What do Working Capital Channel and Habit Tell Us about the Co-movement Problem?*

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Abstract

In empirical studies, consumption in both nondurables and durables tends to fall in response to a contractionary policy shock while in standard models, consumption of durables rises and nondurables falls after a contractionary shock. This anomaly is known as the comovement problem. To reconcile the empirical findings and the model prediction, I study the effects of two channels: working capital and habit formation. Once these two factors are added, I can eliminate the comovement problem.

JEL E21, E30, E31, E32

Keywords: Dynamic New Keynesian model; durable goods; working capital; habit formation; co-movement problem.

1 Introduction

Over the past ten years, the one sector Dynamic New Keynesian model (DNK hereafter) has become the workhorse for modern macroeconomics. It provides a number of important insights about the effects of monetary policy and helps shape modern monetary policy. However, one sector models cannot be used to address the issue of interaction between different

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sectors after a policy shock. Some papers incoporate two sectors to study this problem. For example, Aoki (2001) studies an economy with different degrees of price stickiness for two nondurable goods. Erceg and Levin (2005) focus on the difference between durables and nondurables. Recently, Barsky, House and Kimball (2007) (BHK hereafter) study the economy with sticky nondurable goods sector and flexible durable goods sector.

The study of Erceg and Levin documented the empirical response of durables and nondurables to contractionary policy shocks. They find that both nondurable and durable goods consumption tends to decrease after contractionary shocks. Additionally, durable goods are more interest sensitive than nondurables. However, one puzzling aspect of the DNK, pointed out by BHK, is that when incorporating a flexible price durable goods sector into the sticky price nondurable goods model, monetary policy will have different effects on the durable and nondurable goods. Policies that stimulate nondurable goods will cause a contraction in durable goods and vice versa. In the extreme case, monetary policy does not have any effect on output and employment regardless of how sticky or how large the non-durable goods sector is. This finding seems to overturn the conventional wisdom learned from the one sector sticky price model — monetary policy will affect production in the short run. BHK refers to this surprising outcome of the DNK model as a "comovement problem".

The above implications hinge primarily on the characterization of durable goods as a stock variable. With a low depreciation rate, the stock of durable goods and their associated shadow prices respond very little to a change in the interest rate. Therefore, the elasticity of intertemporal substitution for durable goods is large. Even a small change in the relative price of durable goods will cause a dramatic adjustment in a household's purchase of durable goods. A contractionary policy shock causing a fall in the relative price of durable goods will stimulate a huge increase in the purchase of durable goods, while consumption of nondurable goods will decrease, as conventional studies of monetary policy have suggested.

To reconcile the empirical findings with the model predictions, recent papers try to solve this problem via a variety of mechanisms. Most of these papers focus on sticky wages and credit constraints. Carlstrom and Fuerst (2006) compare both channels of sticky wages and credit constraints and conclude that empirical studies show more evidence in favor of sticky wages over credit constraints. Sticky wages can solve this puzzle because, given that labor is the only production input, nominal wage stickiness will induce a nominal stickiness in prices. Even if the price of durable goods is flexible, as long as wages are sticky durable goods producers will have little incentive to adjust their prices.

Tommaso Monacelli (2008) instead studies the effect of a borrowing constraint using durables as collateral assets. When there is a rise in interest rate, the value of collateral would fall, thus pushing up the user cost of durables. Therefore, a contractionary policy shock will induce a substitution from durables to nondurables. He argues that credit market imperfections could play an even larger role than price stickiness.

This paper intends to solve the comovement problem using two channels which have been studied extensively in the literature: working capital and habit formation in nondurable goods. My paper differs from past work because I do not impose any friction in durable sector to slow down the price adjustment process. Once I add these two features to the standard model, I can eliminate the comovement problem.

Working capital refers to the assumption that a firm needs to borrow in advance to pay for its input. With working capital, policy shocks will have both demand side and supply side effects. Demand side effects refer to the consumption adjustment in different sectors, while the supply side effects refer to the changes in marginal cost and the associated price adjustments after policy shocks. The aggregate labor hours and output fall in response to an increase in the short run interest rate. In contrast to the results of standard model, that aggregate labor hours remain constant in response to a contractionary policy shock, a fall in aggregate labor hours can generate the fall of labor hours in both nondurable and durable goods sectors more easily.

The rational expectation and consumption smoothing of nondurables imply a maximal response of nondurables at the time of the policy shock. The introduction of habit formation in nondurables will change the behavior of households from smoothing consumption to smoothing consumption growth. Given aggregate production does not respond to monetary shocks, a smaller decrease in nondurable production will result in a smaller increase in durable goods production. So, habit formation will improve the negative comovement problem.

Once working capital is added, aggregate labor hours will fall in response to a contractionary policy shock. With habit, labor demand in the nondurable goods sector will fall by less, therefore explaining the fall in the durable goods sector as well. With both working capital and habit in the model, durable and nondurable production will fall in response to an increase in the short run interest rate.

Given the intuition behind working capital channel, if I assume sector specific labor for nondurable and durable goods sectors, I can come up with another way to solve the negative comovement problem. The structure of this paper is as follows: in section 2, I will review and calibrate the basic model. In section 3, I will add working capital and habit to the standard model to study their effects. Also, I will study the case of sector specific labor. Finally, I will conclude and discuss some extensions of this study.

2 Dynamic new keynesian model with flexible durable and sticky nondurable goods sectors

There are three agents in the economy: households, firms, and the monetary authority. Households derive utility from nondurable goods, durable goods, and leisure. There are two types of intermediate firms that produce distinct types of output subject to frictions of price adjustment. Specifically, they produce durable and nondurable goods. The behavior of these agents is described below.

2.1 Households' problem

In every period, households' composite consumption, U_t, includes nondurable goods, C_t, and durable goods, D_t. Their preferences over nondurable goods and durable goods are defined by the CES utility function $U_t = ({\psi_c}^{\frac{1}{\rho}}{C_t}^{1-\frac{1}{\rho}} + {\psi_d}^{\frac{1}{\rho}}{D_t}^{1-\frac{1}{\rho}})^{\frac{\rho}{\rho-1}}$. Therefore the corresponding price index P_t is given by $P_t = (\psi_c {P_{c,t}}^{1-\rho} + \psi_d {P_{x,t}}^{1-\rho})^{\frac{1}{1-\rho}}$ where $P_{c,t}$ and $P_{x,t}$ represent prices of nondurable and durable goods respectively.

The objective of the representative household is defined as below:

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

$$\text{s.t. } P_{c,t}C_t + P_{x,t}X_t \leqslant W_tN_t + \Pi_t + T_t + S_{t-1} - \frac{S_t}{R_t}$$

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

Here E_t is the expectations operator conditional on time t information; $\beta \in (0,1)$ is the discount rate. The household maxmizes its expected lifetime utility subject to both its budget constraint and the law of motion of durable goods. Households enter period t with initial bond holdings of S_{t-1}. They receive wage income, W_tN_t; profits, Π_t; and transfers from the government, T_t; to purchase nondurable goods, C_t; durable goods, X_t; and state contingent risk free bond, $\frac{S_t}{R_t}$.

The first order conditions for nondurable consumption, leisure, durable consumption, and bond holding are as follows:

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

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

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

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

The first equation represents the marginal utility of income in period t. The second equation represents the tradeoff between nondurable goods and durable goods. The third one represents the tradeoff between nondurable consumption and leisure. The fourth one represents the trade off between consumption and bond holdings.

The loglinearized equations are below:

$$\widehat{D}_t = \widehat{D}_{t-1}(1-\delta) + \delta\widehat{X}_t$$

$$-\frac{1}{\rho}\widehat{C}_t+\widehat{P}_{x,t}-\widehat{P}_{c,t} = -\beta(1-\delta))(\frac{1}{\rho}-\frac{1}{\sigma})\widehat{U}_t-(1-\beta(1-\delta))\frac{1}{\rho}\widehat{D}_t$$
$$+\beta(1-\delta)E_t[(\frac{1}{\rho}-\frac{1}{\sigma})\widehat{U}_{t+1}-\frac{1}{\rho}\widehat{C}_{t+1}+\widehat{P}_{x,t+1}-\widehat{P}_{c,t+1}]$$

$$\frac{1}{\eta}\widehat{N}_t=\widehat{W}_t-\widehat{P}_{c,t}+(\frac{1}{\rho}-\frac{1}{\sigma})\widehat{U}_t-\frac{1}{\rho}\widehat{C}_t$$

2.2 Firms and price setting

There are two types of firms in this model. A continuum of nondurable goods firms, and a continuum of durable goods firms. The nondurable goods firms set their prices a la Calvo while the durable goods firm is free to adjust its price every period. Intermediate goods firms are competitive in the factor markets, meaning they take factor prices as given. We allow the factor to move freely from industry to industry and from sector to sector. We describe the firm's problem below.

2.2.1 Nondurable goods firm

There are a continuum of monopolistic firms (f) within the unit circle in the nondurable goods sector, i.e. $f \in (0,1)$, that sell nondurable goods to final goods firms. They set their price $P_{c,t}(f)$ subject to Calvo type frictions. In each period, a portion $1-\theta_c$ in the nondurable goods sector are allowed to reoptimize their price regardless of the time of their last price adjustment. The remaining portion θ_c of the nondurable goods firms charge the same price they posted in the previous period.

The demand faced by each firm depends on the price charged for their products and the total demand for consumption, which takes the following form:

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

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

The objective of the monopolistically competitive firm is to maximize the sum of its discounted profit. Since firms can not reoptimize their price every period, they maximize the discounted sum of their profit when the price is still valid. The profit equals revenue minus the cost to produce output.

Production requires a labor input which takes the following linear form:

$$C_t(f) = A_t N_t(f) \tag{6}$$

A_t is the technology level which is identical across firms.

Since labor is the only production input, the monopolistically competitive firm solves the following problem:

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

subject to demand for its goods (5) and its production function (6).

Λ_{t+j} represents the marginal utility of income for period $t+j$.

The first order conditions are:

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

marginal cost $MC_t = \frac{W_t}{MPL_t}$, where W_t is wage paid and MPL_t is the marginal product of labor.

Also, the price evolution rule under Calvo price setting is

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

Thus, the loglinearized equations take the following form

$$\widehat{MC}_t = \widehat{W}_t - \widehat{A}_t \tag{8}$$

$$\widehat{P}^*_{c,t} = \beta\theta_c \widehat{P}^*_{c,t+1} + (1-\beta\theta_c)\widehat{MC}_t \tag{9}$$

$$\widehat{\pi}_{c,t} = \beta E_t \widehat{\pi}_{c,t+1} + \frac{(1-\beta\theta_c)(1-\theta_c)}{\theta_c} \widehat{MC}_t \tag{10}$$

2.2.2 Durable goods firms

Durable goods firms can reoptimize their price every period. Also they all face the same linear production function and demand function which is described below.

Their objective function is:

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

subject to the production function

$$X_t(f) = A_t N_t(f) \tag{11}$$

and the demand function

$$X_t(f) = \left(\frac{P_{x,t}(f)}{P_{x,t}} \right)^{-\varepsilon} X_t \tag{12}$$

Since the focus of this paper is to study the effects of monetary shocks, I assume the technology level is identical in both the nondurable and durable sector. In a more general setting, we can allow the sector specific technology level to be different. The durable aggregator is, $X_t = \left[\int_0^1 X_t(f)^{\frac{\varepsilon-1}{\varepsilon}} df \right]^{\frac{\varepsilon}{\varepsilon-1}}$, and its corresponding price index is, $P_{x,t} = \left[\int_0^1 P_{x,t}(f)^{1-\varepsilon} df \right]^{\frac{1}{1-\varepsilon}}$.

The first order condition for price implies:

$$P^*_{x,t}(f) = \frac{\varepsilon}{\varepsilon - 1} MC_t \tag{13}$$

With loglinearized equations being:

$$\widehat{MC}_t = \widehat{W}_t - \widehat{A}_t \tag{14}$$

$$\widehat{P}^*_{x,t} = \widehat{MC}_t \tag{15}$$

2.3 Monetary policy and Market Clearing

Monetary policy is conducted using the well-known Taylor rule, under which the monetary authority sets interest rates in response to changes in inflation and output gap.[1] The interest rate will respond more than one to one with changes in inflation rate. We allow the monetary authority to partially adjust toward the optimal interest target.

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

Labor market equilibrium requires

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

Goods market equilibrium requires

$$Y_t = C_t + X_t$$

Loglinearizing these three equations gives us:

$$\widehat{R}_t = \rho_r \widehat{R}_{t-1} + (1-\rho_r)\phi_\pi \widehat{\pi}_t + (1-\rho_r)\phi_y \widehat{y}_t \tag{16}$$

$$\widehat{N}_t = \frac{N_c}{N}\widehat{N}_{c,t} + \frac{N_x}{N}\widehat{N}_{x,t} \tag{17}$$

$$\widehat{Y}_t = \frac{C}{Y}\widehat{C}_t + \frac{X}{Y}\widehat{X}_t \tag{18}$$

2.4 Calibration and results

The above model is very similar to BHK. The main difference between the two lies in how the monetary authority implements its policy. I assume the monetary authority implements its policy through a change in interest rate, similar to a Taylor type of interest rate rule,

[1] Inflation is obtained as a weighted average of nondurable goods inflation and durable goods inflation. Output gap is defined in the similar way.

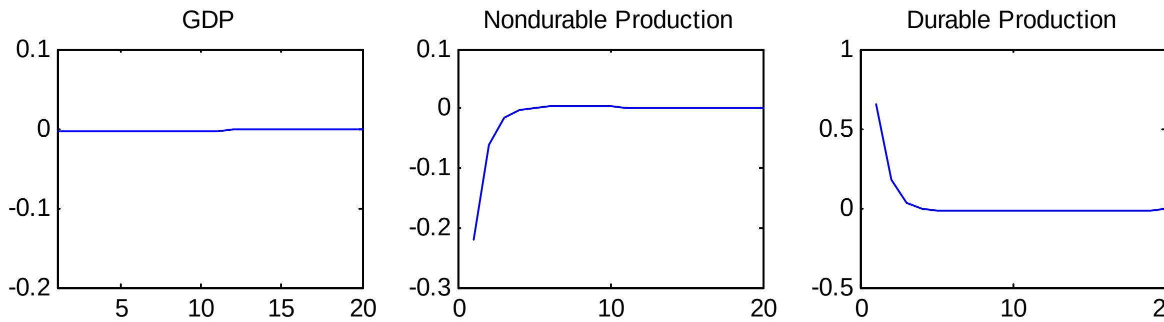

Figure 1: Standard Model

while BHK uses money stock as their policy instrument.[2] I took BHK's parameter values and applied them to the current model, where they set labor supply elasticity to 1. The intertemporal elasticity of substitution is 1, and the subjective time discount factor is 0.995, which implies a 2% annual interest rate. Since my focus is to study the effects of policy shocks, I set technology level equal to 1 across sectors.[3]

The result is shown in Figure 1. In response to a contractionary policy shock, we observe a fall in nondurables, a rise in durables, and aggregate output remains relatively constant. The instrument of the monetary authority does not affect the equilibrium result much. Policy shocks have direct effects on the nondurable goods sector because prices do not adjust immediately. Given the assumption that the durable goods sector can adjust its price instantly, the sector will only be affected indirectly through the the demand for inputs in the nondurable goods sector.

The fall in nondurables and the rise in durables can be deduced from the following reasoning. Combining equation (1) and equation (2), and plugging in $\rho = \sigma = 1$, we can get the following equation

$$\psi_c C_t^{-1} \frac{P_{x,t}}{P_{c,t}} = \psi_d D_t^{-1} + \beta(1-\delta) E_t(\psi_c C_{t+1}^{-1} \frac{P_{x,t+1}}{P_{c,t+1}}) \tag{19}$$

With a small depreciation rate in durable goods, the change in durable stock and its

[2]Carlestrom and Fuerst (2006) considered this modification in their paper and derived the same results.

[3]BHK discuss 3 different cases: (1) symmetric price rigidity, (2) sticky durables prices and flexible nondurables prices, (3) flexible durables prices and sticky nondurables prices. Since negative comovement mainly refers to the third case, we take all parameters from their third case as our baseline model parameters.

associated shadow value would be very small, inducing a small change in $\psi_c C_t^{-1} \frac{P_{x,t}}{P_{c,t}}$. After a contractionary shock, wages will fall. Since wage is the main production cost, flexible durable prices will adjust much faster than sticky nondurable prices, which will cause a fall in relative price $\frac{P_{x,t}}{P_{c,t}}$. Since the value of $\psi_c C_t^{-1} \frac{P_{x,t}}{P_{c,t}}$ is almost constant, the fall in relative price of durable goods $\frac{P_{x,t}}{P_{c,t}}$ will induce the fall in nondurable consumption C_t as well.

Similarly, combining (1) and (4), we can get

$$\phi N_t^{\frac{1}{\eta}} = \frac{W_t}{P_{c,t}} \psi_c C_t^{-1} = \frac{W_t}{P_{x,t}} \frac{P_{x,t}}{P_{c,t}} \psi_c C_t^{-1} = \frac{\varepsilon - 1}{\varepsilon} \frac{P_{x,t}}{P_{c,t}} \psi_c C_t^{-1} \tag{20}$$

The first equality comes from the Euler equation between nondurable consumption and labor supply. The third equality holds as the flexible durable goods firm charges a markup of its marginal cost, i.e. $P_{x,t} = \frac{\varepsilon}{\varepsilon - 1} W_t$. From equation (20) we know the right hand side of the above equation does not respond greatly to changes in monetary shocks, aggregate labor hours will therefore remain relatively constant after policy shocks. Since aggregate labor hours do not respond to policy shocks, the fall in nondurable production will be associated with a rise in durable production; therefore we observe the negative comovement between durables and nondurables in the standard model.

3 Adding in working capital and habit

3.1 Working capital channel

Erceg and Levin (2005) find some evidence of price puzzles. Price puzzles refer to VAR studies examining the increase of the price level in response to a contractionary monetary policy shock that raises the short run interest rate. Barth and Ramey (2001) argue that rising prices following a monetary contraction support the idea that monetary policy operates through both demand and supply sides. During a time of rising short term interest rates, it is not unusual to hear about the rising production costs which will be passed along to consumers in the form of higher prices. If the monetary authority tries to fight inflationary pressure through raising short term interest rates, more inflation will be forthcoming, not less. One version of this view has been 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.

Christiano, Eichenbaum and Evans (2005) use working capital to explain price puzzles. The working capital assumption requires that a firm pays its workers at the beginning of the period, but the firm will not collect revenue until the end of the period. Here, we assume that the firm must borrow all of its wage bill for one period, so the wage bill is now $R_t W_t N_t(i)$, where R_t is the interest rate on each firm's labor cost. This setting represents an extra channel for monetary policy to affect the private sector. After a contractionary policy shock that raises the short run interest rate, the change in marginal costs will depend on the change in wage and the change in interest rates. In a more general setup, I can allow firms to borrow a portion of their wage bill or borrow for more than one period. The rationale for borrowing only part of a wage bill could come from a firm's retained earnings, in other words some wage payment could come from internal financing. Alternatively, firms could borrow for more than one period. If there is a "time to build" aspect to production, labor might need to be paid two periods before revenue is realized. Therefore the effect of the interest rate will be doubled.

Adding working capital to the model, the marginal cost becomes $MC_t = \frac{R_t W_t}{MPL_t}$ and policy shocks will have a direct effect on both nondurable goods sector and durable goods sector.

The loglinearized equations become as below:

$$\widehat{MC}_t = \widehat{W}_t + \widehat{R}_t \tag{21}$$

$$\widehat{P}^*_{c,t} = \beta\theta_c \widehat{P}^*_{c,t+1} + (1-\beta\theta_c)\widehat{MC}_t \tag{22}$$

$$\widehat{P}^*_{x,t} = \widehat{MC}_t \tag{23}$$

3.2 Habit formation in nondurables

In addition to working capital, many existing studies show that VAR responses of nondurable goods consumption to a monetary policy shock are hump shaped. However, standard preferences and rational expectations imply that agents want to smooth their consumption in nondurables. When households forecast an economic boom in the future, they would shift nondurable goods consumption to the present right away. One way to keep economic models' consumption hump shaped is by adding habit formation. With habit formation, households would like to smooth their consumption growth in response to interest rate shocks, therefore creating a hump-shaped response.[4]

In previous sections, utility derived from nondurable goods consumption depends on current consumption only. Once we incorporate habit formation for nondurable goods, the utility of the household will depend on both the current consumption and the previous consumption, i.e.: the habit reference level. The preference over nondurable and durable consumptions changes as below:

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

The parameter b corresponds to the intensity of the reference level relative to current consumption where $b \in (0,1)$. The introduction of habit formation alters the propagation of policy shocks as it modifies the consumption Euler equations and the household's labor supply schedule. With habit, the lagrangian multiplier in (1) becomes

$$\Lambda_t = \psi_c[(C_t - bC_{t-1})^{-1} - b\beta(C_{t+1} - bC_t)^{-1}]$$

The choices of nondurable goods consumption, durable goods consumption, leisure, and bond holdings will all change accordingly. Their loglinearized equations follow:

$$\widehat{\Lambda}_t = \frac{-1}{(1-b)(1-b\beta)}(\widehat{C}_t - b\widehat{C}_{t-1}) + \frac{b\beta}{(1-b)(1-b\beta)} E_t(\widehat{C}_{t+1} - b\widehat{C}_t)$$

$$(\widehat{\Lambda}_t + \widehat{P}_{x,t} - \widehat{P}_{c,t}) = (1 - \beta(1-\delta))(-\widehat{D}_t) + \beta(1-\delta)E_t(\widehat{\Lambda}_{t+1} + \widehat{P}_{x,t+1} - \widehat{P}_{c,t+1})$$

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

[4] The assumption of habit is to decrease the initial response of nondurable goods consumption to policy shocks. Whether the shape is humped or monotonic is not our main concern here.

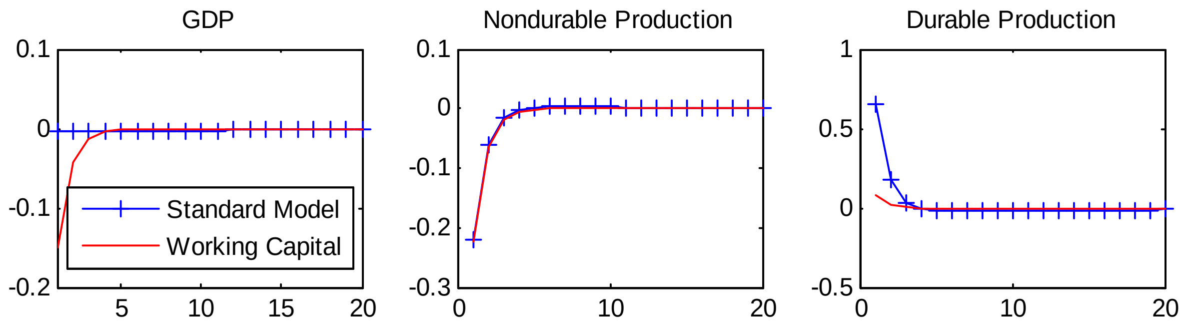

Figure 2: Comparsion between standard model and working capital model

3.3 Calibration and results

To show how each channel can help alleviate the negative comovement puzzle, I will focus on three variables and their responses to policy shocks: durable production, nondurable production, and aggregate output. I will use the same parameter values from the previous section. As the parameter for habit intensity I choose $b = 0.6$ which is plausible according to the literature.[5]

3.3.1 Working capital only

In the calibration results shown in figure 2, we can observe two phenomena: (1) introducing working capital causes a fall in total labor hours after a contractionary policy shock, and (2) working capital alone does not completely eliminate the negative comovement problem.

The first observation is easy to see from the Euler equation that determines labor supply. In the previous section, we know that labor is approximately constant after monetary shocks. With working capital, the price of flexible durable goods will become $P_{x,t} = \frac{\varepsilon}{\varepsilon-1} R_t W_t$, so equation (20) will change accordingly as follows

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

From previous discussion, we know that $\frac{P_{x,t}}{P_{c,t}} \psi_c C_t^{-1}$ is almost constant after monetary

[5]For example, Edge, Laubach and Williams (2003) estimated $b = 0.64$. Boldrin, Christiano, and Fisher (2001), Smets and Wouters (2002) and Christiano, Eichenbaum and Evans (2003) all estimate a similar value of this habit intensity.

shocks, so the aggregate labor hours, N_t, remains relatively constant in the standard model. With working capital, total labor supply will change in response to changes in short run interest rates, R_t. A contractionary monetary policy that raises the short run interest rate will cause a fall in aggregate labor hours. The implication of the standard model, that money will be approximately neutral, will no longer hold. Aggregate production and labor hours fall in the wake of a contractionary policy shock, as conventional wisdom suggests.

Second, the change in nondurable consumption is nearly identical whether we allow working capital to enter the model or not. The fall of labor hours in nondurable goods sector remains relatively constant. The calibration result shows that with a one time working capital effect, i.e. $\widehat{MC}_t = \widehat{W}_t + \widehat{R}_t$, the fall in aggregate labor hours is smaller than the fall in labor hours in nondurable goods sector. So, we will obseve a smaller increase in durable production but still cannot completely eliminate the negative comovement problem.

3.3.2 Habit formation in nondurable goods only

Figure 3 examines the impulse response of nondurable and durable consumption to contractionary policy shocks for the habit formation model. I calibrate the model when b equals 0.6. Setting $b = 0$ corresponds to the standard model, and setting $b = 0.6$ corresponds to the habit formation model studied here. With habit formation in the nondurable goods channel only, the change in aggregate labor hours will remain relatively constant per our previous analysis. So, a fall in the nondurable sector will be associated with a rise in the durable sector; therefore the negative comovement problem will still exist. However, adding habit formation in the standard model will alleviate the negative comovement problem due to a smaller change in nondurable consumption in response to policy shocks.

Without habit formation, nondurable goods consumption falls most dramatically when the contractionary policy shock occurs. In response to this consumption change, labor demand for nondurable production experiences its largest decrease in that period. Since aggregate labor hours do not respond to monetary shocks, labor demand in the durable sector increases most dramatically after policy shocks.

With habit formation in our model, households seek to smooth changes in nondurable consumption from the pre-shock to the current period. The fall in nondurable consumption

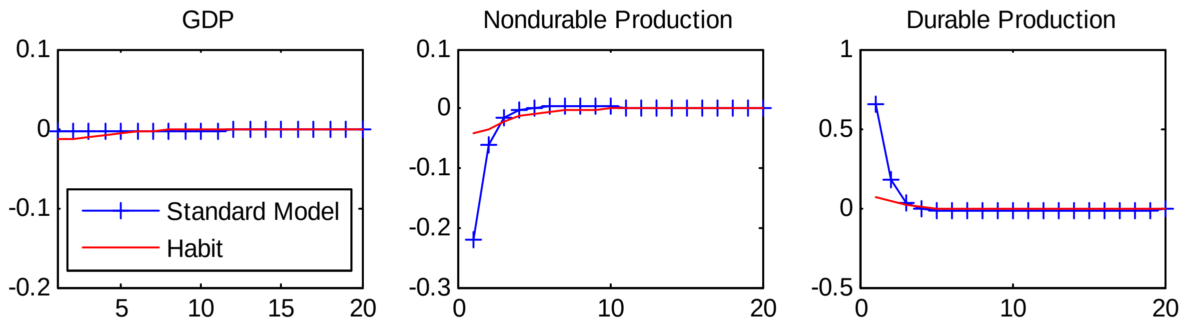

Figure 3: Comparsion between standard model and habit formation model

will be smaller compared to the case without habit formation. Therefore, habit formation in nondurables induces a smaller change in labor demand for the nondurable goods sector, which results in a smaller increase in labor demand in the durable goods sector. A smaller change in labor demand between the durable and nondurable sectors causes a smaller decrease in the respective production levels, and a smaller negative comovement problem.

3.3.3 Both working capital and habit in nondurable goods consumption

Figure 4 demonstrates the result when both working capital and habit formation are added to the model. As explained earlier, the working capital channel induces aggregate labor hours to fall after a contractionary policy shock. Without habit formation, the fall in labor hours in nondurable goods sector will dominate the fall in aggregate labor hours. We will still observe the rise in labor hours in durable goods sector and therefore the negative comovement will still exist. Once habit is incorporated in nondurable goods, the fall in nondurables will be smaller and therefore the fall in aggregate labor hours will dominate causing a fall in durable goods production as well. So with both the working capital channel and habit formation in nondurables, I can solve the negative comovement problem.

3.4 Sector specific labor

Since large swings in durable production stems from the assumption that labor can easily shift across sectors in response to monetary shocks, introducing frictions in the labor market could mitigate these large sectoral disturbance after the shock. I therefore study the frictions

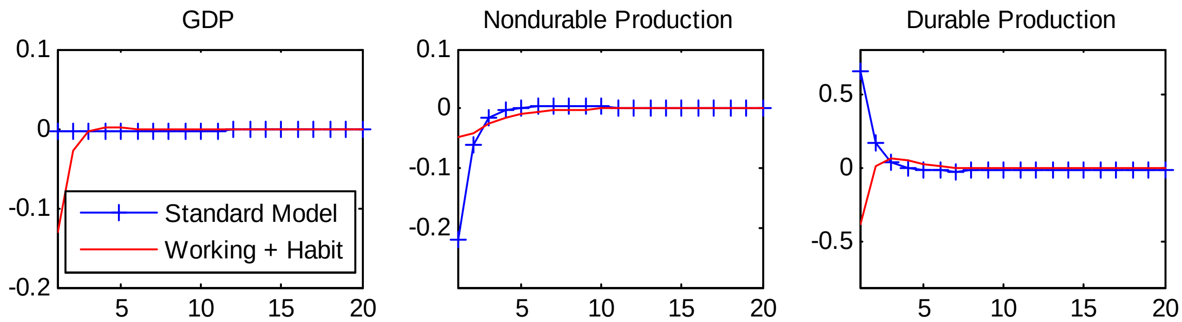

Figure 4: Both working capital and habit

in the labor market that prevent labor movement across sectors in this section

Following BHK, I feature labor market friction by assumng sector specific labor. So the period utility function will become $\frac{1}{1-\frac{1}{\sigma}}[(\psi_c C_t^{1-\frac{1}{\rho}} + \psi_d D_t^{1-\frac{1}{\rho}})^{\frac{\rho}{\rho-1}}]^{1-\frac{1}{\sigma}} - \phi_1 \frac{N_{c,t}^{1+\frac{1}{\eta}}}{1+\frac{1}{\eta}} - \phi_2 \frac{N_{x,t}^{1+\frac{1}{\eta}}}{1+\frac{1}{\eta}}$ and the budget constraint will be $P_{c,t}C_t + P_{x,t}X_t \leqslant W_{c,t}N_{c,t} + W_{x,t}N_{x,t} + \Pi_t + R_{t-1}S_{t-1} - S_t$. Here $N_{c,t}$ and $N_{x,t}$ represent labor hours in nondurable and durable sectors respectively. In the current setting, most Euler equations derived in the previous section will still hold. With this new period utility function, the Euler equation for labor supply in nondurable and durable sectors will become

$$\phi_1 N_{c,t}^{\frac{1}{\eta}} = \frac{W_{c,t}}{P_{c,t}} \psi_c C_t^{-1}$$

$$\phi_2 N_{x,t}^{\frac{1}{\eta}} = \frac{W_{x,t}}{P_{c,t}} \psi_c C_t^{-1}$$

I use the same set of parameter values and the calibration results are shown in Figure 5. We can observe that durables and nondurables both fall in response to a contractionary shock. This result can be seen from the labor supply function in durable goods sector as follows: $\phi_2 N_{x,t}^{\frac{1}{\eta}} = \frac{W_{x,t}}{P_{c,t}} \psi_c C_t^{-1} = \frac{W_{x,t}}{P_{x,t}} \frac{P_{x,t}}{P_{c,t}} \psi_c C_t^{-1}$. With a small depreciation rate in durable goods, the reasoning that $\frac{P_{x,t}}{P_{c,t}} \psi_c C_t^{-1}$ remains relatively constant will still hold. Without working capital, $\phi_2 N_{x,t}^{\frac{1}{\eta}} = \frac{\varepsilon-1}{\varepsilon} \frac{P_{x,t}}{P_{c,t}} \psi_c C_t^{-1}$. The above equation will render constant durable production in response to monetary shocks. Once we incorporate working capital channel, the above equation will become $\phi_2 N_{x,t}^{\frac{1}{\eta}} = \frac{1}{R_t} \frac{\varepsilon-1}{\varepsilon} \frac{P_{x,t}}{P_{c,t}} \psi_c C_t^{-1}$. So the labor hours in the durable goods sector will fall after contractionary policy shocks. The reason that nondurables will

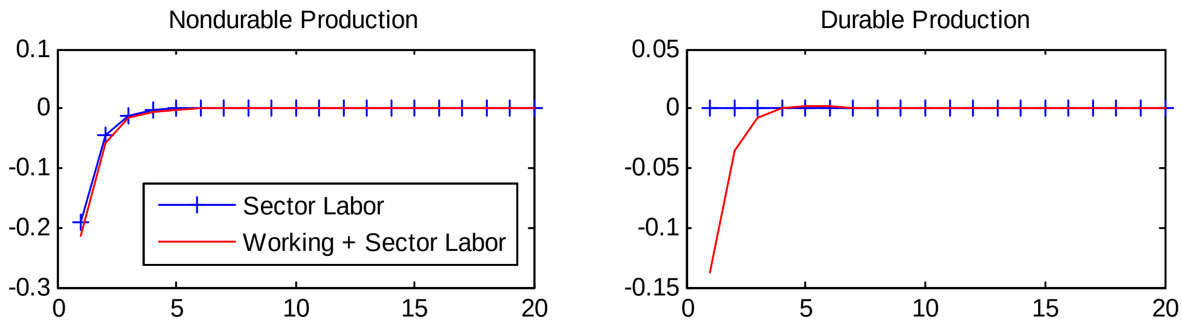

Figure 5: Working capital and sector specific labor

fall is the same as in the previous section. Thus, by incorporating both working capital and sector specific labor, I provide another solution for the negative comovement problem.

4 Conclusion and future direction

In recent macroeconomic modeling, it is common to assume a one sector sticky price model. However, one sector models can not be used to address the interaction between different sectors after a policy shock. Adding flexible durable goods to the standard one sector sticky price model generates negative comovement between durables and nondurables, which is at odds with empirical findings. Due to different degrees of price stickiness, sticky nondurable goods sector will be affected directly by policy shocks, while flexible durable goods sector will only be affected indirectly through the change in labor demand from nondurable goods sector. Following a policy shock, aggregate labor hours remain relatively constant, so a fall in labor hours of nondurable goods sector must be followed by an increase in durable goods sector. Thus the traditional models have a hard time explaining a fall in both durables and nondurables observed in the data.

I propose two ways to solve this problem. One way is to combine working capital and habit formation and another way is to combine working capital and the sector specific labor. Both methods rely on the channel of working capital which allows policy shocks to exert their influences on labor hours through changes in interest rates. In the first method, total labor hours fall in response to an increase in short run interest rate once working capital enters the model. With habit in nondurable goods consumption, labor hours in nondurable goods sector falls a smaller amount, which is dominated by the fall in aggregate labor hours, therefore inducing a fall in labor hours in durable goods sector. In the second method, once I restrict labor from moving between sectors, the working capital channel will affect labor hours in each sector directly. Therefore, I can reconcile empirical studies and model implications by either introducing working capital and habit formation or working capital and sector specific labor.

With these two methods, my findings are consistent with empirical studies: consumption of nondurables and durables decrease after a contractionary policy shock, and the fall in durable production is larger than the fall in nondurable production. I therefore conclude that it is important to incorporate working capital when analyzing the interaction between durable and nondurable in response to a policy shock.

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