding the parameters, $\delta > 0$ is the rate of depreciation of the stock of durable goods, $0 < \beta < 1$ is the discount factor, $\psi_c > 0$ and $\psi_d > 0$ are the weights of nondurable and durable goods in the subutility, and $\phi > 0$ measures the disutility from labor.[6]

Let λ_t and μ_t be the Lagrange multipliers associated with the constraints above. The first-order conditions for the household's problem are then

$$\psi_c c_t^{-1} = \frac{\lambda_t p_{c,t}}{p_t}, \tag{2}$$

$$\mu_t = \psi_d d_t^{-1} + \beta(1-\delta)\mathbb{E}_t[\mu_{t+1}], \tag{3}$$

$$\phi n_t = \lambda_t w_t, \tag{4}$$

$$\frac{\lambda_t p_{x,t}}{p_t} = \mu_t. \tag{5}$$

3.2. Firms

Within both sectors, there are perfectly competitive final good producers and monopolistically competitive intermediate good producers. Because the structure of production is symmetric across sectors, below, we use a generic letter, $g = c, x$, to denote any of the sectors.

The production technology for the final good g_t is given by $g_t = \left[\int_0^1 g_t(i)^{\frac{\epsilon-1}{\epsilon}}\mathrm{d}i\right]^{\frac{\epsilon}{\epsilon-1}}$, where $g_t(i)$ is a differentiated intermediate good. The elasticity of substitution among intermediate goods, $\epsilon > 1$, is assumed to be the same in both sectors. Denoting the price of good i in sector g by $p_{g,t}(i)$, profit maximization of final good producers implies

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[6]The felicity $\psi_c \ln c_t + \psi_d \ln d_t - \frac{\phi}{2}n_t^2$ implies that the intertemporal elasticity of substitution, the intratemporal elasticity of substitution between durables and nondurables consumption, and the Frisch labor supply elasticity equal one.

the demand function

$$g_t(i) = \left(\frac{p_{g,t}(i)}{p_{g,t}}\right)^{-\epsilon} g_t. \tag{6}$$

The production technology for an intermediate good is given by

$$g_t(i) = k_{g,t}(i)^{\alpha} n_{g,t}(i)^{1-\alpha}, \tag{7}$$

where $k_{g,t}(i)$ and $n_{g,t}(i)$ are the capital and labor services hired by firm i operating in sector g. Prices are set a la Calvo (1983). Specifically, each period, only a $1 - \theta_g$ fraction of intermediate good producers can reset their prices. Then, the profit maximization problem of firm i in sector g can be written as

$$\max \mathbb{E}_t \left[\sum_{s=0}^{\infty} (\beta\theta_g)^s \frac{\lambda_{t+s}}{\lambda_t} \left(\frac{p_{g,t}(i)g_{t+s}(i)}{p_{t+s}} - w_{t+s}n_{g,t+s}(i) - r_{t+s}k_{g,t+s}(i)\right)\right],$$

subject to eqs. 6 and 7. The first-order conditions imply the demands for labor and capital services

$$w_t = (1-\alpha)\frac{g_t(i)}{n_{g,t}(i)}mc_t, \tag{8}$$

$$r_t = \alpha\frac{g_t(i)}{k_{g,t}(i)}mc_t, \tag{9}$$

and the optimal price of good i

$$p_{g,t}^*(i) = \frac{\epsilon}{\epsilon - 1}\frac{\sum_{s=0}^{\infty}(\theta_g\beta)^s\mathbb{E}_t[\lambda_{t+s}p_{g,t+s}^{\epsilon}g_{t+s}mc_{t+s}]}{\sum_{s=0}^{\infty}(\theta_g\beta)^s\mathbb{E}_t[\lambda_{t+s}p_{g,t+s}^{\epsilon}g_{t+s}p_{t+s}^{-1}]}, \tag{10}$$

where mc_t is the real marginal cost.[7] Because of the symmetry across intermediate firms within each sector, intermediate firms that can reset their prices set the same price. Therefore, the sectoral price index is

$$p_{g,t}^{1-\epsilon} = \theta_g p_{g,t-1}^{1-\epsilon} + (1-\theta_g)p_{g,t}^{*1-\epsilon}. \tag{11}$$

3.3. Aggregation, Real GDP, and Money

At any point in time, production factors can be divided between the durable and non-durable sectors according to $n_t = n_{c,t} + n_{x,t}$ and $k = k_{c,t} + k_{x,t}$, where $n_{c,t}$ and $k_{c,t}$ ($n_{x,t}$ and $k_{x,t}$) are labor and capital hired in the nondurable (durable) sector. Market clearing

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[7]Note that the real marginal cost is the same in both sectors. This stems from the Cobb-Douglas production function and the perfect mobility of production factors.

implies $n_{g,t} = \int_0^1 n_{g,t}(i)\mathrm{d}i$ and $k_{g,t} = \int_0^1 k_{g,t}(i)\mathrm{d}i$ for $g = c, x$.

The demand for money is motivated by simply assuming that it is proportional to nominal GDP

$$m_t = p_t y_t, \tag{12}$$

where $p_t = \frac{p_{c,t}c_t + p_{x,t}x_t}{y_t}$ is the GDP deflator and $y_t \equiv \bar{p}_c c_t + \bar{p}_x x_t$ is real GDP. Any difference in the money supply from one period to the next is distributed to the household through lump-sum transfers $p_t t_t = m_t - m_{t-1}$. The (log) growth rate of the money supply is simply a mean-zero i.i.d. random variable:

$$\ln \frac{m_t}{m_{t-1}} = \varepsilon_t. \tag{13}$$

4.   Real Wage Rigidities

In our model with real wage rigidities, the real wage differs from the marginal rate of substitution between consumption and leisure – i.e., eq. 4 does not hold. To model real wage rigidities, we follow Blanchard and Gali's (2007) ad hoc but parsimonious formulation. Namely, we assume that the (log) real wage for which the household members are willing to work is a weighted sum of the lagged (log) real wage and the (log) marginal rate of substitution between consumption and leisure

$$\ln w_t = \gamma \ln w_{t-1} + (1 - \gamma) \ln mrs_t, \tag{14}$$

where $0 \leq \gamma \leq 1$ measures the degree of real wage rigidities in the economy, and mrs_t is the marginal rate of substitution between consumption and leisure, $mrs_t \equiv \frac{\phi n_t}{\lambda_t} = \frac{p_{x,t}\phi n_t}{p_t \mu_t}$. That is, to obtain our model, we replace eq. 4 in the standard model with eq. 14.

Next, we analytically assess the role of real wage rigidities in the comovement problem arising under flexibly priced durable goods. Following the neat analysis of BHK (2007), we display a crucial property of the shadow value of durable goods: μ_t is nearly invariant. To this end, we rewrite eq. 3 as

$$\mu_t = \psi_d \mathbb{E}_t \left[\sum_{i=0}^{\infty} (\beta(1 - \delta))^i d_{t+i}^{-1} \right].$$

Two remarks are in order about the shadow value of durable goods. First, the last equation states that the shadow value of durable goods is the expected sum of the discounted value of the marginal utilities of durable goods. With low values of δ, tempo-

rary changes in the marginal utility of durable goods have insignificant effects on their shadow value. Second, because the stock-flow ratio of durable goods is high ($d/x = 1/\delta$ in the steady state), the effect of purchases of durable goods on the stock is also insignificant. These two properties justify treating the shadow value of durable goods as constant in our analytical exposition (i.e., $\mu_t \approx \mu$).

To continue with our analysis of the role of real wage rigidities, we first rewrite eq. 14 as $\left(\frac{w_t^{1/\gamma}}{w_{t-1}}\right)^{\frac{\gamma}{1-\gamma}} = mrs_t = \frac{p_{x,t}\phi n_t}{p_t \mu_t}$. To substitute $p_{x,t}/p_t$ out from the last expression, recall that durable goods' prices are flexible and that the capital-labor ratio is common to all firms, implying that $\frac{p_{x,t}}{p_t} = \frac{\epsilon}{\epsilon-1}mc_t = \frac{\epsilon}{\epsilon-1}\frac{w_t}{(1-\alpha)}\left(\frac{n_t}{k}\right)^\alpha$. This, together with $\mu_t \approx \mu$, enables us to rewrite eq. 14 as

$$\left(\frac{w_t}{w_{t-1}}\right)^{\frac{\gamma}{1-\gamma}} \approx \frac{\epsilon\phi k^{-\alpha}}{(\epsilon-1)(1-\alpha)\mu}n_t^{1+\alpha}. \tag{15}$$

It is now easy to see that in the standard model, i.e., $\gamma = 0$, the only solution to eq. 15 is invariant aggregate employment. Moreover, because $n_t = n_{c,t} + n_{x,t}$, positive comovement between sectoral employment levels is impossible. If $\gamma > 0$, however, aggregate employment moves in the direction of the change in the real wage, and sectoral employment levels may move together. The economic intuition is straightforward. Once the real wage is rigid, marginal costs, which are common to all sectors, become less sensitive to changes in aggregate demand. This, in turn, limits the extent to which prices in both sectors react to changes in aggregate demand, rendering it possible for the output in both sectors to move together.

5. Numerical Simulations

5.1. Calibration

We start by calibrating the parameters. Our choice of parameter values, summarized in Table 1, is the same made by BHK (2007), except that we calibrate our model to quarterly data. The comovement and aggregate neutrality problems are immense when durable goods' prices are flexible. For this reason, we also assume a half-life of two quarters for nominal stickiness in the nondurable sector and that durable goods' prices are flexible, implying that $\theta_c = 0.6534$ and $\theta_x = 0$. Yet, in Section 5.2.3., we consider a wide range of values for θ_c and θ_x.[8]

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[8]In all our experiments, we study the response of key macroeconomic aggregates to a permanent increase in the money supply: The growth rate of the money supply, ε_t, assumes 0.01 at $t = 1$ and zero

We are not aware of direct empirical evidence for the parameter governing the degree of real wage rigidities. In the literature, the values assumed range from 0.5 to 1. Blanchard and Gali (2007) set $\gamma = 0.9$ in their baseline calibration and experiment with both $\gamma = 0.8$ and $\gamma = 0.5$. Duval and Vogel (2007) experiment with $\gamma = 0.79$ and $\gamma = 0.93$. Shimer (2012) assumes that the real wage rate is constant in business cycle frequencies, implying that $\gamma = 1$. To set a benchmark value for γ, we target the standard deviation of US GDP in a version of our model that also allows for total factor productivity shocks. To produce a standard deviation of GDP of 1.72%, we choose $\gamma = 0.9546$.[9] Because this parameter is key to our discussion, we start by assuming not a single value but a range: $\gamma \in [0, 1]$.

5.2.   Results

5.2.1.   The Role of γ

First, we study how the degree of real wage rigidities, γ, affects the responses of four selected variables – GDP, the real wage, durables output, and nondurables output – to a permanent 1% increase in the money supply.[10] To this end, we compute the first-quarter and the first-year (quarterly averaged) responses of these four variables for $\gamma \in [0, 1]$ with a grid of 0.01. Figure 2 illustrates the two measures as a function of γ (first-quarter response as a solid line; first-year response as a dashed line).

The graphs related to GDP and the two sectors' outputs reveal that as γ increases, both problems, aggregate neutrality and negative sectoral comovement, cease to exist. Simultaneously, the first-quarter and the first-year responses of the relative real wage approach empirically plausible values.

The response of GDP is always positive and increasing in γ. Specifically, the first-year response starts increasing at a faster rate around $\gamma = 0.8$; for $\gamma \in [0.8, 1]$ aggregate

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thereafter. Thus the monetary shock expands the money supply once-and-for-all by 1%. The parameters ϕ and ϵ do not play any role in the log-linear model.

[9] Specifically, we assume that the production technology for an intermediate good is given by $g_t(i) = a_t k_{g,t}(i)^\alpha n_{g,t}(i)^{1-\alpha}$, where a_t is total factor productivity and follows $\log(a_t) = 0.95 \log(a_{t-1}) + \nu_{a,t}$. The growth rate of the money supply, ε_t, follows $\log(\varepsilon_t) = 0.49 \log(\varepsilon_{t-1}) + \nu_{m,t}$. The innovations, $\nu_{m,t}$ and $\nu_{a,t}$, are mean-zero i.i.d. random variables with standard deviations of 0.89% and 0.7%. The correlation between the innovations is set to zero. The HP smoothing parameter is set to 1600. Accordingly, 85% of the deviations in output are due to shocks to total factor productivity.

[10] For the sake of brevity, we select only four variables. We select GDP to address aggregate neutrality; we select the sectoral outputs to address the comovement problem; and we select the relative real wage to address real wage rigidities.

non-neutrality is significant. The interval $\gamma \in [0.8, 1]$ also suffices to generate positive comovement between the sectoral outputs in first-quarter responses. Regarding first-year responses, the threshold value of γ generating positive comovement between sectoral outputs is 0.93. In the standard model, i.e., when $\gamma = 0$, the first-quarter response of the real wage is 70 times higher than that of aggregate output. By contrast, the response of the relative real wage decreases in γ, as implied by the law of motion of the real wage, eq. 14. With our baseline calibration, $\gamma = 0.9546$, the first-quarter response of the real wage is 10% of that of aggregate output.

5.2.2. Impulse Response Functions

To gain further intuition, in Figure 3, we contrast the standard model ($\gamma = 0$, solid line) with the model with real wage rigidities ($\gamma = 0.9546$, dashed line) in terms of impulse response functions. Again, the innovation is a permanent 1% increase in the money supply, and durable goods' prices are flexible.

In both models, the impulse response functions for the durable sector illustrate that the reaction of output is the mirror image of that of the price index. The contrast is primarily observed in the impact effects. In the model with real wage rigidities, the durable price index, on impact, undershoots its long-run value by 0.2%. In the standard model, however, it overshoots by 1.5%. Because of these temporary changes in prices, in the standard model, durables output decreases on impact by 5%; with real wage rigidities, it increases by 0.85%. Thus, the most striking aspect of incorporating real wage rigidities into the standard model is the reversal of the durable output response: The household switches expenditure from nondurable to durable goods. This switch in expenditure also attenuates the impact responses of nondurables output and the nondurables price index.

Obviously, the key variable to understand the under- and overshooting of the durables price indices, and, thus, the reversal of the durables output response, is the reaction of the real wage. In the model with real wage rigidities, the response of the real wage is muted, being in line with the VAR evidence reported in Section 2. above and in other studies (see, for example, Altig et al. 2011, Amato and Laubach 2003, and Christiano et al. 2005). With real wage rigidities, thanks to this muted response of the real wage, the durables price index can undershoot its long-run value, allowing durables output to react positively on impact to monetary expansions.

In the standard model, because the sectoral outputs move in opposite directions,

GDP, which is the weighted average of the sectoral outputs, is essentially unchanged. In the model with real wage rigidities, the responses of the sectoral outputs increase simultaneously, and, thus, the response of GDP also increases. In short, with real wage rigidities, we obtain non-neutral money and positive comovement between sectoral outputs.

Ordering the magnitudes of peak-responses of the sectoral variables and GDP reveals that in the model with real wage rigidities, the following results obtain: (i) Durables output reacts sharply to monetary shocks; (ii) GDP and nondurables output react similarly and less dramatically than durables output; and (iii) the durables price index reacts more strongly than the nondurables price index. These results are also in line with the stylized facts documented in Section 2. above, BHK (2003), Erceg and Levin (2006), and Monacelli (2009).

5.2.3. The Roles of θ_c and θ_x

As in the majority of the related literature, in our evaluation thus far, we have only considered the case of flexibly priced durable goods.[11] In their survey of the micro-price studies analyzing data that underlie US consumer and producer price indices, Klenow and Malin (2010) document that while price flexibility increases with durability, durable goods' prices, on average, are not perfectly flexible.

To detect how the imperfect flexibility of durable goods' prices affects the nature of comovement in both models we evaluate, we first compute the first-year effects of a permanent increase in the money supply on nondurables and durables outputs for all possible combinations of ten equally distanced values of θ_c and θ_x in the range $[0.1, 0.9]$. To produce a basic summary statistic of sectoral comovement, we then compute the ratio of the first-year multiplier of nondurables output to that of durables output; positive and negative values imply positive and negative comovement, respectively. Focusing only on the cases in which durable goods' prices are more flexible than nondurable goods' prices, $\theta_x \leq \theta_c$, Table 2 presents how our summary statistic changes with the sectoral price flexibility in the standard model (Panel A) and in the model with real wage rigidities (Panel B).[12] In Table 2, we use bold-faced type to highlight the cases in

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[11]See Bouakez et al. (2011), Carlstrom and Fuerst (2010), and Sudo (2012). Bouakez et al. also experiment with a half-life of one month for nominal stickiness in the durable sector.

[12]In the case of equal flexibility, $\theta_x = \theta_c$, for the two models considered, the statistic ranges between 0.009 and 0.035, implying the lack of sectoral comovement. In the case of extra flexibility in the nondurable goods' prices, $\theta_x > \theta_c$, again, for the two models considered, the statistic ranges between -0.020 and -0.199, implying negative comovement.

which the statistic falls into the empirically plausible range of [10%,50%] (BHK 2003, Erceg and Levin 2006, and Monacelli 2009).

Regarding the standard model, from Panel A of Table 2, we observe that in 30 of all 36 cases considered, we obtain negative comovement. In two cases, we obtain positive comovement, but the effect on nondurables output exceeds that on durables output. Only in four cases is our statistic within the empirically plausible range. Regarding the model with real wage rigidities, from Panel B of Table 2, we observe that in all cases, we obtain positive comovement, and the response of nondurables output is less than that of durables output. In 21 cases, the statistic lies within the empirically plausible range.

Thus, Table 2 confirms our previous argument that in the model with real wage rigidities, the comovement problem disappears as long as durable goods' prices are more flexible than nondurable goods' prices.

5.2.4. Real Versus Nominal Wage Rigidities

In this section, we contrast the implications of real wage rigidities with those of nominal wage rigidities. To embed nominal wage rigidities into the standard model, we make two assumptions. First, each household member supplies differentiated labor, with ϵ_n being the elasticity of substitution between differentiated labor types. Second, nominal wages are set a la Calvo (1983). Specifically, in each period, only a $1 - \theta_n$ fraction of the nominal wages can be reset. Under these two assumptions, utility maximization implies that the optimal nominal wage, W_t^*, is given by

$$(W_t^*)^{\epsilon_n+1} = \left(\frac{\epsilon_n \phi}{\epsilon_n - 1} \right) \frac{\mathbb{E}_t \left[\sum_{s=0}^{\infty} (\theta_n \beta)^s \left(W_{t+s}^{\epsilon_n} n_{t+s} \right)^2 \right]}{\mathbb{E}_t \left[\sum_{s=0}^{\infty} (\theta_n \beta)^s \lambda_{t+s} W_{t+s}^{\epsilon_n} n_{t+s} p_{t+s}^{-1} \right]}, \tag{16}$$

and the law of motion for the aggregate nominal wage, W_t, follows

$$W_t^{1-\epsilon_n} = \theta_n W_{t-1}^{1-\epsilon_n} + (1 - \theta_n)(W_t^*)^{1-\epsilon_n}. \tag{17}$$

Our choice of values for ϵ_n and θ_n is standard in the literature. We set $\epsilon_n = 11$, implying that the real wage in the steady state is 10% higher than the marginal rate of substitution between consumption and leisure. We set $\theta_n = 0.67$, implying that, on average, nominal wages are reset every three quarters.

Figure 4 presents the impulse response functions for three specifications: Two variants of our model with real wage rigidities, one with our benchmark rigidity ($\gamma = 0.9546$;

solid line) and one with full rigidity ($\gamma = 1$; dashed line), and the model with nominal wage rigidities (plus-marked line). In all three specifications, durable goods' prices are flexible. As before, the innovation is a permanent 1% increase in the money supply.

Both calibrations of our model with real wage rigidities solve the comovement puzzle and, thus, generate aggregate non-neutrality of money. The *quantitative* drawback under the benchmark calibration is the negative response of durables output after the fourth quarter and of GDP after the sixth quarter. Other solutions yield similar outcomes (see, for example, Carlstrom and Fuerst 2010, Sudo 2012, and Tsai 2016), but it is more pronounced in our model. This drawback, however, disappears with a higher degree of real wage rigidity. In the extreme case of full real wage rigidity (as in Shimer 2012), the responses of durables output and GDP are never negative following a monetary expansion.

The model with nominal wage rigidities also solves the comovement problem. But it has a *qualitative* drawback: After a monetary expansion, the real wage decreases.[13] As we noted in Section 2., the real wage either slightly comoves with aggregate output or does not comove. In solving a puzzle, the model with nominal wage rigidities generates a new one.

6.   Concluding Remarks

In this paper, we argue that real wage rigidities are a missing element in the standard two-sector New Keynesian model. In the standard model, for aggregate output to increase following a monetary expansion, durable goods' prices must be sticky. If durable goods' prices are flexible, and nondurable goods' prices are sticky, then the standard model predicts negative sectoral comovement in addition to aggregate neutrality. If both durable and nondurable goods' prices are sticky, then the standard model predicts no sectoral comovement. By incorporating real wage rigidities into the standard model, we obtain positive sectoral comovement and, thus, aggregate non-neutrality as long as durable goods' prices are more flexible than nondurable goods' prices.

Real wage rigidities have also been advocated as a missing element in other contexts (Blanchard and Gali 2007, Hall 2005, and Shimer 2012, just to name a few recent examples). Our research thus justifies our agreement with Shimer (2012) that wage rigidities

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[13]Basu and House (2006) report similar counterfactual implications of nominal wage rigidities when they evaluate a medium-scaled New Keynesian model augmented to account for implicit contracts and changes in the labor force composition.

should be placed back at the center of research on macroeconomics. This paper is a contribution to that program.

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Table 1: Benchmark Parameters

|	
Discount factor:	$\beta = 0.9951$
Rate of depreciation:	$\delta = 0.0123$
Relative weight in subutility:	$\psi_c/\psi_d = 3\delta/(1 - \beta(1 - \delta))$
Capital share:	$\alpha = 0.35$
Degree of price stickiness	
in the nondurable sector:	$\theta_c = 0.6534$
in the durable sector:	$\theta_x = 0$
Degree of real wage rigidities:	$\gamma = 0.9546$

Table 2: Sectoral Comovement & Price Stickiness

Panel A: Standard Model ($\gamma = 0$)

	$\theta_c = 0.2$	$\theta_c = 0.3$	$\theta_c = 0.4$	$\theta_c = 0.5$	$\theta_c = 0.6$	$\theta_c = 0.7$	$\theta_c = 0.8$	$\theta_c = 0.9$
$\theta_x = 0.1$	-0.746	-0.458	-0.405	-0.383	-0.372	-0.365	-0.361	-0.363
$\theta_x = 0.2$		-6.730	-0.613	-0.468	-0.419	-0.396	-0.383	-0.380
$\theta_x = 0.3$			1.319	-0.833	-0.534	-0.454	-0.419	-0.405
$\theta_x = 0.4$				0.679	-1.183	-0.609	-0.492	-0.449
$\theta_x = 0.5$					**0.479**	-1.920	-0.701	-0.542
$\theta_x = 0.6$						**0.374**	-5.112	-0.850
$\theta_x = 0.7$							**0.305**	4.956
$\theta_x = 0.8$								**0.245**

Panel B: The Model with Real Wage Rigidities ($\gamma = 0.9546$)

|	$\theta_c = 0.2$	$\theta_c = 0.3$	$\theta_c = 0.4$	$\theta_c = 0.5$	$\theta_c = 0.6$	$\theta_c = 0.7$	$\theta_c = 0.8$	$\theta_c = 0.9$
$\theta_x = 0.1$	**0.252**	**0.496**	0.699	0.833	0.896	0.896	0.838	0.689
$\theta_x = 0.2$		**0.145**	**0.291**	**0.431**	0.548	0.626	0.650	0.581
$\theta_x = 0.3$			**0.110**	0.220	0.331	0.427	0.490	0.477
$\theta_x = 0.4$				0.093	**0.185**	0.278	0.355	0.379
$\theta_x = 0.5$					0.083	**0.164**	0.242	0.287
$\theta_x = 0.6$						0.078	**0.149**	0.204
$\theta_x = 0.7$							0.074	**0.132**
$\theta_x = 0.8$								0.071

Note: The table gives the ratio of first-year multiplier of nondurables output to that of durables output. A negative value implies negative sectoral comovement. Bold-faced type is used to highlight the cases in which the ratio falls into the empirically plausible range: [10%,50%].

Figure 1: Estimated Impulse Responses
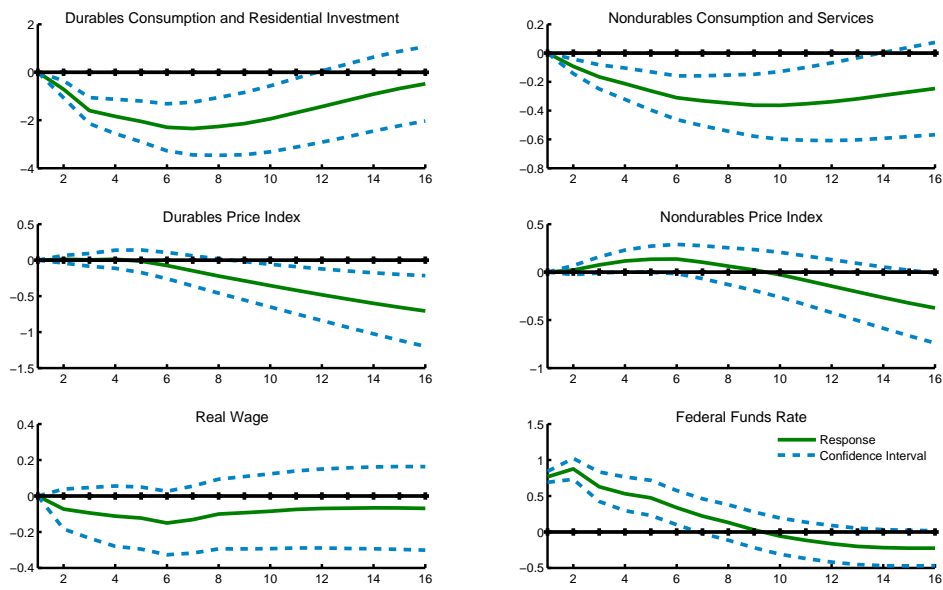
Note: The figure shows estimated impulse responses to a monetary policy tightening (Sample period 1965:3–2016:2, 95% confidence bands).

Figure 2: The Role of Real Wage Rigidities
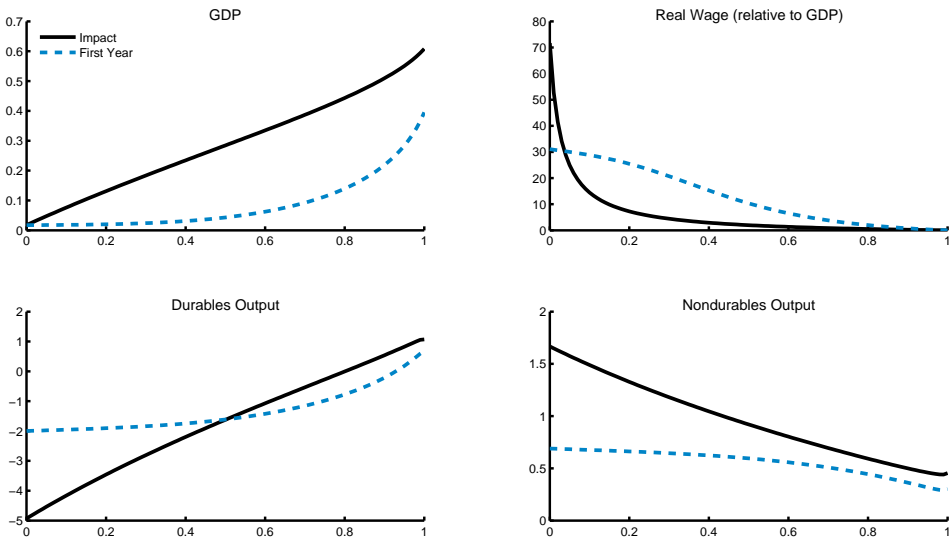
Note: The horizontal axis measures the degree of real wage rigidities, $\gamma \in [0, 1]$. The vertical axis measures the impact (solid line) and first-year quarterly-average (dashed line) responses to a permanent monetary expansion. The rest of the parameters assume their benchmark values.

Figure 3: Standard Model vs Model with Real Wage Rigidities
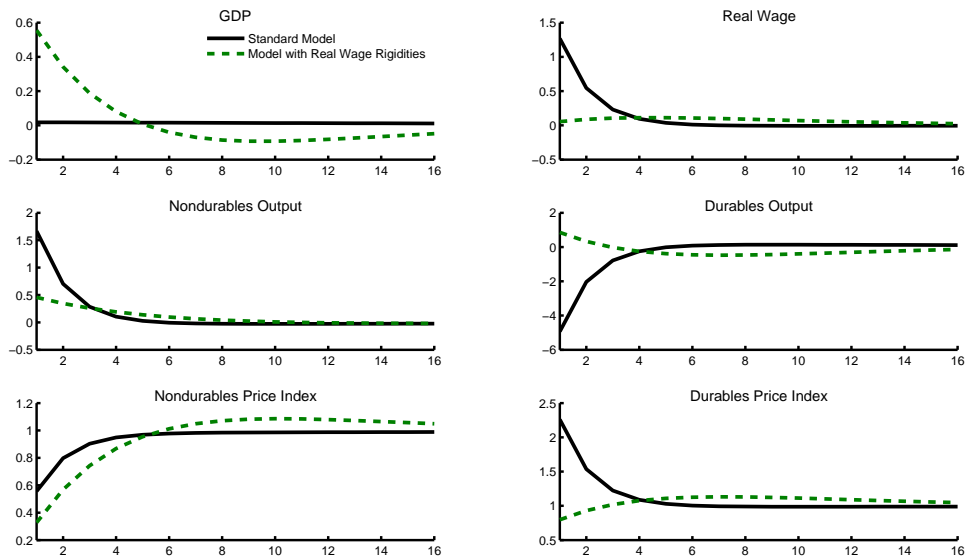
Note: The figure plots the impulse response functions. The horizontal axis measures time in quarters. The vertical axis measures the logarithmic deviation from the steady state. The impulse is a permanent monetary expansion. Solid lines represent the responses in the standard model, $\gamma = 0$, while the dashed lines represent the responses in the model with real wage rigidities, $\gamma = 0.9546$. The rest of the parameters assume their benchmark values.

Figure 4: Real vs Nominal Wage Rigidities
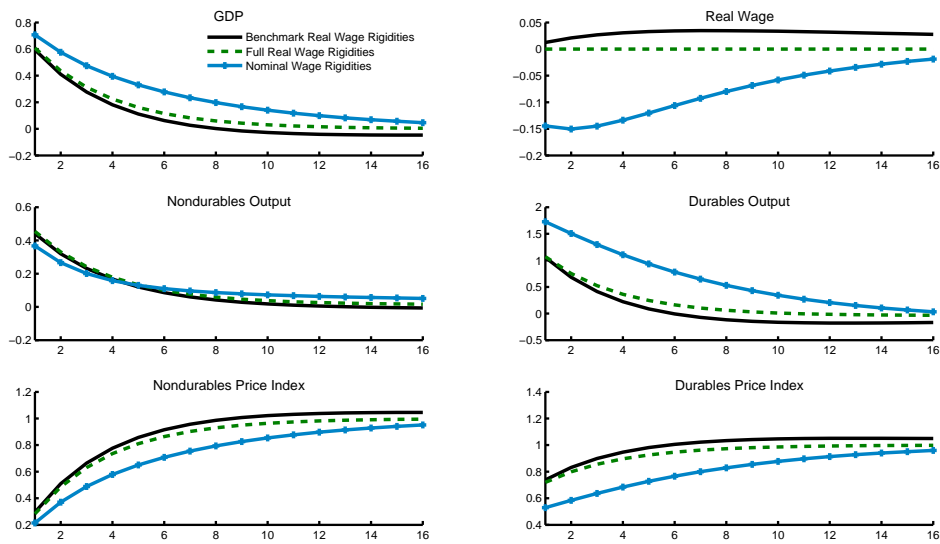
Note: The figure plots the impulse response functions. The horizontal axis measures time in quarters. The vertical axis measures the logarithmic deviation from the steady state. The impulse is a permanent monetary expansion. Solid lines represent the responses in the model with benchmark real wage rigidities, $\gamma = 0.9546$; dashed lines represent the responses in the model with full real wage rigidities, $\gamma = 1$; and the plus-marked lines represent the responses in the model with nominal wage rigidities.