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Deep Habits in New Keynesian model with durable goods*

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Abstract

Empirical evidence for the United States suggests that private consumption of durable and nondurable goods have a positive response to government spending shocks. Moreover, the markups for both goods tend be procyclical on productivity shocks and countercyclical on demand shocks. These facts contrast with the results obtained from standard two-sector New Keynesian models with perfect financial markets. In this paper we address these shortcomings by introducing habit formation on the consumption of both durable and nondurable goods. Habit formation on differentiated goods - i.e. Deep Habits - proves to significantly alter the dynamics of the model. However, the effects from habits on durable goods are only meaningful when defined over purchases rather than stocks. When we introduce capital formation into the model, it continues to be consistent with the responses observed in the data.

Keywords: Durable goods, sticky prices, habit formation, time varying markups

JEL codes: E21, E32, L16

1 Introduction

New Keynesian models, with imperfect competition and price stickiness, have become the standard choice for fiscal and monetary policy analysis. More recently, these have been extended to two-sector models to accommodate the evidence from data, where consumption of durable goods responds negatively and more sharply to monetary policy shocks than consumption of nondurable goods.

However, the baseline two-sector model fails to replicate empirical evidence for monetary-policy shocks when the prices of durable goods are perfectly flexible. Following a interest rate hike, households reduce their nondurable consumption but increase their durable consumption. Most literature using two-sector NK models, such as Monacelli (2009) and Carlstrom and Fuerst (2010), has focused on solving this problem, known as the *comovement problem*.

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Another shortcoming of the model is its inability to replicate the responses, observed in United States (US) data, for consumption of durable and nondurable goods, as well as the response of relative price of durable goods, to increases in government spending. In the two-sector NK model, following an increase in government consumption, the reduction of consumption of both goods is linked to an increase of markups in both sectors, which goes against the empirical evidence found in Rotemberg and Woodford (1991), Monacelli and Perotti (2008) and Afonso and Costa (2013). Likewise, the model generates countercyclical response of markups to total-factor productivity (TFP) shocks, which goes against with empirical evidence for US that shows a positive response of the average markups to supply shocks.

In this paper I begin by analyzing the cyclical properties of markups for manufacturing and services' industries in the US. I find that the assumption of increasing returns is relevant to the cyclical properties of markups at an individual industry level, but not at a more aggregated level. The markups of individual industries tend to be more negatively correlated with output and consumption when we assume increasing returns, as in Rotemberg and Woodford (1991), comparing with constant returns, as in Nekarda and Ramey (2013).

On the other hand, the markup of overall private industries, as well as the markups of durable goods and nondurable goods display identical correlation coefficients, regardless of the assumption made on the returns to scale. Another key finding is that, while inclusion of construction in the consumer durables does not affect significantly the correlation coefficients, if we include services industries in the nondurable industries, the coefficients become more negative for increasing returns and turn positive for constant returns.

Moreover, I find that markups of consumer nondurables are slightly more countercylical than those of durables. Both markups display also similar correlation coefficients when comparing to past deviations of GDP, with the markup of nondurables maintaining more negative correlation coefficients. Taking into account this evidence, one can expect a response to shocks of both markups identical to the one observed for the average markup in the US.

To bring the results from the NK model closer to the ones observed in the data, I introduce deep habits - i.e. habits over differentiated goods - into the two sector NK model. I build on the perfect capital markets model of both Monacelli (2009) and Sterk (2010), extending them to include government spending and TFP shocks. While DH over nondurable goods are formulated in an analogous way to the models with only one type of goods, the specification of DH on durables' consumption is more challenging.

Since consumer durables are goods that do not wear out quickly, consumption of durable goods comprises not only the goods acquired in the period but also the undepreciated stock of durable goods from past periods. Therefore, unlike in the nondurable goods case, it is different if one defines habit formation over the stock of durables consumed or over the purchases of durable goods. While defining habit formation over stocks is appropriate for when we are dealing with a bigger and long-lasting type of durables, e.g. houses, that can be modified/improved over time, habit formation over purchases is suitable for the case of other consumer durables, e.g. electronics, furniture, etc, where one buys a new one instead of repairing it. Here I present the two alternative definitions of habits over durable goods and analyze the results obtained.

DH were originally introduced into general equilibrium models by Ravn et al. (2006). The firms' problem in models with DH is analogous to the ones in models of brand-switching costs[1], where firms decide between lowering prices to capture market share and raising prices to exploit its current locked consumers. However, in DH models the shift in consumption between differentiated goods is gradual and not discrete, which facilitates their incorporation into a dynamic general equilibrium framework.

These models proved to be useful in the study of effects of government spending shocks. With DH, the consumers' demand displays a rigid component linked to past consumption. As such, when consumers increase their spending it only affects the elastic part of demand, leading to a procyclical elasticity. Symmetrically, DH imply countercylical markups by which increases in government spending lead to increases in real wages and private consumption.

Due to the effects of countercyclical markups on inflation, DH were also used in the analysis of effects of monetary policy, where Ravn et al. (2010) and Zubairy (2014) stand as the main examples. Similarly, Gilchrist et al. (2017) introduce DH to help explain the inflation dynamics during the 2008 financial crisis. Other general equilibrium models produce countercyclical markups in response to TFP shocks. Well known examples are models with endogenous firm entry - Jaimovich (2007) and Jaimovich and Floetotto (2008) - or endogenous product variety - Bilbiie et al. (2012).

I find that the two-sector model with DH can generate, even when formed only over nondurable consumption, a positive response of markup of nondurables to TFP shocks and negative response to government spending of both markups. When added to the model, DH over purchases of durable goods amplify the responses of markups to shocks and generates a crowding-in effect of government spending on the consumption of both goods. The model with habits on both goods can also generate a procyclical response of the relative price to demand shocks - monetary and fiscal - and countercyclical to supply-side shocks. Even when we consider that prices in the durable sector fully adjust one period earlier than in the nondurable sector, the results from the model hold.

As aforementioned, I also considered the hypothesis of habits being formed over the stock of durable goods. However, I find that they have a small effect on the results generated by the model. Since stocks of durable goods are disproportionately larger than nondurable consumption and durable purchases, the marginal utility and its volatility are substantially lower and, accordingly, the marginal effects of DH are damped.

Additionally, the determinacy of the model with habits on stocks is only marginally affected by the degree of habits. In contrast, the model with habits over purchases of durable goods exhibits multiple equilibria when the degree of habits is relatively high.

[1]See Klemperer (1995).

The remainder of the paper is organized as follows. Section 2 presents the empirical evidence on cyclical properties of markups for the manufacturing industries in the US. Section 3 describes the NK model with two sectors and deep habits and discusses the results. In Section 4 I present an alternative specification of the model where habits are formed over the stock of durable goods. Section 5 concludes.

2 Empirical Evidence

To assess the performance of models presented in sections 3 and 4, one can estimate how the consumption, markups and prices behave in the data. Despite the extensive empirical literature on the behavior of markups and on the behavior of consumption and prices of durables and nondurables, there is a gap in the knowledge of how they interact. So, to fill this gap one must compute the markups for the industries in the two sectors and analyze how they behave during the business cycle. In this section, using quarterly data on industries of US, I calculate the markups and analyze their cyclical properties. As methodology, I follow two different methodologies: the one in Rotemberg and Woodford (1991) and the other in Nekarda and Ramey (2013) which allow the estimation of markups with data available at industry level[2].

2.1 Methodology

First, theoretical markup of a given industry i at time t can be defined as

$$\mu_t^i = \frac{P_t^i}{MC_t^i}, \tag{1}$$

where P_t^i is average price of output and MC_t^i is average marginal cost of industry i. Assuming that all firms in the industry minimize costs and equalize input prices to their marginal products, the marginal cost is given by $MC_t^i = \frac{W_t}{MPL_t^i}$, where W_t is the nominal wage rate and MPL_t^i is the marginal product of labor.

As in Rotemberg and Woodford (1991) I assume a production function represented by

$$Y_t = F(K_t, z_t H_t) - \Phi_t, \tag{2}$$

[2]By measuring the markups using labor share one is introducing a procyclical bias in it. Since labor does not immediately adjust to shocks, the labor share tends to be countercyclical, which, in turn, produces more procyclical markups. In Rotemberg and Woodford (1991), the authors correct it by making assumptions about returns to scale, while Nekarda and Ramey (2013) present different measures of hours and wages (e.g. overhead labor). In recent years, with increasing availability o microdata and computational capacity, new approaches to measure markups were introduced using the share of intermediates and data at firm level. One key example is Santos et al. (2018), where the authors assumed, supported by their estimates of microeconomic production functions with quantities, that intermediates work as substitutes for labor (e.g. firms can outsource labor). Due to the restricted data availability and for simplification and comparability purposes, in this study, markup are measured using labor share. This may introduce differences to the estimates obtained using the share of intermediate goods.

where K_t is the capital stock, H_t is the labor input, z_t is the labor-augmenting technical progress and Φ_t is the fixed cost, growing at rate of trend output. Then, the markup can be written as

$$\mu_t = \frac{F_H(K_t, z_t H_t) - \phi_t}{w_t}, \tag{3}$$

where ϕ_t is the measure of increasing returns. Assuming that the elasticity of substitution between capital and labor is equal to one (i.e. $F(.)$ is a Cobb-Douglas), the log deviation of the markup from trend is given by

$$\hat{\mu}_t^i = \hat{y}_t^i - \hat{w}_t^i - \hat{h}_t^i - (\mu^{*i} - 1) s_H^i \hat{h}_t^i, \tag{4}$$

where $\hat{y}_t^i$ is log deviation in output, $\hat{w}_t^i$ is log deviation in wages and $\hat{h}_t^i$ is log deviation in hours. From the previous equation it can be defined two different specifications for the log deviation in industries' markups - the constant returns case and increasing returns case.

In presence of constant returns, the fixed costs are ignored and the log deviation in markup is equivalent to the log deviation of the inverse of labor share, $-\hat{s}_{Ht}^i$. This is in line with the baseline specification in Nekarda and Ramey (2013) and the price markup in Galí et al. (2007).

The second case is the full equation used in Rotemberg and Woodford (1991), which includes the effect of increasing returns on markup fluctuations. Since employment, measured by $\hat{h}_t^i$, is correlated with the output, $\hat{\mu}_t^i$ will be more countercyclical (or less procyclical) than in the constant returns model.

2.2 Cyclical properties of markups

To find the cyclical properties ok cross-industry markups in US, I use quarterly data from Current Employment Statistics and NIPA tables for the 1980-2016 period[3]. Specifically, I use data for total gross value added (GVA) and data on aggregate weekly hours and earnings of production and nonsupervisory employees. Since the quarterly data for GVA by industry only covers the period from 2005 onwards, the missing periods were estimated through the interpolation of annual data using auxiliary time series, shown in the Table A.2. Table 1 displays the correlation coefficients of the markups with real GDP (Y), real gross value added of the industry (Y^i) and real personal consumption expenditures (C).

As expected, the markups computed assuming constant returns tend to be procyclical, while in the increasing-returns case they tend to be countercyclical. This is explained by the countercyclical behavior of labor share[4], which is only offset when we consider the increasing returns part of equation 4.

On aggregate level, the markups of manufacturing, as well as the goods-producing industries, tend to be unconditionally countercyclical. Likewise, both durable and nondurable goods industries displaying a

[3]The data that support the findings of this study are available on request from the author.

[4]As aforementioned, this is the main caveat of labor-share approach to markup estimation. Due to the adjustment costs in labor, the labor-share tend to be countercyclical, leading to a more procyclical markup.

countercyclical behavior, although industries of durables only present significant coefficients for increasing returns.

As for services industries, most of them exhibit markups with countercyclical behavior when we consider increasing returns and procyclical or acyclical behavior when considering constant returns. One key exception is the industry of utilities that exhibit unconditional procyclical markups. One reason for this might be the fact that consumption of these services is acyclical and inelastic with respect to households' disposable income.

When comparing with the GVA at industry level, one observes that markups display more positively/less negative correlation coefficients than with the GDP. This effect is most notorious in services industries such as finance, education and retail trade services. In contrast, the mining industries display a more countercylical markup when one considers the GVA at industry level.

Since we are interested in understanding how consumption behavior interacts with markups, the correlation coefficients between markups and private consumption (C) were also included in Table 1. However, these coefficients do not diverge significantly from the correlation coefficients with GDP.

While manufactured goods are a significant part of durable and nondurable consumption, they are not the only component. While nondurable private consumption comprises nondurable goods and services, durable consumption includes manufactured durable goods and residential investment[5]. Therefore, to check the relationship between consumption and markups, Table 1 includes the correlation coefficients for the industries linked to durable and nondurable consumption. While the proxy for durable consumption is given by the industries of manufactured durable goods and construction, the proxy for nondurable consumption is given by nondurable goods plus the industries in "services providing".

The main finding is that, despite the procyclical/acyclical behavior of markups in construction, its inclusion in durable consumption does not affect the behavior of markups in durables. On the other hand, the inclusion of services in nondurable consumption industries turns the markup more procyclical for the case of constant returns and more countercyclical with increasing returns. As a result, the coefficients of durables (plus construction) are slightly less negative than those of nondurables (plus services) for increasing-returns case, but they are significantly more positive in the constant-returns case.

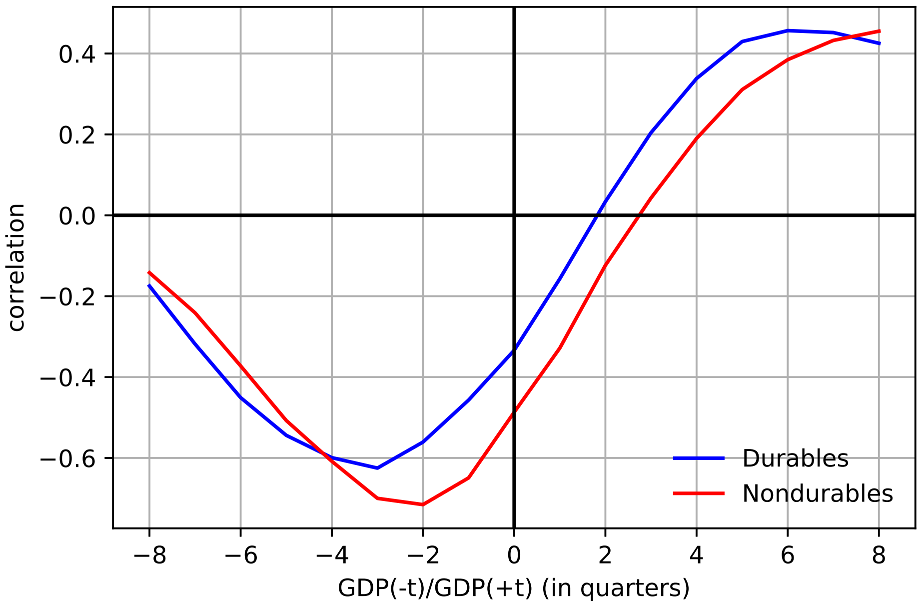
[5]Although, in National Accounts, residential investment is classified as Gross Capital Formation, I considered it as part of durable consumption. The explanation behind this decision is that resident investment is commonly regarded as durable consumption the NK model and my interest is to compare the results from the model to the ones obtained for the US.

Table 1: Unconditional correlation coefficients between markups and real GDP (Y), real industry GVA (Y^i) and real PCE (C) in US (1980:I-2016:IV)

Industry	*Constant returns*			*Increasing returns*		
	Y	Y^i	C	Y	Y^i	C
Private Industries	.018	.063	-.009	-.189**	.145*	-.194**
Mining	.218***	-.428***	.107	.188**	-.466***	.111*
Utilities	.018	.328***	.016	.034	.229***	.014
Construction	.018	.169**	.038	-.085	-.098	-.017
Manufacturing	-.298***	-.100**	-.299***	-.469***	-.280***	-.421***
Durables	-.117	.042	-.143*	-.367***	-.230***	-.337***
Nondurables	-.191**	.180**	-.183**	-.269***	-.145***	-.243***
Wholesale Trade(1)	.311***	.365***	.181*	-.269***	-.145*	-.243***
Retail Trade(1)	-.068	.455***	-.123	-.408***	.202**	-.406***
Transportation and Warehousing(2)	-.120	.300 **	-.192	-.642***	-.197	-.691***
Information(2)	-.037	.635***	-.071	-.286**	.255*	-.289**
Finance, Insuarance and Real Estate(2)	.046	.829***	.117	-.258*	.602***	-.211
Professional and Business Services(2)	-.164	.263*	-.176	-.715***	-.417***	-.677***
Education, Health and Soc. Assist.	-.154*	.595***	-.075	-.186**	.385***	-.096
Arts, Enterteinment, and Recreation	.092	.447***	.118	-.363***	-.033	-.320***
Goods Producing	-.186**	-.200**	-.314***	-.407***	-.047***	-.486***
Services Providing	.148*	.230***	.155*	-.453***	-.368***	-.399***
Durables plus Construction	-.098	-.033	-.128	-.329***	-.272***	-.318***
Nondurables plus Services	.112	.270***	.121	-.479***	-.325***	-.420***

Notes: Asterisks indicate the significance levels for correlation coefficients: 1%(***), 5%(**) and 10% (*); (1) Only data from 1992 to 2016 is available; (2) Only data from 2005 to 2016 is available. All variables are in log deviations. The log deviations for Y, Y^i and C were obtained using HP filter.

Figure 1: Cross-correlation between real GDP and average markups (constant returns) durables plus construction (blue), nondurable plus services (red)



Even when analyzing the correlation coefficients between the markups and past (lags) and future (lead) deviations in GDP, the markup of nondurable consumption continues to display lower correlation coefficients than the markup of durable consumption (Figure 1). Nevertheless, both markups present a negative correlation with past to contemporaneous gaps in GDP and a positive correlation with leading GDP.

The lower cross-correlation with GDP observed for the markup of consumer durables in Figure 1 may be partially explained by the more volatile behavior of durable consumption, mainly during recessions (Figure A.5), that leads to a more volatile markup. This is in line with the findings in Baxter (1996), which suggests that the behavior of durable consumption over the business cycle is more volatile than the nondurable consumption.

Since there is also a comovement in the response to shocks of the consumption of durables and nondurables, one cannot reject that the response of the two average markups has the same signal, in spite of a more acyclical response of the markup of durable industries.

3 Model

3.1 Households

Consider a representative household who derives utility from consumption basket X_t and disutility from supplying labor N_t. The aim of this household it to maximize the expected value of its discounted utility:

$$E_o\left\{\sum_{t=0}^{\infty}\beta^t U(X_t,N_t)\right\}, \quad (5)$$

where X_t is the consumption basket that aggregates, through a CES technology, the habit-adjusted nondurable goods H_t^c and the stock of durable goods D_t,

$$X_t = \left[(1-\gamma)^{1/\eta}H_t^{c(\eta-1)/\eta} + (\gamma)^{1/\eta}D_t^{(\eta-1)/\eta}\right]^{\eta/(\eta-1)}, \quad (6)$$

where $\eta \geq 1$ is the elasticity of substitution between services of nondurable and durable goods. The stock of durable goods evolves according to the law of motion:

$$D_t = (1-\delta)D_{t-1} + H_t^d, \quad (7)$$

where $0 < \delta < 1$ is the depreciation rate and H_t^d is he amount of habit-adjusted durable goods acquired in period t given by

$$H_t^d = \left[\int_0^1 (I_{i,t}^d - \theta_d S_{i,t-1}^d)^{\frac{\varepsilon_d-1}{\varepsilon_d}} di\right]^{\frac{\varepsilon_d}{\varepsilon_d-1}}, \quad \varepsilon_d > 1, \quad (8)$$

where $I_{i,t}^d$ is the durable purchases of varieties indexed by $i \in [0,1]$ in period t, $S_{i,t-1}^d$ represents the stock of external habit in durable good i in period t and ε_d is the elasticity of substitution between differentiated varieties of durable goods. This stock of external habits depends on all durable purchases in the past and evolves according to the following law of motion:

$$S_{i,t}^d = \rho_h S_{i,t-1}^d + (1-\rho_h)I_{i,t}, \quad (9)$$

where $\rho_h \in [0,1]$ is the degree of persistence of external habits. For $\rho_h = 0$, the habits will only depend on the previous consumption period and the consumption adjusts more rapidly. On the other hand, if we define a sufficiently high degree of persistence, e.g. $\rho_h = 0.85$, household will put a greater weight on past levels of consumption and response to shocks will be more moderate. $I_{i,t}$ is defined as the level of consumption of each variety i in the period t.

As for durables the composite habit-adjusted good, H_t^c, formally described as

$$H_t^c = \left[\int_0^1 (C_{i,t} - \theta_c S_{i,t-1}^c)^{\frac{\varepsilon_c-1}{\varepsilon_c}} di\right]^{\frac{\varepsilon_c}{\varepsilon_c-1}}, \quad \varepsilon_c > 1, \quad (10)$$

where $S_{i,t-1}^c$ represents the stock of external habits in nondurable good i in period t and ε_c are the elasticities of substitution of varieties of nondurables. This stock of external habit depends on all nondurable consumption in the past and evolves according to the following law of motion:

$$S_{i,t}^c = \rho_h S_{i,t-1}^c + (1-\rho_h)C_{i,t}, \quad (11)$$

where $C_{i,t}$ is level of consumption of each variety i of nondurable goods in the period t and, as for equation 9, $\rho_h \in [0,1]$.

For any given level of consumption of I_t and C_t, the demand of each differentiated variety of goods $i \in [0,1]$ in period t must solve the dual problem of minimizing total expenditures $\int_0^1 P^d_{i,t} I_{i,t} di$ and $\int_0^1 P^c_{i,t} C_{i,t} di$, subject to the aggregation constraints 8 and 10, where $P^d_{i,t}$ and $P^c_{i,t}$ are the nominal prices of a durable and nondurable goods of varieties i, respectively, at time t.

The optimal level of demand $I^d_{i,t}$ and $C_{i,t}$for $i \in [0,1]$ are given by

$$I^d_{i,t} = \left(\frac{P^d_{i,t}}{P^d_t}\right)^{-\varepsilon_d} H^d_t + \theta_d S^d_{i,t-1}, \tag{12}$$

$$C_{i,t} = \left(\frac{P^c_{i,t}}{P^c_t}\right)^{-\varepsilon_c} H^c_t + \theta_c S^c_{i,t-1}, \tag{13}$$

with P^d_t and P^c_t being the nominal price indices defined as $P^d_t = \left[\int_0^1 \left(P^d_{i,t}\right)^{1-\varepsilon_d} di\right]^{\frac{1}{1-\varepsilon_d}}$ and $P^c_t = \left[\int_0^1 \left(P^c_{i,t}\right)^{1-\varepsilon_c} di\right]^{\frac{1}{1-\varepsilon_c}}$.

The consumer has the following budget constraint:

$$P^c_t C_t + P^d_t I^d_t + R_{t-1} B_{t-1} = B_t + W_t N_t + T_t + \Pi_t, \tag{14}$$

where P^c_t is the price of nondurable goods, P^d_t is the price of durable goods, B_t is nominal debt, R_t is the nominal interest rate, W_t is the nominal wage rate, T_t the taxes paid, and Π_t are the dividends distributed by firms. In real terms, the budget constraint can be expressed as

$$C_t + q_t I^d_t + R_{t-1}\frac{b_{t-1}}{\pi^c_t} = b_t + w_t N_t + \frac{T_t}{P^c_t} + \frac{\Pi_t}{P^c_t}, \tag{15}$$

where $w_t \equiv \frac{W_t}{P^c_t}$ is real wage, $q_t \equiv \frac{P^d_t}{P^c_t}$ is the relative price of durable goods, $b_t \equiv \frac{B_t}{P^c_t}$ is the real debt, and $\pi^c_t \equiv \frac{P^c_t}{P^c_{t-1}}$ measures the evolution of price index of nondurable goods.

The first-order conditions or the representative household's optimization problem are give by

$$\frac{-U_{n,t}}{U_{h^c,t}} = w_t, \tag{16}$$

$$U_{h^c,t} = \lambda_t, \tag{17}$$

$$q_t U_{h^c,t} = U_{d,t} + \beta(1-\delta)E_t\{U_{h^c,t+1} q_{t+1}\}, \tag{18}$$

$$1 = \beta E_t\left\{\frac{U_{h^c,t+1}}{U_{h^c,t}}\frac{R_t}{\pi^c_{t+1}}\right\}. \tag{19}$$

Equation 16 is the standard condition linking the real wage to the marginal rate of substitution between consumption and leisure, i.e. the Frisch labor supply. In equation 18 households equate the marginal utility of nondurable consumption to the shadow value of utility obtained from durables goods that includes not only utility from an additional unit of durable goods today, but also the discounted expected value of undepreciated part of stock of durables in the next period. Equation 19 is the standard Euler consumption equation.

3.2 General Government

Each period, general government balances its budget[6] by collecting T_t from households and spending $G_t P_t^c$ in the acquisition of goods. As in Erceg and Levin (2006) and Cantelmo and Melina (2018), I assume that government only acquires nondurable goods. The real government spending G_t follows the exogenous stochastic process:

$$\ln(G_t/\bar{G}) = \rho_g \ln(G_{t-1}/\bar{G}) + \epsilon_t^g, \tag{20}$$

where $\epsilon_t^g \sim N(0, \sigma_g)$ represents the exogenous innovation to fiscal policy. As in Ravn et al. (2006), I also consider that government allocates spending to the several varieties of nondurable goods through the equation:

$$H_t^g = \left[\int_0^1 (G_{i,t} - \theta_c S_{i,t-1}^g)^{\frac{\varepsilon_c - 1}{\varepsilon_c}} di\right]^{\frac{\varepsilon_c}{\varepsilon_c - 1}}, \tag{21}$$

where $S_{i,t-1}^g$ also represents the stock of external habits formed on government spending over good i in period t. As for households, the stock of habits is given by

$$S_{i,t}^g = \rho_h S_{i,t-1}^g + (1 - \rho_h) G_{i,t}. \tag{22}$$

The rationale behind this that, as stated in Ravn et al. (2006), government spending is not wasteful, as households value it, though separately from private consumption and labor decisions. Moreover, they also form habits over them. This means that is difficult for the general government to cut significantly its expenditure as households are accustomed to certain level of public services. For any given level of G_t, the demand of each variety of goods $i \in [0, 1]$ in period t must solve the dual problem of minimizing total expenditure $\int_0^1 P_{i,t}^c G_{i,t} di$, subject to the aggregation constraint 21.

The demand for $G_{i,t}$, with $i \in [0, 1]$ are given by

$$G_{i,t} = \left(\frac{P_{i,t}^c}{P_t^c}\right)^{-\varepsilon_c} H_t^g + \theta_c S_{i,t-1}^g. \tag{23}$$

[6]With infinitely-living households Ricardian equivalence holds, so not much is lost from using this form.

3.3 Firms

Each variety of good i in sector j is produced using labor via the following linear production function:

$$Y_{i,t}^{j} = A_t N_{i,t}^{j}, \tag{24}$$

where $Y_{i,t}^{j}$ denotes the output of good i in sector $j = c, d$, $N_{i,t}^{j}$ denotes the labor input, and A_t is the aggregate TFP, which follows a first-order autoregressive process:

$$\ln(A_t) = \rho_a \ln(A_t) + \epsilon_t^a, \tag{25}$$

where $\epsilon_t^a \sim N(0, \sigma_a)$ is the exogenous innovation in technology. The profits of each producer i in nondurable and durable sectors are given by

$$\Pi_{i,t}^{c} = C_{i,t}^{c} P_{i,t}^{c} + G_{i,t} P_{i,t}^{c} - W_t N_{i,t}^{c} - \frac{\vartheta_c}{2}\left(\frac{P_{i,t}^{c}}{P_{i,t-1}^{c}} - 1\right)^2 Y_t^c P_t^c, \tag{26}$$

$$\Pi_{i,t}^{d} = I_{i,t}^{d} P_{i,t}^{d} - W_t N_{i,t}^{d} - \frac{\vartheta_d}{2}\left(\frac{P_{i,t}^{d}}{P_{i,t-1}^{d}} - 1\right)^2 Y_t^d P_t^d, \tag{27}$$

where $\frac{\vartheta_j}{2}\left(\frac{P_{i,t}^{j}}{P_{i,t-1}^{j}} - 1\right)^2 Y_t^j P_t^j$ is the quadratic cost of price adjustment proportional to nominal output of each sector.

The firm's problem is to maximize the expected discounted value of profits:

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{U_{h^c,t}}{U_{h^c,0}} \frac{P_o^c}{P_t^c} \Pi_{i,t}^{j}, \tag{28}$$

subject the equilibrium conditions in the markets of nondurable and durable sectors:

$$Y_t^c = C_t + G_t + \frac{\vartheta_c}{2}(\pi_t^c - 1)^2 Y_t^c, \tag{29}$$

$$Y_t^d = I_t^d + \frac{\vartheta_d}{2}(\pi_t^d - 1)^2 Y_t^d, \tag{30}$$

and to the demand equations 13 and 23, in the nondurable sector, and 12 in durable sector, plus the production function of 24 and the equations for the habit accumulation 9, 11 and 22. The first-order conditions for optimization problem of firms in nondurable sector are give by

$$\frac{C_t + G_t}{Y_t^c} - \varepsilon_c \nu_t^c \frac{H_t^c + H_t^g}{Y_t^c} = \vartheta_c(\pi_t^c - 1)\pi_t^c - \beta\vartheta_c E_t\left\{\frac{U_{h^c,t+1}}{U_{h^c,t}} \frac{Y_{t+1}^c}{Y_t^c}(\pi_{t+1}^c - 1)\pi_{t+1}^c\right\}, \tag{31}$$

$$\nu_t^c = 1 - \frac{w_t}{A_t} + (1 - \rho_h)\lambda_t^c, \tag{32}$$

$$\lambda_t^c = \beta E_t \left\{ \frac{U_{h^c,t+1}}{U_{h^c,t}} \left(\theta_c \nu_{t+1}^c + \rho_h \lambda_{t+1}^c\right) \right\}, \tag{33}$$

where ν_t^c and λ_t^c are the Lagrange multipliers for the demand equations, 13 and 23, and habit accumulation equations, 9, 11 and 22, respectively.

From the first-order conditions, we observe that the special case where $\rho_h = 0$ and $\theta_c = 0$, i.e. households do not form habits, is the baseline NK model with two goods. When $\theta_c > 0$, firms know that selling more goods today implies selling more goods tomorrow, as households and government increase their subsistence point over varieties. This means that each firm has an incentive to lower price charged today, in order to capture customers and charge them more in future periods[7]. For the special case where $\rho_h = 0$ and $\theta_c > 0$, one obtains the first order conditions of firms maximization problem in Zubairy (2014).

As in the nondurable sector, the first-order conditions for the maximization problem of durable producers are:

$$\frac{I_t^d}{Y_t^d} - \varepsilon_d \nu_t^d \frac{H_t^d}{Y_t^d} = \vartheta_d (\pi_t^d - 1)\pi_t^d - \beta \vartheta_d E_t \left\{ \frac{U_{h^c,t+1}}{U_{h^c,t}} \frac{q_{t+1}}{q_t} \frac{Y_{t+1}^d}{Y_t^d} (\pi_{t+1}^d - 1)\pi_{t+1}^d \right\}, \tag{34}$$

$$\nu_t^d = 1 - \frac{w_t}{q_t A_t} + (1 - \rho_h)\lambda_t^d, \tag{35}$$

$$\lambda_t^d = \beta E_t \left\{ \frac{U_{h^c,t+1}}{U_{h^c,t}} \frac{q_{t+1}}{q_t} \left(\theta_d \nu_{t+1}^d + \rho_h \lambda_{t+1}^d\right) \right\}, \tag{36}$$

where ν_t^d and λ_t^d are the Lagrange multipliers for the demand equations and habit accumulation equations, respectively.

3.4 Market-clearing conditions

Equilibrium in labor market requires:

$$\sum_i N_{i,t}^c + \sum_i N_{i,t}^d = N_t. \tag{37}$$

The monetary policy rule is given by

$$\frac{R_t}{\bar{R}} = \left(\frac{\tilde{\pi}_t}{\pi}\right)^{\phi_\pi} \exp(\varepsilon_t), \tag{38}$$

where $\tilde{\pi}_t = \pi_{c,t}^{\tau} \pi_{d,t}^{1-\tau}$ is the composite inflation index and the policy shock evolves according to:

[7] This feature is also found in the customer-market pricing models as the one described in Bils (1989). In the customer-market models, monopolists also reduce their markup to attract new customers, that have no prior information on the quality of the product being sold.

$$\exp(\varepsilon_t) = \exp(\varepsilon_{t-1})^{\rho_\pi} u_t, \tag{39}$$

with $u_t \sim N(0, \sigma_a)$ and ρ_π ranging from zero to one.

3.5 Calibration and solution method

The baseline NK model is calibrated following Monacelli (2009) and Sterk (2010). The discount factor β is set to 0.99, which implies a steady-state annual real rate of return of 4 percent. The quarterly depreciation rate for durable goods (δ) is 2.5 percent. As in Tsai (2016), γ, the utility weight of durable goods, is set to 0.25 and the elasticity of substitution between nondurable and durable services (η) is equal to 1. The steady-state level of government spending is set to 20% of aggregate output, which is in line with the weight of general government expenditure in GDP for the US.

Furthermore, I assume that the utility function of household takes the following form:

$$U(X_t, N_t) = \ln(X_t) - \nu \frac{N_t^{1+\chi}}{1+\chi},$$

where the parameter ν is positive and calibrated so that, in steady-state, the labor supply is equal to $1/3$.

The elasticities of substitution between varieties for nondurable and durable goods (ε_c and ε_d) are equal to 6, which implies a steady-state price markup of 1.2. Similarly to Monacelli (2009), the nondurable price adjustment cost parameter (ϑ_c) is calibrated so that firms can adjust their prices every four quarters. It is assumed that the degree of habits on durable purchases is lower than that of nondurable consumption and set θ_c and θ_d equal to 0.6 and 0.3, respectively.

The weight of durable goods in composite inflation is equal to the weight of expenditure on durable goods in total consumption expenditure ($\tau = 0.2$). The coefficient of inflation in the Taylor rule, ϕ_π, is set to 1.5. As in Ravn et al. (2006), the persistence parameters for habits is set to 0.85 and the persistence parameters for productivity shocks and government shocks are set to 0.9. The persistence parameter for monetary policy shocks is set to 0.5. The model is solved by a first-order perturbation method. All IRFs are presented as log deviations from steady-state vales[8].

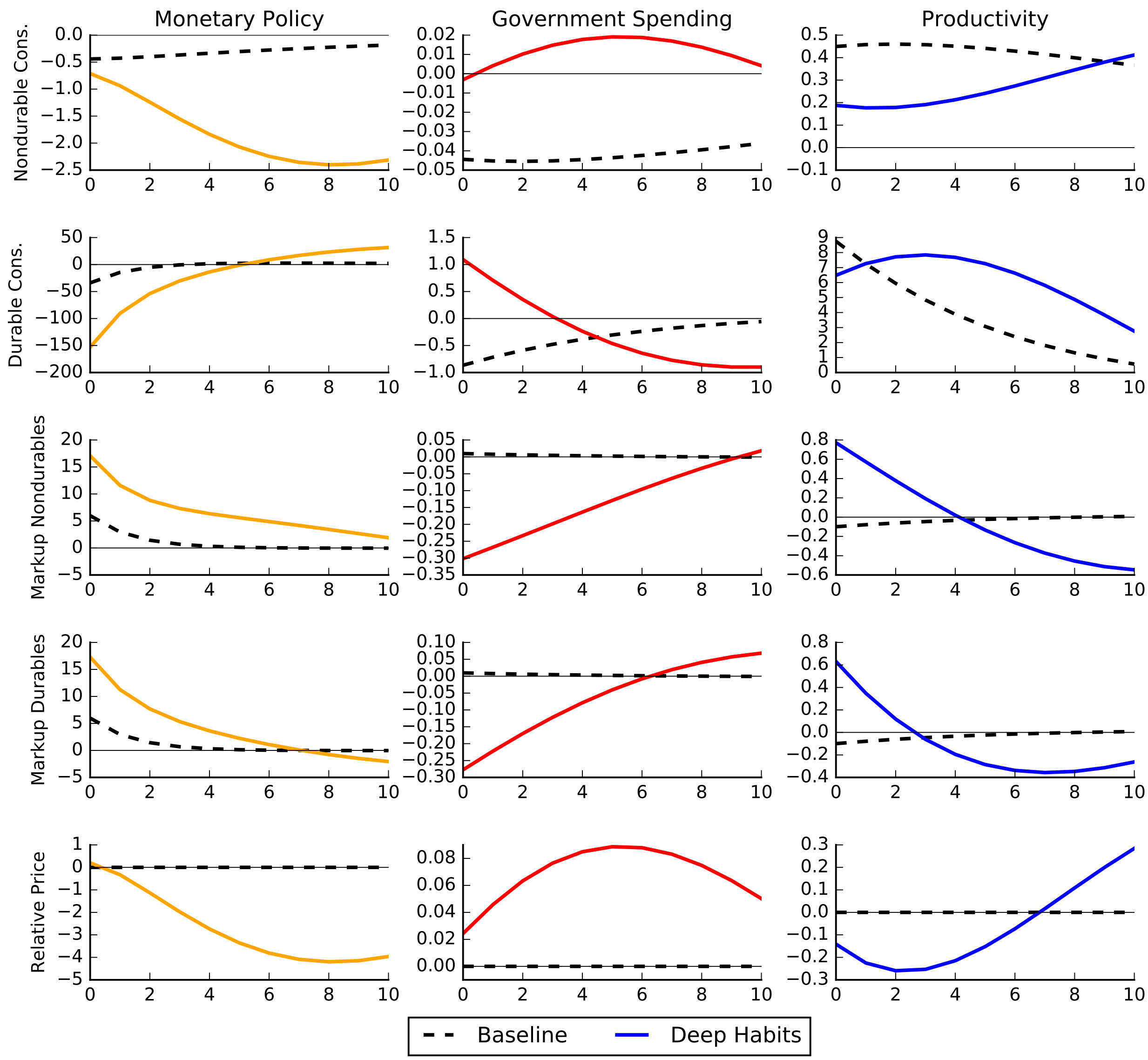
3.6 Results and discussion

The IRFs from the model with the same degree of price adjustment costs in both sectors are shown in Figure 2. When there are no habits, i.e. $\theta_c = \theta_d = 0$, the IRFs of consumption are fairly in line with the ones from a canonical NK model with only one type of goods. Both durable investment (I_t^d) and nondurable consumption (C_t) respond negatively to a policy-rate shock and positively to a technology shock. One

[8]The data and codes that generated the figures in this paper are available on request from the author.

caveat of the plain-vanilla NK model is the crowding-out of private consumption in response to increases in government spending.

Figure 2: Impulse-response functions to one percent monetary-policy (yellow), government-spending (red), and productivity (blue) shocks for the model with and without DH



The responses of markups and the relative price of durable goods to fiscal and technology shocks are also at odds with empirical evidence. Following a positive shock in government spending, firms do not fully adjust their prices in response to an increase in demand for their goods and, therefore, they partially reflect it through the reduction of the real wage paid, which implies a reduction of marginal costs and increase of markups in the two sectors. When there is a temporary TFP shock, the increase in labor productivity is more than offset by the increase in employment and wages, leading to a increase in marginal costs and decrease in markups.

The presence of DH, even when only formed over nondurable goods, enhances the responses of consumption and prices to monetary-policy and TFP shocks (see Figure A.6). For a moderate degree of habit formation, the response to a government-spending shock of private durable and nondurable consumption would be less negative than in the baseline model.

With sticky prices in durable goods, the habits on nondurable consumption alone allows for a decrease in the markup of both sectors. Since the wage rates are the equal for both sectors, the increase of real wages in nondurable sector translate into an increase of real wages in the durable sector.

The introduction of DH on durable purchases leads to considerable improvements in the model. The response of consumption of nondurable goods to increases in government spending becomes positive, while the durable consumption is positive at the beginning, but it then turn, negative.

The response of durable markups and relative price of durables to a TFP shock is now positive and in line with empirical evidence. The IRFs of relative price to demand shocks are also in line with the IRFs we obtained from the data.

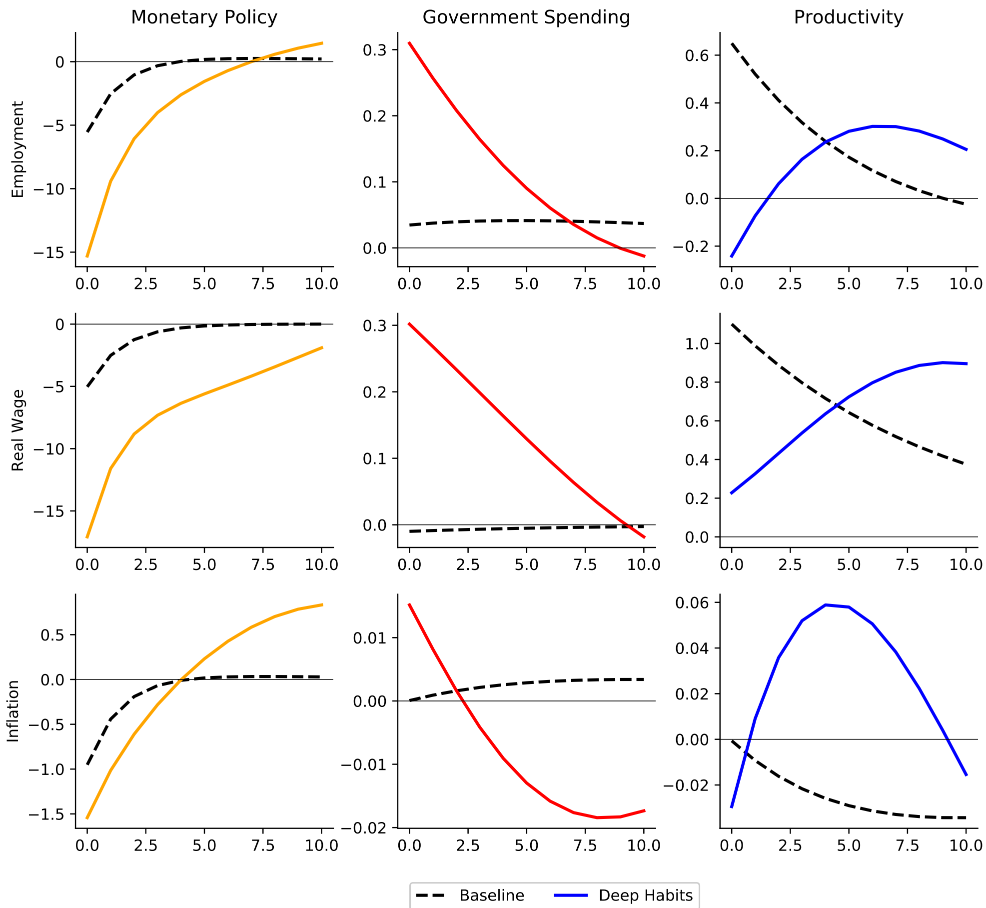
It is also worth noting that the model with DH generates an initial positive response of real wages to a government spending shock that translates into an increase in inflation ($\tilde{\pi}_t$) as the markups do not absorb all the impact in marginal cost.

Likewise, the nonlinear response of inflation to a productivity shock is explained by the different dynamics of markups and real wages. Following the shock, the increase in real wages is lower than the increase in marginal productivity, leading to a decline of marginal cost that more than offset the positive response of the markups. However, as real wages continue to increase and the marginal productivity returns to the steady-state level, the inflation picks up, driven by higher marginal cost. As the wage rate decelerates, the marginal costs stabilizes and the decreasing markup contributes to a decrease in inflation rate.

Although empirical evidence from the literature suggests that prices of goods in the durable sector may be more flexible than in the nondurable sector[9], I only present the results from the model where prices have the same degree of stickiness for both sectors, as the results are qualitatively similar for lower periods of adjustment in prices of durable goods. With different degrees of price rigidity, the signal of responses remains the same, however the profile of IRFs changes significantly with increasing flexibility in prices of durable goods. The initial responses to fiscal spending and TFP shocks are amplified but, because price adjust faster in durable sector, the responses are less persistent.

[9]See Klenow and Malin (2010) and Nakamura and Steinsson (2008) for microeconometric evidence on the frequency of price adjustment. Cantelmo and Melina (2018) estimate an Bayesian DSGE and also find a lower degree of price stickiness in durable goods sectors.

Figure 3: Impulse-response functions to one percent shocks for the variables of employment, wages and inflation



In the same way, the results of the model do not change significantly when I introduce capital accumulation in the model, even though it reduces the effectiveness of habit formation (see appendix B). The differences are an increase in the crowding-out effect in private consumption, in response to a government-spending shock and the change of signal in the response of markups to productivity shocks.

4 Deep Habits over stock of durable goods

Unlike the habit formation over nondurable goods, the modeling of habits over durable goods poses the challenge of whether consumers develop habits over the purchases of durable goods or over utilization of stocks of durable goods. In this section I study the effects of DH over stocks of durables and compare it to the results obtained for flows. Consider that the representative household develops habits over stocks of differentiated durable goods. The habit adjusted stock, H_t^s, is given by

$$H_t^s = \left[\int_0^1 (D_{i,t} - \theta_k D_{i,t-1})^{\frac{\varepsilon_d - 1}{\varepsilon_d}} di \right]^{\frac{\varepsilon_d}{\varepsilon_d - 1}}, \tag{40}$$

where $D_{i,t}$ is stock of each variety i of durable goods at time t and θ_k is the degree of habits on each stock of varieties of durable goods. The accumulation of each variety of goods follows the same law of motion of aggregate durable goods:

$$D_{i,t} = (1-\delta)D_{i,t-1} + I_{i,t}. \tag{41}$$

For simplification, the depreciation rate, δ, is the same across all varieties and continues to be equal to 0.025, which implies a lifespan of 10 years of each variety. As in the baseline model, the consumer must solve the dual problem of minimizing total expenditures $\int_0^1 P_{i,t}^d I_{i,t} di$, subject to the aggregation constraint 40 and the stock accumulation equation 41. The demand for each variety of good I_t is defined by

$$I_{i,t}^d = \left(\frac{P_{i,t}^d}{P_t^d}\right)^{-\varepsilon_d} H_t^s - (1-\delta-\theta_k)D_{i,t-1}. \tag{42}$$

From demand equation 42, we can see that the household defines the optimal quantity of habit-adjusted aggregate stock of durable goods, H_t^s, and then chooses the quantity of each variety it needs, taking into account the undepreciated habit-linked quantity of stocks of differentiated goods.

Firms' profit maximization problem is now constrained by demand equation 42 plus the durable stock accumulation equation 41. The first-order conditions for the maximization problem are given by

$$\frac{I_t^d}{Y_t^d} - \varepsilon_d \nu_t^k \frac{H_t^s}{Y_t^d} = \vartheta_d(\pi_t^d - 1)\pi_t^d - \beta\vartheta_d E_t\left\{\frac{U_{h^c,t+1}}{U_{h^c,t}}\frac{q_{t+1}}{q_t}\frac{Y_{t+1}^d}{Y_t^d}(\pi_{t+1}^d - 1)\pi_{t+1}^d\right\}, \tag{43}$$

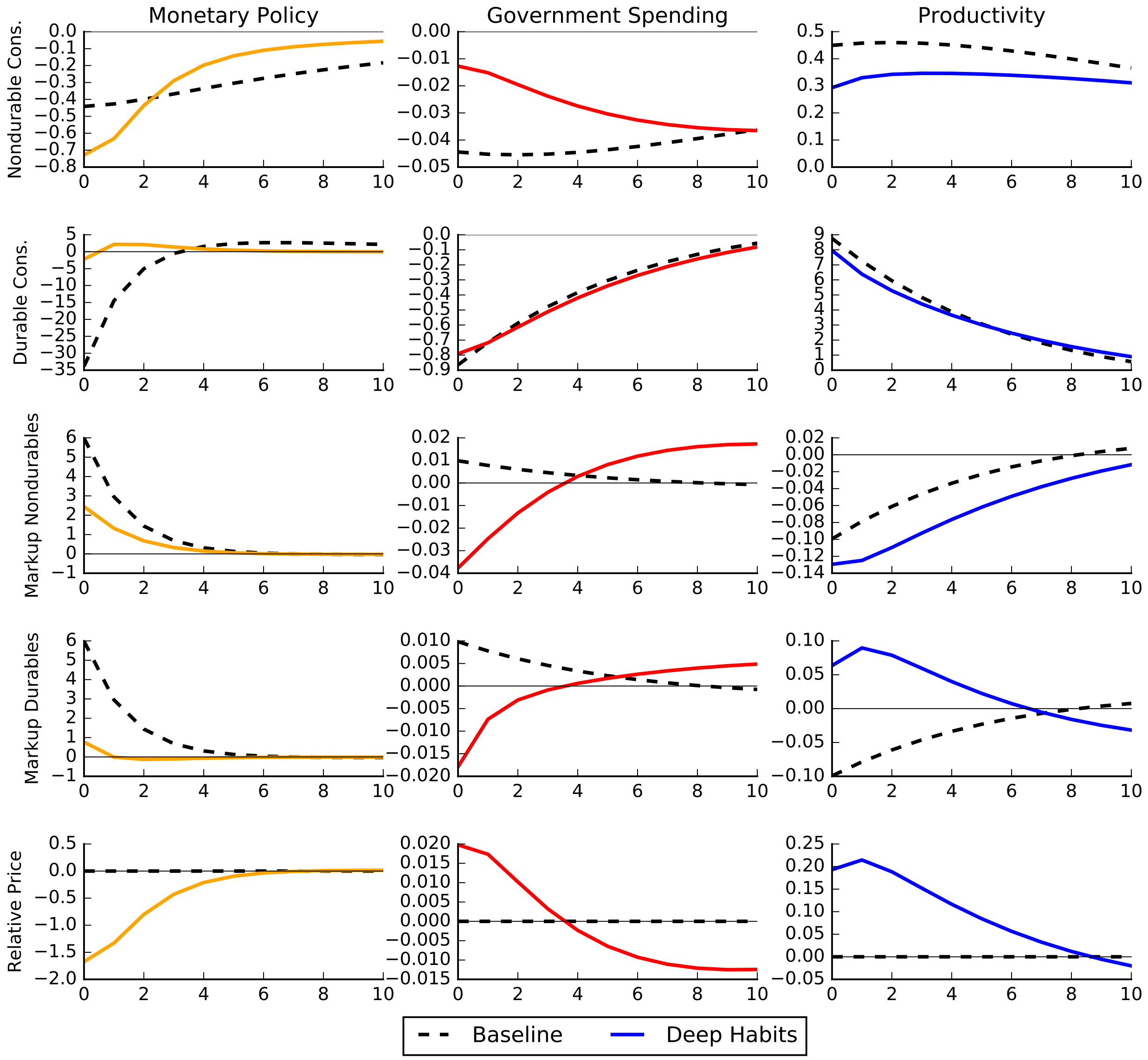
$$\nu_t^k = 1 - \frac{w_t}{q_t A_t} + \lambda_t^k, \tag{44}$$

$$\lambda_t^k = \beta E_t\left\{\frac{U_{h^c,t+1}}{U_{h^c,t}}\frac{q_{t+1}}{q_t}\left[\theta_k \nu_{t+1}^d + (1-\delta)\left(\frac{w_{t+1}}{q_{t+1}A_{t+1}} - 1\right)\right]\right\}, \tag{45}$$

where ν_t^k is the Lagrange multiplier of $I_{i,t}^d$ and λ_t^k is the Lagrange multiplier for $D_{i,t}$.

Even when considering a significant degree of habits, $\theta_k = 0.6$, the model with DH on stocks of durables performs relatively worse than the model with habits only on nondurables - see Figure A.6. The new aggregation of durable goods leads to a countercyclical demand elasticity, which is not offset by a habit parameter of $\theta_k < 1-\delta$. This can be explained by the demand elasticity of equation 42, which for $\delta + \theta_k < 1$ is countercyclical. Moreover, since stocks of durables are much less volatile than durable purchases, habits on stocks have marginal effects on consumption and the model is unresponsive to variations in the costs of price adjustment in durable sector.

Figure 4: Impulse-response functions to one percent monetary-policy (yellow), government-spending (red), and productivity (blue) shocks for model with deep habits over durable stocks



5 Conclusion

Empirical evidence for the US suggests that price markups of both durables and nondurables are unconditionally countercyclical. Moreover, the markup for consumer durables has the same countercyclical properties of the average markup of durables' industries, while the markup of consumer nondurable goods and services is slightly less countercyclical than the average markup of nondurables.

Nevertheless, empirical evidence data suggests that, despite the higher volatility of the consumer durable markups, both consumer markups display similar correlation coefficients. Therefore, it points out to a comovement in the response to supply and demand of the markups for both types of consumer goods.

The New Keynesian model with two goods, despite being able to replicate the responses to monetary-policy shocks, fails to replicate the response of consumption and markups in response to other shocks. In the standard New Keynesian model, government spending generates a crowding-out effect on consumption, as markups also increase due to the adjustment costs, while TFP shocks produce a negative response of markups. Furthermore, when firms in both sectors have the same price adjustment costs relative price of durable goods is constant, which contrasts with behavior observed in the data.

In this paper, I introduced habit formation into a two-sector New Keynesian framework in order to improve the fitness of the model to US data. Habit formation over the consumption of each variety generates procyclical demand elasticity that, in turn, induces countercyclical responses of markups to demand shocks. As in the single-sector models, incorporating deep habits in the model generates countercyclical markups in response to demand shocks in both sectors, even when defined only over consumption of nondurable goods. As a result, the model can generate positive responses of nondurable consumption, real wages and relative price to shocks in government spending. Even when capital formation is introduced into the model, it produces similar results to those of the model without capital.

Additionally, I also considered the case where habits are formed over stocks of varieties of durable goods. The model with this specification performs relatively worse than the model with only habits on nondurable consumption. The explanation lies on the relative stability of the stocks of durable goods, in opposition to the volatility of purchases of durable and nondurable goods, leading to a small impact on the elasticity of demand. Similarly to the impulse-responses functions, the determinacy of the model with habits on stocks of durables is only marginally affected by the higher degrees of habit formation.

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A Data sources and model

Table A.2: Auxiliary Indicators

Industry	*Source*	*Indicator*
Mining	Board of Gov. of the Federal Reserve	Industrial Production Index
Utilities	Board of Gov.of the Federal Reserve	Industrial Production Index
Construction	BEA - NIPA	Private Fixed Invest. in Structures
Manufacturing	Board of Gov. of the Federal Reserve	Industrial Production Index
Durables	Board of Gov. of the Federal Reserve	Industrial Production Index
Nondurables	Board of Gov. of the Federal Reserve	Industrial Production Index
Wholesale Trade	U.S. Bureau of the Census	Merchant Wholesalers Sales
Retail Trade	U.S. Bureau of the Census	Retailers Sales
Education, Health and Soc. Assist.	BEA - NIPA	PCE - Health Care
Arts, Enterteinment, and Recreation	BEA - NIPA	PCE - Food and Accomodations

Figure A.5: Markups (incr. returns) of consumer durables (blue), nondurable plus services (red) and recession periods (shadows) for 1980:I to 2016:IV

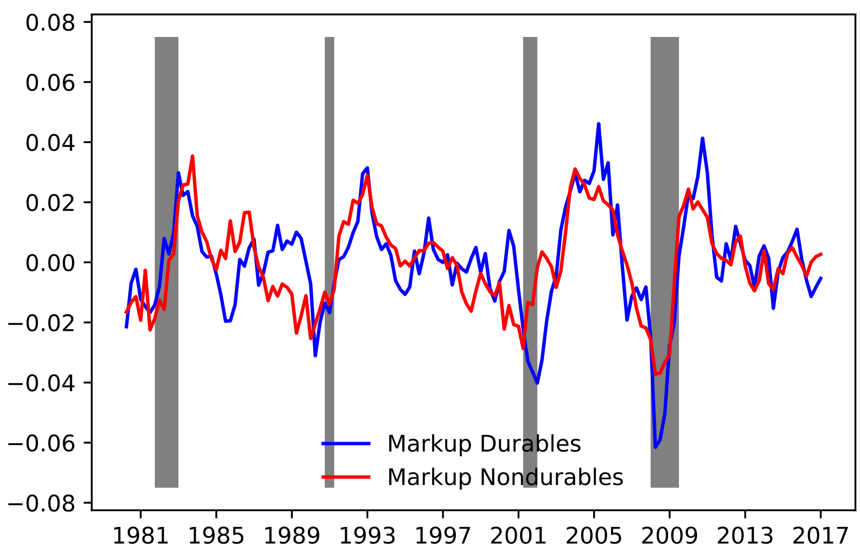
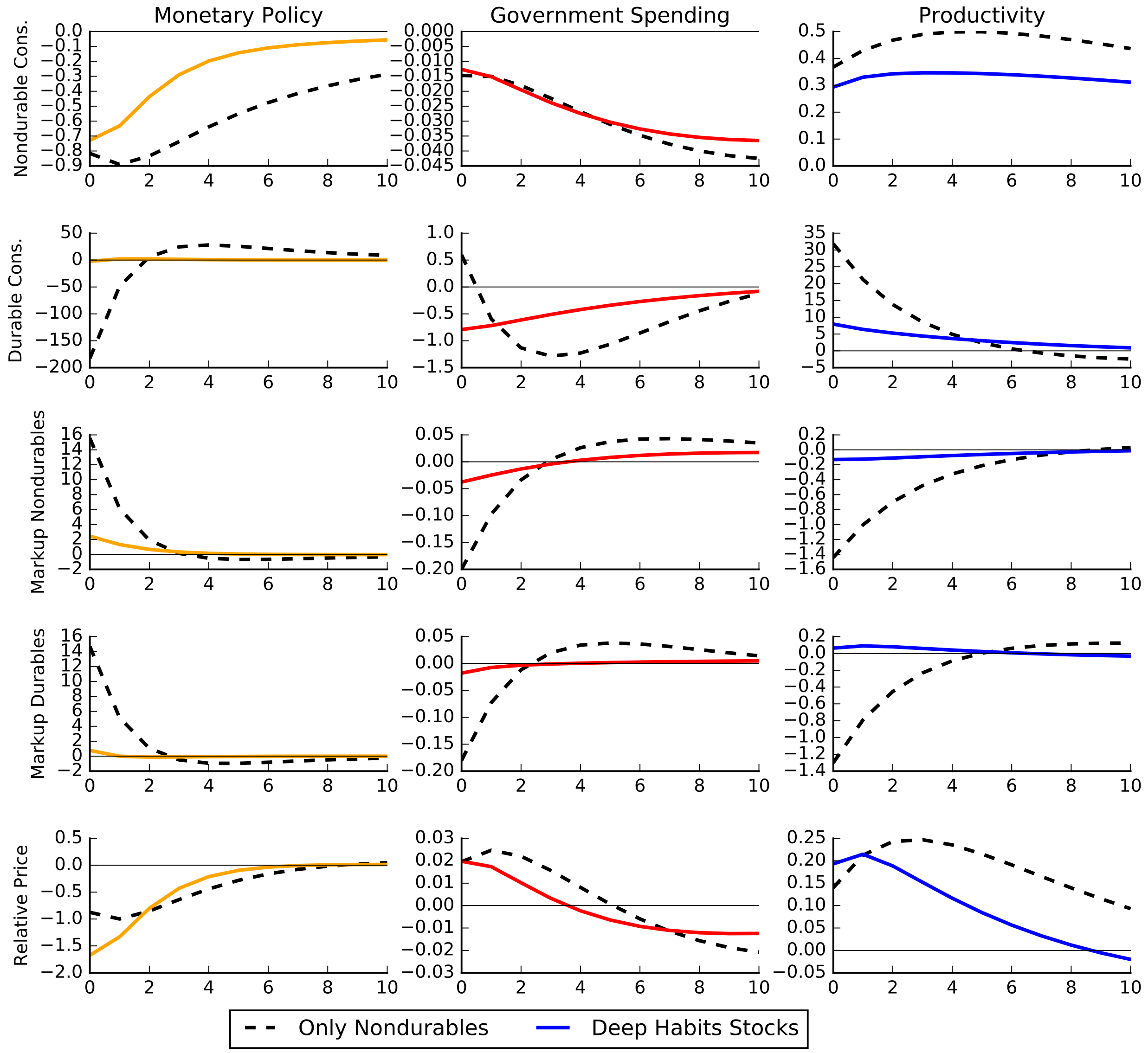


Figure A.6: Impulse-response functions to a one percent shock for model with Deep Habits only on nondurables, and the model with Deep Habits on nondurables and stocks



B Model with capital accumulation

Here we introduce capital accumulation into the model. The firms in durables' sector produce both consumer durables and capital goods, which are used as an input in the production of both durables and nondurables.

Now we consider that representative household accumulates capital goods and has investment adjustment costs, defined closely to Christiano et al. (2005). The stock of capital evolves according to

$$K_{i,t+1} = (1-\delta_k)K_t + \left[1 - \frac{\psi}{2}\left(\frac{I_t^k}{I_{t-1}^k} - 1\right)^2\right] I_t^k, \tag{B.46}$$

where K is the capital stock, I^k is the investment, $0 < \delta_k < 1$ is the depreciation rate of capital and ψ the parameter measuring the degree of adjustment costs. The household has a new budget constraint given by

$$C_t + q_t(I_t^d + I_t^k) + R_{t-1}\frac{b_{t-1}}{\pi_t^c} = b_t + w_t N_t + r_k K_t + \frac{T_t}{P_t^c} + \frac{\Pi_t}{P_t^c}, \tag{B.47}$$

where r_k is the real return on capital. In addition to the first order conditions 16 - 19, the household has now two more first order equations

$$\mu_t = \beta E_t\left\{(1-\delta_k)\mu_{t+1} + U_{h^c,t+1} r_{k,t+1}\right\}, \tag{B.48}$$

$$q_t U_{h^c,t} = \mu_t \left(1 - \frac{\psi}{2}\left(\frac{I_t^k}{I_{t-1}^k} - 1\right)^2 - \psi\left(\frac{I_t^k}{I_{t-1}^k} - 1\right)\frac{I_t^k}{I_{t-1}^k}\right) + \beta E_t\left\{\mu_{t+1}\psi\left(\frac{I_{t+1}^k}{I_t^k} - 1\right)\left(\frac{I_{t+1}^k}{I_t^k}\right)^2\right\}, \tag{B.49}$$

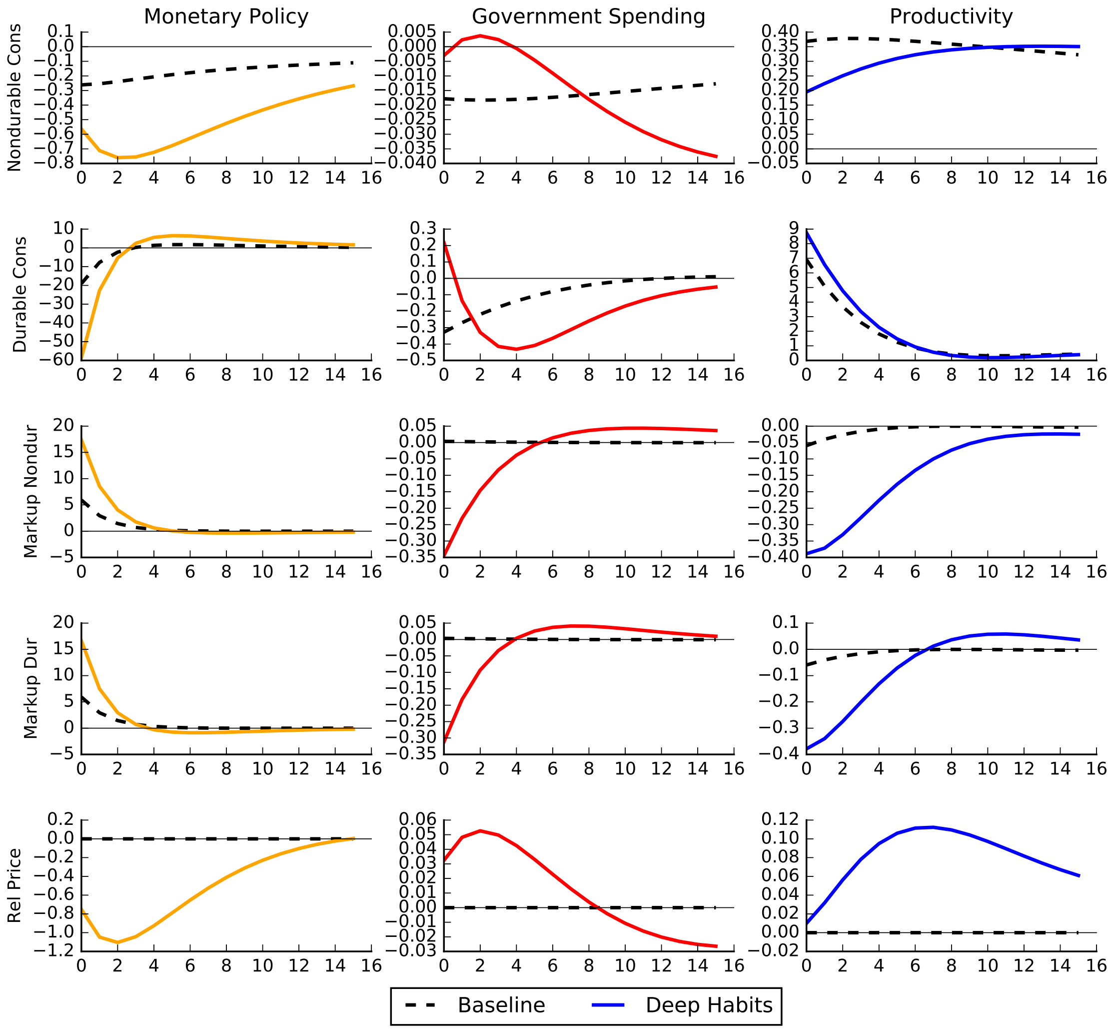
where μ is the Lagrangian multiplier associated with capital accumulation equation.

The firms in both sectors have now a Cobb-Douglas production function

$$Y_{i,t}^j = A_t\left(K_{i,t}^j\right)^\alpha \left(N_{i,t}^j\right)^{1-\alpha},\ j = c, d. \tag{B.50}$$

We set the new parameters in the model as $\delta_k = \delta = 0.025$, $\psi = 1$ and $\alpha = 0.3$. To ensure the determinacy of the model and the smoothness of IRFs, we increase the habit degrees in the model to $\theta_c = 0.6$ and $\theta_d = 0.3$. Figures B.7 presents the IRFs to government spending, TFP shocks and monetary policy.

Figure B.7: Impulse-response functions for model with capital accumulation



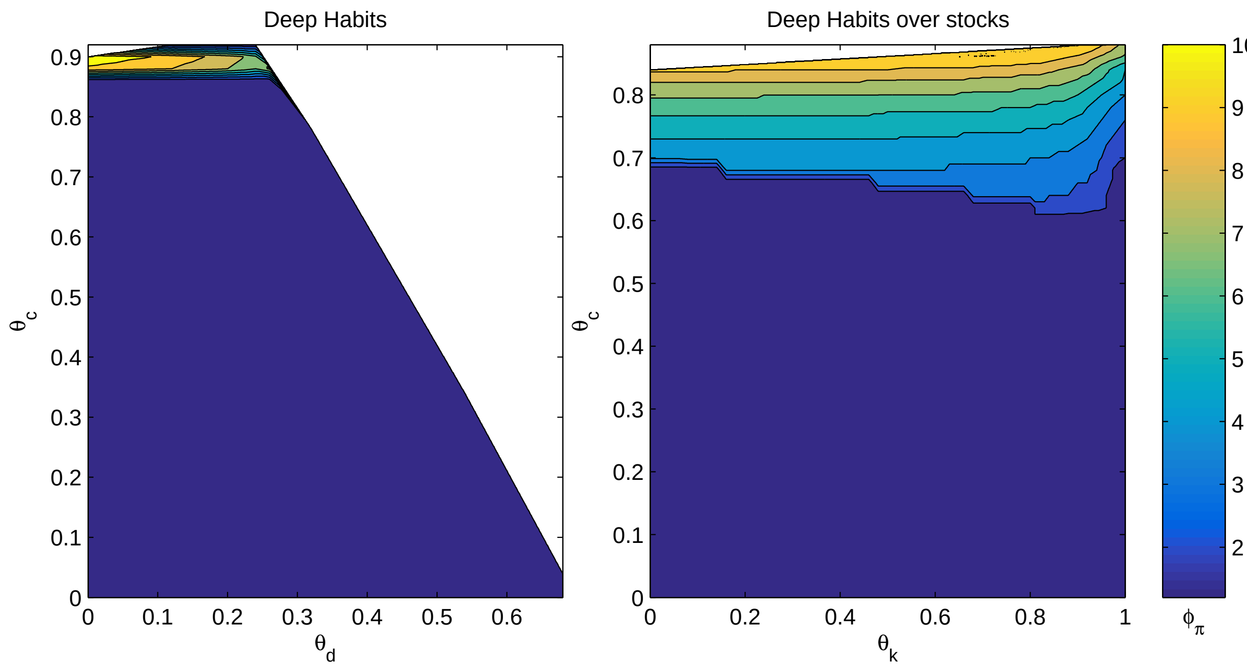
One major difference, resulting from the incorporation of capital in the model, is the dampening of the response of the nondurable consumption to fiscal shocks. This is explained by the lower impact of DH over durable goods in the durable market dynamics, as a result of introduction of demand for capital goods. Apart from this aspect, the responses obtained from the model with capital are relatively similar to the ones obtained from our core model.

When comparing with empirical evidence presented previously, the model with capital can also replicate more accurately the behavior of relative price.

In response to a shock in A_t, the household channels more funds to capital goods at the expense of the increase in consumption. At the same time, part of demand for durable goods is not influenced by habit formation. This leads to a decrease of markups in both goods and a positive response of the relative price of durable goods.

C Determinacy

Figure C.8: Determinacy regions for depp habits models



In the models we presented earlier, we defined the habits degree of nondurables, θ_c, to be 0.6, while the degree of habit formation on durable goods, θ_d, was 0.3. These values are substantially below the values usually considered in the models with DH (see Ravn et al. (2006) and Gilchrist et al. (2017)). Unlike when we consider DH only on nondurable goods (or in a single good model), the models with habits on purchases of durable goods require lower values of θ (or high levels of ϕ_π) in order to have a unique solution. Figure C.8 presents the determinacy regions for the models we presented in the previous subsections. As it can be observed in Figure C.8, for $\theta_d = 0$, the models without capital have a unique solution for reasonable values of ϕ_π and $\theta_c < 0.7$. In this case, the uniqueness of solution for each value of θ_c does not vary between models.

However, for $\theta_d > 0$ this is not the case. While for the main model the increase in θ_d requires higher levels of ϕ_π, in the model with DH over stocks, the increases of θ_k have no significant impact on the determinacy of the model. As expected, in the same way habits over stocks do not produce significantly different IRFs, they also do not affect the determinacy of the model.

As for the model with capital accumulation, the results are similar to the model without capital but the determinacy region is reduced over the axis of θ_d.