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WITH DURABLE AND NON-DURABLE GOODS

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Abstract

The durable goods sector is much more interest sensitive than the non-durables sector, and these sectoral differences have important implications for monetary policy. In this paper, we perform VAR analysis of quarterly US data and find that a monetary policy innovation has a peak impact on durable expenditures that is roughly five times as large as its impact on non-durable expenditures. We then proceed to formulate and calibrate a two-sector dynamic general equilibrium model that roughly matches the impulse response functions of the data. While the social welfare function involves sector-specific output gaps and inflation rates, we find that performance of the optimal policy rule can be closely approximated by a very simple rule that targets a weighted average of aggregate wage and price inflation rates. In contrast, some commonly-prescribed policy rules (such as strict price inflation targeting and Taylor's rule) perform very poorly in terms of social welfare.

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Non-Technical Summary

It has long been recognized that the effects of monetary policy actions differ substantially across sectors of the economy. However, while there is a growing literature investigating the normative performance of alternative monetary policy rules, attention has mainly focused on models with a single productive sector. It remains an open question whether *any* rule in which monetary policy responds only to aggregate variables would perform well in an environment with pronounced structural differences across economic sectors.

We investigate this question within the context of a model with two productive sectors, a durable and nondurable goods sector. We calibrate the structural parameters of the model so that the interest sensitivity of each sector roughly matches the responses derived from an empirical vector autoregression; thus, output in the durable goods sector is about five times as interest-sensitive as in the nondurables sector. Our model incorporates nominal price and wage rigidities in each sector, so that the monetary policymaker faces a nontrivial stabilization problem. Within our simple framework, we show that a quadratic approximation to the social welfare function depends on the volatility of the output gaps and the relative wages and prices in each sector. Using this welfare function, we derive the optimal monetary policy reaction function under the assumption that the policymaker can make a credible commitment to a specific rule. As might be expected, this optimal reaction function involves responding to sector-specific variables.

We find that certain commonly-prescribed aggregate policy rules (including strict price inflation targeting and Taylor's Rule) perform very poorly in terms of social welfare, because these rules generate relatively high volatility in sectoral output gaps, especially in the interest-sensitive sector. Given that the social welfare function involves sector-specific variables, one might expect to obtain relatively poor welfare outcomes from *any* policy rule that responds solely to aggregate variables. In fact, however, we find that targeting a weighted average of aggregate wage and price inflation rates performs remarkably well. Although this policy does not smooth output variability in the durable goods sector quite as much as the optimal rule, it succeeds it keeping sectoral output gap dispersion reasonably low given the observed distribution of shocks. Interestingly, while this hybrid rule effectively stabilizes the aggregate output gap and hence could in principle be achieved through targeting the output gap directly, the hybrid rule does not require knowledge of the level of potential output.

1   Introduction

In past decades, macroeconomists were acutely aware of the extent to which the effects of monetary policy differ widely across sectors of the economy.[1] These differences were particularly evident during the U.S. disinflationary episode of 1981-82, when high real interest rates induced dramatic declines in auto sales and residential construction. However, more recent studies of optimal monetary policy and simple policy rules have focused almost exclusively on models with a single production sector.[2]

In this paper, we document that the durable goods sector is indeed much more interest-sensitive than the non-durables sector, and we demonstrate that these sectoral differences have important implications for monetary policy. In particular, we perform vector autoregression (VAR) analysis of quarterly U.S. output and price data, disaggregated into durable and non-durable expenditures. Under fairly standard identifying assumptions, we find that a monetary policy innovation has a peak impact on durable expenditures that is roughly five times as large as its impact on non-durable expenditures.

Next, we formulate and calibrate a two-sector dynamic general equilibrium model that roughly matches the empirical impulse response functions associated with a monetary innovation. Our model incorporates nominal price and wage rigidities in each sector, so that the monetary policymaker faces a nontrivial stabilization problem For this model, social welfare can be expressed in terms of the unconditional variances of the sectoral output gaps and relative wages and prices in each sector. Using this welfare function, we obtain the optimal monetary policy rule under full commitment, and characterize its prescriptions in response to aggregate and sector-specific shocks.

Finally, we consider the performance of simple monetary policy rules. We find that certain commonly-prescribed policy rules (including strict price inflation targeting and Taylor's Rule) perform very poorly in terms of social welfare, because these rules generate relatively high volatility in sectoral output gaps, especially in the interest-sensitive sector. Given that the social welfare function involves sector-specific variables, one might expect to obtain relatively poor welfare outcomes from any policy rule that responds solely to aggregate variables. In fact, however, we find that targeting a weighted average of aggregate wage and price inflation rates performs remarkably well. In particular, just as with the optimal policy rule, this simple wage-price targeting rule avoids large cross-sectoral divergences in output gaps and inflation rates.

The remainder of this paper is organized as follows: Section 2 considers the empirical evidence on sectoral responses to monetary policy shocks. Section 3 outlines the dynamic general equilibrium model, and Section 4 describes the solution method and parameter calibration. Section 5 analyzes the properties of the baseline model.

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[1] Notable examples include Hamburger 1967; Parks 1974; Mishkin 1976; Mankiw 1985; Gali 1993; Baxter 1996.

[2] For example, Rotemberg and Woodford (1997) consider an economy with a continuum of producers that manufacture differentiated non-durable goods; see also Goodfriend and King (1997), King and Wolman (1999), Erceg et al. (2000); Fuhrer (2000). Notable exceptions include Aoki (2001) and Benigno (2001).

Section 6 considers the welfare function.   Section 7 characterizes optimal monetary policy and evaluates the performance of alternative policy rules.   Section 8 concludes.

2   Empirical Evidence

A large literature has utilized identified VARs to measure the response of aggregate output and prices to a monetary policy shock (cf. Sims 1980; Christiano, Eichenbaum, and Evans 1995).   For example, one commonly-used specification is to analyze a 4-variable VAR involving real GDP, the GDP price index, an index of commodity prices, and the federal funds rate, and to identify the monetary policy shock using a Cholesky decomposition.   Here we follow this approach to investigate the extent to which a shock has differential effects on output in the durable and non-durable sectors of the economy.

   We start by considering five expenditure components of chain-weighted real GDP: consumer durables, residential structures, business equipment, business structures, and all other goods and services.   We specify an 8-variable VAR that involves the logarithms of these five variables as well as the logarithm of the GDP price index, the logarithm of the IMF commodity price index, and the level of the federal funds rate.   The VAR includes 4 lags of each variable, and is estimated using OLS over the period 1960:1 to 2001:4.   Using a Cholesky decomposition (ordering the variables as listed above), we compute the response of these variables to a one-standard-deviation innovation to the federal funds rate.   Finally, Monte Carlo simulations are used to obtain 95 percent confidence bands for each impulse response function (IRF).

   As shown in Figure 1, these IRFs indicate that durable expenditures are much more interest-sensitive than non-durable expenditures.   In particular, the monetary policy shock induces an initial rise of about 75 basis points in the federal funds rate; this increase is largely reversed within the next several quarters.   Non-durable spending exhibits a peak response of about 0.2 percent to this shock; given that non-durables account for about three-quarters of nominal GDP, it is not too surprising that the magnitude of this response is roughly similar to that obtained for total GDP in a typical 4-variable VAR.   In contrast, the peak response is roughly five times larger for consumer durables, business equipment, and business structures, and is about ten times larger for residential investment.   (These components account for 8, 7, 4, and 4 percent of GDP, respectively.)   It is also interesting to note the differences in timing of the peak response, which occurs within the first year for non-durables, consumer durables, and residential investment, but takes about twice as long for business equipment and structures.

   In the subsequent analysis, we will formulate a two-sector model that abstracts from endogenous capital accumulation and focuses on the behavior of durable expenditures that contribute directly to household utility.   To analyze the empirical analogues of these two components of aggregate output, we now disaggregate real GDP into only two types of expenditures: a chain-weighted index of consumer durables and residential investment, and a chain-weighted composite of all other expenditures (including business fixed investment).   Since our analytic work will consider sector-

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specific price dynamics, we also construct a chain-weighted price index for each type of expenditure. Now we proceed to estimate a 6-variable VAR involving the two expenditure variables and the corresponding price indices as well as the IMF commodity price index and the federal funds rate. We compute IRFs using this order for the variables in the Cholesky decomposition, and then construct bootstrapped confidence intervals via Monte Carlo simulation.

As shown in Figure 2, the composite of consumer durables and residential investment spending exhibits a peak response of about 1.25 percent, compared with a peak response of about 0.2 percent for all other expenditures. As shown below, we calibrate the parameters of the model to roughly match the magnitudes of these responses. Finally, it is interesting to note that the price responses for these two categories of expenditures are quite similar despite the differences in quantity responses, suggesting the importance of short-run nominal inertia.

3 The Model

3.1 Firms and Price Setting

Henceforth we use the subscript m to refer to the sector that produces durable goods ("manufacturing"), while the subscript s refers to the sector that produces non-durables ("services"). Within each sector, a continuum of monopolistically competitive firms (indexed on the unit interval) fabricate differentiated products $Y_{jt}(f)$ for $j \in \{m, s\}$ and $f \in [0, 1]$. Because households have identical Dixit-Stiglitz preferences, it is convenient to assume that a representative aggregator combines the differentiated products of each sector into a single sectoral output index Y_{jt}:

$$Y_{jt} = \left[\int_0^1 Y_{jt}(f)^{\frac{1}{1+\theta_{pj}}} df \right]^{1+\theta_{pj}} \tag{1}$$

where $\theta_{pj} > 0$. The aggregator chooses the bundle of goods that minimizes the cost of fabricating a given quantity of the sectoral output index Y_{jt}, taking the price $P_{jt}(f)$ of each good $Y_{jt}(f)$ as given. The aggregator sells units of each sectoral output index at its unit cost P_{jt}:

$$P_{jt} = \left[\int_0^1 P_{jt}(f)^{\frac{-1}{\theta_{pj}}} df \right]^{-\theta_{pj}} \tag{2}$$

It is natural to interpret P_{jt} as the sectoral price index. Given the relative size λ_m of the manufacturing sector, the aggregate price index P_t (also referred to as the GDP price deflator) is defined as:

$$P_t = P_{mt}^{\lambda_m} P_{st}^{1-\lambda_m} \tag{3}$$

The aggregator's demand for each good $Y_{jt}(f)$–or equivalently total household demand for this good – is given by

$$Y_{jt}(f) = \left[\frac{P_{jt}(f)}{P_{jt}} \right]^{\frac{-\left(1+\theta_{pj}\right)}{\theta_{pj}}} Y_{jt} \tag{4}$$

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for $j \in \{m, s\}$ and $f \in [0, 1]$.

Each differentiated good is produced by a single firm that hires capital services $K_{jt}(f)$ and a labor index $L_{jt}(f)$ defined below. All firms within each sector face the same Cobb-Douglas production function, with an identical level of total factor productivity A_{jt}:

$$Y_{jt}(f) = A_{jt}K_{jt}(f)^{\alpha_j}L_{jt}(f)^{1-\alpha_j} \tag{5}$$

Capital and labor are perfectly mobile across the firms within each sector, but cannot be moved between sectors. Furthermore, each sector's total capital stock is fixed at $\bar{K}_j$. Each firm chooses $K_{jt}(f)$ and $L_{jt}(f)$, taking as given the sectoral rental price of capital P_{jt}^k and the sectoral wage index W_{jt} defined below. The standard static first-order conditions for cost minimization imply that all firms within each sector have identical marginal costs per unit of output (MC_{jt}), which can be expressed as a function of the sectoral labor index L_{jt}, as well as the sectoral wage index, capital stock, and total factor productivity:

$$MC_{jt} = \frac{W_{jt}L_{jt}^{\alpha_j}}{(1-\alpha_j)A_{jt}\bar{K}_j^{\alpha_j}} \tag{6}$$

Note that real marginal cost (deflated by the sectoral price index) can be equivalently expressed as the ratio of the sectoral real wage to the marginal product of labor:

$$\frac{MC_{jt}}{P_{jt}} = \frac{\frac{W_{jt}}{P_{jt}}}{MPL_{jt}} \tag{7}$$

$$MPL_{jt} = (1-\alpha_j)A_{jt}\bar{K}^{\alpha_j}L_{jt}^{-\alpha_j} \tag{8}$$

We assume that the prices of intermediate goods are determined by staggered nominal contracts of fixed duration (as in Taylor, 1980). Each price contract lasts four quarters, and one-fourth of the firms in each sector reset their prices in a given period. Thus, individual producers may be indexed so that every firm with index $f \in [0, 0.25]$ resets its contract price $P_{jt}(f)$ whenever the date is evenly divisible by 4; similarly, firms with index $f \in [0.25, 0.5]$ set prices during periods in which mod(t,4) =1, and so forth. Whenever the firm is not allowed to reset its contract, the firm's price is automatically increased at the unconditional mean rate of gross inflation, Π. Thus, if firm f in sector j has not adjusted its contract price since period t, then its price i periods later is given by $P_{j,t+i}(f) = P_{jt}(f)\Pi^i$.

When a firm is allowed to reset its price in period t, the firm maximizes the following profit functional with respect to its contract price, $P_{jt}(f)$:

$$\mathcal{E}_t \sum_{i=0}^{3} \psi_{t,t+i}((1+\tau_{pj})\Pi^i P_{jt}(f)Y_{j,t+i}(f) - MC_{j,t+i}Y_{j,t+i}(f)) \tag{9}$$

The operator $\mathcal{E}_t$ represents the conditional expectation based on information through period t and taken over states of nature in which the firm is not allowed to reset its

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price. The firm's output is subsidized at a fixed rate τ_{pj}. The firm discounts profits received at date $t + i$ by the state-contingent discount factor $\psi_{t,t+i}$; for notational simplicity, we have suppressed all of the state indices from this expression. Let $\gamma_{t,t+i}$ denote the price in period t of a claim that pays one dollar if the specified state occurs in period $t + i$; then the corresponding element of $\psi_{t,t+i}$ is given by $\gamma_{t,t+i}$ divided by the probability that the specified state will occur.

By differentiating this profit functional with respect to $P_{jt}(f)$, we obtain the following first-order condition:

$$\mathcal{E}_t \sum_{i=0}^{3} \psi_{t,t+i} \left[(1 + \tau_{pj}) \Pi^i P_{jt}(f) - (1 + \theta_{pj}) MC_{j,t+i} \right] Y_{j,t+i}(f) = 0 \qquad (10)$$

Thus, the firm sets its price so that the sum of its expected discounted nominal revenue (inclusive of subsidies) is equal to the price markup factor $(1 + \theta_{pj})$ multiplied by the sum of discounted nominal costs. We assume that production is subsidized to eliminate the monopolistic distortion in each sector; that is, $\tau_{pj} = \theta_{pj}$ for $j \in \{m, s\}$. Thus, in the steady state of the model, prices are equated to marginal cost in each sector, or equivalently, the sectoral marginal product of labor is equal to the sectoral real wage, as in a perfectly competitive economy.

3.2 Households and Wage Setting

We assume that a continuum of households is indexed on the unit interval, and each household supplies differentiated labor services. Within every household, a fixed number of members ν_m work exclusively in the manufacturing sector, while the remaining ν_s members work exclusively in the service sector. All members of a given household $h \in [0, 1]$ who work in a given sector $j \in \{m, s\}$ have the same wage rate $W_{jt}(h)$ and supply the same number of hours $N_{jt}(h)$. As in the firm's problem described above, it is convenient to assume that a representative labor aggregator (or "employment agency") combines individual labor hours into a sectoral labor index L_{jt} using the same proportions that firms would choose:

$$L_{jt} = \nu_j \left[\int_0^1 N_{jt}(h)^{\frac{1}{1+\theta_{wj}}} dh \right]^{1+\theta_{wj}} \qquad (11)$$

where $\theta_{wj} > 0$. The aggregator minimizes the cost of producing a given amount of the aggregate labor index, taking the wage rate $W_{jt}(h)$ for each household member as given, and then sells units of the labor index to the production sector at unit cost W_{jt}:

$$W_{jt} = \left[\int_0^1 W_{jt}(h)^{\frac{-1}{\theta_{wj}}} dh \right]^{-\theta_{wj}} \qquad (12)$$

It is natural to interpret W_{jt} as the sectoral wage index. The aggregator's demand for the labor hours of household h – or equivalently, the total demand for this household's labor by all goods-producing firms – is given by

$$\nu_j N_{jt}(h) = \left[\frac{W_{jt}(h)}{W_{jt}} \right]^{-\frac{1+\theta_{wj}}{\theta_{wj}}} L_{jt} \qquad (13)$$

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In each period, the household purchases $Y_{mt}(h)$ units of durable goods at price P_{mt}, and $C_t(h)$ units of services at price P_{st}. To generate a source of demand for money, we assume that services must be purchased using cash balances, while durable goods can be purchased using credit. The household's stock of durable goods $D_t(h)$ evolves as follows:

$$D_{t+1}(h) = (1 - \delta) D_t(h) + Y_{mt}(h) \tag{14}$$

where the depreciation rate δ satisfies the condition $0 < \delta \leq 1$.

The household's expected lifetime utility is given by

$$\mathcal{E}_t \sum_{i=0}^{\infty} \beta^i \mathbb{W}_{t+i}(h) \tag{15}$$

The operator $\mathcal{E}_t$ here represents the conditional expectation over all states of nature, and the discount factor β satisfies $0 < \beta < 1$. The period utility function $\mathbb{W}_t(h)$ is additively separable with respect to the household's durables stock $D_t(h)$, its services consumption $C_t(h)$, the leisure of each household member, and the household's nominal money balances $M_t(h)$ deflated by the aggregate price index P_{st}:

$$\mathbb{W}_t(h) = \mathbb{U}\left(\breve{D}_t(h)\right) + \mathbb{S}(C_t(h)) + \mathbb{V}(N_{mt}(h)) + \mathbb{Z}(N_{st}(h)) + \mathbb{M}\left(\frac{M_t(h)}{P_{st}}\right) \tag{16}$$

In particular, the household receives period utility $\mathbb{U}(\widetilde{D}_t(h))$ from its current durables stock net of adjustment costs, $\widetilde{D}_t(h)$:

$$\mathbb{U}\left(\widetilde{D}_t(h)\right) = \frac{\left[\widetilde{D}_t(h)\right]^{1-\sigma_m}}{1 - \sigma_m} \tag{17}$$

where

$$\widetilde{D}_t(h) = D_t(h) - 0.5\phi \frac{(Y_{mt}(h) - \delta D_t(h))^2}{D_t(h)} \tag{18}$$

and the parameters $\sigma_m > 0$ and $\phi \geq 0$. The remaining components of period utility are given as follows:

$$\mathbb{S}(C_t(h)) = s_o \frac{[C_t(h)]^{1-\sigma_s}}{1 - \sigma_s} \tag{19}$$

$$\mathbb{V}(N_{mt}(h)) = v_m \frac{[1 - N_{mt}(h)]^{1-\chi_m}}{1 - \chi_m} \tag{20}$$

$$\mathbb{Z}(N_{st}(h)) = v_s \frac{[1 - N_{st}(h)]^{1-\chi_s}}{1 - \chi_s} \tag{21}$$

$$\mathbb{M}\left(\frac{M_t(h)}{P_{st}}\right) = \frac{\mu_0}{1 - \mu}\left(\frac{M_t(h)}{P_{st}}\right)^{1-\mu} \tag{22}$$

where the parameters s_o, σ_s, χ_m, χ_s, μ, and μ_0 are all strictly positive. We will utilize $\mathbb{U}'_t(h)$ to denote the derivative of $\mathbb{U}\left(\widetilde{D}_t(h)\right)$ with respect to $\widetilde{D}_t(h)$, along with similar

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notation for the derivatives of each of the other components of the household's period utility.

Household h's budget constraint in period t states that consumption expenditures plus asset accumulation must equal disposable income:

$$P_{mt}Y_{mt}(h) + P_{st}C_{st}(h)$$

$$+M_{t+1}(h) - M_t(h) + \int \gamma_{t,t+1}B_{t+1}(h) - B_t(h)$$

$$= \nu_m(1+\tau_{wm})W_{mt}(h)N_{mt}(h) + \nu_s(1+\tau_{ws})W_{st}(h)N_{st}(h)$$

$$+\Gamma_{mt}(h) + \Gamma_{st}(h) - T_t(h)$$

(23)

Financial asset accumulation consists of increases in money holdings and the net acquisition of state-contingent claims. As noted above, $\gamma_{t,t+1}$ represents the price of an asset that will pay one unit of currency in a particular state of nature in the subsequent period, while $B_{t+1}(h)$ represents the quantity of such claims purchased by the household at time t. Total expenditure on new state-contingent claims is given by integrating over all states at time $t+1$, while $B_t(h)$ indicates the value of the household's existing claims given the realized state of nature. Labor income in each sector is subsidized at a fixed rate τ_{wj}. Each household owns an equal share of all firms and of the aggregate capital stock, and receives an aliquot share $\Gamma_{jt}(h)$ of each sector's profits and rental income.[3] Finally, each household pays a lump-sum tax $T_t(h)$ to the government.

Nominal wage rates are determined by staggered fixed duration contracts, under assumptions symmetric to those stated earlier for price contracts. In particular, the duration of the wage contract of each household member is four quarters. Whenever the household is not allowed to reset the wage contract, the wage rate is automatically increased at the unconditional mean rate of gross inflation, Π. Thus, if the wage contract of the household member has not been adjusted since period t, then the wage rate i periods later is given by $W_{j,t+i}(h) = W_{jt}(h)\Pi^i$.

In every period t, each household h maximizes its expected lifetime utility with respect to its choice of consumption, its holdings of money, and its holdings of contingent claims: subject to the demand for its labor, equation (13), and its budget constraint, equation (23).

The first-order conditions for services consumption and holdings of state-contingent claims imply the familiar "consumption Euler equation" linking the marginal cost of foregoing a unit of services consumption in the current period to the expected marginal benefit in the following period:

$$\mathbb{S}'_t = \mathcal{E}_t\left[\beta(1+R_{st})\mathbb{S}'_{t+1}\right] = \mathcal{E}_t\left[\beta(1+I_t)\frac{P_{st}}{P_{st+1}}\mathbb{S}'_{t+1}\right]$$

(24)

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[3]Thus, sectoral profits $\Gamma_{jt}(h)$ are determined by the following identity:

$$\int_0^1 \Gamma_{jt}(h)\,dh = \int_0^1 [(1+\tau_j)P_{jt}(f)Y_{jt}(f) - W_{jt}L_{jt}(f)]df,$$

where the risk-free real interest rate R_{st} is the rate of return on an asset that pays one unit of services consumption under every state of nature at time $t+1$, and the nominal interest rate I_t is the rate of return on an asset that pays one unit of currency under every state of nature at time $t+1$. Note that the omission of the household-specific index in equation (24) reflects our assumption of complete contingent claims markets for consumption (although not for leisure), so that each type of consumption is identical across all households in every period; that is, $C_t = C_t(h)$, $Y_{mt} = Y_{mt}(h)$, and $D_t = D_t(h)$ for all $h \in [0,1]$.

The first-order condition for durable goods expenditures can be expressed as

$$Q_t \mathbb{S}'_t = \mathcal{E}_t \left[\beta(1-\delta_d)Q_{t+1}\mathbb{S}'_{t+1} + \beta(1+\phi\tfrac{\Delta D_{t+2}}{D_{t+1}} + \tfrac{\phi}{2}\tfrac{\Delta D_{t+2}^2}{D_{t+1}^2})\mathbb{U}'_{t+1} - \phi\tfrac{\Delta D_{t+1}}{D_t}\mathbb{U}'_t \right] \quad (25)$$

where Q_t denotes the relative price ratio P_{mt}/P_{st}.

In any period t in which the household is able to reset the wage contract for its members working in the manufacturing sector, the household maximizes its expected lifetime utility with respect to the new contract wage rate $W_{mt}(h)$, yielding the following first-order condition:

$$\mathcal{E}_t \sum_{i=0}^{3} \beta^i \left((1+\tau_{wm})\frac{\Pi^i W_{mt}(h)}{P_{m,t+i}}Q_{t+i}\mathbb{S}'_{t+i} + (1+\theta_{wm})\mathbb{V}'_{t+i}(h) \right) N_{m,t+i}(h) = 0 \quad (26)$$

where $\mathcal{E}_t$ here indicates the conditional expectation taken only over states of nature in which the household is unable to reset its manufacturing wage contract. Similarly, in any period t in which the household is able to reset the wage contract for its members working in the service sector, the household maximizes its expected lifetime utility with respect to $W_{st}(h)$, yielding the following first-order condition:

$$\mathcal{E}_t \sum_{i=0}^{3} \beta^i (1+\tau_{ws})\frac{\Pi^i W_{st}(h)}{P_{s,t+i}}\mathbb{S}'_{t+i} + (1+\theta_{ws})\mathbb{Z}'_{t+i}(h) N_{s,t+i}(h) = 0 \quad (27)$$

In this case, $\mathcal{E}_t$ indicates the conditional expectation taken only over states of nature in which the household is unable to reset its service-sector wage contract.

We assume that employment is subsidized to eliminate the monopolistic distortion in each sector; that is, $\tau_{wj} = \theta_{wj}$ for $j \in \{m,s\}$. Thus, the steady state of the model satisfies the efficiency condition that the marginal rate of substitution in each sector equals the real wage, as in a perfectly competitive economy.

3.3 Fiscal and Monetary Policy

The government's budget is balanced every period, so that total lump-sum taxes plus seignorage revenue are equal to output and labor subsidies plus the cost of government purchases:

$$M_t - M_{t-1} + \int_0^1 T_t(h)\, dh = \int_0^1 \tau_m P_{mt}(f) Y_{mt}(f)\, df + \int_0^1 \tau_s P_{st}(f) Y_{st}(f)\, df$$

$$+ \int_0^1 \tau_{wm} W_{mt}(h) N_{mt}(h)\, dh + \int_0^1 \tau_{ws} W_{st}(h) N_{st}(h)\, dh + P_{st} G_t \tag{28}$$

where G_t indicates real government purchases from the service sector. Finally, the total output of the service sector is subject to the following resource constraint:

$$Y_{st} = C_t + G_t \tag{29}$$

We assume that the short-term nominal interest rate is used as the instrument of monetary policy, and that the policymaker is able to commit to a time-invariant rule. We consider alternative specifications of the monetary policy rule in our analysis, including both rules that can be regarded as reasonable characterizations of recent historical experience, and rules derived from maximizing a social welfare function.

4 Solution and Calibration

To analyze the behavior of the model, we log-linearize the model's equations around the non-stochastic steady state. Nominal variables, such as the contract price and wage, are rendered stationary by suitable transformations. We then compute the reduced-form solution of the model for a given set of parameters using the numerical numerical algorithm of Anderson and Moore (1985). Their procedure provides an efficient implementation of the solution method proposed by Blanchard and Kahn (1980).

4.1 Parameters of Private Sector Behavioral Equations

The model is calibrated at a quarterly frequency. Thus, we assume that the discount factor $\beta = .993$, consistent with a steady-state annualized real interest rate $\overline{r}$ of about 3 percent. We assume that the preference parameters $\sigma_m = \sigma_s = 2$, implying that preferences over both durables and nondurables exhibit a somewhat lower intertemporal substitution elasticity than the logarithmic case; these settings for the preference parameters are well within the range typically estimated in the empirical literature. The leisure preference parameters $\chi_m = \chi_s = 3$. The capital share parameters $\alpha_m = \alpha_s = 0.3$. The quarterly depreciation rate of the durables stock $\delta = 0.025$, consistent with an annual depreciation rate of 10 percent. This choice is motivated by our specification of the durables sector to include both consumer durables and residential investment, which have annual depreciation rates of about 20 percent and 3 percent, respectively. The sectoral price and wage markup parameters $\theta_{Ps} = \theta_{Ws} = \theta_{Pm} = \theta_{Wm} = 0.3$. As noted above, price and wage contracts in each sector are specified to last four quarters. The share of the durables sector in both production and employment is set equal to 0.125, in line with the average share over the last forty years (this determines the preference scaling parameters ν_s and

ν_m). The share of government spending in nondurables production is set to 0.25, implying that the government share of total output is a bit over 20 percent. Finally, as described below, we set the cost of adjusting the stock of durables parameter $\phi = 600$ in order to match the magnitude of the response of durable goods output to a monetary innovation.

4.2 Monetary Policy Rule

In our baseline specification, we assume that the central bank adjusts the short-term nominal interest rate in response to the four-quarter average inflation rate and to the current and lagged output gaps:

$$i_t = \gamma_i i_{t-1} + \gamma_\pi \pi_t^{(4)} + \gamma_{y,1} g_t + \gamma_{y,2} g_{t-1} + e_t \tag{30}$$

where the four-quarter average inflation rate $\pi_t^{(4)} = \frac{1}{4} \sum_{j=0}^{3} \pi_{t-j}$, g_t is the aggregate output gap, and e_t is a monetary policy innovation; note that constant terms involving the inflation target and steady-state real interest rate are suppressed for simplicity. This form of the interest rate reaction function was estimated by Orphanides and Wieland (1998), who found that it provided a good in-sample fit over their 1980:1-1996:4 estimation period. We regard it as a reasonable (though admittedly very simple) characterization of the monetary policy rule in place in the Volcker-Greenspan era. Using the estimated parameter values found by Orphanides and Wieland, we set $\gamma_i = 0.795$, $\gamma_\pi = 0.625$, $\gamma_{y,1} = 1.17$, and $\gamma_{y,2} = -0.97$.

4.3 Evolution of Real Shocks

Our model involves stochastic innovations to three exogenous variables: total factor productivity of durables output (A_{mt}), total factor productivity of non-durable output (A_{st}), and government spending that is exclusively comprised of non-durables output (G_t).

These three exogenous variables are assumed to follow a trivariate first-order VAR:

$$\begin{bmatrix} A_{mt} \\ A_{st} \\ G_t \end{bmatrix} = \begin{bmatrix} \rho_m & 0 & 0 \\ 0 & \rho_s & 0 \\ 0 & 0 & \rho_G \end{bmatrix} \begin{bmatrix} A_{mt-1} \\ A_{st-1} \\ G_{t-1} \end{bmatrix} + \begin{bmatrix} e_{mt-1} \\ e_{st-1} \\ e_{Gt-1} \end{bmatrix} \tag{31}$$

where the innovations are assumed to be i.i.d. with contemporaneous covariance matrix Ω. Note that we assume that the innovations to sectoral productivity may be mutually correlated, but are assumed to be uncorrelated with the innovation to real government expenditures. Using the estimates of Christiano and Eichenbaum (1992), we set the government spending persistence parameter $\rho_G = 0.96$. To calibrate the parameters determining the evolution of the technology shocks, we utilize the estimates of a bivariate process for productivity in durables and nondurables production given by Hornstein and Prashnik (1997). After translating these parameters to a quarterly frequency, we obtain $\rho_m = \rho_s = 0.975$.

Finally, our model includes a monetary policy shock e_t that is assumed uncorrelated with the real innovations.

5   Properties of the Baseline Model

We begin by illustrating the responses of our baseline model to a monetary policy innovation, an innovation in aggregate total factor productivity, and an innovation in government spending , respectively.   Impulse response functions to a monetary policy innovation are shown in Figure 3.   The policy shock induces an initial rise in the short-term nominal interest rate (the measure of the policy rate in our model) of about 75 basis points, inducing a fall in non-durables output of nearly 0.3 percentage point. These responses are very close to those shown in the empirical VARs in Figures 1 and 2.   Given the high sensitivity of the user cost of durables to the interest rate, the output of the durables sector is much more responsive to the interest rate change than the non-durables sector.   The parameter determining the cost of adjusting the stock of durables is calibrated to match roughly the expenditure-weighted average response of consumer durables and residential investment shown in Figure 2 (which suggest that durables are roughly five times as volatile as nondurables). Finally, equilibrium in the market for durable goods requires that the rise in the user cost associated with the higher interest rate be offset partly by a fall in the relative price of durable goods.

Figure 4 compares impulse responses to an aggregate productivity shock in the baseline model to the case in which prices and wages are fully flexible.   Turning first to the case of full-flexibility, the shock induces a roughly proportional rise in non-durables output.   If the user cost of durables remained constant, this rise in demand for the nondurable good would raise the demand for durables, causing demand to exceed the available stock (which is fixed in the period of the shock). Thus, the user cost of durables must rise.   This rise in the user cost of durables is accomplished in part through a large and immediate rise in the relative price of durables, and in part though the expectation of a future capital loss on holding the durable (since the relative price is expected to fall in the future).

This sharp initial relative price adjustment is a key feature of the fully-flexible equilibrium: the relative price adjustment retards most of the increase in the demand for the stock of durables that would occur if relative prices remained constant.   By contrast, with sticky prices in both the durable and non-durable goods sectors, there is a much smaller increase in the relative price of durables. The household's equilibrium demand condition for durables is satisfied through a much larger desired increase in the stock of new durable goods. Thus, while durables output and the relative price of durables both increase on the order of 1 percent in the flexible price equilibrium, the increase in output is nearly 10 times as large as the relative price increase in our baseline specification.

It is important to recognize that the presence of price rigidities in both sectors makes monetary policy unable to achieve the flexible price equilibrium. Attainment of the flexible price equilibrium would require both setting the real interest rate on nondurables (which falls in the case of this shock) and the path of the relative price

of durables equal to their values under flexible prices; but this is infeasible given the assumed nature of price rigidities.

Figure 5 depicts impulse responses to a temporary rise in government spending in the nondurables sector. Under full-flexibility of prices and wages, the rise in government spending would induce an outward shift in labor supply in the nondurables sector due to a negative wealth effect (since government consumption is assumed to be wasted). While the output of nondurables rises (as shown), nondurables consumption contracts, which acts as negative demand shock to the demand for durables. Because sector-specific shocks have no effect on production in the other sector, implying that the path of durables is unaffected by the shock, equilibrium must be achieved solely through a fall in the user cost. Thus, the relative price of durables drops sharply in response to the government spending increase.

In our baseline model in which prices are sticky, producers of new durable goods adjust their prices downward much more slowly than under flexible prices. As a result, the user cost of durables falls by less than under flexible prices, inducing a contraction in the desired stock of durables (and correspondingly, in the flow demand). Thus, incomplete relative price adjustment causes a sector-specific shock to have spillover effects in the baseline model; moreover, equilibrium requires that the muted adjustment of relative prices be associated with much greater output volatility.

6   The Welfare Function

To provide a normative assessment of alternative monetary policy choices, we measure social welfare as the unconditional expectation of average household welfare:

$$SW = \mathcal{E} \int_0^1 \left[\mathcal{E}_t \sum_{i=0}^{\infty} \beta^i \, \mathbb{W}_{t+i}(h) \right] \, dh \qquad (32)$$

For this purpose, it is useful to decompose period utility $\mathbb{W}_t(h)$ as follows:

$$\mathbb{W}_t(h) = \mathbb{W}_t^s(h) + \mathbb{W}_t^m(h) + \mathbb{M}(\tfrac{M_t(h)}{P_{st}})$$

$$\mathbb{W}_t^s(h) = \mathbb{S}(C_t(h)) + \mathbb{Z}(N_{st}(h)) \qquad (33)$$

$$\mathbb{W}_t^m(h) = \mathbb{U}(\widetilde{D}_t(h)) + \mathbb{V}(N_{mt}(h))$$

where $\mathbb{W}_t^s(h)$ indicates the household's period utility associated with non-durables consumption and service-sector employment, while $\mathbb{W}_t^m(h)$ denotes the period utility associated with durables consumption and manufacturing employment. In the subsequent analysis, we assume that the welfare losses of fluctuations in real money balances can be safely neglected; that is, μ_0 is arbitrarily small. Then we follow the seminal analysis of Rotemberg and Woodford (1997) in deriving the second-order approximation to each component of the social welfare function and computing its deviation from the welfare of the Pareto-opimal equilibrium under flexible wages and

prices. Finally, we express each component of welfare in terms of the equivalent amount of steady-state non-durables consumption.

The welfare associated with non-durable consumption and employment depends on the volatility of the sectoral output gap, and on the inefficiencies due to dispersion of prices across firms and dispersion of wages across workers in this sector. In particular, we obtain an expression that closely parallels that of Erceg et al. (2000):

$$\left(\frac{1}{C\,\mathbb{S}_C}\right)\mathcal{E}\sum_{i=0}^{\infty}\beta^i\left(\mathbb{W}_{t+i}^s - \mathbb{W}_{t+i}^{s\,*}\right)\approx -\tfrac{1}{2}\left(\mu_{mrs}^s + \mu_{mpl}^s\right)\mathcal{V}ar\left(\hat{Y}_{st} - \hat{Y}_{st}^*\right)$$

$$-\tfrac{1}{8}\eta_{ps}\sum_{j=0}^{3}\mathcal{V}ar\ln\left(\tilde{P}_{s,t-j}\,/\,P_{st}\right) \tag{34}$$

$$-\tfrac{1}{8}\eta_{ws}\left(1-\alpha_s\right)\left(1-\eta_{ws}\chi_s\ell_s\right)\sum_{j=0}^{3}\mathcal{V}ar\ln\left(\tilde{W}_{s,t-j}\,/\,W_{st}\right)$$

where an asterisk denotes the Pareto-optimal value of the specified variable, a hat denotes the logarithmic deviation from steady state, and $\mathcal{V}ar\left(\cdot\right)$ denotes the unconditional variance. Furthermore, $\tilde{P}_{s,t-j}$ indicates the contract price signed by firms at period $t-j$, while $\tilde{W}_{s,t-j}$ indicates the contract wage signed by households at period $t-j$ (for $j=0,...,3$).

It should be noted that our assumption of fixed-duration ("Taylor-style") contracts has important implications for the welfare costs of inflation volatility.[4] Under the alternative, commonly-used assumption of random-duration ("Calvo-style") contracts, some contracts remain unchanged over long stretches of time, even if the average contract duration is relatively short. Thus under random-duration contracts, fluctuations in aggregate inflation tend to have highly persistent effects on cross-sectional dispersion, and hence the welfare cost of inflation volatility is roughly two orders of magnitude greater than the welfare cost of output gap volatility (cf. Rotemberg and Woodford 1997; Erceg et al. 2000). In contrast, fixed-duration contracts induce much less intrinsic persistence of cross-sectional dispersion, and hence imply that the welfare cost of inflation volatility is much smaller, and in fact roughly comparable in magnitude to the costs of output gap volatility.

Now consider the component of welfare that depends on durables consumption and employment. Taking a second-order approximation to this component of welfare for a given household h yields the following expression:

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[4]It should also be noted that under fixed-duration contracts, the welfare costs of cross-sectional dispersion cannot be summarized solely in terms of the variances of wage and price inflation, but must be given explicitly in terms of the variances of relative wages and prices.

$$\mathcal{E}_t \sum_{i=0}^{\infty} \beta^i \mathbb{W}_{t+i}^m (h) \approx \mathcal{E}_t \sum_{i=0}^{\infty} \beta^i \left(DU_D \; \hat{D}_{t+i} \right.$$

$$+ \; D^2 U_{DD} \; \hat{D}_{t+i}^2 - \phi DU_D (\hat{D}_{t+i} - \hat{D}_{t+i-1})^2 \tag{35}$$

$$\left. + \; NV_N \; \hat{N}_{m,t+i} (h) + N^2 V_{NN} \; \hat{N}_{m,t+i}^2 (h) \right)$$

where the absence of a time subscript denotes the steady-state value of the specified variable.[5] Next, take a second-order approximation of equation (14), which describes the evolution of the durables stock:

$$\hat{D}_t \approx (1-\delta) \, \hat{D}_{t-1} + \delta \hat{Y}_{m,t-1} + \frac{\delta(1-\delta)}{2} \left(\hat{Y}_{m,t-1} - \hat{D}_{t-1} \right)^2. \tag{36}$$

Substituting this formula into the previous equation, taking unconditional expectations, and aggregating across households, we obtain the following expression for the durables component of social welfare:

$$\frac{1}{C\mathbb{S}_C} \mathcal{E} \sum_{i=0}^{\infty} \beta^i \left(\mathbb{W}_{t+i}^m - \mathbb{W}_{t+i}^{m\,*} \right) \approx -\frac{1}{2} \left(\mu_{mrs}^m + \mu_{mpl}^m \right) \mathcal{V}ar \left(\hat{Y}_{mt} - \hat{Y}_{mt}^* \right)$$

$$+ (1-\alpha_m) \left(\mu_{mrs}^m + \mu_{mpl}^m \right) \mathcal{C}ov \left(\hat{Y}_{mt} - \hat{Y}_{mt}^*, \, \hat{L}_{mt}^* \right)$$

$$-\frac{1}{2} \left[\mathcal{V}ar \left(\hat{Y}_{mt} - \hat{D}_t \right) - \mathcal{V}ar \left(\hat{Y}_t^* - \hat{D}_t^* \right) \right]$$

$$-\frac{\phi}{2} \left[\mathcal{V}ar(\hat{D}_t - \hat{D}_{t-1}) - \mathcal{V}ar(\hat{D}_t^* - \hat{D}_{t-1}^*) \right] \tag{37}$$

$$-\frac{1}{8} \eta_{pm} \left(\frac{1-\alpha_s}{1-\alpha_m} \right) \sum_{j=0}^{3} \mathcal{V}ar \ln \left(\tilde{P}_{m,t-j} / P_{mt} \right)$$

$$-\frac{1}{8} \eta_{wm} (1-\alpha_m) (1 - \eta_{wm} \chi_m \ell_m) \sum_{j=0}^{3} \mathcal{V}ar \ln \left(\tilde{W}_{m,t-j} / W_{mt} \right)$$

Thus, just as with the non-durables component, the welfare associated with durables consumption and employment depends on the volatility of the sectoral output gap and on the variability of relative wages and prices. In this case, however, welfare involves some additional terms that arise due to the durability of output and to the quadratic costs of adjusting the stock of durable goods.

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[5] Note that the durables stock is identical across households under our assumption of complete contingent claims markets for consumption.

7 Monetary Policy Rules

In this section, we begin by examining the performance of several alternative policy rules in which the policy instrument reacts only to aggregate variables. We then compare the performance of these aggregate rules to policy rules that include explicit sectoral variables (including the optimal rule under full commitment).

7.1 Dynamic Responses

Figure 6 shows the effects of a government spending shock under three alternative policies. These include the case of strict aggregate inflation targeting, strict aggregate output gap targeting, and the optimal rule under full commitment (which maximizes the social welfare function in equation (32). As we show below, a hybrid rule targeting a weighted average of aggregate price and wage inflation essentially stabilizes the aggregate output gap, provided that the weights on the wage and price inflation rates are chosen to minimize welfare losses. For expositional simplicity, we focus on aggregate output gap targeting, keeping in mind that it may be achieved either by directly targeting the true output gap, or (at least nearly) by following the hybrid wage-price rule.

The response of the sectoral output gaps is clearly very sensitive to the form of the monetary policy rule. The policy that succeeds in stabilizing aggregate price inflation keeps nondurables output much closer to potential than the alternative policies, and also induces a sharper decline in the relative price of durables. However, inflation-stabilization clearly induces much larger fluctuations in the output gap in the durables sector than the alternatives.

To understand these results, it is helpful to recognize that the policymaker must maintain a relatively tight monetary policy stance under inflation-targeting. Output in nondurables must remain close to potential to keep inflation in nondurables at a low positive level; moreover, the policy must exert a contractionary enough effect on production in the durable goods sector to generate the relative price adjustment required to keep aggregate inflation stable. The only way to achieve this objective is through keeping the real interest rate on nondurables much higher than under the alternative policies. In fact, the long-run real interest rate – which can be regarded as a forward-looking average of the short-term real rates shown in the figure – rises about as much as in the "full-flexibility" case. The larger increase in the real interest rate implies (via the demand function for durables) that either the stock of durables must contract more sharply, or that the relative price must fall by more than under the alternative policies. With prices sluggish to adjust, most of the burden of achieving equilibrium in the market for durables falls on a large downward adjustment in the flow supply of durable goods. Hence, output contracts much more substantially in the durable goods sector (generating only slightly more relative price adjustment in the process).

The alternative policy of aggregate output gap targeting allows a substantially greater rise in nondurables output above potential, and correspondingly a smaller negative output gap in the durables sector (due to the smaller real interest rate

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increase on the nondurable goods).   This looser policy implies some rise in the aggregate price inflation rate, since it allows a higher rate of inflation in nondurables, and somewhat smaller fall in the relative price of durables.   While this policy moves in the direction of the full-commitment rule, it is actually somewhat tighter than the latter.   The full-commitment rule induces a somewhat larger positive output gap in nondurables, while implying considerably less volatility in durables. Impulse responses under the baseline monetary policy lie between the cases of strict inflation targeting and output gap targeting, as can be seen by comparing Figure 6 with Figure 5.   We defer momentarily a consideration of the welfare consequences of the alternative policies.

Figure 7 shows impulse responses to an aggregate productivity shock under the same set of alternative monetary policies.   Inflation-stabilization turns out to be a much "looser" policy than either aggregate output gap targeting, the full-commitment rule, or the baseline monetary policy stance (as can be seen by comparing Figures 7 and 5).   Clearly, the real interest rate on nondurables under inflation-targeting is much lower than under the alternative policies, while output gap fluctuations in both sectors are nearly an order of magnitude higher.   These results depend importantly on our model specification that includes both nominal wage and price rigidities.   As in a one sector model, the rise in productivity puts downward pressure on costs in each sector if output remains close to (its new higher) potential;   hence, price sta- bilization requires a positive output gap.   In our two-sector model, the fall in the real interest rate on nondurables associated with keeping aggregate inflation stable induces a substantially larger rise in the relative price of durables than under the al- ternative policies, and extremely large output boom in durables.   By contrast, output gap targeting appears to come remarkably close to the optimal full-commitment rule; the latter only damps fluctuations in the output gap in durables slightly relative to aggregate output gap targeting.   The baseline monetary policy lies between the case of inflation-targeting, and aggregate output gap targeting.

7.2   Welfare Implications

Tables 3A, 3B, and 3C allow an assessment of the welfare costs of alternative poli- cies using the quadratic approximation to the social welfare function as the relevant measure of welfare.   The welfare loss reported in column 3 for each policy can be interpreted in terms of units of foregone consumption of the nondurable good (multiplied by a constant scale factor).   Welfare losses are reported for a one stan- dard deviation innovation to government spending (Table 3A), aggregate total factor productivity (Table 3B), and to productivity in services (Table 3C).   We will also subsequently consider welfare losses under the estimated distribution of shocks.

As suggested by the impulse responses, inflation-targeting induces a much higher level of volatility in both sectoral output gaps in response to productivity shocks than the alternative policies, and induces considerably larger fluctuations in the output gap in durables in response to a government spending shock.   Although social welfare depends on both the sectoral price and wage inflation rates in addition to the sectoral output gaps, the output gaps are much more variable than sectoral wage or price

inflation rates; accordingly, policies such as inflation targeting that lead to a high level of volatility in sectoral output gaps perform very poorly using our welfare criterion. Thus, inflation-targeting is associated with a welfare loss that is nearly double that of the full-commitment policy in the case of a one standard deviation rise in government spending (mainly because it results in a doubling of the volatility of durables output). For either aggregate or sectoral productivity shocks, inflation-targeting causes output gap volatility in both sectors to be several times larger than under the optimal policy, resulting in welfare losses on the order of 5-10 times higher.

Aggregate output gap targeting markedly reduces sectoral output gap volatility relative to inflation targeting. Accordingly, aggregate output gap targeting results in much smaller welfare costs than inflation-targeting for all of the shocks considered. The table shows that aggregate output gap targeting does induce somewhat higher volatility in durables output than the optimal rule, while overly damping variation in the nondurables sector. Thus, there would be some gain to a rule that damped variation in the output gap in the durables sector. But although aggregate output gap targeting does not take account of sectoral output dispersion explicitly (as does the full commitment rule), the level of sectoral output dispersion implied by such a policy turns out to be quite low *given the magnitude and nature of the shocks considered*. Thus, the benefits of a rule that takes into account that squared sectoral gaps matter in the welfare function is quite modest: welfare improvements of shifting to the optimal rule range from 5 percent in the case of an aggregate productivity shock, to 15 percent in the case of a government spending shock.

Table 4 indicates that aggregate output gap targeting in fact performs very well relative to the full commitment rule given the empirical distribution of the three real shocks in our model (to productivity in each sector, and to government spending). In particular, the loss under aggregate output gap targeting are only on the order of 10 percent given the observed distribution of shocks. Thus, while it is clear from examining the individual shocks in Table 3 that aggregate output gap targeting induces somewhat excessive volatility in durables output relative to the optimal rule, the losses of associated with a simple policy of output gap targeting given the historical distribution of shocks do not appear large. However, we emphasize that the benefits of a sectoral rule – such as the full commitment rule or even a simple approximation that includes a reaction to sectoral output gaps – is quite dependent on the distribution of the shocks. For example, in our model calibration, government spending shocks are effectively very small, since government spending is a small fraction of GDP, and is not very volatile. With significantly greater variation in the shocks, the benefits of shifting to a rule including reaction to sectoral variables would increase markedly.

The baseline (or estimated) rule – which is intended to provide a simple description of historical U.S. monetary policy – implies sectoral output gap movement in response to shocks that is roughly a weighted average of the extreme cases considered. Accordingly, the baseline rule induces much greater volatility in the output gap in durables than either the full-commitment optimal rule, or aggregate output gap targeting. Losses under the baseline rule are roughly double what occurs under the optimal rule in the cases of the productivity shocks, as seen in Tables 3B and 3C

(while losses in the case of government spending shocks are smaller). The tables indicate that even a "modified" Taylor Rule, which puts a coefficient of unity on both inflation and the (true) output gap, is associated with welfare losses about as large as under the baseline estimated rule. By extension, monetary policy rules that put a larger relative weight on inflation than the modified Taylor Rule induce greater sectoral output volatility, and hence are associated with higher welfare losses (as suggested by our consideration of the case of strict inflation targeting); whereas rules that place a larger weight on the aggregate output gap lead to improved outcomes.

Finally, given that in practice the concept of "flexible price" potential output utilized in our model is not observable to the central bank, it is interesting to consider an alternative rule that targets a weighted average of price and wage inflation. Tables 3 and 4 report results for a wage-price inflation rule in which the coefficients are chosen to minimize the unconditional welfare function given the historical distribution of shocks. As noted above, this hybrid rule essentially stabilizes the aggregate output gap. Accordingly, this rule induces fluctuations in the sectoral output gaps that are similar to the case of direct output gap targeting, and hence also generates only small losses compared with the full-commitment optimal rule.

8 Conclusions

Our analysis indicates that it may *not* be necessary for a well-designed monetary policy rule to respond to sector-specific variables, even if social welfare depends explicitly upon them. In particular, while it seems clear that aggressive stabilization of final goods prices is undesirable, our results suggest that a somewhat broader concept of inflation-targeting in which the underlying basket is comprised of an index of both final goods prices and aggregate labor costs may perform well. With the appropriately chosen weights on aggregate price and wage inflation, such a policy comes close to stabilizing aggregate output at potential. Furthermore, given the estimated distribution of shocks, the level of sectoral output dispersion is close to that implied by the optimal full-commitment rule. Such a rule is clearly easier to implement and convey to market participants than the full-commitment rule. Moreover, while it achieves a similar outcome as a rule that directly targets the (true) aggregate output gap, it does not require direct knowledge of the level of potential output.

Finally, we caution that while our analysis suggests that certain aggregate rules may work well if the distribution of shocks resembles the historical average in U.S.data, it might be desirable to depart from such rules in the case of an increase in the variability of underlying shocks, or in the case of an unusually large shock. In the presence of shocks that generated a much higher degree of cross-sectional output dispersion, there would be larger potential gains in responding to sector-specific variables than indicated by our analysis.

Table 3A. Welfare under Alternative Policies: One Standard Deviation Shock to Govt Spending

	sdev(g_M)	sdev(g_S)	Welfare Loss	Loss cp to Opt
Full Commitment	0.54	0.15	0.39	0
Inflation Target	1.25	0.02	0.75	92.3
Output Gap Target	0.74	0.11	0.45	15.4
Estimated Rule	0.91	0.06	0.50	28.2
Wage-Price	0.88	0.07	0.46	17.9
Taylor (true gap)	0.96	0.06	0.92	136

Table 3B. Welfare under Alternative Policies: One Standard Deviation Shock to Aggregate Productivity

	sdev(g_M)	sdev(g_S)	Welfare Loss	Loss cp to Opt
Full Commitment	0.97	0.22	3.25	0
Inflation Target	6.99	1.23	34.1	949
Output Gap Target	1.18	0.17	3.41	4.9
Estimated Rule	2.35	0.25	7.64	135
Wage-Price	1.43	0.14	3.44	5.8
Taylor (true gap)	2.41	0.17	9.31	186

Table 3C. Welfare under Alternative Policies: One Standard Deviation Shock to Services Productivity

	sdev(g_M)	sdev(g_S)	Welfare Loss	Loss cp to Opt
Full Commitment	1.31	0.39	3.59	0
Inflation Target	6.74	0.91	26.8	647
Output Gap Target	1.86	0.27	3.97	10.6
Estimated Rule	3.06	0.19	7.55	110
Wage-Price	2.24	0.19	4.10	14.2
Taylor (true gap)	3.16	0.11	9.00	151

Table 4. Welfare under Alternative Policies: Estimated Variance-Covariance Matrix of Shocks

	sdev(g_M)	sdev(g_S)	Welfare Loss	Loss cp to Opt
Full Commitment	1.22	0.41	4.79	0
Inflation Target	6.37	1.30	32.7	583
Output Gap Target	1.86	0.27	5.25	9.6
Estimated Rule	2.81	0.30	9.21	92.3
Wage-Price	2.37	0.19	5.53	15.4
Taylor (true gap)	2.81	0.24	11.0	130

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FIgure 1
Empirical Response to Monetary Policy Shock: Components of Durable Expenditures
(± 2 standard errors)
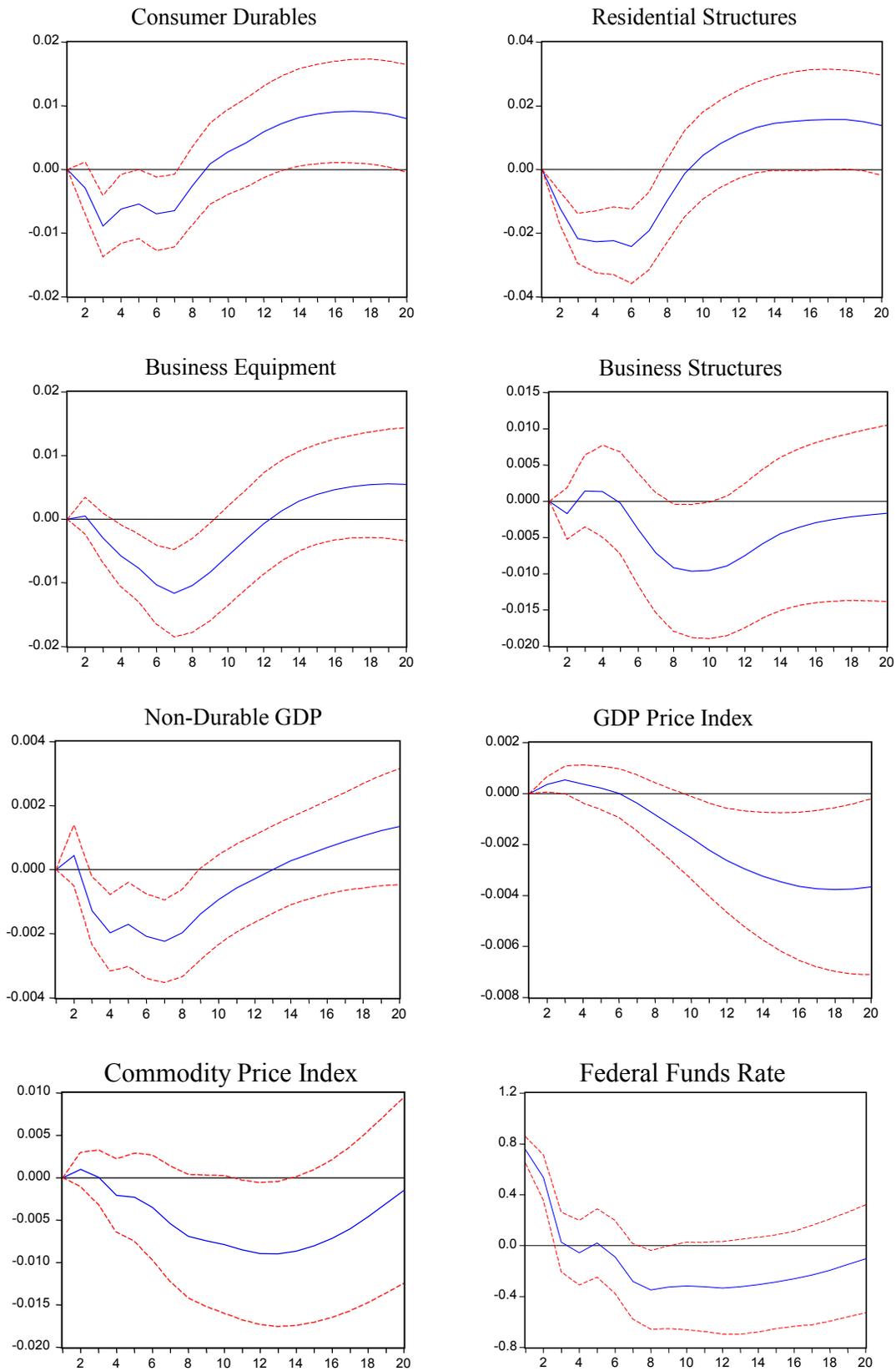
FIgure 2
Empirical Response to Monetary Policy Shock: Disaggregated Price Indices
(± 2 standard errors)

Consumer Durables + Residential Inv.
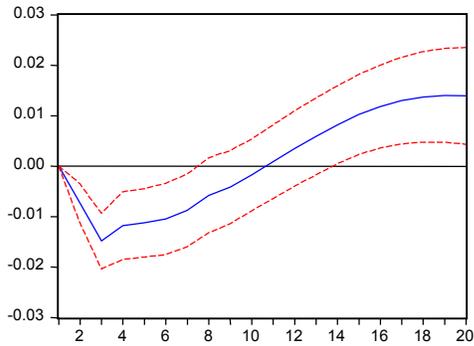
Other GDP Components
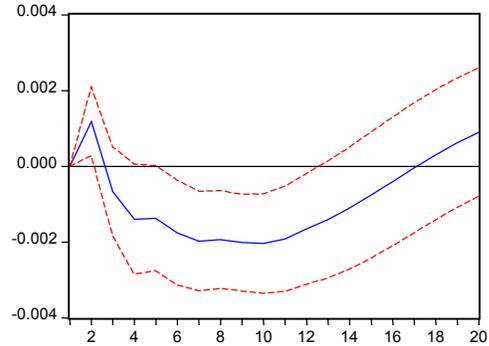
Price Index of Cons.Durables+Resid.Inv.
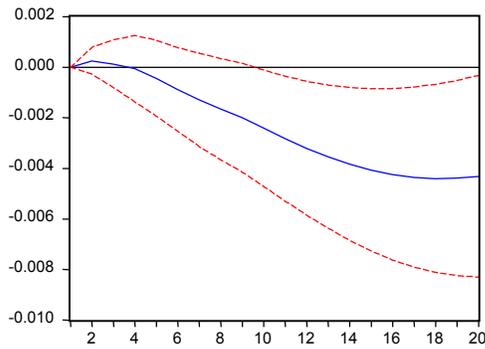
Price Index of Other GDP Components
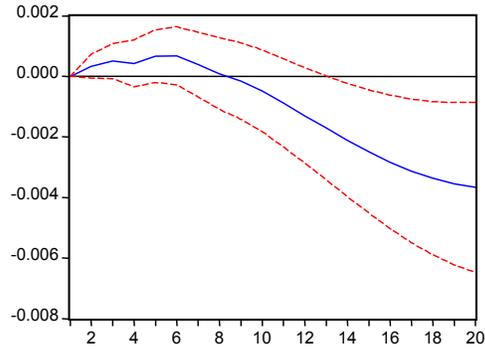
Commodity Price Index
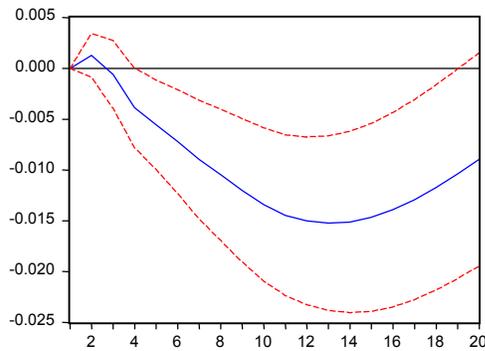
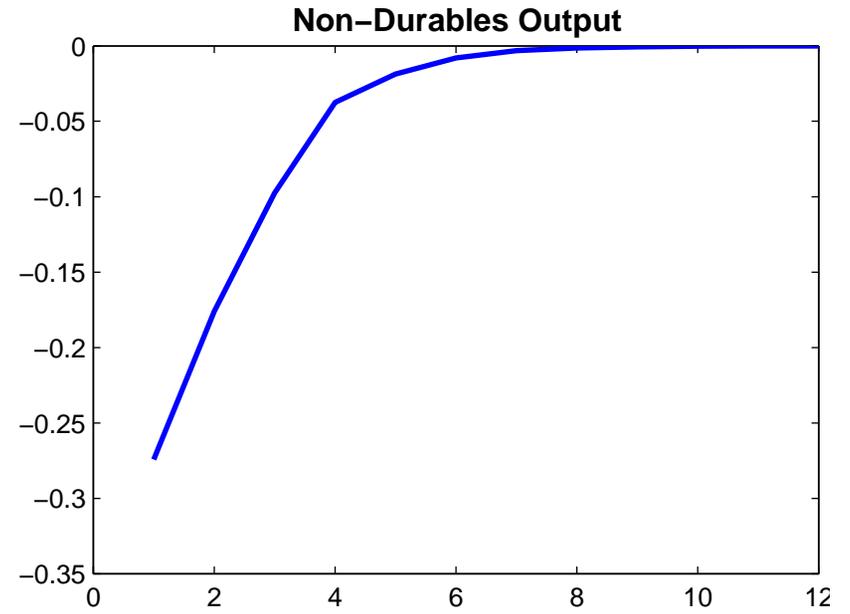Federal Funds Rate
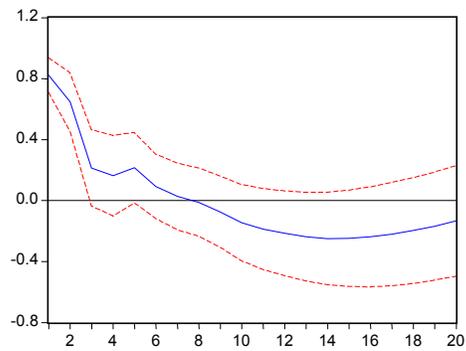
Figure 3
Baseline Model Dynamics: Monetary Policy Shock
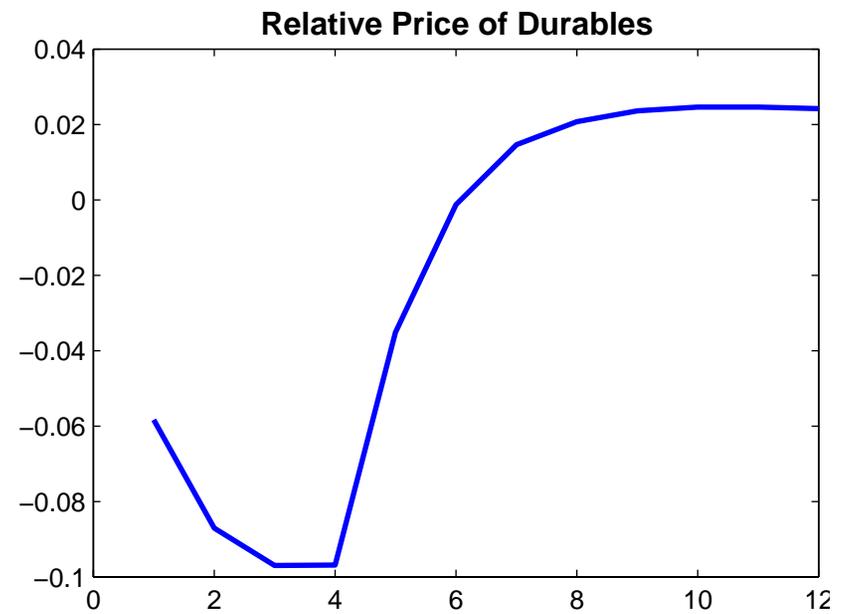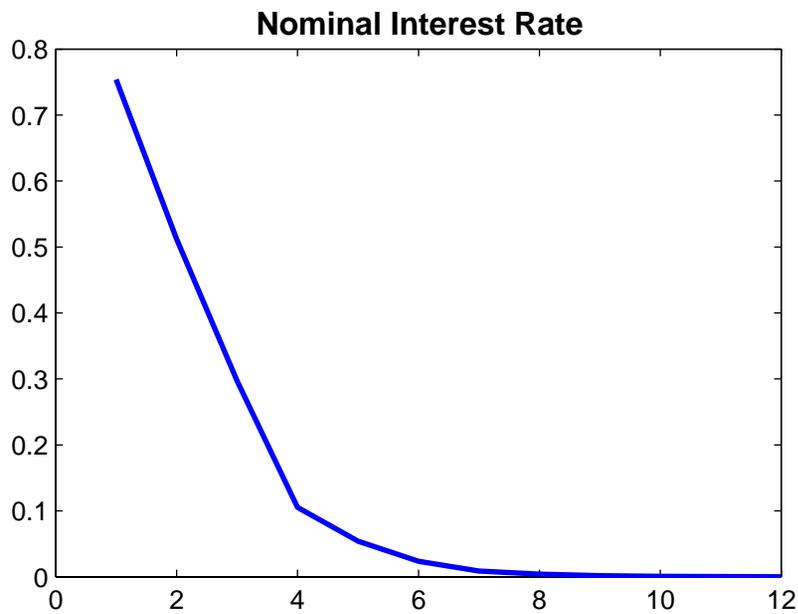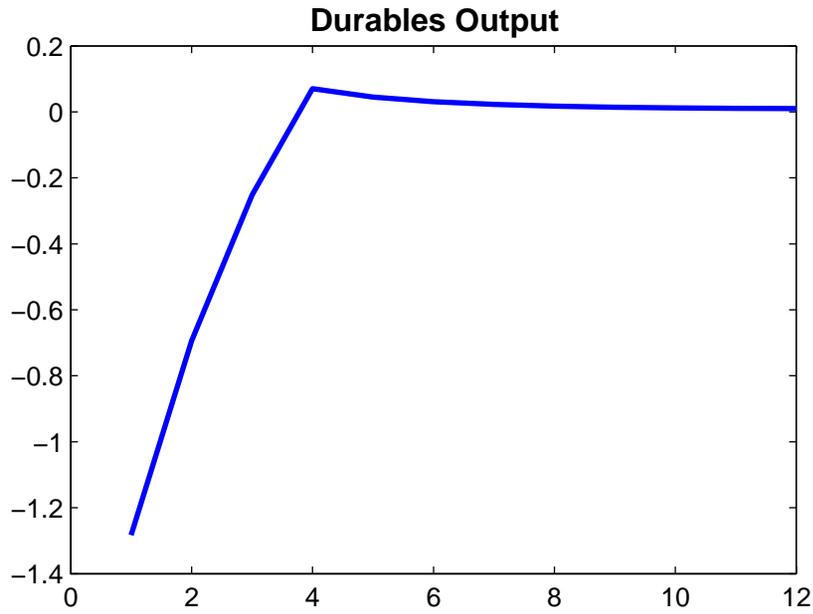
Figure 4
Baseline Model Dynamics: Aggregate Productivity Shock
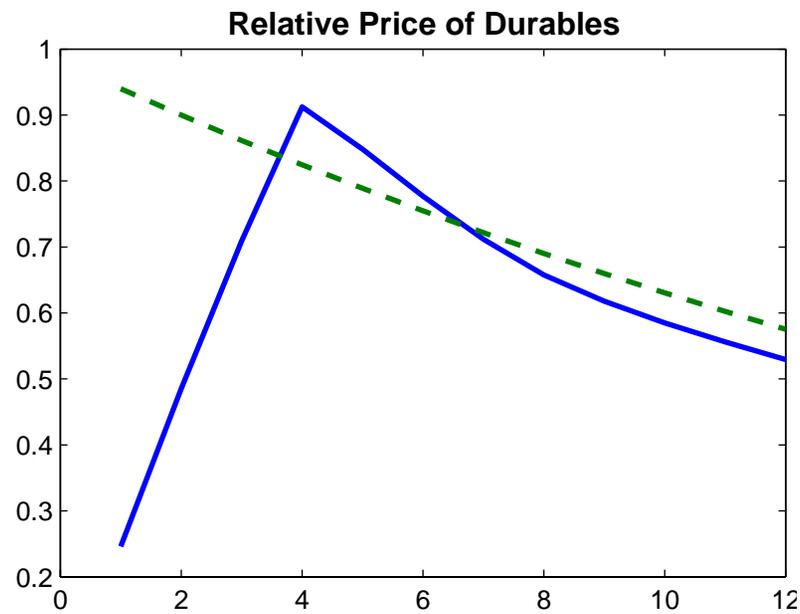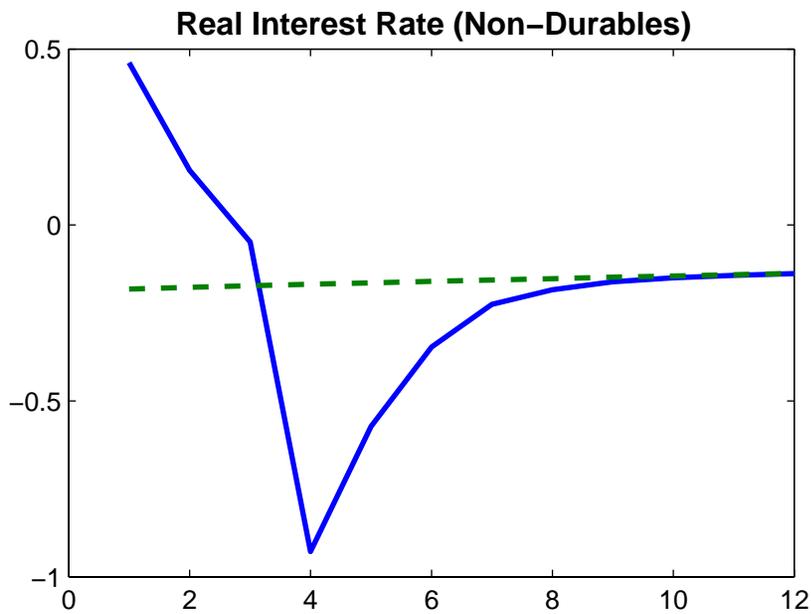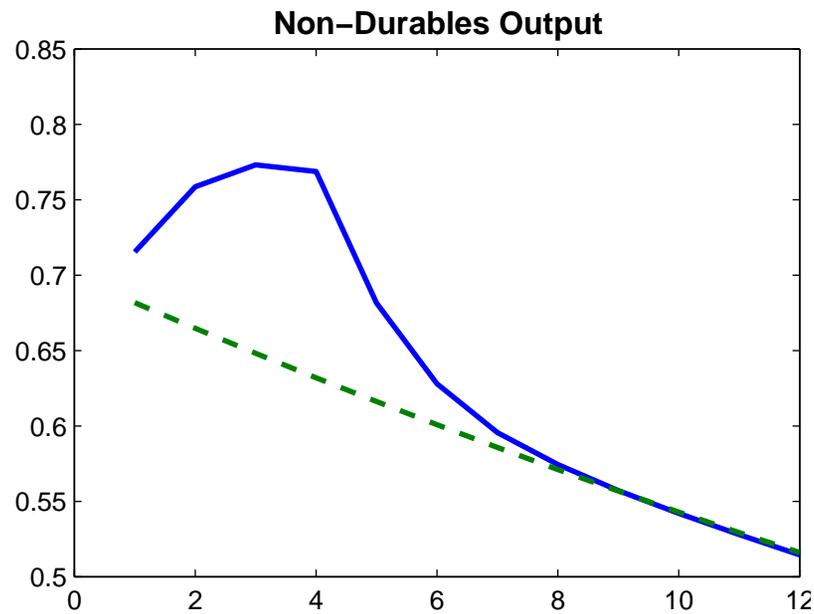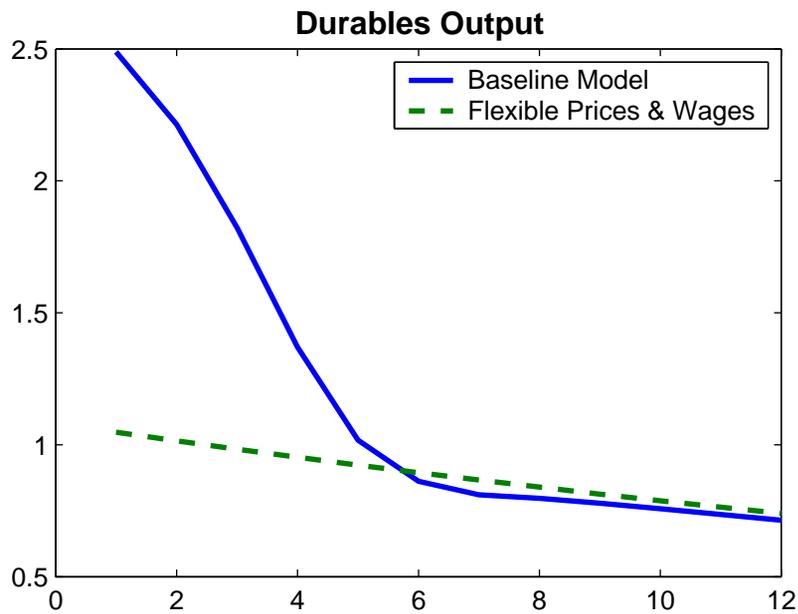
Figure 5
Baseline Model Dynamics: Government Spending Shock

Durables Output

Non−Durables Output

Baseline Model
Flexible Prices & Wages

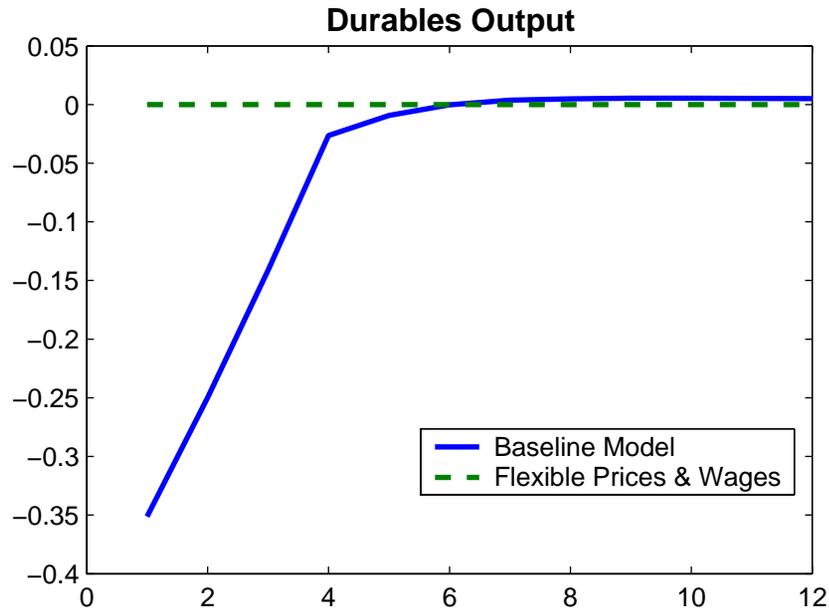**Real Interest Rate (Non−Durables)**

Relative Price of Durables
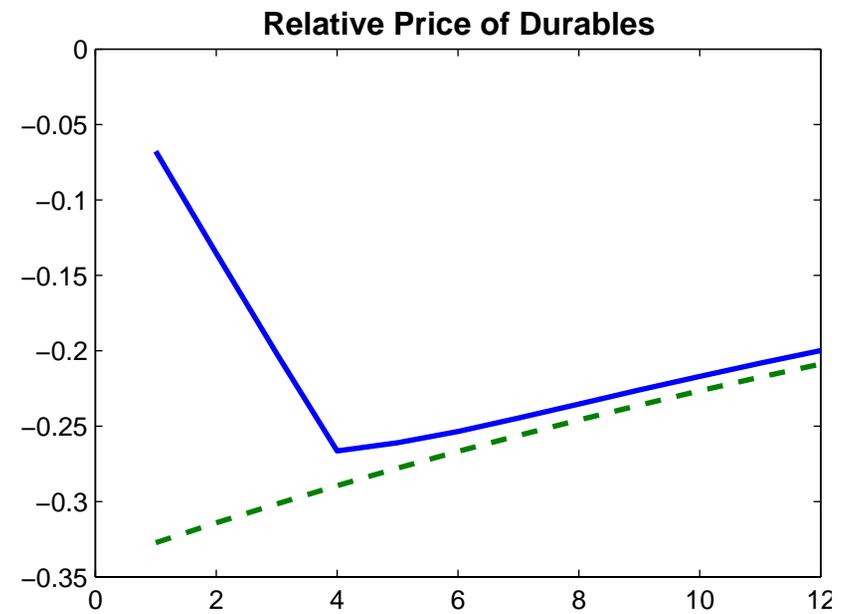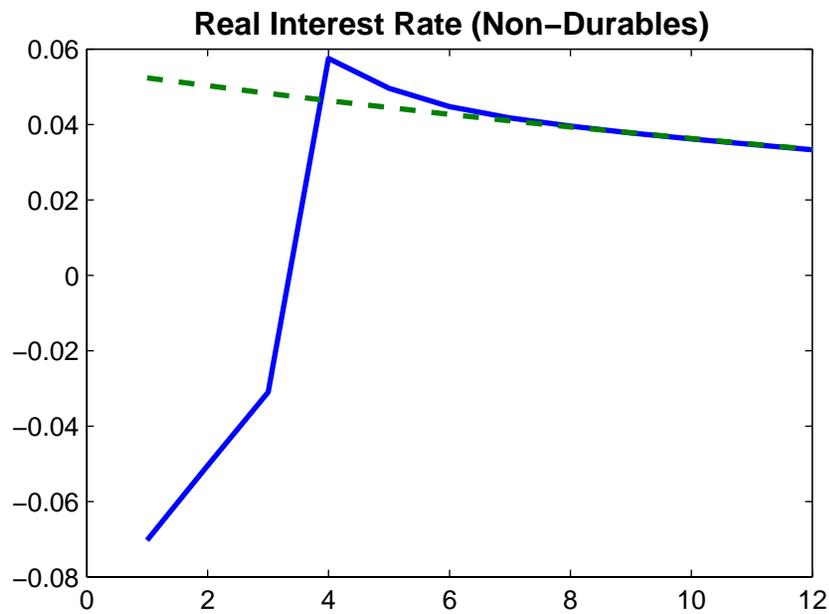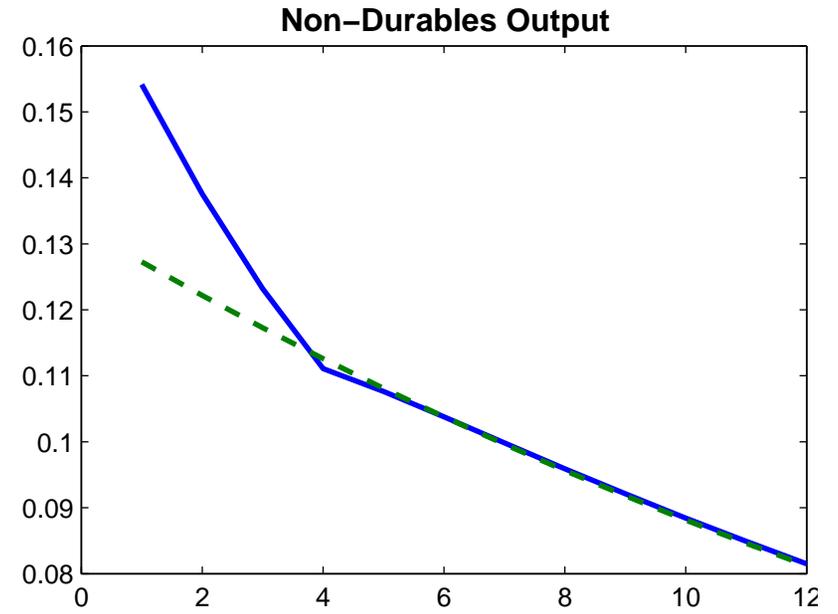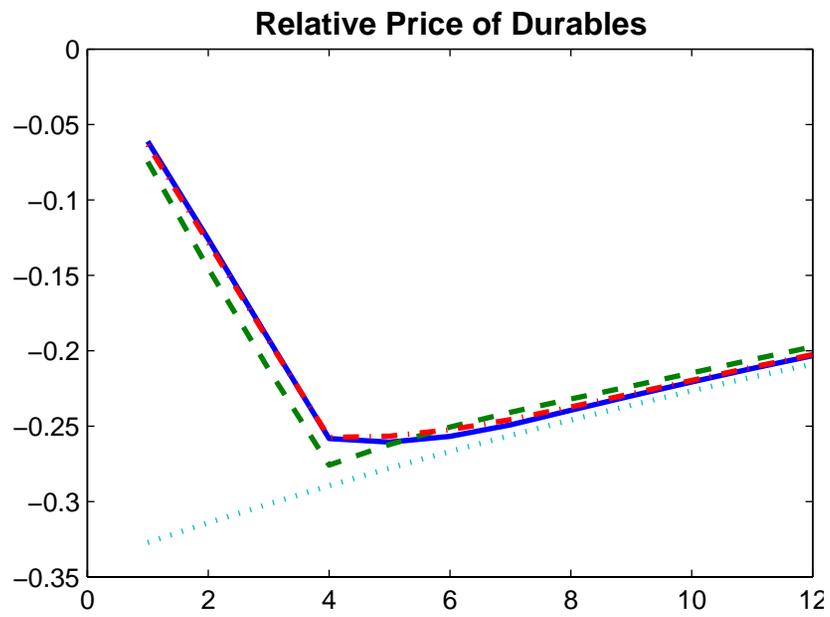
Figure 6
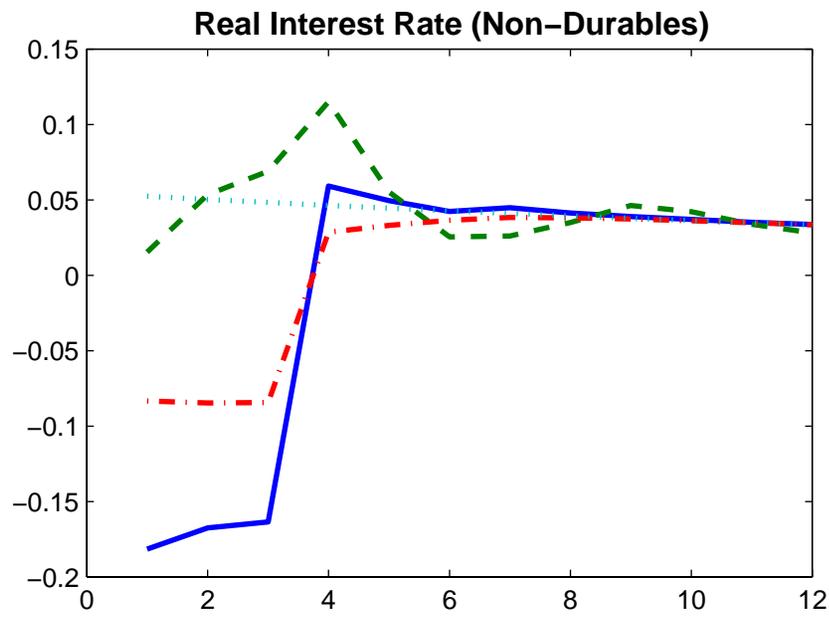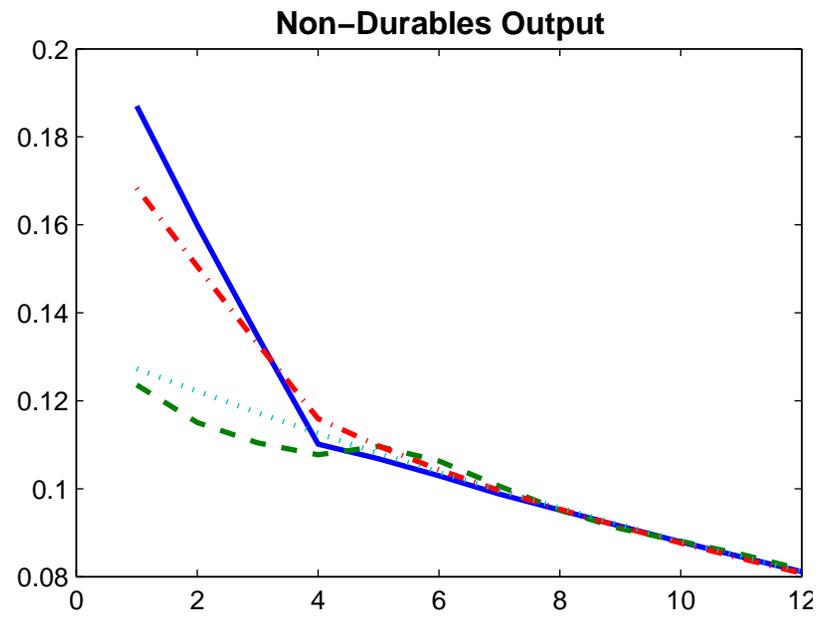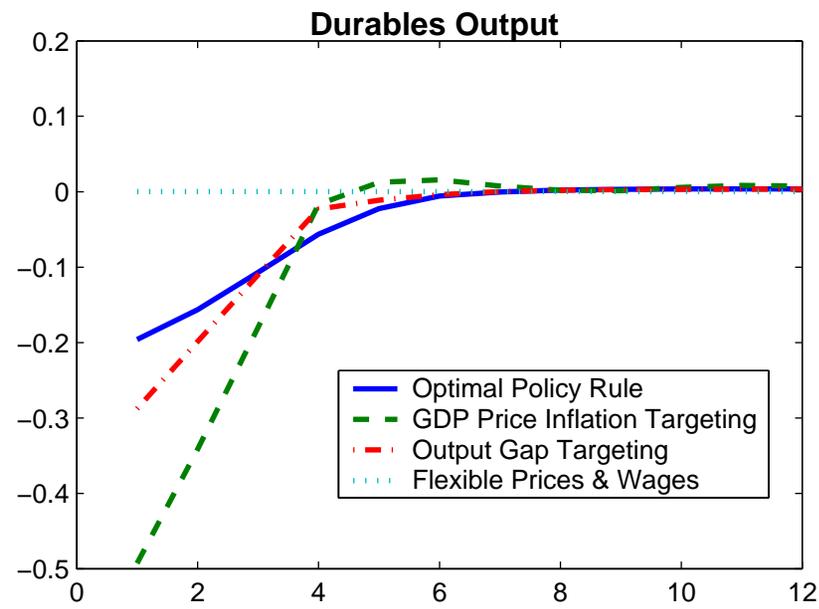## Policy Rule Comparison: Government Spending Shock

Figure 7
Policy Rule Comparison: Aggregate Productivity Shock

Durables Output

Non−Durables Output

Optimal Policy Rule
GDP Price Inflation Targeting
Output Gap Targeting
Flexible Prices & Wages

Real Interest Rate (Non−Durables)

Relative Price of Durables