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Essays on Dynamics of Durable Goods

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Sayed Mehdi Naji Esfahani

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Dissertation Committee:

Dr. Marcelle Chauvet, Chairperson
Dr. Aman Ullah
Dr. Tae-Hwy Lee

The Dissertation of Sayed Mehdi Naji Esfahani is approved:

Committee Chairperson

University of California, Riverside

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I am grateful to my adviser, Professor Marcelle Chauvet, for all the support.

To my love and life, Elaheh.

ABSTRACT OF THE DISSERTATION

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This dissertation is comprised of three chapters. In the first chapter, two independent empirical studies are performed to shed more light on the cross-sectoral impacts of monetary policy. High degree of interest sensitivity of durable goods is now a stylized fact in the literature of monetary policy. This literature, however, does not provide a clear and consensual explanation for the modalities of this stylized fact. The results of the first study indicate that there is no straightforward relationship between the degree of durability and the interest-sensitivity of durables. While, the second study concludes that, in response to monetary policy shocks, productive durables behave differently from consumer durables.

The Second chapter questions the traditional assumption under which consumer goods and capital have perfectly distinguished applications. This chapter then explores some macroeconomic implications of including overlapping functions of consumer durables and capital in a new Keynesian general equilibrium model. The simulated results of the model show that introducing overlapping functions of consumer durables and capital improves the quantitative performance of the standard new Keynesian model along several dimensions. Moreover, the model is able to resolve durable co-movement puzzle and to generate co-moving 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 observations.

The third chapter investigates the role of durables in the transmission mechanism of energy price shocks. This chapter shows that considering a separate sector for durables in a new Keynesian dynamic general equilibrium model may improve the quantitative results of the model to generate the impulse response functions which are more inline with empirical evidence. The simulated results of the model show that the response of output to energy price shocks would be more sensitive, when durables are considered as a separate sector. However, in this model the total consumption, including both durables and non-durables, rises. Such a reaction is at odds with empirical evidence. However, considering the assumption of overlapping functions of durables and capital can eliminate this peculiar reaction of the model. The simulated results of this model also show that there is a positive direct relationship between the level of durability and the sensitivity of output response to energy price shocks.

Contents

List of Figures

List of Tables

1 Durable Goods and Sectoral Effects of Monetary Policy

1.1 Introduction

Plenty of studies have investigated the transmission mechanism of monetary policy shocks through the economy. Monetary policy shocks propagate asymmetrically across sectors of the economy. Some sectors may absorb more of a shock compared to the other sectors. Investigation of asymmetric responses of different sectors to monetary policy shocks may help monetary authorities to make more efficient policies. It also helps economists to find better explanation for some economy's features that cannot be simply explained by standard modeling. This chapter performs two independent studies of sectoral impacts of monetary policy shocks in the economy. These two studies, however, are common in two aspects. First, in both studies, sectors are determined based on durability of products. Second, the methodology applied in both studies is structural vector auto-regression, VAR.

Sectoral impacts of monetary policy have recently attracted the interest of economists and policy-makers. Many papers in the literature document asymmetric cross sectoral impacts of monetary policy[1]. Guiso et al. (2000) show that the use of disaggregated data improves the identification of factors which are more sensitive to monetary policy shocks and more crucial in the monetary transmission. Bernanke and Gertler (1995), using a VAR model, show the different impacts of monetary policy on spend-

[1] Among them are, Dale and Haldane (1995), Gertler and Gilchrist (1994), Ganley and Salmon (1997), Raddatz and Rigobon (2003)

ing components of the economy. Following Bernanke and Gertler (1995), several studies investigate the sectoral effects of monetary policy on the economy. Ganley and Salmon (1997) studies industry data for the United Kingdom and shows that some sectors, such as construction, respond more sensitively and rapidly to monetary policy shocks. In a similar study, Hayo and Uhlenbrock (1999) focus on the manufacturing industries in Germany. They consider 28 industries in their study and conclude that heavy industries are more sensitive to monetary policy shocks than non-durable industries such as food and clothing. Dedola and Lippi (2000) document the cross-industry heterogeneity of monetary policy effects in five OECD countries. They show that there is no significant cross-country differences in sectoral channels of monetary policy transmission. Fares and Srour (2001), investigate the sectoral monetary transmission in Canada. They consider two types of disaggregation, one at the level of final expenditures and the other at the level of production. They conclude that, at the level of final expenditures, investment responds most substantially and exports respond most quickly among other sectors. While, among the sectors at the level of production, construction is the most quickly responder and manufacturing has the strongest response to monetary policy shocks. Ibrahim (2005) studies sectoral monetary effects on the economy of Malaysia and concludes that manufacturing, construction, finance, insurance, real estate and business services sectors are the deriving force behind the aggregate fluctuations. Peersman and Smets (2005) estimate the effects of a sectoral monetary effects in eleven industries and seven euro area countries, and find that cross-industry differences of policy effects are related to financial structure and firm size.

Durable goods sector is one of the economy's sectors which has been documented as one of the most sensitive sector in response to monetary policy shocks. (Ganley and Salmon (1997), Fares and Srour (2001), Dedola and Lippi (2000), Peersman and

Smets (2005)). Recent empirical studies on the monetary transmission mechanism (e.g. Barsky et al. (2003), Erceg and Levin (2002, 2006), Monacelli (2009)) have revealed two special features for durable spending in response to monetary policy shocks. First, durable goods sector is significantly more sensitive to monetary policy shocks compared to other sectors. Second, in response to a monetary policy shock, durable sector spending co-moves closely along with other sectors. In their VAR analysis, Erceg and Levin (2002) disaggregate the total output in five major expenditure components: consumer durables, residential structures, business equipment, business structures, and other goods and services. Aside from the last sector, labeled as non-durable GDP in the paper, other four sectors are durables. This paper documents that the peak impact of a monetary policy shock on durable expenditures is roughly five times as large as that on non-durable expenditures. Barsky et al. (2003), instead, perform a VAR study considering a sector for non-durable goods and three sectors for durable goods, i.e. durables expenditures, residential investment, and automobile sales. This chapter shows that after a contractionary monetary policy innovation durable goods sectors contract very sharply while non-durable goods and overall GDP do not. In a separate paper, Erceg and Levin (2006) perform another VAR analysis in which real GDP is disaggregated into two types of expenditures: a chain-weighted index of consumer durables and residential investment, and a chain-weighted composite of all other GDP components. The result of this paper confirms previous documented results in the literature. That is, the decline of consumer durables spending caused by monetary policy shocks is over three times as large as that for the other GDP components. It also verifies the co-movement of both sectors in response to monetary policy shocks. In a slightly different VAR analysis, Monacelli (2009) confirms these two, now, stylized facts about durables sector. Monacelli incorporates total real household debt as one of the role player in the analysis. Two disaggregated sectors in Monacelli are real durable consumption along with real non-durable consumption and services. His paper shows that, in response to monetary policy shocks, household debt also gradually and very closely co-moves with non-durable sector.

This chapter performs two independent simple VAR analyses regarding the role of durable goods in transmission of monetary policy shocks. The first study examines that to what extent the durability of a sector's output can be attributed to the strength and the rapidity of the sector's responses to monetary policy innovations. In this study, eight different industrial sectors of the economy are ranked based on the durability of their output. Then, the responses of each sector are ranked based on the period and the amount of the strongest response. The comparisons of the ranking of durability with the ranking of response strength and the ranking of response swiftness are then documented and interpreted.

The second study compares the responses of durable goods with different functions to monetary policy shocks. Some durables are utility-deriving and others are productive. This study addresses the question that how the function of durable goods affect their responses to the monetary policy shocks. As mentioned above, there are numerous empirical studies that investigate sectoral effects of monetary policy shocks in the economy. Some of them document the special role of durable goods in the transmission of monetary policy. The function-effect of durables, however, has not been investigated in the literature. Therefore, this section reports a VAR analysis in which the real GDP is disaggregated based on two characteristics: durability and function. Hence, three disaggregated sectors in this model are as follows. Non-durable sector consists of products which are purchased by households, so are utility deriving, and are non-durable. Consumer durables sector consists of durable goods purchased by households. Capital sector consists of durable goods purchased by firms. This analysis complements other similar studies, e.g. Erceg and Levin (2002) and Monacelli (2009), by comparing responses of durable goods with different functions, i.e. utility deriving durables and productive durables (capital).

The key findings of this analysis are as follows. Consumer durable expenditures closely co-moves with non-durable spending and declines in response to contractionary monetary policy shock; however, consumer durable spending responds more sensitively. Also, in short run, the response of capital investment is in opposite direction of the response of two other sectors. In the long term, capital investment follows two other sectors and declines. Moreover, the results show that inclusion of the residential investment into consumer durable sector does not change the qualitative behavior of three sectors in response to monetary policy innovations.

The plan of this chapter is the following. Section 1.2 explains the methodology and the identification strategy in this paper. Section 1.3 covers the first empirical study in this paper. That is, a study of the relationship between the durability level and the cross-sector transmission of monetary policy. Section 1.4 covers another independent empirical study which investigates the role of productive and non-productive durables in the cross-sector transmission of monetary policy. Finally, 1.5 concludes this chapter.

1.2 The VAR methodology

To initiate the VAR analysis and to investigate the relationship between each sectoral output and other macroeconomic variables, let start with the general form of a structural VAR model, which is given by the following equation:

$$AY_t = C + B_1 Y_{t-1} + B_2 Y_{t-2} + ... + B_k Y_{t-k} + \varepsilon_t \tag{1.1}$$

where Y_t is a vector of variables, A and B_j's are nxn matrices of coefficients, n denotes the number of observations in each series, C is a vector, of order n, of deterministic variables, and ε_t is a nx1 vector of unobservable zero mean white noise processes and represents structural shocks in the economy. Hence,

$$\varepsilon_t \sim \mathcal{N}(0, \mathbf{I})$$

Pre-multiplying equation (1.1) by A^{-1}, the reduced form is obtained as follows.

$$Y_t = \mathbf{c} + \mathbf{b_1} Y_{t-1} + \mathbf{b_2} Y_{t-2} + ... + \mathbf{b_k} Y_{t-k} + \mathbf{e_t} \tag{1.2}$$

where $\mathbf{c} = A^{-1}C$, $\mathbf{b_j} = A^{-1}B_j$, and $\mathbf{e_t} = A^{-1}\varepsilon_t$ is a reduced-form VAR residual which satisfies following condition:

$$\mathbf{e_t} \sim \mathcal{N}(0, \Sigma_e)$$

where Σ_e is a nxn symmetric, positive definite matrix which can be estimated from the data. Here is the relationship between the variance-covariance matrix of the estimated residuals, Σ_e, and the variance-covariance matrix of the structural innovations, Σ_ε:

$$\Sigma_e = A^{-1}\Sigma_\varepsilon A^{-1'} = A^{-1}A^{-1'}$$

since $\Sigma_\varepsilon = \mathbf{I}$. As $\varepsilon_t = A\mathbf{e_t}$ and $B_j = A\mathbf{b_j}$, if we pin down A, the mission is accomplished and we would know the structural representation of the economy.

The number of unknowns, which are elements of $A^{-1}A^{-1'}$, is n^2. While, the number of equations is $\dfrac{n^2+n}{2}$, because the variance-covariance matrix of Σ_e is symmetric. Therefore, this system is not identified.

Identification process

In order for the system to be identified, sufficient restrictions must be applied so as to recover all structural innovations of the system from the estimation of the reduced form of VAR. Among various identification schemes, following Christiano 1999, the recursive identification scheme is used in this paper. To perform this scheme, based on an specific ordering of variables in vector Y_t, matrix A can be reasonably restricted to be lower triangle. If A is lower triangle, the number of unknowns is $\frac{n^2+n}{2}$, which is exactly equal to the number of equations and the system is perfectly identified. For example, for the case in which 3 variables contribute in the VAR analysis:

$$AY_t = \begin{bmatrix} \alpha_{11} & 0 & 0 \\ \alpha_{21} & \alpha_{22} & 0 \\ \alpha_{31} & \alpha_{32} & \alpha_{33} \end{bmatrix} \begin{bmatrix} Y_{1,t} \\ Y_{2,t} \\ Y_{3,t} \end{bmatrix}$$

According to above schematic identification, the structural shock in the first sector $\varepsilon_{1,t}$ may have contemporaneous impact on all three sectors. While, the structural shock in the second sector contemporaneously affects the second and third variables, i.e. $Y_{2,t}$ and $Y_{3,t}$. The structural shock in the third sector may solely have contemporaneous affect on the variable of the same sector, i.e. $Y_{3,t}$.

Therefore, in order to apply recursive identification process, we just need to identify the ordering of variables placed in Y_t, assuming that the matrix A is restricted to be lower triangle.

Stationary issue

The above introduced structural VAR analysis is designed for stationary variables, while none of the variables used in this study are stationary. One solution is to use co-integration of variables in the study. However, co-integration may lead to some sort of information loss. The trade-off between the loss of efficiency, in VAR estimation of levels, and loss of information, in VAR estimation of first-differences, has been studied by Ramaswamy and Slok (1998). They recommend not to enforce co-integration to the VAR, unless we have a prior economic theory that may suggest how long-run relationships. Therefore, following Ramaswamy and Slok (1998), this VAR study is specified in levels.

Estimation of the reduced form

In order to make the estimation process more straightforward, let integrate observed data to the reduced form of VAR(k) and present equation (1.2) as the following format:

$$\mathcal{Y} = \mathcal{B}\mathcal{Z} + \mathcal{E}$$

Therefore, matrices in above equation can be defined as follows.

$$\mathcal{Y} = \begin{bmatrix} Y_k & Y_{k+1} & \cdots & Y_T \end{bmatrix}_{n\times(T-k)}$$

$$\mathcal{B} = \begin{bmatrix} \mathbf{c} & \mathbf{b_1} & \mathbf{b_2} & \cdots & \mathbf{b_k} \end{bmatrix}_{n\times(nk+1)}$$

$$\mathcal{Z} = \begin{bmatrix} 1 & 1 & \cdots & 1 \\ Y_{k-1} & Y_k & \cdots & Y_{T-1} \\ Y_{k-2} & Y_{k-1} & \cdots & Y_{T-2} \\ \vdots & \vdots & \ddots & \vdots \\ Y_0 & Y_1 & \cdots & Y_{T-k} \end{bmatrix}_{(nk+1)\times(T-k)}$$

$$\mathcal{E} = \begin{bmatrix} e_k & e_{k+1} & \cdots & e_T \end{bmatrix}_{n \times (T-k)}$$

where $T+1$ denotes the number of observations for each vector, i.e. Y_0 through Y_T, n is the number variables, and k is the number of lags in the VAR.

In this study, $\mathcal{B}$ is estimated using multivariate least squares (MLS). Based on above definitions of matrices, the estimation of $\mathcal{B}$ is

$$\hat{\mathcal{B}} = \mathcal{Y}\mathcal{Z}\left(\mathcal{Z}\mathcal{Z}'\right)^{-1}$$

In following sections, the above equation is applied on the introduced data and the results are presented.

1.3 Durability and cross-sector monetary policy channels

High sensitivity of durable goods in response to monetary policy shocks have been broadly documented in the literature. This section compares the strength and quickness of responses of different industrial sectors to monetary policy and addresses following question: To what extent the degree of durability is related to the strength and the quickness of responses?

As the first step, the total output of the economy is disaggregated into eight major sectors. These sectors are shown in Table 1.1. Next, the sectors are ranked by their durability level; 1 as the most durable and 8 as the least durable sector. The ranking is based on the Table 3 in Baxter (1996), which indicates the percentage of each sector's output that is consumed and the percentage of it that is invested. Boxter defines the industries that produce predominantly consumption goods, such as agriculture and utilities, as "consumption good sector" and other industries as "durable goods sector".

Instead of categorizing industries into two sectors, based on the information of Table 3 in Baxter (1996), I rank the industries from 1 to 8 for their degree of durability. The second column of Table 1.1 indicates the rank assigned to each sector.

Industry	Code	Degree of Durability	
Construction	CNS	1	Durable
Mining	MIN	2	↑
Manufacturing	MAN	3	|
Transportation, Communication, and Utilities	TCU	4	|
Wholesale and Retail Trade	WRT	5	|
Finance, Insurance, and Real Estate	FIR	6	|
Services	SRV	7	↓
Agriculture	AGR	8	Non-durable

Table 1.1: Ranking of sectoral output based on degree of durability

In order to compare the monetary responses of each sector, I estimate separate VARs for each industrial sector and then compare the effect of a monetary policy shock on each sector's output. The vector of variables in each VAR analysis comprises four variables respectively: (i) real GDP, (ii) the sector's output, (iii), GDP deflator, and (iv) federal funds rate. The data are sourced from the Bureau of Economic Analysis data tables and covers the window of 1969:1 to 2007:2. All variables apart from federal funds rate are in log terms.

Empirical Results

Table A.1 shows the degree of Akaike information criterion (AIC) for each VAR. However, in order to have a consistent comparison results across a series of VARs, I impose a common lag length of six on each of them[2].

The major results of this section is summarized in Table 1.2. This table shows the size and the quarter of maximum reduction of output in each sector in response to

[2]This study is replicated for common lag of four and five and the quantitative results did not change.

monetary policy shocks. The results do not indicate any clear relationship between the degree of durability and the size of response to monetary policy shocks. Although two strongest responses to monetary policy refer to construction sector and mining sector, which are two sectors with highest degree of durability, the response of agriculture sector and service sector, two sectors with low degree of durability, are also sizable compared to other sectors responses. As the results of this table show, the strongest response to monetary policy shocks refers to the mining sector, while the weakest response is for the sector of wholesale and retail trade.

Industry	Durability rank	Maximum output reduction			
		Size	Size rank	Quarter	Quickness rank
CNS	1	-0.0077	2	10	3
MIN	2	-0.011	1	20	6
MAN	3	-0.0043	4	8	1
TCU	4	-0.0033	6	26	7
WRT	5	-0.0022	8	9	2
FIR	6	-0.0029	7	62	8
SRV	7	-0.0035	5	18	5
AGR	8	-0.0057	3	13	4

Table 1.2: Ranking of sectors based on size and quickness of responses

The comparison of the degree of durability with the quickness of responses of sectors does not show an obvious relationship either. The sector of manufacturing has the fastest response to monetary policy, while the slowest response refers to the sector of Finance, Insurance, and Real Estate. In ranking of quickness responses, construction sector, with the highest degree of durability, and agriculture sector, with the lowest degree of durability, are neighbors. This means that necessarily there is no significant relationship between the degree of durability of sectors and their rapidity of response to monetary policy shocks. The results shown in Table 1.2 also reveals this fact that the size and the timing rankings of maximum output reduction of sectors do not have an obvious relationship.

Note that the results of this study do not contradict to the well-known stylized fact indicating that durables sector is significantly more interest-sensitive than the sector of non-durables. Rather, this study shows that this feature of durables sector cannot be exclusively explained by the durability characteristics of products. In order to show that the results of this study is consistent with the literature, I performed two other VARs with two parent sectors, i.e. durables sector and non-durables sector. Following Baxter, the non-durables sector is defined as the aggregation of agriculture sector, sector of transport, communication, and utilities, sector of wholesale and retail trade, sector of finance, insurance, and real estate, sector of service, and the non-durable part of manufacturing sector. The durable sector consists of construction sector, mining sector, and the durable part of manufacturing sector. Table 1.3 summarizes the results of these two VARs. As it is indicated in this table, the response of durables sector is more than three times stronger than the response of non-durables sector to monetary policy innovations. Durables sector also responds faster than non-durables sector. Figure A.2 illustrates the impulse response functions of durables and non-durables sector.

Sector	Maximum output reduction	
	Size	Quarter
Durables	-0.0079	9
Non-durables	-0.0021	13

Table 1.3: Size and quickness of responses of durables and non-durables to monetary policy shocks

1.4 Consumption durables vs. productive durables: another VAR analysis

This section accomplish an independent VAR analysis regarding the role of durables in transmission of monetary policy through the economy. The focus of this study is on the functions of durables. Not all durable goods have similar functions. Some, purchased by households, are mostly utility deriving and others, purchased by firms, are mostly productive. In national accounting, the former is called consumer durables, while the latter is capital. In this study, total output is disaggregated based on two characteristics of products: durability and function. Therefore, three major sectors are considered in the economy: consumer durables sector, consumer non-durables sector, and capital sector.

There is no consensus in the literature of macroeconomics about how to identify residential constructions in the models. Many studies, following national accounting, consider residential investment as a part of total (business) investment, there are a number of papers which identify this category of products as consumer durables. As this study tries to differentiate between productive and utility-deriving durables, the classification of residential investment is crucial. Therefore, this study considers and addresses both possibilities. That is, this section introduces and investigates two alternative models, which their only difference is the way that they classify residential investment. So, the major variable vectors of these two alternative models are introduced as follows.

In model I, the variable vector of Y_t is respectively composed of six variables: (1) real GDP, (2) personal consumption expenditures on durable goods, (3) gross private domestic investment, (4) personal consumption expenditures on non-durable goods and services, (5) the GDP deflator, and (6) the federal funds rate. While in model II, Y_t is respectively consists of the following six variables: (1) GDP, (2) personal consumption expenditures on durable goods plus residential fixed investment, (3) gross private domestic investment minus residential fixed investment, (4) personal consumption expenditures on non-durable goods and services, (5) the GDP deflator, and (6) the federal funds rate. All above variables, except for federal funds rate, are in real term and in logarithm. As mentioned above, the order of variables, indicates the recursive identification scheme. In ordering of variables, I followed Christiano et al. (1999), Erceg and Levin (2002), and Monacelli (2009).

This study[3] follows the approach of Christiano et al. (1999) to investigate the behavior of three major sectors in response to monetary policy innovations. Both above models are estimated using the quarterly data over the period 1954:III – 2007:II with the total number of 212 observations.

Empirical results

Table A.2 presents the values of Akaike's Information Criterion (AIC) for both models. Based on the information provided in this table, lag lengths of four and three are respectively selected for model$I$ and model II. Estimates of coefficient matrices are reported in Table A.3 to table A.11. Figure 1.1 and Figure 1.2 show the impulse response functions of GDP, durables, non-durables and investment in Model I and Model II respectively. According to these two figures, both models show that the response of consumer durables is significantly stronger than the response of non-durables, or even the response of total GDP, to monetary policy shocks. Furthermore, in both models, capital investment sector first has a short rise and then falls together with other sectors, while consumer durables sector co-moves with non-durables sector and GDP. Capital investment, is also significantly more interest-sensitive than the total output and non-durables.

[3]The results of this analysis are robust to different alternative specifications of orderings.

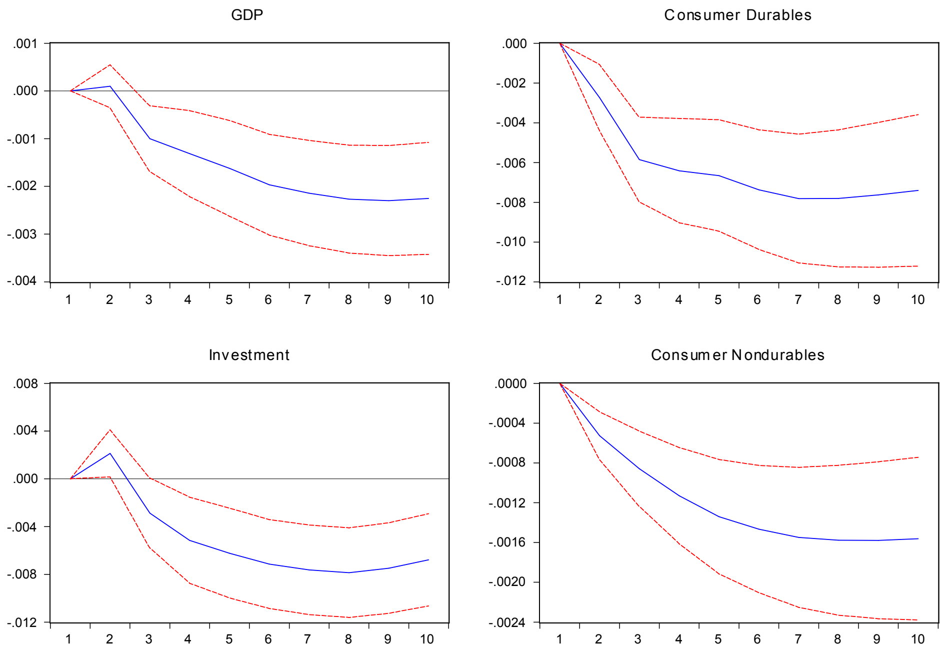

Figure 1.1: Impulse Responses of Model I:
Residential fixed investment is considered as capital investment.

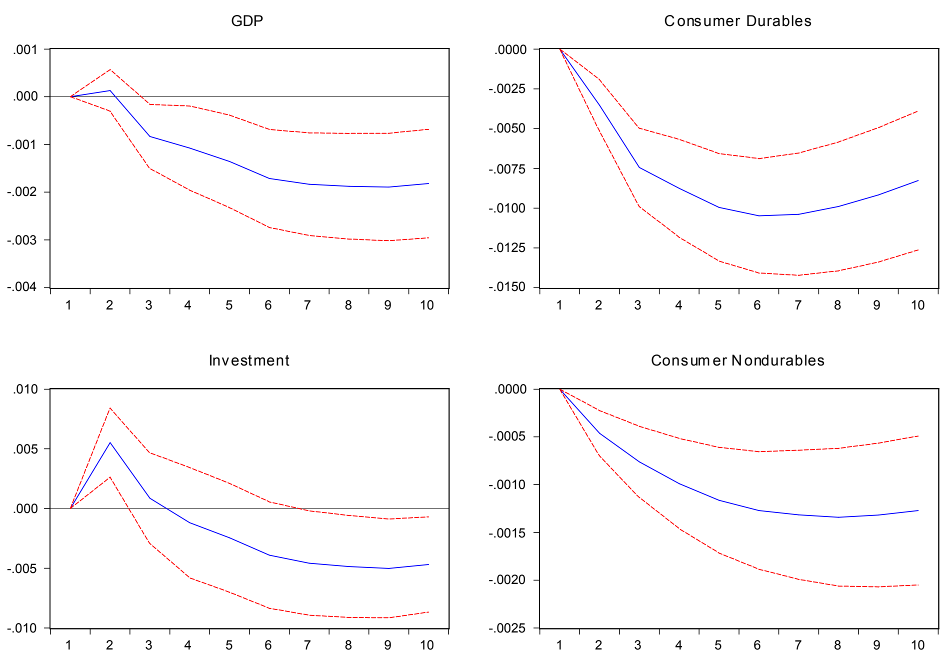

Figure 1.2: Impulse Responses of Model II:
Residential fixed investment is considered as consumer durables.

The consumer durables sector in Model II is slightly more sensitive to the consumer durables sector in model I. The initial rise of capital investment is stronger in Model II, in which residential investment is excluded from investment, than model I, which consider residential investment as a part of investment. While, the trough of investment in model I is more serious than in model II. This may mean that although consumer durable sector co-moves with non-durable sector in response to monetary policy shocks, investment does not co-move with them at least in short run. In conclusion, even though capital investment sector and consumer durables sector both consist of durable products, at least in short run, they co-move negatively in response to monetary policy shocks. However, after a few quarters both sectors positively co-move along with other sectors and with the total output.

1.5 Conclusion

This chapter, using a simple VAR methodology, performs two independent studies, both of which try to shed light on the behavior of durable goods in response to monetary policy shocks. Each study investigates one of the following research questions: (i) To what extent the interest-sensitivity of a sector in the economy can be attributed to the degree of durability in the sector? (ii) Is the application, i.e. being whether productive or utility-deriving, of a durable good critical in determining the behavior of it in response to monetary policy shocks? To address the first question, I disaggregate the total output in eight separate industrial sectors, ranked based on their degree of durability, and compare the responses of sectors to monetary policy shocks, using a simple vector autoregression (VAR) analysis. The results of this study show that there is no straightforward relationship between the degree of durability and the strength or the quickness of responses to monetary policy innovations. The second question is addressed in another cross-sectoral VAR analysis, in which the total output is disaggregated in three major sectors; consumer non-durable goods, consumer durable goods, and productive durable goods (capital). This study shows that despite the large interest-sensitivity of all types of durables compared to non-durables, productive durables are slightly less sensitive to monetary policy shocks. It also indicates that the immediate response of productive durables to monetary shocks is inverse to the response of other sectors and with total GDP in response to monetary policy shocks. However, after a couple of quarters it co-moves with other sectors.

2 Overlapping Functions of Consumer Durables and Capital

2.1 Introduction

Although consumer durables[4] and capital, as they are defined in national accounting, to the large extent are distinguishable, it does not mean that they have perfectly distinguished functions. Plenty of actual instances indicate that durables may contribute in production and that capital may contribute in household's utility function. However, this interdependence between consumers and producers has received less attention in the standard theory. In the theory, it is traditional to assume that consumer durables, or consumption in general, exclusively participate in utility functions and that capital exclusively contribute in production. This paper revises this tradition and explores some of the implications of introducing overlapping function of durables and capital; where durables have some influences on production and capital plays

[4]Throughout this paper, the terms "durables" and "durable spending" refer to "consumer durable goods" and "personal consumption expenditures on durable goods", respectively.

some utility-deriving roles. In other words, it is not possible to distinguish durables from capital only by their functions.

Capital, namely physical asset, is not only a factor of production but also a significant portion of individuals' wealth formation and, hence, it can provide utility. On the other hand, typical workers 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, which are considered as the firm's capital. For example, workers directly benefit from the air-conditioners, restrooms, light, coffee machines, microwaves, fridges, chairs, office supplies, and the free transportation or parking spot provided by firms. Larger offices or workplaces for workers can also directly increase their satisfaction. They also may benefit from the computers, copy machines, scanners, and other office supplies. All these are examples of capital products from which workers can directly derive utility. Therefore, capital, besides the personal consumption, may contribute in the utility function of households, even though its key role is being a factor of production.

On the other hand, a significant portion of workers in the U.S. works from home[5]. They, hence, would take advantage of their personal possessions, e.g. home office, garage, and computer, to produce goods or services. Besides, the majority of workers commute to work using their own vehicles[6]. Commuting to work is, to the large extent, a production activity. Thus, personal vehicles that transport workers to their workplaces contribute in the production of firms, even though in national accounting they are considered as consumer durables. Furthermore, modern personal devices like smart-phones and tablets, which are widely used by individuals, are enormously

[5]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.

[6]The American Community Survey (ACS) documents that in 2008-2012 5-year period 86.2 percent of workers drove alone or carpooled to work.

helping business communications. In most cases, however, they are counted as consumer durables. Therefore, households' durables may contribute also in production, even though their key role is utility deriving.

Therefore, this paper modifies the two-sector new Keynesian general equilibrium model by replacing the implicit traditional assumption of perfectly distinguished (or separate) functions of durables and capital, hereafter SFDK, with the new assumption of overlapping functions of durables and capital, hereafter OFDK. The simulated results show that this modification can simply improve quantitative performance of the model to replicate empirical evidence.

The OFDK assumption, in this paper, is formulated in a way that SFDK can be studied as an extreme especial case of it. A comparison of the results generated by the model under two scenarios, i.e. OFDK and SFDK, shows that the assumption of separate functions of capital and durables can be a source of standard models' failure to capture the co-movement of durable spending with non-durable spending in response to monetary policy shocks as found in the data. Moreover, it is shown that this assumption can also temper the extraordinarily sensitive responses of both durables and capital to monetary policy shocks.

The paper is organized as follows. Section 2.2 presents a framework of two-sector new-Keynesian model with standard features. Section 2.3 introduces two scenarios for functional distinguishability of durables and capital. Section 2.4 presents the calibration of model parameters. Section 2.5 analyzes the results and studies the sensitivity of the results. Finally, Section 2.8 presents concluding remarks.

2.2 Model

Consider an economy composed of two sectors, one for non-lasting goods, i.e. non-durables, and the other for lasting goods, namely capital and durables. The economy is populated by infinitely lived households (of measure of one) who derive utility from consumption of non-durables, leisure, and services of lasting products, which have been purchased by either households or firms. Each sector consists of a large number of monopolistic competitive final good producers that buy homogeneous intermediate goods from many homogeneous intermediate good producers (common across 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.

2.2.1 Intermediate good producers

A large number of intermediate firms produce homogeneous 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 based on the production function of

$$Y_t = \zeta_{A,t} \tilde{K}_t^{\alpha} N_t^{1-\alpha} \tag{2.1}$$

where N_t is the labor demand and Y_t is the intermediate output. $\tilde{K}_t$ is a CES aggregation of lasting goods, purchased either by households or by firms, which participate in production. In the special case in which functions of capital and durables are distinguishable, as it is assumed in standard theory, consumer durables do not participate in production, and therefor$\tilde{K}_t$ will be exclusively equal to the stock of capital, i.e. K_t. Also, $\zeta_{A,t}$ denotes technology shocks which its logarithm follows an AR(1) process.

2.2.2 Final good producers

Let index the sector of non-lasting (non-durables) goods by C, and the sector of lasting goods (capital and durables) by X. In each sector, final good producers independently buy homogeneous 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 $Y_{j,t}^{f}$ is the following composite of individual final producer outputs:

$$Y_{j,t}^{f} = \left(\int_0^1 Y_{j,t}(z)^{\frac{1}{\mu_j}} dz \right)^{\mu_j} \tag{2.2}$$

where $j = C, X$ is the sector index and μ_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:

$$Y_{j,t}(z) = \left(\frac{P_{j,t}}{P_{j,t}(z)} \right)^{\frac{\mu_j}{\mu_j - 1}} Y_{j,t}^{f} \tag{2.3}$$

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).

2.2.3 Households

A typical household in each period uses a consumption basket consisting of the consumption of non-durables, C_t, and the service of the aggregation of accumulated capital and durables, $\tilde{D}_t$. This basket, Θ_t, is formed based on the following aggregation process:

$$\Theta_t = \left[(1-\gamma)^{\frac{1}{\sigma}} (C_t)^{\frac{\sigma-1}{\sigma}} + \gamma^{\frac{1}{\sigma}} \left(\tilde{D}_t\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} \tag{2.4}$$

where $1-\gamma$ represents the share of non-durables in the consumption basket and σ denotes the elasticity of substitution between consumption of non-durables and service of lasting goods. $\tilde{D}_t$ is a CES aggregation of household's capital and durables. However, assuming that functions of capital and durables are distinguishable, as it is in standard theory, $\tilde{D}_t$ will be exclusively equal to the stock of durables, i.e. D_t.

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

$$E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \log(\Theta_t) - \frac{\nu (N_t)^{1+\varphi}}{1+\varphi} \right\} \tag{2.5}$$

subject to the sequence of budget constraints of

$$C_t + p_{X,t}(I_{D,t} + I_{K,t}) + b_t = p_{w,t} Y_t + f_t + R_{t-1} \frac{b_{t-1}}{\pi_{C,t}} + T_t \tag{2.6}$$

which is shown in real terms[7], where $p_{X,t}$ is the relative price of lasting goods, b_t is the real debt, $p_{w,t}$ is the relative wholesale price of intermediate goods, Y_t is the output of

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

intermediate producers, f_t is the final good producers' lump-sum real profit[8]. Also, $I_{D,t}$ denotes the flow of durables (i.e. the durable purchases added to 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.

Investments in capital and durables follow the following processes:

$$D_t = (1 - \delta_D) D_{t-1} + I_{D,t} \tag{2.7}$$

$$K_{t+1} = (1 - \delta_K) K_t + I_{K,t} \tag{2.8}$$

where δ_D and δ_K are the depreciation rates of durable goods and capital respectively. The difference in timing of durable flows and capital investment refers to the idea that once households buy a durable they can start using it right away, while once they invest in capital they need some time to establish it in a production framework.

2.2.4 Monetary policy

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

$$\frac{R_t}{R} = \left(\frac{\pi_t}{\pi}\right)^{\phi} \zeta_{M,t} \tag{2.9}$$

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

$$\pi_{C,t}^{\tau_C} \pi_{X,t}^{\tau_X} = \pi_t \tag{2.10}$$

[8]All real variables and relative prices are in units of non-durables.

where τ_j, where $j = C, X$, is the share of sector j in economy's inflation. Finally, the policy shock follows

$$\ln\zeta_{M,t} = \rho_M \ln\zeta_{M,t-1} + \varepsilon_{M,t} \tag{2.11}$$

where $\varepsilon_{M,t}$ is i.i.d. process with variance of σ_M^2.

2.3 Two scenarios

In order to facilitate the comparative study, this section introduces two different scenarios for function distinguishability of durables and capital.

2.3.1 SFDK Scenario: The benchmark

The first scenario is based on the standard assumption in which durables and capital are functionally distinguishable. In this scenario, the roles of durables and capital are perfectly distinguished . Durable goods, which are purchased by households, just participate in utility function and capital, which is purchased by firms, exclusively work as production factors. This scenario can be embedded into the model by following equations:

$$\tilde{K}_t = K_t \tag{2.12}$$

$$\tilde{D}_t = D_t \tag{2.13}$$

2.3.2 OFDK scenario

The second scenario, instead, refers to the new assumption of overlapping functions of durables and capital. Note that categorizing lasting products into 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 functions.

OFDK[9] scenario assumes that considering the definitions of consumer durables and capital in national accounting, their functions are not necessarily separable. This scenario is expressed by following equations:

$$\tilde{D}_t = D_t^{\eta_1} K_t^{1-\eta_1} \tag{2.14}$$

$$\tilde{K}_t = K_t^{\eta_2} D_t^{1-\eta_2} \tag{2.15}$$

These equations imply that when η_1 and η_2 tend to one, OFDK scenario tends to the standard scenario of SFDK. In this scenario, it is assumed that η_1 and η_2 are independent. The shares of consumer durables (or capital) in utility function plus in production function can be more than one. In other words, a consumer durable (or capital) can participate in production and utility functions at the same time. However, as the major role of capital is being productive, we expect that $0.5 < \eta_2 < 1$. Similarly, as the major role of durables is utility deriving, it should be the case that $0.5 < \eta_1 < 1$.

2.4 Calibration

The model is calibrated based on quarterly data. The discount factor, β, is set to 0.99, assuming the annual rate of return of 4 percent. Unless stated otherwise, both depreciation rates, i.e. δ_D and δ_K, are set to 0.025, which is consistent with 10 percent annual depreciation rate. The non-durables share in utility function, $1 - \gamma$, is set in

[9] "**O**verlapping **F**unctions of **D**urables and (**K**)apital"

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, μ_j, are set to 1.2 to show 20% of net mark-up. The elasticity of substitution between durables and non-durables, σ, and the inverse elasticity of labor supply, φ, 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 θ_j are calibrated so that prices are updated once a year in the non-durable sector and every three quarters in the sector of capital and durables.

As it is standard in the literature on Taylor rules, the monetary policy parameter, ϕ, is set to 1.5. The capital share parameter, α, is calibrated to 0.35. Finally, the preference parameter, ν, is obtained in such way that households are assumed to work one third of their time endowment in steady state.

As simulated results reveals, the model generate almost the most consistent results with the data when $\eta_1 = 0.75$ and $\eta_2 = 0.7$. The simulated results of the model under different values of η_1 and η_2 will be shown in section 2.5.

2.5 Cyclical properties comparison

This section compares the cyclical properties of the model with those from the data. Table 2.1 reveals certain statistics from the actual data and those from simulations of the model under two alternative scenarios. Panel A of the table summarizes the behavior of the U.S. quarterly data, in logarithm, for the period of 1954:3 - 2007:2, after being filtered using the Hodrick-Prescott technique. Panel B and C present statistics of generated results when the model is simulated under SFDK and OFDK respectively. Statistics are computed for three series of variables: non-durable consumption, durable spending, and investment. For each series x, each panel provides the percentage standard deviation of x relative to the percentage standard deviation of y and the correlation of $\hat{x}$ with $\hat{y}$, the hats representing logarithm.

	$x =$	C	I_D	I_K
A. U.S. Data	$\frac{std(\hat{x})}{std(\hat{y})}$	0.44	2.44	3.51
	$corr(\hat{x}, \hat{y})$	0.86	0.86	0.95
B. SFDK Model	$\frac{std(\hat{x})}{std(\hat{y})}$	0.70	5.63	3.81
	$corr(\hat{x}, \hat{y})$	0.89	0.24	0.53
C. OFDK Model	$\frac{std(\hat{x})}{std(\hat{y})}$	0.43	2.04	2.46
	$corr(\hat{x}, \hat{y})$	0.96	0.73	0.80

Table 2.1: Cyclical properties comparison

As it is shown in table 2.1, the OFDK scenario is considerably preferable over SFDK scenario in several aspects. The OFDK model can well generate the volatility of non-durable consumption relative to output. While, non-durable consumption is too volatile under SFDK scenario. Moreover, volatility of durable spending relative to output is notably close to the data in OFDK model compared with that in SFDK model. Nevertheless, investment in OFDK model is not volatile enough relative to output. Additionally, in comparison with the standard model, OFDK model can improve the correlations of durable spending and investment with output.

2.6 Durable co-movement puzzle

This section concentrates on the interest rate sensitivity of durables. Several empirical studies, e.g. Barsky et al. (2007, 2003), Erceg and Levin (2006), have documented that durable spending exhibits two key features in response to monetary policy shocks: it positively co-moves with non-durables, and it is more sensitive to monetary policy shocks than non-durables and other components of GDP. While standard new-Keynesian models are unable to generate the first feature, they produce high sensitivity of durable spending 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 durables and 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 categories of 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.

After presenting a simple identified VAR study which shows the co-moving behavior of durable spending with non-durables in response to monetary policy shocks, this section will investigate the contributions of the new assumption of overlapping function of durables and capital in resolving the co-movement puzzle.

Figure 2.1 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. Durable spending and investment, though, respond disparately under alternative scenarios. Under the standard scenario in which durables and capital are functionally distinguished, the co-movement puzzle of durables exists, and durable spending and capital investment 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.

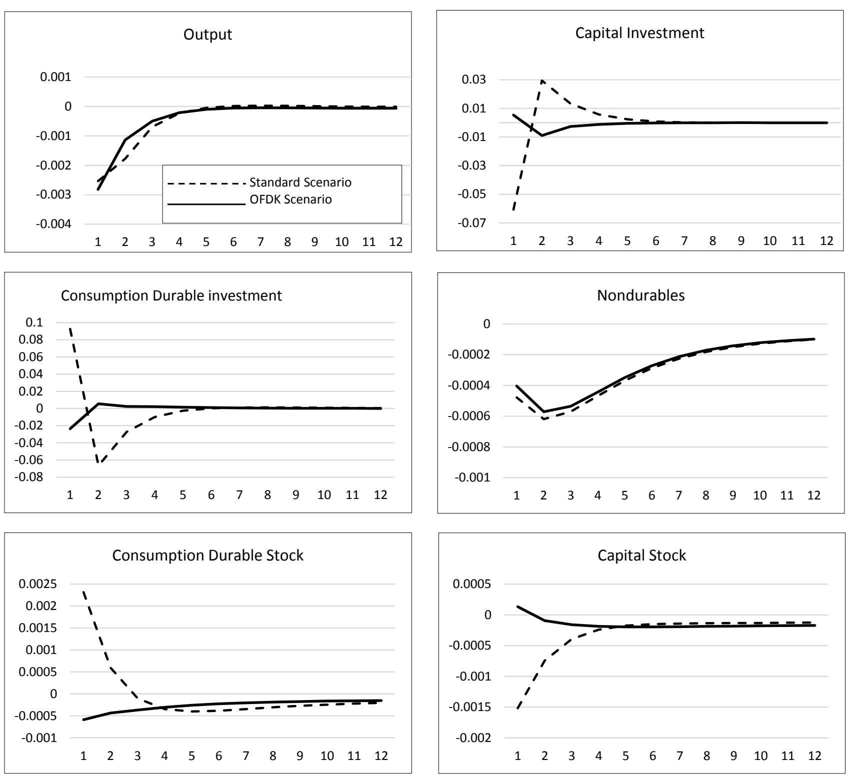

Figure 2.1: Impulse response functions under two alternative scenarios: Standard scenario (Separate Functions of Durables and Kapital(SFDK)) and OFDK scenario (Overlapping Functions of Durables and Capital).

2.7 Sensitivity Analysis

This section analyzes the sensitivity of the simulated results under different parameterizations. Figure 2.2 consists of 16 panels each of which illustrates simulated results of the model for a particular pair of stickiness in two sectors of the model and for different possible values for $\eta_1$and η_2. In each panel, the black area shows the parametrizations under which the sign of immediate responses of non-durables, durable spending, and capital investment are consistent with data. While, the gray area shows the parametrizations under which the durables co-movement problem is resolved, however the immediate response of capital investment is not consistent with data.[10] As it is clear from this figure, the assumption that price stickiness in durable-capital sector is lower than in non-durable sector is crucial for the model to resolve the puzzle. Moreover, the SFDK scenario, in which $\eta_1 = \eta_2 = 1$, could not resolve the puzzle in any of the simulations. While, some level of functional overlapping, e.g. when $\eta_1 = 0.7$ and $\eta_2 = 0.75$, can resolve the co-movement puzzle in all of the panels in which the durable prices is more flexible than non-durable prices.

Similarly, Figure 2.3 shows how the simulated results are sensitive to different values of depreciation rates for durables and capital. The figure shows that overlapping scenario can resolve the co-movement puzzle only if depreciation rates of durables are more than of or equal to depreciation of capital.

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[10] Therefore, each panel consists of 1681 simulations for different pairs of $\eta_1$and η_2.

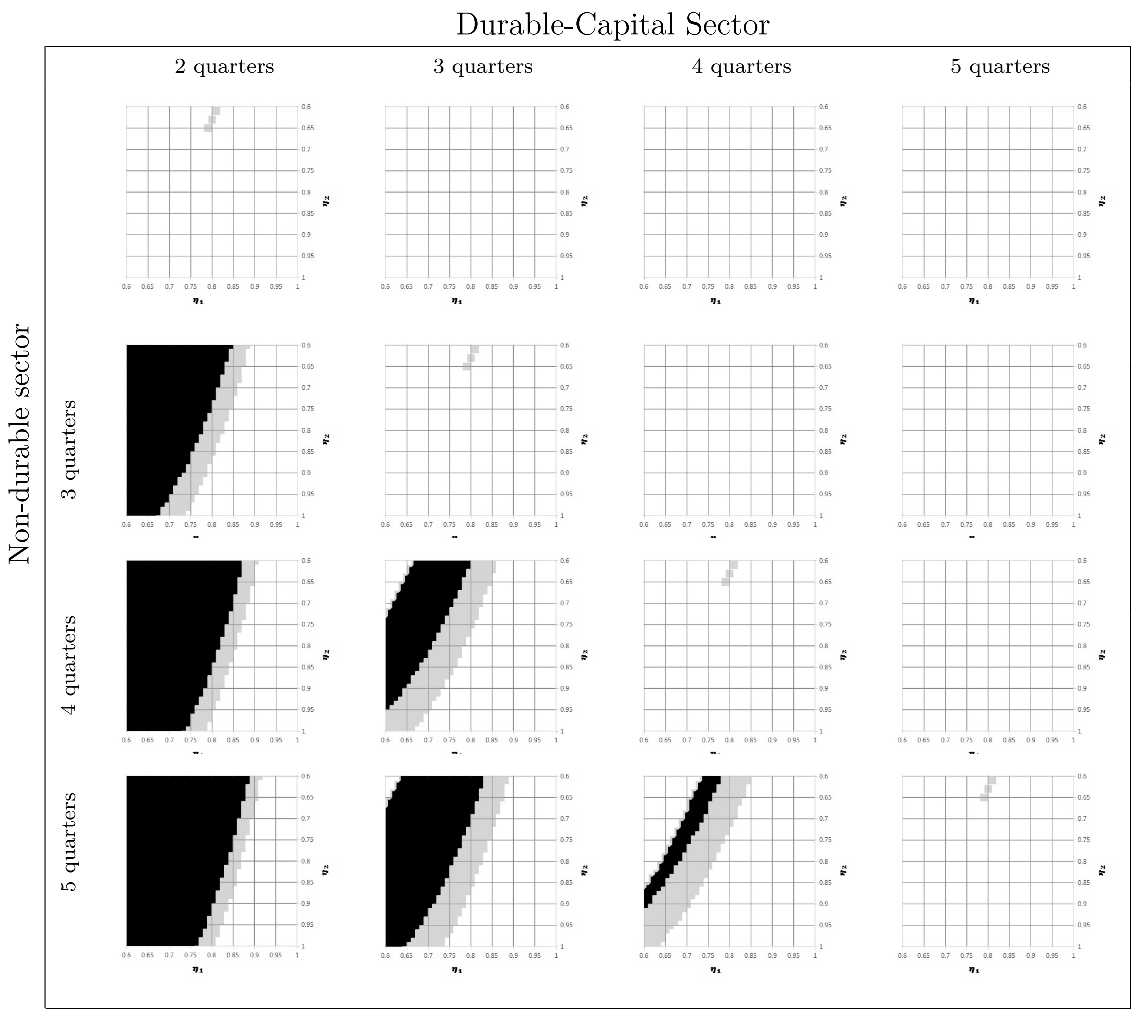

Figure 2.2: Sensitivity Analysis: Overlapping Functions and Price Stickiness

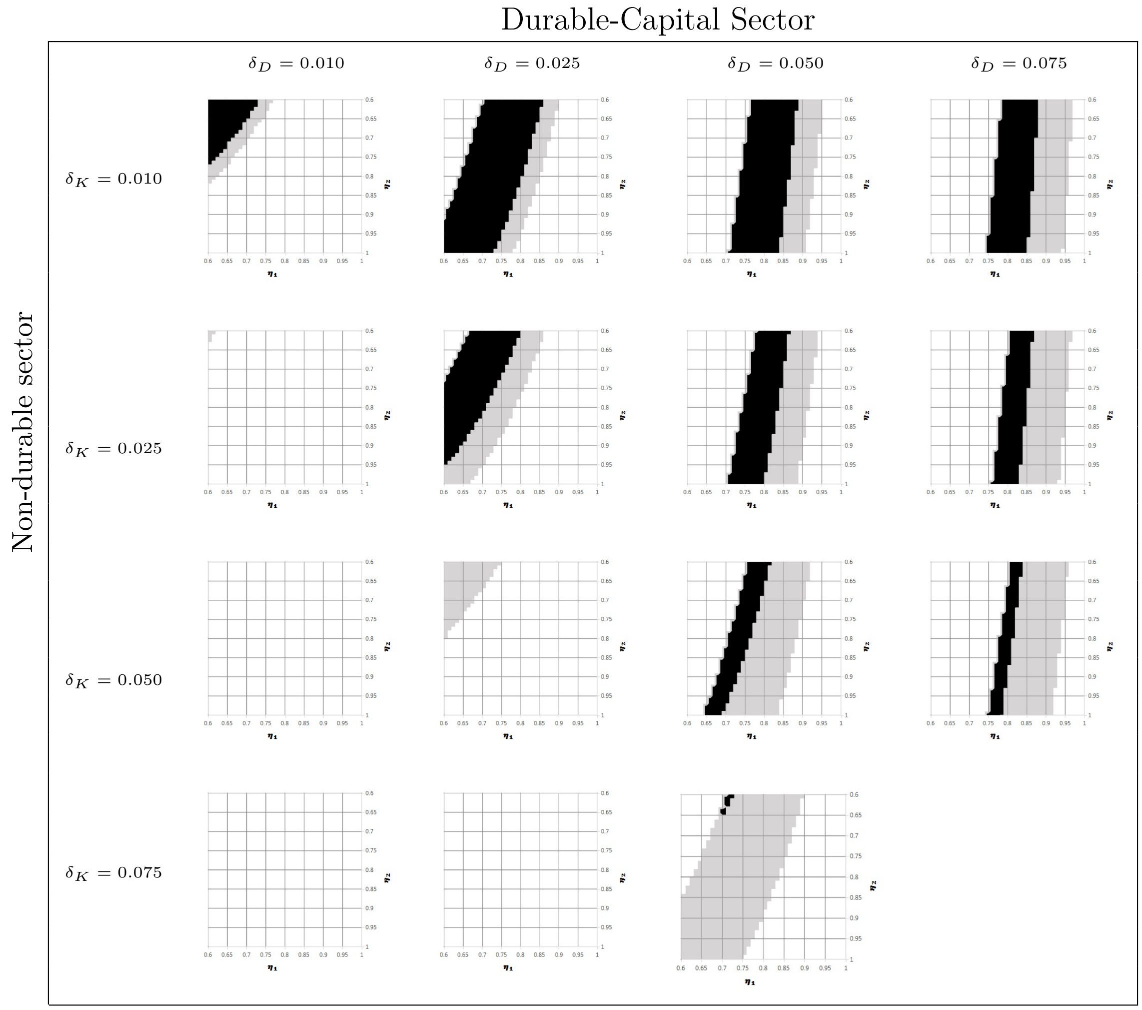

Figure 2.3: Sensitivity Analysis: Overlapping Functions and Durability

2.8 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, this paper considers positive production externality for consumer durables and positive consumption externality for capital. In other words, 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 "overlapping functions of consumer durables and capital". It is demonstrated in this paper that an alternative two-sector new Keynesian general equilibrium model consisting this new assumption 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 durable spending and capital investment to monetary policy shocks. Furthermore, the sensitivity of the results to different calibration mechanisms is investigated.

Finally, it is worth mentioning that this paper is not criticizing the methods by which national accounting is performed. It is also not modifying the definitions of durables or capital. The assumption of overlapping roles for durables and capital just focuses on some non-market external effects of durables and capital. Therefore, this model uses the data as it is.

3 Durable Goods and Energy Price Shocks

3.1 Introduction

Almost every recession in the U.S. after the second war was preceded by a spike in energy prices (Hamilton and Herrera (2004), Hamilton (2005)). Nevertheless, a lot of attempts in economic theory has focused on the issue that how to explain the significant impacts of energy price shocks, while energy constitutes a small share of GDP. One of the popular solutions proposed for this puzzle is that the monetary policy reactions to energy price shocks exacerbate the recessions. This chapter, investigates the role of durable goods in this context, using a general equilibrium model. Durable goods are known as being interest-sensitive. Moreover, most of durables need energy to be utilized. Therefore, durable goods may have a significant effect on the results of a study that aims to investigate that to what extent monetary policy should be blamed for the recessionary consequences of energy price shocks.

Several papers have tried to explain the significant effect of energy price shocks in theory. In a dynamic general equilibrium model, Kim and Loungani (1992) consider energy use exclusively in the production function. They show that energy price shock cannot generate the most part of output fluctuations observed in the data. So, they conclude that output fluctuations are due mainly to technology shocks. Rotemberg and Woodford (1996), however, show how it is possible to see a considerable role for an oil price shock affecting output fluctuations by assuming imperfect competition with an implicit collusion into the model. On the other hand, Finn (2000) shows that the assumption of imperfect competition is not necessary to explain the impacts of energy price shocks on output fluctuations. She, by presenting a perfect competitive model, generates similar results as Rotemberg and Woodford (1996). The brilliant part of Finn's model is the assumption under which the capital requires energy in order to be utilized in the production.

Hamilton (2005), however, proposes that the effects of oil price shocks on spending of goods are considerable. He explains that following an oil price shock consumers may postpone their purchase of durable goods. Based on this idea, Dhawan and Jeske (2008), extended the model proposed by Kim and Loungani (1992) by explicitly modeling household consumption of durable goods and energy use. The simulated results of their model indicate that even with incorporation of durable goods in the model, the energy price shocks still are not a major cause of business cycle fluctuations.

As low share of energy has not let a reasonable explanation of significant recessions after oil price shocks, many economists blame monetary policy that made in response to oil price shocks as a major reason of recessions. Several studies, however, have addressed the question that which one is the major responsible of business cycle fluctuations; oil price shocks or monetary policy. Bernanke et al. (1997) shows that, in response to high oil prices, interest rates have been highly increased and exacerbated the recessions that had been caused by high oil prices. However, Hamilton and Herrera (2004) challenge the results of Bernanke et al. (1997) due to model misspecifications and show that under different specifications the model of Bernanke et al. (1997) can have significantly different results indicating larger role for the oil price shocks. In another study, Bernanke et al. (2004), using a VAR model, conduct a counter-factual experiment by adding unexpected monetary policy innovations to the VAR so that the funds rate remains stable even after oil price shocks. The results of their model indicate that a major part of negative impact of oil price shocks refers to endogenous contractionary monetary policy which responds the shocks. Leduc and Sill (2004) address the above question using a calibrated general equilibrium model. In their model, following Finn (2000), they assume that the oil is exclusively used to utilize capital. The results of their benchmark model show that, in contrast to Bernanke et al. (1997) and Bernanke et al. (2004), monetary policy is responsible for only about 40 percent of the recessions following an oil price shock. They also have studied the impacts of oil price shocks under various monetary policy specifications and conclude that, although they can play a significant role, central banks cannot fully offset the impacts of oil price shocks in the economy. Several other papers have studied above question under the condition of optimal monetary policy. NATAL (2012) shows that as energy is an input to both production and consumption the policy trade-off is nontrivial. He concludes that perfectly price stabilizing monetary policies entail large welfare costs. He also finds that optimal monetary policy response to a persistent increase of oil price is similar to the typical response of inflation targeting policies. Kormilitsina (2011) estimates a dynamic stochastic general equilibrium model and shows that even though monetary policy amplified the negative effects of energy price shocks, the optimal monetary policy could have caused even a higher interest rates that had been seen in the past.

This chapter investigates that how the incorporation of durable goods may improve our understanding of energy price shock effects on the economy. It also compares the simulated results of the model under two specification scenarios, i.e. with and without consumer durables, and assess the role of monetary policy in amplification of energy price shocks. In this model energy usage is considered for utilization of all durables, including productive or non-productive. Moreover, following Finn (2000), the depreciation rates of consumer durables and capital are both endogenous and based on the extent that they are utilized. In other words, the durability of consumer durables and capital, which is a crucial feature especially in the literature of monetary policy, are now dependent of their utilizations, which in turn depend on the energy price.

The plan of this chapter is the following. Section 3.2 presents a framework of three-sector new-Keynesian model, in which a separate sector is considered for the energy. Section 3.3 explains how the model is calibrated. The simulated results of the model are presented in three following sections. Section 3.4 compares the simulated results of the introduced model with the results of a standard model in which consumer durable spending is considered as a part of total consumption expenditures. Section 3.5 investigates that how the durability of products may influence the impacts of energy price shocks on output. Section 3.6 investigates that to what extent monetary policy should be blamed for the recessions that come after energy price shocks. Finally 3.7 concludes the chapter.

3.2 Model

In many aspects this model is similar to the one introduced in chapter 2. There are, however, three sectors in this model: 1) non-lasting products sector, indexed by C, consisting non-durable goods and services, 2) lasting products sector, indexed by X, consisting consumer durables and capital, and 3) energy sector, indexed by E. The economy is populated by infinitely lived households (of measure of one) who derive utility from consumption of non-durables, leisure, and services of lasting products, which have been purchased by either households or firms. That is the OFDK scenario, i.e. the assumption of overlapping functions of consumer durables and capital, is also considered in this model. However, the results will be reported for both cases of standard and OFDK scenarios. Each sector consists of a large number of monopolistic competitive final good producers that buy homogeneous intermediate goods from many homogeneous intermediate good producers (common across 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.

In order to introduce energy in the economy in this model, following Finn(2000), it is assumed that energy exclusively used for utilization of other goods. There are two major goods which need energy to be utilized: durables and capital. In this model, the energy purchased and used to utilize durables and capital is denoted as $E_{D,t}$ and $E_{K,t}$ respectively. In fact, it is utilized capital $\tilde{K}_t$ and utilized durables $\tilde{D}_t$ that contribute in production and utility functions. Utilized capital and utilized durables are defined using two utilization variables, i.e. $u_{K,t}$and $u_{D,t}$, as follows:

$$\tilde{K}_t = u_{K,t} K_t \tag{3.1}$$

$$\tilde{D}_t = u_{D,t} D_t \tag{3.2}$$

where K_t and D_t are total stock of capital and consumer durables respectively; and both $u_{K,t}$ and $u_{D,t}$ are fractions between zero and one.

Since the more a good is being utilized the more it would be depreciated, it is also assumed in this model that both depreciation rates of capital and durable goods are function of their utilizations. Again, following Finn(2000), those functions are defined as:

$$\delta_K \left(u_{K,t}\right) = \frac{\delta_0^K}{\delta_1^K} \left(u_{K,t}\right)^{\delta_1^K} \tag{3.3}$$

$$\delta_D \left(u_{D,t}\right) = \frac{\delta_0^D}{\delta_1^D} \left(u_{D,t}\right)^{\delta_1^D} \tag{3.4}$$

Furthermore, as capital and durable goods need energy to be utilized, there should be a direct relationship between the energy ration for each group, i.e. $a_{K,t}$and $a_{D,t}$, and the utilization of each groups of goods. These relationships are defined as:

$$a_K \left(u_{K,t}\right) = \frac{E_{K,t}}{K_t} = \frac{a_0^K}{a_1^K} \left(u_{K,t}\right)^{a_1^K} \tag{3.5}$$

$$a_D \left(u_{D,t}\right) = \frac{E_{D,t}}{D_t} = \frac{a_0^D}{a_1^D} \left(u_{D,t}\right)^{a_1^D} \tag{3.6}$$

3.2.1 Intermediate good producers

A large number of intermediate firms produce homogeneous 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 based on the production function of

$$Y_t = \zeta_{A,t} \left(\tilde{K}_t^{\eta_2} \tilde{D}_t^{1-\eta_2} \right)^{\alpha} N_t^{1-\alpha} \tag{3.7}$$

where N_t is the labor demand and Y_t is the intermediate output. η_2 is the parameter associated with OFDK scenario in production. $\tilde{K}_t$ denotes utilized capital and $\tilde{D}_t$ denotes utilized consumer durables, and $\zeta_{A,t}$ denotes technology shocks which its logarithm follows an AR(1) process.

3.2.2 Final good producers

Final good producers, in each sector of non-lasting products and lasting products, independently buy homogeneous intermediate goods at $P_{w,t}$ in a competitive market, differentiate them at no cost, and then re-sell the heterogeneous output to households. While, energy suppliers, i.e final good producers in the energy sector, buy homogeneous intermediate goods at $P_{w,t}$ in a competitive market, and trade it with imported energy with the exogenous price of $\tilde{P}_{E,t}$, assuming trade balance. Then, they differentiate the imported energy at no cost, and re-sell it to households.

In each sector, indexed by $j = C, X$, and E, there are many heterogeneous final good producers, which are a continuum of mass one and indexed by z. Therefore, $Y_{j,t}\left(z\right)$denotes the amount of intermediate output sold by the final producer z in section j and $P_{j,t}\left(z\right)$ is the price of zth final good in sector j. Then, the total amount of final goods in a sector, i.e. $Y_{j,t}^{f}$, is assumed to follow the CES aggregation of outputs of all final producers in that sector.

$$Y_{j,t}^{f} = \left(\int_0^1 Y_{j,t}(z)^{\frac{1}{\mu_j}} \, dz \right)^{\mu_j} \tag{3.8}$$

where μ_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:

$$Y_{j,t}(z) = \left(\frac{P_{j,t}}{P_{j,t}(z)} \right)^{\frac{\mu_j}{\mu_j - 1}} Y_{j,t}^{f} \tag{3.9}$$

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).

3.2.3 Households

A typical household in each period uses a consumption basket consisting of the consumption of non-durables, C_t, and the service of the utilized consumer durables, $\tilde{D}_t$, and utilized capital, $\tilde{K}_t$. This basket, Θ_t, is formed based on the following aggregation process:

$$\Theta_t = \left[(1-\gamma)^{\frac{1}{\sigma}} (C_t)^{\frac{\sigma-1}{\sigma}} + \gamma^{\frac{1}{\sigma}} \left(\tilde{D}_t^{\eta_1} \tilde{K}_t^{1-\eta_1} \right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \tag{3.10}$$

where $1 - \gamma$ represents the share of non-durables in the consumption basket and σ denotes the elasticity of substitution between consumption of non-durables and service of lasting goods. η_1 is the parameter associated with OFDK scenario in utility function and once it is one we can study the standard case in which capital and durables are perfectly distinguishable.

A representative household maximizes the following expected lifetime utility:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \log(\Theta_t) - \frac{\nu (N_t)^{1+\varphi}}{1+\varphi} \right\} \tag{3.11}$$

subject to the sequence of budget constraints of

$$C_t + p_{X,t}\left(I_{D,t} + I_{K,t}\right) + p_{E,t}\left(E_{D,t} + E_{K,t}\right) + b_t = p_{w,t}Y_t + f_t + R_{t-1}\frac{b_{t-1}}{\pi_{C,t}} + T_t \quad (3.12)$$

which is shown in real terms[11], where $p_{X,t}$ is the relative price of lasting goods, p_E is the relative price of energy, 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[12]. Also, $I_{D,t}$ denotes the flow of durables (i.e. the durable purchases added to 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.

Investments in capital and durables follow the following processes:

$$D_t = \left(1 - \delta_D\left(u_{D,t}\right)\right) D_{t-1} + I_{D,t} \quad (3.13)$$

$$K_t = \left(1 - \delta_K\left(u_{K,t}\right)\right) K_{t-1} + I_{K,t} \quad (3.14)$$

where $\delta_D\left(u_{D,t}\right)$ and $\delta_K\left(u_{K,t}\right)$ are the depreciation rates of durable goods and capital respectively. As mentioned above, depreciation rates of capital and durable goods are functions of the utilizations of capital and durable stock.

[11] The above real budget constraint is equivalent to the nominal budget constraint of $P_{C,t}C_t + P_{X,t}\left(I_{D,t} + I_{K,t}\right) + P_{E,t}\left(E_{D,t} + E_{K,t}\right) + B_t = P_{w,t}Y_t + F_t + R_{t-1}B_{t-1} + P_{C,t}T_t$

[12] All real variables and relative prices are in units of non-durables.

3.2.4 Monetary policy

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

$$\frac{R_t}{R} = \left(\frac{\pi_t}{\pi}\right)^{\phi_\pi} \left(\frac{Y_t}{Y}\right)^{\phi_Y} \zeta_{M,t} \tag{3.15}$$

where $\zeta_{M,t}$ is monetary policy shock, and R, π, and Y are steady states of gross nominal interest rate, gross inflation rate, and output respectively. π_t is the economy's gross inflation rate that is a compound index of sectoral gross inflation rates so that:

$$\pi_{C,t}^{\tau_C} \pi_{X,t}^{\tau_X} \pi_{E,t}^{\tau_E} = \pi_t \tag{3.16}$$

where τ_j, where $j = C, X, E$, is the share of sector j in economy's inflation.

The policy shock follows

$$\ln\zeta_{M,t} = \rho_M \ln\zeta_{M,t-1} + \varepsilon_{M,t} \tag{3.17}$$

where $\varepsilon_{M,t}$ is i.i.d. process with variance of σ_M^2.

3.3 Calibration

The model is calibrated based on quarterly data. The discount factor, β, is set to 0.99, assuming the annual rate of return of 4 percent. Following Dhawan and Jeske (2008), the steady state of depreciation rates, i.e. δ_D and δ_K, are respectively set to 0.0682 and 0.0156. In addition, the steady states of the energy share in consumer durables and in capital, i.e. a_D and a_K, are respectively set as 0.0333 and 0.0043, computed from the calibration process of Dhawan and Jeske (2008). Also the ration of consumer durables to output, i.e. $\frac{D}{Y_{real}}$, is set to 1.3668. Following Finn (2000), four parameters of δ_0^D, δ_0^K, a_0^D, and a_0^K are set to zero. The markup parameters in all sectors, μ_j, are set to 1.2 to show 20% of net mark-up. The elasticity of substitution between durables and non-durables, σ, and the inverse elasticity of labor supply, φ, 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 θ_j are calibrated so that prices are updated once a year in the non-durable sector and every three quarters in the sector of capital and durables.

As it is standard in the literature on Taylor rules, the monetary policy parameters, i.e.ϕ_π and ϕ_Y , are set to 1.53 and 0.27. The capital share parameter, α, is calibrated to 0.35. Finally, the preference parameter, ν, is obtained in such way that households are assumed to work one third of their time endowment in steady state. The OFDK parameters, i.e. η_1 and η_2, are set as 0.75 and 0.7.

3.4 Inclusion of Durables

Does inclusion of consumer durables in a standard model change our understanding from the impacts of energy price shocks on the economy? This is the major question which is addressed in this study. Unlike non-durables, consumer durables have two[13] particular characteristics which should not be ignored in modeling. First, they are durable. That is they would be used for a longer time (at least for several units of time, e.g. a year or a quarter), so they are very sensitive to temporary shocks, as the buyer needs to have a longer period of usage in mind when buying a durable good. Second, in most cases, durables need energy to be utilized. This feature make them more sensitive to energy shocks than non-durables, because an energy price shock is also a shock in the utilization cost of a durable for example. The model in this study

[13]Another particular characteristic of durables may be that they are mostly not as crucial and necessary as non-durables. This feature has not been modeled in this study though.

has considered a separate section for durable goods with above two characteristics to study how the inclusion of durables in a standard model of energy would change the simulated results.

Figure 3.1 summarizes the simulated results of the model under three calibration scenarios. This figure reveals the impulse response functions of total consumption, total output, capital investment, capital stock, consumer durables spending, and consumer durables stock, to an energy price shock. Model I is the standard model with no specific consideration of consumer durables. Model II is the model in which consumer durables have been considered even though the OFDK assumption is relaxed. That is, in model II, η_1 and η_2 are calibrated as being equal to one. However, the OFDK assumption is considered in model III.

As can be seen in this figure, inclusion of consumer durables may cause a significant change in the behavior of impulse response functions. In model II, the total consumption, including both durables and non-durables, sharply rises after an energy price shock. Such a behavior is clearly in odd with empirical evidence(Kormilitsina (2011)). However, with consideration of overlapping function of consumer durables and capital this peculiar behavior of consumption would be significantly gone. In addition, in model II and III, total output is obviously more sensitive to an energy price shock than in the model I. This means inclusion of consumer durables can improve the results of a standard model to generate the sensitivity of the economy to energy price shocks.

3.5 Durability of Goods

This section investigates that how durability of products may influence the impacts of energy price shocks on output. Figure 3.2 and Figure 3.3 show the results of the

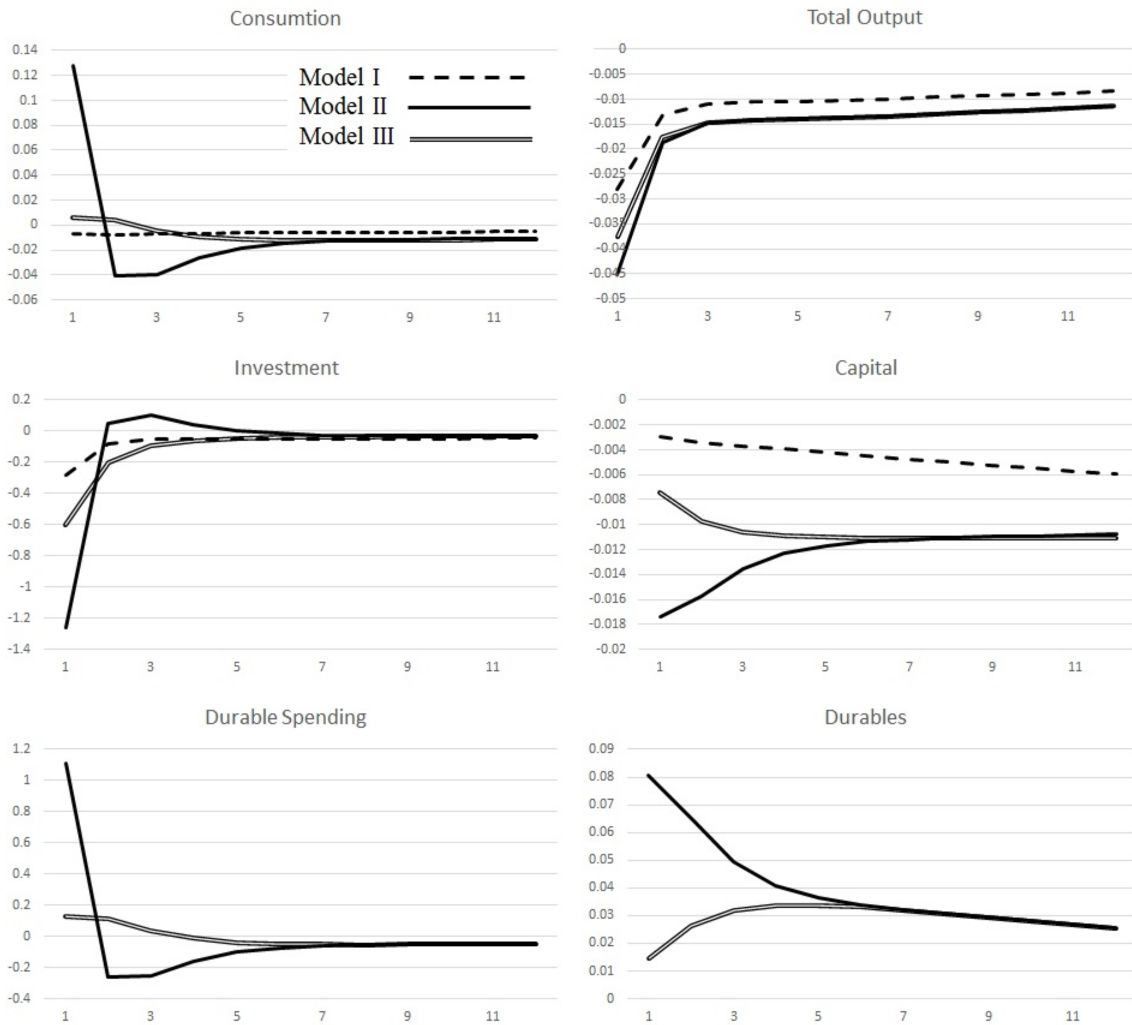

Figure 3.1: Simulated impulse responses under three calibration scenarios:
Model I (no explicit consideration of consumer durables),
Model II (Separate Functions of Durables and Capital (SFDK)), and
Model III (Overlapping Functions of Durables and Capital (OFDK))

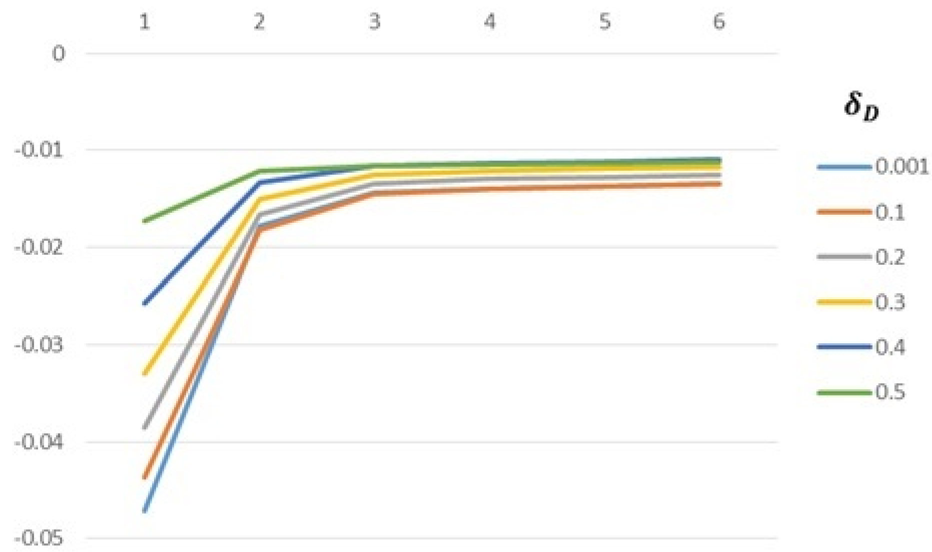

Figure 3.2: The sensitivity of results over the durability of consumer durables

model3.5 under different values for depreciation in consumer durables and in capital respectively. As it is shown in these figures, the more durable are the products the stronger is the response of economy's output to the energy price shocks. The response of output to an energy price shock can be more than doubled when the depreciation rate of consumer durables varies from 0.5 to 0.1. Also the output response can become almost tripled when the depreciation rate of capital goods varies from 0.5 to 0.1. However, when the capital depreciation rate tends to zero, the impact of energy price shocks to output seems to be declined. This feature may be due to the inter-influential effects of durability in different sectors. To shed more light on this issue, we need to compare the results when both δ_D and δ_K vary. To do so, Table 3.1 presents the immediate response of output to an energy price shock under different values for δ_K and δ_D. As it is clear from this table, the strongest response to an energy price shock is for the case in which both capital and consumer durable goods have the most durability.

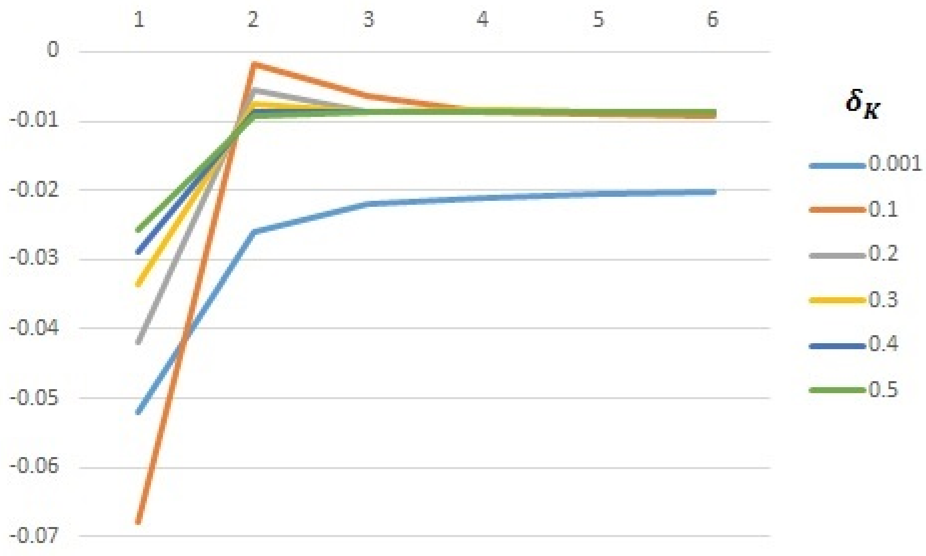

Figure 3.3: The sensitivity of results over the durability of capital goods

	δ_K							
	0.001	**0.01**	**0.025**	**0.05**	**0.075**	**0.1**	**0.25**	**0.5**
δ_D =**0.001**	-0.0229	-0.0189	-0.0168	-0.0154	-0.0148	-0.0145	-0.0139	-0.0133
δ_D =**0.01**	-0.0217	-0.0180	-0.0160	-0.0147	-0.0141	-0.0140	-0.0135	-0.0130
δ_D =**0.025**	-0.0210	-0.0174	-0.0155	-0.0142	-0.0136	-0.0134	-0.0128	-0.0124
δ_D =**0.05**	-0.0202	-0.0167	-0.0150	-0.0138	-0.0131	-0.0127	-0.0119	-0.0116
δ_D =**0.075**	-0.0195	-0.0162	-0.0146	-0.0135	-0.0128	-0.0124	-0.0114	-0.0112
δ_D =**0.1**	-0.0190	-0.0158	-0.0143	-0.0132	-0.0126	-0.0122	-0.0112	-0.0110
δ_D =**0.25**	-0.0162	-0.0138	-0.0127	-0.0120	-0.0117	-0.0115	-0.0111	-0.0110
δ_D =**0.5**	-0.0124	-0.0109	-0.0106	-0.0107	-0.0147	-0.0155	NA	NA

Table 3.1: Immediate responses of output to an energy price shock under different values for δ_K and δ_D.

3.6 The Role of Monetary Policy

One of the hot questions in the literature of energy price shocks is that to what extent monetary policy should be blamed for the recessions that come after energy price shocks. This question is addressed here by running three models: (i) the model with no separate sector for durables, (ii) the model with durable sector under the assumption of SFDK, i.e. separate functions for durables and capital, and (iii) the model with durable sector under the assumption of OFDK, i.e. overlapping function of durables and capital. Each model has been simulated under two monetary policy scenarios: a regular Taylor rule in which both target inflation and potential output has been considered, i.e. 3.15, and the other is an independent and fixed monetary policy in which interest rate is exogenously fixed and equal to its long-run value. The latter scenario helps us to distinguish the impact of monetary policy from the energy price shocks impact. The results, i.e. the impulse response functions, under the latter scenario are considered as purely results of energy price shocks and the difference of the results of two scenarios are considered as the exclusive effects of monetary policy. Table 3.2 presents the results of this exercise. This table shows that to what extent an output drop, which follows an energy price shock, would refer to the energy price shock itself and to what extent it refers to the systematic monetary policy which follows the shock. The results of each model come in two rows; one considers the deepest (strongest) drop of output, and the other considers the cumulative (4 quarters) drops in output.

The results of this table show that the role of systematic monetary policy in amplifying the impacts of energy price shock is not negligible. However, the role of energy price shock itself is still the major factor of output drops. These results are pretty close to the results of the benchmark model of Leduc and Sill (2004), in which

		energy shock	monetary policy
Model I:	Strongest	% 70.83	% 29.17
No Explicit Consideration of Durables	Cumulative	% 73.73	% 26.27
Model II:(SFDK)	Strongest	% 59.76	% 40.24
Explicit Consideration of Durables	Cumulative	% 68.83	% 31.17
Model III:(OFDK)	Strongest	% 68.98	% 31.02
Explicit Consideration of Durables	Cumulative	% 69.30	% 30.70

Table 3.2: Contributions of systematic monetary policy and energy price shocks to recessions following energy shocks

about 37 percent of the fall in output is attributed to systematic monetary policy. The results presented in table 3.2 indicates that, inclusion of explicit sector of durables in a standard model, would cause an increase in the responsibility of monetary policy for the output drops following energy price shocks. This increase, however, is more significant when the model is simulated under the assumption of separate functions of durables.

3.7 Conclusion

Durable goods are known to have some distinctive characteristics such as high-degree of interest-sensitivity, high intertemporal elasticity of substitution, and lower price stickiness than non-durables. These characteristics of durables have made them an important economy's sector which should not been ignored in economic modeling. This paper investigates that how considering a separate sector for durables in a new Keynesian dynamic general equilibrium model may improve our understanding of energy price shock impacts on an energy-importer economy. The simulated results of the model show that the response of output to energy price shocks would be more sensitive and more inline with the empirical evidence, when durables are considered as a separate sector. However, in this model the total consumption, including both durables and non-durables, rises. Such a reaction is at odds with empirical evidence.

However, considering the assumption of overlapping functions of durables and capital can eliminate this peculiar reaction of the model. The simulated results of this model also show that there is a positive direct relationship between the level durability and the sensitivity of output response to energy price shocks. In another exercise, the simulated results of the model show that inclusion of durables as a separate sector in a standard model would increase the role of monetary policy in output drops following energy price shocks; however, it is still the energy price shock itself which is the major responsible of the drops.

A Appendix

A.1 Tables

	AGR	MIN	CNS	MAN	TCU	WRT	FIR	SRV
0	-2.409	-0.951	-3.999	-3.839	-4.227	-4.311	-4.548	-4.876
1	-19.865	-20.930	-23.046	-22.937	-22.582	-23.072	-23.354	-23.226
2	-20.429	-21.427	-23.749	-23.441	-23.061	-23.529	-23.675	-23.680
3	-20.555	**-21.545***	-23.816	-23.517	**-23.179***	**-23.630***	-23.712	**-23.737***
4	-20.535	-21.480	-23.792	-23.475	-23.124	-23.502	-23.622	-23.631
5	-20.607	-21.415	-23.756	-23.425	-23.112	-23.457	-23.637	-23.612
6	**-20.754***	-21.507	**-23.831***	**-23.546***	-23.163	-23.526	**-23.739***	-23.622
7	-20.624	-21.479	-23.812	-23.480	-23.078	-23.494	-23.622	-23.510
8	-20.531	-21.417	-23.739	-23.361	-22.933	-23.353	-23.522	-23.377
9	-20.550	-21.457	-23.769	-23.396	-22.899	-23.382	-23.468	-23.411
10	-20.543	-21.439	-23.701	-23.325	-22.901	-23.297	-23.367	-23.349
11	-20.579	-21.489	-23.803	-23.391	-22.980	-23.424	-23.473	-23.406
12	-20.522	-21.411	-23.739	-23.311	-22.882	-23.361	-23.413	-23.298

Table A.1: Akaike information criterion (AIC) for each VAR model

Lags	Model I	Model II
0	-14.65899	-14.12795
1	-39.17172	-38.34259
2	-40.12433	-39.26116
3	-40.20345	**-39.35888**
4	**-40.21515**	-39.33770
5	-40.15696	-39.26086
6	-40.14080	-39.27453
7	-39.98957	-39.18539
8	-39.89323	-39.02521

Table A.2: Values of Akaike Information Criterion (AIC) for different lag lengths for both models

-0.014183
(-0.03473)
[-0.40844]
-0.228674
(-0.12666)
[-1.80548]
-0.06811
(-0.15125)
[-0.45032]
-0.015605
(-0.01799)
[-0.86727]
0.005748
(-0.01288)
[0.44620]
-2.084349
(-8.81748)
[-0.23639]

Table A.3: Model I: Matrix **c**

0.700121	0.018355	0.051606	0.781191	0.335561	0.000127
(-0.16481)	(-0.0252)	(-0.03153)	(-0.16593)	(-0.20642)	(-0.0003)
[4.24800]	[0.72837]	[1.63676]	[4.70802]	[1.62561]	[0.42765]
-0.539578	0.599524	0.32931	1.802587	-0.552373	-0.003601
(-0.60112)	(-0.09191)	(-0.115)	(-0.60519)	(-0.75289)	(-0.00108)
[-0.89762]	[6.52262]	[2.86363]	[2.97853]	[-0.73367]	[-3.33415]
-1.612962	0.315929	1.102388	3.852001	1.530281	0.002798
(-0.71785)	(-0.10976)	(-0.13733)	(-0.72271)	(-0.89909)	(-0.00129)
[-2.24693]	[2.87829]	[8.02742]	[5.32994]	[1.70204]	[2.16897]
0.002944	0.001281	0.023307	1.180243	0.176444	-0.000694
(-0.0854)	(-0.01306)	(-0.01634)	(-0.08598)	(-0.10696)	(-0.00015)
[0.03447]	[0.09808]	[1.42664]	[13.7275]	[1.64965]	[-4.51979]
0.032095	-0.001639	-0.008391	0.054728	1.421746	0.000271
(-0.06114)	(-0.00935)	(-0.0117)	(-0.06156)	(-0.07658)	(-0.00011)
[0.52491]	[-0.17529]	[-0.71740]	[0.88906]	[18.5653]	[2.46460]
30.45466	4.858554	11.7427	39.1485	147.949	1.076957
(-41.849)	(-6.39891)	(-8.00589)	(-42.1323)	(-52.4147)	(-0.0752)
[0.72773]	[0.75928]	[1.46676]	[0.92918]	[2.82266]	[14.3220]

Table A.4: Model I- Matrix $\mathbf{b_1}$

0.235166	-0.033932	-0.048635	-0.423366	-0.230824	-0.001172
(-0.23416)	(-0.03163)	(-0.0447)	(-0.25693)	(-0.35719)	(-0.00043)
[1.00429]	[-1.07275]	[-1.08792]	[-1.64778]	[-0.64621]	[-2.72422]
0.294754	0.193352	-0.076799	-0.916619	0.762875	-0.001118
(-0.85406)	(-0.11537)	(-0.16305)	(-0.93711)	(-1.30281)	(-0.00157)
[0.34512]	[1.67596]	[-0.47101]	[-0.97813]	[0.58556]	[-0.71278]
1.166166	-0.263001	-0.214653	-2.985295	-2.149798	-0.006271
(-1.01991)	(-0.13777)	(-0.19471)	(-1.11909)	(-1.55579)	(-0.00187)
[1.14341]	[-1.90898]	[-1.10240]	[-2.66762]	[-1.38181]	[-3.34726]
0.015854	0.001404	-0.016248	-0.256999	-0.225405	0.000326
(-0.12133)	(-0.01639)	(-0.02316)	(-0.13313)	(-0.18508)	(-0.00022)
[0.13067]	[0.08567]	[-0.70144]	[-1.93043]	[-1.21786]	[1.46303]
0.073241	-0.011578	-0.009649	-0.197267	-0.146616	-5.31E-05
(-0.08687)	(-0.01173)	(-0.01659)	(-0.09532)	(-0.13252)	(-0.00016)
[0.84310]	[-0.98667]	[-0.58181]	[-2.06954]	[-1.10640]	[-0.33281]
96.52689	-22.87376	-21.44821	-165.158	-47.31843	-0.487665
(-59.4581)	(-8.03166)	(-11.3514)	(-65.24)	(-90.6988)	(-0.10922)
[1.62344]	[-2.84795]	[-1.88948]	[-2.53154]	[-0.52171]	[-4.46480]

Table A.5: Model I- Matrix $\mathbf{b_2}$

-0.042379	-0.016306	-0.010277	0.024468	-0.578783	0.001146
(-0.23449)	(-0.03221)	(-0.04398)	(-0.26213)	(-0.36334)	(-0.00044)
[-0.18073]	[-0.50632]	[-0.23366]	[0.09334]	[-1.59294]	[2.59053]
0.00754	0.025091	-0.109884	-0.07093	0.07384	0.002837
(-0.85527)	(-0.11746)	(-0.16042)	(-0.95607)	(-1.32523)	(-0.00161)
[0.00882]	[0.21360]	[-0.68497]	[-0.07419]	[0.05572]	[1.75870]
-0.203892	-0.153075	0.005123	0.984562	-0.82034	0.003966
(-1.02135)	(-0.14027)	(-0.19157)	(-1.14172)	(-1.58257)	(-0.00193)
[-0.19963]	[-1.09127]	[0.02674]	[0.86235]	[-0.51836]	[2.05916]
-0.073709	0.020217	0.020613	0.205152	0.036099	-8.36E-05
(-0.1215)	(-0.01669)	(-0.02279)	(-0.13582)	(-0.18827)	(-0.00023)
[-0.60664]	[1.21150]	[0.90450]	[1.51043]	[0.19174]	[-0.36488]
-0.112038	0.012026	0.025125	0.190333	-0.194897	-0.000227
(-0.08699)	(-0.01195)	(-0.01632)	(-0.09725)	(-0.1348)	(-0.00016)
[-1.28787]	[1.00651]	[1.53975]	[1.95720]	[-1.44585]	[-1.38372]
-121.9616	13.00756	14.31722	213.1557	-158.3492	0.37028
(-59.5423)	(-8.17755)	(-11.1682)	(-66.5597)	(-92.2601)	(-0.11229)
[-2.04832]	[1.59064]	[1.28197]	[3.20248]	[-1.71633]	[3.29762]

Table A.6: Model I- Matrix $\mathbf{b_3}$

-0.070897	0.015102	0.019708	-0.18492	0.46706	-0.000344
(-0.16781)	(-0.02502)	(-0.02934)	(-0.17516)	(-0.21531)	(-0.00032)
[-0.42249]	[0.60361]	[0.67178]	[-1.05575]	[2.16929]	[-1.06977]
-0.131043	0.076831	-0.016898	-0.377368	-0.320739	0.001258
(-0.61205)	(-0.09125)	(-0.107)	(-0.63885)	(-0.78529)	(-0.00117)
[-0.21411]	[0.84195]	[-0.15792]	[-0.59070]	[-0.40843]	[1.07351]
-0.099784	0.10984	0.001229	-0.932244	1.388344	-0.001089
(-0.7309)	(-0.10897)	(-0.12778)	(-0.76291)	(-0.93778)	(-0.0014)
[-0.13652]	[1.00794]	[0.00961]	[-1.22197]	[1.48046]	[-0.77882]
0.086467	-0.032923	-0.019451	-0.15798	0.015344	0.00031
(-0.08695)	(-0.01296)	(-0.0152)	(-0.09076)	(-0.11156)	(-0.00017)
[0.99445]	[-2.53956]	[-1.27954]	[-1.74068]	[0.13754]	[1.86137]
-0.00946	0.007549	-0.009608	-0.031706	-0.086265	0.000132
(-0.06226)	(-0.00928)	(-0.01088)	(-0.06498)	(-0.07988)	(-0.00012)
[-0.15196]	[0.81324]	[-0.88274]	[-0.48792]	[-1.07998]	[1.11034]
5.021531	1.426908	0.231724	-100.3444	60.79111	-0.098885
(-42.6095)	(-6.35297)	(-7.44935)	(-44.4756)	(-54.6705)	(-0.08155)
[0.11785]	[0.22461]	[0.03111]	[-2.25617]	[1.11196]	[-1.21253]

Table A.7: Model I- Matrix $\mathbf{b_4}$

0.013943
(-0.03887)
[0.35873]
0.212847
(-0.13539)
[1.57213]
-0.500616
(-0.24927)
[-2.00829]
0.006692
(-0.02057)
[0.32530]
-0.020808
(-0.01412)
[-1.47412]
-4.711793
(-9.80402)
[-0.48060]

Table A.8: Model II- Matrix **c**

0.778249	0.068254	0.010452	0.685772	0.122854	1.86E-05
(-0.15086)	(-0.0266)	(-0.01908)	(-0.16803)	(-0.19701)	(-0.00028)
[5.15872]	[2.56633]	[0.54780]	[4.08119]	[0.62359]	[0.06725]
-1.324455	1.193297	0.160995	2.495327	0.026803	-0.005075
(-0.52549)	(-0.09264)	(-0.06646)	(-0.5853)	(-0.68624)	(-0.00096)
[-2.52042]	[12.8809]	[2.42248]	[4.26332]	[0.03906]	[-5.25982]
-0.294807	0.464216	0.727287	3.385218	1.581894	0.006707
(-0.96753)	(-0.17057)	(-0.12236)	(-1.07766)	(-1.2635)	(-0.00178)
[-0.30470]	[2.72154]	[5.94364]	[3.14128]	[1.25200]	[3.77510]
-0.004004	0.020895	0.014316	1.207563	0.082936	-0.000675
(-0.07985)	(-0.01408)	(-0.0101)	(-0.08894)	(-0.10428)	(-0.00015)
[-0.05015]	[1.48430]	[1.41758]	[13.5775]	[0.79536]	[-4.60616]
0.044982	0.004395	-0.011388	0.018404	1.437854	0.000268
(-0.05479)	(-0.00966)	(-0.00693)	(-0.06102)	(-0.07155)	(-0.0001)
[0.82104]	[0.45508]	[-1.64358]	[0.30158]	[20.0968]	[2.66700]
39.46958	17.98231	4.055552	29.67987	80.80342	1.049924
(-38.0531)	(-6.70858)	(-4.81259)	(-42.3844)	(-49.6936)	(-0.06987)
[1.03722]	[2.68049]	[0.84270]	[0.70025]	[1.62603]	[15.0258]

Table A.9: Model II- Matrix $\mathbf{b_1}$

0.248892	-0.059946	-0.021218	-0.465067	-0.246221	-0.000618
(-0.21347)	(-0.04057)	(-0.02502)	(-0.25461)	(-0.35766)	(-0.00042)
[1.16594]	[-1.47748]	[-0.84798]	[-1.82657]	[-0.68842]	[-1.45950]
0.760501	-0.133662	-0.096059	-2.06787	0.112823	0.001849
(-0.74357)	(-0.14133)	(-0.08716)	(-0.88688)	(-1.24582)	(-0.00148)
[1.02277]	[-0.94575]	[-1.10213]	[-2.33161]	[0.09056]	[1.25363]
1.147734	-0.357995	0.005239	-3.457698	-3.278694	-0.007773
(-1.36906)	(-0.26021)	(-0.16047)	(-1.63293)	(-2.29381)	(-0.00272)
[0.83834]	[-1.37577]	[0.03265]	[-2.11748]	[-1.42937]	[-2.86169]
0.033882	-0.010552	-0.00975	-0.231236	-0.164162	0.00051
(-0.11299)	(-0.02148)	(-0.01324)	(-0.13477)	(-0.18931)	(-0.00022)
[0.29988]	[-0.49136]	[-0.73621]	[-1.71584]	[-0.86717]	[2.27552]
0.036347	-0.005283	-0.002878	-0.148475	-0.105219	-3.42E-05
(-0.07752)	(-0.01473)	(-0.00909)	(-0.09247)	(-0.12989)	(-0.00015)
[0.46884]	[-0.35857]	[-0.31673]	[-1.60573]	[-0.81007]	[-0.22259]
82.93538	-33.55938	-9.01573	-155.9226	-23.35204	-0.334949
(-53.8452)	(-10.2343)	(-6.31147)	(-64.2234)	(-90.216)	(-0.10683)
[1.54025]	[-3.27912]	[-1.42847]	[-2.42781]	[-0.25885]	[-3.13543]

Table A.10: Model II- Matrix $\mathbf{b_2}$

-0.135098	-0.004495	0.007642	-0.10811	0.118706	0.000509
(-0.1553)	(-0.0251)	(-0.01839)	(-0.1749)	(-0.19625)	(-0.00032)
[-0.86993]	[-0.17906]	[0.41558]	[-0.61813]	[0.60487]	[1.59563]
-0.388883	-0.144201	0.037292	0.538912	-0.194234	0.001529
(-0.54095)	(-0.08744)	(-0.06405)	(-0.60921)	(-0.68359)	(-0.00111)
[-0.71889]	[-1.64905]	[0.58219]	[0.88460]	[-0.28414]	[1.37719]
-0.520926	-0.042495	0.051769	-0.03019	1.701825	0.00195
(-0.99599)	(-0.161)	(-0.11794)	(-1.12168)	(-1.25863)	(-0.00204)
[-0.52302]	[-0.26394]	[0.43895]	[-0.02691]	[1.35213]	[0.95398]
-0.008855	-0.010675	-0.003074	-0.000751	0.081598	0.00011
(-0.0822)	(-0.01329)	(-0.00973)	(-0.09257)	(-0.10387)	(-0.00017)
[-0.10773]	[-0.80336]	[-0.31586]	[-0.00811]	[0.78555]	[0.65391]
-0.06401	0.00664	0.008141	0.119556	-0.336765	-7.79E-05
(-0.0564)	(-0.00912)	(-0.00668)	(-0.06352)	(-0.07127)	(-0.00012)
[-1.13496]	[0.72831]	[1.21907]	[1.88229]	[-4.72515]	[-0.67306]
-92.9544	20.15583	1.212097	94.32041	-54.91019	0.23596
(-39.1724)	(-6.33229)	(-4.63852)	(-44.116)	(-49.5021)	(-0.0804)
[-2.37295]	[3.18302]	[0.26131]	[2.13801]	[-1.10925]	[2.93488]

Table A.11: Model II- Matrix $\mathbf{b_3}$

A.2 Figures

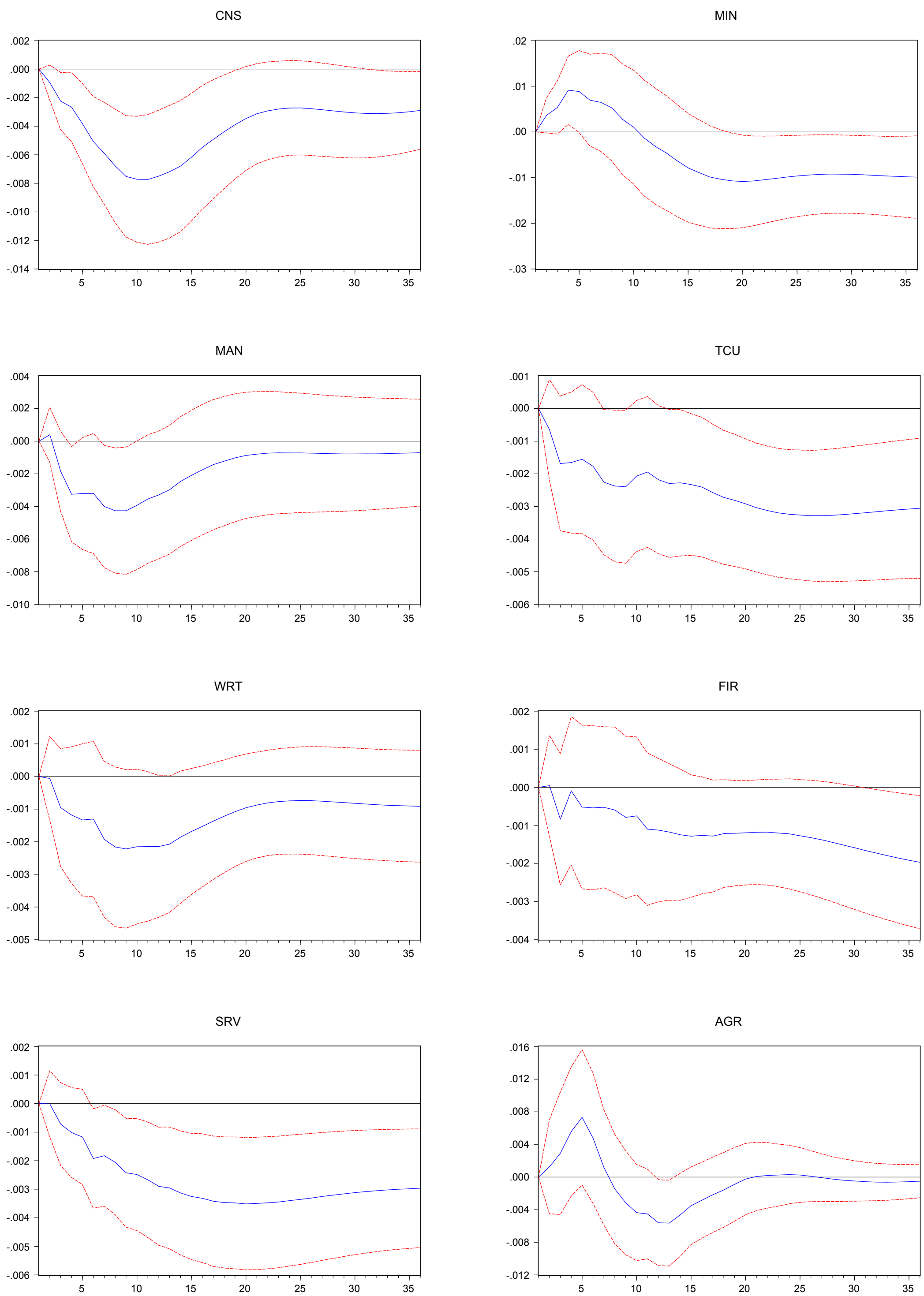

Figure A.1: Impulse responses of introduced sectors to monetary policy shocks

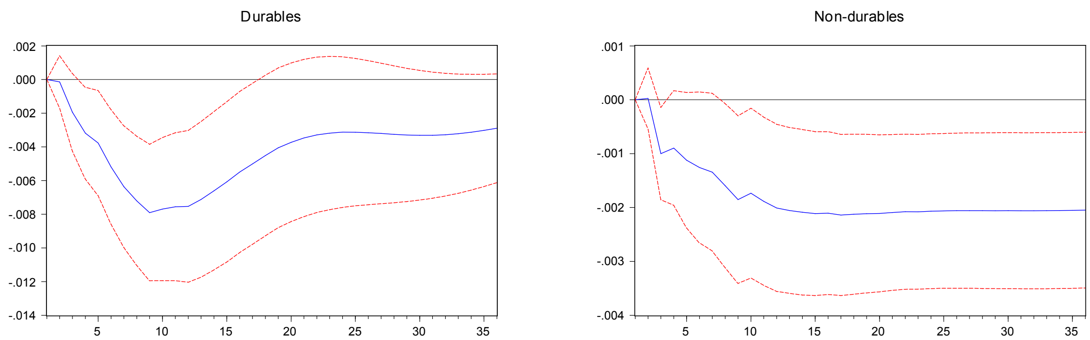

Figure A.2: Impulse responses of durables and non-durables to monetary policy shocks

A.3 Log-linearized equations

A.3.1 Model ...

$$\hat{p}^{*}_{j,t} = \hat{\Psi_{j,t}} - \hat{\Omega}_{j,t} \qquad \text{[e-1 to 3]}$$

$$\hat{\Psi}_{j,t} = \frac{Y_j^f \mu_j p^w}{\Psi_j}\left(\hat{Y}^f_{j,t} + \hat{\mu}_{j,t} + \hat{p}^w_t\right) + \beta_H \theta_j E_t \left(\frac{\mu_j}{\mu_j - 1}\hat{\pi}_{j,t+1} + \hat{\pi}_{C,t+1} + \hat{\Psi}_{j,t+1}\right) \qquad \text{[e-4 to 6]}$$

$$\hat{\Omega}_{j,t} = \frac{Y_j}{\Omega_j}\hat{Y}^f_{j,t} + \beta_H \theta_j E_t \left(\frac{\mu_j}{\mu_j - 1}\hat{\pi}_{j,t+1} + \hat{\Omega}_{j,t+1}\right) \qquad \text{[e-7 to 9]}$$

$$\hat{p}^{*}_{j,t} = \hat{p}_{j,t} + \frac{\theta_j}{1-\theta_j}\hat{\pi}_{j,t} \qquad \text{[e- 10 to 12]}$$

$$\hat{\pi}_{j,t} = \hat{p}_{j,t} - \hat{p}_{j,t-1} + \hat{\pi}_{C,t} \qquad \text{[e-13 \& 14]}$$

$$\hat{\hat{q}}_{j,t} = \theta_j \hat{\hat{q}}_{j,t-1} \quad \text{[e- 15 to 17]}$$

$$E_t\left(\hat{R}_t - \hat{\pi}_{C,t+1} + \hat{\zeta}_{U,t+1} - \hat{\zeta}_{U,t} - \hat{C}^{'}_{t+1} + \hat{C}^{'}_t\right) = 0 \quad \text{[e-18]}$$

$$\varphi \hat{N}^{'}_t = \hat{w}_t - \hat{C}^{'}_t \quad \text{[e-19]}$$

$$p_D \hat{p}_{D,t} = \left(\frac{\gamma}{1-\gamma}\right)\frac{1}{\Upsilon_1}\left(\hat{C}^{'}_t - \hat{D}^{'}_t\right) + \beta_H\left(1-\delta_D\right)E_t p_D\left(\hat{p}_{D,t+1} + \hat{\zeta}_{U,t+1} - \hat{\zeta}_{U,t} + \hat{C}^{'}_t - \hat{C}^{'}_{t+1}\right) \quad \text{[e-20]}$$

$$C^{'}\hat{C}^{'}_t + \frac{\mu_D}{\mu_C}\delta_D D^{'}\left(\hat{p}_{D,t} + \hat{I}^{'}_{D,t}\right) + Rb^{'}\left(\hat{R}_{t-1} + \hat{b}^{'}_{t-1} - \hat{\pi}_{C,t}\right) = wN^{'}\left(\hat{w}_t + \hat{N}^{'}_t\right) + b^{'}\hat{b}^{'}_t + f^{'}\hat{f}^{'}_t + T^{'}\hat{T}^{'}_t \quad \text{[e-21]}$$

$$\delta_D \hat{I}^{'}_{D,t} = \hat{D}^{'}_t - \left(1-\delta_D\right)\hat{D}^{'}_{t-1} \quad \text{[e-22]}$$

$$\hat{Y}_t = \hat{\zeta}_{A,t} + \alpha \hat{K}_{t-1} + \left(1-\alpha\right)\hat{N}_t \quad \text{[e-23]}$$

$$\hat{Y}_t - \hat{N}_t = \hat{w}_t - \hat{p}^{w}_t \quad \text{[e-24]}$$

$$X\hat{X}_t = -\beta_H \hat{R}_t - \beta_E E_t \left(\hat{\zeta}_{U,t+1} - \hat{\zeta}_{U,t} + \hat{C}_t - \hat{C}_{t+1} - \hat{\pi}_{C,t+1}\right) \quad \text{[e-25]}$$

$$\begin{aligned}\hat{p}_{D,t} = \Upsilon_5 \left(\hat{C}_t - \hat{D}_t\right) + \beta_E \left(1-\delta_D\right) E_t \left(\hat{\zeta}_{U,t+1} - \hat{\zeta}_{U,t} + \hat{C}_t - \hat{C}_{t+1} + \hat{p}_{D,t+1}\right) \quad \text{[e-26]} \\ + \left(1-\chi_D\right)\left(1-\delta_D\right) X E_t \left(\hat{p}_{D,t} + \hat{X}_t + \hat{\pi}_{D,t+1}\right)\end{aligned}$$

$$\begin{aligned}\hat{\lambda}_{3,t} - \beta_E \left(1-\delta_K\right) E_t \hat{\lambda}_{3,t+1} = \Upsilon_2 E_t \left(\hat{\zeta}_{U,t+1} - \hat{C}_{t+1} + \hat{p}^w_{t+1} + \hat{Y}_{t+1} - \hat{K}_t\right) \quad \text{[e-27]} \\ + \left(1-\chi_K\right)\left(1-\delta_K\right) X E_t \left(\hat{p}_{K,t} + \hat{\zeta}_{U,t} - \hat{C}_t + \hat{X}_t + \hat{\pi}_{K,t+1}\right)\end{aligned}$$

$$\hat{\zeta}_{U,t} - \hat{C}_t + \hat{p}_{K,t} = \hat{\lambda}_{3,t} - S'' \left(\hat{\zeta}_{I,t} + \hat{I}_{K,t} - \hat{I}_{K,t-1}\right) + \beta_E S'' E_t \left(\hat{\zeta}_{I,t+1} + \hat{I}_{K,t+1} - \hat{I}_{K,t}\right) \quad \text{[e-28]}$$

$$\begin{aligned}C\hat{C}_t + p_D I_D \left(\hat{p}_{D,t} + \hat{I}_{D,t}\right) + p_K I_K \left(\hat{p}_{K,t} + \hat{I}_{K,t}\right) \quad \text{[e-29]} \\ + Rb\left(\hat{R}_{t-1} + \hat{b}_{t-1} - \hat{\pi}_{C,t}\right) + wN\left(\hat{w}_t + \hat{N}_t\right) \\ = p^w Y \left(\hat{p}^w_t + \hat{Y}_t\right) + b\hat{b}_t + T\hat{T}_t\end{aligned}$$

$$I_D \hat{I}_{D,t} = D\hat{D}_t - \left(1-\delta_D\right) D\hat{D}_{t-1} \quad \text{[e-30]}$$

$$I_K \hat{I}_{K,t} = K\hat{K}_t - \left(1-\delta_K\right) K\hat{K}_{t-1} \quad \text{[e-31]}$$

$$Rb\left(\hat{R}_t + \hat{b}_t\right) = E_t\Big[(1-\chi_D)(1-\delta_D)\,p_D D\left(\hat{\pi}_{C,t+1} + \hat{p}_{D,t+1} + \hat{D}_t\right) \tag{e-32}$$
$$+ (1-\chi_K)(1-\delta_K)p_K K\left(\hat{\pi}_{C,t+1} + \hat{p}_{K,t+1} + \hat{K}_t\right)\Big]$$

$$Y_C^f\left(\hat{Y}_{C,t}^f - \hat{\tilde{q}}_{C,t}\right) + Y_D^f\left(\hat{Y}_{D,t}^f - \hat{\tilde{q}}_{D,t}\right) + Y_K^f\left(\hat{Y}_{K,t}^f - \hat{\tilde{q}}_{K,t}\right) = Y\hat{Y}_t \tag{e-33}$$

$$Y_{C,t}^f\hat{Y}_{C,t}^f = C\hat{C}_t + C'\hat{C}_t' \tag{e-34}$$

$$Y_D^f\hat{Y}_{D,t}^f = I_D\hat{I}_{D,t} + I_D'\hat{I}_{D,t}' \tag{e-35}$$

$$\hat{Y}_{K,t}^f = \hat{I}_{K,t} \tag{e-36}$$

$$f'\hat{f}_t' = Y_C^f\hat{Y}_{C,t}^f + p_D Y_D^f\left(\hat{p}_{D,t} + \hat{Y}_{D,t}^f\right) + p_K Y_K^f\left(\hat{p}_{K,t} + \hat{Y}_{K,t}^f\right) - p^w Y\left(\hat{p}_t^w + \hat{Y}_t\right)$$

$$\hat{N}_t = \hat{N}_t' \tag{e-37}$$

$$\hat{b}_t' = \hat{b}_t \tag{e-38}$$

$$\Longrightarrow \hat{R}_t = \phi\tau_C\hat{\pi}_{C,t} + \phi\tau_D\hat{\pi}_{D,t} + \phi\tau_K\hat{\pi}_{K,t} + \hat{\zeta}_{M,t} \quad \text{[e-39]}$$

A.3.2 Model ...

Good Producers

$$\hat{p}^*_{j,t} = \hat{\Psi_{j,t}} - \hat{\Omega}_{j,t} \quad \text{[e-1 to 3]}$$

$$\hat{\Psi}_{j,t} = \frac{Y_j^f \mu_j p^w}{\Psi_j}\left(\hat{Y}^f_{j,t} + \hat{\mu}_{j,t} + \hat{p}_{w,t}\right) + \beta\theta_j E_t\left(\frac{\mu_j}{\mu_j - 1}\hat{\pi}_{j,t+1} + \hat{\pi}_{C,t+1} + \hat{\Psi}_{j,t+1}\right) \quad \text{[e-4 to 5]}$$

$$\hat{\Psi}_{E,t} = \frac{Y_E^f \mu_E \tilde{p_E}}{\Psi_E}\left(\hat{Y}^f_{E,t} + \hat{\mu}_{E,t} + \hat{\tilde{p}}_{E,t}\right) + \beta\theta_E E_t\left(\frac{\mu_E}{\mu_E - 1}\hat{\pi}_{E,t+1} + \hat{\pi}_{C,t+1} + \hat{\Psi}_{E,t+1}\right) \quad \text{[e-6]}$$

$$\hat{\Omega}_{j,t} = \frac{Y_j}{\Omega_j}\hat{Y}^f_{j,t} + \beta_H\theta_j E_t\left(\frac{\mu_j}{\mu_j - 1}\hat{\pi}_{j,t+1} + \hat{\Omega}_{j,t+1}\right) \quad \text{[e-7 to 9]}$$

$$\hat{p}^*_{j,t} = \hat{p}_{j,t} + \frac{\theta_j}{1-\theta_j}\hat{\pi}_{j,t} \quad \text{[e- 10 to 12]}$$

$$\hat{\pi}_{j,t} = \hat{p}_{j,t} - \hat{p}_{j,t-1} + \hat{\pi}_{C,t} \quad \text{[e-13 and 14]}$$

$$\hat{\tilde{q}}_{j,t} = \theta_j\hat{\tilde{q}}_{j,t-1} \quad \text{[e- 15 to 17]}$$

Households

$$E_t\left(\hat{R}_t - \hat{\pi}_{C,t+1} + \hat{\zeta}_{U,t+1} - \hat{\zeta}_{U,t} - \hat{C}_{t+1} + \hat{C}_t\right) = 0 \qquad \text{[e-18]}$$

$$\begin{aligned} p_E a_D\left(\hat{p}_{E,t} + \hat{a}_{D,t}\right) = {} & \eta_1 \frac{\gamma}{1-\gamma}\frac{C}{D}\left(\hat{C}_t - \hat{D}_t\right) + \alpha\left(1-\eta_2\right) p_w \frac{Y}{D}\left(\hat{p}_{w,t} + \hat{Y}_t - \hat{D}_t\right) \qquad \text{[e-19]} \\ & + \beta p_X\left(1-\delta_D\right)\left(\hat{\zeta}_{U,t+1} - \hat{\zeta}_{U,t} + \hat{C}_t - \hat{C}_{t+1} + \hat{p}_{X,t+1}\right) \\ & - \beta\delta_D p_X \hat{\delta}_{D,t+1} - p_X \hat{p}_{X,t} \end{aligned}$$

$$\begin{aligned} p_E a_K\left(\hat{p}_{E,t} + \hat{a}_{K,t}\right) = {} & \left(1-\eta_1\right) \frac{\gamma}{1-\gamma}\frac{C}{K}\left(\hat{C}_t - \hat{K}_t\right) + \alpha\eta_2 p_w \frac{Y}{K}\left(\hat{p}_{w,t} + \hat{Y}_t - \hat{K}_t\right) \qquad \text{[e-20]} \\ & + \beta p_X\left(1-\delta_K\right)\left(\hat{\zeta}_{U,t+1} - \hat{\zeta}_{U,t} + \hat{C}_t - \hat{C}_{t+1} + \hat{p}_{X,t+1}\right) \\ & - \beta\delta_K p_X \hat{\delta}_{K,t+1} - p_X \hat{p}_{X,t} \end{aligned}$$

$$\left(1+\varphi\right)\hat{N}_t = \hat{p}_{w,t} + \hat{Y}_t - \hat{C}_t \qquad \text{[e-21]}$$

$$\begin{aligned} \frac{\gamma}{1-\gamma}\eta_1 C\hat{C}_t + \alpha\left(1-\eta_2\right) p_w Y\left(\hat{p}_{w,t} + \hat{Y}_t\right) = {} & \delta_0^D p_X D\left(u_D\right)^{\delta_1^D}\left(\hat{p}_{X,t} + \hat{D}_{t-1} + \delta_1^D \hat{u}_{D,t}\right) \qquad \text{[e-22]} \\ & + a_0^D p_E D\left(u_D\right)^{a_1^D}\left(\hat{p}_{E,t} + \hat{D}_t + a_1^D \hat{u}_{D,t}\right) \end{aligned}$$

$$\frac{\gamma}{1-\gamma}\left(1-\eta_1\right)C\hat{C}_t+\alpha\eta_2 p_w Y\left(\hat{p}_{w,t}+\hat{Y}_t\right)=\delta_0^K p_X K\left(u_K\right)^{\delta_1^K}\left(\hat{p}_{X,t}+\hat{K}_{t-1}+\delta_1^K\hat{u}_{K,t}\right)$$

[e-23]

$$+a_0^K p_E K\left(u_K\right)^{a_1^K}\left(\hat{p}_{E,t}+\hat{K}_t+a_1^K\hat{u}_{K,t}\right)$$

$$C\hat{C}_t+p_X\left(I_D+I_K\right)\hat{p}_{X,t}+p_X\left(I_D\hat{I}_{D,t}+I_K\hat{I}_{K,t}\right)$$ [e-24]

$$+p_E\left(E_D+E_K\right)\hat{p}_{E,t}+p_E\left(E_D\hat{E}_{D,t}+E_K\hat{E}_{K,t}\right)$$

$$=p_w Y\left(\hat{p}_{w,t}+\hat{Y}_t\right)+f\hat{f}_t$$

$$\hat{D}_t=\left(1-\delta_D\right)\hat{D}_{t-1}-\delta_D\hat{\delta}_{D,t}+\delta_D\hat{I}_{D,t}$$ [e-25]

$$\hat{K}_t=\left(1-\delta_K\right)\hat{K}_{t-1}-\delta_K\hat{\delta}_{K,t}+\delta_K\hat{I}_{K,t}$$ [e-26]

$$\hat{E}_{D,t}-\hat{D}_t=\hat{a}_{D,t}$$ [e-27]

$$\hat{E}_{K,t}-\hat{K}_t=\hat{a}_{K,t}$$ [e-28]

$$\hat{\delta}_{D,t}=\delta_1^D\hat{u}_{D,t}$$ [e-29]

$$\hat{\delta}_{K,t} = \delta_1^K \hat{u}_{K,t} \qquad \text{[e-30]}$$

$$\hat{a}_{D,t} = a_1^D \hat{u}_{D,t} \qquad \text{[e-31]}$$

$$\hat{a}_{K,t} = a_1^K \hat{u}_{K,t} \qquad \text{[e-32]}$$

$$\hat{Y}_t = \hat{\zeta}_{A,t} + \alpha\eta_2 \left(\hat{u}_{k,t} + \hat{K}\right) + \alpha\left(1-\eta_2\right)\left(\hat{u}_{D,t} + \hat{D}_t\right) + \left(1-\alpha\right)\hat{N}_t \qquad \text{[e-33]}$$

Market Clearing

$$Y_C^f\left(\hat{Y}_{C,t}^f - \hat{\tilde{q}}_{C,t}\right) + Y_X^f\left(\hat{Y}_{X,t}^f - \hat{\tilde{q}}_{X,t}\right) + \frac{\tilde{p}_E}{p_w} Y_E^f\left(\hat{\tilde{p}}_{E,t} - \hat{p}_{w,t} + \hat{Y}_{E,t}^f - \hat{\tilde{q}}_{E,t}\right) = Y\hat{Y}_t \qquad \text{[e-34]}$$

$$\hat{Y}_{C,t}^f = \hat{C}_t$$

$$Y_X^f \hat{Y}_{X,t}^f = I_D \hat{I}_{D,t} + I_K \hat{I}_{K,t} \qquad \text{[e-35]}$$

$$Y_E^f \hat{Y}_{E,t}^f = E_D \hat{E}_{D,t} + E_K \hat{E}_{K,t} \qquad \text{[e-36]}$$

$$f'\,\hat{f}_t' = Y_C^f \hat{Y}_{C,t}^f + p_X Y_X^f\left(\hat{p}_{X,t} + \hat{Y}_{X,t}^f\right) + p_E Y_E^f\left(\hat{p}_{E,t} + \hat{Y}_{E,t}^f\right) - p^w Y\left(\hat{p}_t^w + \hat{Y}_t\right) \qquad \text{[e-37]}$$

Monetary Policy

ib

$$\hat{R}_t = (1-\phi_R)\left[(1+\phi_\pi)\left(\tau_C\hat{\pi}_{C,t-1} + \tau_X\hat{\pi}_{X,t-1} + \tau_E\hat{\pi}_{E,t-1}\right) + \phi_Y\hat{Y}_{t-1}\right] + \phi_R\hat{R}_{t-1} + \hat{\zeta}_{M,t} \quad \text{[e-38]}$$

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