Co-movement Puzzle and the Overlapping Roles of Consumer Durables and Capital

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Abstract

This paper develops an alternative new Keynesian dynamic stochastic general equilibrium model that assumes, as a new feature, overlapping roles for capital and consumer durables. The model is able to generate co-movement responses of durable spending and non-durable spending to monetary policy shocks, consistently with the empirical evidence. Additionally, in contrast with the standard theory that finds a counter-factual extraordinary sensitive responses of consumer durables and capital to monetary policy shocks, the model yields responses more in tune with actual observation.

1 Introduction

This paper revises the traditional assumption of distinguishability between the functions of productive durables (capital) and consumer durables, and shows that this assumption can be a source of standard models’ failure to capture the co-movement of durable spending with non-durable spending as found in the data. The proposed two-sector new Keynesian general equilibrium model assumes overlapping roles for consumer durables and capital and, as a result, resolves the co-movement puzzle. Moreover, it is shown that this
assumption can also temper the extraordinarily sensitive responses of both consumer durables and capital to monetary policy shocks.

Several empirical studies, e.g. Erceg and Levin (2006); Barsky et al. (2003, 2007), have documented that durable output exhibits two key features in response to monetary policy shocks: it positively co-moves with non-durable output, and it is more sensitive to monetary policy shocks than non-durable output and other components of GDP. While standard new-Keynesian models are unable to generate the first feature, they produce high sensitivity of durables in response to monetary policy shocks. As discussed in Barsky et al. (2007), characteristics such as low rate of depreciation, high stock-flow ratio, and large intertemporal elasticity of substitution are responsible for high sensitivity of durable spending to monetary policy shocks. These characteristics are common in both subcategories of durable goods, i.e. households’ durables and firms’ durables (capital), and cause them to strongly react to monetary policy shock in standard models. However, standard models generate roughly symmetric and opposite monetary responses for these two types of durable products, as will be shown in this paper.

The extant literature introduces some features that result in the counter-factual response of durable spending to monetary policy shocks. Barsky et al. (2003) argue that financial imperfection and nominal wage rigidity are the responsible mechanisms. Monacelli (2009), Sterk (2010), Tsai (2014), and Chen and Liao (2014) investigate financial imperfection, while Carlstrom and Fuerst (2006, 2010) examine the role of nominal wage rigidity. Bouakez et al. (2011) and Sudo (2012) investigate another possible mechanism for this puzzle - the input-output structure between non-durables and durables. Finally, Kim and Katayama (2013) discuss that non-separability between aggregate consumption and labor can explain and resolve the puzzle.

In contrast to the literature, this paper finds the assumption of distinguishable roles for capital and consumer durable the key mechanism responsible for the counter-factual behavior of durable spending in standard theory. This paper assumes that consumer durables and capital have non-observable overlapping roles. Capital, as an asset, is not only a factor of production but also a signal of wealth and, hence, it provides utility. Aside from that, typical workers who work a full journey a day spend almost one third of the endowed daily time away from their home and possessions. In this period, they benefit from the firm’s available facilities, most of which are considered
as the firm’s capital.\footnote{Among many examples of firm’s capital that can affect the satisfaction of a worker, in a non-market way, we can think of chairs, desks, computers, air-conditioners, restrooms, paper, light, coffee machines, microwaves, fridges, and the free transportation or parking spot provided by firms.} Therefore, the capital of firms, besides the personal consumption of workers, may be part of the utility function, even though its key role is being a factor of production. On the other hand, households’ assets can directly be part of the production.\footnote{This concept has already been discussed by scholars. For example, Benhabib et al. (1991) and Greenwood and Hercowitz (1991) consider consumer durables as a factor of home production. This paper, however, does not separate firms’ production from home production.} For example, a significant portion of workers in the U.S. works from home and, hence, takes advantage of their personal possessions to produce services (e.g. home office, computer, and desk, etc.).\footnote{The Survey of Income and Program Participation (SIPP) reports that the percentage of workers who worked at home at least 1 day a week increased from 7.0 percent in 1997 to 9.5 percent in 2010.} Moreover, the majority of workers commute to work using their own vehicles.\footnote{The American Community Survey (ACS) documents that in 2008-2012 5-year period 86.2 percent of workers drove alone or carpooled to work.} This activity, i.e. commuting to work, can be counted as production activity as well as utility deriving activity. Therefore, households’ durables act as a factor of production, even though their key role is utility deriving.

The paper is organized as follows. Section 2 provides some VAR evidence on the dynamics of non-durables, consumer durable spending, and capital investment. Section 3 presents the benchmark two-sector new-Keynesian model with standard features. Section 4 introduces two scenarios for simple distinguishability of consumer durables and capital in order to study the role of this feature in solving the co-movement puzzle. Section 5 presents the calibration of model parameters. Section 6 analyzes the models’ dynamics and studies the sensitivity of the results. Finally, Section 7 presents concluding remarks.

### 2 Empirical evidence

This section reveals the responses to monetary policy shocks of non-durables, consumer durable spending, and capital investment using a quarterly identified four-lag vector auto-regression analysis (VAR) of the U.S. economy.
This study complements the VAR studies of Barsky et al. (2003), Erceg and Levin (2006), and Monacelli (2009) by separating and considering both types of durable spending, i.e. consumer durable spending and capital investment. To identify monetary policy shocks, this study follows the standard recursive identification scheme of Christiano et al. (1999). The vector variable consists of the real values of GDP, productive investment, consumer durable spending, non-durable consumption, all in logarithm, along with the GDP deflator and the federal funds rate. Durable spending in this analysis consists of the sum of personal consumption expenditures on durable products plus residential investment, while productive investment refers to gross private domestic investment less residential investment.

Figure 1 shows the responses to monetary policy shocks of GDP, durable spending, non-durable spending, and investment with two-standard error ranges. Among three GDP components, for which monetary responses are illustrated, both durable and non-durable spendings decline in response to contractionary monetary policy shock and durable spending responds more sensitively. The immediate response of capital investment (i.e. in a half year), however, is opposed to other two components of GDP. It is positive and is as sensitive as immediate response of durable spending as if the two were symmetrically opposite.

3 Model

Consider an economy composed of two sectors: non-durable goods and durable goods. It is populated by infinitely lived households (of measure of one) which derive utility from consumption of non-durable final goods, leisure, and services of durable final goods, which have been purchased by either households or firms. Each sector consists of a large number of monopolistic competitive final good producers that buy homogenous intermediate goods from

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5The data is obtained from FRB Flow of Funds and FRED and covers the window of 1954:3 to 2007:2

6In another independent VAR study, instead of the above mentioned durable spending and productive investment, personal consumption expenditures on durable goods and gross private domestic investment are considered respectively as consumer durables and capital. Despite, no significant differences were found between the results of two studies. The results of the alternative study can be seen in the Appendix.

7The results of this analysis are robust to different alternative specifications of orderings and number of lags.
many homogenous intermediate good producers, common for all sectors, in a perfectly competitive market. Final good producers are also the source of nominal rigidity. Finally, a monetary authority is in charge of monetary policy.

3.1 Intermediate good producers

A large number of intermediate firms produce homogenous intermediate goods, using a Cobb-Douglass constant-return-to-scale production framework, and sell those goods to final good producers, of all sectors, at a perfectly competitive price of $P_{w,t}$. Intermediate producers produce base on the production function of

$$Y_t = \tilde{K}^\alpha N_t^{1-\alpha}$$  \hspace{1cm} (1)

where $N_t$ is the labor demand and $Y_t$ is the intermediate output. $\tilde{K}_t$
is a CES aggregation of all durables, purchased either by households or by firms, which participate in production. Assuming that functions of productive durables and consumption durables are distinguishable, as it is in standard theory, \( \tilde{K}_t \) will be exclusively equal to the stock of capital investment, i.e. \( K_t \).

### 3.2 Final good producers

There are two different sectors assumed in this model: a non-durables sector, indexed by \( C \), and a durable sector, indexed by \( X \). In each sector, final good producers independently buy homogenous intermediate goods at \( P_{w,t} \) in a competitive market, differentiate them at no cost, and then re-sell the heterogeneous output to households.

To show how final good producers differentiate intermediate goods, we assume in each sector they are heterogeneous, i.e. a continuum of mass one, and indexed by \( z \). Therefore, let \( Y_{j,t}(z) \), where \( j = C, X \), be the quantity of output sold by the final producer \( z \) in section \( j \) and let \( P_{j,t}(z) \) be the nominal price of the final good in that sector. Then, we assume the total amount of final goods in sector \( Y_{jt}^f \) is the following composite of individual final producer outputs:

\[
Y_{jt}^f = \left( \int_0^1 Y_{j,t}(z) \frac{1}{\mu_j} dz \right)^{\mu_j} \tag{2}
\]

where \( j = C, X \) refers to sectors of non-durables and durables respectively and \( \mu_j \) is the markup of the final goods market in sector \( j \). Therefore, the individual demand curve of final good producer \( z \) in sector \( j \) will be:

\[
Y_{j,t}(z) = \left( \frac{P_{j,t}}{P_{j,t}(z)} \right)^{\frac{\mu_j}{\mu_j - 1}} Y_{jt}^f \tag{3}
\]

where \( P_{j,t}(z) \) is the price set by the final good producer \( z \) in sector \( j \) and \( P_{j,t} \) is the aggregate price level in sector \( j \) in time \( t \).

To initiate price rigidity, we assume that final price rigidities are free to update their prices to the optimum level for a given period only with probability of \( 1 - \theta_j \), following Calvo (1983).
3.3 Households

A typical household in each period uses a consumption basket consisting of the consumption of non-durables, $C_t$, and the service of durables stock that they have already accumulated, $\bar{D}_t$. This basket, $\Theta_t$, is formed based on the following aggregation process:

$$\Theta_t = \left[ (1 - \gamma)^{\frac{1}{\sigma}} (C_t)^{\frac{\sigma - 1}{\sigma}} + \gamma^{\frac{1}{\sigma}} \left( \bar{D}_t \right)^{\frac{\sigma - 1}{\sigma}} \right]^{\frac{\sigma}{\sigma - 1}}$$

(4)

where $\gamma$ represents the share of durables in the consumption basket and $\sigma$ denotes the elasticity of substitution between non-durables’ consumption and durables’ service. $\bar{D}_t$ is a CES aggregation of all of the household’s durables, purchased either by households or by firms. However, assuming that functions of productive durables and consumption durables are distinguishable, as it is in standard theory, $\bar{D}_t$ will be exclusively equal to the stock of consumer durables, i.e. $D_t$.

Therefore, a representative household maximizes the following expected lifetime utility:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \log (\Theta_t) - \frac{\nu (N_t)^{1+\varphi}}{1 + \varphi} \right\}$$

(5)

subject to the sequence of budget constraints of

$$C_t + p_{X,t} (I_{D,t} + I_{K,t}) + b_t = p_{w,t} Y_t + f_t + R_{t-1} \frac{b_{t-1}}{\pi_{C,t}} + T_t$$

(6)

which is shown in real terms$^8$, where $p_{X,t}$ is the relative price of durables, $b_t$ is the real debt, $p_{w,t}$ is the relative wholesale price of intermediate goods, $Y_t$ is the output of intermediate producers, $f_t$ is the final good producers’ lump-sum real profit$^9$. Also, $I_{D,t}$ denotes the flow of consumer durables (i.e. the consumer durable purchases added to consumer durable stock in time $t$), $I_{K,t}$ denotes capital investment, $R_t$ is the gross nominal interest rate at time $t$, and $\pi_{C,t}$ is the gross inflation rate in the non-durable goods’ sector.

Durable accumulations follow the following processes:

$^8$The above real budget constraint is equivalent to the nominal budget constraint of $P_{C,t} C_t + P_{X,t} (I_{D,t} + I_{K,t}) + B_t = P_{w,t} Y_t + F_t + R_{t-1} B_{t-1} + P_{C,t} T_t$

$^9$All real variables and relative prices are in units of non-durables.
\[ D_t = (1 - \delta_D) D_{t-1} + I_{D,t} \]  

(7)

\[ K_{t+1} = (1 - \delta_K) K_t + I_{K,t} \]  

(8)

where \( \delta_D \) and \( \delta_K \) are the depreciation rates of consumer durable goods and productive durable goods respectively. The difference in timing of consumer durable investment and capital investment refers to the idea that once households buy a consumer durable they can start using it right away, while once they buy a productive durable they need some time to establish it in a production framework.

### 3.4 Monetary policy

The Monetary authority is assumed to follow a simple Taylor rule of:

\[ \frac{R_t}{R} = \left( \frac{\pi_t}{\pi} \right) ^\phi \zeta_{M,t} \]  

(9)

where \( \zeta_{M,t} \) is monetary policy shock, and \( R \) and \( \pi \) are steady states of gross nominal interest rate and gross inflation rate, respectively. \( \pi_t \) is the economy’s gross inflation rate that is a compound index of sectoral gross inflation rates so that:

\[ \pi_{C,t}^{T_C} \pi_{X,t}^{T_X} = \pi_{t} \]  

(10)

where \( \tau_j \), where \( j = C, X \), is the share of sector \( j \) in economy’s inflation. The policy shock follows

\[ \ln \zeta_{M,t} = \rho_M \ln \zeta_{M,t-1} + \varepsilon_{M,t} \]  

(11)

where \( \varepsilon_{M,t} \) is i.i.d. process with variance of \( \sigma_M^2 \).

### 4 Two scenarios

This section introduces two different scenarios for function distinguishability of household’s durables and firms’ capital.
4.1 Standard scenario

The first scenario is based on the standard assumption in which consumer durables and capital are functionally distinguishable. In this scenario, each product exclusively serves the purpose it is purchased for. Durable goods purchased by households just participate in utility function and ones purchased by firms exclusively work as production factors. This scenario can be embedded into the model by following equations:

\[ \tilde{K}_t = K_t \]  \hfill (12)
\[ \tilde{D}_t = D_t \]  \hfill (13)

4.2 OFDK\textsuperscript{10} scenario

The second scenario, instead, refers to the new assumption of overlapping functions of consumer durables and capital. Note that categorizing durables products into consumer durables and capital will not be complicated in this scenario. Because, they are categorized based on the agent who purchase them and not based on their function. OFDK scenario assumes that even if we categorize consumer durables and capital durables in spending, their functions are not separable. This scenario is expressed by following equations:

\[ \tilde{K}_t = K_t^{\eta_2} D_t^{1-\eta_2} \]  \hfill (14)
\[ \tilde{D}_t = D_t^{\eta_1} K_t^{1-\eta_1} \]  \hfill (15)

These equations imply that when \( \eta_1 \) and \( \eta_2 \) tend to one, OFDK scenario tends to the standard scenario.

5 Calibration

The model is calibrated based on quarterly data. The discount factor, \( \beta \), is set to 0.99, assuming the annual rate of return of 4 percent. Unless stated otherwise, both depreciation rates, i.e. \( \delta_D \) and \( \delta_K \), are set to 0.025, which is

\textsuperscript{10}\textit{Overlapping Functions of consumer Durables and (K)apital durables}
consistent with 10 percent annual depreciation rate. The non-durables share in utility function, \(1 - \gamma\), is set in such a way that the share of non-durable spending in total private spending, i.e. personal consumption expenditure plus gross private domestic investment, is 0.68. The markup parameters in all sectors, \(\mu_j\), are set to 1.2 to show 20% of net mark-up. The elasticity of substitution between durables and non-durables, \(\sigma\), and the inverse elasticity of labor supply, \(\varphi\), are set to one.

Following Bils and Klenow (2004) that document less stickiness for durable prices than for non-durable prices, the price rigidity parameters \(\theta_j\) are calibrated so that prices are updated once a year in the non-durable sector and every three quarters in the durable sector.

As it is standard in the literature on Taylor rules, the monetary policy parameter, \(\phi\), is set to 1.5. The policy shock persistence, \(\rho_M\), is set to 0.5 and the variance, \(\sigma^2_M\), is set for a 25 basis points innovation in the policy rule. The capital share parameter, \(\alpha\), is calibrated to 0.35. Finally, the preference parameter, \(\nu\), is obtained in such way that households are assumed to work one third of their time endowment in steady state.

6 Analysis of the results

This section compares the results of OFDK model to the results of standard model and shows that when the roles of consumer durables and capital overlap, the co-movement puzzle disappears. Besides, the sensitivity analysis of the OFDK model’s results will be discussed in a separate subsection.

6.1 OFDK model versus standard model

Figure 2 displays the model’s impulse response functions of different variables to an innovation in the monetary policy and under alternative scenarios. Both scenarios lead to similar monetary responses for GDP and non-durable products. Investments in consumption durables and capital, though, respond disparately under alternative scenarios. Under the standard scenario in which consumer durables and capital are functionally distinguished, the co-movement puzzle of durables exists, and durables and capital have extraordinarily strong responses to the monetary policy shock. However, the new scenario of OFDK, not only resolves the co-movement puzzle, but also it tempers the anomaly of extraordinary sensitive responses of investments.
in both durables and capital.

In addition, in the model with OFDK scenario, capital investment’s immediate response to a monetary policy shock is counter-cyclical which is consistent with the data. While, the model with standard assumption of distinguishable functions of durables and capital generates pro-cyclical responses for capital investment.

6.2 Overlapping degree, durability, and price stickiness

This section shows how the results of the OFDK model change as we vary the degree of price stickiness in different sectors, the depreciation rates of
Table 1: Sensitivity Analysis: durability versus overlapping

<table>
<thead>
<tr>
<th></th>
<th>High Overlapping</th>
<th>Low Overlapping</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\eta = 0.6$</td>
<td>$\delta = 0.01$</td>
<td>$\delta = 0.025$</td>
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<tr>
<td>$C$</td>
<td>-0.048</td>
<td>0.058</td>
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<tr>
<td>$I_K$</td>
<td>12.237</td>
<td>11.332</td>
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<td>$\delta = 0.05$</td>
<td>$\delta = 0.075$</td>
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<tr>
<td>$C$</td>
<td>0.076</td>
<td>-0.051</td>
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Table 1 reports the immediate response of non-durable products, consumer durable investment, and capital investment for different values of depreciation rates and degree of functional overlapping of consumer durables and capital. It is assumed that depreciation rates of consumer durables and capital are equal, i.e. $\delta_D = \delta_K = \delta$. Correspondingly, the contribution degrees of consumer durables in production function assumed to be equal to the contribution degree of capital in utility function, i.e. $\eta_1 = \eta_2 = \eta$. As this table shows, the co-movement puzzle would not exist if overlapping degree decreases when depreciation rates increase. For example, when depreciation rates are 0.01, 0.025, 0.05, 0.075 the co-movement puzzle will be resolved if $\eta$ values are 0.6, 0.7, 0.8, 0.9, respectively. Furthermore, the co-movement puzzle is not resolved for any of the documented values of depreciation rates when there is no functional overlapping between capital and consumer durables, i.e. $\eta = 1$. In other words, durability along with functional overlapping are two features that together can explain the co-movement puzzle. Table 1 also shows that the sensitivity of durable responses becomes lower as depreciation rates and the overlapping degree increase.

Table 2 reveals the importance of $\eta_1$ and $\eta_2$ in the OFDK model. This table
documents the immediate responses of three sectors outputs to a monetary policy shock for different values of $\eta_1$ and $\eta_2$. According to this table, when $\eta_2 = 1$, this model is unable to resolve the co-movement puzzle. That is the contribution of consumer durables in the production function is essential for the OFDK model to be able to resolve the puzzle. On the other hand, the model can still resolve the puzzle for $\eta_1 = 1$, i.e. no contribution of capital in utility function, only if the participation of consumer durables in production function is high, i.e. $\eta_2 = 0.5$. Table 2 also implies that $\eta_1$ and $\eta_2$ can play complementary roles in order to solve the puzzle. That is when $\eta_1$ is low, e.g. 0.5, a higher value of $\eta_2$, e.g. 0.8 is needed for puzzle to disappear and when $\eta_1$ is high, $\eta_2$ needs to be low to eliminate the puzzle.

One of the important features of durable goods that has been discussed in the literature is that their prices are less sticky compared to non-durables. As mentioned above, this paper takes this feature into account and calibrates lower price stickiness for durable sector. To investigate how this feature is

<table>
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<tr>
<th>$\eta_1$</th>
<th>$\eta_2$</th>
<th>$C$</th>
<th>$I_D$</th>
<th>$I_K$</th>
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<td>-0.116</td>
<td>20.248</td>
<td>-6.416</td>
</tr>
</tbody>
</table>

Table 2: Sensitivity analysis: Overlapping functions

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Table 3: Sensitivity analysis: price stickiness of sectors

<table>
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<td>Flexible</td>
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<td>$I_K$</td>
<td>0.595</td>
<td>3.572</td>
<td>2.477</td>
<td>-0.854</td>
<td>-3.103</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 quarters</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I_K$</td>
<td>0.672</td>
<td>4.841</td>
<td>6.555</td>
<td>2.842</td>
<td>-1.510</td>
</tr>
</tbody>
</table>

essential for the OFDK model to resolve the co-movement puzzle, table 3 shows the model results for different stickiness values in two sectors. It first shows that, for the model to still resolve the puzzle, some sort of price stickiness in both sectors is essential. Moreover, all cases with no co-movement issue interestingly drop below the diagonal of the table, where the price stickiness in durable sector is lower then the price stickiness in non-durable sector. Strictly speaking, it is essential for the model that prices in durable sector are more flexible than prices in non-durable sector.

7 Conclusion

This paper addresses the co-movement puzzle in durable goods by revising one of the traditional assumptions in the standard theory, that is functional distinguishability of consumer durables and capital. In contrast to that assumption, it is assumed that consumer durable goods, beside their main role of utility deriving, can contribute in production. Similarly, capital goods are assumed to participate in utility function, beside their major role as a
factor of production. This coincident joint features of consumer durables and capital, is called in this paper “functional overlapping of consumer durables and capital”. It is demonstrated in this paper that an alternative two-sector new Keynesian general equilibrium model consisting the new assumption of functional overlapping of consumer durables and capital can resolve the co-movement puzzle. The model, also, is able to temper the extraordinary sensitivity that a model with standard features generates for responses of consumer durables and capital to monetary policy shocks. Finally, the sensitivity of the results to different calibration mechanisms is investigated.

References


