BANK OF ENGLAND

Staff Working Paper No. 623

Labour market frictions, monetary policy and durable goods

Federico Di Pace and Matthias Hertweck

October 2016

BANK OF ENGLAND

Staff Working Paper No. 623

Labour market frictions, monetary policy and durable goods

Federico Di Pace[(1)] and Matthias Hertweck[(2)]

Abstract

This paper provides a quantitative answer to the 'sectoral comovement puzzle'. We extend the two-sector New Keynesian model with flexible durable good prices and sticky non-durable good prices by (i) labour search and matching frictions and (ii) internal habit formation in non-durable consumption. Search and matching frictions generate comovement and increase the persistence of sectoral outputs, whereas habit formation helps to appropriately distribute the impact of a given shock over the two sectors. As a result, our estimated model closely replicates the amplitude and the curvature of the empirical impulse responses in both sectors.

Key words: Durable production, labour market frictions, sectoral comovement, monetary policy.

JEL classification: E21, E23, E31, E52.

(1) Bank of England. Email: federico.dipace@bankofengland.co.uk
(2) University of Konstanz. Email: matthias.hertweck@uni-konstanz.de

The views expressed in this paper are those of the authors, and not necessarily those of the Bank of England or its committees. Without implication, we would like to thank Almuth Scholl, Yunus Askoy, Henrique Basso, Bjoern Brey, Lawrence Christiano, John Driffill, Keith Kuester, André Kurmann, Volker Hahn, Matteo Iacoviello, Michal Marenčák, Patrick Pintus, Morten Ravn, Paulo Santos Monteiro and Bradley Speigner, as well as conference participants at CEF 2012 (Prague), Dynare 2012 (Zurich), EEA 2011 (Oslo), Essex-Konstanz Macro 2013, MMM 2012 (Notre Dame), VfS 2012 (Göttingen) and seminar audiences at RWTH Aachen, Bath, Berne, Bielefeld, Edinburgh, Lausanne, the FRB Philadelphia and St. Andrews for extensive comments and suggestions. Part of this research project was conducted while Matthias Hertweck was affiliated with the University of Basel, supported by the Swiss National Science Foundation (Project No. 118306), and visiting the University of Pennsylvania. This paper is a substantially revised version of the 2012 *Dynare Working Paper No. 20*.

Information on the Bank's working paper series can be found at
www.bankofengland.co.uk/research/Pages/workingpapers/default.aspx

Publications Team, Bank of England, Threadneedle Street, London, EC2R 8AH
Telephone +44 (0)20 7601 4030 Fax +44 (0)20 7601 3298 email publications@bankofengland.co.uk

ISSN 1749-9135 (on-line)

1 Introduction

As demonstrated by Barsky, House & Kimball (2007), the two-sector New Keynesian model with flexible durable good prices and sticky non-durable good prices (consistent with Bils & Klenow 2004 and Klenow & Kryvtsov 2008) fails to generate sectoral comovement after a monetary contraction. Given that durable good prices fall steeply — but their shadow value is near-constant — the representative household has incentives to build up the stock of durable goods at low cost. With Walrasian labour markets, this scenario is indeed an equilibrium outcome. The drop in non-durable consumption reduces wages in both sectors so strongly that durable producers are willing to expand production (Carlstrom & Fuerst 2010). The opposing responses of sectoral outputs almost offset each other, which implies that monetary policy shocks are close to neutral for aggregate output. This result is clearly at odds with the observation that an exogenous monetary contraction causes an economy-wide downturn. Beyond that, the standard model suffers from a lack of internal propagation: the model generated responses fall sharply on impact — whereas their empirical counterparts reach a trough with a delay of several quarters.

This paper provides a quantitative answer to the "sectoral comovement puzzle". We show analytically that, under Walrasian labour markets, the near-constant shadow value of durable goods implies that total hours worked are near-constant as well — which explains why monetary shocks are close to neutral for aggregate output. For this reason, we extend the Barsky et al. (2007) model by adding search and matching frictions in the labour market (Pissarides 2000). This modification changes the monetary transmission mechanism in two ways. First, search and matching frictions introduce an extensive margin of labour adjustment, which breaks the near-constancy relationship. Hence, real marginal costs become less elastic and, consequently, durable good prices also fall less sharply. For this reason, new purchases of durable goods fall in equilibrium. The strength of this channel depends on the value of the replacement rate. Second, with long-run employment relationships, shocks are propagated through changes in the stock of sectoral employment (as in Hairault 2002). This increases the persistence of sectoral outputs. In addition to search and matching frictions, we also allow for internal habit formation in non-durable consumption (Constantinides 1990). With habit formation in non-durable consumption, the durable goods sector absorbs a larger fraction of the aggregate shock (Fuhrer 2000). This helps the model to generate comovement at conventional values of the replacement rate. As a result, our estimated model generates not only sectoral comovement, but also closely replicates the amplitude and the curvature of the empirical impulse responses.

The main contribution of our paper is to replicate empirical regularities using a relatively parsimonious model. Previous demand-side approaches to addressing the sectoral comovement puzzle generally question the representative household's ability to use durable goods as an investment device to smooth aggregate consumption.[1] Supply-side approaches, on the other hand, generally focus on channels that limit the elasticity of real marginal costs in the durable goods

[1]Demand-side approaches include Monacelli (2009), Iacoviello & Neri (2010), Sterk (2010), or Chen & Liao (2014), who examine the effects of collateral constrains (akin to Iacoviello 2005); Levin & Yun (2011), who develop a model with uninsurable preference shocks; Kim & Katayama (2013), who propose a model where non-durable consumption and labour are complements; and Dey & Tsai (2014), who evaluate habit-adjusted Greenwood, Hercowitz & Huffman (1988) preferences.

sector.[2] However, among the growing literature, only a few exceptions replicate the magnitude and the curvature of the empirical impulse responses. These contributions have two features in common. Besides habit formation in non-durable consumption (see above), the assumption of adjustment costs in durable production (Christiano, Eichenbaum & Evans 2005) "mechanically" increases the gradual adjustment in durable output. In addition — to generate sectoral comovement — Carlstrom & Fuerst (2010) introduce sticky nominal wages, which dampen the fall of real marginal costs in both sectors; Katayama & Kim (2013) evaluate sticky nominal wages together with non-separable preferences between consumption and labour (see Footnote 1); and Kitamura & Takamura (2016) argue that firm-specific production factors effectively limit the impact of the economy-wide decline in the demand for production factors on real marginal costs in the durable sector, whereas sticky information mitigates the strong asymmetry in price flexibility.[3,4] By contrast, search and matching frictions help to generate comovement *and* persistence at the same time. Due to this dual effect, our relatively parsimonious model can go such a long way.

We perform a number of robustness checks to test the sensitivity of our results. First, we assume that labour is sector-specific, i.e. workers are immobile across sectors. Second, we estimate all parameters of the generalised Taylor rule, not just a subset. Third, we re-estimate the model when wages are determined by an alternating offers bargaining protocol. Fourth, we allow for stickiness in durable good prices.

The remainder of this paper is organised as follows. Section 2 develops a two-sector New Keynesian model with search frictions and habit formation. Section 3 discusses the estimation strategy. Section 4 present the results. Section 5 inspects the model mechanism. Section 6 evaluates alternative model specifications. Section 7 concludes.

2 The Model

We introduce labour search and matching frictions into a two-sector New Keynesian model akin to Barsky et al. (2007). Individual utility depends on (*i*) habit-adjusted consumption of non-durable goods and (*ii*) on the flow of services from the stock of durable goods. Both, new purchases of non-durable goods and for new durable goods are constant elasticity of substitution (CES) aggregates of differentiated goods. These goods are produced by sector-specific monopolistically competitive good firms. Final good firms in the non-durable good sector face Calvo (1983) type restrictions in price setting. The production of final goods requires intermediate goods that are purchased in perfectly competitive markets. Sector-specific hiring firms recruit

[2] To establish a direct link between (sticky) non-durable good prices and real marginal costs in the durable goods sector, Bouakez, Cardia & Ruge-Murcia (2011) and Sudo (2012) introduce an input-output structure with inter-sectoral linkages (see Petrella, Rossi & Santoro 2016 for a work that studies the implications for optimal monetary policy in this environment). Moreover, Tsai (2016) demonstrates that a rise in the nominal interest rate increases the cost of borrowing working capital, which dampens the fall in real marginal costs in both sectors

[3] To facilitate comparison across papers, we here refer to the model version with a feedback rule for the nominal interest rate. In an alternative version with a money-growth rule, Kitamura & Takamura (2016) show that sticky information alone has the potential to generate comovement and long-lived impulse responses in both sectors.

[4] Using a two-sector model with investment instead of durable goods, also DiCecio (2009) generates sectoral comovement and long-lived impulse responses. Apart from habit formation in consumption and adjustment costs in investment, the model features working capital, variable capital utilization, and sticky nominal wages.

workers in frictional labour markets in order to produce intermediate goods. Sectoral wages are negotiated period-by-period through a Nash protocol.

2.1 The Labour Market

At the beginning of period t, a share u_t of the labour force (which is normalised to unity) searches for employment opportunities in both sectors. Along with them, there is an infinite mass of potential hiring firms with unfilled positions (den Haan, Ramey & Watson 2000). Each hiring firm can hire at most one worker. Hiring firms with an unfilled position may decide whether or not to post a sector-specific vacancy. Let $v_{c,t}$ and $v_{d,t}$ denote the number of vacancies that are posted by hiring firms in the non-durable (c) and durable (d) sector, respectively. The number of newly formed firm-worker pairs is given by a Cobb-Douglas matching function with constant returns to scale. The matching function relates aggregate job matches, m_t, to the number of aggregate vacancies, $v_t = v_{c,t} + v_{d,t}$, and the number of job searchers, u_t, in the labour market:

$$m_t = m\left(v_t, u_t\right) = \bar{m} v_t^{\xi} u_t^{1-\xi},$$

where ξ denotes the elasticity of the matching function with respect to aggregate vacancies and $\bar{m}$ is the efficiency of the matching process. By linear homogeneity of the matching function, the aggregate job finding rate, $p(\theta_t)$, and the aggregate vacancy filling rate, $q\left(\theta_t\right)$, depend only on the value of aggregate labour market tightness, ($\theta_t = v_t/u_t$):

$$p\left(\theta_t\right) = \frac{m_t}{u_t} = \theta_t \frac{m_t}{v_t} = \theta_t q\left(\theta_t\right).$$

Note that the tighter the aggregate labour market, the shorter the expected time searching for a job (and vice versa). We assume that job searchers are randomly matched with vacancies from both sectors (this assumption is relaxed in Section 6.1). Hence, the aggregate job finding rate equals the sum of the sectoral job finding rates:

$$p\left(\theta_t\right) = \frac{m_t}{u_t}\left(\frac{v_{c,t}}{v_t}\right) + \frac{m_t}{u_t}\left(\frac{v_{d,t}}{v_t}\right) = p(\theta_{c,t}) + p(\theta_{d,t}) = \left(\theta_{c,t} + \theta_{d,t}\right) q\left(\theta_t\right),$$

where $\theta_{s,t} = v_{s,t}/u_t$ is the sector-specific measure of labour market tightness. Furthermore, given free entry into the labour market, random matching entails that the vacancy filling rate is equalised across sectors:

$$q\left(\theta_{s,t}\right) = \frac{v_{s,t}}{v_t}\frac{m\left(v_t, u_t\right)}{v_{s,t}} = q\left(\theta_t\right).$$

Following Ravenna & Walsh (2008) and Blanchard & Gali (2010), we impose that new matches become immediately productive.[5] Moreover, at the end of period t, a constant share ρ of pre-

[5] As demonstrated by Thomas & Zanetti (2009), it is reasonable to assume instantaneous matching in models that are calibrated to a quarterly frequency.

existing employment relationships in both sectors is terminated.[6] The evolution of sectoral employment, $n_{s,t}$, is therefore governed by:

$$n_{s,t} = \frac{v_{s,t}}{v_t} m\left(v_t, u_t\right) + \left(1-\rho\right) n_{s,t-1}. \tag{1}$$

Accordingly, the number of job searchers at the beginning of period t, u_t, equals the share of individuals who did not have a job in the previous period, $1 - n_{c,t-1} - n_{d,t-1}$, minus the flow of workers who have just lost their jobs, $\rho(n_{c,t-1} + n_{d,t-1})$:

$$u_t = 1 - \left(1-\rho\right)\left(n_{c,t-1} + n_{d,t-1}\right). \tag{2}$$

2.2 Households

There is a large number of identical households with unit measure, each of which consists of a continuum of individuals. The members of the representative household are either employed by sector-specific hiring firms or search for a job in the labour market. The expected life-time utility of an individual household member j can be represented by:

$$\mathcal{H}_t^j = E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \mathcal{U}\left(\mathcal{C}_\tau^j\right) = E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \left[\left(\mathcal{C}_t^j\right)^{1-\sigma} - 1\right] \Big/ \left(1-\sigma\right),$$

where E_t is the expectation operator conditional on the household's information set at the beginning of period t. In particular, we assume that households — as well as firms, see below — solve their maximization problems before the monetary policy decision in period t is revealed.[7] $\beta \in (0,1)$ denotes the discount factor, $\mathcal{U}\left(\mathcal{C}_\tau^j\right)$ individual per-period utility, $\mathcal{C}_t^j$ the habit-adjusted composite consumption good, and σ the inverse of the inter-temporal elasticity of substitution.

2.2.1 The Habit-Adjusted Composite Consumption Good

The habit-adjusted composite consumption good, $\mathcal{C}_t^j$, consists of a CES aggregate of non-durable consumption goods, c_t^j, and the flow of services from the stock of durable goods, d_t^j:

$$\mathcal{C}_t^j = \left(c_t^j - \psi c_{t-1}^j\right)^{\zeta} \left(d_t^j\right)^{1-\zeta},$$

where ζ governs the steady-state share of non-durable consumption.[8] The parameter ψ captures the degree of internal habit formation (Constantinides 1990) in non-durable consumption, i.e. the utility of household j from non-durable consumption depends on the current level, c_t^j, relative to the household's own level in the previous period, c_{t-1}^j (Bouakez, Cardia & Ruge-Murcia 2005). As demonstrated by Fuhrer (2000) and Christiano et al. (2005), habit formation helps to reconcile

[6] As shown by Shimer (2012), Fujita & Ramey (2009), and Hertweck & Sigrist (2015) most of the cyclical variation in employment in the U.S. is due to job creation rather than job separation. Thus, for simplicity, we assume that all separations are exogenous.

[7] We thus adopt the "limited information" approach of Rotemberg & Woodford (1997), but with a decision lag of one period (as in Christiano et al. 2005) instead of two periods.

[8] The results of our paper remain unchanged when durable and non-durable goods are imperfect complements. Only in the extreme case when durable and non-durable goods are near-Leontief, the model of Barsky et al. (2007) is able to generate comovement across sectors. Such a high degree of complementarity, however, cannot be found in the data (Bernanke 1984).

a hump-shaped response in (non-durable) consumption to transitory monetary policy shocks. In the limit, when σ approaches unity, the period utility of an individual household member j becomes separable in habit-adjusted non-durable consumption and the flow of durable services:

$$\mathcal{U}\left(\mathcal{C}^j_\tau\right) = \zeta \ln\left(c^j_t - \psi c^j_{t-1}\right) + (1-\zeta)\ln d^j_t.$$

Non-durable consumption is a CES aggregate of differentiated non-durable goods:

$$c^j_t = \left[\int_0^1 \left(c^{ji}_t\right)^{1-1/\epsilon} di\right]^{1/(1-1/\epsilon)}, \tag{3}$$

where $\epsilon > 1$ denotes the intra-temporal elasticity of substitution (IES) among individual varieties of non-durable goods c^{ji}_t. Given that $P^i_{c,t}$ denotes the nominal price of the non-durable good i, expenditure minimisation implies that its relative demand is given as:

$$c^{ji}_t = \left(\frac{P^i_{c,t}}{P_{c,t}}\right)^{-\epsilon} c^j_t. \tag{4}$$

By integrating equation (4) and imposing (3), we obtain the associated price index of non-durable consumption (as in Christiano et al. 2005):

$$P_{c,t} = \left[\int_0^1 \left(P^i_{c,t}\right)^{1-\epsilon} di\right]^{1/(1-\epsilon)}.$$

Newly acquired **durable goods purchases** are represented by the following CES aggregate:

$$x^j_t = \left[\int_0^1 \left(x^{ji}_t\right)^{1-1/\epsilon} di\right]^{1/(1-1/\epsilon)}, \tag{5}$$

where the IES among varieties of new durable goods, ϵ, is assumed to be the same as among non-durable goods. The law of motion for the aggregate stock of durable good is given by:

$$x^j_t = d^j_t - (1-\delta)\, d^j_{t-1}, \tag{6}$$

where δ denotes the depreciation rate of the stock of durable goods. Given that $P^i_{d,t}$ denotes the nominal price of the durable good i, expenditure minimisation implies that the relative demand for the durable-good variety x^{ji}_t is given as:

$$x^{ji}_t = \left(\frac{P^i_{d,t}}{P_{d,t}}\right)^{-\epsilon} x^j_t. \tag{7}$$

As above, we integrate equation (7) and impose (5) to obtain the associated price index of newly acquired durable goods:

$$P_{d,t} = \left[\int_0^1 \left(P^i_{d,t}\right)^{1-\epsilon} di\right]^{1/(1-\epsilon)}.$$

2.2.2 Evolution of Sectoral Employment

From the perspective of the representative household, aggregate employment in sector s evolves according to:

$$n_{s,t} = (1-\rho)\, n_{s,t-1} + \theta_{s,t} q\left(\theta_{s,t}\right) u_t \quad \text{for} \quad s = \{c, d\}\,, \tag{8}$$

where the sectoral job finding rate, $\theta_{s,t} q\left(\theta_t\right)$, is exogenous to the household's decision problem.

2.2.3 Budget Constraint

Following Merz (1995) and Andolfatto (1996), we assume that employed and unemployed household members insure each other completely against idiosyncratic income risk from unemployment. Thus, the nominal budget constraint of the representative household reads as:

$$P_{c,t}c_t + P_{d,t}x_t + B_t = R_{t-1}B_{t-1} + \sum_{s=\{c,d\}} \left[\int_0^1 W^j_{s,t} n^j_{s,t} dj + \Phi_{s,t}\right] + \left(1 - n_{c,t} - n_{d,t}\right) P_{c,t}\bar{b} - \bar{T}_t. \tag{9}$$

Employed household members earn the nominal sector-specific wage rate, $W_{s,t}$, while the share of unemployed household members, $(1 - n_{c,t} - n_{d,t})$, receives nominal unemployment benefits $P_{c,t}\bar{b}$. The lump-sum transfer $\bar{T}_t$ imposed by the government finances unemployment benefits and rebates any seigniorage revenue to the representative household (see Section 2.6). Nominal risk-free government bonds, B_t, pay a nominal interest rate, R_t, in period $t + 1$. Moreover, the representative household receives lump-sum dividends, $\Phi_{c,t}$ and $\Phi_{d,t}$, remitted by retail and hiring firms in both sectors.

2.2.4 First Order Conditions

The representative household maximises the unweighted expected life-time utilities of its individual household members, $\int_0^1 \mathcal{H}^j_{s,t} dj$, subject to the evolution of sectoral employment (8), the budget constraint (9), a set of initial conditions for the state variables $\{d_{-1},\ n_{s,-1},\ R_{-1},\ c_{-1}\}$ and a stochastic time path for R_t. The representative household takes all aggregate variables as given. Therefore, the choices with respect to c_t, B_t and d_t have to satisfy the following first order conditions (given that the decision of the members of the household are identical in equilibrium, we omit j superscripts in the following):

$$\lambda_t = \zeta \frac{\mathcal{C}_t^{1-\sigma}}{c_t - \psi c_{t-1}} - \zeta\beta\psi E_t \left\{\frac{\mathcal{C}_{t+1}^{1-\sigma}}{c_{t+1} - \psi c_t}\right\}, \tag{10}$$

$$\lambda_t = \beta E_t \left\{\lambda_{t+1} R_t \frac{P_{c,t}}{P_{c,t+1}}\right\}, \tag{11}$$

$$\lambda_t \varphi_{d,t} = \frac{(1-\zeta)\,\mathcal{C}_t^{1-\sigma}}{d_t} + \beta\,(1-\delta)\, E_t\left\{\lambda_{t+1}\varphi_{d,t+1},\right\} \tag{12}$$

where λ_t is the Lagrange multiplier associated with the budget constraint (9) and $\varphi_{d,t} = P_{d,t}/P_{c,t}$ is the (real) price of durable goods relative to the price of non-durable goods. We define gross inflation in sector s as $\pi_{s,t} = P_{s,t}/P_{s,t-1}$. The first order conditions describe the marginal utility of the habit-adjusted composite consumption good (equation 10), the standard Euler equation for government bonds (equation 11) and the asset pricing equation for durable goods (equation 12). By forward iteration of equation (12), we can express the relative price of durable goods (in utility units) as the present discounted value of future rents generated by services from the stock of durable goods.

2.2.5 The Net Marginal Value of Employment

The net marginal value of employment to the representative household is given by:

$$\mathcal{W}_{s,t}^{j} = w_{s,t}^{j} - \bar{b} + \beta (1-\rho) E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \left[\mathcal{W}_{s,t+1}^{j} - \sum_{l=\{c,d\}} q(\theta_{t+1}) \theta_{l,t+1} (\mathcal{W}_{l,t+1}) \right] \right\},$$

where $w_{s,t}^{j} = W_{s,t}^{j}/P_{c,t}$ denotes the current real wage rate in sector s. If an unemployed household member finds a job in sector s, the net income of the representative household increases. In addition, the household gains the continuation value of employment at that firm, minus the opportunity cost of searching for a job and finding it elsewhere.

2.3 Final Good Producers - Retailers

There is a continuum of monopolistically competitive retailers, indexed by $i \in [0,1]$, in both sectors of the model economy. Each retailer produces a distinct final good variety, $y_{s,t}^{i}$, according to the following linear production technology:

$$y_{s,t}^{i} = \bar{y}_{s,t}^{i}, \tag{13}$$

with sector-specific intermediate goods, $\bar{y}_{s,t}^{i}$, as the only factor of production. We assume that final good firms buy these intermediate goods from hiring firms on a perfectly competitive market.

In the non-durable retail market, final good firms face Calvo (1983) type restrictions in price setting. At the beginning of period t, before the monetary policy decision is revealed (see Footnote 7), only a fraction, $1-\vartheta_c$, of final good firms is able to re-optimise the price of its variety i. All final good firms that are able to re-optimise prices choose the same retail price, $P_{c,t}^{*}$, given that they all solve the same optimisation problem. Final good firms that cannot re-optimise simply index their prices to the lagged inflation rate in the non-durable goods sector, $\pi_{c,t-1}$, where χ_c denotes the degree of price indexation (Gali & Gertler 1999, Smets & Wouters 2003).[9] The optimisation problem of non-durable final good firms thus reads as (Sahuc 2006):

$$E_t \sum_{\tau=t}^{\infty} (\beta \vartheta_c)^{\tau-t} \frac{\lambda_\tau}{\lambda_t} \left[\frac{P_{c,t}^{*}}{P_{c,\tau}} \left(\frac{P_{c,\tau-1}}{P_{c,t-1}} \right)^{\chi_c} - \varphi_{c,\tau}^{m} \right] \left(\frac{P_{c,t}^{*}}{P_{c,\tau}} \left(\frac{P_{c,\tau-1}}{P_{c,t-1}} \right)^{\chi_c} \right)^{-\epsilon} c_\tau, \tag{14}$$

[9] We allow for indexation to replicate the muted u-shaped response of inflation. As demonstrated by Trabandt (2007), also sticky information (Mankiw & Reis 2002) has the potential to replicate this pattern. Indexation thus likely represents other frictions such as sticky information not captured by our parsimonious model. See Kitamura & Takamura (2016) for a two-sector business cycle model with sticky information.

where $\varphi^m_{c,t}$ denotes real marginal costs in the non-durable goods sector. The optimisation problem entails the following first order condition:

$$\frac{P^*_{c,t}}{P_{c,t}} = \frac{\epsilon}{\epsilon-1}\left[\frac{E_t\sum_{\tau=t}^{\infty}(\beta\vartheta_c)^{\tau-t}\,\frac{\lambda_\tau}{\lambda_t}\varphi^m_{c,\tau}\left(\frac{P_{c,t}}{P_{c,\tau}}\left(\frac{P_{c,\tau-1}}{P_{c,t-1}}\right)^{\chi_c}\right)^{-\epsilon}y_{c,\tau}}{E_t\sum_{\tau=t}^{\infty}(\beta\vartheta_c)^{\tau-t}\,\frac{\lambda_\tau}{\lambda_t}\left(\frac{P_{c,t}}{P_{c,\tau}}\left(\frac{P_{c,\tau-1}}{P_{c,t-1}}\right)^{\chi_c}\right)^{1-\epsilon}y_{c,\tau}}\right]. \tag{15}$$

The associated price level in the non-durable goods sector is given as:

$$P_{c,t} = \left[\vartheta_c\left(\pi^{\chi_c}_{c,t-1}P_{c,t-1}\right)^{1-\epsilon} + (1-\vartheta_c)\left(P^*_{c,t}\right)^{1-\epsilon}\right]^{1/(1-\epsilon)}. \tag{16}$$

In the durable retail market, on the contrary, prices are assumed to be perfectly flexible. Thus, profit maximising durable producers set their prices, $P^i_{d,t}$, as a constant mark-up over marginal costs, $P^m_{d,t}$:

$$P_{d,t} = \frac{\epsilon}{\epsilon-1}P^m_{d,t} \quad \Rightarrow \quad \varphi_{d,t} = \frac{\epsilon}{\epsilon-1}\varphi^m_{d,t}. \tag{17}$$

Furthermore, we note that the ratio of durable inflation to non-durable inflation equals the period change in the relative price of durable goods:

$$\frac{\varphi_{d,t}}{\varphi_{d,t-1}} = \frac{\pi_{d,t}}{\pi_{c,t}}. \tag{18}$$

2.4 Hiring Firms

Hiring firms produce sector-specific intermediate goods, which are then sold to final good producers.[10] There is an infinite mass of potential hiring firms with unfilled positions. Each hiring firm can employ at most one worker j. Inactive firms may decide whether or not to hire an unemployed job searcher. For hiring firms in both sectors, the cost of meeting a worker, κx_t, is proportional to the aggregate hiring rate, $x_t = m_t/(1-u_t)$, and taken as given by the hiring firm. This cost function nests quadratic labour adjustment costs, as used by Gertler & Trigari (2009), in a one-firm-one-worker framework; i.e., the marginal cost to hire an additional worker increases linearly in x_t. This specification captures the notion that effective hiring costs are mainly determined by the actual number of hires — rather than by the job advertising and selection process — and that these costs are clearly convex at the aggregate level (Yashiv 2000*a*).[11] In return, firm j gains the value of a sector-specific filled position, $\mathcal{J}^j_{s,t}$. Free entry into the labour market ensures that the following non-arbitrage condition holds:

$$\kappa\frac{m_t}{1-u_t} = \mathcal{J}^j_{s,t}. \tag{19}$$

Given that the cost of hiring a worker is equal across firms and sectors, the net marginal value of employment must be equal across all hiring firms in both sectors as well.

[10] The current section borrows from the corresponding section in Hertweck (2013).

[11] King & Thomas (2006) show how the evidence of partial adjustment at the aggregate level can be reconciled with the fact that hiring behaviour at the firm level is rather discrete and occasional. The proportionality assumption between effective hiring cost and labour market tightness suggested by the textbook search and matching model has also been questioned by Pissarides (2009) and Christiano, Eichenbaum & Trabandt (2016).

Intermediate goods produced by hiring firm j in sector s, $\bar{y}^j_{s,t}$, are sold to final good firms at the competitive price $\varphi^m_{s,t}$. Hence, real per-period profits of hiring firm j are given by: $\phi^j_{s,t} = \varphi^m_{s,t} - w^j_{s,t}$. Thus, the value of employment for firm j in sector s is equal to:

$$\mathcal{J}^j_{s,t} = \varphi^m_{s,t} - w^j_{s,t} + \beta (1 - \rho) E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \mathcal{J}^j_{s,t+1} \right\}, \tag{20}$$

where the second term denotes the expected continuation value of employment for the firm — conditional on surviving exogenous job destruction at the end of period t. Combining (20) with (19) yields the sectoral job creation condition:

$$\kappa \frac{m_t}{1 - u_t} = \varphi^m_{s,t} - w^j_{s,t} + \beta (1 - \rho) \kappa E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \frac{m_{t+1}}{1 - u_{t+1}} \right\}. \tag{21}$$

2.5 Wage Determination

Frictions in the labour market create economic rents between matched firm-worker pairs. These rents are shared through wage bargaining. Following Andolfatto (1996), the representative household takes the labour supply decision for all its members. In particular, we assume that each member of the representative household bargains with each employer separately, while taking wages in all other matches as given (Pissarides 2000, Chapter 3). The two parties agree on a real wage rate, $w^j_{s,t}$, according to the Nash rule.[12] This bargaining protocol assumes that sectoral real wage rates are determined in order to maximise the weighted product of each party's surplus share:

$$\max_{w^j_{s,t}} \quad \left(\mathcal{W}^j_{s,t} \right)^{\gamma} \left(\mathcal{J}^j_{s,t} \right)^{1-\gamma},$$

where γ is the bargaining power of the household. Thus, the first order conditions with respect to $w^j_{s,t}$ are:

$$\gamma \mathcal{J}^j_{s,t} = (1 - \gamma) \mathcal{W}^j_{s,t}$$

We assume that this optimality condition also holds in expectations. After rearranging, the sectoral real wage is given by:

$$w^j_{s,t} = w_{s,t} = \gamma \varphi^m_{s,t} + (1 - \gamma) \bar{b} + \beta \gamma \kappa (1 - \rho) E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \frac{q(\theta_{t+1}) \theta_{t+1} m_{t+1}}{1 - u_{t+1}} \right\} \tag{22}$$

The real wage at firm j in sector s is a linear weighted average between the price of the sector-specific intermediate good and the opportunity costs of finding a job elsewhere. Consequently, also wages must be equal across firms and sectors: $w^j_{c,t} = w^j_{d,t} = w_{c,t} = w_{d,t}$.

[12] We note that, since real wages are re-negotiated every period and both parties take prices $P_{c,t}$ as given, real and nominal wage bargaining lead to the same outcome.

2.6 Government and Monetary Authority

The government finances unemployment benefits $\bar{b}$, issues bonds B_t that pay a nominal interest rate R_t in period $t+1$ and rebates any seigniorage revenue to the representative household. Each period, the budget balance is maintained by imposing a lump-sum tax $\bar{T}$:

$$\bar{T}_t + B_t - R_{t-1}B_{t-1} = (1 - n_{c,t} - n_{d,t})\,\bar{b}P_{c,t}.$$

When setting the nominal interest rate, the monetary authority obeys a generalised Taylor (1993) rule akin to Bianchi (2013), Justiniano, Primiceri & Tambalotti (2013), and Christiano, Eichenbaum & Trabandt (2015):

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{r_r}\left[\left(\left(\frac{\pi_{c,t}}{\pi_c}\right)^{c/y}\left(\frac{\pi_{d,t}}{\pi_d}\right)^{1-(c/y)}\right)^{r_p}\left(\frac{y_t}{y_{t-1}}\right)^{r_y}\right]^{1-r_r}\varepsilon_{r,t}, \quad \text{with} \quad \varepsilon_{r,t} \sim N\left(0, \varsigma_r\right), \tag{23}$$

where $0 \leq r_r < 1$ governs the degree of monetary policy inertia. The parameters $r_p \geq 1$ and $r_y \geq 0$ control the responsiveness of the monetary authority to temporary shifts in aggregate price inflation — defined as the average of durable goods, $\pi_{d,t}$, and non-durable goods price inflation, $\pi_{c,t}$, weighted with the ratio of non-durable consumption to aggregate output (Monacelli 2009) — and aggregate output growth, y_t/y_{t-1} — where the latter is defined as the sum of non-durable goods and durable goods in terms of the price of non-durable goods (see Section 2.7). Letters without a time subscript refer to the steady-state value of the associated variable.

2.7 Market Clearing

Given the linear production technology for final goods (13), the quantity of sector-specific intermediate goods must be equal to sector-specific output:

$$\bar{y}_{s,t} = n_{s,t} = \int_0^1 \bar{y}^j_{s,t}dj = \int_0^1 \bar{y}^i_{s,t}di = \int_0^1 y^i_{s,t}di = y_{s,t}, \quad \text{for} \quad s = \{c,d\}$$

where $n_{s,t}$ denotes the employment rate in sector s. Moreover, we assume that hirings costs, $\kappa m_t^2/\left(1-u_t\right)$, in both sectors are bundled using the same technology as the non-durable CES aggregator.[13] Hence the sectoral resource constraints can be written as:

$$y_{c,t} = c_t + \kappa\frac{m_t^2}{1-u_t}, \tag{24}$$

$$y_{d,t} = x_t = d_t - (1-\delta)\,d_{t-1}. \tag{25}$$

Finally, aggregate output, y_t, is defined as the sum of non-durable goods, y_c, and durable goods, y_d, in terms of the price of non-durable goods:

$$y_t = y_{c,t} + \varphi_{d,t}x_t. \tag{26}$$

[13] This assumption is made for simplicity. Results are robust when hiring costs in each sector are cleared in terms of sector-specific output, simply because hiring costs are small (see also the following section).

2.8 Competitive Equilibrium

A stationary competitive equilibrium is a set of endogenous stationary processes, $y_{s,t}$, y_t, x_t, λ_t, c_t, d_t, $w_{s,t}$, $\varphi_{d,t}$, $n_{s,t}$, $v_{s,t}$, u_t, $\varphi^m_{s,t}$, R_t, $\pi_{s,t}$ and an exogenous process $\{\varepsilon_{r,t}\}_{t=0}^{\infty}$ satisfying equation (1), (2), (6) and (10)-(25), given initial conditions for c_{-1}, d_{-1}, $n_{s,-1}$, $\pi_{c,-1}$, and R_{-1}.

3 Model Evaluation

We evaluate the quantitative performance of our model by matching the model generated impulse responses with those from a structural VAR. For this purpose, we first estimate the cross-sectoral effects of a contractionary monetary policy shock. Secondly, we assign numerical values to the set of parameters and deep ratios for which there exists independent evidence (see Appendix A). Our parametrisation implies that one model period corresponds to one quarter. Thirdly, we estimate the vector containing the key parameters of interest, η, to minimize the distance between the empirical and the model generated impulse responses. The vector η contains the following variables: the replacement ratio, $\bar{b}/w$, the degree of internal habit formation, ψ, the degree of price stickiness in the non-durable goods sector, ϑ_c, the degree of price indexation in the non-durable goods sector, χ_c, the inertia of the monetary policy rule, r_r, and the standard deviation of the monetary policy rule, ς_r.

3.1 Structural Vector Autoregression

3.1.1 Data, Identification & Estimation

To estimate the cross-sectoral effects of a contractionary monetary policy shock, we consider the following reduced-form VAR:[14]

$$
\begin{aligned}
x_t &= a + B(L)x_{t-1} + e_t, \\
x_t &= \begin{bmatrix} z_t & R_t \end{bmatrix}', \\
z_t &= \begin{bmatrix} c_t & y_{d,t} & \pi_{c,t} & n_{c,t} & n_{d,t} \end{bmatrix}',
\end{aligned}
$$

where $B(L)$ is a lag polynomial of order M, c_t denotes the natural logarithm of real non-durable purchases per capita, $y_{d,t}$ the natural logarithm of real new purchases of durable goods per capita, $\pi_{c,t}$ the quarter-on-quarter inflation rate in the non-durable sector (in percentage points), $n_{c,t}$ the natural logarithm of the employment rate in the non-durable sector, $n_{d,t}$ the natural logarithm of the employment rate in the durable sector, and R_t the de-annualized Federal Funds rate (in percentage points). Our sample period covers US data between 1964Q1 and 2007Q4.[15] Except for the Federal Funds rate, all data are seasonally adjusted (precise definitions can be found in the Appendix, see Tables 1 and 2). We also include constant terms as well as linear and quadratic trends.[16] Following the AIC rule (with $M_{max} = 8$), the VAR order is set to $M = 3$.

[14] The description of the estimation strategy follows Ravn & Simonelli (2007).

[15] The end of our sample marks the start of the Great Recession when the Fed adopted several unconventional monetary policy measures, which are unlikely to be appropriately captured by our identification procedure.

[16] We include the trends to control for low-frequency cycles in the data, particularly in the inflation rate.

The resulting VAR is estimated using ordinary least squares. By premultiplying with β_0, we obtain the structural VAR:

$$\beta_0 x_t = \alpha + \beta(L)x_{t-1} + \epsilon_t,$$

where ϵ_t denotes the vector of fundamental shocks. The orthogonality assumption implies that its covariance matrix $V_\epsilon = E(\epsilon_t' \epsilon_t)$ is diagonal. Moreover, we normalise the diagonal of β_0 to a 6x1 vector of ones.

Our strategy to identify the contractionary monetary policy shock is based on a recursive ordering scheme.[17] Following Christiano, Eichenbaum & Evans (1996), we impose that, when setting the nominal interest rate, the Fed's information set contains the current (and past) values of all other variables in our SVAR (Ravn & Simonelli 2007). This assumption implies that no other variable may respond contemporaneously to an unexpected change in the Federal Funds rate. Hence, the last column of the contemporaneous coefficient matrix β_0 consists of zeros, apart from the last element which is normalised to unity. Our strategy to identify monetary policy shocks is consistent with the assumption that the decisions of all agents in our model economy at time t are based on the information set available at time $t-1$ (see Footnote 7).

3.1.2 Empirical Impulse Responses

Figure 1 illustrates the Cholesky orthogonalised impulse responses to an unexpected increase in the de-annualized Federal Funds rate. We examine a one-standard-deviation shock at horizons up to 15 quarters. The black solid line is the point estimate. The dark (light) gray area illustrates the 66% (95%) centred confidence band of the empirical impulse responses. In line with our identifying assumptions, the impact of the monetary policy shock is temporary. After the initial increase, we find that the Federal Funds rate remains above its steady state level for about six quarters. Consistent with Sims (1992), the impulse response of non-durable inflation is positive on impact before becoming persistently negative.[18]

Our results document that a contractionary monetary policy shock causes a persistent economic downturn across the entire economy.[19] Thus, the durable sector accounts for almost 50% of the variance in aggregate employment, even though it accounts for less than 20% of all employees. Moreover, changes in new purchases of durable goods account for even more than 50% of the variance in total consumption expenditures, even though new durable purchases accounts for less than 20% of total consumption. This result implies that the durable goods sector is key to understanding the business cycle.

3.2 Parametrisation

The current paper attempts to estimate two parameters (amongst other parameters) that affect the non-stochastic steady state of the model economy — namely, the degree of internal habit persistence, ψ, and the replacement rate, $\bar{b}/w$. This implies that the non-stochastic steady state

[17] Given that our papers addresses a qualitative puzzle, we prefer this method over a sign restriction approach.

[18] The shape and magnitude of the inflation response is robust to the inclusion of a commodity price index.

[19] The estimated impulse responses are broadly consistent with those estimated by Bernanke & Gertler (1995), Erceg & Levin (2006), Monacelli (2009), Katayama & Kim (2013) or Sterk & Tenreyro (2013). Note that, in Erceg & Levin (2006), both the monetary contraction and the impulses of sectoral outputs are more short-lived. However, their sample draws exclusively on the post-Volcker era.

of our model economy must be re-calculated at each iteration step. Our estimation strategy (below) takes this issue into account. Moreover, we ensure that all structural parameters — except for the degree of price stickiness and the degree of durability — are symmetric across sectors. Further details on the parameterisation can be found in the Appendix A.

3.2.1 Pre-Set Parameters and Deep Ratios

To ensure that the non-stochastic steady state of the model economy is consistent with US post-war data, we first pre-set the following deep ratios (see Table 3): the steady-state unemployment rate, $1-n$, is set to its long-run average of 6% (Shimer 2012); in line with NIPA expenditure shares, steady-state aggregate output is made up of 80% non-durable consumption, c, and 19% durable good purchases, y_d; hiring costs account for the remaining 1% of aggregate output (in terms of non-durable goods);[20] and the steady-state vacancy filling rate is equal to 70% per quarter in both quarters (see van Ours & Ridder 1992 or den Haan et al. 2000).

Secondly, we choose the following set of model parameters (also summarised in Table 3). The value for the quarterly job separation rate, $\rho = 0.10$, is taken from the same source (Shimer 2012) as the value for the steady-state unemployment rate (see above). This choice implies that the steady-state job finding rate is equal to $p(\theta) = 0.61$ per quarter, the steady-state fraction of job searchers, u, is close to 15%, and that the hiring cost parameter, κ is equal to 0.9. Given the value of κ, we can then infer the steady-state employment share in the non-durable goods sector as follows:

$$n_c = \frac{y + \left(\frac{\kappa\rho^2}{(1-\rho)}\right)\delta n\left(\frac{d}{c}\right)}{1+\delta\left(\frac{d}{c}\right)} = 0.76. \tag{27}$$

The corresponding steady-state employment share in the durable sector is given by: $n_d = n - n_c = 0.18$. Since both sectors are parametrised symmetrically, the sectoral allocation of vacancies, matches, and unemployment is proportional to the employment share. The matching elasticity of vacancies, $\xi = 0.5$, is set within the interval proposed by Petrongolo & Pissarides (2001). The implied level of matching efficiency, $\bar{m}$, is equal to 0.65.

The service life of durable goods owned by consumers has been documented by Fraumeni (1997). Accordingly, the service life ranges from three years (e.g. auto parts) to 40 years (e.g. residential investment). Thus, we set the quarterly depreciation rate of durable goods equal to $\delta = 0.025$, corresponding to a mid-life of about ten years (Erceg & Levin 2006). The discount factor, $\beta = 0.99$, is chosen to match an annual real interest rate of four percent. Furthermore, we assume logarithmic preferences in the composite consumption good ($\sigma = 1$), such that within-period utility of the representative household is separable in non-durable consumption and durable services (as in Barsky et al. 2007). The elasticity of substitution among sectoral varieties is set to $\epsilon = 11$. This value is consistent with a steady-state value of sectoral mark-ups equal to 10%, i.e. $\varphi^m = 0.91$. Thus, we can use the job creation condition (equation 21) to pin down the wage rate, w:

$$w = \varphi^m - \kappa\frac{\rho}{1-\rho}\left[1-(1-\rho)\beta\right]. \tag{28}$$

[20] Based on the estimate of Yashiv (2000*b*, 0.7%), assuming that total hiring costs amount to 1% of aggregate output is common in the literature (see, e.g., Gertler & Trigari 2009, or Blanchard & Gali 2010).

Steady-state inflation is zero in both sectors. We assume perfect price flexibility in the durable goods sector, i.e. $\vartheta_d = 0$. Importantly, we note that the "comovement puzzle" is aggravated by a strong asymmetry in cross-sectoral price flexibility imposed by perfect price flexibility in the durable goods sector. Finally, the generalised Taylor rule parameters are set within the intervals estimated by Bianchi (2013): $r_p = 1.5$ and $r_y = 0.1$.[21]

3.2.2 Implied Steady-State Values

We now discuss the impact of the degree of internal habit formation, ψ, and the replacement rate, $\bar{b}/w$, on the steady state of the model economy. First, with internal habit formation in non-durable consumption, a given level of non-durable goods generates less utility than otherwise. Therefore, we adjust the preference weight for habit-adjusted non-durable consumption, ζ, such that the consumption pattern remains consistent with the fraction of income spent on durable and non-durable, respectively. More formally, we substitute equation (10) into equation (12) and then solve for the corresponding value of ζ:

$$\zeta = \frac{(1-\psi)/((1-\beta(1-\delta))(1-\beta\psi))c}{\varphi_d y_d/\delta + (1-\psi)/((1-\beta(1-\delta))(1-\beta\psi))c}. \tag{29}$$

Similarly, a higher replacement rate, $\bar{b}/w$, causes *ceteris paribus* an increase in the unemployment rate.[22] For this reason, we ensure that a higher (lower) estimate of the replacement rate, $\bar{b}/w$, goes along with a lower (higher) worker's bargaining power, γ, such that the steady-state unemployment rate in our model economy remains unchanged. We identify the corresponding value of the worker's bargaining power, γ, using the wage equation (22):

$$\gamma = \frac{w\left[1 - \left(\bar{b}/w\right)\right]}{\varphi - \left(\bar{b}/w\right)w + \beta\kappa\rho^2\left(u/n\right)}. \tag{30}$$

Thus, an increase in the replacement rate, $\bar{b}/w$, does not change the level of the wage (see also equation 28), but only reduces its elasticity over the business cycle.

3.3 Estimation Strategy

Following Rotemberg & Woodford (1997), we estimate the vector containing the key parameters of interest, η, to minimize the weighted distance between the model generated impulse responses, $\Gamma(\eta)$, and their empirical counterparts, Γ:[23]

$$\eta^* = \arg\min_{\eta} \left(\Gamma - \Gamma(\eta)\right)' \Psi^{-1} \left(\Gamma - \Gamma(\eta)\right), \tag{31}$$

[21] Note that these values appear to be identical to the conventional values suggested by Clarida, Gali & Gertler (1999) and Christiano et al. (2005). In contrast to these authors, however, we include output growth and not the output gap into the generalised Taylor rule.

[22] The effect in our model works not through a higher wage, which is given by equation (28). Instead, a higher replacement rate, $\bar{b}/w$, in combination with a constant wage, w, implies that the product of the job finding rate, $q(\theta)\theta$, and the hiring rate, $m/(1-u)$, must fall. This implies an increase in the unemployment rate.

[23] The model generated impulse responses are computed using Dynare 4.2.5 (Adjemian, Bastani, Juillard, Mihoubi, Perendia, Ratto & Villemot 2011). The code to match model generated impulse responses with those from a structural VAR was kindly shared by Georg Duernecker, which is gratefully acknowledged.

where Ψ is a diagonal matrix with the sample variances of the empirical impulse responses along the diagonal (as in Christiano et al. 2005).

4 Results

4.1 Estimated Parameter Values

Table 4 summarises the estimated model parameters. The estimated replacement rate, $\bar{b}/w = 0.75$, is within the range of conventional values based on independent evidence (Hall & Milgrom 2008, 0.71, Mortensen & Nagypál 2007, 0.73, or Costain & Reiter 2008, 0.75). At the same time, our estimate remains clearly below the "small surplus" (Hagedorn & Manovskii 2008) estimates of closely-related one-sector models (Gertler, Sala & Trigari 2008, 0.98, Christiano et al. 2016, 0.88).[24] The implied value of the worker's bargaining power is $\gamma = 0.78$, which is only slightly higher than the estimates of Gertler et al. (2008, 0.62) or Krause, Lopez-Salido & Lubik (2008*b*, 0.67). The estimated degree of internal habit persistence $\psi = 0.85$ is very close to the estimates of Gertler et al. (2008, 0.80) and Christiano et al. (2016, 0.81). The estimate for the degree of price stickiness in the non-durable goods sector, $\vartheta_c = 0.95$, is somewhat higher than the estimates of Gertler et al. (2008, 0.57) and Christiano et al. (2016, 0.74). This is not surprising, however, given that, in our two-sector model, only prices of non-durable goods are subject to Calvo type rigidities, whereas durable good prices are perfectly flexible.[25] In addition, the estimated degree of price indexation in the non-durable goods sector, $\chi_c = 1.00$, implies full price indexation (as in Christiano et al. 2005). Note that, when all firms that cannot re-optimise index their prices to the lagged inflation rate, the degree of price stickiness is actually smaller than suggested by the high Calvo parameter. The estimated degree of inertia in the monetary policy rule, $r_r = 0.90$, is slightly above other estimates (Smets & Wouters 2007, 0.81, Christiano et al. 2016, 0.84), but within the same range. Finally, the estimate for the standard deviation of the monetary policy rule is $\varsigma_r = 0.16$.

4.2 Properties of the Estimated Model

Figure 2 depicts the impulse responses of the estimated model to a contractionary monetary policy shock (black solid lines), as well as the associated confidence intervals from the structural VAR (grey shaded areas). The estimated standard deviation of the monetary policy rule, $\varsigma_r = 0.16$, matches closely the initial response of the Federal Funds rate. In the following period, the decline in durable good prices allows the central bank to relax the monetary tightening by about 1/3 of the initial hike (like in the data, but one period earlier). The estimated degree of inertia in the monetary policy rule, $r_r = 0.90$, then ensures that the impulse response always remains within the 95% confidence interval while converging monotonously to its steady-state level. Owing to "limited information" (see Footnote 7), all other model generated responses only respond with a delay of one quarter. For instance, the estimated fraction of non-durable good

[24] We here refer to the estimates of Gertler et al. (2008) and Christiano et al. (2016) when wages are subject to Nash bargaining. Also note that that there is some variation of definitions across different authors. For instance, Gertler et al. (2008, p. 1732) define the replacement rate in terms of the worker's contribution to the job.

[25] Note that Christiano et al. (2005) also find a price stickiness parameter of 0.92 when they estimate their model without variable capital utilization.

firms that is able to re-optimize prices in the period *after* the shock is equal to $1 - \vartheta_c = 0.05$. Together with full indexation in the non-durable goods sector, $\chi_c = 1.00$, this small estimate helps the model to replicate the muted u-shaped inflation response (see Footnote 9). Jointly, the hike in the nominal interest rate and the muted u-shaped inflation response generate a temporary, but persistent increase in the real interest rate.

As can be seen from the graph, the rise in the real interest rate causes a significant economy-wide downturn. As in the data, the dynamic adjustment paths show marked u-shaped responses in both sectors which bottom out not before one year after the monetary contraction. Our model also replicates the fact that the responses in the durable goods sector are much more amplified than the responses in the non-durable goods sector (by about factor five). In particular, the model generated response of non-durable consumption very closely matches the amplitude and the curvature of its VAR counterpart; the response remains within the 66% confidence interval for the entire forecast horizon. Similarly, the model generated response of durable goods purchases replicates the curvature of its VAR counterpart, but shows a slightly smaller amplitude; the response always remains within the 95% confidence interval. In both sectors, the model generated responses of employment lead their VAR counterpart slightly. Both impulse responses remain for almost the entire forecast horizon within the 95% confidence interval.

5 Discussion

5.1 The Near Constancy Result

Our finding that a contractionary monetary policy shock causes a significant economy-wide downturn may sound natural — but it is not. As demonstrated by Barsky et al. (2007), the two-sector New Keynesian model with flexible durable good prices and sticky non-durable good prices (in line with Bils & Klenow 2004 as well as Klenow & Kryvtsov 2008) predicts that sectoral outputs move in opposite directions. The opposing responses of sectoral outputs almost offset each other, which implies that monetary policy shocks are close to neutral for aggregate output. This outcome is clearly at odds with the data. Moreover, the model suffers from a lack of internal propagation: the model generated responses peak on impact — whereas their empirical counterparts peak with a delay of several quarters. The main contribution of the current paper is to show that two additional standard DSGE features — namely, search and matching frictions in the labour market and internal habit formation in non-durable consumption — suffice not only to generate comovement across sectors, but also to closely replicate the amplitude and the curvature of the empirical impulse responses in both sectors.

The key equation to understand the dynamic effects of a contractionary monetary policy shock is the asset pricing equation for durable goods, equation (12). Given that the depreciation rate, δ, is low and the subjective discount factor, β, is close to unity, short-run fluctuations in durable purchases have only little effect on the aggregate stock of durable goods. As a result, the shadow value of durable goods; i.e., the right hand side of equation (12), remains essentially unchanged after a temporary monetary contraction:

$$\lambda_t \varphi_{d,t} \approx \bar{D}. \tag{32}$$

As explained by Barsky et al. (2007), the "near constancy" property of the shadow value of durable goods, $\bar{D}$, entails that the marginal utility of consumption, λ_t, and the relative price of durable goods, $\varphi_{d,t}$, move in opposite directions. This implies that a contractionary monetary policy shock leads not only to a *rise* in the marginal utility of consumption (via the standard Euler equation 11), but also to a *fall* in the relative price of durable goods. Moreover, equation (12) further predicts that the stock of durable goods declines if, and only if, the percentage rise in the marginal utility of consumption is greater than the percentage fall in the relative price of durable goods. Otherwise, as in Barsky et al. (2007), the representative household has incentives to build up the stock of durable goods, d_t, at low cost in the aftermath of a contractionary monetary policy shock.

With Walrasian labour markets, the described scenario is indeed an equilibrium outcome. Given that prices of durable goods are perfectly flexible, durable goods producers always charge a constant mark-up over real marginal costs. This implies that the percentage decline of the relative price of durable goods is equal to the percentage decline of real marginal costs in the durable goods sector. Real marginal costs in the durable goods sector fall deeply, given the slump in the economy-wide real wage (which is mainly determined by the contraction in the non-durable goods sector). In equilibrium, the plans of durable goods producers are consistent with the plan of the representative households to increase purchases of durable goods.

Furthermore, with Walrasian labour markets, the "near constancy" property of the shadow value of durable goods, $\bar{D}$, entails that labour input (total hours) are near-constant as well: $\bar{h}$. This result is due to the first order condition which requires that the marginal revenue product of hours (which depends on sectoral real marginal costs and, thus, the relative price of durables, $\varphi_{d,t}$) equals the marginal rate of substitution between leisure and consumption (which depends on the marginal utility of consumption, λ_t). Importantly, this optimality condition holds not only under Walrasian labour markets (as in Barsky et al. 2007), but also in search and matching models with an intensive margin of employment adjustment (hours per worker) as long as wages are subject to Nash bargaining (Trigari 2009). The only difference is that, in models with Walrasian labour markets, the optimality condition implies that *total* hours are near-constant — while in search and matching models the optimality condition implies that hours *per worker* are near-constant. In the following, we prove this proposition in the context of a search and matching model.

Proposition 5.1. *In a two-sector NK model with flexible durable good prices, sticky non-durable good prices, search frictions in the labour market, Nash bargaining, and perfect labour mobility across sectors, hours per worker are near-constant in response to monetary policy shocks.*

Proof. Let us generalise the net marginal value of employment to the representative household (equation 13) and hiring firm j (equation 20) to allow for flexible hours per worker:

$$\tilde{\mathcal{W}}^j_{s,t} = w^j_{s,t} - \left[\bar{b} + \frac{\nu\left(h^j_{s,t}\right)^{1+\phi}}{(1+\phi)\,\lambda_t}\right] + \beta\,(1-\rho)\,E_t\left\{\frac{\lambda_{t+1}}{\lambda_t}\left[\tilde{\mathcal{W}}^j_{s,t+1} - \sum_{l=\{c,d\}} q\,(\theta_{t+1})\,\theta_{l,t+1}\left(\tilde{\mathcal{W}}_{l,t+1}\right)\right]\right\}, \tag{33}$$

$$\tilde{\mathcal{J}}^j_{s,t} = \varphi^m_{s,t} h_{s,t} - w^j_{s,t} h_{s,t} + \beta\,(1-\rho)\,E_t\left\{\frac{\lambda_{t+1}}{\lambda_t}\tilde{\mathcal{J}}^j_{s,t+1}\right\}, \tag{34}$$

where $h^j_{s,t}$ denotes the number of hours worked by worker j in sector s, ν is the utility cost parameter in sector-specific labour supply, and ϕ denotes the labour supply elasticity along the intensive margin of individuals employed in sector s.[26]

Under Nash bargaining, the sectoral real wage, $w^j_{s,t}$, and hours per worker, $h^j_{s,t}$, are determined jointly in order to maximise the weighted product of each party's surplus share:

$$\max_{w^j_{s,t}, h^j_{s,t}} \quad \left(\tilde{\mathcal{W}}^j_{s,t}\right)^{\gamma} \left(\tilde{\mathcal{J}}^j_{s,t}\right)^{1-\gamma},$$

where γ is the bargaining power of the household. Thus, the first order conditions with respect to $w^j_{s,t}$ and $h^j_{s,t}$ are:

$$\gamma \mathcal{J}^j_{s,t} = (1-\gamma)\, \mathcal{W}^j_{s,t}, \tag{35}$$

$$\lambda_t \varphi^m_{s,t} = \nu \left(h^j_{s,t}\right)^{\phi}. \tag{36}$$

Accordingly, the real wage $w^j_{s,t}$ splits the joint surplus into two shares (equation 35). We assume that these optimality conditions also hold in expectations and impose symmetry. Then we solve equation (35) for the real wage per worker in sector s:

$$w_{s,t}h_{s,t} = \gamma \varphi^m_{s,t} h_{s,t} + (1-\gamma)\left[\bar{b} + \frac{\nu\,(h_t)^{1+\phi}}{(1+\phi)\,\lambda_t}\right] + \beta\gamma\kappa\,(1-\rho)\,E_t\left\{\frac{\lambda_{t+1}}{\lambda_t}\frac{q\,(\theta_{t+1})\,\theta_{t+1}m_{t+1}}{1-u_{t+1}}\right\}. \tag{37}$$

The second first order condition, equation (36), entails that hours per worker, $h^j_{s,t}$ are set to maximise the joint surplus. This requires that the marginal revenue product of labour (i.e., the real marginal costs in sector s), $\varphi^m_{s,t}$, equals the marginal rate of substitution between labour and consumption, $\chi h^{\phi}_t/\lambda_t$.

Importantly, when durable good prices are perfectly flexible, profit maximising durable producers set their prices as a constant mark-up over real marginal cost (see equation 17). Combining this finding with the first order condition for hours per worker (equation 36), and the "near constancy" result (equation 32) then implies that hours per worker in the durable goods sector, $h_{d,t}$, are extremely inelastic in response to monetary policy shocks:

$$\nu h^{\phi}_{d,t} = \lambda_t \varphi^m_{d,t} = \lambda_t \frac{\epsilon-1}{\epsilon}\varphi_{d,t} \approx \frac{\epsilon-1}{\epsilon}\bar{D}. \tag{38}$$

To complete the proof, we need to show that real marginal costs in both sectors follow the same dynamics after a monetary innovation — if labour is perfectly mobile across sectors. Therefore, we modify equation (43) to account for flexible hours per worker:

$$h^j_{s,t}\varphi^m_{s,t} = w^j_{s,t}h^j_{s,t} + \kappa\frac{m_t}{1-u_t} - \beta\,(1-\rho)\,\kappa E_t\left\{\frac{\lambda_{t+1}}{\lambda_t}\frac{m_{t+1}}{1-u_{t+1}}\right\}, \tag{39}$$

and then use equation (37) to substitute the wage per worker. This yields:

$$h_{s,t}\varphi^m_{s,t} = \left[\bar{b} + \frac{\nu\,(h_{s,t})^{1+\phi}}{(1+\phi)\,\lambda_t}\right] + \frac{\kappa}{1-\gamma}\frac{m_t}{1-u_t} - E_t\left\{\left[1-\gamma q(\theta_{t+1})\theta_{t+1}\right]\beta\,(1-\rho)\,\frac{\kappa}{1-\gamma}\frac{\lambda_{t+1}}{\lambda_t}\frac{m_{t+1}}{1-u_{t+1}}\right\}. \tag{40}$$

[26] Note that, for the ease of exposition, we assume that output of each small hiring firm is linear in hours, but the results also hold under decreasing returns.

Hence, we need to demonstrate that the following equation holds:

$$\varphi_{c,t}^{m} h_{c,t} + \frac{\nu \left(h_{c,t}\right)^{1+\phi}}{\left(1+\phi\right)\lambda_{t}} = \varphi_{d,t}^{m} h_{d,t} + \frac{\nu \left(h_{d,t}\right)^{1+\phi}}{\left(1+\phi\right)\lambda_{t}}. \tag{41}$$

Using equation (36), we can show that this is indeed the case:

$$\varphi_{c,t}^{m}\left(\lambda_{t}\frac{\varphi_{c,t}^{m}}{\nu}\right)^{\frac{1}{\phi}} + \frac{\nu\left(\lambda_{t}\frac{\varphi_{c,t}^{m}}{\nu}\right)^{\frac{1+\phi}{\phi}}}{\left(1+\phi\right)\lambda_{t}} = \varphi_{d,t}^{m}\left(\frac{\lambda_{t}\varphi_{d,t}^{m}}{\nu}\right)^{\frac{1}{\phi}} + \frac{\nu\left(\frac{\lambda_{t}\varphi_{d,t}^{m}}{\nu}\right)^{\frac{1+\phi}{\phi}}}{\left(1+\phi\right)\lambda_{t}} \Rightarrow \varphi_{c,t}^{m} = \varphi_{d,t}^{m}. \tag{42}$$

□

5.2 The Role of Search and Matching Frictions

In order to address the sectoral comovement puzzle — and the near constancy result — we extend the Barsky et al. (2007) model by search and matching frictions in the labour market (Pissarides 2000). This modification changes the monetary transmission mechanism in two ways.

First, search and matching frictions introduce an extensive margin of labour adjustment, which breaks the near constancy relationship. To illustrate this channel, we use the job creation condition (equation 21) to decompose real marginal costs, $\varphi_{s,t}^{m}$, into the real wage per worker, $w_{s,t}$, and a correction term that captures the difference between current hiring costs per worker and expected savings on hiring costs in the next period (as in Krause et al. 2008*b*):

$$\varphi_{s,t}^{m} = w_{s,t}^{j} + \kappa\frac{m_{t}}{1-u_{t}} - \beta\left(1-\rho\right)\kappa E_{t}\left\{\frac{\lambda_{t+1}}{\lambda_{t}}\frac{m_{t+1}}{1-u_{t+1}}\right\}. \tag{43}$$

Surprisingly, Krause et al. (2008*b*) find that search and matching frictions change the cyclical behaviour of real marginal costs only little. Actually, any imposed rigidity on the real wage may be even offset by an increase in the volatility of the correction term (see Krause & Lubik 2007 or Faccini, Millard & Zanetti 2013). In contrast to these papers, however, our model adopts the hiring cost specification of Gertler & Trigari (2009) instead of standard linear vacancy posting costs. As illustrated in Figure 3, the former specification generates substantially less volatility in hiring costs than the latter — simply because the gross hiring rate, $m_t/(1-u_t)$, is much less elastic and less persistent than the inverse of the vacancy filling rate, $1/q(\theta_t)$. Furthermore, substituting equation (22) into equation (43) shows that, besides the gross hiring rate, the real opportunity cost of labour, the constant $\bar{b}$, is the main determinant of real marginal costs:

$$\varphi_{s,t}^{m} = \bar{b} + \frac{\kappa}{1-\gamma}\frac{m_{t}}{1-u_{t}} - E_{t}\left\{\left[1-\gamma q(\theta_{t+1})\theta_{t+1}\right]\beta\left(1-\rho\right)\frac{\kappa}{1-\gamma}\frac{\lambda_{t+1}}{\lambda_{t}}\frac{m_{t+1}}{1-u_{t+1}}\right\}. \tag{44}$$

Hence, in our two-sector monetary business cycle model, an increase in the real opportunity cost of labour, $\bar{b}$, elicits the following two effects. First, the less elastic real wage amplifies the decline in aggregate employment and, consequently, output (see Hagedorn & Manovskii 2008, and the subsequent literature). This implies that monetary policy shocks are no longer "near neutral". Secondly, the less elastic real wage *effectively* reduces the elasticity of real marginal costs — and consequently the elasticity of the relative price of durable goods — given that the (negative) feedback effect through an increase in the volatility of the correction term is substantially weaker.[27] If the replacement rate, $\bar{b}/w$, reaches a certain threshold, this effect becomes sufficiently strong such that the representative household no longer has incentives to increase purchases of durable goods (or, alternatively, no durable good firm has incentives to increase production) after a monetary contraction. Thus, we observe comovement across sectors.

Second, with long-run employment relationships, shocks are propagated through changes in the stock of sectoral employment (as in Hairault 2002). This increases the persistence of sectoral outputs. Beyond that, our hiring cost specification reinforces this effect. When firms pay per hire and not per vacancy, hiring costs are even less volatile and less persistent (see Figure 3). This provides further incentives to amplify and to smooth hiring activities over several periods. Consequently, the hump-shape in sectoral outputs becomes even more pronounced (compare Figures 2 and 4).

In summary, the introduction of search and matching frictions generates comovement and persistent impulse responses. This dual effect explains why our relatively parsimonious model can go such a long way. The associated estimates are within the range of conventional values, which provides further support for our approach.

5.3 The Role of Habit Formation in Non-durable Consumption

The previous section has shown that increasing the real opportunity cost of labour, $\bar{b}$, helps (i) to amplify the responses of aggregate employment and output and (ii) to generate comovement across sectors — provided that a certain threshold of $\bar{b}$ is reached. The current section argues that this threshold depends crucially on the degree of internal habit formation in non-durable consumption. To illustrate this relationship, we perform the following two experiments. First, we leave all (pre-set and estimated) model parameters unchanged, but assume no habit formation in non-durable consumption: $\psi = 0$. As can be seen in Figure 5, our estimated model no longer generates comovement across sectors. This means that, at conventional values of $\bar{b}/w$, the "search frictions" channel alone does not suffice. Secondly, we then increase the level of the replacement rate, $\bar{b}/w$. Figure 6 shows that comovement returns when we increase the replacement rate to $\bar{b}/w = 0.98$ or even higher (note that, in the first period after the shock, we still observe a positive hike in durable goods). At the same time, however, the extremely high value of the replacement rate amplifies aggregate employment and output strongly — much stronger than observed in the data.

Habit formation helps to generate comovement at conventional values of the replacement rate, $\bar{b}/w$, in that it changes the household's optimization problem. Under habit formation, households no longer aim at smoothing the level, but the habit-adjusted growth rate of non-durable consumption. This greatly limits the decline in non-durable consumption. Instead, the model with internal habit formation generates a very smooth u-shaped decline, which bottoms out about five quarters after the shock (as in the data, see Figure 2). At the same time, habit formation leaves the magnitude of all aggregate responses (output and employment) almost

[27] Alternatively, (Carlstrom & Fuerst 2010) develop a model where households are monopolistic suppliers of a particular labour type (as in Erceg, Henderson & Levin 2000) and where nominal wages are sticky (Calvo 1983). Sticky wages reduce the elasticity of real marginal cost in the durable sector and, hence, help to generate comovement across sectors.

unchanged.[28] This implies that the durable goods sector now needs to absorb a much larger fraction of the aggregate shock, i.e. durable goods purchases fall strongly. In other words, habit formation in non-durable consumption helps to appropriately distribute the impact of a given shock over the two sectors. For this reason, the model with habit formation requires a lower replacement rate, $\bar{b}/w$, to generate comovement across sectors. Moreover, with a low replacement rate, the model no longer generates excess volatility in aggregate output and employment. This explains why our estimated model closely matches the amplitude and curvature of the empirical impulse responses.[29]

6 Alternative Model Specifications

6.1 Cross-Sectoral Reallocation Frictions

The baseline version of our model assumes that job searchers are randomly matched with hiring firms from both sectors. This assumption seems reasonable, given the high degree of inter-industry mobility of workers in the U.S. documented by Kambourov & Manovskii (2008) or Herz & van Rens (2015). In order to examine the role of cross-sectoral worker mobility more thoroughly, the current subsection presents a model version where job searchers are immobile across sectors. In particular, we assume that there is a separate matching market for workers previously employed in the durable good and in the non-durable sector respectively. These job searchers can only be matched with hiring firms from the same sector.

Figure 7 presents the impulse responses when labour markets are sector-specific, but the non-stochastic steady state is identical to our baseline specification. We observe that the impulse responses are fairly similar, but the responses of the durable goods sector are somewhat less amplified. The value of the quadratic form rises from 30.3 (common labour market) to 47.0 (sector-specific labour markets). When we re-estimate the model with sector-specific labour markets, the estimated value of the replacement rate rises to $\bar{b}/w = 0.87$ (all other estimates remain largely unchanged, see Table 4). The associated impulse responses are observationally equivalent to the one of the baseline version (not shown here); also the value of the quadratic form (32.1) is only slightly higher than under one common labour market. This leads us to the conclusion that (i) the model's ability to amplify the durable goods sector is stronger when workers are perfectly mobile across sectors, but (ii) the weaker amplification mechanism under sector-specific labour markets can be compensated by a higher value of the replacement rate.

The main difference between the two specifications is that, with one common labour market, there is one common job finding rate, $q(\theta_t)\theta_t$. Thus, all unemployed job searchers compete with each other for jobs in both sectors. As a result, cross-sectoral congestion externalities arise. With sector-specific labour markets, instead, the job finding rate, $q(\theta_{s,t})\theta_{s,t}$, is sector-specific:

[28] Put differently, habit formation alone does not help to solve the comovement puzzle. The aggregate responses remain "near neutral".

[29] More technically, habit formation generates comovement not by reducing the elasticity of the relative price of durable goods (like the "search frictions" channel), but by increasing the elasticity of the marginal utility of consumption. Under habit formation, the marginal utility rises stronger because households, in the period after the shock, are unable to smooth the habit-adjusted growth rate of non-durable consumption (households are unable to adjust c_{t-1}, see equation 10). Without habit formation, instead, households only take current and future levels of consumption into account. Thus, households with habit formation suffer more from a discrete drop in non-durable consumption (which manifests itself as a larger increase in the marginal utility of consumption).

unemployed job searchers compete only with other unemployed from the same sector for jobs in the same sector; here congestion externalities arise only within each sector. Figure 8 illustrates that, with sector-specific labour markets, the job finding rate in the non-durable sector falls less, while the job finding rate in the durable goods sector falls even more than the common job finding rate in the model with perfect worker mobility. This implies that, with cross-sectoral mobility, there is a (positive) net re-allocation flow of former workers from the durable goods sector to the non-durable goods sector. Consequently, employment in the (non-)durable goods sector falls stronger (weaker) than under sector-specific labour markets. This effect explains why cross-sectoral mobility amplifies the responses in the durable goods sector, but dampens the responses in the non-durable goods sector.[30,31]

To sum up, our model closely matches the empirical impulse responses — irrespective of whether workers are able to move freely across sectors or not. Free labour mobility improves the model's amplification mechanism, tough. The estimates for the value of the replacement rate, $\bar{b}/w$, thus range from 0.75 (one common labour market) to 0.87 (sector-specific labour markets). We therefore expect that a more general model of worker re-allocation across sectors (e.g., along the lines of Mehrotra & Sergeyev 2013) will be useful in identifying a more precise estimate within this interval. Such a detailed analysis, however, is beyond the scope of this paper.

6.2 Estimated Taylor Rule

In the baseline version of our model, we only estimate the standard deviation, ς_r, and the policy inertia parameter, r_r, of the generalised Taylor rule (equation 23), while the other two remaining parameters — i.e, the responsiveness to inflation, $r_p = 1.5$, and the responsiveness to output growth, $r_y = 0.1$ — are set within the interval estimated by Bianchi (2013). In the following, we re-estimate our baseline version, but additionally include these two parameters in the set of estimated parameters, η. In line with the estimates of Bianchi (2013) and Justiniano et al. (2013), we restrict the inflation responsiveness parameter, r_p, to lie within the interval $[1, 2]$; the output growth responsiveness parameter, r_y, is restricted to lie within the interval $[0, 1]$.

As can be seen from Table 4, we find interior estimates for both parameters: $r_p = 1.36$ and $r_y = 0.80$. The estimated responsiveness to inflation is close to the estimate of Christiano et al. (2015, 1.66), while the estimated responsiveness to output growth is close to the estimate of Justiniano et al. (2013, 0.85).[32] The value of the quadratic form is $26.4 < 30.3$, which indicates a superior fit to the empirical impulse responses than the baseline version of our

[30] Quantitatively, the former effect is stronger than the latter. Thus, cross-sectoral mobility also helps to amplify aggregate output and employment. This explains why the estimated model with sector-specific labour markets requires a higher replacement rate, $\bar{b}/w$, and not a higher degree of habit persistence, ψ, to match the empirical impulse responses.

[31] The same conclusion can be drawn by examining the behaviour of real marginal costs in both sectors. As can be seen from equation (44), the expected job finding rate, $q(\theta_{t+1})\theta_{t+1}$, directly determines real marginal costs, $\varphi^m_{s,t}$. This channel equalises real marginal costs across sectors when labour is perfectly mobile. But with sector-specific labour markets, the cross-sectoral no arbitrage condition for job creation no longer holds. This implies that real marginal costs in the durable goods sector, $\varphi^m_{d,t}$, fall not only stronger than in the non-durable goods sector, $\varphi^m_{c,t}$, but also stronger than under perfect labour mobility $\varphi^m_{s,t}$. The strong fall in production costs mitigates durable good firms' incentives to reduce production (or alternatively, the stronger decline in the relative price of durable goods, $\varphi_{d,t}$, provides households with weaker incentives to reduce purchases of durable goods).

[32] According to Bianchi (2013), the estimated combination of parameters appears to be rather "dovish"; i.e. the responsiveness to inflation is rather weak and the responsiveness to output growth is rather strong. Bianchi's estimates for r_p range from 0.95 to 2.39, whereas his estimates for r_y range from 0.05 to 0.31.

model (see Figure 9). The main difference compared to the baseline version is that the Federal Reserve relaxes the monetary tightening in the period after the shock not by about 1/3, but by almost 50%. The model generated impulse response thus stays within the 66% confidence interval at forecast horizons between 2-9 quarters. Consistent with the shape of the empirical impulse response of the nominal interest rate, we now estimate a higher standard deviation of the generalised Taylor rule ($\varsigma_r = 0.18 > 0.16$), together with a lower policy inertia parameter ($r_r = 0.87 < 0.90$).

6.3 Strategic Wage Bargaining

As shown in Section 5, the value of the replacement ratio, $\bar{b}/w$, plays a key role in generating comovement across sectors. A high value of the replacement ratio reduces the elasticity of the real wage rate and real marginal costs (see equation 44) and, consequently, limits the fall in the relative price of durable goods. As demonstrated by Hertweck (2013) and Christiano et al. (2016), a very similar dampening effect on the elasticity of the real wage (and, consequently, real marginal costs) can be observed when the real wage is the outcome of a strategic bargaining game (following Hall & Milgrom 2008). Accordingly, the generated impulse responses are observationally equivalent to the standard Nash solution, but rely on a substantially lower replacement ratio $\bar{b}/w$. This may be advantageous, given that a high replacement ratio may adversely affect the steady-state properties of search and matching models (see Costain & Reiter 2008 or Hornstein, Krusell & Violante 2011). Even though our "conventional" estimate of the replacement rate, $\bar{b}/w = 0.75$, does not give rise to major concerns, we explore the potential of this approach in the following.

A common interpretation of the standard Nash solution is that the firm and the household engage in a Rubinstein (1982) game of alternating offers and responses with a high risk of bargaining breakdown.[33] Therefore, the firm's and the household's surplus share are defined as the respective value of employment net of the outside alternative, i.e., the value of labour market search. By contrast, Hall & Milgrom (2008) argue that, in the search and matching model, the risk of bargaining breakdown is low. Rather, the prospective joint surplus gives both parties strong incentives to conclude a wage contract by mutual agreement. For this reason, an unsatisfactory offer is typically rejected and responded by a counter-offer. This implies that the surplus shares should not be defined relative to the outside alternative, but relative to the value of delaying the bargaining process by one period (this bargaining game is referred to as the time-preference Nash solution, see Binmore, Rubinstein & Wolinsky 1986). During this period, which can be interpreted as a strike, we assume that the worker receives income from strike funds, μ, and the firm receives a zero profit flow, while both parties retain the continuation value of employment (as in Jung & Kuester 2011). The resulting real wage is given as the linear weighted average between the price of sector-specific intermediate goods and the flow income from strike funds, μ:

$$w^j_{s,t} = w_{s,t} = \gamma \varphi^m_{s,t} + (1-\gamma)\,\mu \tag{45}$$

We now assume that the share ω of all firm-worker pairs perceives the risk of bargaining breakdown to be prevalent. These matches engage in standard Nash bargaining. On the other

[33] The following paragraphs borrow from Hertweck (2013).

hand, the share $1-\omega$ perceives the risk of bargaining breakdown to be negligible. These matches engage in time-preference Nash bargaining. The risk assessment of each firm-worker pair follows an *i.i.d.* process. Therefore, the average real wage reads as:

$$w_{s,t} = \gamma\varphi_{s,t}^{m} + (1-\gamma)\left[\omega\left\langle \bar{b} + \frac{\beta\gamma\kappa}{1-\gamma}(1-\rho)E_t\left\{\frac{\lambda_{t+1}}{\lambda_t}\frac{q(\theta_{t+1})\theta_{t+1}m_{t+1}}{1-u_{t+1}}\right\}\right\rangle + (1-\omega)\mu\right]. \quad (46)$$

As explained by Hall & Milgrom (2008), the key difference between the standard Nash and the time-preference solution is that the worker's outside alternative of labour market search is clearly pro-cyclical, while the flow income from strike funds is basically a-cyclical. Consequently, the smaller the value of ω, the less elastically the real wage behaves over the business cycle.[34]

Indeed, our estimates suggest that only $\omega = 49\%$ of all firm-worker pairs engage in standard Nash bargaining (see Table 4). The remaining $1-\omega = 51\%$ engage in time-preference Nash bargaining. The impact of the a-cyclical flow income from strike fund effectively reduces the elasticity of the real wage, $w_{c,t}$, and, consequently, real marginal costs, $\varphi_{s,t}^{m}$, as well as the relative price of durable goods, $\varphi_{d,t}$. Due to its stronger amplification mechanism, the strategic wage bargaining model requires a substantially lower replacement rate, $\bar{b}/w = 0.55 < 0.75$, to match the empirical impulse responses. All other estimates remain essentially unchanged. The value of the quadratic form falls slightly ($29.8 < 30.3$). As expected, the corresponding impulse responses are observationally equivalent to those of our baseline version (see Figure 10).

6.4 Durable Price Stickiness

Finally, the last column of Table 4 shows the results when we allow for Calvo-type rigidities in the prices of durable goods. The estimates imply that every period 94% of all durable producers may re-optimise prices and that 81% of the remaining durable producers index their prices to the lagged inflation rate in the durable goods sector. All estimated parameters remain essentially unchanged, also the value of the quadratic form falls only very little ($30.2 < 30.3$). Consequently, the model generated impulse responses are observationally equivalent to the baseline version (see Figure 11). This indicates that the assumption of perfectly flexible durable goods prices is a valid approximation.

7 Conclusion

The durable goods sector is key to understanding the dynamic effects of monetary policy shocks: even though its share in the aggregate economy is relatively small ($< 20\%$), fluctuations in new purchases of durable goods account for more than 50% of the variance in aggregate output. Despite its importance, however, the role of the durable goods sector in the transmission of monetary shocks is not well understood. In particular, the New Keynesian model with flexible durable good prices and sticky non-durable good prices (consistent with Bils & Klenow 2004 and Klenow & Kryvtsov 2008) predicts that sectoral outputs move in opposite directions (Barsky et al. 2007). The opposing responses of sectoral outputs almost offset each other, which implies that monetary policy shocks are close to neutral for aggregate output. This result is clearly at

[34] We target the same steady-state real wage for both types of firm-worker pairs. This requires to set the flow income from strike funds, μ, equal to the steady-state outside alternative.

odds with the empirical observation that a monetary contraction causes a downturn across the entire economy. Beyond that, the standard model suffers from a lack of internal propagation: the model generated responses fall sharply on impact — whereas their empirical counterparts reach a trough with a delay of several quarters.

This paper provides a quantitative answer to the "sectoral comovement puzzle". For this purpose, we extend the standard model by (*i*) search and matching frictions in the labour market and (*ii*) internal habit formation in non-durable consumption. The introduction of these two standard DSGE features suffices not only to generate comovement across sectors, but also to closely replicate the u-shaped cross-sectoral impulse responses after a monetary contraction. In particular, we show that search frictions in the labour market effectively limit the elasticity of real marginal costs and, consequently, also the elasticity of durable prices. The strength of this channel depends on the value of the replacement rate. With habit formation in non-durable consumption, the durable sector absorbs a larger fraction of the aggregate shock. This helps the model to generate comovement at conventional values of the replacement rate. As a result, our estimated model generates not only comovement, but also closely replicates the amplitude and the curvature of the empirical impulse responses.

So far, search and matching frictions have received only little attention in the New Keynesian literature (notable exception are Walsh 2005 or Trigari 2009). Likely, because search and matching frictions seem to matter little in explaining inflation dynamics (Krause, Lopez-Salido & Lubik 2008*a*, Krause et al. 2008*b*). In a similar vein, Gertler et al. (2008) argue that the introduction of search and matching frictions does not improve the fit compared to conventional one-sector models (Christiano et al. 2005, Smets & Wouters 2007). However, given that the Federal Reserve Board's multi-sector DSGE model (Edo, see Edge, Kiley & Laforte 2010) exhibits particularly large forecast errors in aggregate labour input and residential investment (a durable good), our results imply that a more careful consideration of search and matching frictions in New Keynesian models could solve two problems at the same time.

References

Adjemian, S., Bastani, H., Juillard, M., Mihoubi, F., Perendia, G., Ratto, M. & Villemot, S. (2011), Dynare: Reference Manual, Version 4, Dynare Working Papers No. 1, CEPREMAP. Date of revision: July 2014, with Karamé, F., Maih, J. & Pfeifer, J.

Andolfatto, D. (1996), 'Business cycles and labor-market search', *American Economic Review* **86**(1), 112–132.

Barsky, R. B., House, C. L. & Kimball, M. S. (2007), 'Sticky-price models and durable goods', *American Economic Review* **97**(3), 984–998.

Bernanke, B. S. (1984), 'Permanent income, liquidity, and expenditure on automobiles: Evidence from panel data', *The Quarterly Journal of Economics* **99**(3), 587–614.

Bernanke, B. S. & Gertler, M. (1995), 'Inside the black box: The credit channel of monetary policy transmission', *Journal of Economic Perspectives* **9**(4), 27–48.

Bianchi, F. (2013), 'Regime switches, agents' beliefs, and post-World War II U.S. macroeconomic dynamics', *Review of Economic Studies* **80**(2), 463–490.

Bils, M. & Klenow, P. J. (2004), 'Some evidence on the importance of sticky prices', *Journal of Political Economy* **112**(5), 947–985.

Binmore, K., Rubinstein, A. & Wolinsky, A. (1986), 'The Nash bargaining solution in economic modeling', *The RAND Journal of Economics* **17**(2), 176–188.

Blanchard, O. & Gali, J. (2010), 'Labor markets and monetary policy: A New Keynesian model with unemployment', *American Economic Journal: Macroeconomics* **2**(2), 1–30.

Bouakez, H., Cardia, E. & Ruge-Murcia, F. J. (2005), 'Habit formation and the persistence of monetary shocks', *Journal of Monetary Economics* **52**(6), 1073–1088.

Bouakez, H., Cardia, E. & Ruge-Murcia, F. J. (2011), 'Durable goods, inter-sectoral linkages and monetary policy', *Journal of Economic Dynamics and Control* **35**(5), 730–745.

Calvo, G. A. (1983), 'Staggered prices in a utility-maximizing framework', *Journal of Monetary Economics* **12**(3), 383–398.

Carlstrom, C. T. & Fuerst, T. S. (2010), 'Nominal rigidities, residential investment, and adjustment costs', *Macroeconomic Dynamics* **14**(1), 136–148.

Chen, B.-L. & Liao, S.-Y. (2014), 'Capital, credit constraints and the comovement between consumer durables and nondurables', *Journal of Economic Dynamics and Control* **39**(C), 127–139.

Christiano, L. J., Eichenbaum, M. & Evans, C. L. (1996), 'The effects of monetary policy shocks: Evidence from the flow of funds', *Review of Economics and Statistics* **78**(1), 16–34.

Christiano, L. J., Eichenbaum, M. & Evans, C. L. (2005), 'Nominal rigidities and the dynamic effects of a shock to monetary policy', *Journal of Political Economy* **113**(1), 1–45.

Christiano, L. J., Eichenbaum, M. S. & Trabandt, M. (2015), 'Understanding the Great Recession', *American Economic Journal: Macroeconomics* **7**(1), 110–67.

Christiano, L. J., Eichenbaum, M. S. & Trabandt, M. (2016), 'Unemployment and business cycles', *Econometrica* . Forthcoming.

Clarida, R., Gali, J. & Gertler, M. (1999), ‘The science of monetary policy: A New Keynesian perspective’, *Journal of Economic Literature* **37**(4), 1661–1707.

Constantinides, G. M. (1990), ‘Habit formation: A resolution of the equity premium puzzle’, *Journal of Political Economy* **98**(3), 519–43.

Costain, J. S. & Reiter, M. (2008), ‘Business cycles, unemployment insurance, and the calibration of matching models’, *Journal of Economic Dynamics and Control* **32**(4), 1120–1155.

den Haan, W. J., Ramey, G. & Watson, J. (2000), ‘Job destruction and propagation of shocks’, *American Economic Review* **90**(3), 482–498.

Dey, J. & Tsai, Y.-C. (2014), Explaining the durable goods co-movement puzzle: A Bayesian approach, Unpublished manuscript, Saint Louis University and National Taiwan University.

DiCecio, R. (2009), ‘Sticky wages and sectoral labor comovement’, *Journal of Economic Dynamics and Control* **33**(3), 538–553.

Edge, R. M., Kiley, M. T. & Laforte, J.-P. (2010), ‘A comparison of forecast performance between Federal Reserve staff forecasts, simple reduced-form models, and a DSGE model’, *Journal of Applied Econometrics* **25**(4), 720–754.

Erceg, C. J., Henderson, D. W. & Levin, A. T. (2000), ‘Optimal monetary policy with staggered wage and price contracts’, *Journal of Monetary Economics* **46**(2), 281–313.

Erceg, C. & Levin, A. (2006), ‘Optimal monetary policy with durable consumption goods’, *Journal of Monetary Economics* **53**(7), 1341–1359.

Faccini, R., Millard, S. & Zanetti, F. (2013), ‘Wage rigidities in an estimated dynamic, stochastic, general equilibrium model of the UK labour market’, *Manchester School* **81**, 66–99.

Fraumeni, B. (1997), ‘The measurement of depreciation in the U.S. national income and product accounts’, *Survey of Current Business* **77**, 7–23.

Fuhrer, J. C. (2000), ‘Habit formation in consumption and its implications for monetary-policy models’, *American Economic Review* **90**(3), 367–390.

Fujita, S. & Ramey, G. (2009), ‘The cyclicality of separation and job finding rates’, *International Economic Review* **50**(2), 415–430.

Gali, J. & Gertler, M. (1999), ‘Inflation dynamics: A structural econometric analysis’, *Journal of Monetary Economics* **44**(2), 195–222.

Gertler, M., Sala, L. & Trigari, A. (2008), ‘An estimated monetary DSGE model with unemployment and staggered nominal wage bargaining’, *Journal of Money, Credit and Banking* **40**(8), 1713–1764.

Gertler, M. & Trigari, A. (2009), ‘Unemployment fluctuations with staggered nash wage bargaining’, *Journal of Political Economy* **117**(1), 38–86.

Greenwood, J., Hercowitz, Z. & Huffman, G. W. (1988), ‘Investment, capacity utilization, and the real business cycle’, *American Economic Review* **78**(3), 402–417.

Hagedorn, M. & Manovskii, I. (2008), ‘The cyclical behavior of equilibrium unemployment and vacancies revisited’, *American Economic Review* **98**(4), 1692–1706.

Hairault, J.-O. (2002), ‘Labor-market search and international business cycles’, *Review of Economic Dynamics* **5**, 535–558.

Hall, R. E. & Milgrom, P. R. (2008), 'The limited influence of unemployment on the wage bargain', *American Economic Review* **98**(4), 1653–1674.

Hertweck, M. S. (2013), 'Strategic wage bargaining, labor market volatility, and persistence', *The B.E. Journal of Macroeconomics* **13**(1), 123–49.

Hertweck, M. S. & Sigrist, O. (2015), 'The ins and outs of German unemployment: A transatlantic perspective', *Oxford Economic Papers* **67**(4), 1078–1095.

Herz, B. & van Rens, T. (2015), Accounting for mismatch employment, The Warwick Economics Research Paper Series No. 1061, University of Warwick, Department of Economics.

Hornstein, A., Krusell, P. & Violante, G. L. (2011), 'Frictional wage dispersion in search models: A quantitative assessment', *American Economic Review* **101**(7), 2873–2898.

Iacoviello, M. (2005), 'House prices, borrowing constraints, and monetary policy in the business cycle', *American Economic Review* **95**(3), 739–764.

Iacoviello, M. & Neri, S. (2010), 'Housing market spillovers: Evidence from an estimated DSGE model', *American Economic Journal: Macroeconomics* **2**(2), 125–164.

Jung, P. & Kuester, K. (2011), 'The (un)importance of unemployment fluctuations for the welfare cost of business cycles', *Journal of Economic Dynamics and Control* **35**(10), 1744–1768.

Justiniano, A., Primiceri, G. E. & Tambalotti, A. (2013), 'Is there a trade-off between inflation and output stabilization?', *American Economic Journal: Macroeconomics* **5**(2), 1–31.

Kambourov, G. & Manovskii, I. (2008), 'Rising occupational and industry mobility in the United States: 1968-97', *International Economic Review* **49**(1), 41–79.

Katayama, M. & Kim, K. H. (2013), 'The delayed effects of monetary shocks in a two-sector New Keynesian model', *Journal of Macroeconomics* **38**(Part B), 243–259.

Kim, K. H. & Katayama, M. (2013), 'Non-separability and sectoral comovement in a sticky price model', *Journal of Economic Dynamics and Control* **37**(9), 1715–1735.

King, R. G. & Thomas, J. K. (2006), 'Partial Adjustment Without Apology', *International Economic Review* **47**(3), 779–809.

Kitamura, T. & Takamura, T. (2016), Output comovement and inflation dynamics in a two-sector model with durable goods: The role of sticky information and heterogeneous factor markets, Staff Working Papers No. 16-36, Bank of Canada.

Klenow, P. J. & Kryvtsov, O. (2008), 'State-dependent or time-dependent pricing: Does it matter for recent U.S. inflation?', *The Quarterly Journal of Economics* **123**(3), 863–904.

Krause, M. U., Lopez-Salido, D. J. & Lubik, T. A. (2008*a*), 'Do search frictions matter for inflation dynamics?', *European Economic Review* **52**(8), 1464–1479.

Krause, M. U., Lopez-Salido, D. & Lubik, T. A. (2008*b*), 'Inflation dynamics with search frictions: A structural econometric analysis', *Journal of Monetary Economics* **55**(5), 892–916.

Krause, M. U. & Lubik, T. A. (2007), 'The (ir)relevance of real wage rigidity in the New Keynesian model with search frictions', *Journal of Monetary Economics* **54**(3), 706–727.

Levin, A. & Yun, T. (2011), Durable goods and persistent recession, Unpublished manuscript, Federal Reserve Board.

Mankiw, N. G. & Reis, R. (2002), 'Sticky information versus sticky prices: A proposal to replace the New Keynesian Phillips curve', *The Quarterly Journal of Economics* **117**(4), 1295–1328.

Mehrotra, N. & Sergeyev, D. (2013), Sectoral shocks, the Beveridge curve and monetary policy, 2013 Meeting Papers No. 919, Society for Economic Dynamics.

Merz, M. (1995), 'Search in the labor market and the real business cycle', *Journal of Monetary Economics* **36**(2), 269–300.

Monacelli, T. (2009), 'New Keynesian models, durable goods, and collateral constraints', *Journal of Monetary Economics* **56**(2), 242–254.

Mortensen, D. T. & Nagypál, É. (2007), 'More on unemployment and vacancy fluctuations', *Review of Economic Dynamics* **10**(3), 327–347.

Nash, J. (1953), 'Two-person cooperative games', *Econometrica* **21**, 128–140.

Petrella, I., Rossi, R. & Santoro, E. (2016), Monetary policy with sectoral trade-offs, Unpublished manuscript, University of Copenhagen.

Petrongolo, B. & Pissarides, C. A. (2001), 'Looking into the black box: A survey of the matching function', *Journal of Economic Literature* **39**(2), 390–431.

Pissarides, C. (2000), *Equilibrium Unemployment Theory*, MIT Press.

Pissarides, C. A. (2009), 'The unemployment volatility puzzle: Is wage stickiness the answer?', *Econometrica* **77**(5), 1339–1369.

Ravenna, F. & Walsh, C. E. (2008), 'Vacancies, unemployment, and the Phillips curve', *European Economic Review* **52**(8), 1494–1521.

Ravn, M. O. & Simonelli, S. (2007), 'Labor market dynamics and the business cycle: Structural evidence for the United States', *Scandinavian Journal of Economics* **109**(4), 743–777.

Rotemberg, J. J. & Woodford, M. (1997), An optimization-based econometric framework for the evaluation of monetary policy, *in* B. S. Bernanke & J. Rotemberg, eds, 'NBER Macroeconomics Annual 1997', Vol. 12 of *NBER Macroeconomics Annual*, MIT Press, Cambridge, MA, pp. 297–361.

Rubinstein, A. (1982), 'Perfect equilibrium in a bargaining model', *Econometrica* **50**(1), 97–109.

Sahuc, J.-G. (2006), 'Partial indexation, trend inflation, and the hybrid Phillips curve', *Economics Letters* **90**(1), 42–50.

Shimer, R. (2012), 'Reassessing the ins and outs of unemployment', *Review of Economic Dynamics* **15**(2), 127–148.

Sims, C. A. (1992), 'Interpreting the macroeconomic time series facts: The effects of monetary policy', *European Economic Review* **36**(5), 975–1000.

Smets, F. & Wouters, R. (2003), 'An estimated Dynamic Stochastic General Equilibrium model of the Euro Area', *Journal of the European Economic Association* **1**(5), 1123–1175.

Smets, F. & Wouters, R. (2007), 'Shocks and frictions in US business cycles: A Bayesian DSGE approach', *American Economic Review* **97**(3), 586–606.

Sterk, V. (2010), 'Credit frictions and the comovement between durable and non-durable consumption', *Journal of Monetary Economics* **57**(2), 217–225.

Sterk, V. & Tenreyro, S. (2013), The transmission of monetary policy operations through redistributions and durable purchases, CEP Discussion Papers No. dp1249, Centre for Economic Performance, LSE.

Sudo, N. (2012), 'Sectoral co-movement, monetary-policy shock, and input-output structure', *Journal of Money, Credit and Banking* **44**(6), 1225–1244.

Taylor, J. B. (1993), 'Discretion versus policy rules in practice', *Carnegie-Rochester Conference Series on Public Policy* **39**(1), 195–214.

Thomas, C. & Zanetti, F. (2009), 'Labor market reform and price stability: An application to the Euro Area', *Journal of Monetary Economics* **56**(6), 885–899.

Törnqvist, L. (1936), 'The Bank of Finland's consumption price index', *Bank of Finland Monthly Bulletin* **10**, 1–8.

Trabandt, M. (2007), Sticky information vs. sticky prices: A horse race in a DSGE framework, Working Paper Series No. 209, Sveriges Riksbank (Central Bank of Sweden).

Trigari, A. (2009), 'Equilibrium unemployment, job flows, and inflation dynamics', *Journal of Money, Credit and Banking* **41**(1), 1–33.

Tsai, Y.-C. (2016), 'What do working capital and habit tell us about the co-movement problem?', *Macroeconomic Dynamics* **20**(01), 342–361.

van Ours, J. & Ridder, G. (1992), 'Vacancies and the recruitment of new employees', *Journal of Labor Economics* **10**(2), 138–55.

Walsh, C. E. (2005), 'Labor market search, sticky prices, and interest rate policies', *Review of Economic Dynamics* **8**(4), 829–849.

Yashiv, E. (2000*a*), 'The determinants of equilibrium unemployment', *American Economic Review* **90**(5), 1297–1322.

Yashiv, E. (2000*b*), 'Hiring as investment behavior', *Review of Economic Dynamics* **3**(3), 486–522.

A The Non-Stochastic Steady State

$$\frac{c}{y} = 0.8, \quad \frac{hc}{y} = 0.01, \quad \varphi_d = 1, \quad q = 0.7, \quad \pi_c = 1, \quad \pi_d = 1 \quad \text{and} \quad n = 0.94. \tag{47}$$

$$R = \frac{1}{\beta}, \tag{48}$$

$$u = 1 - (1-\rho)\, n, \tag{49}$$

$$\varphi_c^m = \frac{\epsilon - 1}{\epsilon} \Rightarrow \varphi_c^m = \varphi_d^m, \tag{50}$$

$$y = n, \tag{51}$$

$$v = \rho \frac{N}{Q}, \tag{52}$$

$$m = vq, \tag{53}$$

$$\frac{q\delta y_d}{y} = 1 - \frac{c}{y} - \frac{hc}{y}, \tag{54}$$

$$\frac{\varphi_d d}{y} = \frac{q\delta y_d}{y\delta}, \tag{55}$$

$$\zeta = \frac{\frac{1-\psi}{[1-\beta(1-\delta)](1-\beta\psi)}\frac{c}{y}}{\frac{\varphi_d d}{y} + \frac{1-\psi}{[1-\beta(1-\delta)](1-\beta\psi)}\frac{c}{y}}, \tag{56}$$

$$A_1 = \frac{(1-\zeta)(1-\psi)}{\{\zeta [1 - \beta (1-\delta)]\} (1 - \beta\psi)}, \tag{57}$$

$$\kappa = \frac{hc}{y} y \frac{(1-u)}{m^2}, \tag{58}$$

$$n_c = \frac{y + \frac{\kappa\rho^2}{1-\rho} n\delta A_1}{1 + \delta A_1}, \tag{59}$$

$$n_d = n - n_c, \tag{60}$$

$$TD = \frac{n}{n_d}, \tag{61}$$

$$v_d = v\frac{1}{TD}, \tag{62}$$

$$v_c = v - v_d, \tag{63}$$

$$c = n_c - \frac{\kappa\rho^2}{1-\rho} n, \tag{64}$$

$$d = \frac{n_d}{\delta}, \tag{65}$$

$$y_d = n_d, \tag{66}$$

$$y_c = n_c, \tag{67}$$

$$\bar{m} = q\left(\frac{v}{u}\right)^{1-\xi}, \tag{68}$$

$$w_c = \varphi_c^m - \kappa\frac{\rho}{1-\rho}\left[1 - (1-\rho)\,\beta\right]), \tag{69}$$

$$w_d = w_c, \tag{70}$$

$$\omega = [(1-\psi)\,c]^{\zeta}\,d^{1-\zeta}, \tag{71}$$

$$\lambda = \frac{\zeta\,(1-\beta\psi)\,\omega^{1-\sigma}}{(1-\psi)\,c}, \tag{72}$$

$$\gamma = \frac{w\,(1-RR)}{\varphi_c^m - RRw_c + \beta\kappa\rho^2\frac{N}{U}}, \tag{73}$$

$$\bar{b} = RRw_c, \tag{74}$$

$$\tilde{u} = 1 - n_c - n_d, \tag{75}$$

$$\theta_c = \frac{v_c}{u}, \tag{76}$$

$$\theta_d = \frac{v_d}{u}. \tag{77}$$

B Tables

B.1 Sources and Definitions of Data

Series	Definition	Source	Mnemonic
NG_d	nominal durable goods	BEA	Table 1.1.5, Line 4
NG_n	nominal non-durable goods	BEA	Table 1.1.5, Line 5
NG_s	nominal services	BEA	Table 1.1.5, Line 6
NG_i	nominal residential investment	BEA	Table 1.1.5, Line 12
PD_d	price deflator, durable goods	BEA	Table 1.1.9, Line 4
PD_n	price deflator, non-durable goods	BEA	Table 1.1.9, Line 5
PD_s	price deflator, services	BEA	Table 1.1.9, Line 6
PD_i	price deflator, residential investment	BEA	Table 1.1.9, Line 12
EM_s	employees, services	BLS	CES0800000006
EM_c	employees, construction	BLS	CES2000000006
EM_d	employees, durable goods	BLS	CES3100000006
EM_n	employees, non-durable goods	BLS	CES3200000006
POP	civilian non-institutional population 16+	FRED	CNP16OV
FFR	effective Federal Funds rate	FRED	FEDFUNDS

Table 1: This table displays the definitions of the raw series used. The monthly series are aggregated to quarterly data. All time series are seasonally adjusted (where applicable). We define the durable sector (D) as the sum of durable goods (d) and residential investment (i) when using BEA data and the sum of durable goods (d) and construction (c) when using BSL data, respectively. Accordingly, the non-durable sector (N) is defined as the sum of the non-durable goods (n) and services (s) in both databases used (BEA, BLS). We then use nominal quantity series and price deflators to compute real Törnqvist (1936) quantity indices (QI_N, QI_D).

B.2 Definition of Variables in the SVAR

Variable	Symbol	Definition
real non-durable expenditures per capita	c_t	log of (QI_N/POP)
real durable expenditures per capita	y_t^d	log of (QI_D/POP)
inflation rate in the non-durable sector	π_t	first difference of log (PD_C)
employment rate in the non-durable sector	n_t^c	log of (EM_N/POP)
employment rate in the durable sector	n_t^d	log of (EM_D/POP)
Federal Funds rate	r_t	FFR

Table 2: This table displays the variables that enter the SVAR.

Table 3: Parameter Values - Baseline Calibration

Description	Parameter	Value
Deep Ratios		
aggregate unemployment rate	$1 - n_c - n_d$	0.06
share of non-durable consumption in output	c/y	0.80
share of durable expenditures in output (implied)	$\varphi_d y_d/y$	0.19
share of hiring costs in output	$\kappa m^2/(1-u)y$	0.01
job filling rate	$q(\theta)$	0.70
Production and Technology		
durable depreciation rate	δ	0.025
Preferences		
discount factor	β	0.99
inverse of the inter-temporal elasticity of substitution	σ	1
elasticity of substitution between varieties	ϵ	11
Search in the Labour Market		
separation rate	ρ	0.10
job finding rate (implied)	$p(\theta)$	0.61
aggregate job searchers (implied)	u	0.15
hiring cost parameter (implied)	κ	0.90
matching elasticity of vacancies	ξ	0.5
efficiency of the matching function (implied)	$\bar{m}$	0.65
Price Stickiness and Monetary Policy		
Calvo price stickiness in sector d	ϑ_d	0
Taylor rule responsiveness to inflation	r_p	1.5
Taylor rule responsiveness output growth	r_y	0.1

B.3 Estimated Parameter Values

Parameter	Description	Initial Value	Baseline	Sector-Specific	Taylor Rule	Hall & Milgrom	Durable Stickiness
ψ	degree of internal habit persistence	0.70	0.85	0.86	0.85	0.85	0.85
$\bar{b}/w$	replacement rate	0.80	0.75	0.87	0.79	0.55	0.74
ω	standard Nash bargaining	0.50				0.49	
ϑ_c	degree of price stickiness in the non-durable sector	0.90	0.95	0.91	0.95	0.94	0.94
χ_c	non-durable price indexation	0.90	1.00	1.00	1.00	1.00	1.00
ϑ_d	degree of price stickiness in the durable sector	0.20					0.06
χ_d	durable price indexation	0.50					0.81
r_r	Taylor rule interest rate inertia	0.80	0.90	0.91	0.87	0.90	0.90
r_p	Taylor rule responsiveness to inflation	1.50			1.36		
r_y	Taylor rule responsiveness to output growth	0.13			0.80		
ς_r	Taylor rule standard deviation	0.35	0.16	0.16	0.18	0.16	0.16
	minimized value of the quadratic form		30.3	32.1	26.4	29.8	30.2

Table 4: This table displays the estimated parameter values

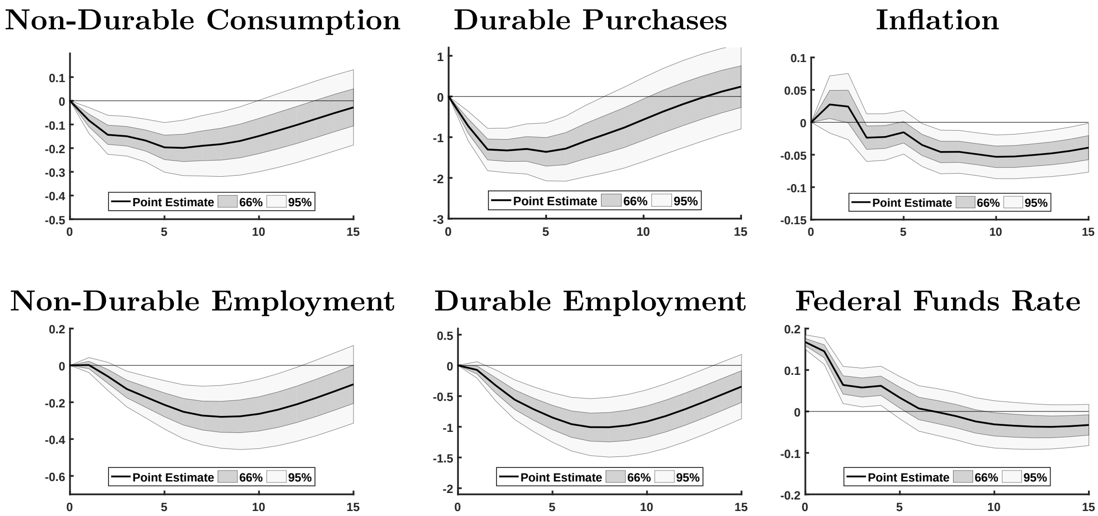

Figure 1: The figure illustrates the Cholesky orthogonalised impulse responses to a contractionary monetary policy shock. The black solid line is the point estimate. The dark (light) grey area illustrates the 66% (95%) centred confidence bands of the empirical impulse responses at horizons up to 15 quarters.

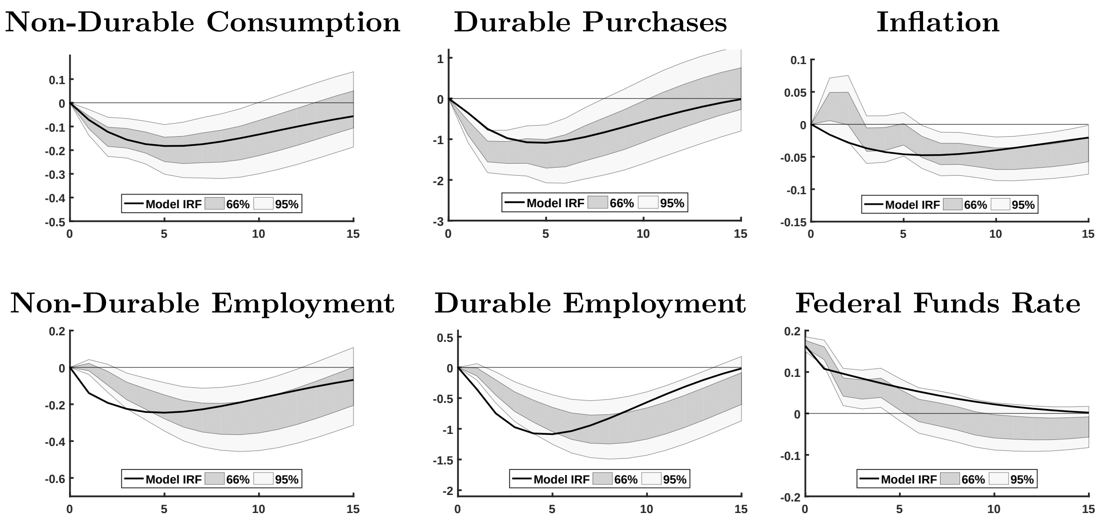

Figure 2: The dark (light) gray areas illustrate the 66% (95%) centred confidence bands of the empirical impulse responses at horizons up to 15 quarters. The black solid lines represent the impulse responses of the estimated model.

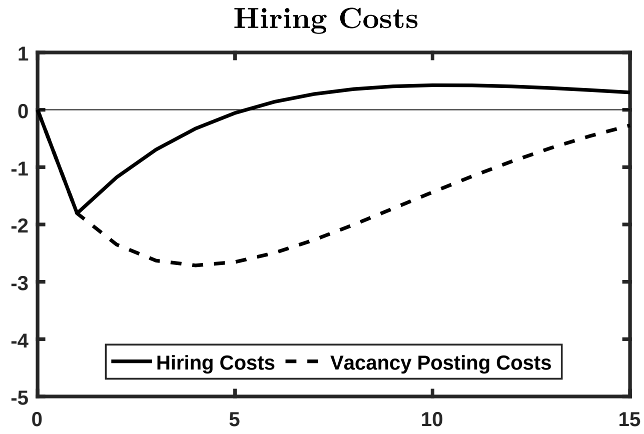

Figure 3: The figure illustrates the percentage fall in hiring costs at horizons up to 15 quarters. The black solid line represents the (actual) impulse response when firm pay a cost per hire, the black dashed line represents the (hypothetical) impulse response when firms pay per vacancy.

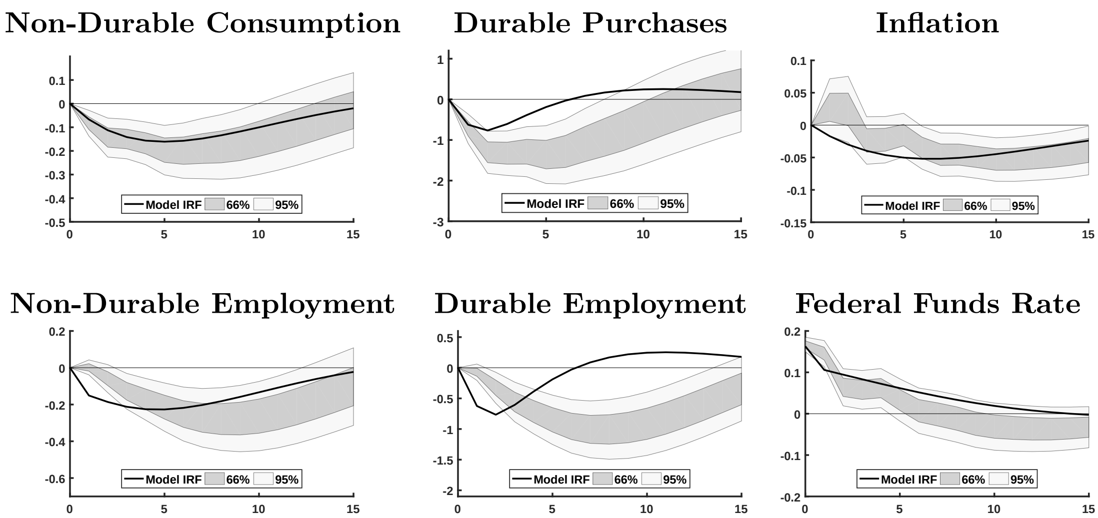

Figure 4: The dark (light) gray areas illustrate the 66% (95%) centred confidence bands of the empirical impulse responses at horizons up to 15 quarters. The black solid lines represent the impulse responses of the estimated model, but with linear vacancy posting costs instead of hiring costs.

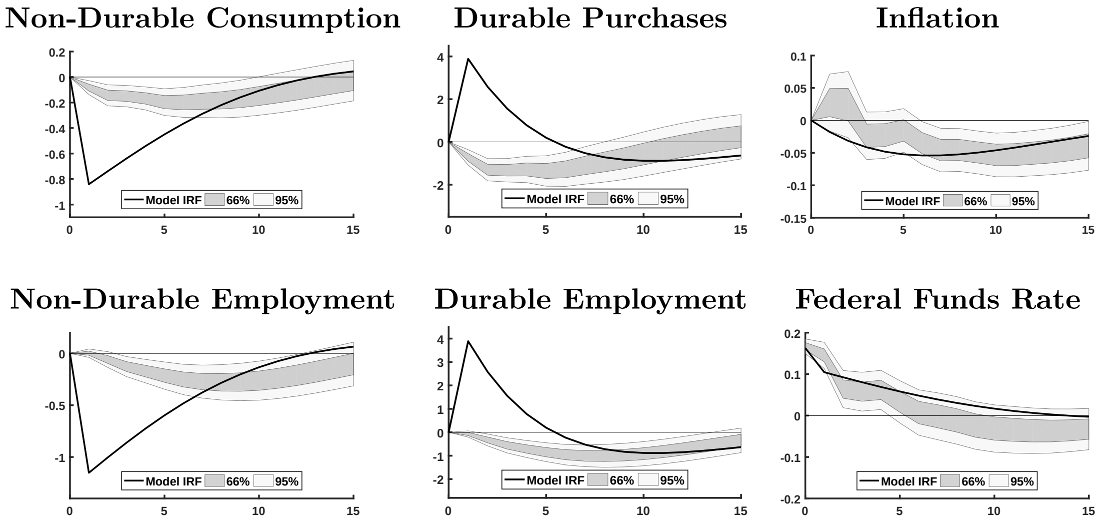

Figure 5: The dark (light) gray areas illustrate the 66% (95%) centred confidence bands of the empirical impulse responses at horizons up to 15 quarters. The black solid lines represent the impulse responses of the estimated model without internal habit formation in consumption, $\psi = 0$, and the estimated replacement rate, $\bar{b}/w = 0.75$.

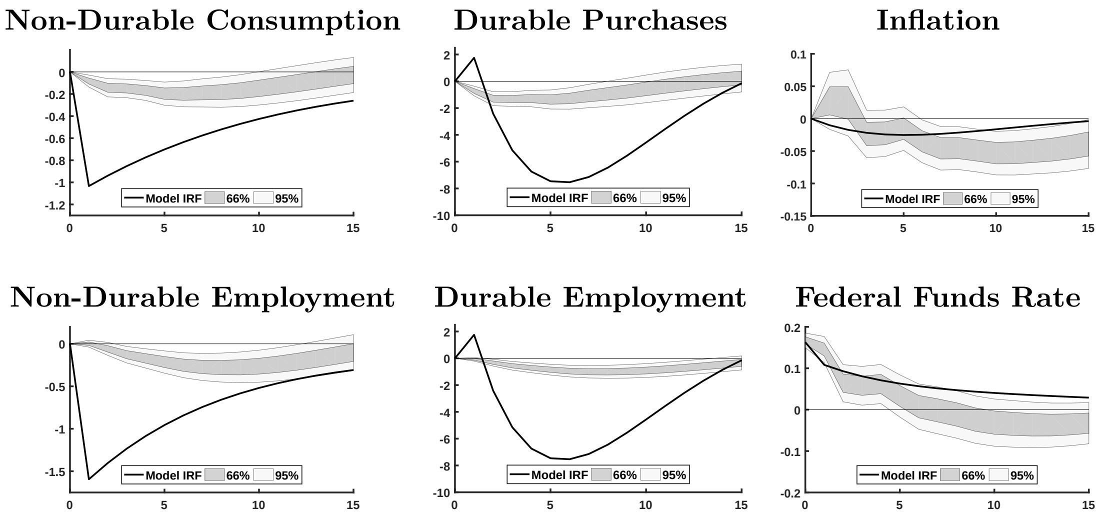

Figure 6: The dark (light) gray areas illustrate the 66% (95%) centred confidence bands of the empirical impulse responses at horizons up to 15 quarters. The black solid lines represent the impulse responses of the estimated model without internal habit formation in consumption, $\psi = 0$, and a high replacement rate, $\bar{b}/w = 0.98$.

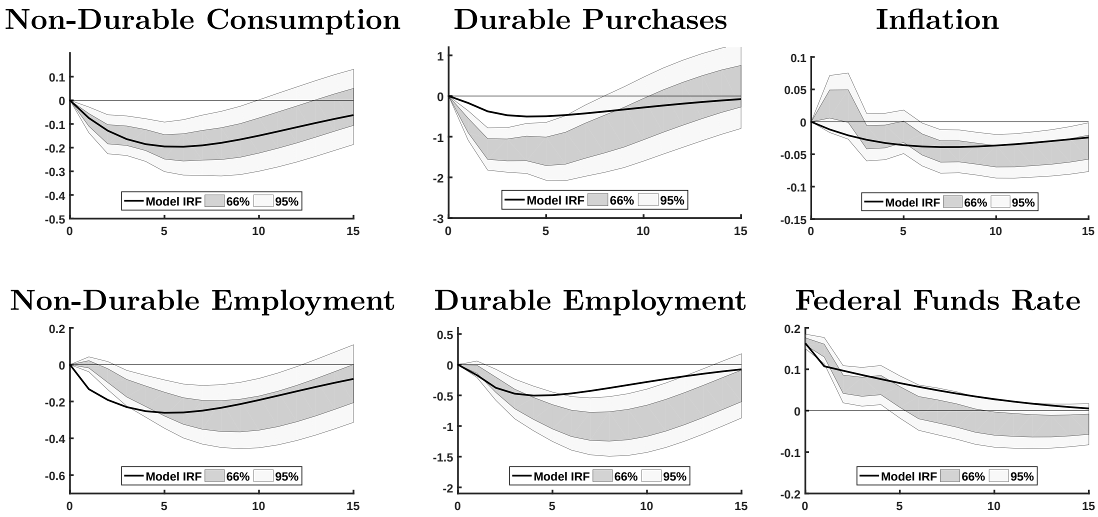

Figure 7: The dark (light) gray areas illustrate the 66% (95%) centred confidence bands of the empirical impulse responses at horizons up to 15 quarters. The black solid lines represent the impulse responses of the estimated model with two segmented labour markets.

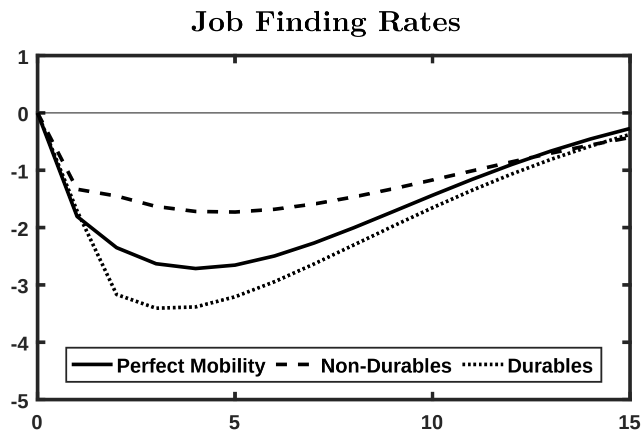

Figure 8: The figure illustrates the percentage fall in the job finding rate at horizons up to 15 quarters. The black solid line represents the impulse response under perfect labour mobility, the black dashed line represents the impulse response in the non-durable goods sector under sector-specific labour markets, and the black dotted line represents the impulse response in the durable good sector under sector-specific labour markets.

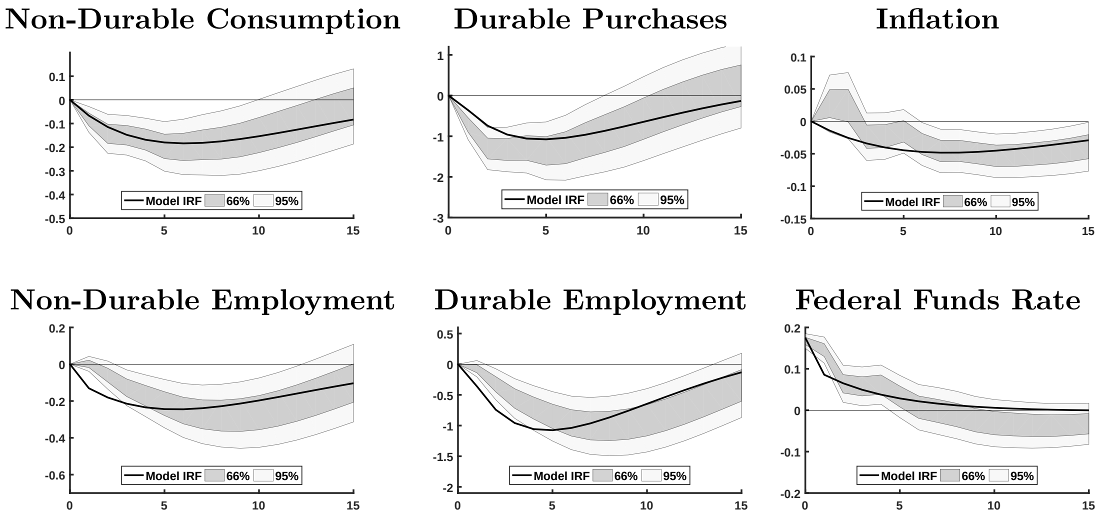

Figure 9: The dark (light) gray areas illustrate the 66% (95%) centred confidence bands of the empirical impulse responses at horizons up to 15 quarters. The black solid lines represent the impulse responses of the model when additionally the two Taylor rule parameters, r_p and r_y, are estimated.

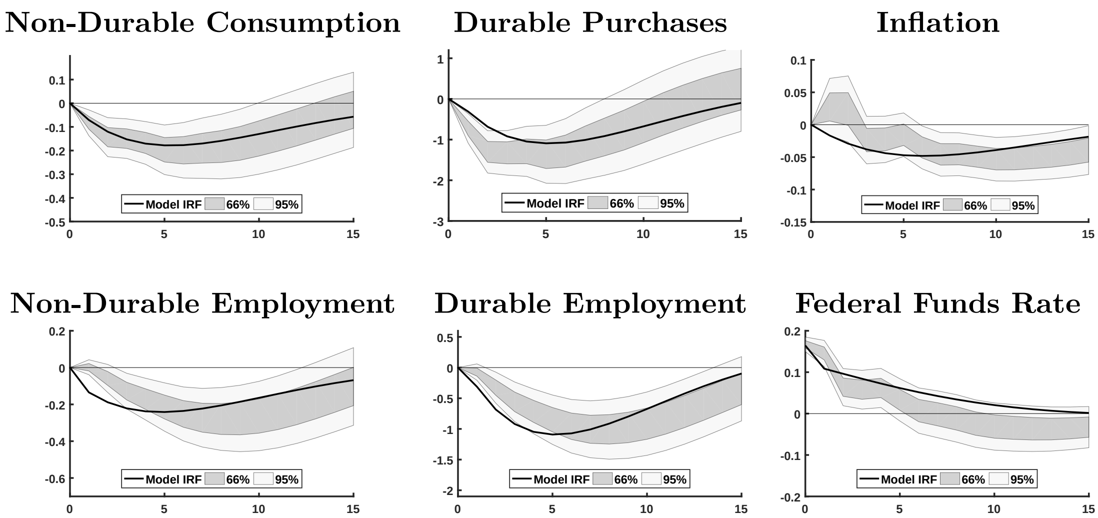

Figure 10: The dark (light) gray areas illustrate the 66% (95%) centred confidence bands of the empirical impulse responses at horizons up to 15 quarters. The black solid lines represent the impulse responses of the model when additionally the Hall & Milgrom (2008) parameter is estimated.

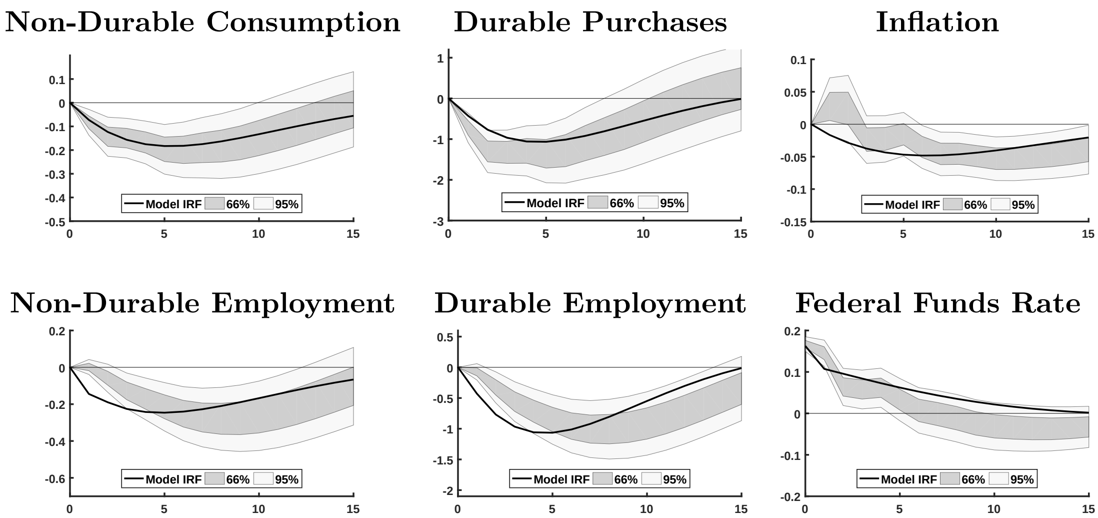

Figure 11: The dark (light) gray areas illustrate the 66% (95%) centred confidence bands of the empirical impulse responses at horizons up to 15 quarters. The black solid lines represent the impulse responses of the model when additionally ϑ_d and χ_d are estimated.