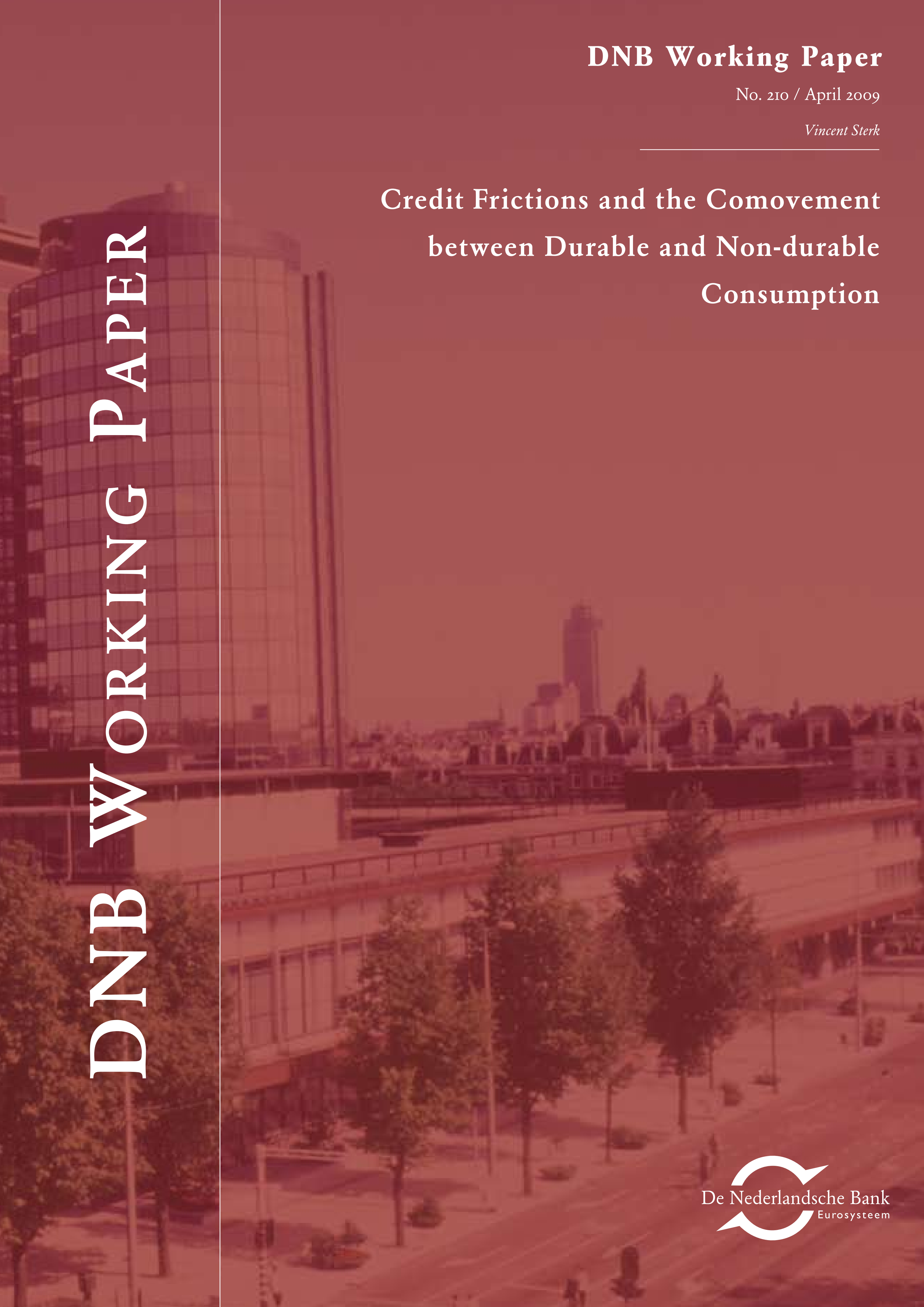

DNB Working Paper

No. 210 / April 2009

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Credit Frictions and the Comovement between Durable and Non-durable Consumption

DNB WORKING PAPER

De Nederlandsche Bank
Eurosysteem

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* Views expressed are those of the author and do not necessarily reflect official positions of De Nederlandsche Bank.

Working Paper No. 210/2009

April 2009

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Credit Frictions and the Comovement between Durable and Non-durable Consumption*

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April 22, 2009

Abstract

According to Monacelli (2009), a standard New-Keynesian model augmented with credit frictions solves the outstanding challenge to generate a joint decline of durable and non-durable consumption during a monetary tightening. This paper shows that his success in generating positive comovement between durables and non-durables is solely due to assumptions about price-stickiness in the durable goods sector and that the introduction of credit frictions actually makes the comovement problem harder to solve.

JEL classification: E44, E52

Keywords: New-Keynesian models, financial frictions, general equilibrium

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*I am grateful to my supervisor Wouter den Haan for his very helpful comments and support. I would also like to thank Pierre Lafourcade, Christian Stoltenberg, and seminar participants at De Nederlandsche Bank and the University of Amsterdam for useful comments, Tommaso Monacelli for providing his programs, and Matteo Iacoviello for a useful idea regarding the accuracy test. All errors are mine.

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1 Introduction

An undesirable feature of standard New-Keynesian models is that they tend to generate counterfactual comovements between durable and non-durable consumption. That is, following a contractionary monetary shock non-durable purchases decrease, but purchases of durables increase. In some cases, the expansion in the durable goods producing sector is so large that the monetary tightening has almost no effect on total aggregate output.

As pointed out by Barsky, House, and Kimball (2007), these predictions are in sharp contrast with the conventional wisdom and empirical evidence that especially durable consumption falls during a monetary tightening.[1] They also show that the comovement problem originates from the fact that in a standard representative agent model without financial frictions the shadow value of durables is quasi-constant. This means that the utility gain from additional durables is almost time-invariant, and the implication is that households only change their labor supply in response to changes in the real wage in units of durables. When producers of durables do not face any costs on price adjustment, they set their prices according to a constant markup over the nominal wage, which implies that the real wage in units of durables is constant.[2][3] It follows that total hours worked and, therefore, total output hardly responds to monetary shocks. At the same time, the relative price of durables decreases following a contractionary monetary shock, because durable prices are flexible and non-durable prices are not. This leads to a substitution from non-durable towards durable purchases, which creates the negative comovement.

Barsky, House, and Kimball (2003) suggest that one reason why standard models have difficulties matching the empirical evidence could be that they assume frictionless financial

[1] For empirical evidence on the effects of monetary shocks on durable and non-durable consumption, see for example Bernanke and Gertler (1995), Barsky, House, and Kimball (2003), and Monacelli (2009).

[2] The literature typically focuses on the extreme case of completely flexible durable prices, when the comovement problem is most severe. According to Barsky, House, and Kimball (2007), prices of new homes are arguably flexible because they are usually the outcomes of negotiations. Concerning categories of durables for which there exists empirical micro-level evidence on price-setting behavior, Bils and Klenow (2004) report a median price duration of only 2 months for new cars.

[3] Labor is the only production input in the models considered in this paper, so nominal marginal costs equal the nominal wage. Barsky, House, and Kimball (2007) analyze models with productive capital and show that the comovement problem also arises in these models.

markets. After a monetary tightening credit constraints may become tighter, and a reduced ability to borrow then forces credit-constrained households to purchases less durables. Monacelli (2009) formalizes this argument by extending the standard model to feature credit-constrained impatient agents who borrow from patient agents who are not at a credit constraint. He shows that *if* one also allows for a moderate degree of price-stickiness in the durable goods producing sector, the model with credit frictions is able to generate a positive comovement between durables and non-durables.

This paper builds on the analysis in Monacelli (2009) and investigates how much the credit frictions contribute to solving the comovement problem, relative to assuming that prices of durable goods are somewhat sticky. By comparing the results of his model to a stripped-down version without credit frictions, it is shown that without credit frictions it is easier to generate positive comovement, that is, less stickiness of durable prices is needed. While it is the case that credit constrained households reduce their durable purchases after a monetary tightening, the other households increase their durable purchases so much that the response of aggregate durable purchases is more positive than in the standard model without credit frictions. In the special case of fully flexible durable prices, the addition of credit frictions leads to a *positive* response of total aggregate output to a monetary tightening, whereas the standard model without credit frictions predicts a flat response.

To understand why adding frictions in lending between households does not help to solve the comovement problem, it is important to keep in mind that the credit frictions typically considered in the literature do not eliminate equilibrium in the bond market. When aggregate borrowing by the credit-constrained households is reduced as a consequence of tighter credit constraints, then the bond market only remains in equilibrium if aggregate savings by the patient households decreases by the exact same amount. Since buying durables is an alternative way of saving, the patient households can avoid a large distortion of their intertemporal plans by purchasing more durables instead of saving trough bonds. This behavior undermines the seemingly straightforward intuition that introducing credit frictions helps to solve the comovement problem by generating a decrease in durable purchases by the credit-constrained households.

But why does the introduction of credit frictions make the comovement problem even more severe? Consider again the shadow value of durables. For savers (and borrowers who are not credit-constrained), the shadow value of durables is again nearly constant, because their optimality conditions are the same as in the model without credit frictions. In contrast, impatient households in the model with credit frictions face an increase in the shadow value of durables during a monetary tightening, because their credit-constraint becomes tighter and durables serve as collateral for borrowing. Thus, credit-constrained households have incentives to dampen the effect of the reduced ability to borrow on their durable purchases, which they achieve by substituting away from non-durables and working more. This pushes down the response of aggregate *non-durable* consumption and pushes up the response of aggregate *total* output, relative to the model without credit frictions. As a consequence, the response of aggregate *durable* purchases is more positive than without credit frictions, so credit frictions make it more difficult to generate positive comovement between durables and non-durables.

2 Two sticky-price models with consumer durables

Two New-Keynesian models with durable and non-durable consumption are analyzed. The first one replicates the model of Monacelli (2009), which describes a standard sticky-price economy augmented with credit frictions. The second is the same model without credit frictions.

2.1 The model with credit frictions

The model features two types of households with different rates of time preference, that is, one group of households is more patient than the other. Because in equilibrium the impatient households borrow from patient households, they are referred to as *borrowers* and *savers*, respectively. Borrowing by the impatient households is restricted by a collateral constraint, which guarantees the existence of a well-defined steady state.[4] The size of the total population is normalized to one and the fraction of borrowers is set equal to ϖ.

[4] Similar constraints are considered in Kiyotaki and Moore (1997) and Iacoviello (2005).

Borrowers. Impatient households discount utility by a factor β. They maximize:

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

where $U(\cdot)$ is a utility function depending on labor supply N_t and a CES consumption basket X_t, that consists of non-durable goods C_t and the *stock* of durable goods D_t:

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

Each period, the borrowers face the following constraints:

$$P_{c,t} C_t + P_{d,t} I_{d,t} + R_{t-1} B_{t-1} = B_t + W_t N_t, \tag{1}$$

$$D_t = (1-\delta) D_{t-1} + I_{d,t}, \tag{2}$$

$$R_t B_t \leq (1-\chi)(1-\delta) E_t \{D_t P_{d,t+1}\}. \tag{3}$$

where $P_{c,t}$ is the price of non-durables, $P_{d,t}$ is the price of durables, $I_{d,t}$ is the amount of durable purchases, R_t is the gross nominal interest rate, B_t is the nominal amount of debt, and W_t is the nominal wage. Equations (1) and (2) are the budget constraint and the evolution of the durable stock, respectively. The collateral constraint (3) states that the level of debt must be such that the amount that has to be repaid in the next period cannot exceed a fraction $(1-\chi)$ of the expected value of the depreciated current durable stock one period ahead. Therefore, χ can be interpreted as a collateral requirement. It is assumed that the collateral constraint always binds.[5] Let ψ_t be defined as the ratio of the Lagrange multiplier of the borrowing constraint to the Lagrange multiplier of the budget constraint. The optimality conditions are:

$$\frac{-U_{n,t}}{U_{c,t}} = \frac{W_t}{P_{c,t}}, \tag{4}$$

$$q_t U_{c,t} = U_{d,t} + \beta (1-\delta) E_t \{U_{c,t+1} q_{t+1}\} + (1-\chi)(1-\delta) U_{c,t} q_t \psi_t E_t \{\pi_{d,t+1}\}, \tag{5}$$

$$R_t \psi_t = 1 - \beta E_t \left\{ \frac{U_{c,t+1}}{U_{c,t}} \frac{R_t}{\pi_{c,t+1}} \right\}, \tag{6}$$

where $-U_{n,t}$, $U_{d,t}$ and $U_{c,t}$ are the marginal utilities of leisure, durables and non-durables, respectively, $q_t \equiv \frac{P_{d,t}}{P_{c,t}}$ is the relative price of durables, and $\pi_{j,t} \equiv \frac{P_{j,t}}{P_{j,t-1}}$ is gross inflation in

[5] It can be shown that the borrowing constraint is binding in the deterministic steady state, so that the borrowers will have a positive level of debt in the steady state. Unlike standard practice, this paper features an accuracy test to check the validity of the assumption that the constraint always binds.

sector j, with $j \in$ {non-durables,durables}. Equation (4) is the standard optimality condition for labor, which equates the marginal utility of leisure to the product of the real wage and the marginal utility of non-durable consumption. The right hand side of Equation (5) is the *shadow value of durables*, which is the sum of the immediate utility gain of an additional unit of durables, the discounted expected value of the undepreciated part of the durable next period and a term reflecting the utility gain from the additional borrowing capacity. This last term is proportional to ψ_t, which measures the tightness of the borrowing constraint. At the optimum, the shadow value of durables must be equal to the marginal utility gain that is derived from buying q_t non-durable goods. Equation (6) would reduce to the standard Euler equation if the constraint would not be binding, that is, when $\psi_t = 0$.

Savers. The patient households or savers have a discount factor $\gamma > \beta$ and their variables are characterized by a tilde. Because of the higher degree of patience, these households purchase the bonds issued by the borrowers in equilibrium. Savers face a similar optimization problem as the borrowers, but without the borrowing constraint. Also, savers own the firms and receive their profits. The optimality conditions of the savers are:

$$\frac{-\widetilde{U}_{n,t}}{\widetilde{U}_{c,t}} = \frac{W_t}{P_{c,t}}, \tag{7}$$

$$q_t \widetilde{U}_{c,t} = \widetilde{U}_{d,t} + \gamma (1-\delta) E_t \left\{ \widetilde{U}_{c,t+1} q_{t+1} \right\}, \tag{8}$$

$$1 = \gamma E_t \left\{ \frac{\widetilde{U}_{c,t+1}}{\widetilde{U}_{c,t}} \frac{R_t}{\pi_{c,t+1}} \right\}. \tag{9}$$

Final goods producers. Final goods producers create bundles from intermediate goods and sell those to households. In each of the two sectors, there is a continuum of intermediate goods indexed by i on $[0,1]$. The final goods markets are perfectly competitive and producers use only the intermediate goods as inputs. Let $Y_{j,t}(i)$ denote the inputs of intermediate good i in sector j and let $Y_{j,t}$ be the quantity of the final good produced. The production function takes the form of the Dixit-Stiglitz aggregator:

$$Y_{j,t} = \left(\int_0^1 Y_{j,t}(i)^{\frac{\varepsilon_j - 1}{\varepsilon_j}} di \right)^{\frac{\varepsilon_j}{\varepsilon_j - 1}}, \varepsilon_j > 1.$$

Profit maximization results in the following well-known equation for demand for intermediate goods:

$$Y_{j,t}(i) = \left(\frac{P_{j,t}(i)}{P_{j,t}}\right)^{-\varepsilon_j} Y_{j,t},$$

with associated price index $P_{j,t} \equiv \left(\int_0^1 P_{j,t}(i)^{1-\varepsilon_j} di\right)^{\frac{1}{1-\varepsilon_j}}$.

Intermediate goods producers. Inputs for the final goods are supplied by intermediate goods producers. Producer i in sector j has the following production function:

$$Y_{j,t}(i) = N_{j,t}(i),$$

where $N_{j,t}(i)$ denotes the amount of labor that is used by producer i in sector j. Since intermediate goods are slightly differentiated, their producers have some price-setting power. Nominal profits at period t are given by

$$\Pi_t = Y_{j,t}(i)P_{j,t}(i) - W_t N_{j,t}(i) - \frac{\vartheta_j}{2}\left(P_{j,t}(i)/P_{j,t-1}(i) - 1\right)^2 Y_{j,t}P_{j,t},$$

where the last term is a quadratic cost of price adjustment. Intermediate goods firms maximize profits using the stochastic discount factor of the savers, i.e., they maximize

$$E_0 \sum_{t=0}^{\infty} \gamma^t \frac{\widetilde{U}_{c,t}}{\widetilde{U}_{c,0}} \frac{P_{c,0}}{P_{c,t}} \Pi_t,$$

subject to their production function and the demand equation. For a symmetric equilibrium, the optimality conditions for the non-durable and durable sector can be written as

$$(1-\varepsilon_c) + \varepsilon_c w_t = \vartheta_c\left(\pi_{c,t} - 1\right)\pi_c - \gamma\vartheta_c E_t\left[\frac{\widetilde{U}_{c,t+1}}{\widetilde{U}_{c,t}}\frac{Y_{c,t+1}}{Y_{c,t}}\left(\pi_{c,t+1} - 1\right)\pi_{c,t+1}\right], \quad (10)$$

$$(1-\varepsilon_d) + \varepsilon_d \frac{w_t}{q_t} = \vartheta_d\left(\pi_{d,t} - 1\right)\pi_{d,t} - \gamma\vartheta_d E_t\left[\frac{\widetilde{U}_{c,t+1}}{\widetilde{U}_{c,t}}\frac{q_{t+1}}{q_t}\frac{Y_{d,t+1}}{Y_{d,t}}\left(\pi_{d,t+1} - 1\right)\pi_{d,t+1}\right], \quad (11)$$

where $w_t \equiv W_t/P_{c,t}$ is the real wage in units of non-durables, and w_t/q_t is the real wage in units of durables. When prices are fully flexible, firms set their prices according to a constant markup over nominal marginal costs, which is the nominal wage in this model. Thus, when prices of durables are fully flexible, i.e. when $\vartheta_d = 0$, the real wage in units of durables $w_t/q_t = W_t/P_{d,t}$ is constant and from Equation (11) it can be seen that it equals $(\varepsilon_d - 1)/\varepsilon_d$.

Market clearing conditions and monetary policy. Goods market clearing requires

$$
\begin{aligned}
Y_{c,t} &= \varpi C_t + (1-\varpi)\widetilde{C}_t + \frac{\vartheta_c}{2}(\pi_{c,t}-1)^2 Y_{c,t}, \\
Y_{d,t} &= \varpi I_{d,t} + (1-\varpi)\widetilde{I}_{d,t} + \frac{\vartheta_d}{2}(\pi_{d,t}-1)^2 Y_{d,t}.
\end{aligned}
$$

Bond market clearing implies

$$\varpi B_t + (1-\varpi)\widetilde{B}_t = 0.$$

Labor market clearing and the production functions give

$$Y_{c,t} + Y_{d,t} = \varpi N_t + (1-\varpi)\widetilde{N}_t, \tag{12}$$

The model is closed by the following monetary policy rule:

$$\frac{R_t}{R} = \left(\frac{\widetilde{\pi}_t}{\widetilde{\pi}}\right)^{\xi_\pi} \exp(\varepsilon_t), \tag{13}$$

where $\widetilde{\pi}_t = \pi_{c,t}^{1-\tau}\pi_{d,t}^{\tau}$ is a composite inflation index and R and $\widetilde{\pi}$ are the steady state levels of the nominal interest rate and the inflation index, respectively. The monetary policy shock, ε_t, evolves according to

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

where $u_t \sim iid$ and ρ lies between zero and one.

2.2 The standard model without credit frictions

The model with credit frictions can be modified to obtain the standard model by simply setting the fraction of borrowers ϖ equal to zero. In the absence of household heterogeneity, debt equals zero in equilibrium.

2.3 The comovement problem in the standard model

As explained by Barsky, House, and Kimball (2007), the key property of the standard model driving the comovement problem is the quasi-constancy of the shadow value of durables. This means that households hardly care about the timing of their durable purchases. Recall that the shadow value of durables is the right hand side of the durable optimality condition (8) and note that this equation can be rewritten as follows:

$$q_t \widetilde{U}_{c,t} = E_t \sum_{k=0}^{\infty} \gamma^k (1-\delta)^k \widetilde{U}_{d,t+k} \approx const. \tag{14}$$

The shadow value of durables is quasi-constant because the marginal utility of durables depends on the *stock* of durables variations, and variations in the *flow* of durables generate only small variations in the stock. Also, the shadow value of durables depends for an important part on the marginal utility of durables in the distant future, which is even less affected by temporary shocks. As a consequence of the near constancy of the shadow value of durables, the relative price of durables q_t and the marginal utility of non-durable consumption $\widetilde{U}_{c,t}$ move in opposite directions. When prices of durables are flexible relative to prices of non-durables, the relative price of durables q_t falls during a monetary tightening, creating more incentives for households to purchase durables. At the same time, the decrease in q_t must be accompanied by an increase in the marginal utility of non-durables $\widetilde{U}_{c,t}$, which is associated with a lower level of non-durable consumption.

More insight in the comovement problem can be obtained by considering the special case of fully flexible durable prices. In the absence of price adjustment costs, the optimal pricing equation for durable producers (11) reduces to

$$\frac{w_t}{q_t} = \frac{\varepsilon_d - 1}{\varepsilon_d},$$

so the real wage in units of durables w_t/q_t is constant. As a consequence, total output is roughly unaffected by monetary shocks. This follows from the labor optimality condition (7). An alternative representation of this condition equates the marginal utility of leisure to the product of the real wage in units of durables w_t/q_t and the shadow value of durables, which equals $q_t \widetilde{U}_{c,t}$:

$$-\widetilde{U}_{n,t} = \frac{w_t}{q_t} q_t \widetilde{U}_{c,t}.$$

Given that the real wage in units of durables is constant and the shadow value of durables is quasi-constant, labor cannot move much either. The same must hold for total output, since labor is the only production input. Also, the relative durable price q_t decreases after a monetary tightening, and the quasi-constancy of $q_t \widetilde{U}_{c,t}$ then implies that with a standard utility function, non-durable consumption also decreases. Since total output remains roughly constant, durable purchases must increase. Hence, durable purchases comove negatively with non-durable purchases.[6]

2.4 Calibration and solution method

Both models are calibrated to a quarterly frequency and the calibration follows Monacelli (2009). Parameter values are shown in Table 1. The utility functions of the borrowers and the savers take the following form:

$$U(X_t, N_t) = \log(X_t) - \frac{\nu N_t^{1+\varphi}}{1+\varphi}, \ \nu > 0,$$

where the parameter ν is set differently for the borrower and the saver and it is calibrated to normalize labor supply to 1/3 in the steady state for each type of household. The parameter α in the CES basket is the same for both types of households and it is calibrated such that in the steady state, aggregate durable expenditures are 20% of aggregate total expenditures.

The parameter τ reflecting the weight of durables in the composite inflation index in the monetary policy rule is set to zero, that is, monetary policy only responds to inflation in the non-durable goods sector.[7] Following Monacelli (2009), the observational equivalence between the log-linearized versions of the Rotemberg model with quadratic price adjustment costs and the Calvo-Yun model is exploited to calibrate the price adjustment cost parameters. The non-durable price adjustment cost parameter ϑ_c is calibrated to correspond to one price adjustment per four quarters on average. Since the durable price adjustment cost parameter has important effects on the model dynamics and empirical evidence regarding this parameter is limited, several values for ϑ_d are considered, ranging from four quarter stickiness to full flexibility. The model is solved by a first-order perturbation method in logarithms.

[6] This argument abstracts from resources used to change prices. In a log-linearized version of the model, these costs are equal to zero.

[7] Monacelli (2009) proposes to set τ equal to α. His numerical results however, are based on a value of τ equal to zero, which means that monetary policy responds only to non-durable prices. To facilitate comparison, τ is also set to zero here. Appendix A investigates the consequences of adopting the assumption that monetary policy also responds to prices of durables. It is shown that it with this more realistic assumption, it becomes more difficult to generate positive comovement.

3 Results

A solution to the comovement problem requires a model that predicts a fall of both non-durable and durable purchases after a monetary tightening as well as a rise of the nominal interest rate.[8] Monacelli (2009) shows that a model with (i) credit frictions and (ii) moderate price-stickiness in the durable sector is able to generate these predictions. In this section, the results of the model *with* credit frictions are compared directly to those of the standard model *without* credit frictions. It is shown that, in contrast to what the results in Monacelli (2009) might suggest, credit frictions are not helpful in solving the comovement problem. In fact, positive comovement between durables and non-durables is more easily generated without them. In addition, the model with credit frictions is shown to suffer from a number of other problems.

3.1 Comparing the two models

Figure 1 plots the Impulse Response Functions (IRFs) for the nominal interest rate, aggregate durable and non-durable purchases, and aggregate total output to a monetary tightening for both models. Each row corresponds to a different level of durable price-stickiness.[9]

First consider the model with credit frictions. The top row shows the results for the case of fully flexible durable prices. The responses of durable and non-durable purchases display the comovement problem as reported in the literature. But while Barsky, House, and Kimball (2007) found that in their model without credit frictions total output remains almost constant after a monetary tightening, the model with credit friction even predicts an increase in total output, which is at odds with the typical decrease found in empirical studies. The IRFs in the bottom row correspond to four quarter durable price-stickiness, so in that case prices of durables and non-durables are equally sticky. For this calibration, both durable and non-durable purchases decrease, but the nominal interest rate moves in the wrong direction. The figure also plots the

[8] It is important to consider the nominal interest rate, because although increasing price stickiness in the durable goods sector is helpful in solving the comovement problem, it actually makes it more difficult to generate a realistic response of the nominal interest rate, as shown by Barsky, House, and Kimball (2007) and Monacelli (2009).

[9] In the context of the model, a monetary tightening is defined as an increase in the exogenous shock variable ε_t, even though the nominal interest rate actually goes down for some calibrations.

case considered Monacelli (2009) that is successful in generating a positive comovement between durables and non-durables, as well as an increase in the nominal interest rate. This is achieved by calibrating durable price-stickiness to two quarters. However, even for this calibration the results are not free of problems. First, although durable purchases initially decline, their response already turns positive after one period, while the empirical evidence shows a persistent decline.[10] Second, the model predicts extremely large volatilities for durable purchases by the borrowers and savers. This can be seen from Figure 2, which plots the IRFs of durable purchases by the savers in the economy and the borrowers in the economy, as well as the IRF of total durable purchases. While aggregate durable purchases falls by less than 0.75 percent, the savers increase their durable purchase by more than 29 percent, while durable purchases by the borrowers decrease by more than 57 percent![11]

Now consider the standard model. The IRFs in the top row show that in the flexible durable price case, the standard model also predicts a negative comovement between durable and non-durable purchases. Without credit frictions, however, total output remains constant instead of displaying the counterfactual increase after a monetary tightening. The IRFs for the case where durable prices are as sticky as non-durable prices are plotted in the bottom row, which show that the nominal interest rate moves in the wrong direction in the standard model as well. The figure also shows that, for any level of durable price-stickiness, removing the credit frictions leads to a more negative response of non-durable purchases and a more positive response of durable purchases. With credit frictions it is, thus, more difficult to generate positive comovement and one needs to rely on a larger degree of durable price-stickiness.

There are two drawbacks to the exercise described above. First, comparing the two models with the same values of ϑ_d may not be fair, because the responses of the nominal interest rate are similar, but not exactly the same. Second, the discussion has focussed on the contemporaneous responses to a monetary shock, while a more complete description of comovements would also include longer horizons. For these reasons, an alternative exercise is carried out. To address

[10] See for example the empirical evidence in Monacelli (2009).

[11] The assumption that the borrowing always binds is another potential problem. Appendix B checks the validity of this assumption numerically and shows that the assumption is not problematic for the calibration considered in this paper.

the first concern, for each of the two models separately, ϑ_d is set as high as possible, but under the restriction the model still predicts a non-negative response of the nominal interest rate.[12] To address the second concern, comovement between durable and non-durable purchases is measured as the cumulative product of their IRFs.[13] Figure 3 plots this comovement measure for both models and shows that the standard model dominates the model with credit frictions at all horizons. The figure also shows that the comovement measure becomes negative for the model with credit frictions after three periods, while it remains positive for the model without credit frictions.

3.2 Why do credit frictions make the comovement problem more severe?

The idea behind introducing credit frictions to solve the comovement problem seems very intuitive. After a monetary tightening, the borrowing constraint becomes tighter, which forces borrowers to reduce both durable and non-durable of purchases. But this intuition is based on only one part of the model and ignores equilibrium aspects. In particular, when borrowing by the impatient households declines as a consequence of tighter credit constraints, equilibrium in the bond market requires that the patient households save less. Since buying durables is an alternative way to save resources, the patient households can be expected to increase their durable purchases as their savings decrease. A priori, it is therefore not obvious that frictions in lending between households contribute anything to generating a more negative response of *aggregate* durable purchases to a monetary tightening. In fact, the results in the previous subsection have shown that the decrease in durable purchases by the borrowers is washed away by an increase in durable purchases by the savers that is so large, that the response of aggregate durable purchases is even more positive than in the model without credit frictions.

The question arises whether this result is robust. That is, does the presence of credit frictions just make it harder to generate positive comovement for the chosen parameters, or is this a

[12] This is achieved by setting ϑ_d consistent with 2.4 quarter durable price stickiness in the standard model and 2.2 quarters in the model with credit frictions. In each of the two models, the nominal interest rate then responds just positively in the period of the shock.

[13] The properties of this measure of comovement are described in den Haan (2000). In particular, it corresponds to the covariance of the forecast errors of the model.

result that one can expect for other calibrations and modified versions of the model as well? The purpose of this section is to argue that there are intuitive reasons for the result that credit frictions make it more difficult to generate positive comovement and that one can expect this result to be true more generally.

It turns out that the differences in dynamics predicted by the model with and without credit frictions can all be traced back to what happens to the shadow value of durables. Define V_t as the shadow value of durables for the borrowers and rewrite their durable optimality condition (5) as

$$V_t = q_t U_{c,t} = \frac{U_{d,t} + \beta\left(1-\delta\right) E_t\left\{V_{t+1}\right\}}{1-\left(1-\chi\right)\left(1-\delta\right)\psi_t\left\{\pi_{d,t+1}\right\}}.$$

A tightening of the collateral constraint, reflected by an increase in ψ_t, will, ceteris paribus, lead to an increase in the shadow value of durables for the borrowers V_t.[14] The intuition is that when the utility gain from additional borrowing increases, the shadow value of durables also increases because durables serve as collateral for loans. Recall that for households who are not credit-constrained the shadow value of durables $\widetilde{V}_t$ is quasi-constant. Appendix C shows that because this is the case in both the model with and without credit frictions, the introduction of credit frictions leaves the responses of prices, wages and the nominal interest rate nearly unchanged.[15]

Given these preliminaries it can be shown that the introduction of credit frictions leads to (i) a more positive response of aggregate total output, (ii) a more negative response of aggregate non-durable consumption, implying (iii) a more positive response of aggregate durable consumption. As borrowers have incentives to dampen the decrease in durable purchases after a tightening of the credit constraint, they will be inclined to work more and use the extra wage income to buy durables. This pushes down the response of aggregate output. Borrowers also have more incentives to substitute away from non-durables and buy durables instead, which leads to a

[14] A monetary tightening also leads to an increase $U_{d,t}$, wich pushes up V_t as well. However, this effect is relatively small because variations in the stock of durables are small. Also, for sufficiently large levels of durable price stickiness, $E_t\left\{\pi_{d,t+1}\right\}$ decreases, which could also offset the increase in ψ_t. But note that the real interest rate in units of durables is quasi-constant, so calibrations for which $E_t\left\{\pi_{d,t+1}\right\}$ increases, are those for wich the nominal interest rate decreases. In our numerical results this effect never dominates as V_t always increases.

[15] Given that $\widetilde{V}_t$ is quasi-constant, it is possible to construct a subsystem that is the same for both models and that only contains the inflation rates, the relative price of durables, the real wage, the nominal interest rate and the monetary policy shock.

larger decrease of aggregate non-durable consumption. A more positive response of aggregate durable purchases then follows from the aggregate resource constraint.

To make this point formally, it is useful to express aggregate total output and aggregate non-durable durables as functions of the shadow values of durables. First consider aggregate total output. Recall that the labor optimality conditions of the households imply that the marginal utility of leisure equals the product of the real wage in units of durables w_t/q_t and the shadow value of durables, i.e.

$$\begin{aligned} \nu N_t &= \frac{w_t}{q_t} V_t, \\ \widetilde{\nu} \widetilde{N}_t &= \frac{w_t}{q_t} \widetilde{V}_t, \end{aligned}$$

where ν and $\widetilde{\nu}$ were defined as positive-valued parameters that pin down the steady state levels of labor. For a given response of the real wage in units of durables, households supply more labor when their shadow value of durables is higher. To proceed, combine the above conditions with the labor market clearing condition (12) to express total aggregate output Y_t^{agg} as

$$Y_t^{agg} \equiv Y_{c,t} + Y_{d,t} = \frac{w_t}{q_t} \left[\frac{\varpi}{\nu} V_t + \frac{1-\varpi}{\widetilde{\nu}} \widetilde{V}_t \right]. \tag{15}$$

It now becomes clear why in the special case of fully flexible durable prices, aggregate total output increases after a monetary tightening in the model with credit frictions. In this case, the real wage in units of durables w_t/q_t is constant because durable prices are set according to a constant markup over the nominal wage. Given that $\widetilde{V}_t$ remains roughly constant, total aggregate output almost perfectly follows the rise in the shadow value of the borrowers V_t when a sudden monetary contraction takes place.

In the more general case with possibly sticky durable prices, Equation (15) still explains why total aggregate output Y_t^{agg} responds more positively to a monetary tightening if the model contains credit frictions. Because the responses of prices and wages are nearly the same in both models, the effect of credit frictions on the response of total aggregate output cannot be explained by a different response of the real wage in durables w_t/q_t. The effect can also not be explained by $\widetilde{V}_t$, as the shadow value of durables for households who are not credit-constrained is quasi-constant in both models. The only variable that can explain why introducing credit frictions changes the response of total aggregate is the shadow value of durables for the credit-constrained households V_t. In the wake of a monetary tightening, V_t rises and shifts up the labor supply curve of the borrowers, which makes total output decrease less or even increase.

Similar logic can be applied to explain why introducing credit frictions lowers the response of aggregate non-durable consumption to a monetary tightening. The optimality conditions for durables (5) and (8) state that the shadow value of durables must be equal to the product of the relative price of durables q_t and the marginal utility of non-durable consumption, that is,

$$\begin{aligned} V_t &= q_t U_{c,t} = (1-\alpha)\, q_t / C_t, \\ \widetilde{V}_t &= q_t \widetilde{U}_{c,t} = (1-\alpha)\, q_t / \widetilde{C}_t. \end{aligned}$$

This allows us to express aggregate non-durable consumption C_t^{agg} as a function of q_t and the shadow values of durables:

$$C_t^{agg} \equiv \varpi C_t + (1-\varpi)\, \widetilde{C}_t = q_t\,(1-\alpha) \left[\frac{\varpi}{V_t} + \frac{1-\varpi}{\widetilde{V}_t} \right].$$

After a monetary tightening, the relative durable price of durables q_t decreases or, equivalently, the relative price of non-durables increases. Households who are not credit-constrained reduce their non-durable purchases proportionally. This is because the shock hardly affects the utility they derive from owning extra durables, as $\widetilde{V}_t$ is roughly constant. So aside from the price change, there are no extra incentives or disincentives to buy non-durables. To the credit-constrained households however, there are reasons to substitute away from non-durables towards durables, which is reflected by a rise in V_t. Given that the response of the relative durable price q_t is almost the same in both models, aggregate consumption must fall more in the model with credit frictions.

It is now straightforward to explain why adding credit frictions leads to a more positive response of aggregate durable purchases. When the response of total output is more positive after adding credit frictions, and non-durable consumption falls more, then the aggregate resource constraint can only remain satisfied if production in the durable goods producing sector responds more positively. Consequently, if the problem is that durables and non-durables move in opposite directions, then augmenting the model with credit frictions makes this problem even worse.[16][17]

4 Conclusion

The idea that frictions in consumer borrowing could lower the response of durable expenditures seems very sensible, and it would definitely work in a partial equilibrium model. In a general equilibrium model, however, the reduction in borrowing and durable purchases by the borrowers has consequences for the agents on other side on the other side of the bond market, i.e., the savers. If savers are not very different from borrowers, then a temporary reallocation of resources directly available to borrowers and savers fails to have important effects on the dynamics of aggregate variables. So the success of introducing credit frictions to a general equilibrium model depends crucially on heterogeneity between borrowers and lenders.

In the model of Monacelli (2009), borrowers are different from savers in the sense that their incentives to buy durables depend positively on the tightness of the credit constraint. This paper has demonstrated that it is exactly this feature that explains why his model has more difficulties in generating a negative response of durable purchases to a monetary tightening than the standard model without credit frictions.

Other modifications of the standard model seem more successful in solving the comovement puzzle. Carlstrom and Fuerst (2006) show that adding frictions in lending from *firms* to households helps to generate positive comovement between durables and non-durables, as does the introduction of sticky wages.

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[16] For the same reasons, increasing the share of borrowers in the total population does not help to solve the comovement problem.

[17] This holds not only for absolute changes, but also for changes expressed as percentage deviations from the steady state, because both models are calibrated to have the same steady state levels of aggregate output, aggregate durable consumption and aggregate non-durable consumption.

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Appendix

A Adopting a more realistic monetary policy rule

Following Monacelli (2009), the benchmark results are generated under the assumption that monetary policy attaches no weight to inflation in the durable goods sector.[18] In this appendix, the more realistic assumption is adopted that monetary policy responds to a composite index of inflation in the durable and non-durable sectors. The weight attached to durable inflation is chosen to reflect the share of durable purchases in total expenditures in the steady state, that is, τ is set to 0.2. Figure 4 plots the IRFs for both models with this monetary policy rule. The main difference with the benchmark rule is that the response of the nominal interest rate is more negative. With the more realistic monetary policy rule, the range of values for the durable price-stickiness parameter ϑ_d for which durable purchases, non-durable purchases, and the nominal interest rate all move in the desired directions right after the shock becomes very small for the standard model. The model with credit frictions performs even worse in the sense that there is no value for ϑ_d for which it generates positive comovement between durables and non-durables and a positive response of the nominal interest rate during the monetary tightening.

B Accuracy test

Monacelli (2009) shows that the borrowing constraint binds in the steady state. Following standard practice in the literature, he *assumes* that the borrowing constraint *always* binds, so that the model can be solved using perturbation methods. This paper also follows this tradition. However, the question arises whether the assumption of an always-binding constraint is correct for a realistic calibration of the model, including the standard deviation of the shocks. To the best of my knowledge, this issue has not been addressed in the literature, except in Iacoviello

[18] The numerical results in Monacelli (2009) are generated by setting τ equal to zero. In his model description, Monacelli (2009) proposes to set τ equal to α but provides no rationale for this choice. Recall that α is the parameter that determines the relative importance of the *stock* of durables in the CES consumption basket. The parameter α is, thus, not equal to the steady state expenditure share of durables.

(2005).[19] This is surprising because the properties of the model are potentially very different if the constraint does not always bind.

The accuracy test is closely related to the standard test of Judd (1992) that checks Euler equation errors and it does not require the use of a global solution technique. The basic idea is to calculate how much debt the borrowers would choose under the assumption that the constraint does not bind and see how often the chosen amount is less than what is allowed by the constraint. That is, the accuracy test checks how often the constraint is *not* binding.[20] The test is carried out by implementing the following steps:

1. Solve the model using a perturbation method (e.g. log-linearization).

2. Using the solution found in step 1, run a simulation of the state variables, and index simulated variables by $t = 1, ..., T$.

3. At each point in the simulation, shut off the borrowing constraint by setting ψ_t equal to zero. In that case, the first order conditions of the borrowers can be rewritten to find expressions for non-durables, durables and labor:

$$\text{from Equation (6)} : \quad C_t^* = \frac{1}{\beta R_t} E_t \left\{ \pi_{c,t+1} C_{t+1} \right\}, \tag{16}$$

$$\text{from Equation (5)} : \quad D_t^* = \frac{\alpha}{1-\alpha} \left(\frac{q_t}{C_t^*} - \beta \left(1-\delta\right) E_t \left\{ \frac{q_{t+1}}{C_{t+1}} \right\} \right)^{-1}, \tag{17}$$

$$\text{from Equation (4)} : \quad N_t^* = \left(\frac{w_t \left(1-\alpha\right)}{\nu C_t^*} \right)^{1/\varphi}, \tag{18}$$

where the stars indicate that variables are calculated under the assumption that the constraint does not bind. The values of R_t, q_t, and w_t are calculated using the policy functions found in step 1. The policy functions from step 1 are also used to approximate the conditional expectations by Gauss-Hermite quadrature.

[19] Iacoviello (2005) investigates the non-linear solution of a simplified partial equilibrium version of his model.

[20] The amount of debt chosen by the borrowers in the absence of a borrowing constraint can be calculated easily from the non-linear equilibrium conditions under the assumption that prices, wages, the nominal interest rate, the state variables and the conditional expectations are those predicted by the model with an always-binding constraint. That is, the assumption is that these variables are consistent with a binding constraint and the procedure checks whether the chosen debt level is consistent with a binding constraint as well.

4. Calculate rel debt from the budget constraint, with real debt defined as $b_t \equiv B_t / P_{c,t}$:

$$b_t^* = C_t^* + q_t \left(D_t^* - (1-\delta) D_{t-1} \right) + R_{t-1} \frac{b_{t-1}}{\pi_t} - w_t N_t^*,$$

and again use the policy functions found in step 1 to calculate q_t, D_{t-1}, R_{t-1}, b_{t-1}, π_t, and w_t.

5. Compare the level of debt in the absence of a binding borrowing constraint b_t^* to b_t, where b_t is the amount of debt chosen when the borrowing constraint always binds, which is calculated using the policy function found in step 1. If b_t^* is lower than b_t at some points in the simulation, then it can be concluded that the borrowing constraint is not always binding. I also investigate the consumption errors that arise from falsely assuming that the constraint binds, by comparing C_t^* to C_t and $I_{d,t}^*$ to $I_{d,t}$ at the points in the simulation where the constraint is found to be non-binding.

Running a simulation of the model requires further assumptions about the distribution of the innovations to the shocks. The assumption here is that they are normally distributed with mean zero and standard deviation σ_u, which is to be calibrated. With larger shocks, a non-binding constraint is a more likely outcome. The strategy followed here is to relate output volatility predicted by the model to output volatility in the data. Output volatility is estimated to be 0.0087 over the sample period 1988q1-2007q4.[21] To remain agnostic about the importance of monetary shocks, several values for the standard deviation of the monetary shocks are considered. These values are chosen such that output volatility predicted by the model is a certain percentage of output volatility in the data, ranging from 10% to 100%.

Another factor that affects the likelihood of the borrowing constraint to be non-binding, is the difference between the discount factor of the savers γ and the discount factor of the borrowers β. In the extreme case where the two types of households are equally patient, that is, when $\beta = \gamma$, the borrowing constraint will never be binding as debt equals zero in equilibrium. Thus, the closer the two discount factors are, the less likely it is that the borrowing constraint always binds. To investigate this issue quantitatively, I not only run the test with β equal to its

[21] The data series used for output is real GDP at a quarterly frequency, taken from the website of the Bureau of Economic Analysis. The log of this series is detrended using the HP-filter with $\lambda = 1600$.

benchmark value 0.98, but I also repeat the test with β equal to 0.985 and 0.989. These values are very close to the discount factor of the savers γ, which is equal to 0.99 in all calibrations.

To evaluate accuracy, criteria are needed. First define the variable I_t, indicating whether the constraint is non-binding:

$$\begin{aligned} I_t &= 1 \text{ if } b_t - b_t^* > 0, \\ I_t &= 0 \text{ otherwise,} \end{aligned}$$

and then define the following criteria:

$$\begin{aligned} \text{criterion 1} &\equiv 100 \times \frac{\sum_{t=1}^{T} I_t}{T}, \\ \text{criterion 2} &\equiv 100 \times \frac{\sum_{t=1}^{T} \frac{|b_t^* - b_t|}{b_t} I_t}{\sum_{t=1}^{T} I_t}, \\ \text{criterion 3} &\equiv 100 \times \frac{\sum_{t=1}^{T} \frac{|C_t^* - C_t|}{C_t} I_t}{\sum_{t=1}^{T} I_t}, \\ \text{criterion 4} &\equiv 100 \times \frac{\sum_{t=1}^{T} \frac{|D_t^* - D_t|}{D_t - (1-\delta) D_{t-1}} I_t}{\sum_{t=1}^{T} I_t}. \end{aligned}$$

The first criterion is the percentage of the cases where the constraint is found to be non-binding. The second, third, and fourth criteria are the average relative errors in the amount of debt, non-durable purchases, and durable purchases by the borrowers, respectively, conditional on the event of a non-binding borrowing constraint.

Table 2 reports the results. For the benchmark calibration with $\beta = 0.98$, the solution under the assumption of an always-binding constraint turns out to be accurate in the sense that in none of the points in the simulation the constraint becomes non-binding, even if the standard deviation of monetary policy shocks is calibrated to be so large that monetary policy shocks explain all output volatility present in the data.[22] Not surprisingly, the table also shows that as β approaches γ, the constraint becomes binding more often, resulting in serious inaccuracies, especially regarding durable purchases by the borrowers, $I_{d,t}$.

[22] This possibly change if one calibrates the model to feature other types of shocks as well. Because results would depend on the particular choice of shocks and their relative volatilities, I have limited the analysis to monetary policy shocks only.

The procedure above is based on a standard accuracy test, in which the conditional expectations are calculated using a very accurate numerical integration procedure. The accuracy test executed here focuses on only one particular feature of the model, namely whether the constraint is binding or not. In this case, it is possible to use a much simpler procedure that avoids using numerical integration. In particular, instead of calculating the conditional expectations in Equations (16) and (17) explicitly, one can use log-linear approximations. These can be obtained by simply adding the equations $x_{1,t} = E_t \{\pi_{c,t+1} C_{t+1}\}$ and $x_{2,t} = E_t \left\{ \frac{q_{t+1}}{C_{t+1}} \right\}$ to the system solved in step 1.[23] Figure 6 plots the two conditional expectations calculated under both methods and suggests that differences are small. Table 3 compares criterion 1, calculated with both procedures, and shows that with the direct log-linear approximation of the conditional expectations, the constraint is non-binding somewhat more often, but the conclusions about accuracy would be the same in all cases.

C Dynamics of prices and wages in the two models

This appendix shows that the introduction of credit frictions has only minor effects on the responses of prices and wages to a monetary shock. The Euler equation of the savers and the definition of the relative price of durables can be rewritten as:

$$\begin{aligned} 1 &= \gamma E_t \left\{ \frac{\widetilde{V}_{t+1}}{\widetilde{V}_t} \frac{R_t}{\pi_{d,t+1}} \right\}, \\ q_t &= \frac{\pi_{d,t}}{\pi_{c,t}} q_{t-1}. \end{aligned}$$

Log-linearizing these equations around a zero inflation steady state gives:

$$\begin{aligned} \widehat{R}_t &= E_t \widehat{\pi}_{d,t+1} + \widehat{\widetilde{V}}_t - E_t \widehat{\widetilde{V}}_{t+1}, \\ \widehat{q}_t &= \widehat{\pi}_{d,t} - \widehat{\pi}_{c,t} - \widehat{q}_{t-1}, \end{aligned}$$

where hatted variables denote log deviations from the steady state. The log-linearized versions the price setting equations (10) and (11), and the monetary policy rule (with only non-durable

[23] I would like to thank Matteo Iacoviello for this idea.

inflation) are:

$$\begin{aligned}
\widehat{\pi}_{c,t} &= \frac{1-\varepsilon_c}{\vartheta_c}\widehat{w}_t + \gamma E_t \widehat{\pi}_{c,t+1}, \\
\widehat{\pi}_{d,t} &= \frac{1-\varepsilon_d}{\vartheta_d}\left(\widehat{w}_t - \widehat{q}_t\right) + \gamma E_t \widehat{\pi}_{d,t+1}, \\
\widehat{R}_t &= \xi_\pi \widehat{\pi}_{c,t} + \varepsilon_t.
\end{aligned}$$

Since the shadow value of the unconstrained households is quasi-constant in both models, $\widehat{\widehat{V}}_t - E_t\widehat{\widehat{V}}_{t+1}$ will be roughly equal to zero. Ignoring this term leaves us with a dynamic system of 5 equations containing 5 endogenous variables, being $\widehat{R}_t$, $\widehat{\pi}_{c,t}$, $\widehat{\pi}_{d,t}$, $\widehat{w}_t$, and $\widehat{q}_t$, and the exogenous shock ε_t. Since this subsystem is found for both models, it follows that the responses of $\widehat{w}_t$, and $\widehat{q}_t$ cannot be very different. Figure 5 shows numerically that the differences in impulse responses generated by the two models for the real wage in units of durables w_t/q_t and the relative price of durables q_t are indeed very small.

Table 1: Parameter settings

parameter	description	Model with credit frictions	Standard model
β	discount factor borrowers	0.98	-
γ	discount factor savers	0.99	0.99
δ	depreciation rate durables	0.01	0.01
ε_c	el. of subst. between nondurable varieties	6	6
ε_d	el. of subst. between durable varieties	6	6
η	el. of subst. between durables and nondurables	1	1
ξ_π	coefficient on inflation in monetary policy rule	1.5	1.5
ϖ	share of borrowers	0.5	0
ρ	persistence parameter monetary policy shocks	0.5	0.5
χ	parameter in borrowing constraint	0.25	-
φ	inverse elasticity of labor supply	1	1

Note: As a robustness check, γ was set to 0.98 for the standard model and this did not affect the conclusions.

Table 2: Accuracy test for the model with credit frictions.

β	$\frac{\text{output volatility model}}{\text{output volatility data}}$	criterion1 (% non-binding)	criterion 2 (% error b_t)	criterion 3 (% error C_t)	criterion 4 (% error $I_{d,t}$)
0.98	10%	0.0	0.0	0.0	0.0
(benchmark)	25%	0.0	0.0	0.0	0.0
	50%	0.0	0.0	0.0	0.0
	100%	0.0	0.0	0.0	0.0
0.985	10%	0.0	0.0	0.0	0.0
	25%	0.0	0.0	0.0	0.0
	50%	0.0	0.0	0.0	0.0
	100%	1.1	0.0	0.0	1.2
0.989	10%	0.0	0.0	0.0	0
	25%	4.0	0.0	0.0	1.1
	50%	18.2	0.2	0.0	33.9
	100%	28.7	0.7	0.1	436.6

Note: The test is based on a simulation of length 51000, starting from the steady state and with the first 1000 observations discarded. Price stickiness of durables is set to 2 quarters. The percentages in the second column denote how much output volatility is predicted by the model with only monetary shocks, relative to output volatility observed in the data. Criterion 1 is the percentage of the cases in which the constraint is non-binding. Criterion 2, 3, and 4 are, respectively, the average of the absolute percentage errors in the amount of real debt, non-durable purchases and durable purchases by the borrowers, conditional on the event of a non-binding borrowing constraint. Conditional expectations are approximated using Gauss-Hermite quadrature with 10 nodes.

Table 3: Accuracy test: comparing the Gauss-Hermite approximation of the conditional expectations to a direct log-linear approximation.

		criterion 1 (% non-binding)	
β	$\frac{\text{output volatility model}}{\text{output volatility data}}$	Gauss-Hermite approximation	direct log-linear approximation
0.98	10%	0.0	0.0
(benchmark)	25%	0.0	0.0
	50%	0.0	0.0
	100%	0.0	0.0
0.985	10%	0.0	0.0
	25%	0.0	0.0
	50%	0.0	0.0
	100%	1.1	1.5
0.989	10%	0.0	0.0
	25%	4.0	4.3
	50%	18.2	20.1
	100%	28.7	33.3

Note: See Table 2.

Figure 1: Responses to a monetary tightening in the model with and without credit frictions, both with only nondurable inflation in the monetary policy rule ($\tau = 0$). The rows correspond to different degrees of durable price stickiness. Responses are plotted as percentage deviations from the steady state.

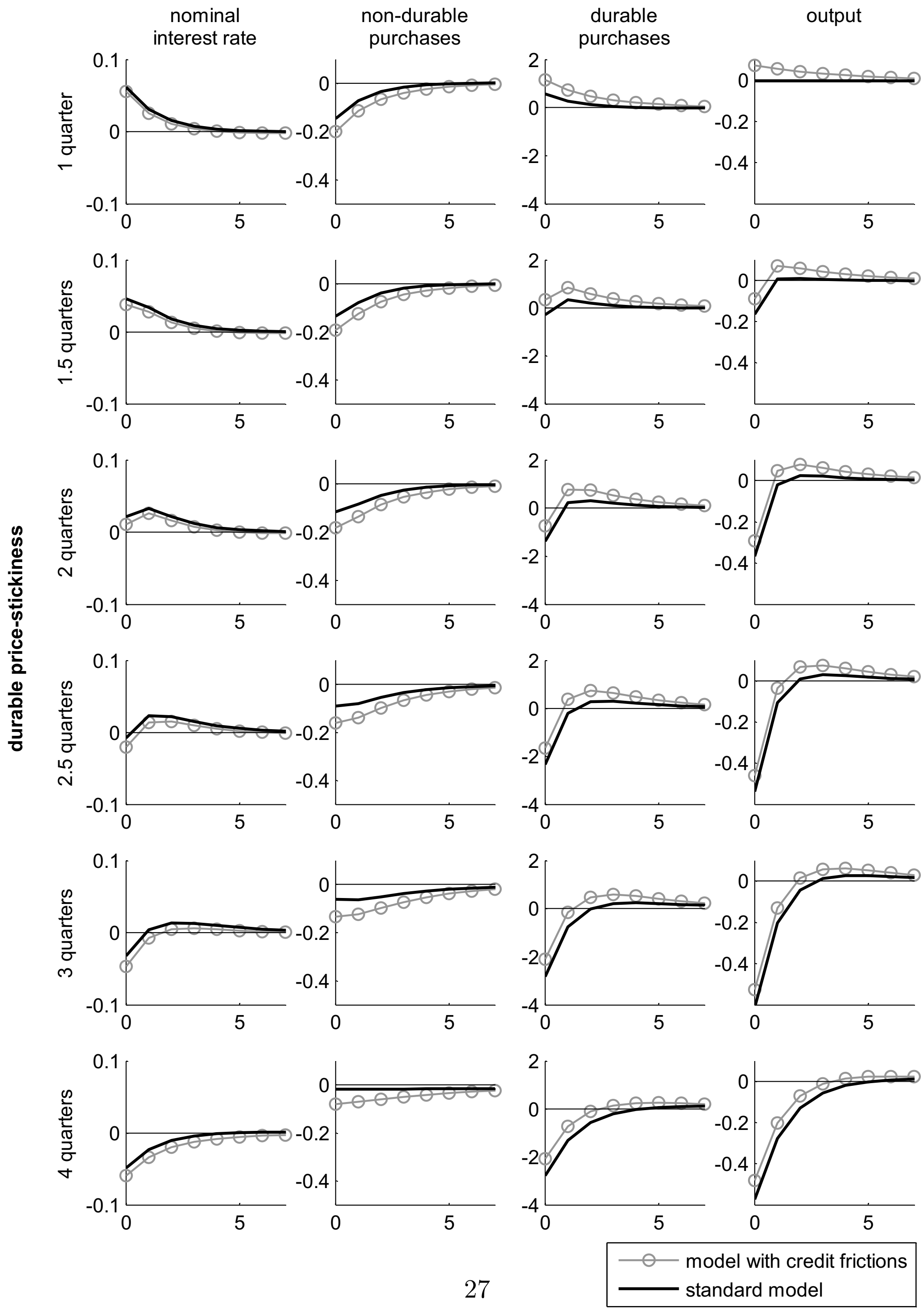


Figure 2: Responses to a monetary tightening of total durable purchases, as well as durable purchases by the borrowers and the savers in the model with credit frictions. Durable price-stickiness is set to 2 quarters. Responses are plotted as percentage deviations from the steady state.

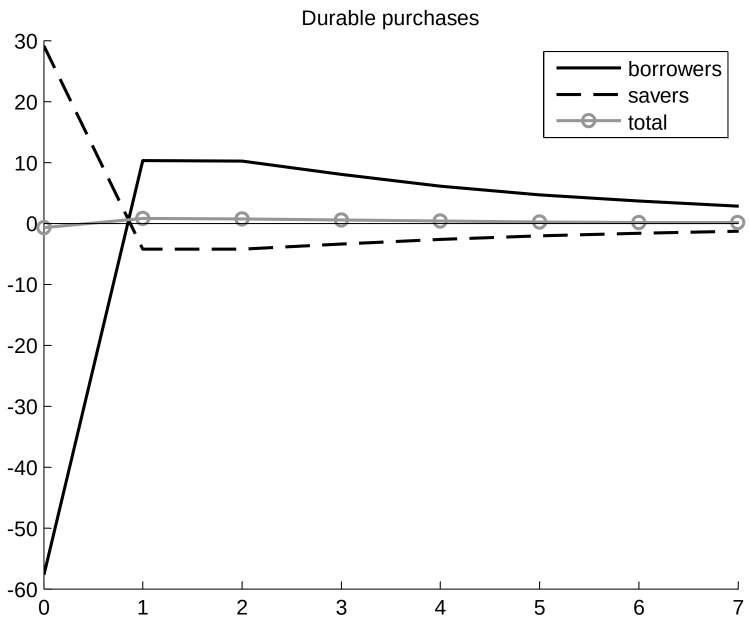
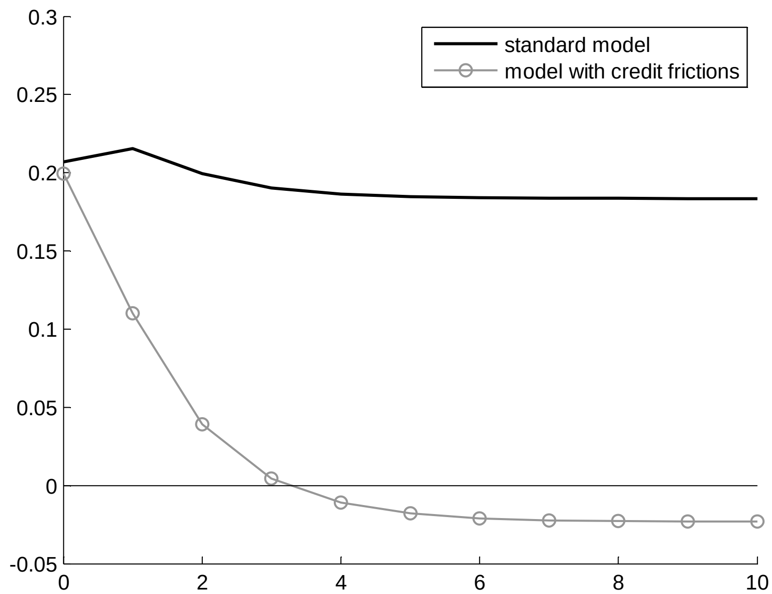


Figure 3: Comovement between durable and non-durable purchases: cumulative product of impulse responses.



Note: Both models are calibrated such that the initial response of the nominal interest rate is just positive. This is achieved by setting durable price stickiness to 2.4 quarters in the standard model and 2.2 quarters in the model with credit frictions.

Figure 4: Responses to a monetary tightening in the model with and without credit frictions, both with a composite inflation index in the monetary policy rule ($\tau = 0.2$). The rows correspond to different degrees of durable price-stickiness. Responses are plotted as percentage deviations from the steady state.

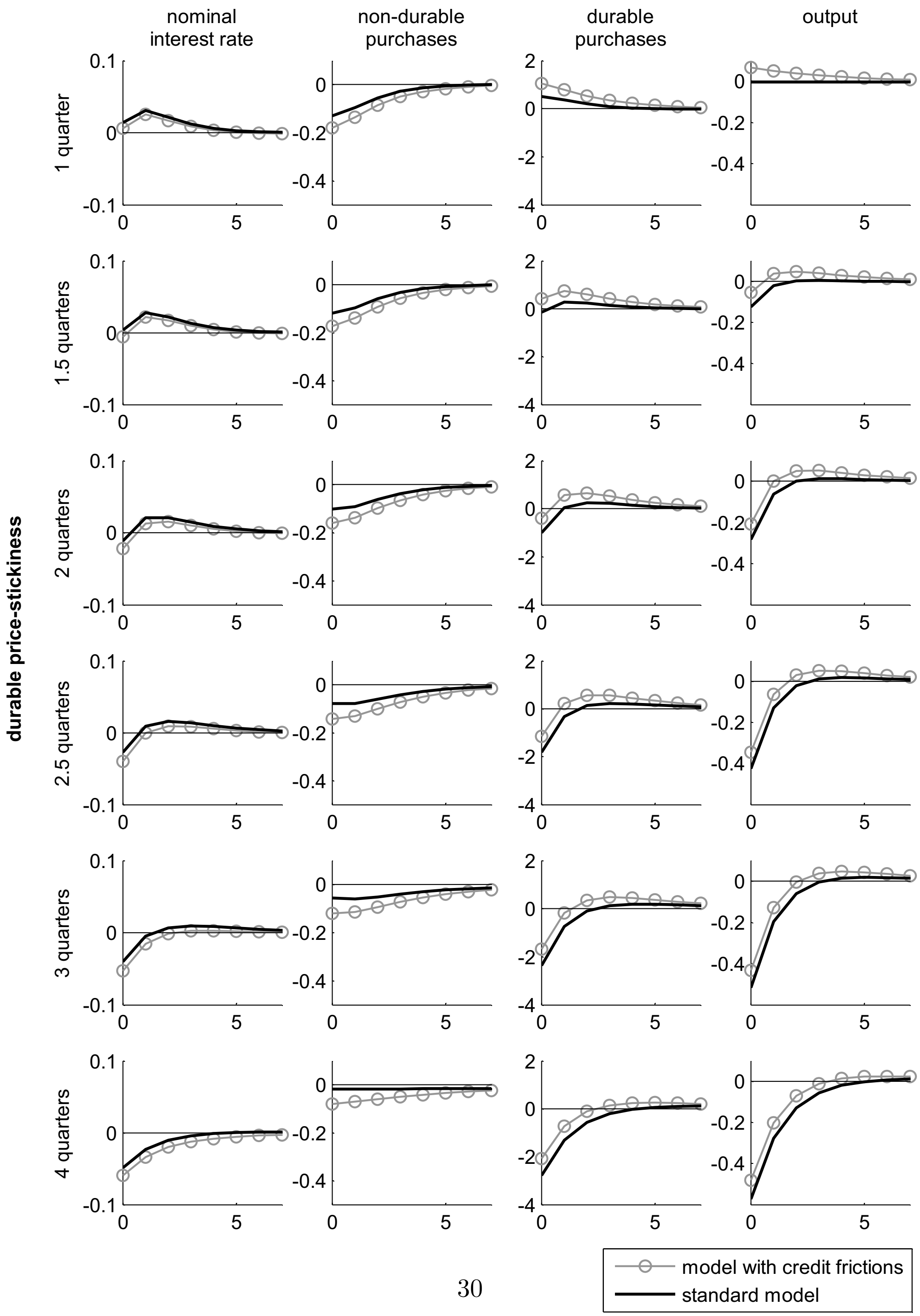


Figure 5: Responses to a monetary tightening of the real wage in units of durables w_t/q_t and the relative price of durables q_t in the model with and without credit frictions. Only non-durable inflation enters the monetary policy rule ($\tau = 0$). The rows correspond to different degrees of durable price-stickiness. Responses are plotted as percentage deviations from the steady state.

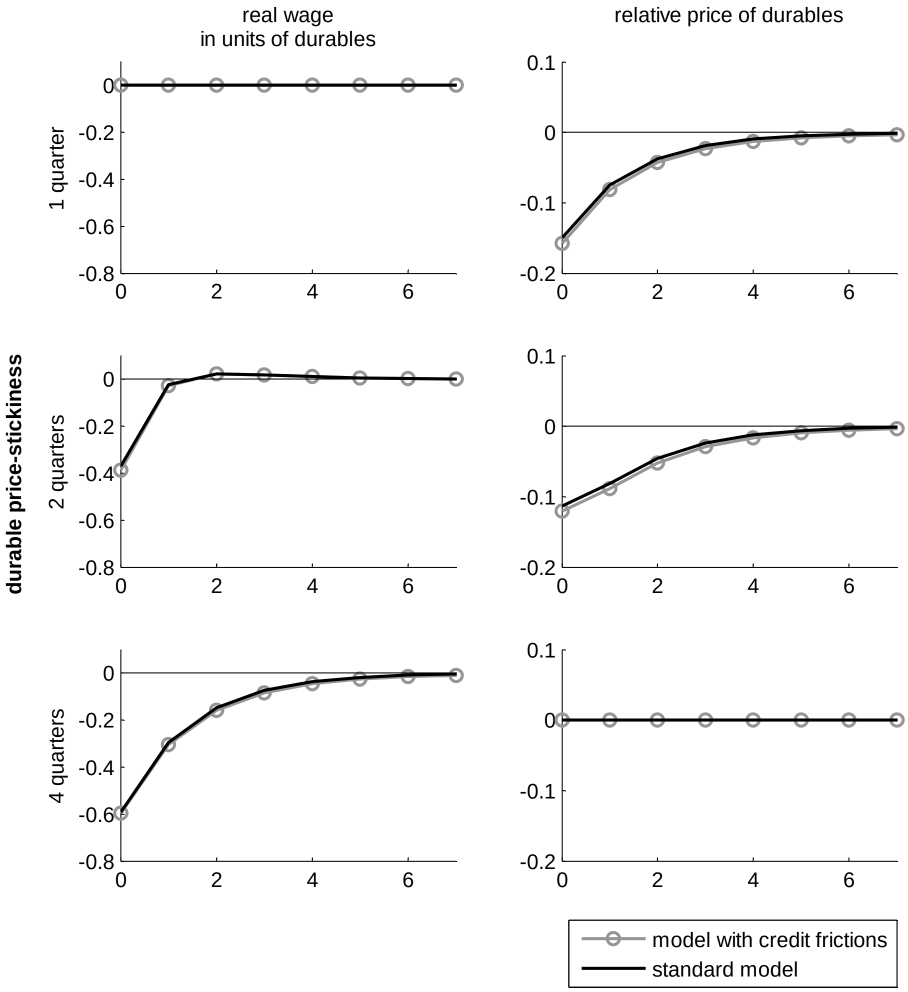
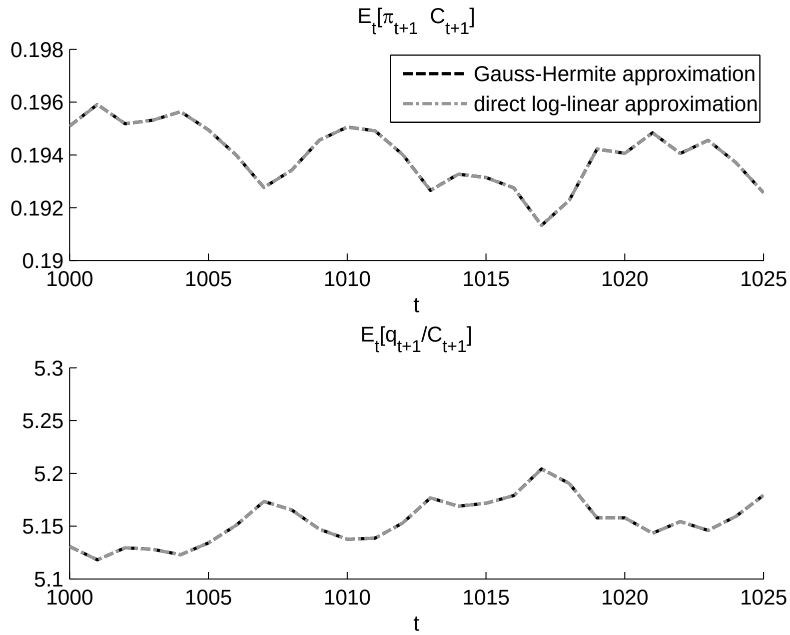


Figure 6: Conditional expectations: Gauss-Hermite approximation versus direct log-linear approximation.



Note: Model simulation with $\beta = 0.989$ and the standard deviation of the shocks calibrated such that output volatility in the model is 50% of output volatility in the data.

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