New Keynesian Models, Durable Goods, and Collateral Constraints

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Abstract

Econometric evidence suggests that, in response to monetary policy shocks, durable and non-durable spending comove positively, and durable spending exhibits a much larger sensitivity to the policy shocks. A standard two-sector New Keynesian model with free borrowing persistently exhibits a comovement problem: if spending contracts in one sector, it expands in the other. We argue that, even when durable prices are flexible, the introduction of a collateral constraint on borrowing and the consideration of durables as collateral assets generate both a correct sectoral comovement and a procyclical response of durable consumption to policy shocks. In this vein, collateral constraints act as a substitute of nominal rigidity in *durable* prices. However, since in the model nominal non-indexed debt and the collateral constraint generate alternative channels for monetary non-neutrality, our framework leaves room for relaxing the assumption of price stickiness also for *non-durable* goods prices, in line with some recent micro-based evidence. In a limit case of fully flexible prices in both sectors, a policy shock still generates a sizeable degree of monetary non-neutrality, as well as the correct sectoral comovement. In this vein, collateral constraints act as a substitute of price stickiness altogether.

Keywords: durable goods, sticky prices, collateral constraint.

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1 Introduction

New Keynesian models of the last generation, featuring imperfect competition and price stickiness as central building blocks, have recently become a workhorse reference for the analysis of business cycles and monetary policy.[1] Surprisingly, most of these models have largely ignored the role played by durable goods, despite their important contribution to the dynamics of aggregate spending. Figure 1 displays the (evolution of the) share of durable consumption and residential investment in total U.S. GDP. This share has historically been fluctuating between 12 and 15 percent. Figure 2 reports a decomposition of total private consumption spending in three main categories: non-durables, services and durables. In the sample period 1952-2005, the share of services has increased remarkably (from 35 to 60 percent), the share of non-durables has decreased (from 50 to 30 percent), whereas the share of durable consumption has remained quite stable, around 12 percent.

A better appreciation of the role of durable spending emerges, however, when considering two additional aspects. First, relative to non-durable consumption, durable spending is a component of GDP much more sensitive to variations in monetary policy. Below we provide statistical (VAR-based) evidence on this point. As a result, the dynamics of durable spending is potentially of significant importance for the evolution of GDP at business cycle frequencies.

A second, and probably more important, feature concerns the role that long-lived durables (especially housing) play as collateral in household borrowing. Among the most important facts observed in several OECD countries in the last decade has been the sizeable increase in asset (house) prices combined with an unprecedented rise in household debt. Figure 3 displays the evolution of total and mortgage household debt as a share of total households' assets in the US. Although clearly driven by a historical trend, this increase in the households' leverage ratio has featured a remarkable acceleration in the last few years. It is generally believed that lower interest rates (and hence lower average inflation) and widespread financial deregulation (leading to an easing of liquidity constraints) have been major determinants of these facts. Furthermore, the increase in both debt and asset prices have been usually perceived as mutually reinforcing phenomena. The rise in house prices has induced households to increasingly extract equity from their accumulated assets thereby encouraging further borrowing against the realized capital gains (Debelle

[1] To name a few, Rotemberg and Woodford (1997), Clarida et al. (1999), Woodford (2003), Goodfriend and King (1997).

(2004)).

Large part of the observed increase in household borrowing has been in the form of collateralized debt. Hence the role of durable goods (especially housing) as debt collateral has also increased over time. According to the 2004 Survey of Consumer Finances, the share of mortgage debt (as a prototype form of secured debt) in total outstanding household debt is about 80%, and has increased from 60% in 1952. Considering also vehicles loans, the current share of collateralized debt in the U.S. reaches roughly 87%.[2]

These two elements peculiar to durable spending (i.e., its larger sensitivity to policy shocks and its role for collateralized borrowing) essentially motivate our analysis. We first show that a baseline New Keynesian model with free borrowing, and simply augmented with a durable sector, exhibits a general *comovement* problem in the response of durable and non-durable spending to monetary shocks: if price stickiness is asymmetric in the two sectors, whenever consumption contracts in one sector it tends to expand in the other.

The basic intuition for the comovement problem is as follows. As noted in Barsky et al.(2005), a key feature of durability is that it makes the shadow value of a new unit of durables very smooth. Suppose non-durable prices are sticky (the intuition is similar in the opposite case), and recall that (under a constant-return-to-scale technology) the markup is the ratio of the marginal disutility of labor to the shadow value of durables. If durable prices are flexible, the markup in that sector must be constant. In turn, under sectoral mobility of labor, also total employment must be constant. Yet, for the latter to remain constant, if employment contracts in the non-durable sector (because of non-neutrality), it must necessarily expand in the durable sector.

This paper shows that the presence of nominal debt and of a collateral constraint on borrowing can reconcile an otherwise standard New Keynesian model with the empirical effects of monetary policy shocks on durable and non-durable spending. In the economy, there are two types of households, a saver and a borrower, with the latter being subject to a collateral constraint. The borrowers may be thought of as the relatively larger share of the population for which acquiring a loan/mortgage requires providing an asset, and in particular their house, as a form of collateral. The two agents are heterogenous in their patience rates. As a result, the borrower does not act as a consumption smoother, but exhibits preferences tilted towards current consumption. The higher the value of borrowing at the margin, the more pronounced this feature of temporal impatience in

[2]See Bucks, Kennickell and Moore (2005), Table 11. Mortgage debt is the sum of debt for primary residence and for other residential property.

consumption. Importantly, the borrowing limit is endogenously tied to the current value of the stock of durables and hence is sensitive to the evolution of the asset price (i.e., the relative price of durables).

The key insight is that, with the simultaneous presence of nominal private debt *and* of a collateral constraint, monetary policy generates *three* additional (endogenous) effects that are absent under free borrowing: (i) a nominal debt effect, (ii) a collateral constraint effect, and (iii) a valuation effect. Consider a monetary policy contraction, and let (for the sake of exposition) durable prices be flexible. First, when debt is predetermined in nominal terms, an interest rate hike - by lowering inflation - raises the real ex-post service cost of debt, thereby increasing the shadow value of borrowing (i.e., tightening the constraint). For the borrower, this is akin to a negative *income* shock. Unlike a standard consumption-smoothing agent, the borrower tends to *decrease* borrowing in the face of a negative income shock. Since acquiring debt requires purchasing durables as a collateral, the borrower's demand for durables *falls*. Simultaneously, the negative income effect - by restricting borrowing - drives also the demand for non-durables down, with this force generating a correct sectoral comovement.

Second, the increased shadow value of borrowing generally affects the user cost of durables. Our analysis shows that a tightening (softening) of the constraint *raises* (lowers) the user cost of durables, producing a substitution towards non-durable (durable) consumption. The latter effect helps in reconciling the model with the evidence that durable consumption is a more sensitive component of spending to monetary policy shocks.

Third, a monetary policy contraction, by lowering the relative price of durables, also lowers the collateral value of the durable stock, thereby affecting the borrowing capability also on the extensive margin (valuation effect). The latter effect acts in the direction of strengthening the income effect described above, generating a complementarity in the demand for durables and non-durables.

Noticeably, all monetary policy channels described above (except the valuation channel) act as a substitute of nominal stickiness in durable goods prices. In fact, nothing requires to assume stickiness in durable goods prices to induce a procyclical response of durable spending to monetary policy shocks. However, those channels represent also a more general source of monetary non-neutrality alternative to price stickiness. This generates natural room for relaxing the assumption of stickiness also in non-durable prices, somewhat in line with recent micro-based evidence on the frequency of price adjustment provided by Bils and Klenow (2004). Interestingly, in our simulations, a sizeable degree of non-neutrality, as well as a correct sectoral comovement, emerge even when prices are flexible in *both* sectors. In this vein, the presence of a collateral constraint and of collateralized debt can more broadly act as a substitute of nominal price stickiness altogether.

The role of durable goods in New Keynesian models has only recently received some attention. Erceg and Levin (2005) study optimal monetary policy in a sticky price model with durable and non-durable goods, but without a collateral constraint. In a similar environment, Barsky et al.(2005) analyze the transmission of monetary shocks and argue that it is largely affected by the assumption on the degree of stickiness of durable goods prices. Our analysis is related to their work, in that it shows that the critical role played by the stickiness (or lack thereof) of durable goods prices can be de-emphasized by the introduction of a collateral constraint. Campbell and Hercowitz (2005) study the role of collateralized debt in a business cycle model (with the observed historical softening of the equity requirements in the U.S. credit markets as a candidate explanation of the so-called Great Moderation), but their analysis is confined to a one-sector, real business cycle model.

The remainder of the paper is as follows. Section 2 presents VAR-based evidence on the response of durable and non-durable spending to monetary policy shocks. Section 3 illustrates the model. Section 4 and 5 analyze the steady state and the calibration. Section 6 studies the dynamics of the model in the absence of collateral constraint. Section 7 illustrates the effects of the introduction of collateral constraint. Section 8 concludes.

2 Some Evidence on the Response of Durable Spending and Debt to Monetary Policy Shocks

In this section we document two stylized features that characterize the dynamic evolution of durable and non-durable spending in response to (identified) monetary policy shocks. First, durable spending comoves positively with non-durable spending in response to those shocks. Second, the sensitivity of durable spending to policy shocks is significantly larger than the one of non-durable spending. In addition, we also provide some evidence on the cyclical behavior of (real) household debt in response to monetary shocks. This evidence is similar to the one documented in Erceg and Levin (2005) and Barsky et al.(2005), with new insights on the implied behavior of private debt.

To assess the impact of monetary policy shocks we estimate a quarterly VAR model for the U.S. economy specified as follows:

$$\mathcal{Y}_t = \sum_{j=1}^{L} A_j \; \mathcal{Y}_{t-j} + B \; \mathcal{E}_t \tag{1}$$

where $\mathcal{E}_t$ is a vector of contemporaneous disturbances. The vector $\mathcal{Y}_t$ comprises six variables: (i) real *GDP*, (ii) real *durable* consumption, (iii) real *non-durable* consumption and services, (iv) the *GDP deflator*, (v) total real *household debt*, and (vi) the *federal funds* rate. Except for the funds rate, all variables are in logs and have been deflated by the GDP deflator. The VAR system features a constant and four lags, and is estimated over the sample 1952:1- 2005:1.

To identify a monetary policy shock, we resort to a standard recursive identification scheme (Christiano et al. (1999)). We assume that monetary policy is conducted by means of a feedback interest rate rule in which the funds rate is the policy instrument. In particular, the element $\varepsilon_{r,t}$ of the vector $\mathcal{E}_t$, which represents the innovation to the policy rule, is assumed to be orthogonal to the current information set available to the monetary authority (and comprising observed values of the variables included in $\mathcal{Y}_t$ other than the funds rate).

Figure 4 displays estimated responses of real GDP, real non-durable spending, real durable spending, and total real household debt to a one standard deviation innovation in the federal funds rate. Dashed lines represent two standard error bands. Hence we see that both components of spending and GDP react negatively to the policy tightening. The smooth and persistent response of these variables is in line with a recent widespread empirical evidence (Rotemberg and Woodford (1997), Christiano et al. (1999)). Importantly, the fall in durable spending peaks earlier than the one of non-durables, and is three times larger at the peak. In addition, we also observe that real debt falls in response to the policy tightening, smoothly and persistently after the shock.[3]

In Figure 5 we refine the analysis and consider the effects of a policy innovation on mortgage debt (as opposed to total household debt) and on a real index of residential investment. Hence we observe that mortgage debt is roughly as sensitive to the policy shock as total debt. However, residential investment shows a much larger sensitivity to

[3] These results are robust to the specification of alternative orderings, less or additional lags, and to the introduction of alternative variables.

a policy shock than durable spending alone. The response of residential investment is almost twice as large at the peak than the one of durable consumption.

3 A Sticky Price Model with a Collateral Constraint

Next we build an optimizing general equilibrium model of monetary non-neutrality with the goal of rationalizing the facts illustrated above. The economy is composed of a continuum of households in the interval $(0, 1)$. There are two types of households, named *borrowers* and *savers*, of measure ω and $1 - \omega$ respectively. Each household's time endowment is equal to one. There are also two *sectors* (producing durable and non durable goods respectively), each populated by a large number of monopolistic competitive firms.

The two types of households have heterogeneous preferences, with the borrower being more impatient than the saver.[4] As argued in Campbell and Hercowitz (2005), the distinction of households into borrowers and savers reflects the characteristics of the distribution of wealth in the U.S. economy, which features private debt being distributed across a large fraction of households (mostly those between the twentieth and the ninetieth percentile) and financial wealth being strongly concentrated above the ninetieth percentile.[5]

All households derive utility from consumption of a non-durable final good and from services of a durable final good. Debt accumulation reflects intertemporal trading between the borrower and the saver. The borrower is subject to a *collateral constraint*, with the borrowing limit tied to the value of the existing stock of durables.

3.1 Final Good Producers

We begin by describing the production of final goods. In each sector $(j = c, d)$ a perfectly competitive final good producer purchases $Y_{j,t}(i)$ units of intermediate good i. Each producer in sector j operates the production function :

$$Y_{j,t} \equiv \left(\int_0^1 Y_{j,t}(i)^{\frac{\varepsilon_j - 1}{\varepsilon_j}} di \right)^{\frac{\varepsilon_j}{\varepsilon_j - 1}} \qquad \varepsilon_j > 1, \;\; j = c, d \tag{2}$$

where $Y_{j,t}(i)$ is the quantity demanded of the intermediate good i by final good producer j, and ε_j is the elasticity of substitution between differentiated varieties in sector j.

[4] For earlier models with heterogeneity in discount rates, see Becker (1980), Becker and Foias (1987), Kiyotaki and Moore (1997), Krusell and Smith (1998), Iacoviello (2004), Campbell and Hercowitz (2005).

[5] See also Bucks, Kennickell and Moore (2005).

Notice, in particular, that in the durable good sector $Y_{d,t}(i)$ refers to expenditure in the *new* durable intermediate good i (rather than services). Maximization of profits yields demand functions for the typical intermediate good i in sector j:

$$Y_{j,t}(i) = \left(\frac{P_{j,t}(i)}{P_{j,t}}\right)^{-\varepsilon_j} Y_{j,t} \qquad j = c, d \tag{3}$$

for all i. In particular, $P_{j,t} \equiv \left(\int_0^1 P_{j,t}(i)^{1-\varepsilon_j} di\right)^{\frac{1}{1-\varepsilon_j}}$ is the price index consistent with the final good producer in sector j earning zero profits.[6]

3.2 Borrower

A typical borrower consumes an index of consumption *services* of durable and *non-durable* final goods, defined as:

$$X_t \equiv \left[(1-\alpha)^{\frac{1}{\eta}} \left(C_t\right)^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} \left(D_t\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \tag{4}$$

where C_t denotes consumption of the final non-durable good, D_t denotes *services* from the stock of the final durable good at the end of period t, $\alpha > 0$ is the share of durable goods in the composite consumption index, and $\eta \geq 0$ is the elasticity of substitution between services of non-durable and durable goods. In the case $\eta \to 0$, non-durable consumption and durable services are perfect complements, whereas if $\eta \to \infty$ the two services are perfect substitutes.[7]

The borrower maximizes the following utility program

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta^t U(X_t, N_t) \right\} \tag{5}$$

subject to the sequence of budget constraints (in *nominal* terms):

$$P_{c,t}\, C_t + P_{d,t}(D_t - (1-\delta)D_{t-1}) + R_{t-1}B_{t-1} = B_t + W_t N_t + T_t \tag{6}$$

[6]Hence the problem of the final good producer j is: $max\ P_{j,t}Y_{j,t} - \int_0^1 P_{j,t}(i)Y_{j,t}(i)di$ subject to (2).

[7]Eichenbaum and Hansen (1990) provide evidence of non-separability between durable and non-durable services. More recently, Ogaki and Reinhart (1998) and Piazzesi et al. (2003) estimate values for η above unity. Qualitatively, however, our results will not hinge on the assumed value for the elasticity of substitution η.

where B_t is end-of-period t nominal debt, R_{t-1} is the nominal lending rate on loan contracts stipulated at time $t-1$, W_t is the nominal wage, N_t is total labor supply, and T_t are lump-sum government transfers/taxes. Labor is assumed to be perfectly mobile across sectors, implying that the nominal wage rate is common across sectors.

In real terms (units of non-durable consumption), (6) reads

$$C_t + q_t(D_t - (1-\delta)D_{t-1}) + R_{t-1}\frac{b_{t-1}}{\pi_{c,t}} = b_t + \frac{W_t}{P_{c,t}}N_t + \frac{T_t}{P_{c,t}} \tag{7}$$

where $q_t \equiv \frac{P_{d,t}}{P_{c,t}}$ is the relative price of the durable good, and $b_t \equiv \frac{B_t}{P_{c,t-1}}$ is real debt.

Below we will specialize the form of the utility function as follows:

$$U(X_t, N_t) = \log(X_t) - \frac{v}{1+\varphi}N_t^{1+\varphi} \tag{8}$$

where φ is the inverse elasticity of labor supply, and v is a scale parameter indexing the amount of hours worked by the borrower in the steady state.

Collateral Constraint Private borrowing is subject to an endogenous limit[8], which is tied to the current value of the durable good holdings:

$$B_t \leq (1-\chi)D_t P_{d,t} \tag{9}$$

where χ is the fraction of the durable good value that cannot be used as a collateral. We assume that the whole stock of debt is collateralized. This is a good approximation in light of the evidence cited above on the overwhelming proportion of secured debt over total household debt in the U.S. economy.

The form of constraint (9) can be rationalized in terms of limited enforcement. Although debt repudiation is in principle feasible for the borrower, this option would entail loosing the entire current value of the assets. Hence the provision of collateral acts against that temptation. In general, one can interpret χ as the down-payment rate, or one minus the *loan-to-value ratio*. Jappelli and Pagano (1989) provide evidence on the presence of liquidity constrained agents by linking their observed share to more structural features of the credit markets. In particular, they find that the share of liquidity constrained agents is larger in countries in which a measure of the loan-to-value ratio is lower. Notice also that movements in the relative price of durables affect the ability of borrowing directly.

[8]Kiyotaki and Moore (1997), Kocherlakota (2000).

This channel will be important in evaluating the transmission of monetary policy shocks in the model.

We assume that, in a neighborhood of the deterministic steady state, equation (9) is always *satisfied with equality*.[9] Hence we can rewrite the collateral constraint in *real* terms (i.e., in units of non-durable consumption) as follows

$$b_t = (1 - \chi)\, q_t D_t \tag{10}$$

Given initial values $\{b_{-1},\, D_{-1}\}$, the borrower chooses $\{N_t,\ b_t,\ D_t,\ C_t\}$ to maximize (5) subject to (7) and (10). By defining λ_t and $\lambda_t \psi_t$ as the multipliers on constraints (7) and (10) respectively, and $U_{\iota,t}$ as the marginal utility of variable $\iota = C, N, D$, efficiency conditions for the above program read:

$$\frac{-U_{n,t}}{U_{c,t}} = \frac{W_t}{P_{c,t}} \tag{11}$$

$$U_{c,t} = \lambda_t \tag{12}$$

$$q_t U_{c,t} = U_{d,t} + \beta(1 - \delta) E_t \left\{ U_{c,t+1} q_{t+1} \right\} + (1 - \chi)\, U_{c,t} q_t \psi_t \tag{13}$$

$$\psi_t = 1 - \beta E_t \left\{ \frac{U_{c,t+1}}{U_{c,t}} \frac{R_t}{\pi_{c,t+1}} \right\} \tag{14}$$

Equation (11) is a standard condition linking the real wage (in units of non-durables) to the borrower's marginal rate of substitution between consumption and leisure. Equation (12) links the borrower's marginal utility of consumption to the shadow value of relaxing the flow constraint (7). Equation (13) is an intertemporal condition on durable demand. It requires the borrower to equate the marginal utility of current non-durable consumption to the marginal gain of durable services. The latter depends on three components: *(i)* the direct utility gain of an additional unit of durable; *(ii)* the expected utility stemming

[9] This condition is always satisfied in the steady state (see below). The assumption that it continues to hold also in the neighborhood of the steady state will allow us to employ standard local approximation methods when analyzing equilibrium dynamics. In turn, this will require a bound on the amplitude of the stochastic driving forces in the model. Notice that, although the constraint is assumed to hold with equality, at least locally, variations in its tightness will still be measurable in terms of its corresponding shadow value.

from the possibility of expanding future consumption by means of the realized resale value of the durable purchased in the previous period; *(iii)* the marginal utility of relaxing the collateral constraint (recall that the impatient agent can purchase new debt only by acquiring durables).

Equation (14) is a modified version of a typical Euler equation. Indeed it reduces to a standard Euler condition in the case of $\psi_t = 0$ for all t (i.e., non-binding collateral constraint). With a binding constraint, the marginal value of borrowing (the left hand side ψ_t) is tied to a payoff (right hand side) that captures the deviation from the Euler condition. Consider, for the sake of argument, ψ_t rising from zero to a positive value. This implies, from (14), that $U_{c,t} > \beta E_t \left\{ U_{c,t+1} \frac{R_t}{\pi_{c,t+1}} \right\}$. In other words, the marginal utility of current consumption exceeds the marginal gain of shifting one unit of consumption intertemporally (or marginal utility of saving). The higher ψ_t, the higher the net marginal benefit of acquiring today the durable asset which allows, by marginally relaxing the collateral constraint, to purchase additional current consumption. Hence a rise in ψ_t is akin to a tightening of the collateral constraint.

3.3 Savers

The economy is composed of a second category of consumers, labeled savers. We assume that the typical saver is the owner of the monopolistic firms in each sector. He/she maximizes the utility program:

$$E_0 \left\{ \sum_{t=0}^{\infty} \gamma^t U(\widetilde{X}_t, \widetilde{D}_t) \right\} \tag{15}$$

The key feature that distinguishes the saver's behavior is the impatience rate. We assume that the saver is *more patient* than the borrower, implying

$$\gamma > \beta$$

The saver's sequence of budget constraints reads (in nominal terms):

$$P_{c,t}\, \widetilde{C}_t + P_{d,t} \left(\widetilde{D}_t - (1-\delta)\widetilde{D}_{t-1} \right) + R_{t-1}\widetilde{B}_{t-1} = \widetilde{B}_t + \widetilde{T}_t + \sum_j \widetilde{\Gamma}_{j,t} \qquad j = c, d \tag{16}$$

where $\widetilde{C}_t$ is saver's non-durable consumption, $\widetilde{D}_t$ denotes saver's utility services from the stock of durable goods, $\widetilde{B}_t$ is end-of-period t nominal debt (credit), $\widetilde{T}_t$ are government transfers/taxes, and $\widetilde{\Gamma}_{j,t}$ are nominal profits from the holding of monopolistic competitive firms in sector j. We disregard the labor supply choice by the saver. The motivation is twofold. First, for the sake of simplicity, this makes the level of output independent of the relative labor share of the two agents. Second, recall that the savers earn income by borrowing funds. If they start with some initial level of wealth, given their preferences, they will end up owning all assets in the steady state (see below). Hence, in equilibrium, they will most likely choose to work very little.

The efficiency conditions for the saver's optimal program are: a standard Euler equation

$$U_{\widetilde{c},t} = \gamma E_t \left\{ U_{\widetilde{c},t+1} \frac{R_t}{\pi_{c,t+1}} \right\} \tag{17}$$

and a durable demand condition (in the absence of a collateral constraint)

$$q_t U_{\widetilde{c},t} = U_{\widetilde{d},t} + \gamma(1-\delta) E_t \left\{ U_{\widetilde{c},t+1} q_{t+1} \right\} \tag{18}$$

3.3.1 User Cost and Collateral Constraint

An alternative interpretation of condition (13) is that it equates the marginal rate of substitution between durable and non-durable consumption to the *user cost* of durables. The latter is the key relative price driving the non-durable/durable margin. In particular, the expression for the user cost Z_t reads

$$Z_t \equiv q_t \left[1 - (1-\chi)\psi_t\right] - \beta(1-\delta) E_t \left\{ \frac{U_{c,t+1}}{U_{c,t}} q_{t+1} \right\} \tag{19}$$

Taking a log-linear approximation of (13) and (14) around the deterministic steady state[10], and using the symbol "$\widehat{\ }$" to denote percent deviations from corresponding steady-state values, we can write

$$\widehat{u}_{d,t} - \widehat{u}_{c,t} = b_q\ \widehat{q}_t\ + \beta(1-\delta)\left(\widehat{rr}_t - E_t\left\{\widehat{q}_{t+1}\right\}\right) + b_\psi\ \widehat{\psi}_t \equiv \widehat{Z}_t \tag{20}$$

with

$$b_q \equiv \left[1 - (1-\chi)\left(1 - \frac{\beta}{\gamma}\right)\right] \in [0,1]$$

[10] In particular, a sectoral zero-inflation steady state with $q = 1$. See below for a more detailed characterization of the steady state.

$$b_\psi \equiv (\gamma - \beta)\left[(1-\delta) - \frac{1-\chi}{\gamma}\right]$$

and where $\widehat{rr}_t \equiv R_t - E_t\left\{\widehat{\pi}_{c,t+1}\right\}$ is the (ex-ante) real interest rate in units of non-durables. Notice that in the case $\gamma = \beta$, i.e., when heterogeneity in patience rates vanishes, we have $b_q = 1$ and $b_\psi = 0$, and therefore the above equation reduces to

$$\widehat{Z}_{n,t} \equiv \widehat{q}_t \; + \beta(1-\delta)\left(\widehat{rr}_t - E_t\left\{\widehat{q}_{t+1}\right\}\right) \tag{21}$$

with $\widehat{Z}_{n,t}$ being the user cost in the *absence* of a collateral constraint. Movements in $\widehat{Z}_{n,t}$ depend positively on the current relative price of durables, but negatively on the expected future price of durables. Intuitively, current demand for durables rises when the expected future price rises, due to the expected asset appreciation. Obviously, this feature vanishes for $\delta \to 1$, i.e., when durability disappears. Also, the user cost depends inversely on the real interest rate, for the latter reflects the opportunity cost of investing in the durable good. Finally, depreciation rises the user cost, because it physically erodes the investment in the durable good.

In the presence of a collateral constraint, the expression for the user cost is affected by an additional element, namely the multiplier ψ_t. As hinted above, a rise in ψ_t signals that the collateral constraint is tighter, for the higher would be the marginal value for the borrower of tilting the consumption plan towards current consumption.

Since the (relative) demand for durables depends on the user cost, a crucial issue -under a collateral constraint- concerns the dynamic behavior of the multiplier ψ_t in response to a monetary policy shock. Equation (20) suggests that the effect on the user cost of a tightening of the constraint is ambiguous. In particular, a rise in $\widehat{\psi}_t$ induces (*ceteris paribus*) a rise in $\widehat{Z}_t$ if the following condition holds:

$$\gamma(1-\delta) + \chi > 1 \tag{22}$$

Notice that condition (22) is more easily satisfied:

- (i) the lower the depreciation rate δ (higher durability);
- (ii) the higher the inverse LTV ratio χ (therefore the lower the ability to translate the value of the collateral into new debt);

- (iii) the higher the saver's patience rate γ (for any given borrower's patience rate β), and therefore the stronger the heterogeneity in patience rates.

The reason for why a rise in ψ_t (eventually induced by a policy tightening) has an ambiguous effect on the user cost is as follows. It is useful to rewrite (20) in the following (equivalent) form

$$\widehat{Z}_t \equiv \widehat{q}_t^e + (1-\delta)\left(\beta\widehat{rr}_t + (\gamma-\beta)\,\widehat{\psi}_t\right) - \beta(1-\delta)E_t\{\widehat{q}_{t+1}\} \tag{23}$$

where $\widehat{q}_t^e \equiv b_q\widehat{q}_t - (1-b_q)\,\widehat{\psi}_t$ can be thought of as the *effective* relative price of durables. Similarly, we may interpret $\beta\widehat{rr}_t + (\gamma-\beta)\,\widehat{\psi}_t$ as the *effective* real interest rate in the presence of a collateral constraint. For one, in light of a rise in ψ_t, the borrower would like to increase the demand for durables, in order to relax the collateral constraint. This is reflected in the fact that the effective relative price of durables depends inversely on ψ_t. However, and all else equal, if the real cost of debt rises, the agent is discouraged from increasing the demand of durables for borrowing purposes, for this will imply a higher future cost of debt repayment. This is akin to a rise in the "effective" real interest rate, and, in turn, of the user cost.

For sufficiently low values of δ, condition (22) will be easily satisfied under our benchmark parameterization (see section 4 below). Hence the relation between ψ_t and Z_t can be thought of being generally *positive*, and especially for the case of long-lived durables (low δ). This implies that a tightening of the collateral constraint leads, all else equal, to a *rise* in the user cost for a large and plausible configuration of the parameters.

Notice, finally, that there is an important additional effect induced by our specification of the collateral constraint. In fact, in equation (10), movements in the asset price q_t affect the ability of borrowing by directly affecting the collateral value of the durable good. A fall in the relative price of durables induces also a fall in the collateral value of the durable asset, which in turn induces a direct fall in borrowing and a further rise in $\widehat{\psi}_t$. We will illustrate the mechanics of this interaction effect below.

3.4 Production and Pricing of Intermediate Goods

A typical intermediate good firm i in sector j hires labor (supplied by the borrowers) to operate a linear production function:

$$Y_{j,t}(i) = \omega N_{j,t}(i) \qquad (24)$$

where, for simplicity, labor productivity is assumed to be constant and normalized to 1 in both sectors. Each firm i has monopolistic power in the production of its own variety and therefore has leverage in setting the price. In so doing it faces a quadratic cost proportional to final goods output, and equal to

$$\frac{\vartheta_j}{2}\left(\frac{P_{j,t}(i)}{P_{j,t-1}(i)} - 1\right)^2 Y_{j,t} \qquad (25)$$

where the parameter ϑ_j measures the degree of sectoral nominal price rigidity. The higher ϑ_j, the more sluggish the adjustment of nominal prices in sector j. In the particular case of $\vartheta_j = 0$, prices are flexible.

The problem of each monopolistic firm is to choose the sequence $\{N_{j,t}(i), P_{j,t}(i)\}_{t=0}^{\infty}$ in order to maximize expected discounted nominal profits:

$$E_0\left\{\sum_{t=0}^{\infty}\Lambda_{j,t}\left(P_{j,t}(i)Y_{j,t}(i) - W_t N_{j,t}(i) - \frac{\vartheta_j}{2}\left(\frac{P_{j,t}(i)}{P_{j,t-1}(i)} - 1\right)^2 P_{j,t}Y_{j,t}\right)\right\} \qquad (26)$$

subject to (24). In (26), $\Lambda_{j,t} \equiv \gamma E_t\left\{\frac{\widetilde{\lambda}_{t+1}}{\widetilde{\lambda}_t}\right\}$ is the saver's stochastic discount factor, and $\widetilde{\lambda}_t$ is the saver's marginal utility of nominal income. Let's denote by $\frac{P_{j,t}(i)}{P_{j,t}}$ the relative price of variety i in sector j. In a *symmetric* equilibrium in which $\frac{P_{j,t}(i)}{P_{j,t}} = 1$ for all i and j, and all firms employ the same amount of labor in each sector, the first order condition of the above problem reads:

$$\begin{aligned}((1-\varepsilon_j) + \varepsilon_j mc_{j,t}) &= \vartheta_j(\pi_{j,t} - 1)\pi_{j,t} && (27)\\ &\quad -\vartheta_j E_t\left\{\frac{\Lambda_{j,t+1}}{\Lambda_{j,t}}\frac{P_{j,t+1}}{P_{j,t}}\frac{Y_{j,t+1}}{Y_{j,t}}(\pi_{j,t+1} - 1)\pi_{j,t+1}\right\} && (j = c, d)\end{aligned}$$

where $\pi_{j,t} \equiv \frac{P_{j,t}}{P_{j,t-1}}$ is the gross inflation rate in sector j, and

$$mc_{j,t} \equiv \frac{W_t}{P_{j,t}} \qquad (28)$$

is the real marginal cost in sector j.[11]

[11] To better interpret the derivation of (27), notice that the following holds:

By log-linearizing around a sectoral zero-inflation steady state, (27) takes the form of a forward-looking New Keynesian Phillips curve[12]

$$\widehat{\pi}_{j,t} = \beta E_t \left\{ \widehat{\pi}_{j,t+1} \right\} + \left(\frac{\varepsilon_j - 1}{\vartheta_j} \right) \widehat{mc}_{j,t} \tag{29}$$

where a "$\widehat{\ }$" denotes percentage deviations from the respective steady state value.

In the particular case of *flexible prices* (in both sectors), the real marginal cost must be constant and equal to the inverse steady-state markup $\frac{\varepsilon_j - 1}{\varepsilon_j}$. By using (11), the pricing condition (27) reads:

$$\frac{-U_{n,t}}{U_{c,t}} = \frac{\varepsilon_c - 1}{\varepsilon_c} \qquad \text{if } j = c \tag{30}$$

$$\frac{-U_{n,t}}{U_{c,t}} q_t^{-1} = \frac{\varepsilon_d - 1}{\varepsilon_d} \qquad \text{if } j = d \tag{31}$$

Notice that, in the durable sector, variations in the relative price of durables (possibly due to a sectoral asymmetric shock) drive a wedge between the marginal product of labor and the marginal rate of substitution between consumption and leisure. Hence the real marginal cost is directly affected by movements in the relative price.

3.4.1 CPI Inflation

To define a utility-based aggregate price index (henceforth CPI) one needs to assume the existence of an additional final good producer, whose task consists in assembling *services* of durable and non durable goods via the production function (4). The price index consistent with maximization of profits by this producer reads

$$P_t \equiv \left[(1-\alpha) \, (P_{c,t})^{1-\eta} + \alpha \, (P_{d,t})^{1-\eta} \right]^{\frac{1}{1-\eta}} \tag{32}$$

$$E_t \left\{ \frac{\Lambda_{t+1}}{\Lambda_t} \frac{P_{c,t+1}}{P_{c,t}} \right\} = E_t \left\{ \frac{U_{\tilde{c},t+1}}{U_{\tilde{c},t}} \right\}, \quad \text{if } \ j = c$$

and

$$E_t \left\{ \frac{\Lambda_{t+1}}{\Lambda_t} \frac{P_{d,t+1}}{P_{d,t}} \right\} = E_t \left\{ \frac{U_{\tilde{c},t+1}}{U_{\tilde{c},t}} \frac{q_{t+1}}{q_t} \right\}, \ \text{if } j = d$$

[12] Galí and Gertler (1999).

Next we can define the following relative price indexes. The CPI-non-durable price ratio can be written as

$$\frac{P_t}{P_{c,t}} = [(1-\alpha) + \alpha \; q_t^{1-\eta}]^{\frac{1}{1-\eta}} \equiv g_{c,t}$$

Similarly we have:

$$\frac{P_t}{P_{d,t}} = [\alpha + (1-\alpha) \; q_t^{-(1-\eta)}]^{\frac{1}{1-\eta}} \equiv g_{d,t} \tag{33}$$

Notice that, regardless of η, we have $\frac{\partial g_{c,t}}{\partial q_t} > 0$ and $\frac{\partial g_{d,t}}{\partial q_t} < 0$. Finally, we can link CPI and sectoral inflation as follows:

$$\pi_{,t} = \pi_{j,t} \frac{g_{j,t}}{g_{j,t-1}} \tag{34}$$

for $j = c, d$, where $g_{j,t} = g_j(q_t)$.

3.5 Monetary Policy

We assume that monetary policy is conducted by means of a simple Taylor-type rule

$$\frac{R_t}{R} = \left(\frac{\widetilde{\pi}_t}{\widetilde{\pi}}\right)^{\phi_\pi} \varepsilon_t \qquad \phi_\pi > 1 \tag{35}$$

where R is the steady-state gross nominal interest rate, $\widetilde{\pi}_t$ is an inflation index, and ε_t is a policy shock which is assumed to evolve according to

$$\exp(\varepsilon_t) = \exp(\varepsilon_{t-1})^{\rho} u_t$$

with u_t˜iid. Depending on the choice of the relevant inflation index, we can define two alternative monetary policy rules: (i) *Non-durable* inflation based (*NDI*) (if $\widetilde{\pi}_t = \pi_{c,t}$); (ii) *CPI inflation* based (if $\widetilde{\pi}_t = \pi_t$).

3.6 Market Clearing

Equilibrium in the goods market of sector $j = c, d$ requires that the production of the final good be allocated to *total* households' expenditure and to resource costs originating from the adjustment of prices

$$Y_{c,t} = \omega C_t + (1-\omega)\widetilde{C}_t + \frac{\vartheta_c}{2}\left(\pi_{c,t}-1\right)^2 \omega Y_{c,t} \tag{36}$$

$$Y_{d,t} = \omega\left(D_t - (1-\delta)D_{t-1}\right) + (1-\omega)\left(\widetilde{D}_t - (1-\delta)\widetilde{D}_{t-1}\right) + \frac{\vartheta_d}{2}\left(\pi_{d,t}-1\right)^2 \omega Y_{d,t} \tag{37}$$

where

$$Y_{j,t} \equiv \int_0^1 Y_{j,t}(i)\ di = \omega \int_0^1 N_{j,t}(i)\ di = \omega N_{j,t} \qquad (j = c, d)$$

Equilibrium in the debt and labor market requires respectively

$$\omega B_t + (1-\omega)\widetilde{B}_t = 0 \tag{38}$$

$$\sum_j N_{j,t} = N_t \tag{39}$$

Finally, we abstract from redistribution via fiscal policy. Hence we set

$$T_t = \widetilde{T}_t = 0$$

3.7 Equilibrium

An (imperfectly) *competitive allocation,* with sticky prices in both sectors and a collateral constraint*,* is a sequence for N_t, $N_{c,t}$, $N_{d,t}$, b_t, D_t, C_t, $\widetilde{C}_t$, $\pi_{j,t}$, R_t, ψ_t, q_t, mc_t satisfying (7), (10), (11), (12), (14), (17), (27), (35), (36), (37), (39), for $j = c, d$.

4 Deterministic Steady State

In the deterministic steady state, due to the assumed heterogeneity in discount rates (i.e., $\beta < \gamma$), the shadow value of borrowing is always positive. In other words, the borrower will always choose to hold a positive amount of debt. To show that, we simply combine the steady-state version of (17), which implies $RR = \frac{1}{\gamma}$, with (14), obtaining:

$$\psi = \left(1 - \frac{\beta}{\gamma}\right) > 0 \tag{40}$$

Notice that, to insure a well-defined steady state, both heterogeneity in patience rates *and* a borrowing limit are required. In fact, if discount rates were equal, the steady-state level of debt would be indeterminate (Becker (1980), Becker and Foias (1987)). In this case, in fact, it would hold $\frac{\beta}{\gamma} = \beta RR = 1$, and the economy would display a well-known problem of dependence of the steady state on the initial conditions.[13] With different discount rates, and yet still free borrowing, the consumption path of the borrower would be tilted downward, and the ratio of consumption to income would asymptotically shrink to zero.[14] Hence a binding collateral constraint allows a constant consumption path to be compatible with heterogeneity in discount rates.

We assume that the steady-state rate of inflation is zero in both sectors. In a flexible-price steady state for both sectors, taking the ratio of (30) and (31), the relative price of durables reads

$$q = \frac{\frac{\varepsilon_d - 1}{\varepsilon_d}}{\frac{\varepsilon_c - 1}{\varepsilon_c}} \tag{41}$$

By evaluating (13) in the steady state, we obtain the borrower's relative consumption of durables:

$$\frac{D}{C} = \frac{\alpha}{(1-\alpha)} \; \{q \; [1 - \beta(1-\delta) - (1-\chi)\psi]\}^{-\eta} \tag{42}$$

If $\delta \to 1$ (no durability), and $\psi = 0$ (collateral constraint not binding), the durable/non-durable margin depends only on the relative price q. In general, a rise in ψ increases the ratio $\frac{D}{C}$. Intuitively, the demand for durables raises when the shadow value of borrowing is higher. Notice that, in the steady state, this effect is unambiguous. This is not a contradiction, however, of our previous observation emphasizing that, in equilibrium, a rise in ψ_t has an ambiguous effect on the user cost (and therefore on the demand for durables).[15] In fact, while in the steady state the borrower must have paid the interest cost on the debt (although not the principal), along the dynamic a higher demand of durables (for borrowing purposes) implies also an increase in the future cost of debt service.

[13] In other words, under $\beta = \gamma$, the economy would constantly replicate the initial (arbitrary) distribution of wealth forever. This is a problem analog to the typical one that attains to small open economies with incomplete markets.

[14] In this case the assumption $\beta < \gamma$ is equivalent to $\beta RR < 1$. In the absence of exogenous growth, this implies that the (gross) growth rate of consumption (βRR) is below the (gross) growth rate of income (which is 1). Hence, the ratio of consumption to output must shrink over time.

[15] See section 3.3.1.

Notice also that a fall in the LTV ratio, captured by a rise in parameter χ, induces a fall in the relative demand for durables. Intuitively, if the ability of transforming the collateral into new debt is diminished, this makes durables less attractive.

Finally, one can express the steady-state leverage ratio as:

$$\frac{b}{D} = (1-\chi) \tag{43}$$

Clearly, a higher LTV ratio $(1-\chi)$ increases the steady-state borrower's leverage ratio.

To pin down the steady-state level of debt we proceed as follows. We choose the preference parameter v in order to set a given level of hours worked $\overline{N}$.[16] By combining (7), (10), and (43), we can write:

$$D = \frac{\overline{N}}{\mu^c \Phi} \tag{44}$$

where $\mu^c \equiv \frac{\varepsilon^c}{\varepsilon^c - 1}$ is the (steady-state) markup in the non-durable sector, and $\Phi \equiv \left\{ \frac{1-\alpha}{\alpha} \left[1 - \beta\left(1-\delta\right) - \psi(1-\chi)\right]^{\eta} + \delta + \frac{(1-\gamma)(1-\chi)}{\gamma} \right\}$. Once obtained D from (44), using (43), one can solve for the unique steady-state level of borrower's debt

$$b = \frac{\left(1-\chi\right)\overline{N}}{\mu^c \Phi} \equiv \overline{b} \tag{45}$$

It is easy to show that, under the assumption $\beta < \gamma$, the steady-state level of debt $\overline{b}$ is stable, i.e., the economy will converge to $\overline{b}$ starting from any initial value different from $\overline{b}$.[17]

5 Calibration and Solution Method

The steady-state real rate of interest is pinned down by the saver's degree of time preference γ. We choose an annual real rate of return of 4%. This implies $\left(\frac{1}{\gamma}\right)^4 = 1.04$, and in turn $\gamma = 0.99$. As to the calibration of the borrower's patience rate, we set $\beta = 0.96$.

[16] See the Appendix for the derivation of the level of hours worked in the steady state. In particular, we will require that the typical borrower devotes to work one third of the time unit.

[17] Notice that the stability of the steady state (i.e., convergence to a unique level of debt from any initial feasible level of wealth) does not necessarily depend on the presence of a borrowing limit. To the extent that condition $\beta RR = \frac{\beta}{\gamma} < 1$ holds, the steady state would be stable also under free borrowing. The drawback of this case, though, would be, as hinted above, that the borrower's steady-state consumption would not be well defined, and that the debt to income ratio would grow disproportionately large.

This value is in a range between 0.98 and 0.95, with these two values being the ones respectively chosen by Krusell and Smith (1993) and estimated by Iacoviello (2004).

We think of borrowers as the majority of the population, in light of the evidence that households between the tenth and the ninetieth percentile own roughly 80 percent of total outstanding collateralized debt (Survey of Consumer Finances 2004). Hence we calibrate the share of borrowers as being $\omega = 0.8$ (although we display later the sensitivity of our results to the assumed value of ω). This choice, in turn, is rooted in two observations. First, mortgage debt is the overwhelming proportion of collateralized debt. Second, for the vast majority of the population acquiring a mortgage always requires providing an asset (namely the house) as a collateral. As in Campbell and Hercowitz (2005), then, we think of the distinction between borrowers and savers essentially as the one between the very few wealthy who are not required to provide any collateral when borrowing for the purchase of a new house and the large majority of the population for which this constraint is unavoidable.

The choice of the physical depreciation rate of durables is complicated by the observed heterogeneity between durables like vehicles, for which the annual depreciation rate is around 15%, and very long-lived durables like housing, for which the annual depreciation rate is much slower and comprised between 1% and 3%. However, the role of durables as collateral assets that we emphasize in the paper is mostly referred to long-lived durables such as housing, so we choose an *annual* depreciation rate of 1%, and calibrate δ on a quarterly basis as $\delta = \frac{0.01}{4}$.

The annual average loan-to-value (LTV) ratio on home mortgages is roughly 0.75. This is the average value over the 1952-2005 period for the U.S. economy. This number has increased over time, as a consequence of financial liberalization, from about 72% at the beginning of the sample to a peak of 78% around the year 2000. The size of the LTV ratio is only slightly higher when considering mortgages on new houses only.[18] Normalizing all outstanding private debt to being collateralized, we set the LTV ratio as $(1 - \chi) = 0.75$, which yields $\chi = 0.25$.

The share of durable consumption in the aggregate spending index, defined by α, is set in such a way that $\delta(\omega D + (1 - \omega)\widetilde{D})$, the steady-state share of durable spending in total spending, is 0.2. This number is consistent with the combined share of durable consumption and residential investment in the NIPA Tables.

[18]The data source is the Federal Housing Finance Board.

The elasticity of substitution between varieties ε_j is set equal to 6 in both sectors, implying a steady-state mark-up of 20%. We set the degree of nominal rigidity in non-durable prices ϑ_c in order to generate a frequency of price adjustment of about four quarters. This is a standard calibration in the recent literature, although somewhat higher than the estimates, based on microeconomic evidence, provided by Bils and Klenow for the U.S. (we will return on this point later). The study of Bils and Klenow does not report a direct evidence on the degree of price stickiness of *long-lived* durables (such as housing, factories or manufacturing plants), which are the ones that more genuinely incorporate the role of collateral asset. In their study, however, prices of durable goods are generally *more flexible* than those of non-durable goods. One argument that typically induces to consider, e.g., house prices as nearly flexible is their perceived behavior as asset prices. In general, though, and as argued in Barsky et al. (2005), more research should be devoted to assessing the degree of stickiness of long-lived durable goods prices. In light of this uncertainty, in our simulations, we experiment with alternative values for the degree of stickiness in durables, ranging from full flexibility ($\vartheta_d = 0$) to sizeable stickiness ($\vartheta_d = \vartheta_c$).

As for the policy rule, we set $\phi_\pi = 1.5$, which is a standard value in the literature on Taylor rules, and a shock persistence parameter $\rho = 0.7$.

Our solution method consists in taking a log-linear approximation of the equilibrium conditions in the neighborhood of the deterministic steady state, in which condition (40) holds, and therefore equation (10) is satisfied with equality at least locally. Our local approximation method is accurate to the extent that we limit the exogenous process $\{\varepsilon_t\}$ to be bounded in the neighborhood of the steady state.

6 Benchmark: Durable Spending Dynamics with Free Borrowing

Next we analyze in detail the equilibrium dynamics of the model economy in response to monetary policy shocks. We start by studying a benchmark case, namely the one of a standard New Keynesian model *without borrowing limits* and simply augmented by the presence of a durable goods sector.

To obtain such a benchmark version of our model, it suffices to evaluate the system of first order conditions (11)-(14) in the particular case of $\psi_t = 0$. In this case the key equations driving the durable-non durable margin and the relative price of durables can be written:[19]

$$q_t = \frac{U_{d,t}}{U_{c,t}} + \beta(1-\delta)E_t\left\{\frac{U_{c,t+1}}{U_{c,t}}q_{t+1}\right\} \tag{46}$$

$$1 = \beta E_t\left\{\frac{U_{c,t+1}}{U_{c,t}}\frac{R_t}{\pi_{c,t+1}}\right\} \tag{47}$$

A rational expectations equilibrium of the New Keynesian model augmented with durable consumption is a set of processes for N_t, $N_{c,t}$, $N_{d,t}$, D_t, C_t, $\pi_{j,t}$, R_t, q_t, mc_t satisfying (11), (27), (35), (36), (37), (39), (46), (47), for $j = c, d$.

6.1 Comovement Problem in Response to Monetary Policy Shocks

In this section we show that the baseline model with free borrowing is characterized by a so-called comovement problem: the equilibrium behavior of durable and non-durable spending in response to a monetary policy shock is at odds with the empirical evidence reported in the early part of the paper. The anomaly is twofold. First, when durable prices are flexible, the response of durable spending to a policy shock is countercyclical (and comoves negatively with non-durable spending). Second, when durable prices are assumed to be sticky, durable consumption correctly contracts in response to a policy tightening, but still exhibits a wrong comovement with consumption in the non-durable sector. To the contrary, the empirical evidence suggests a strongly procyclical response of durable spending, a positive comovement with non-durable spending, and a much larger sensitivity of durable spending to policy shocks.

We consider two scenarios. First, prices sticky only in the *non-durable* sector. Second, prices sticky only in the *durable* sector. Below we assume that monetary policy is conducted via a *NDI rule* and that the elasticity of substitution is $\eta = 1$.[20] When nominal stickiness is assumed, it is the equivalent of four quarters for both sectors.

To understand the effect of the policy shock, it is important to recall a key property of durability. When the physical depreciation rate δ is low enough, the marginal util-

[19] Obviously, this version of the model collapses to a standard representative agent form.

[20] For the sake of exposition we do not report sensitivity results based on (i) employing a CPI Taylor rule; (b) varying the elasticity of substitution η between durable and non-durable consumption. The results are qualitatively unaltered, with the comovement problem still a key feature of the relative dynamics in the two sectors.

ity of durable consumption changes very smoothly. Formally, from equation (46), after integrating forward, we can write

$$U_{c,t}q_t = E_t\left\{\sum_{j=0}^{\infty}\left[\beta\left(1-\delta\right)\right]^j U_{d,t+j}\right\} \tag{48}$$

As argued in Barsky et al. (2005), the right hand side of (48) can be thought of as being roughly constant. In fact, for sufficiently small δ, that term is mostly driven by variations in the marginal utility of durable consumption in the distant future. Unless the shock is very persistent, those components must react very smoothly. This implies that for $U_{c,t}q_t$ to be constant, any variation in the relative price of durables must be matched by a variation in the marginal utility of non-durable consumption $U_{c,t}$ of the opposite sign, and therefore by a variation in non-durable consumption of the same sign.

6.1.1 Sticky Non-Durable Prices

Figure 6 displays the effect on selected variables of a 25 basis points innovation in the policy rule (35) in the model with free borrowing. Solid lines depict the case of sticky *non-durable* prices (and flexible durable prices), whereas dashed lines the case of sticky durable prices (and flexible durables).

When *non-durable* goods prices are *sticky*, we observe the relative price q_t to fall substantially in response to the shock. This is the result of durable prices falling relatively more than non-durable prices. Notice the one-to-one comovement between q_t and non-durable consumption, consistent with equation (48), which generates a fall in non-durable consumption. To better understand why the relative price of durables must fall, consider the consumption Euler condition (47) on non-durables (under log-utility)

$$\frac{C_{t+1}}{C_t} = \beta E_t\left\{\frac{R_t}{\pi_{c,t+1}}\right\} = \beta E_t\left\{\frac{R_t}{\pi_{d,t+1}}\frac{q_{t+1}}{q_t}\right\} \tag{49}$$

While the real interest rate in non-durables rises, the real rate in durables is unchanged (due to price flexibility). Hence the rate of change $\frac{q_{t+1}}{q_t}$ must rise, and current q_t must (initially) fall.

Why do consumption and production (employment) both rise in the durable sector despite the flexibility in prices? It is useful to rewrite the condition driving the consumption-leisure margin (for a representative agent) as follows:

$$\frac{-U_{n,t}}{U_{c,t}} = \frac{W_t}{P_{c,t}} = \frac{W_t}{P_{d,t}} q_t \tag{50}$$

Price flexibility in the durable sector implies that the marginal cost is constant in that sector, i.e., $\frac{-U_{n,t}}{U_{c,t}q_t} = const$. Hence, given that the denominator $U_{c,t}q_t$ is (quasi) constant, both the the product wage $\frac{W_t}{P_{d,t}}$ in the durable sector and $U_{n,t}$ must be constant. In turn, this implies that total employment must be constant in equilibrium, $N_t \approx \overline{N}$. Yet if employment falls in the non-durable sector as a result of the monetary tightening, it must necessarily rise in the durable sector (as we observe in figure 6) to keep total employment unchanged. Hence output and expenditure both contract in the non-durable sector, whereas they simultaneously expand in the durable sector.

6.1.2 Sticky Durable Prices

When durable prices are *sticky* (and yet non-durable prices are flexible), the comovement problem arises again (dashed lines in figure 6). Notice that the relative price of durables rises, thereby dictating a rise also in non-durable consumption (and employment). The reason for why q_t rises is just symmetric to the previous case: now, prices fall relatively more in the non-durable sector. At the same time, flexibility in the non-durable sector implies a constant real marginal cost

$$\frac{-U_{n,t}}{U_{c,t}} = const. \tag{51}$$

Using the consumption-leisure condition we can write

$$-U_{n,t} = \overline{U_c q}\, \frac{W_t}{P_{d,t}} \tag{52}$$

where an upper bar indicates that $\overline{U_c q}$ is a constant (again consistent with equation (48)). Sticky durable prices imply that the product wage must fall in that sector (to accompany a fall in the sectoral real marginal cost). From (52), this implies that $U_{n,t}$ must rise, and therefore total employment must fall. But if consumption and employment in the non-durable sector both rise, then necessarily employment and expenditure must fall in the durable sector.

What would happen with prices *equally* sticky in both sectors? In principle, relative prices should remain unchanged, and this should prevent any counter-factual comovement. It turns out, however, that this conclusion depends critically on the specification of the quadratic cost of adjustment. In the Appendix we show that the slope of the (log-linearized) Phillips curve changes depending on whether the cost of adjusting prices is specified as proportional to sectoral output (as in our baseline case) or, alternatively, as simply proportional to the rate of change in the individual price. In the latter case, it is easy to show that the slope of the log-linearized Phillips curve depends also on the steady-state value of sectoral output. Since steady-state output is larger in the non-durable sector, the Phillips curve in the latter sector exhibits higher slope, implying that non-durable prices are relatively more sensitive to marginal costs in that sector. Hence, in this case, even if prices were assumed to be equally sticky in both sectors ($\vartheta_c = \vartheta_d$), prices would fall relatively more in the non-durable sector in response to a policy tightening, thereby inducing a rise in the relative price q_t. This once again would induce a rise in non-durable consumption and a negative sectoral comovement.

7 The Role of Debt and of the Collateral Constraint

In this section we investigate the hypothesis that the introduction of a collateral constraint on borrowing and, in particular, of durable goods as collateral assets may help in solving the comovement problem discussed above, and therefore reconciling the behavior of the model with our empirical evidence. In particular, we first study the possibility that a collateral constraint may act as a substitute for nominal stickiness in durable prices.

We argue that the simultaneous presence of nominal debt *and* of a collateral constraint produces *three* novel effects of monetary policy variations, in addition to the standard ones related to price stickiness. We will label those effects respectively: (i) *nominal debt*, (ii) *collateral constraint*, and (iii) *valuation* effect.

Nominal Debt Effect With debt predetermined in nominal terms, a rise in the nominal interest rate produces a variation in the ex-post real cost of debt, which amounts to a negative income shock (see equation (7)). Since the borrower does not engage in consumption-smoothing, the reaction to a fall in income is, ceteris paribus, a *reduction* in borrowing. Recall that a standard consumption-smooting agent would instead act in the exactly opposite way, i.e., increase borrowing to soften the impact on current consumption of a fall in income. The reduction in borrowing leads to a corresponding fall in the demand for *both* durables and non-durables. Notice that this effect stems entirely from the feature of the borrower's temporal impatience in consumption, coupled with the presence of nominal non-indexed debt, and is independent of the presence of a collateral constraint.

Collateral Constraint Effect Under a collateral constraint, fluctuations in the shadow value of borrowing affect the user cost. In particular, as already shown above, a tightening of the constraint generally induces (all else equal) a rise in the user cost, and therefore a substitution from durable to non-durable consumption. Importantly, this effect generates a de-linking between the user cost and the relative price of durables. A tight comovement between the user cost and the relative price of durables was instead a defining feature of the baseline model with free borrowing.

Valuation Effect Finally, movements in the relative price of durables affect the ability of borrowing directly, by altering the value of the collateral asset (valuation effect). In turn, the implied variation in the demand for durables will feedback onto the behavior of relative prices, all in a self-reinforcing fashion. Incidentally, the valuation effect will interact with the income effect, since both effects work in the direction of altering the ability of borrowing on the extensive margin.

It is important to emphasize that all but the valuation effects hold regardless of the assumed relative degree of price stickiness in the two sectors. In other words, both the nominal debt and the collateral constraint effect work for any given equilibrium value assumed by the relative price q_t.

Figure 7 depicts impulse responses to a monetary policy tightening in the model with a binding collateral constraint. Throughout we assume that durable prices are *flexible* and that the elasticity of substitution η equals 1 (which implies Cobb-Douglas preferences in durable and non-durable services). We work under the assumption of flexible durable prices because we know that, in this case, the baseline economy with free borrowing delivers the counterfactual implication that durable consumption rises in light of a monetary tightening.[21]

Consider now the effect of introducing a collateral constraint. Notice, first, that the monetary policy tightening induces a rise in the marginal value of borrowing ψ_t. For any

[21] For the sake of exposition, we do not report the results when durable prices are sticky (and non-durable flexible) under a collateral constraint. Qualitatively, the picture is unchanged. In addition, the case of flexible durable prices, when durables are akin to housing in their role as a collateral, is probably the most relevant empirically.

given price q_t, since condition (22) is satisfied in our parameterization, this entails also a *rise* in the user cost. As in the case of free borrowing, the result of the policy shock is a fall in the relative price of durables. However, the dynamics of the user cost and of the relative price of durables are now *de-linked*: the relative price of durables falls whereas the user cost *rises* in response to the shock. This is a defining feature of the model with a collateral constraint relative to its counterpart with free borrowing.

With a collateral constraint the fall in the price q_t has an additional effect: the one of reducing directly the collateral value, further contributing to a tightening of the borrowing conditions. As a result, real debt falls, the demand for durables drops on impact and then starts to gradually revert back towards the steady state as the user cost gradually falls over time. In addition, the observed rise in the user cost produces a substitution effect from durables to non-durables. As a result, the peak impact on durable consumption is larger than the one on non-durable consumption.[22] Notice also that the fall in real debt in response to a policy tightening is qualitatively in line with our empirical evidence discussed in the early part of the paper. Simultaneously, the borrower reduces also the demand of non-durable goods. This is the result of two effects. First, prices are sticky in that sector, so the real interest rate on non durables rises. Second, the reduced ability of borrowing (due to tighter borrowing conditions as well as to the fall in the relative price of durables) affects negatively also the demand for non-durables. In this vein, the presence of an endogenous collateral constraint generates a complementarity between durable and non-durable demand.

Aggregate Responses Figure 8 illustrates the effects of the policy shock on the *aggregate* measures of consumption. We define aggregate non-durable consumption as:

$$C_t^A \equiv \omega C_t + (1-\omega)\widetilde{C}_t \tag{53}$$

and aggregate end-of-period t services of durables as

$$D_t^A \equiv \omega D_t + (1-\omega)\widetilde{D}_t \tag{54}$$

[22]Notice that we are plotting the effect on the end-of-period *stock* of durables D_t, rather than on the flow $I_{d,t} \equiv D_t - (1-\delta)D_{t-1}$. The sensitivity of the latter component would obviously be much larger. One reason for doing this is that, in the standard model with free borrowing, given the assumed form of preferences, the households wishes to smooth fluctuations in D_t rather than in $I_{d,t}$. In order to avoid the counterfactual contemporaneous drop in D_t it would be natural to allow for adjustment costs in changing the stock D_t. All our results would be qualitatively unaltered.

Our interest, motivated by the introductory empirical analysis, is to trace out the *dynamic* responses to a policy shock in the neighborhood of the steady state. When expressing (53) and (54) in log-linearized form, however, the weights on borrowers' and savers' consumption will be affected by their relative steady-state consumption levels. Therefore, for the sake of evaluating aggregate dynamic response, we normalize steady state consumption (in durables and non-durables) to be the same across households' groups, and evaluate the effect on dynamic responses of varying the share of impatient agents ω.

Building those measures requires an understanding of the *savers'* consumption responses to the policy shock (see figure 7 again). Recall that the savers are standard permanent-income agents. Two competing effects drive their demand. For one, a positive income shock, which is the counter-part of the negative income shock for the borrowers. This effect leads the savers to increase both categories of consumption. However, the rise in the real interest rate makes them substitute consumption intertemporally, so that, on balance, savers' non-durable consumption is observed to fall initially. At the same time, since the relative price of durables falls, the savers increase their demand for durables. For these agents, in fact, the relevant user cost is the one prevailing in the absence of any collateral constraint, and therefore it depends heavily on the behavior of the relative price (see equation (23)). In the aggregate, however, we observe that, for a share of borrowers above 50%, the model displays a correct sectoral comovement in response to a policy tightening. In light of our previous observation that the borrowers represent the (relatively larger) share of the population which holds debt (as opposed to the few wealthy savers holding the bulk of financial assets) the result is encouraging on the aggregation properties of the model.

The Role of Depreciation Figure 9 illustrates the role of depreciation. The figure displays the impact on borrower's durable consumption and on the user cost of varying the physical depreciation rate of durable goods, parameterized by δ. We make δ vary from a value of 0 (full depreciation) to a value of 20% per year. The effect of the policy tightening on the user cost is amplified for lower values of δ. Intuitively, from (22), a lower δ amplifies the effect of a rise in ψ_t on the user cost, exacerbating the fall in durable demand. However, while the impact effect on consumption is only barely affected by δ, a lower rate of depreciation strongly affects its persistence. This result indicates once again that the effect of monetary policy via the alleged role of collateral constraints is particularly pronounced for durable goods with a low physical depreciation rate, such as housing. This is consistent with our empirical result (see figure 5) that residential investment is a component of durable spending relatively more sensitive to interest rate variations, both in terms of size and in terms of persistence of the effect.

7.1 Can Borrowing Constraints Substitute for Price Stickiness Altogether?

Thus far we have worked under the assumption that non-durable prices are sticky. Our goal has been to explore the possibility that a collateral constraint on borrowing may act as a substitute of nominal rigidity in durable prices in making the prediction of a standard New Keynesian model in line with the empirical evidence on the effects of monetary policy shocks. Our results suggest that this is indeed the case. Despite the presence of flexible durable prices, the model with collateralized debt induces a sizeable fall in durable spending and a positive comovement with non-durable spending in response to a monetary policy tightening.

It is important to emphasize that the degree of rigidity in non-durable prices assumed thus far is significantly higher than the one reported in a recent (micro-based) study by Bils and Klenow (2004). Their study, which focuses primarily on non-durable goods, suggests that the average frequency of price adjustment in the U.S. is in the order of four months. Hence, in light of the monetary non-neutrality channels emphasized above, our model with a collateral constraint leaves in principle room for decreasing the assumed degree of stickiness also in non-durable prices.

Figure 10 displays selected responses to a policy tightening under alternative degrees of price stickiness in *non-durable* prices. In order to show the quantitative potential of the model we only display *aggregate* consumption responses. Throughout we continue to assume that durable prices are flexible. We present results for three cases: i) Full (non-durable) price flexibility (combined with our maintained assumption of flexible durable prices, this case describes an economy with fully flexible prices in both sectors); ii) L*ow stickiness*, which corresponds to a value of ϑ_c consistent with the evidence in Bils and Klenow; iii) *High stickiness,* which replicates to the standard four-quarter rigidity assumption.

It is clear that decreasing the degree of stickiness in non-durables works in the direction of dampening the response of non-durable consumption. However, the most interesting evidence emerges in the case of *full price flexibility* (both in durables and non-durables).

In that extreme case, prices in both sectors fall on impact, leading to a flat response of the relative price q_t. Despite prices being flexible in *both* sectors, and hence any valuation channel being shut-off (in equilibrium) by the constancy of the relative price of durables, a monetary policy shock displays non-trivial real effects on *both* categories of spending, which continue to exhibit the correct sectoral comovement. This effect is thus only attributable to the contemporaneous presence of nominal non-indexed debt and to its interaction with the collateral constraint.

8 Conclusions

Econometric evidence suggests that, in response to monetary policy shocks, durable and non-durable spending comove positively and that durable spending exhibits a much larger sensitivity to the policy shock. This paper shows that the introduction of collateralized household debt helps in reconciling the behavior of an otherwise baseline New Keynesian model with the empirical effects of monetary policy shocks. Under the standard assumption that non-durable prices are sticky, the model with borrowing limits generates a negative response of durable spending to a policy tightening and a positive sectoral comovement, broadly in line with the empirical evidence. In this vein, a collateral constraint act as a substitute of nominal price stickiness in durable goods.

Importantly, the presence of nominal non-indexed debt represents an alternative mechanism of monetary non-neutrality in the model. This leaves room even for relaxing the assumption of stickiness in non-durable prices, somewhat in line with recent micro evidence provided, e.g., in Bils and Klenow (2004). We show that, quantitatively, even the model with full price flexibility in both sectors still exhibits a sizeable degree of monetary non-neutrality. In this vein, the presence of a collateral constraint and collateralized debt can not only act as a substitute of nominal rigidity in the durable sector, but more broadly as a substitute of nominal stickiness altogether. Noticeably, while many researchers still contend on the empirical relevance of the hypothesis of nominal price stickiness, few would probably argue against the overwhelming practice of issuing private debt in nominal non-indexed form in the U.S. economy.

Our conclusions can be relevant on two grounds. First, Barsky et al.(2005) have recently highlighted that the presence of durable goods, despite their smaller relative share in total spending, can substantially alter the transmission of monetary shocks within a standard New Keynesian sticky price model. In particular, if durable prices are flexible, their model exhibits monetary neutrality, while if durable prices are sticky, the model behaves as a standard sticky price model even if non-durable prices are flexible. Our paper shows that the assumption on the degree of stickiness of durables may become irrelevant once a collateral constraint on borrowing is introduced in the model.

Second, a recent research program has tried to assess the empirical validity of dynamic stochastic general equilibrium (DSGE) models via structural estimation methods (Smets and Wouters (2003), Christiano et al. (2005)). In that research program, credit markets are usually assumed to be frictionless, but the degree of nominal price stickiness generally required to fit the data is largely at odds with recent micro evidence, at least for the U.S. economy. Hence an extension of estimated DSGE models to include a role for collateral constraints may help de-emphasizing the role of nominal price stickiness as a key ingredient for those models to represent a plausible representation of the data.

A Hours in the Steady State

In this appendix we show how to compute the level of (borrower's) hours worked in the steady state. From equation (42), which pins down the consumption ratio $\frac{C}{D}$, we can obtain the share of durables on total spending using the aggregator (4) as

$$\frac{X}{D} \equiv \left[(1-\alpha)^{\frac{1}{\eta}} \left(\frac{C}{D} \right)^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \tag{55}$$

Given $\frac{X}{D}$, and using (44), we can express the steady-state level of total expenditure as a function of the level of hours worked, $X = X(\overline{N})$. In turn, using (55) and (42), we can compute the non-durable share as

$$\frac{C}{X} = \frac{C}{D} \left(\frac{X}{D} \right)^{-1} \tag{56}$$

In a zero inflation steady state, and under functional form (8), condition (30) implies:

$$\frac{v \overline{N}^{\varphi}}{X^{-1}(\overline{N}) \left((1-\alpha)^{\frac{1}{\eta}} \left(\frac{C}{X} \right)^{-\frac{1}{\eta}} \right)} = \mu_c^{-1} \tag{57}$$

where the denominator of the left-hand side corresponds to the marginal utility of non-durable consumption. For given $\left(X, \frac{C}{X}, \mu_c, \varphi, \alpha, \eta\right)$ equation (57) describes a unique mapping between the choice of preference parameter v and the fraction of hours worked.

B Costs of Changing Prices and Sectoral Phillips Curve

In this Appendix we show that, when the cost of changing prices is specified in an alternative way, the comovement problem may arise even in the case of prices equally sticky in both sectors. In our framework, the quadratic cost of changing prices is expressed as proportional to final sectoral output, as in (25). However, one can express the cost of changing prices as simply proportional to the rate of change in the individual price as

$$\frac{\vartheta_j}{2} \left(\frac{P_{j,t}(i)}{P_{j,t-1}(i)} - 1 \right)^2$$

In this case the first order condition for optimal pricing reads

$$
\begin{aligned}
\left((1-\varepsilon_j)+\varepsilon_j mc_{j,t}\right)Y_{j,t} &= \vartheta_j\left(\pi_{j,t}-1\right)\pi_{j,t} \\
&\quad -\vartheta_j E_t\left\{\frac{\Lambda_{j,t+1}}{\Lambda_{j,t}}\frac{P_{j,t+1}}{P_{j,t}}\left(\pi_{j,t+1}-1\right)\pi_{j,t+1}\right\} \qquad (j=c,d)
\end{aligned} \tag{58}
$$

The log-linearized version of the sectoral Phillips curve reads:

$$
\widehat{\pi}_{j,t}=\beta E_t\left\{\widehat{\pi}_{j,t+1}\right\}+\left(\frac{(\varepsilon_j-1)Y_j}{\vartheta_j}\right)\widehat{mc}_{j,t} \qquad (j=c,d) \tag{59}
$$

Notice that in the above specification steady-state sectoral output Y_j affects the slope of the Phillips curve, whereas it does not in (29). Since steady-state output is larger in the non-durable sector, the Phillips curve in the latter sector exhibits higher slope, implying that non-durable prices are relatively more sensitive to marginal costs in that sector. Hence, in this case, even if prices are assumed to be equally sticky in both sectors ($\vartheta_c=\vartheta_d$), prices fall relatively more in the non-durable sector in response to a policy tightening. The rise in the relative price of durables would once again induce a rise in non-durable consumption and, in turn, a negative sectoral comovement.

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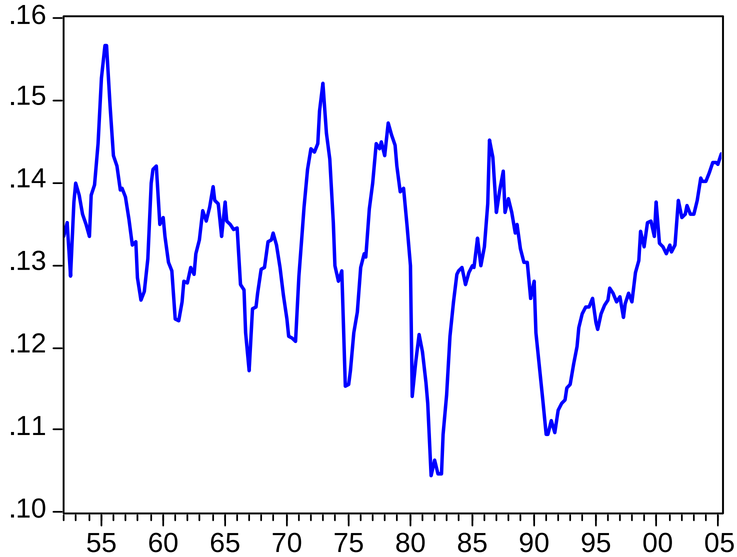

Figure 1: **GDP Share of Durable Consumption and Residential Investment**

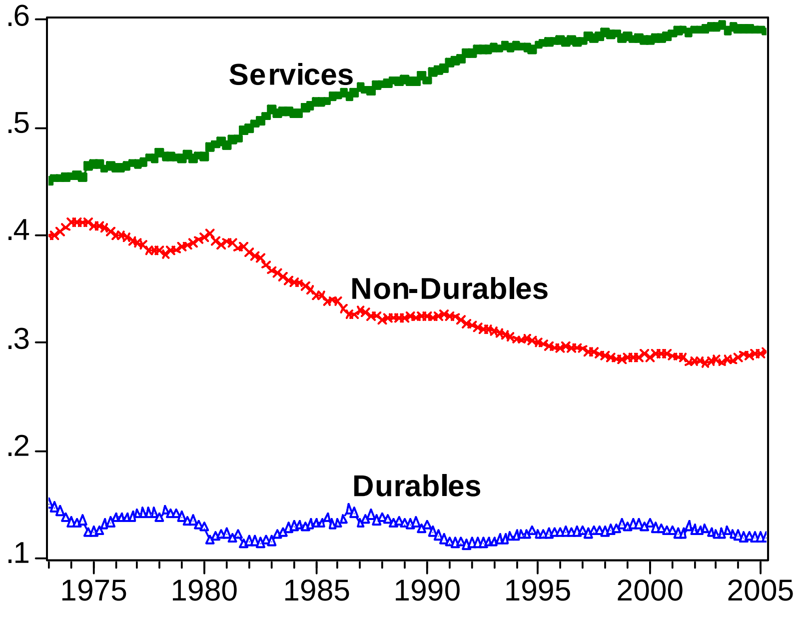

Figure 2: **Consumption Shares in GDP: Durables, Non-Durables, Services.**

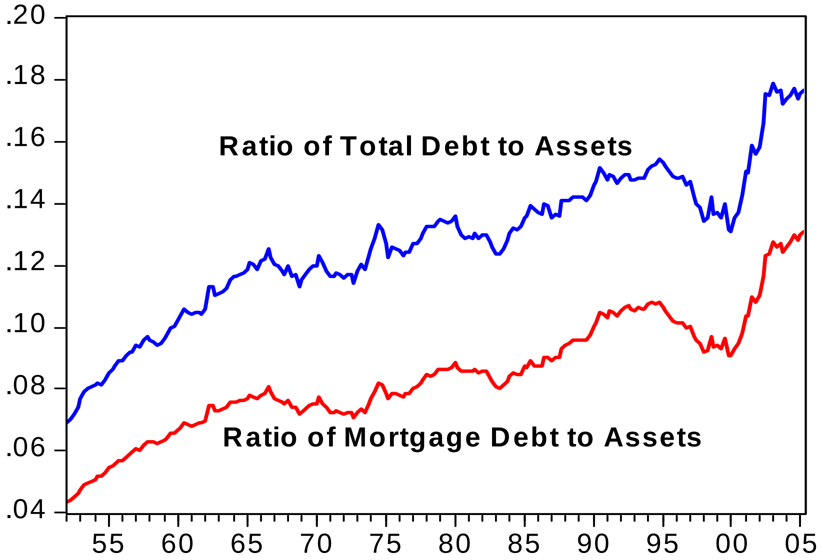

Figure 3: **Household Leverage Ratio**

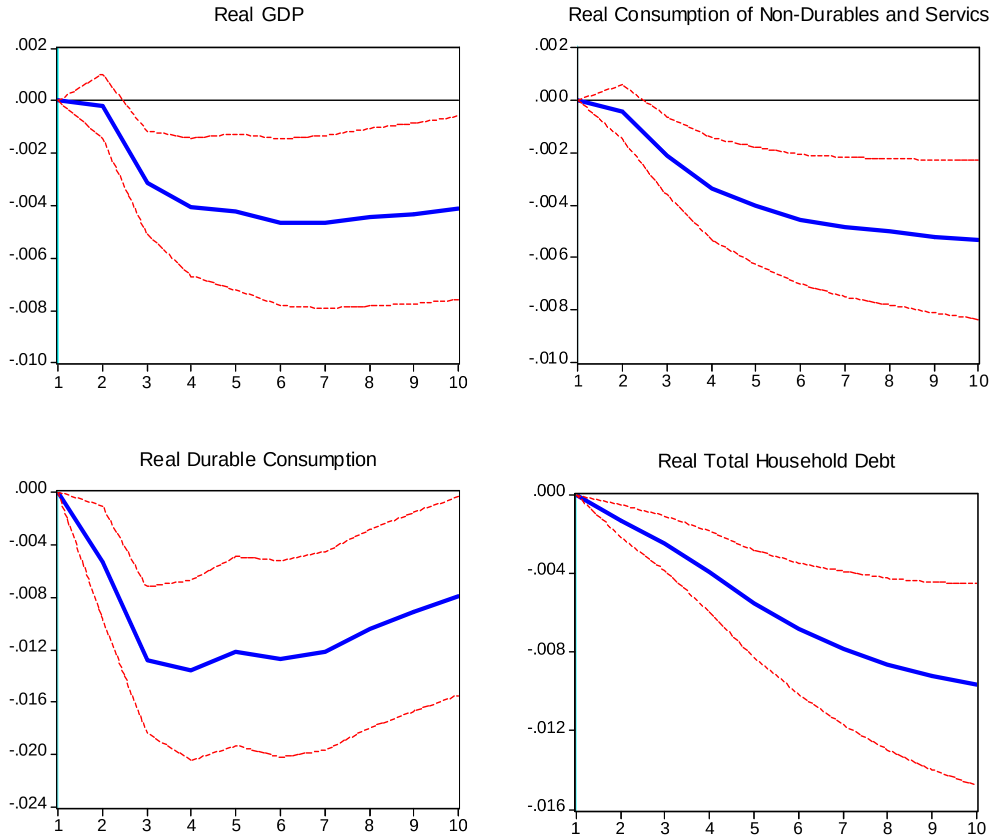

Figure 4: **Estimated Responses to a Monetary Policy Tightening: Baseline VAR**

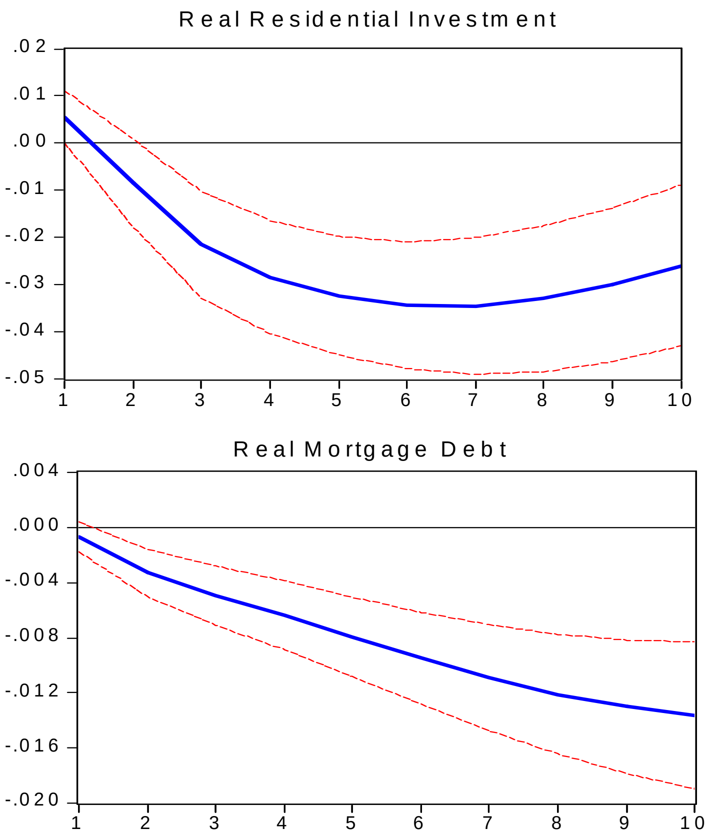

Figure 5: **Estimated Responses to a Monetary Policy Tightening: VAR with Residential Investment and Mortgage Debt**

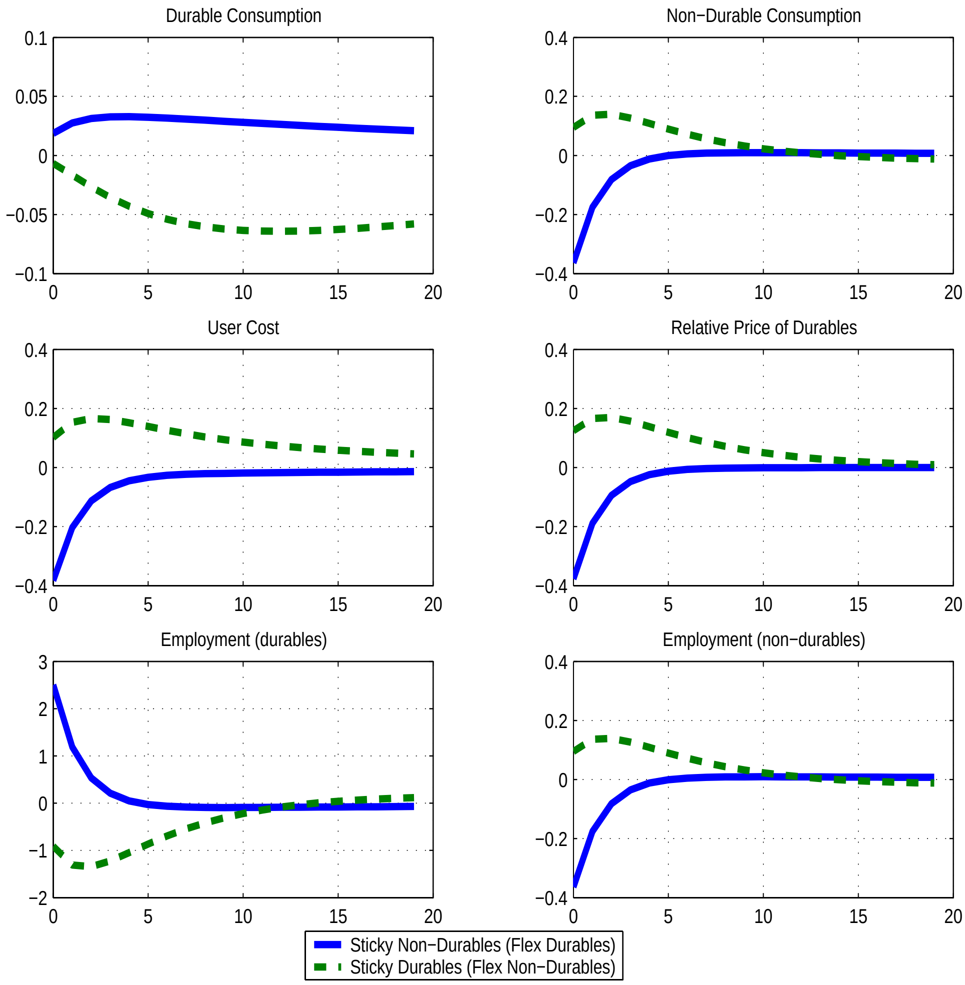

Figure 6: **Comovement Problem under Free Borrowing: Responses to a Monetary Policy Tightening**

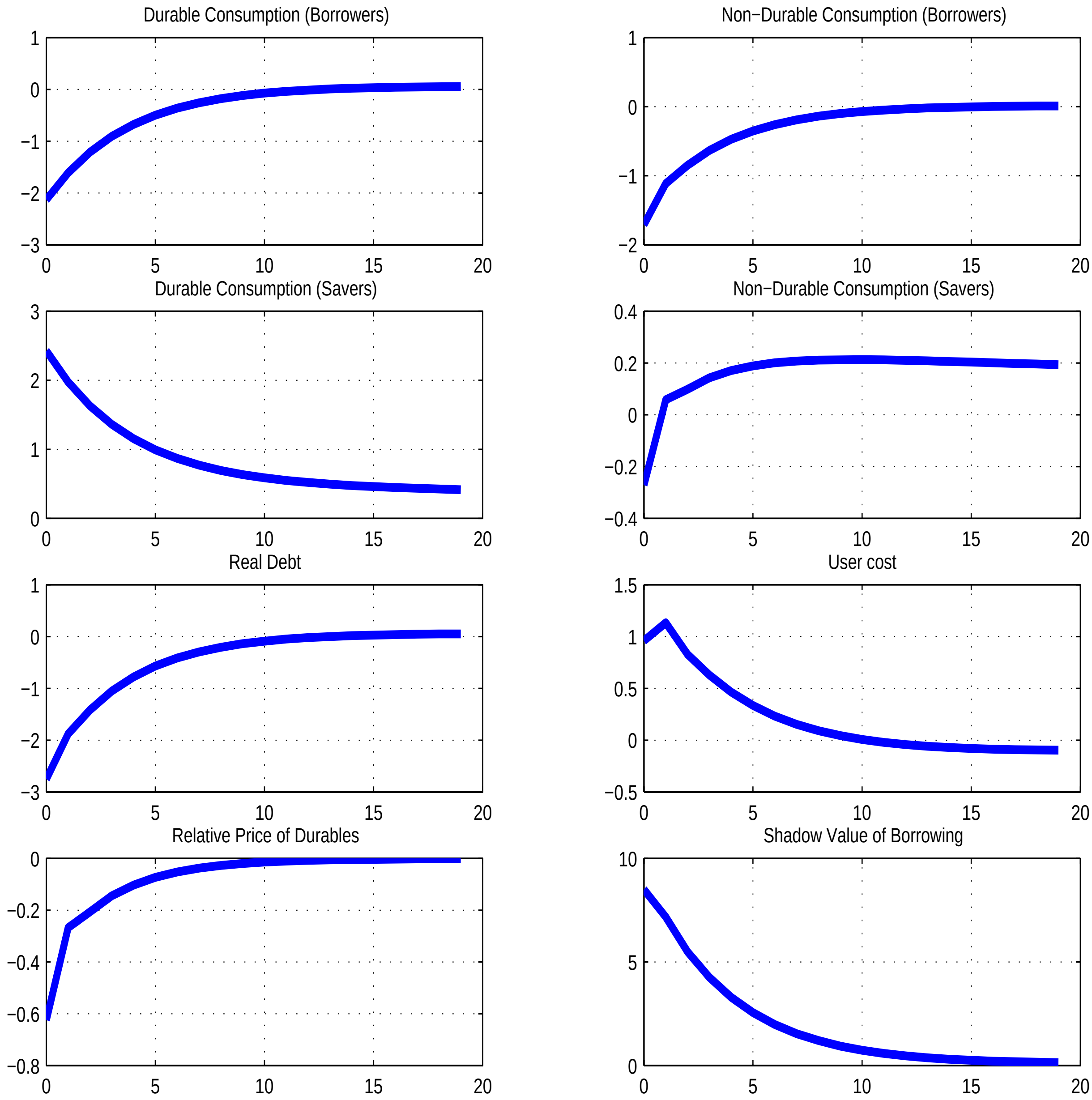

Figure 7: **Response to a Monetary Policy Tightening: Model with Collateral Constraint (flexible durable prices).**

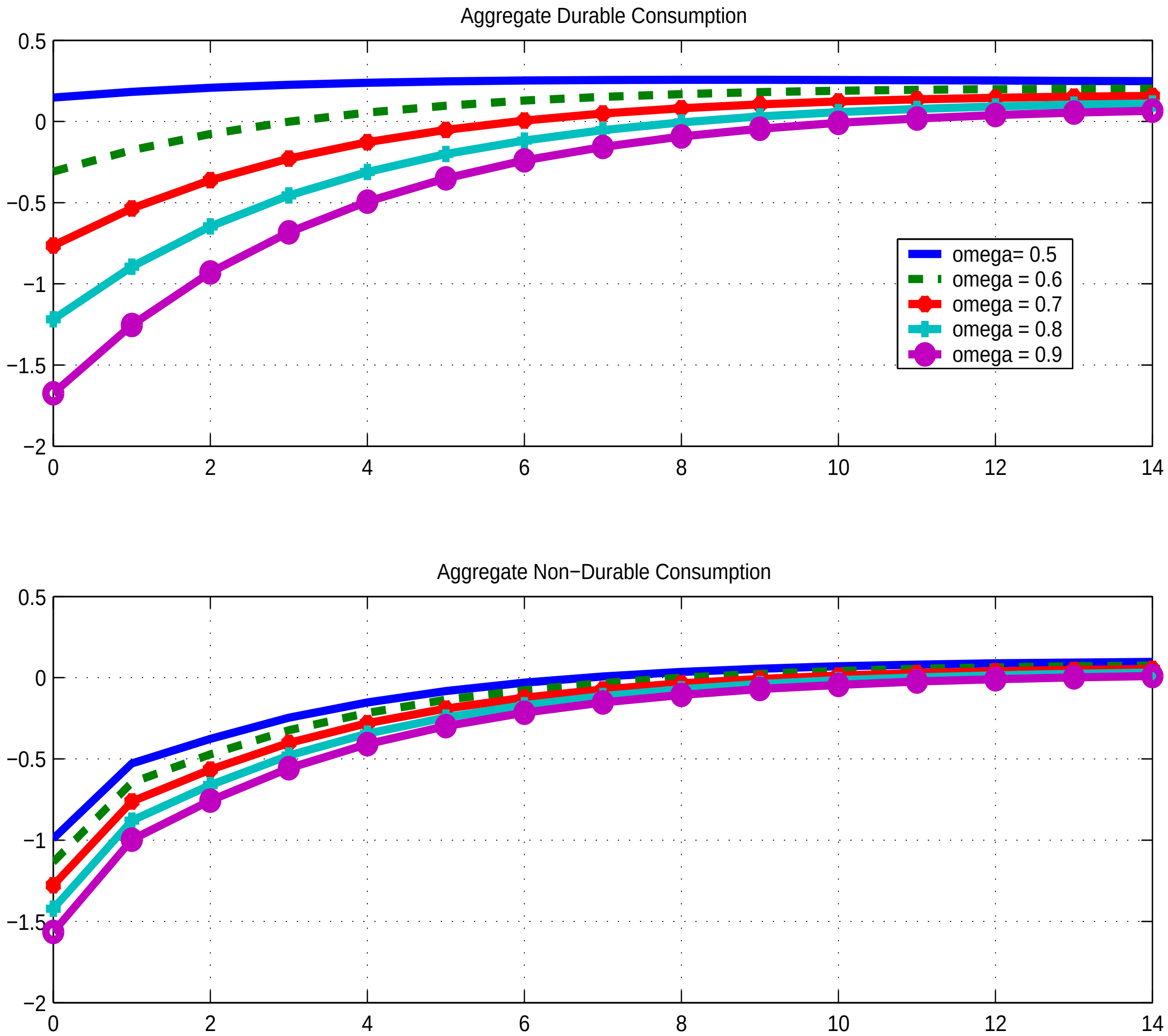

Figure 8: **Response of *Aggregate* Consumption to a Monetary Policy Tightening: Effect of Varying the Share of Impatient Agents** ω **(model with collateral constraint and flexible durable prices).**

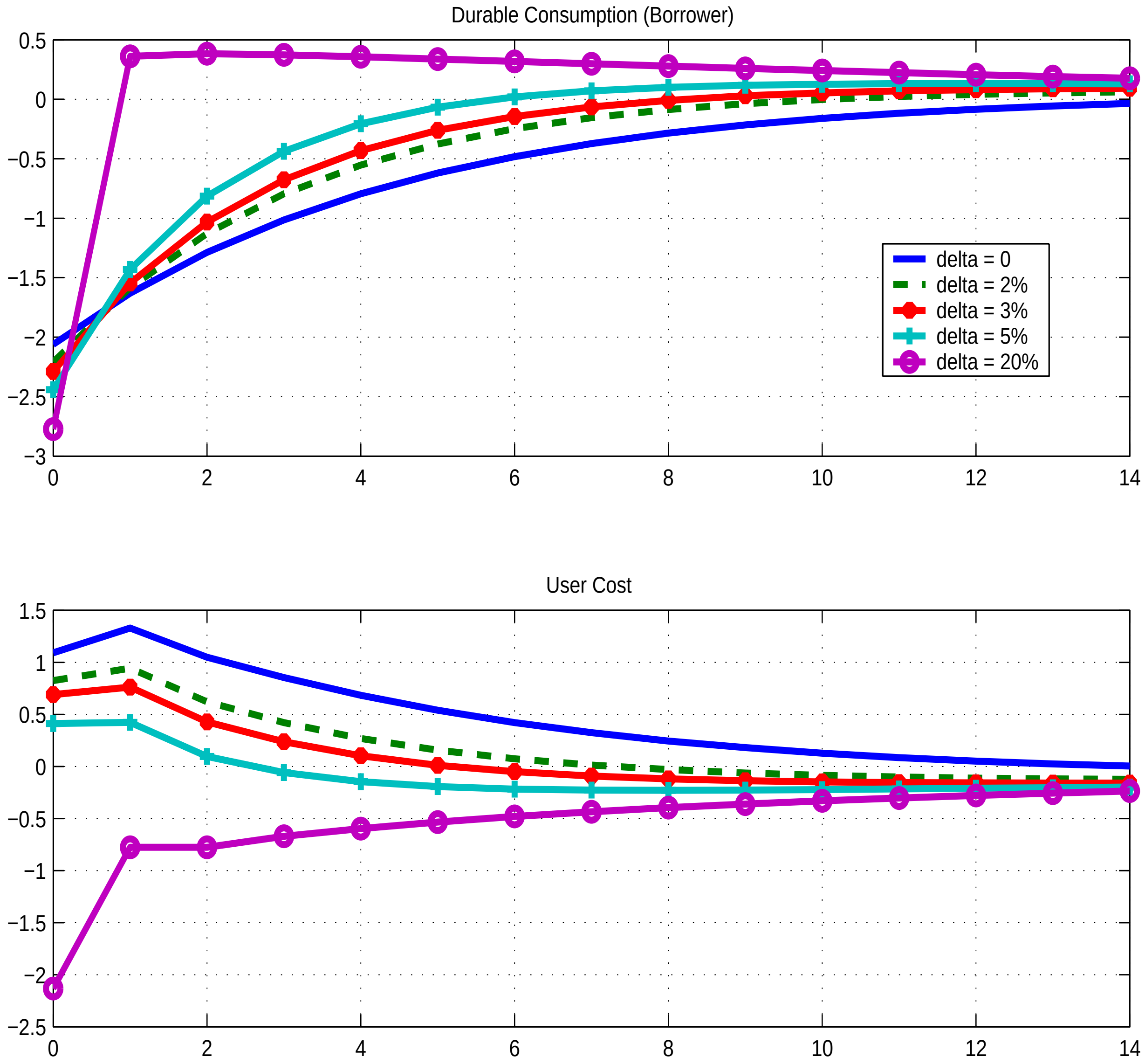

Figure 9: **Effect of Varying the Depreciation Rate δ : Model with Collateral Constraint (flexible durable prices).**

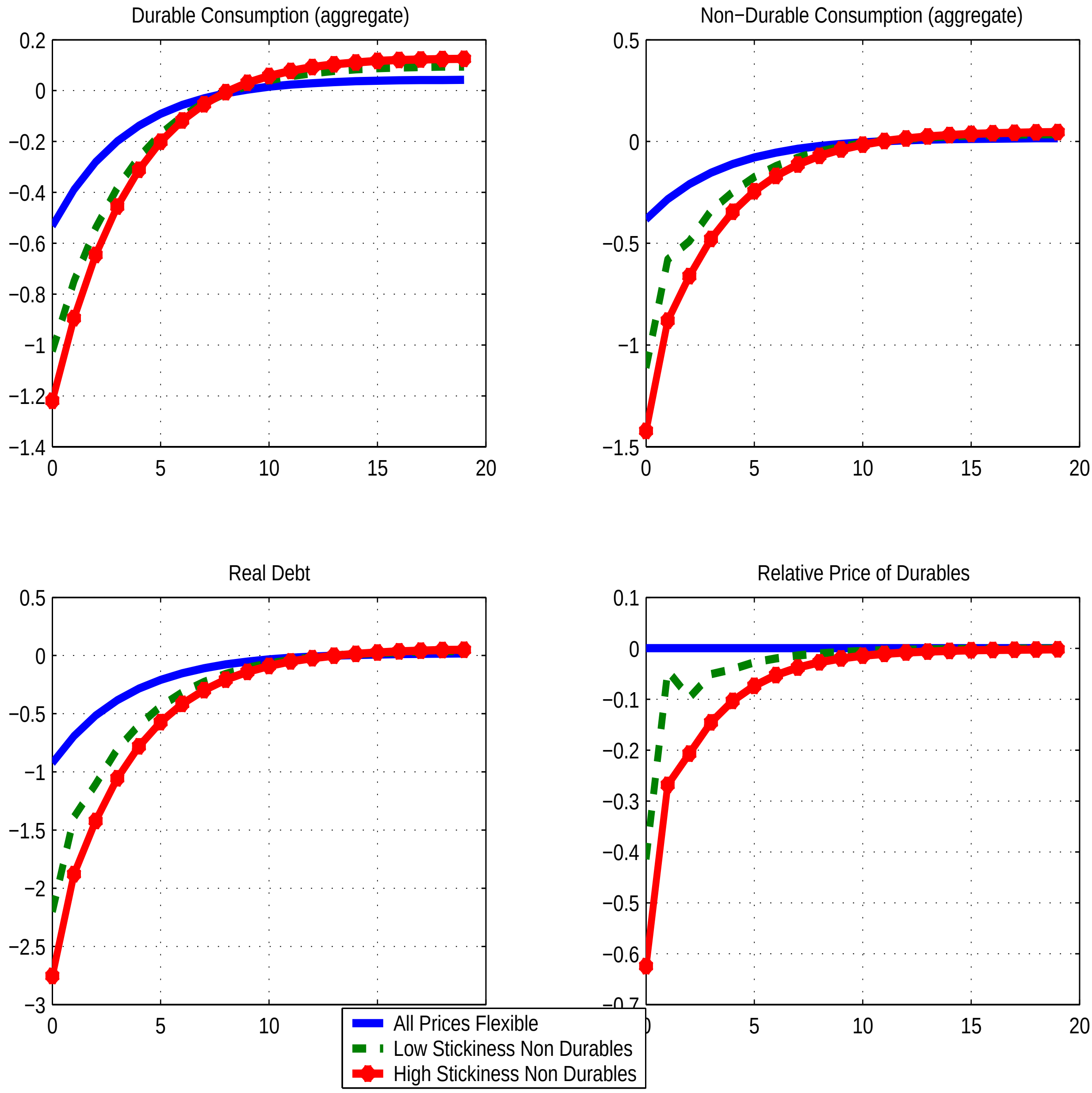

Figure 10: **Effect of Varying the Degree of Stickiness in *Non-Durable* Prices: Model with Collateral Constraint (flexible durable prices).**