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# Optimal Fiscal and Monetary Policy with Durable Goods

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In this paper, we examine the question of how to conduct fiscal and monetary policy in a two-sector Ramsey model with durable and non-durable goods. Due to the fact that the intertemporal elasticity of substitution of durable goods is much higher than that of non-durable goods, the introduction of durable goods changes the policy prescriptions substantially. Specifically, in comparison with the findings in the literature, we find that the labor income tax rate and the interest rate exhibit greater volatility. In addition, the volatilities of the labor income tax rate and the interest rate increase with the decrease in the depreciation rate of durable goods.

*Key Words*: Durable goods; Fiscal and monetary policy; Volatility of the labor income tax rate; Interest rate volatility.

*JEL Classification Numbers*: E52, E61, E63.

## 1. INTRODUCTION

There is no consensus among researchers on how to conduct optimal fiscal and monetary policy in standard Ramsey models. In a model with no nominal rigidities, Chari et al. (1991) find that the inflation rate is highly volatile because the Ramsey planner uses the unanticipated inflation as a non-distortionary tax to finance unexpected innovations in the fiscal deficit. In this way, the Ramsey planner can generate real state-dependent bonds when only nominal non-state-contingent government bonds are available. As a result, the Ramsey planner can keep the labor income tax rate roughly constant over the business cycle. By comparison, after incorporating monopolistic competition and price stickiness into an otherwise standard model *à la* Lucas and Stokey (1983) and Chari et al. (1991), Schmitt-Grohe and Uribe (2004) and Siu (2004) find that the volatility of

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the inflation rate is close to zero even for a low degree of price stickiness. By investigating the impact of sticky wages on optimal fiscal and monetary policy, Chugh (2006) concludes that sticky wages by themselves can lead the Ramsey planner to keep the volatility of the inflation rate low. In a model with costly wage bargaining, Arseneau and Chugh (2008) find that the inflation rate is quite volatile in spite of the wage stickiness, in addition, the volatility of the labor income tax rate is more volatile than in a standard Ramsey model without costly wage bargaining.

However, the conclusions drawn in the above-mentioned Ramsey models base on the assumption that there is only a single non-durable sector in the economy. In reality, monetary policy can have disparate effects across the various sectors of the economy. As documented in Erceg and Levin (2006) , a peak impact of a monetary policy innovation on consumer durable goods spending is several times larger than that on other expenditures. Thus, the incorporation of a durable goods sector can fundamentally change the design of monetary policy due to the fact that they are more sensitive to changes in monetary policy.[1] Whether the introduction of a durable goods sector can change the joint determination of fiscal and monetary policy remains a relatively unexplored area of research. In this paper, we fill the gap and revisit the question of how to conduct optimal fiscal and monetary policy in a two-sector Ramsey model with durable and non-durable goods.

We revise Schmitt-Grohe and Uribe (2004) to incorporate a durable goods sector, in addition to a non-durable goods sector. In either sector, each firm is the monopolistic producer of a differentiated good, but faces adjustment costs when changing prices. The government has only a distortionary labor income tax available to finance the exogenous expenditure, besides one-period nominally risk-free bonds. The Ramsey planner chooses the labor income tax rates and the interest rates to maximize the welfare of the representative household, subject to the competitive equilibrium conditions.

Our main finding is that, under the Ramsey policy, the labor income tax rate, the interest rate, and the inflation rate all become more volatile than in Schmitt-Grohe and Uribe (2004) . In fact, no matter whether durable goods are introduced or not, the Ramsey planner needs to adjust the relative price to achieve efficient resource allocations across sectors when there are two sectors. However, according to Barsky et al. (2007, 2016) , the intertemporal elasticity of substitution of durable goods is much higher than that of non-durable goods. By comparison, since the households choose to smooth consumption, the intertemporal elasticity of substitution of non-durable goods is much lower.

[1] Among many others, see Barsky et al. (2007, 2016) .

In Schmitt-Grohe and Uribe (2004) , the Ramsey planner faces a trade-off in choosing the inflation rate. For one thing, the Ramsey planner would like to increase the volatility of the inflation rate to tax nominal wealth in a non-distorting fashion to keep the distortionary labor income tax rate stable over the business cycle; and for another the increase in the volatility of the inflation rate causes costs due to the presence of the price stickiness. However, the trade-off is shown to favor the price stability, thus, the volatility of the inflation rate is relatively low. In our two-sector model with durable and non-durable goods, besides the above-mentioned trade-off, there is a new consideration for the Ramsey planner to choose the inflation rate, i.e. efficient resource allocations across sectors which can be achieved by adjusting the relative price. Taken together, the volatility of the inflation rate is higher in our model than in Schmitt-Grohe and Uribe (2004) .

Unlike non-durable goods, the intertemporal elasticity of substitution of durable goods is much higher, which means that the Ramsey planner can achieve the intertemporal substitution of durable goods more easily than that of non-durable goods by changing the interest rate. Therefore, to achieve efficient resource allocations dynamically, the Ramsey planner has an incentive to increase the volatility of the interest rate so that it is higher than in Schmitt-Grohe and Uribe (2004) . By introducing a wedge between the real wage and the marginal rate of substitution between consumption and labor supply, the labor income tax rate can be used by the Ramsey planner to change the relative price of labor in terms of consumption. Thus, despite the fact that the labor income tax rate causes distortions in labor market, the Ramsey planner still has the incentive to increase the volatility of the labor tax rate to change the intratemporal allocation of consumption and employment.

Readers may wonder whether our conclusion flows from two types of goods only and has nothing to do with durable goods. To clarify this point, we conduct a numerical simulation experiment and compare the policy prescriptions for several alternative depreciation rates. In one extreme case, we set the depreciation rate to unity, thus our model degenerates into one with two sectors but no durable goods. In another extreme case, we set the depreciation rate to 0.001, thus the durable goods almost approach to be *idealized* in the sense discussed by Barsky et al. (2007, 2016) . Besides the two extreme cases, we also set the depreciation rate to 0.01 and 0.05, respectively, either of which corresponds to the normal two-sector model with durable goods.

Our experiment reveals that, in comparison with the two-sector model without durable goods, the labor income tax rate and the interest rate exhibit greater volatility in our two-sector model with durable goods, however, the relative price keeps stable for various depreciation rates. In addition, the volatilities of the labor income tax rate and the interest rate increase with the decrease in the depreciation rate. Thus, the introduction of durable goods into a standard Ramsey model changes fiscal and monetary policy prescriptions in a nontrivial way.

The rest of the paper is organized as follows. Section 2 lays out the model. Section 3 introduces the Ramsey problem. Section 4 concludes.

## 2. THE MODEL

The economy is populated by a continuum of households with unit mass, each of which has preferences over consumption of durable and non-durable goods, and employment. There are two production sectors, durable and non-durable goods sectors. Within each sector, a continuum of firms employ labor to produce differentiated products, incur cost to adjust prices. The government finances the exogenous spending by levying distortionary labor income taxes, and issuing one-period nominally risk-free bonds.

### 2.1. Households

The representative household maximizes the following expected utility function:

$$\mathbf{E}_0\left\{\sum_{t=0}^{\infty}\beta^t\left[\ln H_t-\xi\frac{N_t^{1+\phi}}{1+\phi}\right]\right\}, \tag{1}$$

in which $\mathbf{E}_t[\cdot]$ is the expectation operator, $\beta\in(0,1)$ is the subjective discount factor, $\phi$ represents the inverse of Frisch elasticity of labor supply, $\xi$ denotes the weight on labor disutility, $N_t$ denotes employment, and $H_t$ is a composite of non-durable and durable consumption goods:

$$H_t=C_t^{1-\upsilon}D_t^{\upsilon}, \tag{2}$$

in which $C_t$ is a non-durable consumption good, $D_t$ denotes the stock of durable good, and $\upsilon$ is the expenditure share of the household on $D_t$. To facilitate the analysis, we assume that labor is perfectly mobile across the two sectors.

The non-durable consumption good $C_t$ is an index given by:

$$C_t=\left[\int_0^1 C_t\left(f_c\right)^{\frac{\varepsilon_c-1}{\varepsilon_c}}df_c\right]^{\frac{\varepsilon_c}{\varepsilon_c-1}},$$

where $f_c\in[0,1]$ denotes the non-durable consumption good variety, $\varepsilon_c$ is the elasticity of substitution between differentiated varieties in the non-durable goods sector. Solving the household's expenditure-minimization problem, we can obtain her demand for variety $f_c\in[0,1]$, which is given by:

$$C_t\left(f\right)=\left(\frac{P_{ct}\left(f_c\right)}{P_{ct}}\right)^{-\varepsilon_c}C_t,$$

in which $P_{ct}=\left[\int_0^1 P_{ct}\left(f_c\right)^{1-\varepsilon_c}df_c\right]^{\frac{1}{1-\varepsilon_c}}$ is an aggregate price index for non-durable consumption goods, $P_{ct}\left(f_c\right)$ is the price of variety $f_c$.

The stock of durable good, $D_t$, accumulates according to the following law of motion:

$$D_t=\left(1-\delta\right)D_{t-1}+I_{dt}, \tag{3}$$

where $\delta$ denotes the depreciation rate of durable good, $I_{dt}$ denotes time $t$ purchases of new durable good, which is a CES aggregation of differentiated varieties:

$$I_{dt}=\left[\int_0^1 I_{dt}\left(f_d\right)^{\frac{\varepsilon_d-1}{\varepsilon_d}}df_d\right]^{\frac{\varepsilon_d}{\varepsilon_d-1}},$$

where $f_d\in[0,1]$ denotes the durable consumption good variety, $\varepsilon_d$ is the elasticity of substitution between differentiated varieties in the durable-goods sectors. The demand for variety $f_d\in[0,1]$ can be derived from solving the household's expenditure-minimization problem, which is given by:

$$I_{dt}\left(f_d\right)=\left(\frac{P_{dt}\left(f_d\right)}{P_{dt}}\right)^{-\varepsilon_d}I_{dt},$$

in which $P_{dt}=\left[\int_0^1 P_{dt}\left(f_d\right)^{1-\varepsilon_d}df_d\right]^{\frac{1}{1-\varepsilon_d}}$ is an aggregate price index for durable consumption goods, $P_{dt}\left(f_d\right)$ is the price of variety $f_d$.

The household's budget constraint is given by:

$$P_{ct}C_t+P_{dt}I_{dt}+B_t=\left(1-\tau_t\right)W_tN_t+R_{t-1}B_{t-1}+\Gamma_t, \tag{4}$$

where $B_t$ is one-period nominally risk-free bond holding, $W_t$ is the nominal wage rate, $\tau_t$ denotes the labor income tax rate, $R_t$ is the nominal interest rate on the bond purchased in period $t$, $\Gamma_t$ denotes profits that are returned to the household through the ownership of firms.

The household chooses $C_t, D_t, N_t, I_{dt}$,and $B_t$ to maximize equation (1) subject to equations (3) and (4). Let $\zeta_t$ be the Lagrange multiplier on the law of motion of the stock of durable good, and $\frac{\lambda_t}{P_{ct}}$ be the Lagrange multiplier on the budget constraint. Then the first-order conditions of the household's maximization problem are

$$\left(1-\tau_t\right)\frac{W_t}{P_{ct}}=\frac{\xi}{1-\upsilon}C_tN_t^{\phi}, \tag{5}$$

$$1=\beta\mathbf{E}_t\left(\frac{C_t}{C_{t+1}}\frac{R_t}{\Pi_{c,t+1}}\right), \tag{6}$$

$$\zeta_t=\upsilon D_t^{-1}+\beta\left(1-\delta\right)\mathbf{E}_t\left(\zeta_{t+1}\right), \tag{7}$$

$$\zeta_t=\left(1-\upsilon\right)C_t^{-1}Q_t, \tag{8}$$

where $\Pi_{c,t+1}=\frac{P_{ct+1}}{P_{ct}}$ is the price inflation rate of non-durable consumption good, $Q_t\equiv\frac{P_{dt}}{P_{ct}}$ denotes the relative price of durable consumption good in terms of non-durable consumption good. Equation (5) describes the household's optimal labor supply, which implies that the real after-tax wage is equal to the marginal rate of substitution between leisure and non-durable consumption good. Given the real wage rate, a rise in the labor income tax rate tends to induce the household consume less or work less. Equation (6) is a standard Euler equation for non-durable consumption good. Equation (7) relates the shadow value of one unit of additional durable good to the discounted flow utility of durable good. Equation (8) is the intratemporal optimality condition to determine the household's optimal consumption mix of durable and non-durable goods. Thus, if the shadow value of durable good is a constant, the consumption of non-durable good and the relative price move in opposite directions.

From equation $(7)$, we can derive the following equation

$$\zeta_t=\upsilon\sum_{k=0}^{\infty}\left[\left[\beta\left(1-\delta\right)\right]^k D_{t+k}^{-1}\right]. \tag{9}$$

Equation (9) implies that the shadow value of durable good is the discounted present value of the marginal utilities of the service flow of durable good, with the discount factor being the product of the subjective rate of time preference and the depreciation rate of durable good.

Following Barsky et al. $(2007, 2016)$, we know that for long-lived durable good, $\zeta_t$ is approximately invariant to transitory shocks. Consequently, the demand for durable good displays an almost infinite elasticity of intertemporal substitution. It means that the demand for durable good is very sensitive to the changes in the interest rate. As we will see below, the introduction of durable good substantially changes optimal fiscal and monetary policy prescriptions.

## 2.2. Firms

A typical firm $f_j\in(0,1)$, $j\in\{c,d\}$ in each sector produces a differentiated good with a linear production function which is given by:

$$Y_{jt}\left(f_j\right)=A_{jt}L_{jt}\left(f_j\right),$$

where $L_{jt}(f_j)$ is the labor input, $A_{jt}$ is a common productivity shock to all firms in sector $j$, which follows the AR(1) process

$$\ln A_{jt} = \rho_j \ln A_{jt-1} + \varepsilon_{jt},$$

in which $\rho_j \in (0,1)$ measures the persistence of the shock, $\varepsilon_{jt}$ is an i.i.d. white noise process with zero mean and standard deviation $\sigma_j$.

Solving firm $f_j's$ cost-minimization problem, we can obtain its real marginal cost

$$RMC_{jt} = \frac{W_t}{P_{jt}A_{jt}}. \tag{10}$$

The demand for the output of firm $f_j$ by households is

$$Y_{jt}(f_j) = \left(\frac{P_{jt}(f_j)}{P_{jt}}\right)^{-\varepsilon_j} Y_{jt}. \tag{11}$$

Following Rotemberg (1982) , we introduce sluggish price adjustment by assuming that, whenever firm $f_j$ resets prices in each period, it incurs a cost of price adjustment, which is expressed in terms of the produced good as

$$\frac{\theta_j}{2}\left(\frac{P_{jt}(f_j)}{P_{jt-1}(f_j)} - 1\right)^2 Y_{jt},$$

in which $\theta_j \geq 0$ measures the degree of price stickiness. When $\theta_j = 0$, prices are flexible.

In period $t$, firm $f_j$ chooses $P_{jt}(f_j)$ to maximize the sum of the period-$t$ nominal profit and the discounted nominal profit in period $t+1$

$$\begin{aligned}&(P_{jt}(f_j) - P_{jt}RMC_{jt})Y_{jt}(f_j) - \frac{\theta_j}{2}\left(\frac{P_{jt}(f_j)}{P_{jt-1}(f_j)} - 1\right)^2 P_{jt}Y_{jt} + \\ &\mathbf{E}_t\left[\beta\frac{\lambda_{t+1}}{\lambda_t\Pi_{c,t+1}}\left[(P_{jt+1}(f_j) - P_{jt+1}RMC_{jt+1})Y_{jt+1}(f_j) - \frac{\theta_j}{2}\left(\frac{P_{jt+1}(f_j)}{P_{jt}(f_j)} - 1\right)^2 P_{jt+1}Y_{jt+1}\right]\right].\end{aligned} \tag{12}$$

Solving the above maximization problem, we can obtain a standard New Keynesian Phillips Curve

$$\theta_j\Pi_{j,t}(\Pi_{j,t} - 1) = (1 - \varepsilon_j + \varepsilon_j RMC_{jt}) + \theta_j\beta\mathbf{E}_t\left[\frac{C_{t+1}^{-1}}{C_t^{-1}}\frac{\Pi_{j,t+1}^2}{\Pi_{c,t+1}}(\Pi_{j,t+1} - 1)\frac{Y_{jt+1}}{Y_{jt}}\right]. \tag{13}$$

When prices are flexible, the real marginal cost is the inverse of the markup.

### 2.3. Fiscal and monetary policy

The government faces a stream of public expenditure $G_t$, which follows the following AR(1) process:

$$\ln G_t = (1-\rho_g)\ln \overline{G} + \rho_g \ln G_{t-1} + \varepsilon_{gt}, \tag{14}$$

in which $\overline{G}$ is the steady state value of $G_t$, $\rho_g$ measures the persistence of $G_t$, $\varepsilon_{gt}$ is an i.i.d. white noise process with zero mean and standard deviation $\sigma_g$.

Following Erceg and Levin (2006) , we assume that the government only purchases non-durable goods. The aggregate public expenditure, $G_t$, is a CES aggregation of differentiated non-durable goods:

$$G_t = \left[\int_0^1 G_t\left(f_c\right)^{\frac{\varepsilon_c-1}{\varepsilon_c}} df_c\right]^{\frac{\varepsilon_c}{\varepsilon_c-1}}.$$

The government finances its expenditure by levying labor income tax at the rate $\tau_t$, and issuing one-period nominally risk-free bond $B_t$. The government's sequential budget constraint is given by:

$$B_t + \tau_t W_t N_t = P_{ct} G_t + R_{t-1} B_{t-1}. \tag{15}$$

The fiscal and monetary policy consists in the joint choice of the nominal interest rate and the labor income tax rate $\{R_t, \tau_t\}$.

### 2.4. Market clearing conditions and Equilibrium

Non-durable goods market clearing condition is

$$Y_{ct} = C_t + G_t + \frac{\theta_c}{2}\left(\Pi_{c,t}-1\right)^2 Y_{ct}. \tag{16}$$

Durable goods market clearing condition implies that

$$Y_{dt} = I_{dt} + \frac{\theta_c}{2}\left(\Pi_{d,t}-1\right)^2 Y_{dt}. \tag{17}$$

The labor market clearing condition implies that labor supply equals labor demand

$$N_t = L_{ct} + L_{dt}. \tag{18}$$

A competitive equilibrium consists of sequences of prices $\{P_{ct}, P_{dt}, Q_t, W_t\}_{t=0}^{\infty}$ and allocations $\{Y_{ct}, Y_{dt}, L_{ct}, L_{dt}, N_t, B_t, C_t, I_{dt}, D_t, \zeta_t\}_{t=0}^{\infty}$ such that $(i)$ taking the fiscal and monetary policy $\{R_t, \tau_t\}_{t=0}^{\infty}$ , shocks $\{A_{ct}, A_{dt}, G_t\}$ , and the prices as given, the allocations solve the optimization problems of the household and the firms, and $(ii)$ all markets clear.

## 3. THE RAMSEY PROBLEM

Following the literature, we assume that the government is benevolent and endowed with full commitment, thus we refer to the government as the Ramsey planner.

The Ramsey planner chooses the fiscal and monetary policy $\{R_t, \tau_t\}_{t=0}^{\infty}$ to maximize

$$\mathbf{E}_0 \left\{ \sum_{t=0}^{\infty} \beta^t \left[ (1-\upsilon) \ln C_t + \upsilon \ln D_t - \xi \frac{N_t^{1+\phi}}{1+\phi} \right] \right\},$$

subject to the competitive equilibrium conditions.

To solve the Ramsey problem, we calibrate our model to the US economy. Then we describe the Ramsey steady state before presenting optimal fiscal and monetary policy based on simulation.

### 3.1. Calibration

The time unit is one quarter, so we set the subjective discount factor $\beta$ to 0.99, which means that the annual real interest rate is 4% in the steady state. Following Chetty et al. (2011), we assign a value of 1.333 to the inverse of Frisch elasticity of labor supply, $\phi$, which implies that the Frisch elasticity of labor supply is 0.75. According to Chen and Liao (2018) , we set the expenditure share of the household on durable good $\upsilon$ to 0.2. To make sure that the steady-state labor supply is equal to one third in the model without durable goods, we set the weight on labor disutility $\xi$ to 9.8268. We equalize the elasticities of substitution between varieties in both sectors so that the desired markup is 20% in the steady state, which implies that $\varepsilon_c = \varepsilon_d = 6$. Following Carlstrom and Fuerst (2010) and Sudo (2012) , we set the quarterly depreciation rate of durable good $\delta$ to 0.025, which implies a 10% annual depreciation rate.

As in the recent literature, we set the degree of price stickiness in the non-durable goods sector $\theta_c$ to 58.2524 so that the frequency of price adjustment is about four quarters. [2] With regard to the degree of price stickiness in the durable goods sector, there is no consensus in the literature. Bils and Klenow (2004) document that durable-goods prices are generally more flexible than non-durable goods prices. However, Nakamura and Steinsson (2008) do not report any evidence to support the findings in Bils and

[2]As in Monacelli (2009) , to pin down the degree of price stickiness in the non-durable goods sector, we set the slope of the Phillips curve in the Calvo–Yun model $\frac{(1-\vartheta)(1-\beta\vartheta)}{\vartheta}$,in which $\vartheta$ is the probability with which a firm's price remains unchanged from the previous period, to be equal to that in our model, which is given by $\frac{\varepsilon_c-1}{\theta_c}$. After simple algebra, we know that $\theta_c = \frac{(\varepsilon_c-1)\vartheta}{(1-\beta\vartheta)(1-\vartheta)}$. In the Calvo–Yun model, an average frequency of price adjustment of one year implies that $\vartheta = 0.75$. With the values of $\varepsilon_c$ and $\beta$ being given as 6 and 0.99 respectively, we can conclude that $\theta_c = 58.2524$.

Klenow (2004) , their estimated results reveal that the average frequency of price adjustment is about four quarters, regardless of durability. Thus, we set the degree of price stickiness in the durable-goods sector $\theta_d$ to be equal to the value of its counterpart in the other sector, namely, 58.2524.

We allow for contemporaneously correlated productivity shocks, and assume that the government spending shock is uncorrelated with productivity shocks. Following Erceg and Levin (2006) , we set the degrees of persistence of the productivity shocks in both sectors to be $\rho_c = 0.87$ and $\rho_d = 0.90$, respectively, the standard deviations of the productivity shocks in both sectors to be $\sigma_c = 0.0096$ and $\sigma_d = 0.0360$, respectively, in addition, the correlation coefficient is set to be $corr\,(\varepsilon_{ct}, \varepsilon_{ct}) = 0.29$. As for the government spending shock, we follow Schmitt-Grohe and Uribe (2004) and calibrate the steady state value $\overline{G}$ so that it accounts for 20 percent of the steady state output, the persistence parameter and the standard deviation are set to be $\rho_g = 0.9, \sigma_g = 0.03$, respectively. Table 1 summarizes the calibration of our model.

**TABLE 1.**

Parameterization

| Description | Parameter | Value |
|---|---|---|
| Subjective discount factor | $\beta$ | 0.99 |
| Expenditure share on durable good | $\nu$ | 0.2 |
| Inverse of Frisch elasticity of labor supply | $\phi$ | 1.333 |
| Steady-state labor supply | $\overline{N}$ | 1/3 |
| Quarterly depreciation rate of durable good | $\delta$ | 0.025 |
| Elasticity of substitution between varieties | $\varepsilon_c, \varepsilon_d$ | 6 |
| Degree of price stickiness | $\theta_c, \theta_d$ | 58.2524 |
| Degree of persistence of the productivity shock | $\rho_c$ | 0.87 |
| Degree of persistence of the productivity shock | $\rho_d$ | 0.90 |
| Degree of persistence of the government spending shock | $\rho_g$ | 0.9 |
| Standard deviation of the productivity shock | $\sigma_c$ | 0.0096 |
| Standard deviation of the productivity shock | $\sigma_d$ | 0.0360 |
| Standard deviation of the government spending shock | $\sigma_g$ | 0.03 |
| Correlation coefficient of the productivity shocks | $corr\,(\varepsilon_{ct}, \varepsilon_{ct})$ | 0.29 |

### 3.2. The Ramsey steady state

It is impossible to arrive at the nonstochastic Ramsey steady-state allocation and policy analytically, we numerically compute them by using the non-linear Ramsey first-order conditions. Since the depreciation rate of durable good plays a central role in our model, we focus on how the Ramsey policy varies with the depreciation rate of durable good.

Table 2 reports the steady-state labor income tax rate, the nominal interest rate, the inflation rates in both sectors, the consumption of non-durable good, the stock of the durable good, the durable-goods output, and the employment for various degrees of depreciation of durable good. To eliminate the costs caused by inflation under price stickiness, the Ramsey planner keeps the price levels constant in both sectors. Thus, the household's Euler equation implies that the nominal interest rate deviates from zero and the Friedman rule is not optimal, which is consistent with Schmitt-Grohe and Uribe (2004) ,and Chugh (2006) .

It is intuitive that, with the depreciation rate of durable good tending to zero, the stock of durable good increases gradually, thus it can be approximately thought of as an *idealized durable* defined by Barsky et al. (2007, 2016). During the transition to the *idealized durable*, the investment in durable good declines by degrees, and the labor moves from the durable goods sector to the non-durable goods sector. As a result, the output in the durable goods sector becomes smaller, by comparison, the consumption of non-durable good increases. With the shrinkage of the durable goods sector, the aggregate employment tends to decline. Facing a shrinking tax base, the Ramsey planner gradually raises the labor income tax rate to meet the exogenous stream of public expenditure.

**TABLE 2.**

Steady states

| Variable | $\delta = 0.001$ | $\delta = 0.01$ | $\delta = 0.025$ | $\delta = 0.05$ |
|---|---|---|---|---|
| $\tau$ | 0.2968 | 0.2960 | 0.2933 | 0.2922 |
| $R$ | 1.0101 | 1.0101 | 1.0101 | 1.0101 |
| $\Pi_c$ | 1 | 1 | 1 | 1 |
| $\Pi_d$ | 1 | 1 | 1 | 1 |
| $C$ | 0.2596 | 0.2459 | 0.2397 | 0.2364 |
| $D$ | 5.9047 | 3.0886 | 1.7247 | 0.9935 |
| $Y_d$ | 0.0059 | 0.0309 | 0.0431 | 0.0497 |
| $N$ | 0.3318 | 0.3459 | 0.3536 | 0.3576 |

### 3.3. Optimal fiscal and monetary policy

As summarized in Schmitt-Grohe and Uribe (2004) , there are two distinct branches of the extant literature on optimal monetary policy, which reach different conclusions. The first branch featuring flexible prices and perfect competition in product and factor markets, including Lucas and Stokey (1983) , Chari et al. (1991) , and Calvo and Guidotti (1993) , concludes that the inflation rate is highly volatile under the Ramsey policy. The reason is that the Ramsey planner uses the highly volatile inflation rate to tax financial wealth in a lump-sum fashion so that nominally risk-free debt becomes state contingent in real terms. In this way, the Ramsey planner can keep the distortionary labor income tax rate stable over the business cycle. The second branch featuring nominal stickiness and imperfect competition, including Erceg et al. (2000) , Gali and Monacelli (2005) , and Gali (2008) , find that the Ramsey planner keeps the inflation rate to zero to eliminate the inefficiency caused by inflation under nominal rigidities.

Generally, the second branch of the extant literature assumes that the government can levy lump-sum taxes to eliminate the distortions associated with imperfect competition. When the government has no access to lump-sum taxes, Schmitt-Grohe and Uribe (2004) ,and Chugh (2006) find that, when facing the costs introduced by nominal rigidities, the Ramsey planner chooses relatively low inflation volatility, thus optimal monetary policy requires price stability.

In this section, we analyze optimal fiscal and monetary policy based on a second-order approximation to the Ramsey planner's decision rules. We follow Schmitt-Grohe and Uribe (2004) ,and Chugh (2006) to compute the sample moments of key macroeconomic variables under the Ramsey policy. To be specific, we first conduct simulation to generate time series of length $T$ periods for the key macroeconomic variables in question and compute first and second moments. We conduct 500 simulations and then compute the average of the moments. To make a comparison with Schmitt-Grohe and Uribe (2004) ,and Chugh (2006) , we set the length of the simulation $T$ to 500.

#### *3.3.1. A comparison with Schmitt-Grohe and Uribe* (2004)

Table 3 displays the sample moments of the key policy variables in several cases. The top panel of Table 3 corresponds to the economy without durable goods, which is examined by Schmitt-Grohe and Uribe (2004), the second panel to the economy in which the prices of non-durable goods are sticky but those of durable goods are flexible, the third panel to the economy in which the prices of durable goods are sticky but those of non-durable goods are flexible, and the bottom panel to the economy in which the prices of both types of goods are sticky.

After we introduce durable goods into the model *à la* Schmitt-Grohe and Uribe (2004) , we find that, under the Ramsey policy, the labor income tax rate, the interest rate, and the inflation rate all become more volatile than before. Our findings flow from the fact the intertemporal elasticity of substitution of durable goods is much higher than that of non-durable goods. According to Barsky et al. (2007, 2016) , when the depreciation rate of durable goods is very low, the shadow value of durable goods is approxi-

**TABLE 3.**

Dynamic properties of the Ramsey allocation (linear approximation)

| Variable | Mean | Std.dev | Auto.corr | Corr$(x, A_c)$ | Corr$(x, A_d)$ | Corr$(x, G)$ |
|---|---|---|---|---|---|---|
| Economy with only non-durable goods | | | | | | |
| $\tau$ | 0.2727 | 0.6224 | 0.9663 | −0.1529 | - | 0.1774 |
| $\Pi_c$ | 1.0000 | 0.0277 | −0.0025 | −0.2676 | - | 0.3601 |
| $R$ | 0.0403 | 0.2938 | 0.6793 | −0.7921 | - | 0.0855 |
| $y_c$ | 0.3335 | 0.0062 | 0.8650 | 0.9146 | - | 0.3393 |
| $n$ | 0.3335 | 0.0025 | 0.8159 | −0.2296 | - | 0.8479 |
| $c$ | 0.2667 | 0.0063 | 0.8832 | 0.9059 | - | −0.3666 |
| Sticky non-durable prices, flexible durable prices | | | | | | |
| $\tau$ | 0.2912 | 0.7534 | 0.9856 | −0.1021 | 0.1999 | 0.0835 |
| $\Pi_c$ | 1.0000 | 0.0593 | −0.1295 | −0.1720 | 0.2163 | 0.1638 |
| $\Pi_d$ | 1.0005 | 3.2628 | 0.1055 | 0.0737 | −0.2561 | 0.0063 |
| $R$ | 0.0404 | 0.9385 | 0.3665 | −0.0793 | 0.5055 | −0.1623 |
| $q$ | 1.0001 | 7.9700 | 0.9076 | 0.2257 | −0.9646 | 0.0175 |
| $y_c$ | 0.3113 | 0.0103 | 0.8504 | 0.4445 | −0.6748 | 0.3416 |
| $y_d$ | 0.0440 | 0.0211 | 0.8283 | 0.0938 | 0.8635 | −0.1092 |
| $n$ | 0.3538 | 0.0099 | 0.8158 | −0.0362 | 0.7822 | 0.1352 |
| $c$ | 0.2404 | 0.0097 | 0.8700 | 0.4778 | −0.7127 | −0.1160 |
| Flexible non-durable prices, sticky durable prices | | | | | | |
| $\tau$ | 0.2867 | 0.8583 | 0.9373 | −0.0347 | −0.2493 | 0.1659 |
| $\Pi_c$ | 1.0009 | 3.6008 | −0.0270 | −0.0789 | 0.2232 | 0.0134 |
| $\Pi_d$ | 1.0002 | 0.0827 | 0.6969 | −0.1110 | −0.4719 | 0.4156 |
| $R$ | 0.0405 | 0.2243 | 0.9770 | −0.0395 | −0.5579 | 0.1513 |
| $q$ | 0.9999 | 8.0111 | 0.8901 | 0.2473 | −0.9650 | −0.0130 |
| $y_c$ | 0.3120 | 0.0104 | 0.8430 | 0.4716 | −0.6557 | 0.2927 |
| $y_d$ | 0.0442 | 0.0213 | 0.8132 | 0.0224 | 0.8730 | −0.0904 |
| $n$ | 0.3547 | 0.0099 | 0.8032 | −0.0420 | 0.8290 | 0.1251 |
| $c$ | 0.2411 | 0.0101 | 0.8435 | 0.4946 | −0.6762 | −0.1608 |
| Sticky non-durable prices, sticky durable prices | | | | | | |
| $\tau$ | 0.2932 | 2.2681 | 0.6635 | 0.1490 | −0.6054 | 0.0619 |
| $\Pi_c$ | 1.0001 | 0.1252 | 0.6329 | −0.1883 | 0.4914 | 0.0871 |
| $\Pi_d$ | 1.0002 | 0.8601 | 0.6494 | 0.1383 | −0.5256 | 0.0092 |
| $R$ | 0.0408 | 0.5013 | 0.6091 | 0.0798 | −0.5118 | 0.0165 |
| $q$ | 0.9999 | 5.3356 | 0.9792 | 0.1884 | −0.8613 | 0.0011 |
| $y_c$ | 0.3106 | 0.0061 | 0.9054 | 0.5193 | 0.2719 | 0.5283 |
| $y_d$ | 0.0441 | 0.0148 | 0.8802 | 0.1509 | 0.8860 | −0.1412 |
| $n$ | 0.3536 | 0.0098 | 0.8047 | −0.0381 | 0.8164 | 0.1303 |
| $c$ | 0.2397 | 0.0054 | 0.9287 | 0.6073 | −0.3060 | −0.2622 |

mately unchanged, which implies that the households are nearly indifferent to when to purchase durable goods, thus, the intertemporal elasticity of substitution of durable goods is nearly infinite. By comparison, the households tend to smooth non-durable goods consumption by the logic of the permanent income hypothesis, which leads to a much lower intertemporal elasticity of substitution.

Due to the presence of the price stickiness, the relative price plays a crucial role in allocating resources when there are two sectors in the economy. Intuitively, when a positive productivity shock occurs in one sector, the relative price needs to adjust so that the households purchase more goods produced in the sector hit by the shock. Simultaneously, labor moves between sectors to clear labor market. However, the adjustment of the relative price incurs the costs associated with the inflation under price stickiness. Thus, the Ramsey planner faces a trade-off between the need to allow the fluctuation in the relative price to reduce distortions in resource allocations, and the desire to achieve the price stability to reduce the costs associated with inflation under price stickiness. The trade-off facing the Ramsey planner can be seen from the comparison of the bottom panel with the second panel and the third panel, respectively. In the second and third panels, in which one sector incurs no cost to adjust the price, the Ramsey planner increases the volatility of the flexible-price inflation rate so that the relative price can fluctuate more strongly in response to the shocks to achieve efficient resource allocations. As a result, the distortionary tax rate fluctuates less strongly to facilitate tax smoothing in both panels.

In addition, the greater volatility of the flexible-price inflation rate in the second and third panels also reveals that the Ramsey planner has the incentive to use the inflation volatility to achieve a state-contingent lump-sum tax or wealth transfer when price changes cause no costs. In this way, the Ramsey planner can avoid the changes in the distortionary tax rate to facilitate tax smoothing. The comparison of the bottom panel with the second and third panels confirms the point.

Since the intertemporal elasticity of substitution of durable goods is much higher than that of non-durable goods, the Ramsey planner can achieve the intertemporal substitution of durable goods more easily than that of non-durable goods by changing the interest rate. Thus, comparing with Schmitt-Grohe and Uribe (2004), the Ramsey planner increases the volatility of the interest rate in our model to achieve efficient resource allocations dynamically. In addition, the Ramsey planner needs to adjust the relative price to achieve intratemporal resource allocations efficiently. Despite the fact that the adjustment of non-durable goods prices comes with a cost, the Ramsey planner raises the volatility of the inflation rate of non-durable goods when we compare it with that in Schmitt-Grohe and Uribe (2004) .

As in Schmitt-Grohe and Uribe (2004) , the labor income tax rate introduces a wedge between the real wage and the marginal rate of substitution between consumption and labor supply. Though the distortionary taxation is a source of welfare loss, it also serves as a tool for the Ramsey planner to adjust the relative price of labor in terms of consumption. The introduction of the durable-goods sector poses a challenge for the Ramsey planner to achieve efficient resource allocations, despite that the interest rate and the inflation rate become more volatile than in Schmitt-Grohe and Uribe (2004) , the Ramsey planner still has the incentive to increase the volatility of the labor tax rate to adjust the intratemporal allocation of consumption and employment in spite of incurring higher welfare loss.

Figure 1 presents a graphic comparison of our baseline model with Schmitt-Grohe and Uribe (2004) ,in Figure 1, N-D stands for non-durable and SGU for Schmitt-Grohe and Uribe. It is evident that the labor income tax rate, the interest rate, and the inflation rate all exhibit greater volatilities after we introduce durable goods into Schmitt-Grohe and Uribe (2004) .

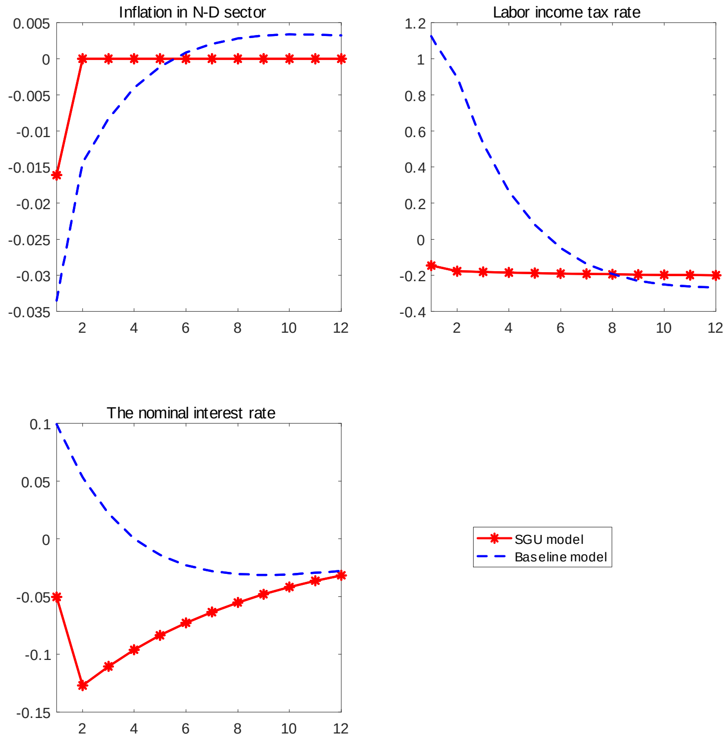
*3.3.2. The effects of the depreciation rate on optimal fiscal and monetary policy*

To distinguish policy prescriptions of our model from those in a two-sector model without durable goods, we set the depreciation rate to unity, which corresponds to the two-sector model without durable goods, and compare the policy prescriptions in this case with those in our model, in which the depreciation rate is between zero and one. In addition, we also examine optimal fiscal and monetary policy when the depreciation rate approaches zero, which corresponds to the *idealized durable* case discussed by Barsky et al. (2007, 2016) .

Table 4 shows the sample moments of the key policy variables for different values of the depreciation rate. The top panel of Table 4 corresponds to the *idealized durable* case approximately, the second and third panels to the two-sector model with durable goods, the bottom panel to the two-sector model without durable goods.

In comparison with the two-sector model without durable goods, the labor income tax rate and the interest rate exhibit greater volatility. As the depreciation rate decreases, this conclusion also holds for the two-sector model with durable goods. The conclusion depends on the property of durable goods, i.e., their intertemporal elasticity of substitution is much higher than that of non-durable goods.

**FIG. 1.** A comparison with Schitt-Grohe and Uribe (2004).




No matter whether there are durable goods or not, the Ramsey planner needs to adjust the relative price to reduce distortions in resource allocations when there are two sectors. The inspection of Table 4 confirms this point, the difference in volatilities of the relative price is small for all depreciation rates. In this way, the Ramsey planner can keep the inflation rates in both sectors stable thus avoid incurring the costs associated with high volatility of the inflation under price stickiness. However, it is worth noticing that when the durable goods nearly tend to be the *idealized durable,* the volatility of the inflation in the durable-goods sector rises but its counterpart in the non-durable goods sector falls. The reason is that, with households' purchases of new durable good being very small, a rise in the volatility of the inflation in the durable-goods sector, together with a fall in the volatility of the inflation in the non-durable goods sector, not only can keep the relative price relatively stable but also can reduce the costs caused by adjusting prices in the non-durable goods sector while incurring a small welfare loss in the durable-goods sector.

Except for the relative price, the Ramsey planner has another policy tool to improve resource allocation efficiency between two sectors in the two-sector model with durable goods, i.e. the interest rate. In general, the changes in the interest rate will influence intratemporal resource allocations. Due to the intertemporal elasticity of substitution of durable goods being much higher than that of non-durable goods, the Ramsey planner can adjust the interest rate to generate asymmetric effects on durable and non-durable goods dynamically, whereas this cannot happen in the two-sector model without durable goods. Thus, in comparison with the two-sector model with non-durable goods, the Ramsey planner increases the volatility of the interest rate to dynamically improve resource allocation efficiency in the two-sector model with durable goods. The smaller the depreciation rate is, the greater the effects of the changes in the interest rate on durable goods are, thus the Ramsey planner has a strong motive to raise the volatility of the interest rate when durable goods become more durable.

**TABLE 4.**

The effects of the depreciation rate on optimal fiscal and monetary policy

| Variable | Mean | Std.dev | Auto.corr | Corr$(x, A_c)$ | Corr$(x, A_d)$ | Corr$(x, G)$ |
|---|---|---|---|---|---|---|
| | | | $\delta = 0.001$ | | | |
| $\tau$ | 0.2838 | 4.9653 | 0.4529 | 0.1039 | −0.1017 | 0.0300 |
| $\Pi_c$ | 1.0004 | 0.2991 | 0.0277 | −0.0329 | 0.0410 | 0.0349 |
| $\Pi_d$ | 1.0005 | 1.0149 | 0.6093 | 0.1312 | −0.4997 | 0.0081 |
| $R$ | 0.0422 | 0.6647 | 0.6637 | 0.0886 | −0.3663 | 0.0009 |
| $Q$ | 0.8922 | 5.4609 | 0.9779 | 0.1833 | −0.8456 | 0.0006 |
| $Y_c$ | 0.3288 | 0.0105 | 0.9615 | 0.2790 | −0.6590 | 0.3380 |
| $Y_d$ | 0.0069 | 0.0249 | 0.8820 | 0.1221 | 0.8599 | −0.1286 |
| $N$ | 0.3341 | 0.0168 | 0.7881 | −0.0101 | 0.8281 | 0.0279 |
| $C$ | 0.2623 | 0.0099 | 0.9741 | 0.3025 | −0.6984 | −0.0833 |
| | | | $\delta = 0.01$ | | | |
| $\tau$ | 0.2982 | 2.4985 | 0.6857 | 0.1641 | −0.6507 | 0.0588 |
| $\Pi_c$ | 1.0002 | 0.1050 | 0.5887 | 0.1838 | 0.4510 | 0.1068 |
| $\Pi_d$ | 1.0002 | 0.8893 | 0.6525 | 0.1387 | −0.5247 | 0.0093 |
| $R$ | 0.0412 | 0.5608 | 0.6319 | 0.0903 | −0.4235 | 0.0048 |
| $Q$ | 0.9833 | 5.3384 | 0.9792 | 0.1881 | −0.8611 | 0.0011 |
| $Y_c$ | 0.3149 | 0.0077 | 0.9428 | 0.3888 | −0.5173 | 0.4473 |
| $Y_d$ | 0.0319 | 0.0196 | 0.9037 | 0.1337 | 0.8926 | −0.1363 |
| $N$ | 0.3454 | 0.0125 | 0.8399 | −0.0217 | 0.8761 | 0.0696 |
| $C$ | 0.2456 | 0.0069 | 0.9642 | 0.4405 | −0.5706 | −0.1605 |

**TABLE 4**—*Continued*

| Variable | Mean | Std.dev | Auto.corr | Corr$(x, A_c)$ | Corr$(x, A_d)$ | Corr$(x, G)$ |
|---|---|---|---|---|---|---|
| | | | $\delta = 0.05$ | | | |
| $\tau$ | 0.2924 | 2.0080 | 0.6291 | 0.1282 | −0.5562 | 0.0671 |
| $\Pi_c$ | 1.0001 | 0.1360 | 0.6488 | −0.1943 | 0.4993 | 0.0822 |
| $\Pi_d$ | 1.0001 | 0.8461 | 0.6469 | 0.1372 | −0.5265 | 0.0097 |
| $R$ | 0.0404 | 0.4525 | 0.6053 | 0.0496 | −0.6114 | 0.0344 |
| $Q$ | 0.9950 | 5.3347 | 0.9792 | 0.1885 | −0.8613 | 0.0011 |
| $Y_c$ | 0.3079 | 0.0056 | 0.8696 | 0.6187 | −0.0087 | 0.5463 |
| $Y_d$ | 0.0504 | 0.0104 | 0.8473 | 0.1744 | 0.8911 | −0.1488 |
| $N$ | 0.3577 | 0.0072 | 0.7550 | −0.0654 | 0.7375 | 0.2245 |
| $C$ | 0.2363 | 0.0049 | 0.8882 | 0.7161 | −0.0047 | −0.3349 |
| | | | $\delta = 1$ | | | |
| $\tau$ | 0.2987 | 0.7509 | 0.8647 | −0.0237 | −0.2003 | 0.0706 |
| $\Pi_c$ | 0.9999 | 0.1562 | 0.6466 | −0.2166 | 0.4947 | 0.0745 |
| $\Pi_d$ | 1.0000 | 0.8258 | 0.6454 | 0.1316 | −0.5280 | 0.0106 |
| $R$ | 0.0399 | 0.3813 | 0.3243 | −0.3431 | −0.2946 | −0.0557 |
| $Q$ | 1.0001 | 5.3337 | 0.9792 | 0.1886 | −0.8614 | 0.0011 |
| $Y_c$ | 0.3035 | 0.0057 | 0.8597 | 0.7611 | 0.2507 | 0.4833 |
| $Y_d$ | 0.0581 | 0.0034 | 0.9617 | 0.1536 | 0.9013 | −0.1456 |
| $N$ | 0.3613 | 0.0031 | 0.7160 | −0.2518 | −0.0009 | 0.7833 |
| $C$ | 0.2311 | 0.0054 | 0.9013 | 0.8268 | 0.2703 | −0.3665 |

Though the mean values of the labor income tax rate remain stable when the depreciation rate decreases, the volatility of the labor income tax rate becomes greater. In general, the labor income tax rate changes the relative price between employment and consumption thus can be used as a tool to achieve efficient resource allocations. Due to the fact that the intertemporal elasticity of substitution of durable goods is much higher than that of non-durable goods, the Ramsey planner needs a greater employment volatility to achieve efficient resource allocation across sectors intratemporally and intertemporally. Thus, the labor income tax rate exhibits greater volatility in the two-sector model with durable goods. The smaller is the depreciation rate, the larger is the intertemporal elasticity of substitution of durable goods, and the Ramsey planner has a stronger incentive to raise the volatility of the labor income tax rate to increase the employment volatility.

## 4. CONCLUSION

In this paper, we introduce durable goods into Schmitt-Grohe and Uribe (2004) to study optimal fiscal and monetary policy. Comparing with Schmitt-Grohe and Uribe (2004) , the Ramsey planner requires the labor income tax rate, the interest rate, and the inflation rate to be more volatile. The conclusion flows from a key feature of durable goods: their intertemporal elasticity of substitution of durable goods is much higher than that of non-durable goods. In a two-sector model, the relative price plays a central role in achieving efficient resource allocations, thus the Ramsey planner raises the non-durable goods inflation volatility to change the relative price in spite of the fact that higher inflation volatility in the non-durable goods sector incurs costs related to price adjustment.

Since the Ramsey planner can achieve the intertemporal substitution of durable goods more easily than that of non-durable goods by changing the interest rate, thus it is rational to increase the volatility of the interest rate to achieve efficient resource allocations dynamically. Though the labor income tax is distortionary, the Ramsey planner can use it as a tool to adjust the relative price of labor in terms of consumption, thus has the incentive to increase its volatility to adjust the intratemporal allocation of consumption and employment. In addition, we also find that, as the depreciation rate decreases, the labor income tax rate and the interest rate exhibit greater volatility.

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