

Sectoral co-movement, monetary policy shocks, and input-flow structure

Nao Sudou*

November 27, 2007

Abstract

Upon the monetary policy innovation, durable goods expenditure and non-durable expenditure respond in the same direction.

Conventional sticky price model, however, imply that they move to the opposite direction (lack of co-movement), if either of the durable goods sector or non-durable sector sets their price in flexible manner. In fact, many literatures assume that the durable goods prices are flexible.

If so, then the theory predicts that lack of co-movement is so severe, and the effect of monetary policy is dampened nearly to the level of monetary neutrality (Barsky et al (2003, 2007)).

Our model offers one solution to this inconsistency. We depart from the prevalent assumption that all the sectors face identical cost structure. In stead, we assume that each sector obey the sector-specific cost structure that is consistent with input-output table.

We find that even when the durable goods sector sets their price flexibly, U.S. input-output matrix may work so as to render the co-movement between the expenditures of the two products. The recovery of co-movement brings back the monetary non-neutrality to the economy.

1 Introduction

Empirical literatures on price-setting behavior of firms level have revealed that the stickiness of prices are diverse across sectors (Bils and Klenow (2004), Nakamura and Steinsson (2006) for U.S. economy, and Dhyne et al (2006) and Alvarez and Luis (2006) for euro area countries). In other words, firms that adjust prices once a month coexists with firms that keep their prices fixed for more than a year. Moreover, the frequency of price change tends to differ by sector. For example, the researches above commonly report that the price of service is adjusted less frequently than the price of goods.

On the other hand, the natural implication of this diversity, in conventional sticky price model (ex. Calvo price model), is that the prices are adjusted at different speed across sectors, after the

*Economist, Institute for Monetary and Economic Studies, Bank of Japan (E-mail: nao.sudou@boj.or.jp) The author would like to thank Robert King, Anton Braun, Simon Gilchrist, Francois Gourio, Adrian Verdelhan, Naohisa Hirakata and the staff of the Institute for Monetary and Economic Studies (IMES), the Bank of Japan, for their useful comments. Views expressed in this paper are those of the authors and do not necessarily reflect the official views of the Bank of Japan.

monetary policy innovation. Since the prices are adjusted differently across products, the relative prices between them are temporarily altered.

Now, a question is what this relative price change brings about to the economy. The literatures, including Ohanian et al (1995), Barsky et al (2003, 2006), Nakamura and Steinsson (2007), point out that it leads to the acyclic response of sector that are flexibly priced (lack of co-movement). In the wake of the monetary policy innovation, the relative price change incurs the substitution across the products by the households. When the size of the relative price change is significant enough, the household reduces their spending on the relatively expensive products, even in the boom.

It is known that this lack of co-movement has the serious implication to the aggregate economy, when the durable goods is considered. Barsky et al (2003), Carlstrom and Fuerst (2006)¹ claim, from the theoretical point of view, that the lack of the co-movement between the durable goods sector and the non-durable sector should occur, because durable goods prices are flexible while non-durable prices are sticky. In this specification, the monetary expansion induces the decline in durable goods expenditure and the rise in non-durable expenditure. In terms of aggregate impact, the effect of the monetary policy shock is significantly dampened, even to the level of monetary neutrality.

In contrast, the macro data indicates that the monetary policy shock induces the co-movement. Figure 1 report the cumulative impulse response functions (CIRs) of the expenditures upon the monetary contraction shock. The CIRs are estimated from the VAR system employed similar to the one in Erceg and Levin (2003). It is evident that both the durable goods expenditure and the non-durable expenditure decline, and that the former declines more sharply.

This co-movement observation from the data is consistent with the other empirical literatures. Erceg and Levin (2002) shows that the disaggregated components of GDP decline upon the monetary contraction shock, and that of the non-durable GDP declines less. Barsky et al (2003) report that the durable goods production decline more sharply than the other sectors.

Thus, we confront the conflict between the theoretical prediction and the empirical evidence. Carlstrom and Fuerst (2006) names this inconsistency “co-movement puzzle.”

The purpose of this paper is to offer one way of solving this co-movement puzzle.

Compared to the precedent researches, Barsky et al (2003, 2006) and Carlstrom and Fuerst (2006), we focus on the production structure of each sector. Instead of assuming that all firms in the two sectors face identical cost structures, we assume that the cost structures of the firms are constructed so as to be consistent with input-flow matrix (or I-O matrix) in U.S. economy. Hence the cost structure of the firms differ by sector.

Reflecting I-O matrix to our multi-sector model has the two advantages.

First, I-O matrix provides the full description of inter-sectoral transaction by firms. The use of the matrix structure gives closer approximation of the actual firms’ cost minimization problem.

Second, it is already known in the literature such as Horvath (1997), Dupor (1999) and Conley and Dupor (2003), that the inter-sectoral transaction in the production process plays the significant role for sector-specific shock is transmitted to the other sectors. While they analyze the role of I-O matrix structure in the context of the sector-specific productivity shocks and the propagation process, we concentrate on the analysis upon the sectoral responses and the propagation upon the aggregate demand shock. The analogical interpretation is possible because the response of the sectors to the monetary policy innovation are diverse, as the frequencies of the price adjustment

¹See appendix for the categorization of durable goods and non-durables.

differ by sector (Bils and Klenow (2004) and Nakamura and Steinsson (2006)). Just like the productivity shock in the other sector is transmitted to own sector by input-flow relationship, the change in the output of the other monopolistic producer affects the production of own sector by the same relationship.

In the context of monetary policy analysis, this interaction across sectors is not fully examined so far. In Bouakez et al (2005), only exception to our knowledge, the sectoral interaction is captured in terms of the demand-side dynamics. For example, the increase in the production of the sticky goods producing sector incurs the demands to the other sectors' product. The size of this inter-sectoral relationship is specified by the I-O matrix. In contrast, our model highlights to the inter-sectoral relationship in supply structure. As we see below, in current model, the most important channel is cost structure. The sectoral response of the material provider sector is transmitted to the user sectors, and alters the response of aggregate economy.

This paper is organized as follows.

Section 2 presents a set up of our model. We employ multi-sector sticky price model ($\bar{M}$ sector model) where each sectors are heterogenous in the following three aspects : (1) degree of nominal rigidity (frequency of price adjustment) d_k , (2) cost structure represented by matrix, Γ and (3) durability of products. Note that our model only differs from Barsky et al (2003, 2007) and Carlstrom and Fuerst (2006) by the aspect (2).

Section 3 demonstrates the working mechanism. The distinct feature of our model appears in price dynamics of the products. In our model, the prices of the each products are determined by (1) and (2) above, while only (1) is important in the economy where I-O matrix is abbreviated. The presence of aspect (2) alters the price dynamics of the products upon the monetary policy shock. Provided the prices across the products, households determine their expenditure decision over the products, referring to their relative prices. As Barsky (2003, 2007) emphasizes, the households' decisions are affected by durability δ of the products.

Section 4 is devoted for numerical exercises. We calculate the impulse response functions of durable goods expenditure and non-durable expenditure, using reasonable parameter sets, and actual I-O matrix of the U.S. economy. In our model, whether the co-movement between durable goods expenditure and non-durable expenditures obtained, depends on the structure of Γ , (2). We find that the U.S. I-O matrix is consistent with the observed co-movement. We then consider the two robustness tests for the co-movement results. One test checks the historical stability of I-O matrix over the periods, since our result is dependent on the structure of the matrix. One other test checks the robustness of our result, when we modify the current two sector model to the six sector model. We disaggregate the non-durable sector into subsectors, keeping durable goods sector the same. This test is motivated by the current observation that the heterogeneity in price stickiness in non-durable sector is large (Bils and Klenow(2004) and Nakamura and Steinsson (2006)). We find the current model passes the two tests in terms of co-movement.

Section 5 concludes.

2 The economy

2.1 Household

There is infinitely-lived representative agent with preferences over consumption composite, C_t , real money balance, $\frac{M_t}{P_t}$, and labor L_t , as described in expected utility function, (1). Labor is completely mobile across sector.

$$U_0 \equiv E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{1-\sigma}}{1-\sigma} - \varphi \frac{L_t^{1+\omega}}{1+\omega} + V \left(\frac{M_t}{P_t} \right) \right] \quad (1)$$

where $\beta \in (0, 1)$ is discount factor, $\sigma > 0$ is the intertemporal elasticity of substitution, $\omega > 0$ is the inverse of the Frisch labor supply elasticity, and φ is the weight on leisure.

Utility from real money balance is separable, where V is concave function of real money balance. C_t is the aggregator, constructed from $\bar{M}$ number of products produced in $\bar{M}$ sectors, denoted as $C(m)$, for $m = 1, \dots, \bar{M}$. Aggregator is expressed as follows, with weight $\psi_m > 0$, $\sum_1^{\bar{M}} \psi_m = 1$.

$$C_t = \prod_{m=1}^{\bar{M}} \left[C_t^{\psi_m}(m) \right] \quad (2)$$

The budget constraint for the households is:

$$\sum_{m=1}^{\bar{M}} P_t^m X_t^m(m) + M_t \leq W_t L_t + \sum_{m=1}^{\bar{M}} \hat{\Pi}(m) + M_{t-1} + \tau_t \quad (3)$$

where $X_t(m)$ is purchase of goods m , and P_t^m is its price, W_t is nominal wage, $\hat{\Pi}_t(m)$ is the profit from sector m . M_t is nominal money stock, τ_t is a lump-sum nominal transfer from monetary authority.

Law of motion for the stock of durable goods is described by the equations below. $\delta_m \in [0, 1]$ is the depreciation rate associated with the stock of goods m . Note that $\delta_m < 1$ implies goods m is durable goods. For non-durables, $C_t(m) = X_t(m)$.

$$C_t(m) = (1 - \delta_m) C_{t-1}(m) + X_t(m) \quad (4)$$

2.2 Firm

The firms in our model is similar to those in Huang et al (2004). We depart from their model in a sense that we have multiple number of sectors present in the economy, and we abbreviate capital, as being assumed in Basu (1995) and Long and Plossar (1993).

Each sector, k , for $1, \dots, \bar{M}$ contains a large number of firms j , each producing a differentiated good, $X_t^g(j, k)$, indexed by $j \in [0, 1]$. Superscript g stands for gross output. Denote a gross output of composite of differentiated goods k , as $X_t^g(k)$, so that

$$X_t^g(k) = \left[\int_0^1 X_t^g(j, k)^{(\theta-1)/\theta} dj \right]^{\theta/(\theta-1)}$$

where $\theta \in (1, \infty)$ are the elasticity of substitution between goods. The composite goods are produced in an aggregation sector that is perfectly competitive. The price of composite goods k , denoted as $P_t^k(k)$, is related to the prices $\{P_t^k(j, k)\}_{j \in [0, 1]}$ of differentiated goods by

$$P_t^k(k) = \left[\int_0^1 P_t^m(j, k)^{(1-\theta)} dj \right]^{1/(1-\theta)}$$

The gross output of composite good $X_t^g(k)$, can serve as final consumption consumed by each i , denoted as $X_t^k(k) = \int_0^1 X_t^k(i, k) di$, and also as intermediate production input used by each firm j in each sector k , denoted as

$$\bar{X}_t^k(k) = \sum_{m=1}^{\bar{M}} \int_0^1 \bar{X}_t(j, k, m) dj$$

where $\bar{X}_t(j, k, m)$ denotes intermediate inputs of goods m used by the firm j in sector k . The gross output of firm j in good k sector, denoted as $X_t^g(j, k)$, requires intermediate production inputs of $\bar{X}_t(j, k, m)$ for $m = 1, \dots, \bar{M}$, labor $L(j, k)$, with production function given by

$$X_t^g(j, k) = \left[\prod_{m=1}^{\bar{M}} \bar{X}_t(j, m, k)^{\gamma(m, k)} \right] L_t(j, k)^{\gamma(w, k)} - F_c \quad (5)$$

where $\gamma(w, k)$ is labor share of sector k , which equals to $1 - \sum_{m=1}^{\bar{M}} \gamma(m, k)$, and F_c is fixed cost that is identical across firms (Huang et al (2004))², and $\gamma(m, k) \in (0, 1)$ for $m = 1, \dots, \bar{M}$, where $\sum_{m=1}^{\bar{M}} \gamma(m, k) \leq 1$ are the elasticity of output, with respect to the each of intermediate input, which equals to the factor share. In matrix form, we denote an input-use matrix for this economy, an $\bar{M} \times \bar{M}$ matrix, Γ ,

$$\Gamma = \begin{bmatrix} \gamma_{11} & \gamma_{12} & \cdots & \gamma_{1\bar{M}-1} & \gamma_{1\bar{M}} \\ \gamma_{21} & \vdots & \vdots & \vdots & \gamma_{2\bar{M}} \\ \vdots & \gamma_{k,m} & \gamma_{k,k} & \gamma_{k,k+1} & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \gamma_{\bar{M}1} & \gamma_{\bar{M}2} & \cdots & \gamma_{\bar{M}\bar{M}-1} & \gamma_{\bar{M}\bar{M}} \end{bmatrix} \quad (6)$$

where $\gamma(m, k)$ indicates the factor share of commodity m , in producing commodity, k .

In this set up, the cost minimization problem of firm j , at sector, k , yields the marginal cost function,

$$MC_t(j, k) = \bar{\phi} W_t^{\gamma(w, k)} \prod_{m=1}^{\bar{M}} (P_t^m)^{\gamma(m, k)} \quad (7)$$

where $\bar{\phi}$ is constant. Firms are price-takers in the inputs markets for input and monopolistic competitors in the products market. Nominal prices $\{P_t^k(j, k)\}_{j \in [0, 1]}$, are chosen optimally in a randomly staggered fashion, governed by the parameter $d_k \in [0, 1]$, which is a probability that firm in sector k , cannot adjust their price at a period (Calvo price setting). The firm j in sector, k , then solves the following problem.

$$\max \left\{ \bar{X}_t^c(j, m, k) \text{ for } m=1, \dots, \bar{M}, L_t(j, k), P_t^k(j, k) \right\} E_t \sum_{s=0}^{\infty} (\beta d_k) \frac{\Lambda_{t+s}}{\Lambda_t} \frac{D_{t+s}(j, k)}{P_{t+s}} \quad (8)$$

²Huang et al (2004) set F_c so that there is no incentive to enter or exit for all sectors. This implies that steady state profit of all sectors are zero. Our specification for F_c is based on theirs.

$$s.t. D_{t+s}(j, k) = P_t^k(j, k) X_t^g(j, k) - \sum_{m=1}^{\bar{M}} P_t^m \bar{X}(j, m, k) - W_t L_t(j, k) \quad (9)$$

where Λ_t is Lagrange multiplier associated with budget constraint (3).

2.3 Government

Monetary policy is conducted via lump-sum transfer so that

$$\tau_t = M_t - M_{t-1}. \quad (10)$$

2.4 Closing the Model

At the symmetric equilibrium, the market clear condition for good, k , is:

$$X_t^g(k) = \left[\int_0^1 X_t^g(j, k)^{(\theta-1)/\theta} dj \right]^{\theta/(\theta-1)} = \sum_{m=1}^M \int_0^1 \bar{X}(j, m, k) dj + X(k) \text{ for } k = 1, \dots, M \quad (11)$$

The first equality tells you that, the gross output of firm j , in sector, k , are converted to the composite goods, $X_t^g(k)$. The gross output from the sector k , $X_t^g(k)$ is distributed to the firms and households. $\bar{X}(j, m, k)$ is composite products, used by firm j , in sector m , as intermediate inputs. $X(k)$ is composite products k , consumed by household.

Labor market is:

$$\sum_{m=1}^{\bar{M}} \int_0^1 L_t^m(j, m) dj = L_t \quad (12)$$

where $L_t^m(j, m)$ is employment by firm j in sector, m , at t .

2.5 Equilibrium

An equilibrium consists in a set of allocations, $\{ X_t^g(j, m), \bar{X}_t(j, m, k), X_t(i, m), P_t^m(m), W_t, M_t \}_{t=0}^{\infty}$, for all $j \in [0, 1]$, $m, k = 1, \dots, \bar{M}$, that satisfies the following condition: (i) the household's allocation solve its utility maximization problem, (ii) each producer's allocations and price solve its profit maximization problem taking the wage and all prices of intermediate goods. (iii) all markets clear.

3 Working mechanism

General discussion

Our model differs from other multi-sector sticky price models, such as Ohanian et al (1995), Barsky et al (2003, 2006), Carvalho (2006) and Nakamura and Steinsson (2007), by having I-O matrix Γ . The important role of Γ is that it transmits the price dynamics of the material provider to its users. The channel is similar to the one discussed in Dupor (1999) and Horvath (1998), along the line of sector-specific shock.

Upon the monetary policy shock, when the inter-sectoral relationship in the production process is abbreviated, the price dynamics of each products reflects its own frequency of price adjustment, and labor (Carlstrom and Fuerst (2006)).

When matrix I-O matrix Γ is explicitly considered, price dynamics of sectoral products reflect d_k of its intermediate inputs, as well as its own frequency of price adjustment. Therefore, as long as there is a link in intermediate inputs-flow, the price dynamics of the economy becomes distinct.

For the households side, the price dynamics of each products (and the products' depreciation rate as we explain shortly) are the only issue taken into consideration, when they determine their expenditure plan over the products. Therefore, I-O matrix Γ affects the households' expenditures, by affecting relative price movement.

Firms' price setting decisions

We start describing working forces of our model from price setting behavior of firms, because it splits our model from precedents. In short, we show that persistency of products is determined by two factors : (i) producers' own frequency of price adjustment, and (ii) stickiness of its intermediate inputs. Note that precedent literature stresses the role of (i) in the price dynamics upon the monetary policy shock, but not the role of (ii).

When a sector that sets the price flexibly employ the products from the other sectors whose prices are also flexible, then its product prices do not demonstrate the persistency. On the other hand, when flexible sector import sticky products, its output inherits portion of stickiness originated from the inputs.

In Calvo price setting framework we employ, newly set price at t , $P_t^*(k, j)$, chosen by active firm j , in sector k , satisfies the following relationship with the future nominal marginal cost $mc_{t+s}(k)$.

$$\tilde{p}_t^*(k, j) = (1 - d_k\beta) E_t \left\{ \sum_{s=0}^{\infty} (d_k\beta)^s (m\tilde{c}_{t+s}(k)) \right\} \quad (13)$$

where $\tilde{z}_t$ denotes the log-deviation of the variables Z_t , and so $\tilde{p}_t^*(k, j)$ and $m\tilde{c}_{t+s}(k)$ are the log-deviation of $P_t^*(k, j)$, $mc_{t+s}(k)$, respectively.

Now nominal marginal cost for sector k , $m\tilde{c}_{t+s}(k)$ is determined by,

$$m\tilde{c}_{t+s}(k) = (\Gamma_k)^T \tilde{p}_{t+s} + \gamma(w, k) \tilde{w}_{t+s} \quad (14)$$

where Γ_k is the k th column vector of I-O matrix Γ , T denotes transpose, and $\tilde{p}_{t+s}$ is column vector whose m -th element is price deviation of products m at period $t + s$, $\tilde{p}_{t+s}(m)$. From the term $(\Gamma_k)^T \tilde{p}_{t+s}$, it is observable that the nominal marginal cost for sector k , $m\tilde{c}_{t+s}(k)$ can be expressed by the linear combination of prices of other sectors' product $\tilde{p}_{t+s}(m)$. The relative significance of the specific sector in terms of prices may be measured by $\gamma(m, k)$.

The two equations above (13), (14) indicate that the price dynamics of the product from sector k inherits price dynamics of product m . This is the case when sector k employs the product from sector m as its intermediate inputs (That is, $\gamma(m, k) \neq 0$). In view point of persistency of sector k , apart from the effect from d_k , higher weight on sticky sectors as intermediate inputs brings about higher stickiness of price of products k . Hence even when product k is flexibly priced, if Γ_k contains large nonzero element for some sticky sector, say h , then $p_t(k)$ may be more persistent than the product of slightly sticky sector, depending on the size of $\gamma(h, k)$ and stickiness of h .

Households' expenditure decision

For the change of expenditures upon the monetary policy shock, the relative price and the depreciation rate of the each products are responsible. Households decide their expenditure plan over the set of products, $m = 1, \dots, \bar{M}$, referring to the relative prices movement across the products. When δ_m is smaller than 1, then the relative prices are not the only factor that determines the households' decision.

The first order conditions of households' utility maximization problem yields following equations for non-durables $m = m_1, m_2$, (15), and for durable goods $m = m_3$, (16), respectively. Note that $X_t(m_3) \neq C_t(m_3)$ for durables goods³.

$$\frac{C_t(m_1)^{-\sigma}}{C_t(m_2)^{-\sigma}} = \frac{P_t^{m_1}}{P_t^{m_2}} \quad (15)$$

$$\frac{C_t^{1-\sigma}}{C_t(m_1)} \frac{P_t^{m_1}}{P_t^{m_3}} = E_t \left[\sum_{s=0}^{\infty} \beta^s (1 - \delta_{m_3})^s \frac{C_{t+s}^{1-\sigma}}{C_{t+s}(m_3)} \right] \quad (16)$$

where E_t denotes expectations, conditional on the information set available at time t .

As ((15)) indicates, when both products are non-durables, the consumption (expenditure) path for two products, $C_t(m_1)$ and $C_t(m_2)$ is direct reflection of the discrepancy in relative prices between the two products. Higher relative price implies lower expenditure, and vice versa. Whether the expenditure of the product drops below the steady state is determined by the size of relative price change.

When the durable goods is considered, the expenditure pattern is affected by the intertemporal choice ((16)), and the equation becomes more difficult to interpret. There are two views onto how the size of depreciation rate δ affects the households' expenditure plan.

Bils and Klenow (1998) points out that smaller depreciation rate implies that, a given change in the durable goods consumption requires greater percentage in its expenditure. This claim applies in the current model, since we assume that the consumption flow from the durable goods is proportional to the stock (2). When the household reduces the consumption of durable goods and non-durable by the same ratio, the expenditure on the durable goods tends to decline more as δ is smaller.

For another view, Barsky et al (2003, 2007) claim that when short-lived shocks, like monetary shocks, are considered, RHS of ((16)) may be approximated by constant. This is because marginal

³Our numerical exercise is conducted using Cobb-Douglas type of utility function. It is possible, however, to assume that utility function has the shape such as $C_t = \sum_{m=1}^{\bar{M}} \left[\psi_m C_t(m)^{\frac{\rho-1}{\rho}} \right]^{\frac{\rho}{\rho-1}}$ where ρ is elasticity of substitution, instead of Cobb-Douglas. Carlstrom and Fuerst (2006) shows that the co-movement is only obtained when ρ is unrealistically small.

utility is to short-lived shocks, when δ is sufficiently small. If this argument holds true, the demand for the durable goods displays an almost infinite elasticity of intertemporal substitution (Barsky et al (2003,2007)), and the households' expenditure becomes sensitive to the price change. As a result, a significant decline in the relative price of the durable goods may lead to the increase in its expenditure, even during the monetary contraction.

We will see in the next section that, either Bils and Klenow (1994)s' view or Barsky et al (2003 2007)'s view may hold in the current model, depending on the size of relative price change incurred by monetary policy innovation. In monetary contraction, if the durable goods' prices are for any reason low enough, the latter effect is dominant and the lack of co-movement is realized. When the prices are low, the former channel becomes dominant and the co-movement is realized.

4 Co-movement across sectors

General discussion

This section conducts the numerical exercise. Our exercises follow the specification of the preceding researches by Barsky et al (2003, 2007) and Carlstrom and Fuerst (2006), other than the cost structure of the firms. We show that using the information of I-O matrix of U.S. economy, co-movement puzzle is solved. Moreover, as a consequence of the co-movement between durable goods expenditure and non-durable expenditure, money neutrality result obtained in Barsky et al (2003, 2007) are overturned.

As we will see, the co-movement result is brought about by the specific characteristic of U.S. I-O matrix structure. That is, the observation of U.S. I-O matrix indicates that the firms in the durable goods sector employ large amount of non-durables as intermediate inputs⁴. In other word, as we saw in (14), the marginal cost of durable goods production is significantly affected by the price dynamics of the non-durables. From (13), it is equivalent to saying that the prices of the durable goods are affected by the price dynamics of the non-durables. Thus even when the prices of durable goods are adjusted flexibly, price dynamics of the durable goods display some persistency. Since the households make their expenditure decisions by the relative price between durable goods and non-durables ((16)), the co-movement in the expenditure is generated through this channel.

Throughout the numerical exercises, we consider that the monetary policy shock is a permanent decrease of money supply by 1% at period $t = 1$. We consider an economy where steady state inflation rate is zero. We report the impulse response functions (IRFs) of the variables to the monetary policy innovation, and the summary table. The IRFs are calculated in terms of the deviation from the steady state unless otherwise noted. The IRFs of the durable goods are depicted by the expenditure flow term.

The exercise are conducted quarterly, following the treatment of the literatures that handles I-O matrix, such as Horvath (2000), Bouakez et al (2003).

The specification of the model other than the production function of firms are constructed so that the implications are comparable to those of Barsky et al (2003,2006), Carlstrom and Fuerst (2006). See appendix for details.

⁴This characteristic of I-O matrix is also stressed in Hornstein and Praschnik (1997).

The lack of co-movement and co-movement

We start our numerical exercise by showing the lack of co-movement result. Figure 4a and Figure 4b display the impulse response functions (IRFs) of the variables in the economy, where the production functions are linear with respect to the labor inputs. In both the durable goods sector and the non-durable sector, firms produce their output independently.

Figure 4a illustrates the lack of co-movement between the durable goods expenditure and the non-durable expenditure. While the non-durable expenditure declines, the durable goods expenditure responds significantly, but in the opposite direction.

Figure 4b depicts the IRFs of aggregate variables (GDP⁵ and total labor supply). Note that the response of the two variables are insignificant. As Barsky et al (2003, 2007) point out, since the expenditures on the two products change in the opposite direction, the impact of the monetary policy shock on the economy becomes negligibly small, in terms of the aggregate variables (money neutrality)

Next, we show the co-movement. We incorporate following 2×2 matrix, Γ whose elements are taken from the actual U.S. I-O matrix, of year 2005.

$$\Gamma_{M=2}^{2005} = \begin{pmatrix} .370 & .278 \\ .056 & .279 \end{pmatrix}$$

The first row indicates the share of non-durable inputs in the non-durable production (element $\gamma(1,1)$), and the share in the durable goods production (element $\gamma(1,2)$), respectively. Similarly, the second row indicates the share of durable goods inputs in the non-durable production (element $\gamma(2,1)$), and in the durable goods production (element $\gamma(2,2)$), respectively.

The noticeable feature from this matrix Γ is asymmetry in the intermediate inputs between non-durable sector and durable goods sector. While the intermediate inputs in non-durable production are mostly the products of its own sector, large portion of the intermediate inputs in durable goods production is the products of the non-durable sector.

In other word, this heterogeneity in the row sums between the two sectors indicates that the non-durable sector is a relatively large material supplier to the economy than durable goods sector. From this point, it is predictable, from the corollary to the arguments made in Dopor (1999), that sectoral response of the non-durable sector has a disproportionately larger effect on the aggregate economy.

Figure 4c and 4d show the IRFs of the variables in the economy where I-O matrix $\Gamma_{M=2}^{2005}$ is incorporated. Both durable goods expenditure and non-durable expenditure decline upon the monetary contraction (Figure 4c). Thus the co-movement is recovered. It is also seen that the decline of durable goods expenditure is larger than that of non-durables, as stressed by Bils and Klenow (1994).

In terms of the aggregate variables, both GDP and labor supply declines significantly, compared to the IRFs displayed in Figure 4b. Thus money non-neutrality is recovered, too, even though we follow the specification of Barsky et al (2007) that the durable goods prices are flexible.

Working mechanism

⁵We define GDP as the weighted sum of the durable goods expenditure and the non-durable expenditure. Following Barsky et al (2003, 2007), the nominal expenditure share of each expenditure at the steady state is used as the weight.

The working mechanism that yields the co-movement between the expenditures is generated from the specific characteristic of I-O matrix. Especially, among the four elements of $\Gamma_{M=2}^{2005}$, the size of $\gamma(1, 2)$ plays the important role. Note that $\gamma(1, 2)$ stands for the share of non-durable intermediate inputs in durable goods production.

To see what separates the economy into the lack of co-movement and co-movement, and to clarify the role of $\gamma(1, 2)$, we calculate the IRFs of the variables using the different Γ . In this exercise, we keep both the production structure of the non-durable producing sector, and the share of intermediate inputs in the durable goods producing sector ($\gamma(1, 2) + \gamma(2, 2)$) unaltered. We alter the share of the non-durable inputs in the durable goods production, $\gamma(1, 2)$ from .01 to .40, and depict the IRFs of the variables for each economy.

Figure 4e, f, g, h, i, j, k demonstrate the IRFs of the variables when the share of non-durable, $\gamma(1, 2)$ rise from .01 to .40.

Figure 4e indicates the response of nominal marginal cost in durable goods producing sector. When non-durable share is small, the nominal marginal cost overshoots in the short run⁶. The cost appears to be more persistent as $\gamma(1, 2)$ rises. As shown in the equation (14), higher $\gamma(1, 2)$ implies that the marginal cost of durable producing firms are affected more, by the price dynamics of non-durables. Since non-durable producing sector has sticky price, realized price of durable goods price inherits some of that property, as $\gamma(1, 2)$ increases. As a consequence, the relative price change between durable goods price and non-durable price shrink smaller (Figure 4f).

Figure 4g and 4h show the expenditures of non-durables and durable goods for the different size of $\gamma(1, 2)$.

For the former, varying non-durable share does not seem to play the important role. Upon the monetary contraction, it declines to around -.37 % from the steady state at the impact.

For the latter, alteration in the size of $\gamma(1, 2)$ induces change in both the sign and the size of the IRF. When it is small, the durable goods expenditure rises more than 2% from the steady state. This lack of co-movement observation is similar to the one reported in Barsky et al (2007). When $\gamma(1, 2)$ becomes larger, the co-movement is recovered. The decline of the expenditure is more than 1%, which is bigger than that of non-durables.

Figure 4i, 4j and 4k show the IRFs of the aggregate variables. It is noted that in our model, the short run dynamics of both total labor supply and the labor productivity are affected by the size of $\gamma(1, 2)$ ⁷. As the co-movement is recovered in the disaggregate components and the drop of the durable goods expenditure becomes bigger, both aggregate variables decline more prominently. The response of GDP departs from the money neutrality accordingly.

Table 2 summarizes the results. It reports the cumulative impulse response (CIR) of durable goods expenditure and non-durable expenditure for the first two years after the monetary contraction shock. The elements of each row are CIR of the variables for different value of $\gamma(1, 2)$. The co-movement is obtained only when $\gamma(1, 2)$ is bigger than .20. The response of durable goods expenditure becomes greater than that of non-durable expenditure, only $\gamma(1, 2)$ is larger than .25.

⁶The same phenomena is observed in Barsky et al (2003).

⁷Labor productivity is defined as $\frac{GDP_t}{L_t}$. As Basu (1995) and Huang and Liu (2001) discuss, the monetary policy innovation can induce the temporal change in the labor productivity, when the sticky intermediate goods price is incorporated. In the current exercises, both sticky intermediate goods price and flexible intermediate goods price are present. The rise of $\gamma(1, 2)$ implies the rise in the share of the former. The change in the labor productivity becomes prominent accordingly.

Combining those results imply that as $\gamma(1, 2)$ rises, the view stressed by Bils and Klenow (1994) becomes more effective than the view stressed by Barsky et al (2003, 2007).

Sensitivity to the historical change in I-O matrix

In the following two subsections, we conduct two tests. The tests aim to check the robustness of the co-movement result.

First test asks if the property of U.S. I-O matrix that yields the co-movement between durable goods expenditure and non-durable expenditure has been stable over time. We conduct this test by calculating IRFs of durable goods expenditure and non-durable expenditure using I-O matrix of the year that is different from 2005. U.S. I-O matrix is constructed in every five years, we repeat the same exercise we did in the previous section using the matrix constructed before 2005.

Second test asks if the property of U.S. I-O matrix that yields the co-movement between durable goods expenditure and non-durable expenditure has been robust when non-durable sector is disaggregated into subsectors. The researches about the frequency of price adjustment report the heterogeneity in price stickiness across the subsectors of non-durable sector (Bils and Klenow (2004), Nakamura and Steinsson (2006)). We decompose the current non-durable sector into five subsectors and see whether the co-movement result is robust to this disaggregation.

For the first purpose, we calculate the elements of 2×2 matrix Γ again, using I-O table of U.S. economy from year 1963 to 2000. We then repeat the same numerical exercise as we did in the subsections above, using newly obtained Γ of each year. We keep the other parameters, such as the share of value added ψ_k , and the frequency of price adjustment d_k , and the depreciation rate δ , the same as the precedent exercises. Especially, although the observed nominal share of value added of non-durable and durable goods are changing over this sample period, we concentrate on the analysis of the change in I-O matrix Γ , and abbreviate the effect from the other parameters.

Figure T-1 provides the calculated time-series of the four elements of I-O matrix Γ over the sample periods. The figures in each element are not completely constant, but huge fluctuations are not observed. Similar to the figures of year 2005, the non-durable producing sector stays as the large material supplier to the durable goods producing sector during the period, though the share $\gamma(1, 2)$ is to some extent, shifting around. The production structure of non-durable producing firms are almost constant during the period.

Figure T-2 and T-3 are IRFs of non-durable expenditure and durable goods expenditure to the monetary contraction shock, respectively. Each lines are labelled by the year from which the matrix Γ is constructed.

The responses of non-durable expenditure are always positive, and there is no significant difference in the shape of IRFs across years. As for the responses of durable goods expenditure, on the other hand, there is a significant variation in the shape of IRFs across years. Especially, for the year 1963 and 1972, where the figure of $\gamma(1, 2)$ is comparatively smaller than the other years, the response of durable goods expenditure is modest.

From the comparison between Figure T-2 and Figure T-3, it is observable that the property that durable goods expenditure respond more than does non-durable expenditure is not obtained for year 1963 and 1972. For other years, durable goods expenditure responds more than does non-durables. The co-movement between the durable goods expenditure and non-durable expenditure, however, are robust throughout the sample period, including year 1963 and 1972.

Sensitivity to categorization

In the second test, we divide non-durable sectors into several subsectors. We disaggregate the

I-O matrix, too. The criteria of this disaggregation process is the reported frequency of price change d_k .

While “non-durable”, in our terminology, include the broad category of products that may be differ in price stickiness d_k , the current two-sector model treats those products as having the same degree of price stickiness. However, recent empirical observation conducted by Bils and Klenow (2004) and Nakamura and Steinsson (2006) reveal that the frequency of price adjustment is diverse across subsectors of “non-durable” sector. For example, prices of utilities, travel and unprocessed food are said to be comparatively flexible.

Note that the effectiveness of current model as a solution to the co-movement puzzle relies on the frequency of price adjustment d_k of specific intermediate inputs that are used in durable goods production. For instance, when the subset of non-durables inputs supplied to durable goods producing firms happen to be those whose prices are relatively flexible among non-durables, then the channel argued so far may not be operative.

In order to test the robustness of co-movement result, we decompose non-durable sector into four subsectors and the rest (Five sectors for total). The rules of the decomposition are service-and-non-durable goods distinction, and the observed difference in the frequency of price adjustment. Among the products of service, we extract utilities and transportation for their reported frequency of price adjustment is high (Nakamura and Steinsson (2006)). We extract food from non-durable goods by the same reason. This procedure extends the number of sectors to six.

With renewed those five sectors, we calculate $\Gamma_{\bar{M}=6}$ again, and conduct calibration.

Figure T-5, displays the IRFs of the non-durable expenditure and durable goods expenditure, generated from the same six sector model. In this experiment, Γ is neglected and linear production with respect to labor inputs are assumed for each sector. The frequencies of price adjustment for each sector d_k are the same as those used in the experiment displayed in Figure T-6. Apparently the co-movement is not obtained.

Figure T-4 shows the IRFs of non-durables expenditure and durable goods expenditure in monetary contraction, in six sector economy. 6×6 I-O matrix Γ is constructed from U.S. I-O table of year 2005. Note that in this economy, non-durable expenditure is the sum of the five different products (other service, food, other non-durable goods, utility and transportation), produced from the five different sectors. For each sector, the frequency of price adjustment is specified according to the micro-level finding of Bils and Klenow (2004).

This six sector model should capture the impact of the heterogeneity within the subsectors of broad “non-durable” sector. It is seen from the figure T-4 that the co-movement between aggregate non-durable expenditure and durable goods expenditure is obtained in this specification, too. Moreover, the durable goods expenditure declines more than that of non-durable expenditure as observed in the Table 1. Thus co-movement results is robust to the disaggregation of non-durable sector at least into five sectors.

5 Conclusion

In the current paper, we offer one solution to the co-movement puzzle proposed by Barsky et al (2003) and Carlstrom and Fuerst (2006).

The co-movement between non-durables expenditure and durable goods' expenditure upon monetary policy innovation may be generated through I-O matrix, in the case where non-durable prices are sticky and durable goods prices are flexible. As a consequence of recovery of the co-movement, money non-neutrality is obtained within the framework where durable goods price are completely flexible. This results contrasts with the results in Barsky et al (2007).

Our outcome is generated from the specific characteristic of U.S. input-output structure. In U.S. I-O matrix, non-durable producing sector serves as disproportionately large material supplier to durable goods sector. Thus price dynamics of durable goods is affected by the price dynamics of non-durables. We showed that this inter-sectoral relationship between the sectors prevents the drastic departure of relative prices across the products. Since the relative price change is mitigated, the households' expenditure over the two products respond to the same direction, upon the monetary policy shock (co-movement).

In order to check the robustness, two sensitive tests are conducted. We confirm that U.S. I-O matrix keeps the specific structure that yields the co-movement over long period time. We also confirm that U.S. I-O matrix keeps the structure that yields the co-movement even when non-durable sector is disaggregated into several subsectors.

6 Appendix 1 parameters

Parameters are chosen, following Carlstrom and Fuerst (2006).

Baseline parameters

Parameter	Value	Description
β	$(1.04)^{-1}$	Yearly subjective discount rate
σ	2	Intertemporal elasticity of substitution
ρ	1	Elasticity of substitution
ω^{-1}	1	Frisch labor supply elasticity
$\theta_k = \theta$	11	Elasticity of substitution across goods
δ	10%	Annual depreciation rate of durable goods

7 Appendix 2 sector specific parameters

This section explains the estimating methodology and the source of sector specific parameters employed in our calculation. The parameters are input share Γ , value-added share ψ_k and the frequency of price adjustment d_k .

Our calibration contains two sector, six sector level of disaggregation. Γ , ψ_k for each sector are constructed from U.S. use matrix of corresponding year. As for d_k , we refer both Bils and Klenow (2004), Nakamura and Steinsson (2006) and the arguments in Barsky et al (2003).

Categorization

Calculation of Γ and ψ_k is the matter of categorization. The current paper concentrates the analysis on the two sectors, durable goods sector and non-durable sector. Our durable goods categorization is constructed so as to be consistent with the preceding two sector models that explicitly incorporate

the durable goods sector (Barsky et al (2003, 2007), Carlstrom and Fuerst (2006) and Baxter (1996) and Hornstein and Praschnik (1997)). That is, durable goods expenditure includes consumer durable expenditure and investment. This categorization differs from Erceg and Levin (2003).

The most disaggregated category we employ in the current paper is six subsectors. That includes, other service, travel, utility, other non-durable goods, food, and durable goods. As described above, this disaggregation aims to capture the effect of heterogeneity in price stickiness among “non-durables” that is reported in Bils and Klenow (2004) and Nakamura and Steinsson (2006).

Once categorization is settled, we make the correspondence between the sectors in I-O table and the sectors we focus. We aggregate the commodities of the use table to six subsector categorization using the classification methodology used in Baxter (1996).

The table below summarizes.

Sectors	ψ_k	Category in 2005 I-O table
other service	.721	rest ⁸
durable Goods	.156	23, 211-213, 321, 332-339
food	.011	111CA, 113FF
other non-durable goods	.060	311-315, 322-326
utility	.023	22
transportation	.029	481-487

Matrices

The matrices are constructed from “The Use of Commodities by Industries (before definitions), Annual IO Accounts, 2005.” Highscript and subscript of Γ denote the year and the number of sectors. Order of sector for six sector matrix is the same as the table above. Six sector economy is constructed by combining 2nd row and 3rd row to render 2nd row of six sector Γ .

$$\text{for seven sectors, } \Gamma_{\bar{M}=6}^{2005} = \begin{pmatrix} .292 & .200 & .134 & .177 & .025 & .224 \\ .033 & .282 & .032 & .159 & .292 & .063 \\ .002 & .004 & .230 & .074 & .000 & .000 \\ .320 & .049 & .172 & .236 & .010 & .105 \\ .012 & .007 & .018 & .013 & .000 & .003 \\ .010 & .021 & .019 & .030 & .069 & .120 \end{pmatrix}$$

$$\text{for two sectors, } \Gamma_{\bar{M}=2}^{2005} = \begin{pmatrix} .370 & .278 \\ .056 & .279 \end{pmatrix}$$

The frequency of price adjustment

In terms of the frequencies of price adjustment, we focus (i) the difference between the durable goods sector and the non-durable sector, and (ii) the difference within the subsectors of non-durable sector. Since, other than durability of the products, the frequencies are the only factor that differentiates the sectoral movement upon the monetary policy, choice of the frequencies is the central issue of the current paper.

As our model is two sector model along the line of the researches of Barsky et al (2003, 2007) and Carlstrom and Fuerst (2006), we follow their specification of price frequency whenever two sector model

⁸Government activity, scrap and noncomparable imports are excluded from calculation.

is concerned. Thus our two sector model assumes quarterly frequency of price adjustment $d_k = 0$ for durable goods sector and $d_k = .67$ for non-durable sector, that are the setting of Carlstrom and Fuerst (2006).

In the six sector analysis in section 4, we employ the findings from micro data (Bils and Klenow (2004) and Nakamura and Steinsson (2006)), rather than the values of Carlstrom and Fuerst (2006). Since the motivation of six sector analysis itself is to check the implication of the observed heterogeneity in price stickiness in non-durable sector, our specification reflects the figures from the micro data. d_k for subsectors of non-durable, travel, utility and food are taken from Nakamura and Steinsson (2006). d_k for service less travel, and non-durable goods less food are chosen, so that the mean of the frequency of service and non-durable goods, weighted by the relative significance of each items in value-added of year 2005, to be equalized to the figure of service and non-durable goods, reported in Bils and Klenow (2004).

References

- [1] Alvarez, Luis J. (2006) : “Sticky Prices in the Euro Area: A Summary of New Micro-evidence,” *Journal of the European Economic Association*, v. 4, iss. 2-3, pp. 575-84
- [2] Bak, Peter, Chen, Kan, Scheinkman, Jose and Woodford, Michael (1992) : “Aggregate Fluctuations from Independent Sectoral Shocks: Self-Organized Criticality in a Model of Production and Inventory Dynamics,” National Bureau of Economic Research, Inc, NBER Working Papers: 4241
- [3] Barsky, Robert, Christopher L. House, Miles Kimball (2003) : “Do Flexible Durable Goods Prices Undermine Sticky Price Models?,” National Bureau of Economic Research, Inc, NBER Working Papers: 9832.
- [4] Barsky, Robert, Christopher L. House, Miles Kimball (2007) : “Sticky Price Models and Durable Goods,” *American Economic Review*, 97(3).
- [5] Basu, Susanto (1995) : “Intermediate Goods and Business Cycles: Implications for Productivity and Welfare,” *American Economic Review*, 85(3).
- [6] Baxter, Marianne (1996) : “Are Consumer Durables Important for Business Cycles?” *Review of Economics and Statistics*, 78(1).
- [7] Bernanke, Ben S., Boivin, Jean; Elias, Piotr (2005) : “Measuring the Effects of Monetary Policy: A Factor-Augmented Vector Autoregressive (FAVAR) Approach,” *Quarterly Journal of Economics*, 120(1).
- [8] Bils, Mark; Klenow, Peter J (1998) : “Using Consumer Theory to Test Competing Business Cycle Models,” *Journal of Political Economy*, 106(2).
- [9] Bils, Mark, Klenow, Peter J. and Kryvtsov, Oleksiy (2003) : “Sticky Prices and Monetary Policy Shocks,” *Federal Reserve Bank of Minneapolis Quarterly Review*, 27(1).
- [10] Bils, Mark, Peter J. Klenow (2004) : “Some Evidence on the Importance of Sticky Prices,” *Journal of Political Economy*, 112(5).

- [11] Boivin, Jean, Giannoni, Marc and Mihov, Ilian (2007) : “Sticky Prices and Monetary Policy: Evidence from Disaggregated U.S. Data,” National Bureau of Economic Research, Inc, NBER Working Papers: 12824
- [12] Bouakez, Hafed, Emanuela, Carida and Ruge-Murcia, Francisco (2005) : “The Transmission of Monetary Policy in a Multi-Sector Economy”, pp. 43 pages, Universite de Montreal, Departement de sciences economiques, Cahiers de recherche.
- [13] Calvo, Guillermo A (1983) : “Staggered Prices in a Utility-Maximizing Framework,” *Journal of Monetary Economics*, 12(3).
- [14] Carlstrom, Charles T. and Timothy S. Fuerst (2006) : “Co-Movement in Sticky Price Models with Durable Goods,” Federal Reserve Bank of Cleveland, Working Paper 06-14, November.
- [15] Carvalho, Carlos (2006) : “Heterogeneity in Price Stickiness and the Real Effects of Monetary Shocks,” *Frontiers of Macroeconomics*, Vol. 2, No. 1.
- [16] Davis, Steven J. and Haltiwanger, John (2001) : “Sectoral job creation and destruction responses to oil price changes,” *Journal of Monetary Economics*, 48(3).
- [17] DiCecio, Riccardo (2005) : “Comovement: its not a puzzle,” Federal Reserve Bank of St. Louis, Working Papers.
- [18] Dupor, Bill (1999) : “Aggregation and Irrelevance in Multi-sector Models,” *Journal of Monetary Economics*, 43(2).
- [19] Conley, Timothy G., Dupor, Bill (2003) : “A Spatial Analysis of Sectoral Complementarity,” *Journal of Political Economy*, April, v. 111, iss. 2, pp. 311-52
- [20] Erceg, C. J., and A. T. Levin (2002) : “Optimal monetary policy with durable and non-durable goods,” European Central Bank, Working paper series:
- [21] Erceg, C. J., and A. T. Levin (2006) : “Optimal Monetary Policy with Durable Consumption Goods,” *Journal of Monetary Economics*, 53(7).
- [22] Hornstein, Andreas and Jack Praschnik (1997) : “Intermediate Inputs and Sectoral Comovement in the Business Cycle,” *Journal of Monetary Economics*, 40(3).
- [23] Horvath, Michael (1998) : “Cyclicalities and Sectoral Linkages: Aggregate Fluctuations from Independent Sectoral Shocks,” *Review of Economic Dynamics*, 1(4).
- [24] Huang, Kevin X. D. and Liu, Zheng (2001) : “Production Chains and General Equilibrium Aggregate Dynamics,” *Journal of Monetary Economics*, 48(2).
- [25] Huang, Kevin X. D. and Liu Zheng (2001) : “Input-Output Structure and Nominal Staggering: The Persistence Problem Revisited,” Cahiers de recherche CREFE / CREFE Working Papers 145, CREFE, Universite du Quebec a Montreal.
- [26] Huang, Kevin X. D, Zheng Liu, Louis Phaneuf (2004) : “Why Does the Cyclical Behavior of Real Wages Change over Time?,” *American Economic Review*, 94(4).
- [27] Long, John B., Jr and Charles I. Plosser : “Real Business Cycles,” *Journal of Political Economy*, 91(1).

- [28] Ohanian, Lee E., Stockman, Alan C., Kilian, Lutz (1995) : “The Effects of Real and Monetary Shocks in a Business Cycle Model with Some Sticky Prices,” *Journal of Money, Credit, and Banking*, Part 2, 27(4).
- [29] Wolman, Alexander L., Fan Ding (2005) : “Inflation and Changing Expenditure Shares,” *Federal Reserve Bank of Richmond Economic Quarterly* 91(1).

(Table 1)
Cumulative impulse response functions after the monetary policy shock

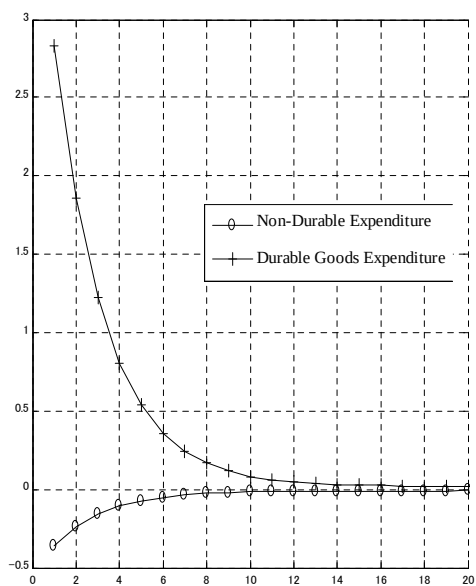
	Cumulative Impulse Functions of first 2 years
Durable goods expenditure	-0.040
Non-durable expenditure	-0.015
the ratio	2.680

We calculated the impact of the monetary policy shock on each sectors by the cumulative impulse response functions (CIRs). The CIRs for the first two years after the monetary policy shock displayed below is used in Davis and Haltiwanger (2001).

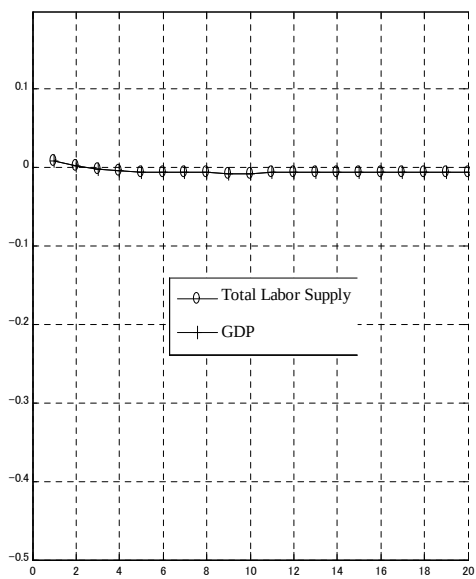
The impulse response functions are calculated from 6-variable VAR that is similar to the one used in Erceg and Levin (2003). Main difference is the disaggregation procedure. Our two sector model, durable goods expenditure stands for the composite weighed index of consumer durables expenditure, residential investment and business investment. Non-durable expenditure stands for the composite of consumption expenditure of non-durable goods and services. The number of lags, the conversion methodologies of the variables, the order of the variables in the current estimation are the same as Erceg and Levin (2003). We use CRS index instead of IMF commodity indices, and estimated over the sample period 1960:1Q - 2005:1Q. The CIRs shown below are generated from the innovation that rises funds rate by 80 basis at the initial point. Those figures are percentage deviation from the baseline.

Lack of Co-movement

(Figure 4a)

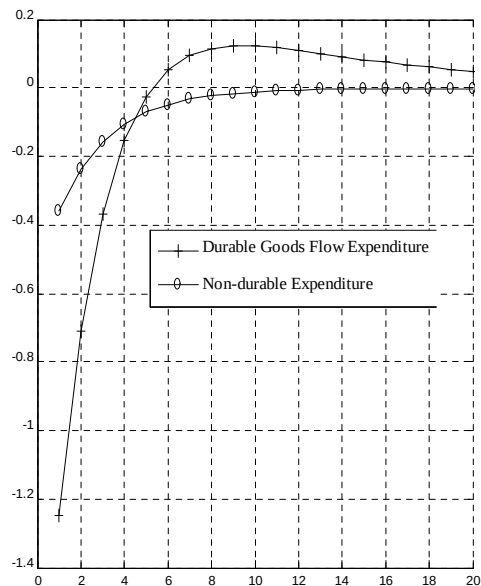


(Figure 4b)

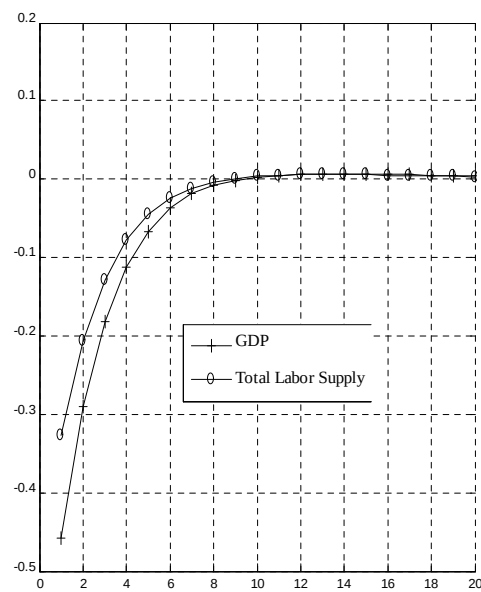


Co-movement

(Figure 4c)

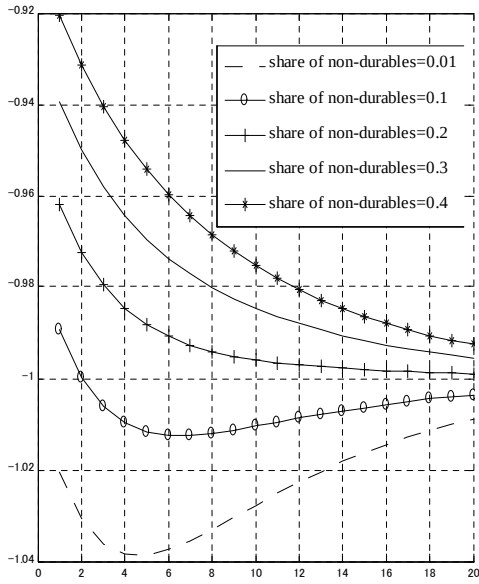


(Figure 4d)

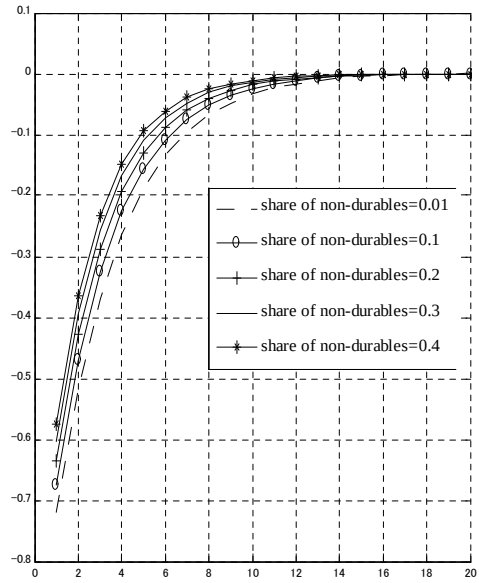


Working Mechanism

(Figure 4e) IRFs of Marginal Cost in Durable Goods Sector

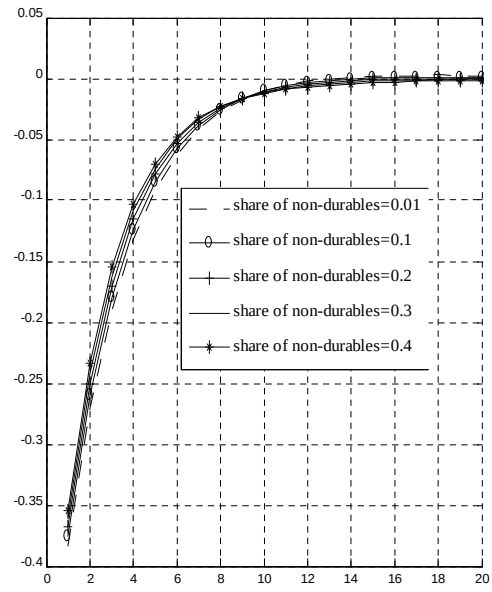


(Figure 4f) IRFs of Relative Price of Durable Goods

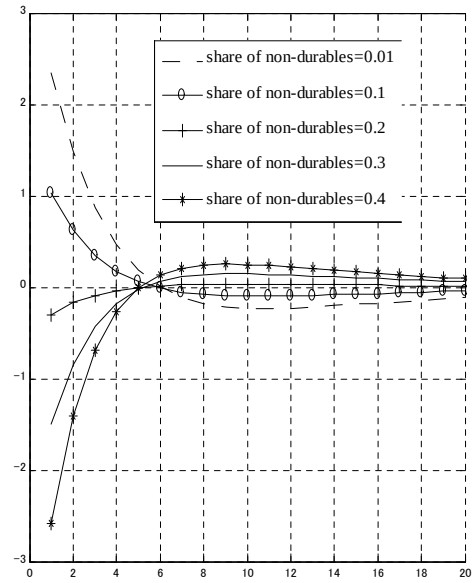


Working Mechanism

(Figure 4g) IRFs of Non-Durable Expenditure

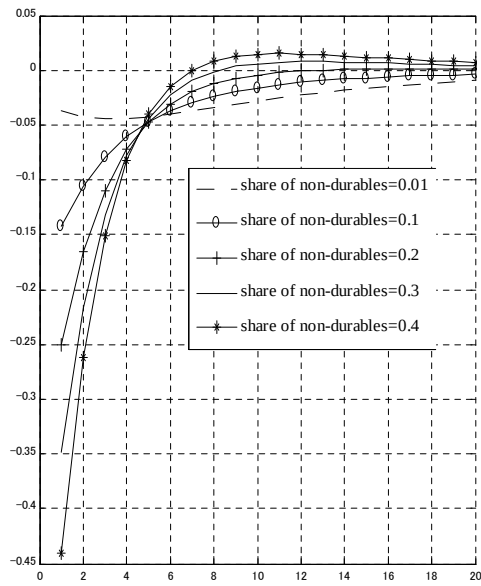


(Figure 4h) IRFs of Durable Goods Expenditure



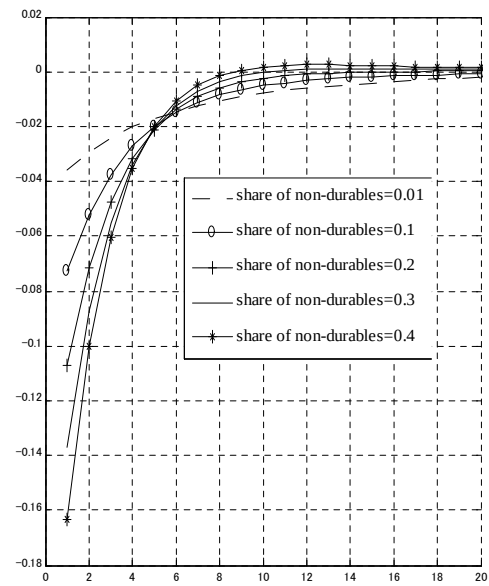
Working Mechanism

(Figure 4i) IRFs of Total Labor Supply

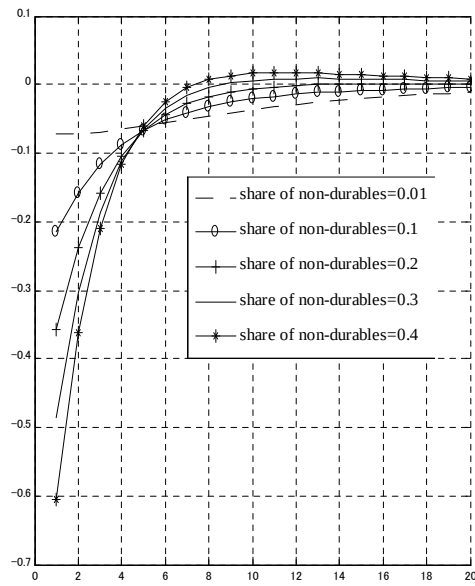


Working Mechanism

(Figure 4j) IRFs of Labor Productivity



(Figure 4k) IRFs of GDP



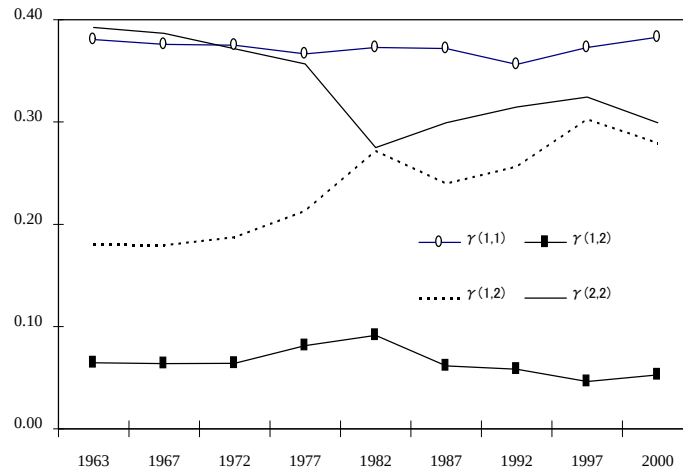
(Table 2)
Cumulative impulse response functions and the share of non-durable inputs

the share	Durable goods	Non-durable	the ratio
0.01	-1.20	5.04	-4.21
0.05	-1.17	3.62	-3.10
0.10	-1.13	2.05	-1.81
0.15	-1.10	0.67	-0.61
0.20	-1.07	-0.57	0.53
0.25	-1.05	-1.67	1.59
0.30	-1.03	-2.67	2.60
0.35	-1.01	-3.57	3.55
0.40	-0.99	-4.40	4.46

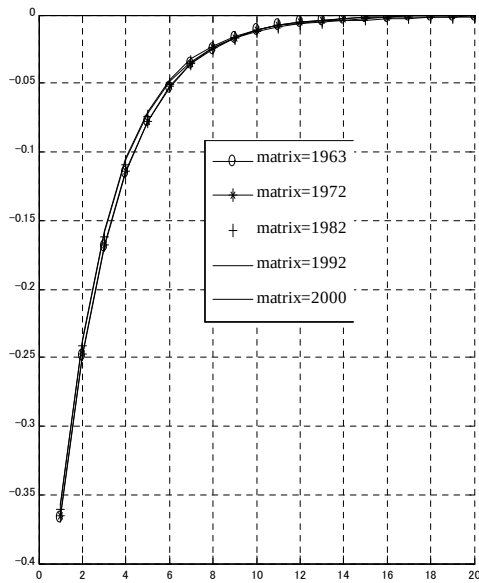
Robustness to change in matrix

Robustness to change in matrix

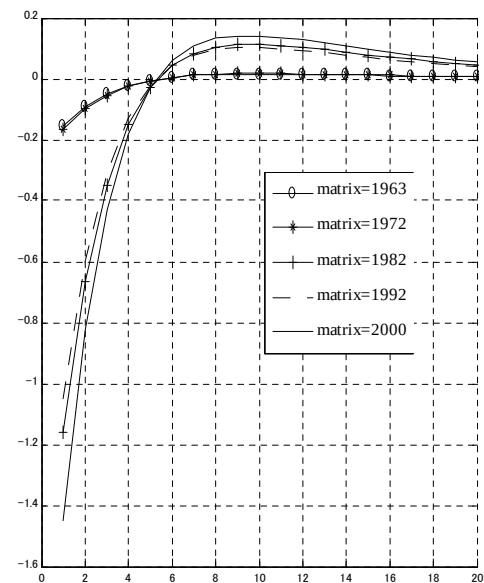
Figure T-1) The value of Γ over the period



(Figure T2) IRFs of Non-Durable Expenditure

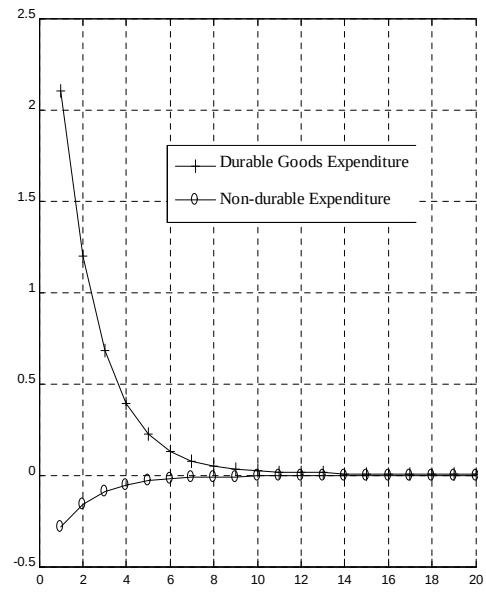


(Figure T3) IRFs of Durable Goods Expenditure



Robustness to categorization

(Figure T4)



(Figure T5)

