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WHAT DO WORKING CAPITAL AND HABIT TELL US ABOUT THE CO-MOVEMENT PROBLEM?

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Empirical studies find that expenditures on both durable and nondurable goods fall following a contractionary monetary policy shock. However, in standard two-sector models with staggered nondurable goods prices and flexible durable goods prices, consumption of durables rises whereas that of nondurables falls in response to a contractionary policy shock. To resolve this co-movement problem, I extend the model to include a realistic financial friction that firms must pay for their productive inputs prior to production, i.e., working capital, along with habit formation in nondurable goods consumption. Following a positive interest rate shock, the working capital channel raises production costs, thereby discouraging production of both durable and nondurable goods. Furthermore, habit formation induces households to smooth the growth rate of nondurable goods consumption, and hence mitigates the fall in the nondurable goods sector. The model solves the co-movement problem and successfully generates a more sensitive response in the durable goods sector, as observed in the data.

Keywords: Durability, Working Capital, Habit Formation, Sectoral Co-movement

1. INTRODUCTION

Over the past decade, one-sector dynamic New Keynesian (DNK) models have become the workhorse of modern macroeconomics. With its emphasis on micro-foundations, this class of models has provided a number of important insights into the effects of monetary policy and thus contributed to the conduct of modern monetary policy.[1] However, one puzzling result of DNK models, as pointed out by Barsky et al. (2003, 2007) (BHK hereafter), is that when a flexibly priced durable goods sector is combined with a sticky price nondurable goods sector, monetary policy that stimulates production in one sector has a contractionary effect on production in the other sector.[2] In an extreme case, monetary policy has no effect on aggregate output and employment regardless of the degree of

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price stickiness or the size of the nondurable goods sector. This finding seems to overturn the implication of standard one-sector sticky price models that monetary policy affects production in the short run. BHK refer to this surprising outcome of multisector DNK models as a "co-movement problem."

The co-movement problem is essentially driven by the fact that the shadow value of a long-lived durable is approximately unchanged in the wake of a monetary policy shock. The near consistency of the shadow value implies that consumers are nearly indifferent to the timing of durable goods purchases. Therefore, even a small change in the relative price of durable goods can cause a dramatic adjustment in household expenditures on durable goods. A contractionary policy shock that causes a fall in the relative price of durable goods thus leads to an increase in the purchase of durable goods. This result, however, is inconsistent with the empirical finding of Erceg and Levin (2006) and BHK (2003, 2007) that expenditures on both durable and nondurable goods fall in response to a contractionary monetary policy shock.

To reconcile this inconsistency between the empirical findings and the model-implied responses of durables and nondurables to monetary policy shocks, I introduce a realistic financial friction that firms must pay for their productive inputs prior to production (i.e., working capital). Following a positive interest rate shock, the working capital channel causes production costs to rise, thereby discouraging production in both durable and nondurable sectors. Furthermore, working capital reduces the fall in the relative price of durables, and hence mitigates the incentive to purchase durable goods. In addition, I introduce habit formation in household consumption of nondurable goods, which dampens the response of consumption of nondurable goods and allows my model to generate a less sensitive response in the nondurable goods sector, as observed in the data. Together, the working capital channel and habit formation solve the co-movement problem.

Several empirical studies provide evidence for the working capital channel. Using U.S. Flow of Funds data, Barth and Ramey (2002) find that a substantial fraction of firms' variable input costs are borrowed in advance. Christiano et al. (1996) and Ravenna and Walsh (2006) provide evidence supporting the working capital channel, under which firms' marginal cost depends directly on nominal interest rates. Moreover, working capital has been used in recent business cycle models as a propagation mechanism to transmit interest rate shocks to real outcomes; see, for example, Christiano et al. (2005) and Neumeyer and Perri (2005). Although these existing studies all emphasize the importance of working capital, their focus has been limited to one-sector models. To my knowledge, this paper is the first to study the effects of working capital in a multisector model.

Most existing studies that solve the co-movement puzzle rely on mechanisms that induce price stickiness in the durable goods sector and thus reduce the fall in the relative price of durable goods. A smaller fall in the relative price of durables mitigates the incentive to purchase durable goods and helps resolve the co-movement problem. For example, Carlstrom and Fuerst (2006, 2010) introduce sticky wages into the baseline model of BHK (2003, 2007).[3] As labor is the only production input, sticky wages induce stickiness in durable goods prices and reduce the fall in the relative price of durables. Kitamura and Takamura (2010) introduce sticky information. With costs associated with information gathering, firms only update their information infrequently, which causes a delay in the adjustment of the relative price of durable goods and helps resolve the problem. Sudo (2012) and Bouakez et al. (2011) use input–output structures to resolve the co-movement problem. In their models, nondurable goods with sticky prices are used as intermediate inputs for production of durable goods, and therefore the nominal rigidity in nondurable goods is transmitted to the prices of durable goods, which again reduces the fall in the relative prices of durables.

Similarly to these studies, my paper with the working capital channel also generates a smaller fall in the relative price of durables and resolves the co-movement problem. In contrast to these studies, my paper focuses on the financial frictions on the production side that firms need to pay for their productive inputs prior to production.

Similarly to my model, Monacelli (2009) stresses the importance of financial frictions on the consumer side in generating co-movement. However, financial frictions affect the production behavior of firms in my paper, whereas financial frictions affect the consumption behavior of households in Monacelli (2009). In addition, whereas Monacelli (2009) finds that the presence of collateral constraints is important for the co-movement problem, a recent paper by Sterk (2010) shows that the co-movement results of Monacelli (2009) are due to the assumption that the price for durables is sticky. In other words, the collateral constraint in Monacelli (2009) is unable to generate co-movement when the prices of durables are perfectly flexible, whereas financial frictions help my model deliver co-movement irrespective of whether the price of durables is sticky or flexible.

Finally, except for my paper and Carlstrom and Fuerst (2010), all existing literature that solves the co-movement problem fails to generate the hump-shaped responses for nondurables. Compared with Carlstrom and Fuerst (2010), my model requires fewer model ingredients to simultaneously generate a more sensitive response in durables and a hump-shaped response for nondurables. Therefore, when an empirical investigation is implemented, a smaller set of parameters need to be estimated for my model.

A recent paper by Dey and Tsai (2011) solves the co-movement problem by introducing nonseparable preferences with zero wealth effect on labor hours. Dey and Tsai (2011) also compare three alternative channels via Bayesian methods and find that the working capital channel performs the best. Their findings suggest that financial frictions might be more important than other mechanisms that induce price stickiness into durable goods sectors.

The structure of this paper is as follows. In Section 2, I develop and simulate a baseline model based on BHK (2003, 2007) and Carlstrom and Fuerst (2006, 2010). In Section 3, I introduce working capital and habit formation in nondurables into the baseline model and show that my model successfully solves the co-movement problem. I also implement several sensitivity analyses and extend my model to incorporate physical capital. Finally, Section 4 concludes.

2. BASELINE BHK MODEL

In this section, I first develop a baseline model of BHK (2003, 2007) and Carlstrom and Fuerst (2006). There are three types of agents in this economy: households, firms, and the monetary authority. Households derive utility from consumption of nondurable and durable goods and from leisure. On the production side, there are two sectors: the durable and nondurable goods sectors. In each sector, there is a continuum of monopolistically competitive intermediate firms, each producing a differentiated product. The behavior of each type of agent is described in the following.

2.1. Households

In every period, households' composite consumption, U_t, consists of nondurable goods, C_t, and the stock of durable goods, D_t. Their preference over nondurable goods and durable goods is defined by the CES utility function $U_t = (\psi_c {C_t}^{1-1/\rho} + \psi_d D_t^{1-1/\rho})^{\rho/(\rho-1)}$. The price index P_t is given by $P_t = (\psi_c^{\rho} {P_{c,t}}^{1-\rho} + \psi_d^{\rho} {P_{x,t}}^{1-\rho})^{1/(1-\rho)}$, where $P_{c,t}$ and $P_{x,t}$ denote prices of nondurable and durable goods, respectively. A representative household enters period t with initial bond holdings of S_{t-1}, receives wage income $W_t N_t$, profits Π_t, and government transfers T_t, and purchases nondurable goods C_t, durable goods X_t, and a risk- free bond $\frac{S_t}{R_t}$.

The household maximizes its expected lifetime utility subject to its budget constraint and the law of motion of durable goods:

$$\max \sum_{t=0}^{\infty} E_0 \beta^t \left\{ \frac{1}{1-\sigma} \left[\left(\psi_c C_t^{1-\frac{1}{\rho}} + \psi_d D_t^{1-\frac{1}{\rho}} \right)^{\frac{\rho}{\rho-1}} \right]^{1-\sigma} - \phi \frac{N_t^{1+\frac{1}{\eta}}}{1+\frac{1}{\eta}} \right\},$$

subject to

$$P_{c,t} C_t + P_{x,t} X_t \leqslant W_t N_t + \Pi_t + T_t + S_{t-1} - \frac{S_t}{R_t},$$

$$D_t = D_{t-1}(1-\delta) + X_t,$$

where S_{-1} and D_{-1} are given, E_t is the expectation operator conditional on information in period t, and β is a discount factor.

The first-order conditions for nondurable consumption, durable consumption, leisure, and bond holdings are

$$\Lambda_t = \psi_c U_t^{\frac{1}{\rho}-\sigma} C_t^{-\frac{1}{\rho}}, \tag{1}$$

$$\Lambda_t \frac{P_{x,t}}{P_{c,t}} = U_t^{\frac{1}{\rho}-\sigma} \psi_d D_t^{-\frac{1}{\rho}} + \beta(1-\delta)E_t(\Lambda_{t+1}\frac{P_{x,t+1}}{P_{c,t+1}}), \quad (2)$$

$$\phi N_t^{\frac{1}{\eta}} = \frac{W_t}{P_{c,t}}\Lambda_t, \quad (3)$$

and

$$\frac{\Lambda_t}{P_{c,t}} = \beta E_t[\Lambda_{t+1}\frac{R_t}{P_{c,t+1}}]. \quad (4)$$

Equation (1) represents the marginal utility of nondurable consumption, equation (2) represents the trade-off between nondurable and durable goods, equation (3) represents the trade-off between nondurable consumption and leisure, and equation (4) represents the trade-off between nondurable consumption and bond holdings.

2.2. Firms

There are two types of firms: a continuum of nondurable goods producers and a continuum of durable goods producers. Nondurable goods firms set their prices à la Calvo, whereas durable goods firms can adjust their prices frictionlessly every period. These intermediate goods firms are competitive in the factor market and take factor prices as given. I allow the factor to move freely within and between sectors.

Nondurable goods firms. There is a continuum of monopolistically competitive firms in the nondurable goods sector indexed by $f \in (0, 1)$, which sell nondurable goods to final goods producers. They set a price $P_{c,t}(f)$ subject to Calvo price setting. In each period, a fraction $1 - \theta_c$ of firms in this sector reoptimize their prices regardless of the time of their last price adjustment. The remaining fraction θ_c of the firms use the same price as in the previous period.

Demand faced by each firm depends on the price of its product and the total demand for nondurable goods,

$$C_t(f) = \left[\frac{P_{c,t}(f)}{P_{c,t}}\right]^{-\varepsilon} C_t, \quad (5)$$

where $C_t = [\int_0^1 C_t(f)^{(\varepsilon-1)/\varepsilon} df]^{\varepsilon/(\varepsilon-1)}$ is the consumption aggregator, and $P_{c,t} = [\int_0^1 P_{c,t}(f)^{1-\varepsilon} df]^{1/(1-\varepsilon)}$ represents the price index for nondurable goods.

Production requires labor input

$$C_t(f) = A_t N_t(f), \quad (6)$$

where A_t denotes aggregate productivity.

A nondurable goods producer f chooses $P^*_{c,t}(f)$ to maximize its discounted profit,

$$\max_{P^*_{c,t}(f)} \sum_{j=0}^{\infty} (\beta\theta_c)^j E_t \frac{\Lambda_{t+j}}{P_{c,t+j}} \left[P_{c,t+j}(f) C_{t+j}(f) - W_{t+j}N_{t+j}(f)\right],$$

subject to demand for its product (5) and to its production function (6), where Λ_{t+j} denotes the marginal utility of consumption for period $t + j$.

The first-order condition is

$$P_{c,t}^{*}(f) = \frac{\varepsilon}{\varepsilon - 1} \frac{\sum_{j=0}^{\infty} (\beta\theta_c)^j \, E_t \Lambda_{t+j} \mathrm{MC}_{t+j} \left(\frac{1}{P_{c,t+j}}\right)^{1-\varepsilon} C_{t+j}}{\sum_{j=0}^{\infty} (\beta\theta_c)^j \, E_t \Lambda_{t+j} \left(\frac{1}{P_{c,t+j}}\right)^{1-\varepsilon} C_{t+j}}, \quad (7)$$

where marginal cost $\mathrm{MC}_t = W_t/\mathrm{MPL}_t$, W_t is the wage, and MPL_t is the marginal product of labor, which equals A_t.

The nondurable price index is written as

$$P_{c,t} = \left[(1 - \theta_c)\, P_{c,t}^{*1-\varepsilon} + \theta_c P_{c,t-1}^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}.$$

Durable goods firms. In the durable goods sector, there is a continuum of monopolistically competitive firms, and unlike firms in the nondurable goods sector, durable goods firms reoptimize their prices every period and face identical linear production and demand.

A durable goods firm f chooses its price $P_{x,t}^{*}(f)$ to maximize its current profit,

$$\max_{P_{x,t}^{*}(f)} P_{x,t}(f) X_t(f) - W_t N_t(f),$$

subject to the production function

$$X_t(f) = A_t N_t(f) \quad (8)$$

and the demand function

$$X_t(f) = \left[\frac{P_{x,t}(f)}{P_{x,t}}\right]^{-\varepsilon} X_t, \quad (9)$$

where $X_t = [\int_0^1 X_t(f)^{\frac{\varepsilon-1}{\varepsilon}} df]^{\varepsilon/(\varepsilon-1)}$ and $P_{x,t} = [\int_0^1 P_{x,t}(f)^{1-\varepsilon} df]^{1/(1-\varepsilon)}$.

Because the focus of this paper is on studying the effects of monetary policy shocks, I assume that production technology is identical in both sectors. In a more general setting, this assumption may be relaxed to allow for sector-specific technology. The first-order condition for price is

$$P_{x,t}^{*}(f) = \frac{\varepsilon}{\varepsilon - 1} \mathrm{MC}_t. \quad (10)$$

2.3. Monetary Policy and Market Clearing

I assume that the monetary authority follows the Taylor rule, under which the interest rate responds to changes in inflation and output gap.[4] In addition, I allow the monetary authority to partially adjust toward the optimal interest target,

$$R_t = R_{t-1}^{\rho_r} (\pi_t)^{(1-\rho_r)\phi_\pi} (y_t)^{(1-\rho_r)\phi_y} \epsilon_t.$$

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TABLE 1. Parameterization for the benchmark simulation

Parameter	Value	Meaning
η	1.5	Frisch elasticity of labor supply
β	0.99	Subjective discount factor (quarterly)
σ	1	Intertemporal elasticity of substitution
ρ	1	Intratemporal elasticity of substitution between durables and nondurables
ψ_c	0.75	Utility weight on nondurables
ψ_d	0.25	Utility weight on durables
α	0.7	Labor share in Cobb–Douglas production function
$1-\alpha$	0.3	Capital share in Cobb–Douglas production function
θ_c	0.67	Probability of not reoptimizing price
θ_x	0	Perfectly flexible price
ε	11	Elasticity of substitution between differentiated products
κ	4	Capital adjustment cost parameter
δ	0.025	Depreciation rate of durable goods (quarterly)
δ_k	0.025	Depreciation rate of capital stock (quarterly)
ρ_r	0.6	Interest rate smoothing
ϕ_π	1.5	Interest rate response to inflation
ϕ_y	0.5	Interest rate response to output gap

Labor market equilibrium requires

$$N_t = N_{c,t} + N_{x,t}.$$

Goods market equilibrium requires

$$Y_t = C_t + X_t.$$

2.4. Simulation and Results

Parameter values. Most of the parameter values are taken from BHK (2007). I set the subjective discount factor, β, equal to 0.99, and the Frisch labor-supply elasticity, η, equals 1.5. The depreciation rate of durable goods, δ, is 0.025, which implies an annual depreciation rate of 10%. The intertemporal elasticity of substitution, σ, and the intratemporal elasticity of substitution between durables and nondurables, ρ, are both set equal to 1. The probability that a firm in the nondurable goods sector cannot reoptimize its price in any given period, θ_c, is set to 2/3. The elasticity of substitution between differentiated products, ε, is set to 11 so that the steady state markup equals 10%. I assume that the monetary authority partially adjusts its policy rate toward the optimal interest target, and set $\rho_r = 0.6$. Following the literature, I set $\phi_y = 0.5$ and $\phi_\pi = 1.5$. The latter implies that the monetary policy rate responds more than one-for-one to changes in inflation, and this ensures a unique equilibrium. Table 1 summarizes the parameter values.

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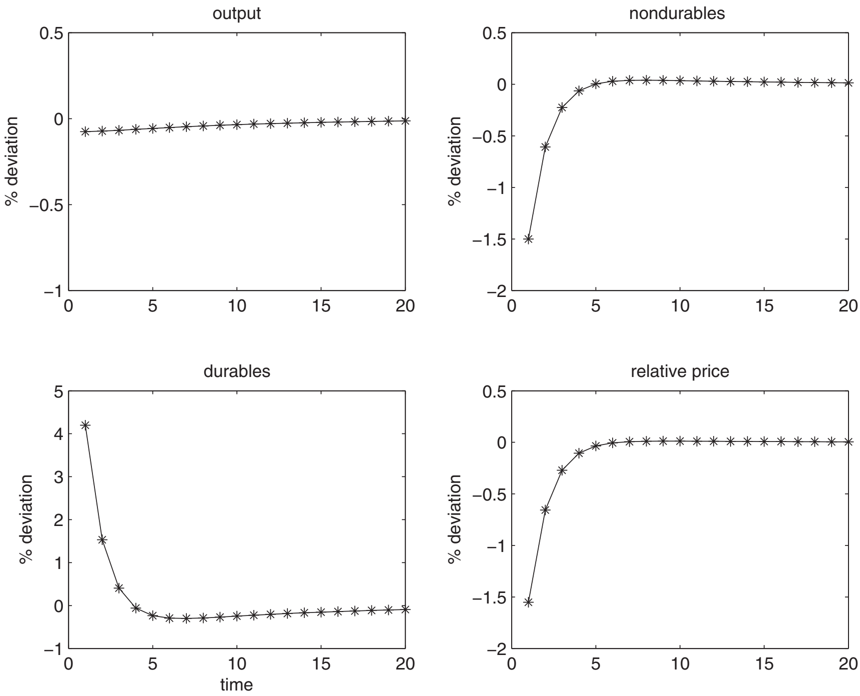

FIGURE 1. Standard model responses to a contractionary monetary policy shock.

Throughout the paper, I focus on the responses of nondurable goods consumption, durable goods consumption, the relative price of durable goods, and aggregate production to a contractionary monetary policy shock, as in the literature. Results from the baseline model are shown in Figure 1. In response to a contractionary policy shock, we observe a fall in nondurables and a rise in durables, whereas aggregate output remains nearly constant. Policy shocks have direct effects on output in the nondurable goods sector, where prices do not adjust immediately. Because durable goods producers can adjust their prices instantly, output in this sector is affected only indirectly through the changes in demand for inputs in the nondurable goods sector.

To understand the mechanism of this economy, we combine equations (1) and (2) to get

$$\psi_c C_t^{-1} \frac{P_{x,t}}{P_{c,t}} = \psi_d D_t^{-1} + \beta(1-\delta) E_t \left(\psi_c C_{t+1}^{-1} \frac{P_{x,t+1}}{P_{c,t+1}} \right). \tag{11}$$

With a low depreciation rate for durable goods, changes in the stock of durable goods and its associated shadow value after a temporary policy shock are small, inducing only a small change in $\psi_c C_t^{-1} \frac{P_{x,t}}{P_{c,t}}$. On the other hand, a fall in the wage, the only production cost, following the shock leads to larger movements in $P_{x,t}$

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than in $P_{c,t}$, as prices of durable goods are flexible. This results in a fall in relative price, $\frac{P_{x,t}}{P_{c,t}}$, and because the value of $\psi_c C_t^{-1} \frac{P_{x,t}}{P_{c,t}}$ is almost constant, consumption of nondurable goods falls.

Next, combining (1) and (3) and imposing $\sigma = \rho = 1$, we get

$$\phi N_t^{\frac{1}{\eta}} = \frac{W_t}{P_{c,t}} \psi_c C_t^{-1} = \frac{\varepsilon - 1}{\varepsilon} A_t \frac{P_{x,t}}{P_{c,t}} \psi_c C_t^{-1}. \tag{12}$$

The second equality follows by substituting out W_t using the price of durable goods, $P_{x,t} = \frac{\varepsilon}{\varepsilon-1} \frac{W_t}{A_t}$. Because the right-hand side of equation (12) changes little in response to the monetary policy shock, aggregate labor hours remain relatively constant. This implies that the fall in nondurable production is associated with a rise in durable production, and we observe durables and nondurables responding in opposite directions.

3. ADDING WORKING CAPITAL AND HABIT

I showed in the previous section that the baseline New Keynesian model with only demand-side effects cannot generate simultaneous falls in production of both durables and nondurables because aggregate production remains relatively constant after monetary shocks. However, several empirical studies find that monetary policy can affect output through changes in production costs (a supply-side channel) in addition to the traditional demand-side channels through a spending mechanism.[5] To study the supply channel of monetary policy, I now assume that firms must pay for labor input prior to production. This timing difference between when costs are incurred and when revenue is realized creates a need for working capital. This modification introduces an additional transmission mechanism through which nominal interest rates affect the level of economic activity.

3.1. Working Capital Channel

I study the supply-side effect of monetary policy by assuming that firms in both durable and nondurable sectors must borrow working capital to finance the wage bill prior to production.[6] In this setting, the labor cost is now $R_t^{\gamma_j} W_t N_t(i)$, $j = c, d$, where γ_j measures the effect of the interest rate on each firm's cost in each sector. The presence of the working-capital requirement introduces a financial cost of labor that is increasing in the nominal interest rate. This implies that a contractionary monetary policy shock that raises the interest rate increases firms' production costs and induces firms to cut back on their scale of operations, so that aggregate output declines. In effect, the policy shock acts as a negative supply shock in addition to the standard demand channel.

With working capital, marginal cost in each sector becomes $\mathrm{MC}_{j,t} = R_t^{\gamma_j} W_t / A_t$, $j = c, d$. As all firms face the same factor prices and have access to the same production technology, marginal costs are identical across firms, independent of whether or not they are resetting their prices.

3.2. Habit Formation in Nondurables

Standard preferences and rational expectations imply that agents smooth the level of consumption. This implies that when households expect an economic boom in the future, they immediately shift consumption to the present, generating a maximal response of consumption on impact of the shock. With habit formation, households instead smooth the growth rate of consumption, and this dampens the initial response of nondurable goods consumption.[7]

In the models studied thus far, household utility derived from nondurable goods consumption depends only on current consumption. I now introduce habit formation for nondurable goods so that the utility depends on both current and past consumption, the latter serving as the habit reference level. The consumption aggregate over nondurable and durable goods is now

$$U_t = \left[\psi_c (C_t - bC_{t-1})^{1-\frac{1}{\rho}} + \psi_d D_t^{1-\frac{1}{\rho}}\right]^{\frac{\rho}{\rho-1}},$$

where b denotes the intensity of consumption habit. The introduction of habit formation changes the consumption Euler equations and the household's labor supply schedule, and hence alters the propagation of monetary policy shocks. With habit, the Lagrangian multiplier in (1) is replaced by

$$\Lambda_t = \psi_c \left[U_t^{\frac{1}{\rho}-\sigma} (C_t - bC_{t-1})^{-\frac{1}{\rho}} - b\beta U_{t+1}^{\frac{1}{\rho}-\sigma} (C_{t+1} - bC_t)^{-\frac{1}{\rho}}\right].$$

The choices of nondurable goods consumption, durable goods consumption, leisure, and bond holdings all change accordingly.

3.3. Simulation Results

To simulate the model with working capital and habit formation, I assume that the shares of the wage bill borrowed in both sectors, γ_c and γ_d, equal 1.[8] The value of the habit intensity parameter, b, is set to 0.7.[9] The remaining model parameters remain unchanged from the previous sections.

Figure 2 shows the dynamic responses of nondurable, durable, and aggregate production and the relative price of durables following a contractionary monetary policy shock in the model with working capital and habit formation. We now find that with a smaller fall in the relative price of durables, nondurable, durable, and aggregate production all fall in response to the shock, resolving the co-movement problem.

With working capital, the price of flexible durable goods becomes $P_{x,t} = \frac{\varepsilon}{\varepsilon-1}\frac{R_t W_t}{A_t}$. Following a contractionary policy shock, interest rate rises while wages fall, which induces a smaller fall in the price of durable goods. As the price for nondurables is sticky, a smaller fall in the durable goods price means a smaller fall in the relative price of durable goods, which reduces the incentive to purchase the durable goods.

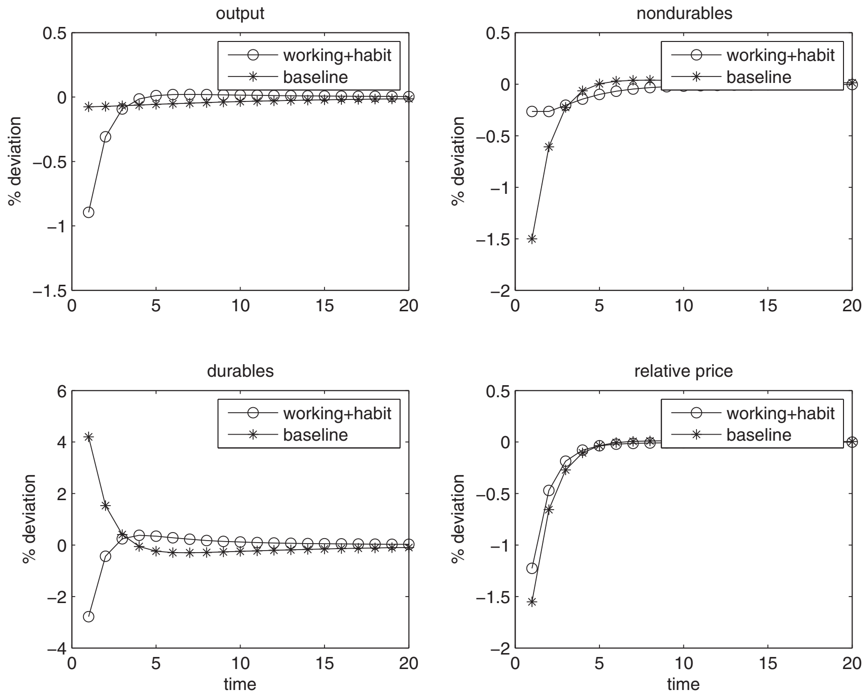

FIGURE 2. Working capital and habit model responses to a contractionary monetary policy shock.

The fall in aggregate production is clear from the Euler equation that determines labor supply. With working capital, equation (12) is now written as

$$\phi N_t^{\frac{1}{\eta}} = \frac{1}{R_t}\frac{\varepsilon - 1}{\varepsilon} A_t \frac{P_{x,t}}{P_{c,t}} \psi_c C_t^{-1}.$$

From our discussion of the baseline model, $\frac{P_{x,t}}{P_{c,t}} \psi_c C_t^{-1}$ is almost constant following a monetary policy shock, and hence aggregate labor hours, N_t, remain relatively constant. However, the need for working capital to finance the wage bill makes labor sensitive to the interest rate, and a contractionary monetary policy that raises the short-run interest rate causes a fall in aggregate labor hours and aggregate production. Therefore, the implication of the baseline model, that money is almost neutral, no longer holds, and the shock leads to falls in expenditures on both durable and nondurable goods.

Moreover, once habit is incorporated into nondurable goods, households dislike large, rapid cuts in nondurable goods consumption. With habit formation, households now seek to smooth changes in nondurable goods consumption, and hence the fall in nondurable goods consumption is dampened, leading to a smaller decline in labor demand in this sector.

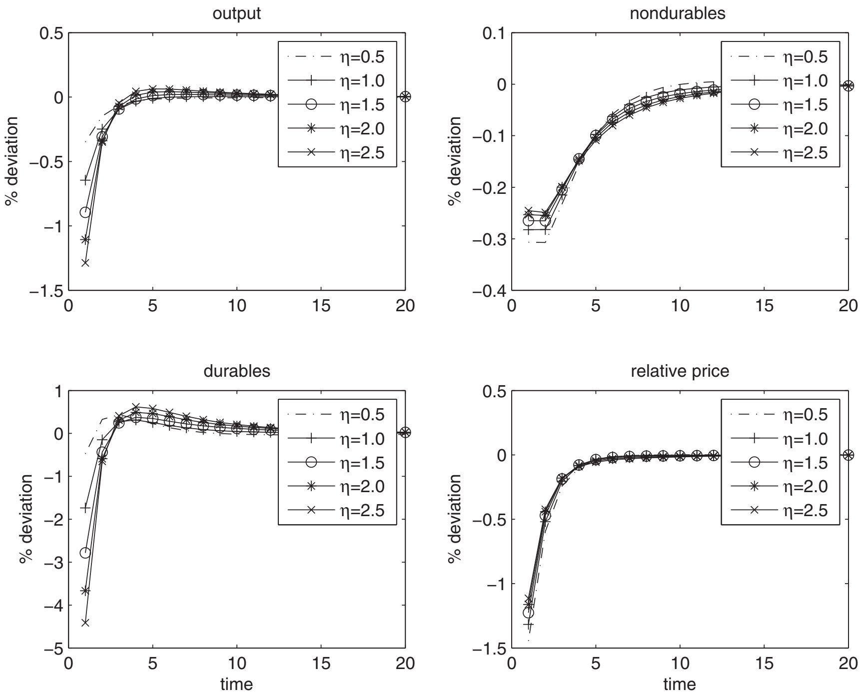

FIGURE 3. Extended model responses to a contractionary monetary policy shock under different values of Frisch elasticity of labor supply.

Together, the working capital channel and habit formation make the fall in nondurables smaller than the fall in durables and therefore resolve the co-movement problem.

3.4. Sensitivity Analysis

In this section, I test the sensitivity of my results to perturbations in the values of key parameters, using the model with working capital and habit. In particular, I vary the values of the Frisch elasticity of labor supply and the intensity of habit formation.

I first look at the model's sensitivity to the Frisch elasticity of labor supply. Because the magnitude of the fall in equilibrium employment depends on the elasticity of labor supply with respect to wage, I vary the Frisch elasticity of labor supply and set it equal to 0.5, 1, 1.5, 2, and 2.5.[10] Figure 3 plots the responses of the production of aggregate output, nondurables, and durables and the relative price of durables to a policy shock for different values of the Frisch elasticity of labor supply. We see that changing the labor supply elasticity does not overturn the model's ability to solve the co-movement problem and generate a larger response of durable goods consumption than nondurable goods consumption. Although the

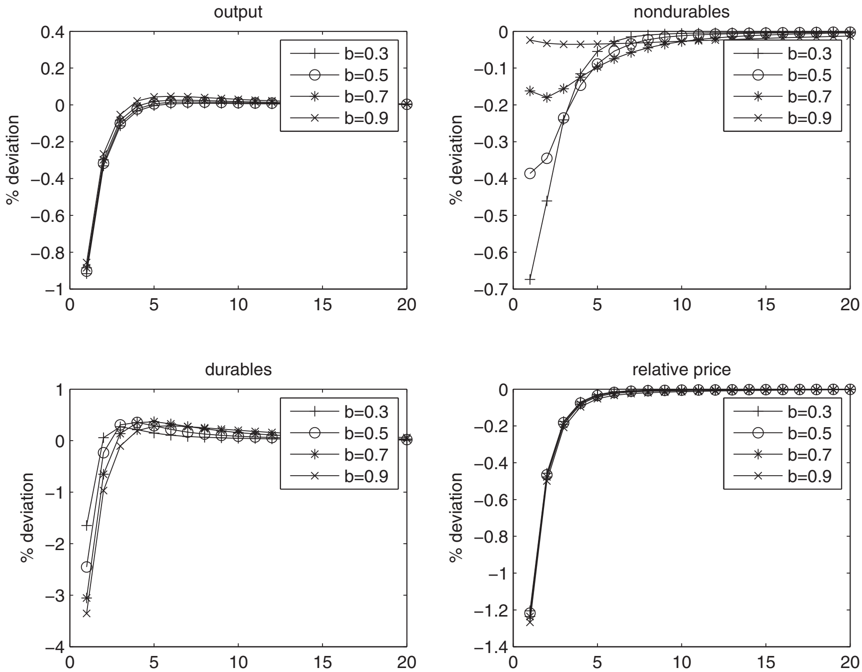

FIGURE 4. Extended model responses to a contractionary monetary policy shock under different values of habit intensity.

labor supply elasticity has little effect on nondurables, the response of durables and hence aggregate production is amplified as labor supply becomes more elastic (larger η).

In addition, I vary the intensity of habit formation of nondurables and set it equal to 0.3, 0.5, 0.7, and 0.9. Figure 4 shows that with higher degrees of habit intensity, the fall in production of nondurables becomes smaller as households smooth changes in consumption of these goods even more. Moreover, as the intensity of habit formation increases from 0.5 to 0.7, nondurables production begins to exhibit a hump-shaped response, which in line with VAR studies from Erceg and Levin (2006) and Monacelli (2009).

3.5. Extension: Productive Capital

In this subsection, I incorporate productive capital into my benchmark model with working capital and habit formation in nondurables.[11] The household has to decide how much capital to invest along with making choices on durable consumption, nondurable consumption, labor hours, and bond holdings. So its budget constraint

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becomes

$$P_{c,t}C_t + P_{x,t}X_t + P_{x,t}I_t \leqslant W_tN_t + R_{k,t}K_t + \Pi_t + T_t + S_{t-1} - \frac{S_t}{R_t}, \qquad (13)$$

and the law of motion associated with capital stock is

$$K_{t+1} = K_t(1-\delta_k) + I_t + \kappa\frac{(K_{t+1}-K_t)^2}{K_t}, \qquad (14)$$

where K_0 is given, δ_k is the depreciation rate for capital stock, and κ is the parameter of capital adjustment costs.

The first-order condition for capital stock is

$$\Lambda_t\frac{P_{x,t}}{P_{c,t}} + \Lambda_t\frac{P_{x,t}}{P_{c,t}}\kappa\frac{K_{t+1}-K_t}{K_t} = \beta\Lambda_t\frac{R_{k,t+1}}{P_{c,t+1}} + \beta\Lambda_{t+1}\frac{P_{x,t+1}}{P_{c,t+1}}(1-\delta_k)$$
$$+ \beta\kappa\Lambda_{t+1}\frac{P_{x,t+1}}{P_{c,t+1}}\frac{K_{t+2}-K_{t+1}}{K_{t+1}} + \frac{1}{2}\beta\kappa\Lambda_{t+1}\frac{P_{x,t+1}}{P_{c,t+1}}\left(\frac{K_{t+2}-K_{t+1}}{K_{t+1}}\right)^2.$$

Production of durables and nondurables now requires labor and capital:

$$Y_{j,t}(f) = A_tN_{j,t}(f)^{1-\alpha}K_{j,t}(f)^{\alpha}, \qquad (15)$$

where $j \in \{c, d\}$ and the optimal prices are

$$P^*_{j,t}(f) = \frac{\varepsilon}{\varepsilon-1}\frac{\sum_{l=0}^{\infty}\left(\beta\theta_j\right)^l E_t\Lambda_{t+j}\mathrm{MC}_{j,t+l}\left(\frac{1}{P_{j,t+l}}\right)^{1-\varepsilon}Y_{j,t+l}}{\sum_{l=0}^{\infty}\left(\beta\theta_j\right)^l E_t\Lambda_{t+l}\left(\frac{1}{P_{j,t+l}}\right)^{1-\varepsilon}Y_{j,t+l}}, \qquad (16)$$

where $j \in \{c, d\}$, and marginal cost is

$$\mathrm{MC}_{jt} = \frac{W_tR_t}{\frac{\partial F(K_{jt},N_{jt})}{\partial N_{jt}}}.$$

Labor market equilibrium requires

$$N_t = N_{c,t} + N_{x,t}.$$

Capital market equilibrium requires

$$K_t = K_{c,t} + K_{x,t}.$$

Finally, the nondurable goods are used as consumption, whereas durable goods can be used either as consumption or as investment. Goods market equilibrium requires

$$Y_{c,t} = C_t,$$
$$Y_{x,t} = X_t + I_t.$$

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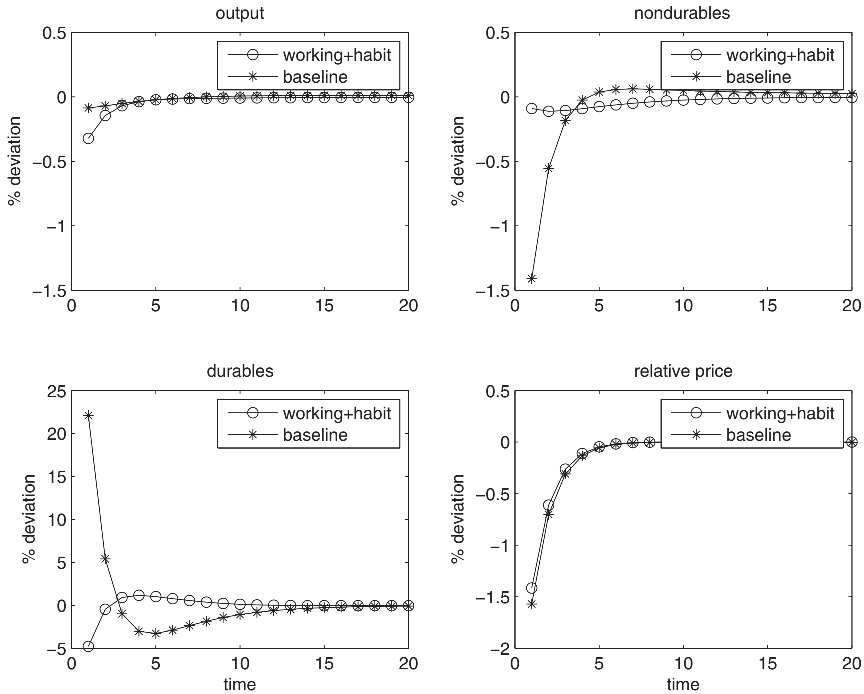

FIGURE 5. Extended model responses to a contractionary monetary policy shock with productive capital.

To simulate the model, I assume the capital share, α, and labor share, $1-\alpha$, in the production functions are 0.3 and 0.7, respectively. The parameter of the capital adjustment cost, κ, equals 4. The depreciation rate of capital, δ_k, is 0.025, which implies an annual depreciation rate of 10%. Figure 5 plots the dynamics of aggregate output, nondurable consumption, durable consumption, and the relative price of durable goods following a contractionary policy shock. Quantitative implications of my model with working capital channels do not change under the alternative assumption about capital, and nondurable consumption, durable consumption, aggregate production all fall in response to the shock. This can be seen from the Euler equation that determines labor supply, which is

$$\phi N_t^{\frac{1}{\eta}} = \frac{W_t}{\mathrm{MC}_{d,t}} \frac{\varepsilon - 1}{\varepsilon} \frac{P_{x,t}}{P_{c,t}} \psi_c C_t^{-1},$$

where the marginal cost of production of durable goods is the labor costs required to produce an additional unit of output. With labor and capital free to move from one sector to the other and constant-returns-to-scale production functions, the marginal cost of production is the same across sectors, i.e., $\mathrm{MC}_t = \mathrm{MC}_{d,t} = \mathrm{MC}_{c,t}$. When

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we consider the working capital channel, the marginal cost of production is

$$\mathrm{MC}_t = \frac{W_t R_t}{\frac{\partial F(K_t, N_t)}{\partial N_t}},$$

whereas the marginal cost becomes

$$\mathrm{MC}_t = \frac{W_t}{\frac{\partial F(K_t, N_t)}{\partial N_t}}$$

when the working capital channel is absent from the model. As capital, K_t, is predetermined and the shadow value of durables, $\frac{P_{x,t}}{P_{c,t}} \psi_c C_t^{-1}$, remains relatively constant following the policy shock, aggregate labor hours remain relatively constant when the working capital channel is absent from the model, i.e., $\phi N_t^{1/\eta} = \frac{\partial N_t}{\partial F(K_t, N_t)} \frac{\varepsilon - 1}{\varepsilon} \frac{P_{x,t}}{P_{c,t}} \psi_c C_t^{-1}$. In contrast, aggregate labor hours fall following a contractionary policy shock when I incorporate the working capital channel, $\phi N_t^{1/\eta} = \frac{1}{R_t} \frac{\partial N_t}{\partial F(K_t, N_t)} \frac{\varepsilon - 1}{\varepsilon} \frac{P_{x,t}}{P_{c,t}} \psi_c C_t^{-1}$. Furthermore, habit formation mitigates the fall in nondurable goods consumption. Together, the working capital channel and habit formation solve the co-movement problem and successfully generate a more sensitive response in the durable goods sector.

4. CONCLUSION

The co-movement of output across the durable and nondurable goods sectors is a well-established observation in the empirical monetary business-cycle literature. However, standard sticky-price models with sectoral heterogeneity in price stickiness fail to generate this feature. We add two prominent features of the data, namely working capital and habit formation in nondurable goods consumption, to the standard model. Following a contractionary monetary policy shock, a rise in the interest rate induces firms that need working capital to cut back on production, and aggregate output declines. With habit in nondurable goods consumption, the nondurable goods sector is less sensitive to the interest rate than the durable goods sector is. Therefore, these two features resolve the co-movement problem and successfully generate a more sensitive response of the durables to policy shocks, in line with VAR evidence.

NOTES

1. The rationale for one-sector models is justified by the fact that nondurable goods account for nearly 80% of total consumption. However, durable goods represent an important segment of the economy, ranging from ordinary household appliances to business products such as computers and fax machines. Furthermore, even though the durable goods sector only accounts for a small fraction of GDP, expenditures on durable goods are more volatile than those on nondurables. Hence, incorporating the durable sector into a standard model allows us to account for a large fraction of GDP volatility over the business cycle.

2. BHK use Romer dates as indicators of pronounced monetary tightness. They find that the price of new houses relative to the CPI for nondurables falls by 12% after the Romer dates. The relative price of cars falls by more than 6%. The price of durables relative to nondurables (measured by their CPIs) falls by 4.8% following a Romer date.

3. In addition to sticky wages, Carlstrom and Fuerst (2010) also introduce house construction adjustment costs and habit formation in consumption of both durables and nondurables. To investigate the impacts of habit on the consumption of durables, I have simulated my model with habit in the consumption of both durables and nondurables. Introducing habit into the consumption of durables dampens the response in the durable stock and the corresponding purchase of durable goods. Its impacts on consumption of nondurables and the relative price of durables are very small. These results are available on request.

4. Inflation is defined as a weighted average of nondurable goods inflation and durable goods inflation, $\widehat{\pi}_t = \frac{C}{Y}\widehat{\pi}_{ct} + \frac{X}{Y}\widehat{\pi}_{xt}$.

5. Rising short-term interest rates are often associated with rising production costs, which are then passed along to consumers through higher prices. One version of this view is called the Wright Patman effect after Congressman Wright Patman, who argued that raising interest rates to fight inflation was like throwing gasoline on a fire.

6. Whether a firm borrows or not, the opportunity cost is the forgone interest rate as long as the timing of when costs are incurred and when revenue is realized is different.

7. Carsltrom and Fuerst (2010) introduce habit formation in the consumption of both durable and nondurable goods. Once habit is incorporated into the consumption of durable goods, households seek to smooth changes in durable stock and therefore the fall in durable stock is damped, which can further reduce the fall in the consumption of durables.

8. For simplicity, I assume that $\gamma_c = \gamma_d$. The results of my model do not depend on the assumption that the impacts of cost channel are identical across sectors. In particular, I simulate my model with a wide range of different degrees of working capital across sectors. These results are available upon request.

9. For example, Edge et al. (2003) estimate $b = 0.64$. Boldrin et al. (2001) estimate $b = 0.73$. Smets and Wouters (2003) and Christiano et al. (2005) all estimate a similar value.

10. Macroeconomic models typically use high estimates for the Frisch elasticity of labor supply. For instance, King and Rebelo (1999) use an elasticity of 4 in their survey of RBC models. Rotemberg and Woodford (1997) use an elasticity close to 9 to evaluate the effects of alternative policy rules for the U.S. economy.

11. Most existing studies typically consider a model that abstracts from capital or where capital is fixed, for example, Barsky et al. (2003, 2007) and Carlstrom and Fuerst (2006, 2010). The quantitative implications of my model do not change under the alternative assumption about capital.

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APPENDIX

In this Appendix we describe the equilibrium conditions of the standard model in the main text. We express all variables as log deviations from their respective steady-state values:

$$\widehat{\Lambda}_t = \left(\frac{1}{\rho} - \sigma\right)\widehat{U}_t - \frac{1}{\rho}\widehat{C}_t, \tag{A.1}$$

$$\begin{aligned}\left(\widehat{\Lambda}_t + \widehat{P}_{x,t} - \widehat{P}_{c,t}\right) &= [1-\beta(1-\delta)]\left[\left(\frac{1}{\rho}-\sigma\right)\widehat{U}_t - \frac{1}{\rho}\widehat{D}_t\right] \\ &\quad + \beta(1-\delta)E_t\left(\widehat{\Lambda}_{t+1} + \widehat{P}_{x,t+1} - \widehat{P}_{c,t+1}\right), \\ \left(\widehat{\Lambda}_t + \widehat{P}_{x,t} - \widehat{P}_{c,t}\right) + \kappa(\widehat{K}_{t+1} - \widehat{K}_t) &= [1-\beta(1-\delta)]E_t\left(\widehat{\Lambda}_{t+1} + \widehat{R}_{k,t+1} - \widehat{P}_{c,t+1}\right) \\ &\quad + \beta(1-\delta)E_t\left(\widehat{\Lambda}_{t+1} + \widehat{P}_{x,t+1} - \widehat{P}_{c,t+1}\right) \\ &\quad + \beta\kappa(\widehat{K}_{t+2} - \widehat{K}_{t+1}),\end{aligned} \tag{A.2}$$

$$\frac{1}{\eta}\widehat{N}_t = \widehat{W}_t - \widehat{P}_{c,t} + \widehat{\Lambda}_t, \tag{A.3}$$

$$\widehat{D}_t = \widehat{D}_{t-1}(1-\delta) + \delta\widehat{X}_t, \tag{A.4}$$

$$\widehat{K}_{t+1} = \widehat{K}_t(1-\delta_k) + \delta_k\widehat{I}_t, \tag{A.5}$$

$$\widehat{\mathrm{MC}}_t = \alpha\widehat{W}_t + (1-\alpha)\widehat{R}_{k,t} - \widehat{A}_t, \tag{A.6}$$

$$\widehat{P}^*_{c,t} = \beta\theta_c\widehat{P}^*_{c,t+1} + (1-\beta\theta_c)\widehat{\mathrm{MC}}_t, \tag{A.7}$$

$$\widehat{\pi}_{c,t} = \beta E_t\widehat{\pi}_{c,t+1} + \frac{(1-\beta\theta_c)(1-\theta_c)}{\theta_c}\widehat{\mathrm{MC}}_t, \tag{A.8}$$

$$\widehat{P}^*_{x,t} = \widehat{\mathrm{MC}}_t, \tag{A.9}$$

$$\widehat{R}_t = \rho_r\widehat{R}_{t-1} + (1-\rho_r)\phi_\pi\widehat{\pi}_t + (1-\rho_r)\phi_y\widehat{Y}_t + \epsilon_t, \tag{A.10}$$

$$\widehat{N}_t = \frac{N_c}{N}\widehat{N}_{c,t} + \frac{N_x}{N}\widehat{N}_{x,t}, \tag{A.11}$$

$$\widehat{Y}_t = \frac{Y_c}{Y}\widehat{Y}_{c,t} + \frac{Y_x}{Y}\widehat{Y}_{x,t}, \tag{A.12}$$

$$\widehat{Y}_{c,t} = \widehat{C}_t, \tag{A.13}$$

$$\widehat{Y}_{x,t} = \frac{I}{Y_x}\widehat{I}_t + \frac{X}{Y_x}\widehat{X}_t. \tag{A.14}$$

With working capital, the marginal cost in (17) is replaced by

$$\widehat{\mathrm{MC}}_t = \alpha\widehat{W}_t + (1-\alpha)\widehat{R}_{k,t} - \widehat{A}_t + \widehat{R}_t. \tag{A.15}$$

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With habit, the Lagrangian multiplier in (13) is replaced by

$$\widehat{\Lambda}_t = \frac{\frac{1}{\rho} - \sigma}{1 - b\beta}\left(\widehat{U}_t - b\beta E_t \widehat{U}_{t+1}\right) - \frac{1}{\rho(1-b)(1-b\beta)}(\widehat{C}_t - b\widehat{C}_{t-1}) + \frac{b\beta}{\rho(1-b)(1-b\beta)} E_t(\widehat{C}_{t+1} - b\widehat{C}_t).$$

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