Department of Economics

Working Paper Series

Nominal Rigidities, Monetary Policy and Pigou Cycles

11-007

Stéphane Auray
CREST-Ensai, Université du Littoral Côte d'Opale (EQUIPPE), GREDI and CIRPEE

Paul Gomme
Concordia University and CIREQ

Shen Guo
School of Public Finance and Public Policy, Central University of Finance and Economics, Beijing, China

UNIVERSITÉ Concordia UNIVERSITY

Department of Economics, 1455 De Maisonneuve Blvd. West, Montreal, Quebec, Canada H3G 1M8
Tel 514–848–2424 # 3900 · Fax 514–848–4536 · econ@alcor.concordia.ca · alcor.concordia.ca/~econ/repec

Nominal Rigidities, Monetary Policy and Pigou Cycles*

Stéphane Auray
CREST-Ensai,
Université du Littoral Côte d'Opale (EQUIPPE),
GREDI and CIRPEE

Paul Gomme
Concordia University and CIREQ

Shen Guo
School of Public Finance and Public Policy,
Central University of Finance and Economics, Beijing, China.

March 8, 2012

Abstract

This paper makes two contributions to the literature. First, it explores the role of monetary policy in generating Pigou cycles. Second, the paper provides a partial resolution of the comovement problem associated with monetary policy shocks. The paper estimates a two sector dynamic new Keynesian model with sticky prices. The estimated interest rate rule allows for Pigou cycles – an immediate boom in economic activity upon receipt of perfectly informative news of a future productivity improvement. For Pigou cycles to occur, there has to be sufficient movement in durable and nondurable sector inflation rates to lead to a sharp increase in the relative price of durables following a nondurable sector news shock. An interest rate rule with a larger coefficient on inflation keeps sectoral inflation rates closer to their steady state values, leading to a more moderate increase in the relative price of durables. The Ramsey-optimal policy likewise dampens the movements in sectoral inflation rates and avoids Pigou cycles. Thus, Pigou cycles emerge in the estimated model for the simple reason that the central bank accommodates them. The paper also provides a partial resolution of the comovement problem: the impact effect of a monetary policy shock leads to positive comovement between the durables and nondurable sectors, as seen in the data. The paper shows that the comovement problem arises when durable sector prices are less rigid than estimated, and the elasticity of substitution between durables and nondurables is higher than estimated.

*We are grateful to the editor, Wouter den Haan and two referees for insightful comments that lead to a substantial revision of the paper. The paper also received valuables comments from the participants at various seminars and conferences.

1 Introduction

Recent interest in Pigou cycles was piqued by Beaudry and Portier (2004). In essence, Pigou cycles refer to economic fluctuations driven, at least in part, by *news shocks*. A news shock is a perfectly anticipated future change in productivity.[1] According to Beaudry and Portier, a Pigou cycle requires that a positive news shock should result in a boom in economic activity prior to the realization of the shock. This paper makes two contributions to the literature. First, it explores the role of monetary policy in generating Pigou cycles. Second, it provides a partial resolution of the *comovement problem:* The fact that many models have a problem in generating a fall in durable and nondurable sector outputs in response to a monetary tightening.

The model includes a number of key components. News shocks are needed to be able to consider Pigou cycles. The model is new Keynesian with sticky prices and money-in-the-utility function because of its wide acceptance as a model of monetary policy. As in Beaudry and Portier (2004), the production side is characterized by two sectors, durables and nondurables. This two sector setup allows us to address the comovement problem. Each sector is populated by monopolistically competitive intermediate goods producers whose goods serve as inputs to a sector-specific final good. Following the dynamic new Keynesian literature, intermediate goods firms periodically reoptimize their prices as in Calvo (1983). Details of the model are presented in Section 2. In other words, the model has the minimal set of features required to address both the Pigou cycle literature as well as the comovement problem.

While some of the parameters of the benchmark model are calibrated, key model parameters are estimated using Bayesian methods. The estimated parameters consist of: the weights on inflation and output in the interest rate rule governing monetary policy; the degree of price stickiness in the durable and nondurable sectors; the elasticity of substitution between durables and nondurables in the utility function; and the stochastic processes of the model – those governing total factor productivity in the two sectors as well as the monetary policy shock. The lag between observing a news shock and realizing its effects on productivity is obtained by estimating the model with various lags and choosing the lag with the highest likelihood. As pointed out by Leeper, Walker, and Yang (2011), there are important econometric problems in identifying anticipated (news) shocks using astructural methods. Estimating

[1] In particular, news shocks are *not* sunspots which represent extrinsic uncertainty.

a structural model, as do Schmitt-Grohé and Uribe (2010), imposes sufficient structure to enable the identification of several anticipated shocks. That the key parameters of the model have been estimated imposes considerable discipline on the results generated.

A key finding in this paper is that the estimated monetary policy rule leads to Pigou cycles in response to a nondurable sector news shock. In contrast, the Ramsey-optimal policy does *not* generate Pigou cycles. In this sense, monetary policy can be said to be responsible for Pigou cycles. Roughly speaking, sticky prices are needed so that intermediate goods producers are forward-looking in their pricing decisions. A positive nondurable sector news shock leads nondurable intermediate producers to curb the rise in their prices in advance of the realization of this shock. To generate Pigou cycles, it is crucial that the relative price of durables rise rapidly so that households will want to buy those durables in advance of their relative price increase – which is exactly what happens under the estimated monetary policy rule. In contrast, the Ramsey-optimal policy seeks, in large part, to minimize within-sector price dispersion which is accomplished by keeping sectoral inflation rates close to their steady state values. As a consequence, the relative price of durables rises more gradually than implied by the estimated policy. Households are, then, willing to put off their durables purchases, and there is a modest decline in durable sector output prior to the realization of the news shock. In summary, Pigou cycles come about when monetary policy permits sufficient price movements to generate a rapid rise in the relative price of durables that leads households to purchase durables before their price rises too much.

A great deal of sensitivity analysis is conducted. Price stickiness is an essential ingredient. When all prices are flexible, intermediate goods producers are no longer forward-looking in their pricing behavior and there is no change in the relative price of durables until the news shock actually takes place. Furthermore, durables prices need to be sufficiently sticky; when their prices are more flexible than is estimated, the relative price of durables rises then falls in the periods between the announcement of the news shock and its realization. As a result, durables output first rises, then falls below steady state. It is important to remember that the degree of price rigidity in the two sectors was estimated and so are not free parameters. The estimated price stickiness is within the range of estimates in the literature. Further, the degree of durable sector price rigidity is less than in the nondurable sector, a finding consistent with the empirical work of Bils and Klenow (2004).

Regarding the comovement problem, Erceg and Levin (2006) provide empirical evidence that a monetary tightening is associated with a fall in output in both the durable and nondurable good sectors. As pointed out by Barsky, House, and Kimball (2007), many macroeconomic models – particularly those with flexible prices – have difficulty delivering this positive comovement between durable and nondurable sector outputs. On impact, the estimated benchmark model generates a positive comovement between durable and nondurable outputs, followed by a subsequent negative comovement. Thus, the model provides a partial resolution of the comovement problem. To understand this result, consider what happens when durables prices are flexible. In this case, a tightening of monetary policy results in a large decline in the relative price of durables. While the direct contractionary effect of monetary policy is to reduce consumption of both durables and nondurables, the fall in the price of durables is so large that households are willing to purchase more durables, hence the comovement problem. However, nominal price rigidity in the durable goods sector leads to rigidity in the relative price of durables, thus moderating the fall in this relative price. For the benchmark estimates, there is more than sufficient nominal durable price rigidity to ensure that the relative price of durables does not fall enough to lead households to increase their durables purchases. Hence, the positive comovement between durables and nondurables in response to a monetary policy shock, at least on impact. While the estimated durable sector rigidity implies an average duration between price reoptimizations of 3.67 quarters, the model nonetheless generates positive sectoral comovement for shorter considerably durations – certainly as little as 1.25 quarters (perfectly flexible prices mean an average duration between price reoptimizations of 1 quarter).

Our estimate of the elasticity of substitution between durables and nondurables is less than one which implies that durables and nondurables are complements in utility. In Beaudry and Portier's (2004) pioneering work on Pigou cycles, it is assumed that these goods are complements in utility; in fact, they use an even smaller elasticity. In the literature addressing the comovement problem, it is common to assume an elasticity of one (that is, a Cobb-Douglas aggregator over durables and nondurables); see Barsky, House, and Kimball (2007) and related works. Setting this elasticity very close to one, we find that the comovement problem develops for a larger range of durable sector price rigidity. There is no particularly good reason to think that this elasticity should equal one, and values different from one cannot be ruled out by, say, balanced growth considerations. In brief, our partial resolution of the comovement problem can be attributed to the estimated elasticity of substitution between durables and nondurables – specifically that durables and nondurables are complements in utility.

The paper assesses the historical role of the model's shocks, news and contemporaneous total factor productivity shocks in the durable and nondurable sectors as well as monetary policy shocks. Viewed through the model, over the last 50 years, durable sector shocks have contributed little to real output fluctuations. While nondurable sector shocks individually make substantial impacts on output, their joint contribution is small owing to a negative correlation between the nondurable news and nondurable contemporaneous shocks. Monetary policy has had a large effect on output fluctuations, particularly: in the late-1960s and early 1970s; the early- to mid-1980s; and the late 1990s and early 2000s. The model speaks to the recent financial crisis period, 2008-present, saying that this episode is primarily due to nondurable sector shocks and monetary policy shocks that have pushed output down. At the end of this period, durable sector shocks also contributed to lower economic performance.

We also simulated the model using the estimated news and contemporaneous total factor productivity shocks, but using decision rules derived under the Ramsey-optimal monetary policy. The Ramsey policy leads to a much smoother inflation experience than was actually observed. Interestingly, this policy implies output fluctuations of a similar magnitude to those observed in the U.S., presumably because the Ramsey policy largely accommodates those fluctuations that are due to productivity changes. In addition, the Ramsey-optimal policy avoids the most recent recession associated with the financial crisis. Viewed through this model, the financial crisis can be attributed to suboptimal monetary policy.

The current paper is related to a number of others in the literature. Barsky, House, and Kimball (2007) is of particular importance due to its role as an early contributor to the analysis of durables and nondurables in a new Keynesian model. They find that price stickiness in the durable sector is central to the behavior of their model; price rigidity in the nondurable sector is far less important. Barsky, House, and Kimball seem to be the first identify the comovement problem associated with monetary policy shocks. Bouakez, Cardia, and Ruge-Murcia (2011) add inter-sectoral linkages and limited labor mobility to the Barsky, House, and Kimball model; they find that even if durables prices are flexible, a monetary shock leads to positive comovement between sectors.

In the Pigou cycle literature, Beaudry and Portier (2007) characterize conditions under which Pigou cycles emerge in "simple" neo-classical settings. Jaimovich and Rebelo (2009) go beyond such simple settings, incorporating variable capital utilization and investment adjustment costs in a one sector model. They find that Pigou cycles appear when the short run wealth effect on labor supply is sufficiently weak. Along different lines, Den Haan and Kaltenbrunner (2009) show that a model with labor market matching frictions can be reasonably parameterized such that firms have an incentive to increase their investment in new projects and vacancies prior to the realization of a news shock. Den Haan and Lozej (2011) show that whereas Den Haan and Kaltenbrunner generate Pigou cycles for a small set of parameter values, an open-economy version of the model more robustly generates Pigou cycles. Sterk (2010) shows that financial frictions exacerbate the comovement problem in a sticky price model with durables and nondurables. Carlstrom and Fuerst (2006) find that wage rigidity along with firm-level adjustment costs on the level of production can resolve the comovement problem in a two sector new Keynesian model.

A number of other papers estimate structural models with news shocks, including Schmitt-Grohé and Uribe (2010), Khan and Tsoukalas (2011) and Gortz and Tsoukalas (2011). All of these papers find that news shocks are a significant source of macroeconomic fluctuations. More recently, Barksy and Sims (forthcoming), noting that changes in consumer confidence Granger-cause income and consumption (but not the other way around), run a horse race between the 'animal spirits' and news shock hypotheses. They do so by fitting the parameters of a reasonably standard new Keynesian model so that its impulse responses minimize the distance between the model's impulses and those of a VAR that includes a measure of consumer confidence. They find that news shocks are the most plausible and importance source of variation in consumer confidence.

Kobayashi and Nutahara (2010) deserve special mention since they also focus on the role of monetary policy in generating Pigou cycles. They use a one sector new Keynesian model with investment adjustment costs and sticky prices. There are a number of key differences between Kobayashi and Nutahara and the current paper. First, they provide little justification for their parameter choices whereas we use a combination of calibration and estimation which imposes considerable discipline on our analysis. Second, since we characterize the Ramsey-optimal monetary policy while Kobayashi and Nutahara do not, we are able to place more of the "blame" for Pigou cycles on the central bank.

Similarly, Christiano, Ilut, Motto, and Rostagno (2008) deserve special mention. They build a model with real frictions (internal habit persistence and investment adjustment costs) as well as nominal rigidities (both wage and price stickiness). Their chief finding is that an inflation targeting central bank along with nominal wage rigidities lead to Pigou (boom-bust) cycles. This finding contrasts with our finding that inflation targeting central banks do not experience Pigou cycles. In both cases, an inflation fighting central bank ends up smoothing fluctuations in a relative price – the real wage in Christiano et al., the relative price of durables in this paper. Consider a positive news shock and an inflation fighting central banker. In Christiano et al., such a shock necessitates an increase in the real wage. With wage stickiness, it takes time for the nominal wage to adjust, and with an inflation fighting central bank, the price level cannot do the job very quickly. Consequently, the real wage is lower than it "should" be, firms hire more workers, and a Pigou cycle results. In our paper, a news shock under an inflation fighting central bank leads to a moderately increasing path for the relative price of durables. As discussed above, under such a scenario, households do not buy up durables in anticipation of much higher prices down the road. Consequently, there are no Pigou cycles in our model for this scenario; it is only when the central bank weakly targets inflation that the path of the relative price of durables rises rapidly, households push up their purchases of durables, and a Pigou cycle results. In a sense, the mechanics in the two papers is the same: an inflation fighting central bank limits movements in a relative price.[2] The difference is which relative price is affected, and whether or not Pigou cycles occur.

The model is presented in Section 2; it is estimated and simulated in Section 3. Section 4 investigates the sources of Pigou cycles in our modeling environment. Section 5 presents the historical contribution of each of the model's shocks to output. Section 6 contains some concluding remarks.

2 Economic Environment

There are two sectors, durables and nondurables. Each sector has a continuum of sector-specific intermediate good producers, and a continuum of final good producers. Each intermediate good producer uses labor to produce a differentiated good, and so acts as a monopolistic competitor. Prices are set in a staggered fashion à la Calvo (1983). Final good producers bundle together sector-specific intermediate

[2] In Christiano et al. (2008), the relative price of capital goods is not constant due to the investment adjustment costs. In their paper, if households tried to purchase more capital goods, this would simply push up the effective price of capital goods since the adjustment costs would increase.

goods to produce a sector-specific final good, acting as perfect competitors. Households supply labor and buy final goods. A central bank conducts monetary policy.

2.1 Households

The representative household has preferences over state contingent streams of nondurables, C_t, durables, D_t, labor, N_t, and real money balances, M_t/P_t, summarized by

$$E_0 \sum_{t=0}^{\infty} \beta^t U\left(C_t, D_t, N_t, \frac{M_t}{P_t}\right), \quad 0<\beta<1. \tag{1}$$

The functional form of U is

$$U\left(C, D, N, \frac{M}{P}\right) = \ln\left[(1-\alpha)^{\frac{1}{\eta}} C^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} D^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} - \upsilon \frac{N^{1+\sigma}}{1+\sigma} + \chi \frac{(M_t/P_t)^{1-\mu}}{1-\mu}, \tag{2}$$

where $\eta > 0$ is the elasticity of substitution between durables and nondurables, α governs the importance of durables relative to nondurables, υ determines the disutility of labor, $1/\sigma$ is the Frisch labor supply elasticity, and υ gives the importance of real money balances.[3]

The household hires out its time, N_t, at nominal wage W_t. In addition to money balances, the household also brings into the period bonds, B_{t-1}, that pay a gross rate of return, R_{t-1}. The household also receives a transfer from government, T_t, and its share of profits from intermediate nondurable goods producers, Π_{ct}, and from intermediate durable goods producers, Π_{dt}. The household's budget constraint is, then,

$$P_{ct}C_t + P_{dt}\left[D_t - (1-\delta)D_{t-1}\right] + B_t + M_t = W_t N_t + R_{t-1}B_{t-1} + M_{t-1} + T_t + \Pi_{ct} + \Pi_{dt}, \tag{3}$$

where P_{ct} is the price of nondurables, P_{dt} the price of durables and M_{t-1} is nominal money balances brought into the period. The term in square brackets is newly purchased durables; δ is their depreciation

[3] In Barsky, House, and Kimball (2007), money demand is proportional to nominal purchases. This specification of money demand abstracts from the transactional distortions of money, focusing instead on the deleterious effects of relative price distortions. Identical results are obtained by specifying money demand as being proportional to nominal purchases as in Barsky, House, and Kimball. The reason why the results are identical is that, in both cases, money does not affect the remaining equations characterizing equilibrium of the model.

rate.

The household chooses contingent sequences, $\{C_t, D_t, N_t, B_t, M_t\}_{t=0}^{\infty}$, to maximize Eq. (1) subject to Eq. (3) given B_{-1} and M_{-1}. The Euler equations are

$$q_t U_c\left(C_t, D_t, N_t, \frac{M_t}{P_t}\right) = U_d\left(C_t, D_t, N_t, \frac{M_t}{P_t}\right) + \beta E_t\left\{q_{t+1} U_c\left(C_{t+1}, D_{t+1}, N_{t+1}, \frac{M_{t+1}}{P_{t+1}}\right)(1-\delta)\right\}, \quad (4)$$

$$\frac{U_c\left(C_t, D_t, N_t, \frac{M_t}{P_t}\right)}{P_{c,t}} = \beta E_t\left\{R_t \frac{U_c\left(C_{t+1}, D_{t+1}, N_{t+1}, \frac{M_{t+1}}{P_{t+1}}\right)}{P_{c,t+1}}\right\}, \quad (5)$$

$$U_n\left(C_t, D_t, N_t, \frac{M_t}{P_t}\right) + \frac{W_t}{P_{c,t}} U_c\left(C_t, D_t, N_t, \frac{M_t}{P_t}\right) = 0, \quad (6)$$

$$\frac{U_c\left(C_t, D_t, N_t, \frac{M_t}{P_t}\right)}{P_{c,t}} = \frac{U_m\left(C_t, D_t, N_t, \frac{M_t}{P_t}\right)}{P_t} + \beta E_t\left\{\frac{U_c\left(C_{t+t}, D_{t+t}, N_{t+t}, \frac{M_{t+t}}{P_{t+t}}\right)}{P_{c,t+1}}\right\}, \quad (7)$$

where $q_t \equiv P_{dt}/P_{ct}$ is the price of durables relative to nondurables. Eq. (4) is the durables accumulation equation, trading off the benefits of an additional unit of durables against its cost in foregone nondurable consumption. Eq. (5) determines the accumulation of bonds. Eq. (6) governs the labor-leisure choice. Finally, Eq. (7) is the money accumulation equation.

As pointed out by Barsky, House, and Kimball (2007), when durables are long lived, the shadow price of durables is roughly constant following a temporary shock. To see this point, let γ_t be the shadow price of a unit of durables and iterate forward on Eq. (4):

$$\begin{aligned} \gamma_t &= q_t U_c\left(C_t, D_t, N_t, \frac{M_t}{P_t}\right) \\ &= U_d\left(C_t, D_t, N_t, \frac{M_t}{P_t}\right) + \beta(1-\delta) E_t\left\{U_d\left(C_{t+1}, D_{t+1}, N_{t+1}, \frac{M_{t+1}}{P_{t+1}}\right)\right\} \\ &\quad + \beta^2(1-\delta)^2 E_t\left\{U_d\left(C_{t+2}, D_{t+2}, N_{t+2}, \frac{M_{t+2}}{P_{t+2}}\right)\right\} + \cdots . \end{aligned} \quad (8)$$

If durables are long lived, then their depreciation rate, δ, is close to zero and the stock of durables is large relative to investment in durables. In this case, the stock of durables does not change much in response to shocks to the economy, either news shocks or conventional (contemporaneous) total factor productivity shocks. Consequently, the right-hand side of Eq. (8) is roughly constant in the face of such shocks. Fluctuations in the relative price of durables will manifest themselves in changes in nondurable consumption in order to bring the marginal utility of nondurables in line with the near constant right-hand side of Eq. (8).

Eq. (4) can, alternatively, be written as

$$U_d\left(C_t, D_t, N_t, \frac{M_t}{P_t}\right) = U_c\left(C_t, D_t, N_t, \frac{M_t}{P_t}\right)\underbrace{\left[q_t - \beta(1-\delta)E_t\left\{q_{t+1}\frac{U_c\left(C_{t+1}, D_{t+1}, N_{t+1}, \frac{M_{t+1}}{P_{t+1}}\right)}{U_c\left(C_t, D_t, N_t, \frac{M_t}{P_t}\right)}\right\}\right]}_{\text{user cost}}. \tag{9}$$

Eq. (9) says that if the household gives up one unit of durables at t, at utility cost $U_d\left(C_t, D_t, N_t, \frac{M_t}{P_t}\right)$, it can purchase q_t units of nondurables. These additional units of nondurables increase utility by $q_t U_c\left(C_t, D_t, N_t, \frac{M_t}{P_t}\right)$. However, the household will have fewer durables in the future which lowers its utility; this effect is captured by the remaining terms in Eq. (9). Put differently, the user cost of durables is its (relative) purchase price less the present value of its resale value.

2.2 Final Good Producers

The durable and nondurable goods sectors are, in terms of notation, the same. So, consider sector j (either durables, d, or nondurables, c). Perfectly competitive final goods producers purchase intermediate goods, $Y_{jt}(i)$, to "assemble" final goods using the technology

$$Y_{jt} = \left[\int_0^1 Y_{jt}(i)^{\frac{\varepsilon_j - 1}{\varepsilon_j}} di\right]^{\frac{\varepsilon_j}{\varepsilon_j - 1}}, \tag{10}$$

where $\varepsilon_j > 0$ is the elasticity of substitution between the differentiated goods in sector j. This setup is quite common in the new Keynesian literature. The final goods firm's cost minimization problem leads to the demand function for intermediate good i,

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

where $P_{jt} = \left(\int_0^1 P_{jt}(i)^{1-\varepsilon_j} di\right)^{\frac{1}{1-\varepsilon_j}}$ is the price of final good j.

2.3 Intermediate Goods Firms

Each sector is populated by a continuum of intermediate firms indexed by $i \in [0,1]$. Firm i faces the demand function Eq. (11) and has access to a technology that only uses labor:

$$Y_{jt}(i) = A_{jt} N_{jt}(i), \tag{12}$$

where A_{jt} is the sector-wide state of technology in sector j.

As in much of the new Keynesian literature, firms probabilistically are able to reoptimize their prices as in Calvo (1983). Specifically, with probability $(1-\omega_j)$, a firm in sector j is able to reoptimize its price; with probability ω_j it cannot. The reoptimization probability is independently and identically distributed across firms and over time. Firms that do not reoptimize their price increase their price by the steady state inflation rate. When a firm can reoptimize its price, it sets its price P^*_{jt} to maximize the following expression for expected discounted profits:

$$E_t \sum_{k=0}^{\infty} \omega_j^k \Delta_{t,t+k} \left[\frac{(1+\tau_j)\pi^k P^*_{jt}}{P_{c,t+k}} Y_{j,t+k} - MC_{j,t+k} Y_{j,t+k} \right], \tag{13}$$

where $MC_{jt} = W_t/(A_{jt}P_{ct})$ is the firm's real marginal cost, π is the steady state gross inflation rate, and $\Delta_{t,t+k}$ is the firm's stochastic discount factor. Since firms are assumed to act in the best interests of their owners (that is, households), $\Delta_{t,t+k} = \beta^k U_c\left(C_{t+k}, D_{t+k}, N_{t+k}, \frac{M_{t+k}}{P_{t+k}}\right) / U_c\left(C_t, D_t, N_t, \frac{M_t}{P_t}\right)$, meaning that the firm discounts real profits (measured in units of the nondurable good), the term in square brackets in Eq. (13), according to the marginal rate of substitution for nondurable goods over time.

In Eq. (13), τ_j is a fixed subsidy rate. As in Rotemberg and Woodford (1997), setting $\tau_j = \frac{1}{\varepsilon_j - 1}$ offsets the distortions to steady state output induced by the markup associated with monopolistic pricing.

In setting its price at t, the firm takes into account the fact that it may have to wait some time until it is able to reoptimize its price. In particular, the probability of not reoptimizing between dates t and $t+k$ is ω_j^k. Since all reoptimizing firms face the same problem, all will choose the same P^*_{jt}. The first-order condition of Eq. (13) yields

$$P_{jt}^{*}=\frac{1}{1+\tau_j}\frac{\varepsilon_j}{\varepsilon_j-1}\frac{E_t\sum_{k=0}^{\infty}\omega_j^k\beta^k\pi^{-\varepsilon_j k}U_c\left(C_{t+k},D_{t+k},N_{t+k},\frac{M_{t+k}}{P_{t+k}}\right)MC_{j,t+k}Y_{j,t+k}P_{j,t+k}^{\varepsilon_j-1}P_{c,t+k}}{E_t\sum_{k=0}^{\infty}\omega_j^k\beta^k\pi^{(1-\varepsilon_j)k}U_c\left(C_{t+k},D_{t+k},N_{t+k},\frac{M_{t+k}}{P_{t+k}}\right)Y_{j,t+k}P_{j,t+k}^{\varepsilon_j-1}}. \tag{14}$$

Given that the opportunity to reoptimize prices arrives probabilistically to each firm each period, the sectoral price index satisfies the recursion,

$$P_{jt}=\left[(1-\omega_j)(P_{jt}^{*})^{1-\varepsilon_j}+\omega_j(\pi P_{j,t-1})^{1-\varepsilon_j}\right]^{\frac{1}{1-\varepsilon_j}}. \tag{15}$$

For future reference, the sectoral gross inflation rate is $\pi_{jt}\equiv P_{jt}/P_{j,t-1}$.

Given how nondurable and durable goods aggregate in preferences (see Eq. (2)), the price index for aggregate final goods is given by

$$P_t=(P_{ct}Y_{ct}+P_{dt}Y_{dt})/(Y_{ct}+Y_{dt}), \tag{16}$$

and the aggregate gross inflation rate is $\pi_t\equiv P_t/P_{t-1}$.

2.4 Productivity

As in Beaudry and Portier (2004) and Christiano et al. (2008), total factor productivity in sector j follows an autoregressive process:

$$\ln A_{jt}=\rho_j\ln A_{j,t-1}+\xi_{j,t-p}+\zeta_{jt},\quad |\rho_j|<1, \tag{17}$$

where $\xi_{j,t-p}\sim N(0,\sigma_{\xi j}^2)$ is the *news shock* while $\zeta\sim N(0,\sigma_{\zeta j}^2)$ is a conventional, *contemporary productivity shock*. Given the setup in Eq. (17), a news shock is a noisy signal of the future state of technology in a sector.

2.5 Monetary Policy

Two alternative characterizations of monetary policy are considered: (1) the central bank follows an interest rate rule; and (2) the central bank follows the policy prescribed by solving a Ramsey problem.

2.5.1 Interest Rate Rule

Here, the central bank follows a Taylor (1993)-style interest rate rule:

$$\ln R_t = \ln R^* + \rho_\pi(\ln \pi_t - \ln \pi) + \rho_y(\ln Y_t - \ln Y) + e_t, \tag{18}$$

where Y_t is aggregate real output, given by $Y_t = Y_{ct} + q_t Y_{dt}$. R^*, π, Y are steady-state interest rate, inflation and aggregate output respectively, and $e_t \sim N(0, \sigma_e^2)$ is a shock to monetary policy.

2.5.2 Ramsey-Optimal Monetary Policy

Alternatively, suppose that the central bank sets its policy according to the solution to a Ramsey problem, as in Levin, Onatski, Williams, and Williams (2006), Kahn, King, and Wolman (2003), Siu (2004), Schmitt-Grohé and Uribe (2004), among others. The central bank's problem is to maximize the representative household's expected lifetime utility, Eq. (1), subject to the households Euler equations and constraints, Eqs. (3)–(7), price setting behavior of reoptimizing firms, Eq. (14), and market clearing conditions, Eqs. (21)–(23). The resulting first-order conditions, along with the equations characterizing firm and household optimization and market clearing conditions, give the solution of the model under the Ramsey-optimal monetary policy.[4]

2.6 Aggregation and Equilibrium

Aggregation follows familiar steps from the new Keynesian literature. Integrating both sides of the intermediate goods production technology, Eq. (12), gives

$$\int_0^1 Y_{jt}(i) = \int_0^1 A_{jt} N_{jt}(i) di = A_{jt} N_{jt}, \tag{19}$$

[4] Allocations under the Ramsey-optimal policy are obtained using Dynare's 'ramsey_policy' command.

where $N_{jt} = \int_0^1 N_{jt}(i)di$. Substituting for $Y_{jt}(i)$ in Eq. (19) using the demand function, Eq. (11), delivers

$$\underbrace{\left[\int_0^1 \left(\frac{P_{jt}(i)}{P_{jt}}\right)^{-\varepsilon_j} di\right]}_{s_{jt}} Y_{jt} = A_{jt} N_{jt}, \tag{20}$$

where s_{jt} captures the inefficiencies associated with price dispersion arising from the Calvo (1983)-style staggered price reoptimization. Recall that at time t, only a fraction $1-\omega_j$ of intermediate good producers are afforded the opportunity to reoptimize their prices.

The definition of a (recursive) equilibrium is fairly standard and is omitted for the sake of brevity. The market clearing conditions are:

$$Y_{ct} = C_t \qquad \text{Nondurables} \tag{21}$$

$$Y_{dt} = D_t - (1-\delta)D_{t-1} \qquad \text{Durables} \tag{22}$$

$$N_t = N_{ct} + N_{dt} \qquad \text{Labor} \tag{23}$$

The equations characterizing equilibrium, including transformations to render nominal magnitudes stationary, are collected in Appendix B.

3 Estimation and Simulation

As An and Schorfheide (2007) point out, estimates of structural parameters generated with straight maximum likelihood procedures based on a set of observations are often at odds with the results obtained in previous micro-econometric or macro-econometric studies. The use of Bayesian techniques incorporates this prior information. This is the approach employed below. Given the estimated parameter values, impulse-responses are, then, generated. The goal is to see whether the model can produce Pigou cycles, meaning a boom in economic activity following receipt of a news shock.

3.1 Baseline Estimation

Some parameters are difficult to estimate because they have very little effect on the likelihood; see Smets and Wouters (2003) and Ireland (2001), among others. These parameters are set based on *a priori* information and are summarized in Table 1. As in Rotemberg and Woodford (1992) and Ireland (2001), the elasticity of demand for retail goods, is set to 6 so that the steady-state markup of retail price over wholesale goods price is 20%. The parameter μ, which governs the curvature of preferences over real money balances, is set to 2.56 so that the interest elasticity of money demand is 0.39, the value estimated by Chari, Kehoe, and McGrattan (2000). The parameter χ, which scales real money balances in preferences, is set to 0.0001 so that the ratio of real money balance to output is equal to 0.13, a value consistent with the ratio of M1 to GDP measured using postwar U.S. data. The remaining parameters/targets are fairly self-explanatory and/or standard in the literature.

The remaining parameters are estimated via Bayesian techniques as in Schorfheide (2000), Smets and Wouters (2003), Lubik and Schorfheide (2004), Rabanal and Rubio-Ramirez (2005), Lubik and Schorfheide (2006) and Smets and Wouters (2007). Estimation requires first casting the model in a state space representation and applying the Kalman filter to calculate the likelihood function as in Hamilton (1994). This likelihood function is then combined with a prior density for the model parameters to obtain the posterior distribution of the parameters. The five variables appearing in the observation equation are: average labor productivity in the nondurable goods sector, A_{ct}[5]; average labor productivity in the durable goods sector, A_{dt}; aggregate output, Y_t; the nominal interest rate, R_t; and the inflation rate, π_t. The model is estimated using U.S. data over the period 1964Q1–2011Q2. Sectoral productivities are measured by sectoral output per hour worked, where durable sector output is measured by real per capita durable goods consumption, and nondurable sector output is measured by real per capita nondurable consumption plus services; aggregate output is measured by the real per capita GDP; the nominal interest rate is measured by the federal fund rate. The data are described in more detail in Appendix A.

The third to fifth columns in Table 2 reports the assumptions regarding the prior distribution of the parameters to be estimated. The prior distribution of the model's parameters are formed following the practice in the Bayesian estimation literature; see, for example, Schorfheide (2000), Smets and Wouters

[5]Given that output is linear in labor, average labor productivity coincides with total factor productivity.

Table 1: Calibrated Parameters

Parameter	Value	Target	Value
β	0.99	Annual real interest rate	4%
δ	0.058	Quarterly depreciation rate	5.8%
α	0.77	Durables share of output	0.25
σ	1	Frisch labor supply elasticity	1
υ	0.94	Steady state labor	1
μ	2.56	Interest elasticity of money demand	0.39
χ	0.0001	Steady state money to output ratio	0.129
ε_c, ε_d	6	Steady state markup	20%
π	1.01	Annual steady state inflation rate	4%

(2003), Lubik and Schorfheide (2004), Rabanal and Rubio-Ramirez (2005), Lubik and Schorfheide (2006) and Smets and Wouters (2007). The prior over the elasticity of substitution between durables and nondurables is a gamma with mean 0.2 and standard deviation 0.05. The mean is the same value used by Beaudry and Portier (2004). As in Smets and Wouters (2003), the priors governing the nominal rigidities in the two sectors is set to a beta with mean 0.75 and standard deviation 0.1. The use of a beta distribution ensures that the probability that a firm does not reoptimize its price is strictly between zero and one. The mean corresponds to an average duration between price adjustments of four quarters which is consistent with the empirical evidence as surveyed by Taylor (1999). The standard deviation implies fairly diffuse priors (see Figure 1) and so covers previous estimates in the literature. The priors over the coefficients in the interest rate rule are gamma, as in Lubik and Schorfheide (2006) and Smets and Wouters (2007), and centered on conventional values for the Taylor rule. Priors for the autoregressive parameters in the two sectors are beta with mean 0.7 and standard deviation 0.05. Schmitt-Grohé and Uribe (2010) use the same distribution and mean, but a more dispersed prior. Gamma distributions are chosen for the prior over the shocks. As Schmitt-Grohé and Uribe (2010) point out, the use of a gamma distribution, rather than the more usual inverse gamma, allows for positive density at zero, and so allowing for the possibility that some of the shocks simply do not matter. For the technology shocks, the means are set to 0.05 and the standard deviations to 0.025. The mean for the monetary policy shock is smaller, 0.01. Finally, the correlations over the shocks have priors that are normally distributed with means of zero and standard deviations of 0.3. Figure 2 shows that these priors are diffuse.

Figures 1 and 2 plot the prior and posterior distributions while Table 2 reports the means and 90%

confidence intervals of the posterior distributions of the model's parameters (see columns six through eight). The posterior for the elasticity of substitution between durables and nondurables, η, is 0.3673 which means that durables and nondurables are complements in utility. This value is larger than that used by Beaudry and Portier (2004); an implication is that the estimated value allows more substitution between durables and nondurables than Beaudry and Portier. Table 11 reveals that estimation of this parameter is sensitive to the prior distribution. In Table 11, the prior for η is uniform with a mean of 0.99 (close to the Cobb-Douglas case). The posterior mean is around 0.85, much higher than reported in Table 2.

The estimated probability of *not* reoptimizing prices are 0.8162 for nondurables and 0.7272 for durables. These probabilities imply an average duration between price reoptimizations of 5.44 quarters in the nondurable goods sector, and 3.67 quarters in the durable goods sector. This ordering is consistent with observations in Bils and Klenow (2004) that prices are less sticky for durable goods than for nondurables. Table 6 reports estimates when the probability of nonadjustment is 0.5, the value used by Lubik and Schorfheide (2004), which corresponds to an average duration between price reoptimization of two quarters, a value conformable with the evidence presented in Bils and Klenow (2004). The parameter estimates are not very sensitive to the priors over these parameters.

The policy parameters are estimated to be slightly lower than their prior means, but are nonetheless close to those estimated by Taylor (1993) and Clarida, Galí, and Gertler (2000). Lowering the prior mean on the output parameter and raising that on inflation to bring the prior means closer to the estimated values in Clarida, Galí, and Gertler (2000) has little effect on the estimated parameters; see Table 7.

The level of technology is estimated to be quite persistent. Nondurable sector total factor productivity has an autoregressive parameter of 0.9307 which is fairly close to the conventional value used in the real business cycle literature, 0.95. The autoregressive parameter in the durable sector is less persistent; its estimated value is 0.7493. Table 8 provides estimates under more dispersed priors for these autoregressive parameters. For both parameters, looser priors result in somewhat higher values.

In both sectors, the standard deviation of the news shock is estimated to be *slightly* larger than that of the contemporaneous shock. The volatility of the durable sector shocks are considerably higher than the nondurable sector shocks, although the lower autoregressive parameter in the durable sector dampens

Table 2: Benchmark Estimation Results

Parameter	Description	Prior Distribution			Posterior Distribution		
		Type	Mean	Std. Dev.	Mean	90% interval	
η	elasticity of substitution between nondurables and durables	gamma	0.2	0.05	0.3673	0.2704	0.5019
ω_c	nominal rigidity in nondurable sector	beta	0.75	0.1	0.8162	0.8069	0.8264
ω_d	nominal rigidity in durable sector	beta	0.75	0.1	0.7272	0.7008	0.7546
ρ_y	policy reaction to output	gamma	0.5	0.05	0.3870	0.3365	0.4395
ρ_π	policy reaction to inflation	gamma	1.5	0.1	1.4615	1.3731	1.5383
ρ_c	persistence of shocks in nondurable sector	beta	0.7	0.05	0.9307	0.9275	0.9327
ρ_d	persistence of shocks in durable sector	beta	0.7	0.05	0.7493	0.7107	0.7830
Standard deviations:							
$\sigma_{\xi c}$	nondurable sector news shock	gamma	0.05	0.025	0.0184	0.0170	0.0198
$\sigma_{\zeta c}$	nondurable sector contemporaneous shock	gamma	0.05	0.025	0.0180	0.0157	0.0195
$\sigma_{\xi d}$	durable sector news shock	gamma	0.05	0.025	0.0639	0.0558	0.0725
$\sigma_{\zeta d}$	durable sector contemporaneous shock	gamma	0.05	0.025	0.0629	0.0564	0.0710
σ_e	monetary shock	gamma	0.01	0.005	0.0163	0.0145	0.0179
Shock correlations:							
$\sigma_{\xi c\zeta c}$	nondurable news, nondurable contemporaneous	normal	0.0	0.3	−0.5807	−0.6712	−0.4701
$\sigma_{\xi c\xi d}$	nondurable news, durable news	normal	0.0	0.3	−0.6269	−0.6973	−0.5598
$\sigma_{\xi c\zeta d}$	nondurable news, durable contemporaneous	normal	0.0	0.3	−0.1210	−0.2159	−0.0034
$\sigma_{\xi ce}$	nondurable news, monetary	normal	0.0	0.3	0.0682	−0.0218	0.1640
$\sigma_{\zeta c\xi d}$	nondurable contemporaneous, durable news	normal	0.0	0.3	0.4598	0.3837	0.5607
$\sigma_{\zeta c\zeta d}$	nondurable contemporaneous, durable contemporaneous	normal	0.0	0.3	−0.3914	−0.4952	−0.2861
$\sigma_{\zeta ce}$	nondurable contemporaneous, monetary	normal	0.0	0.3	−0.0834	−0.1850	0.0294
$\sigma_{\xi d\zeta d}$	durable news, durable contemporaneous	normal	0.0	0.3	−0.0783	−0.2145	0.0684
$\sigma_{\xi de}$	durable news, monetary	normal	0.0	0.3	−0.0337	−0.1583	0.0957
$\sigma_{\zeta de}$	durable contemporaneous, monetary	normal	0.0	0.3	−0.0313	−0.1436	0.1021
log data density	−2527.16						

Figure 1: Prior and Posterior Distributions

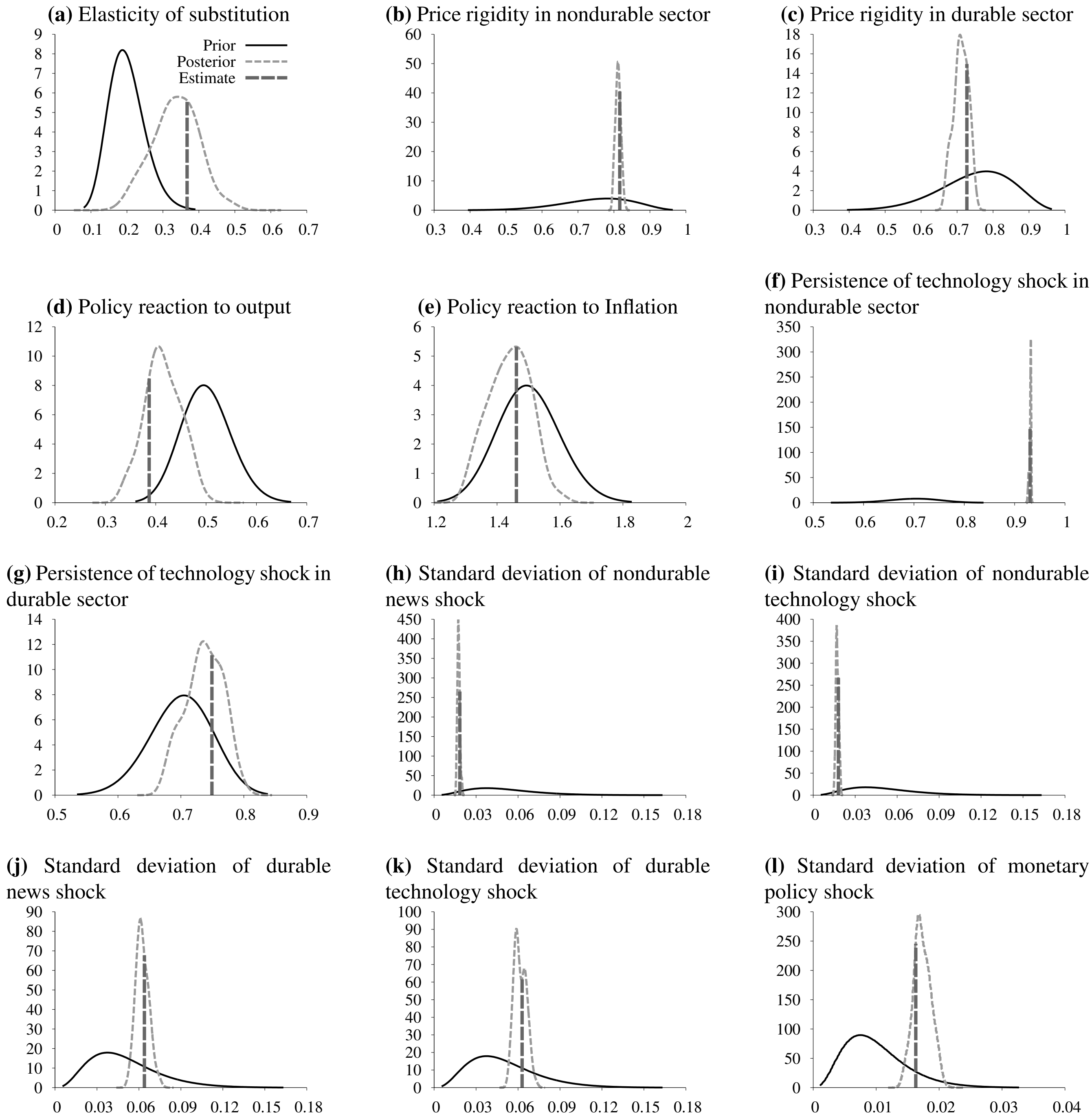
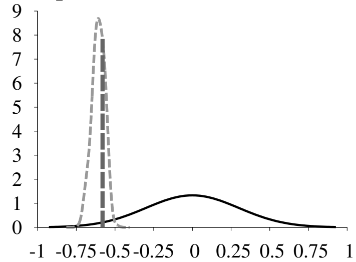
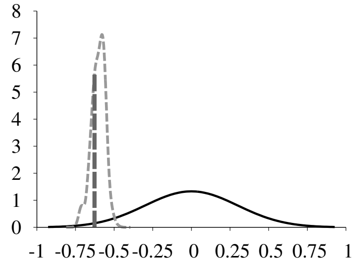


Figure 2: Prior and Posterior Distributions: Shock Correlations

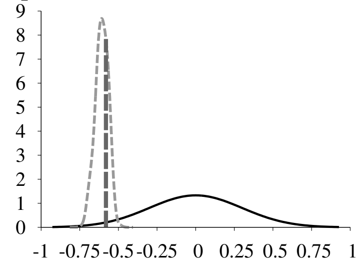
(a) Nondurable news, nondurable contemporaneous



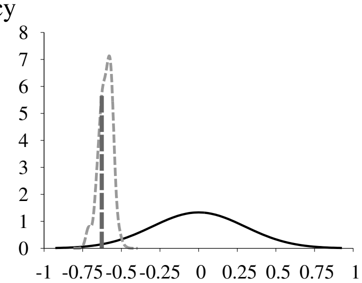
(b) Nondurable news, durable news



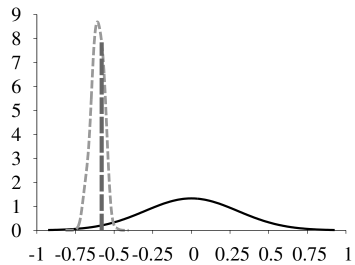
(c) Nondurable news, durable contemporaneous



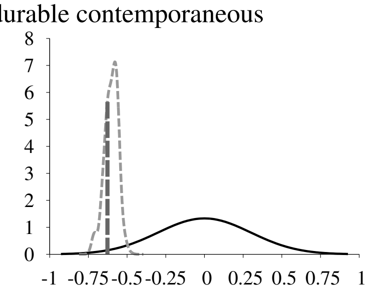
(d) Nondurable news, monetary policy



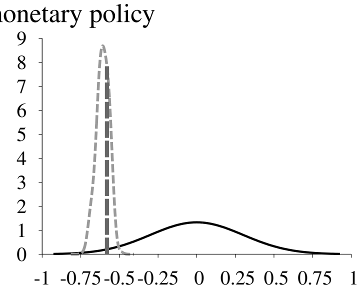
(e) Nondurable contemporaneous, durable news



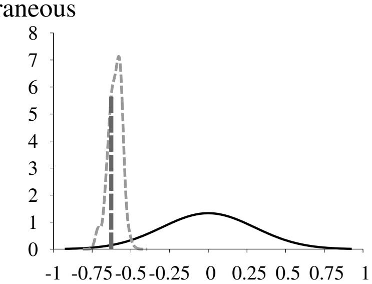
(f) Nondurable contemporaneous, durable contemporaneous



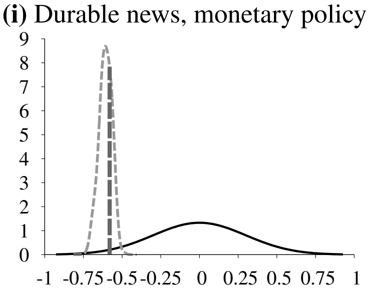
(g) Nondurable contemporaneous, monetary policy



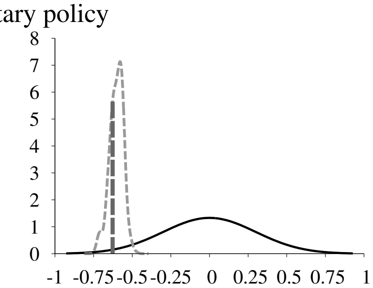
(h) Durable news, durable contemporaneous



(i) Durable news, monetary policy



(j) Durable contemporaneous, monetary policy



the effect on the level of total factor productivity. As well, the durable sector is considerably smaller than the nondurable sector which means that durable sector shocks have a relatively small effect on aggregate output. Table 9 re-estimates the model imposing a prior with a much lower mean on the standard deviations of the contemporaneous shocks; Table 10 repeats the exercise for news shocks. In both cases, the model's estimates are little changed.

Turn next to the correlations between the shocks. Recall that the priors over these correlations are quite disperse, allowing the data to speak more forcefully. To start, the correlation between the nondurable sector shocks is estimated to be large and negative, -0.5807, implying that news shocks in this sector are largely offset by subsequent contemporaneous shocks. In contrast, the correlation between the durable sector shocks is indistinguishable from zero. The correlation between the two news shocks is also large and negative: -0.6269. Similarly, the correlation between the two contemporaneous shocks is sizable and negative, -0.3914. These last two correlations stand in contrast to the two sector interpretation of the one sector growth model in which the correlation between the shocks in the two sectors is necessarily one. The other correlation that is substantially different from zero is that between the contemporary shock in the nondurable sector and the durable sector news shock; its value is 0.4598. It is, perhaps, of interest that the correlations with the monetary policy shock are all estimated to be insignificantly different from zero.

There is a final parameter to comment upon: p, the number of periods in advance that a news shock is revealed. The model is estimated for a variety of values for p; Table 2 corresponds to $p = 7$ which maximizes the (log) data density.

3.2 Impulse-Responses

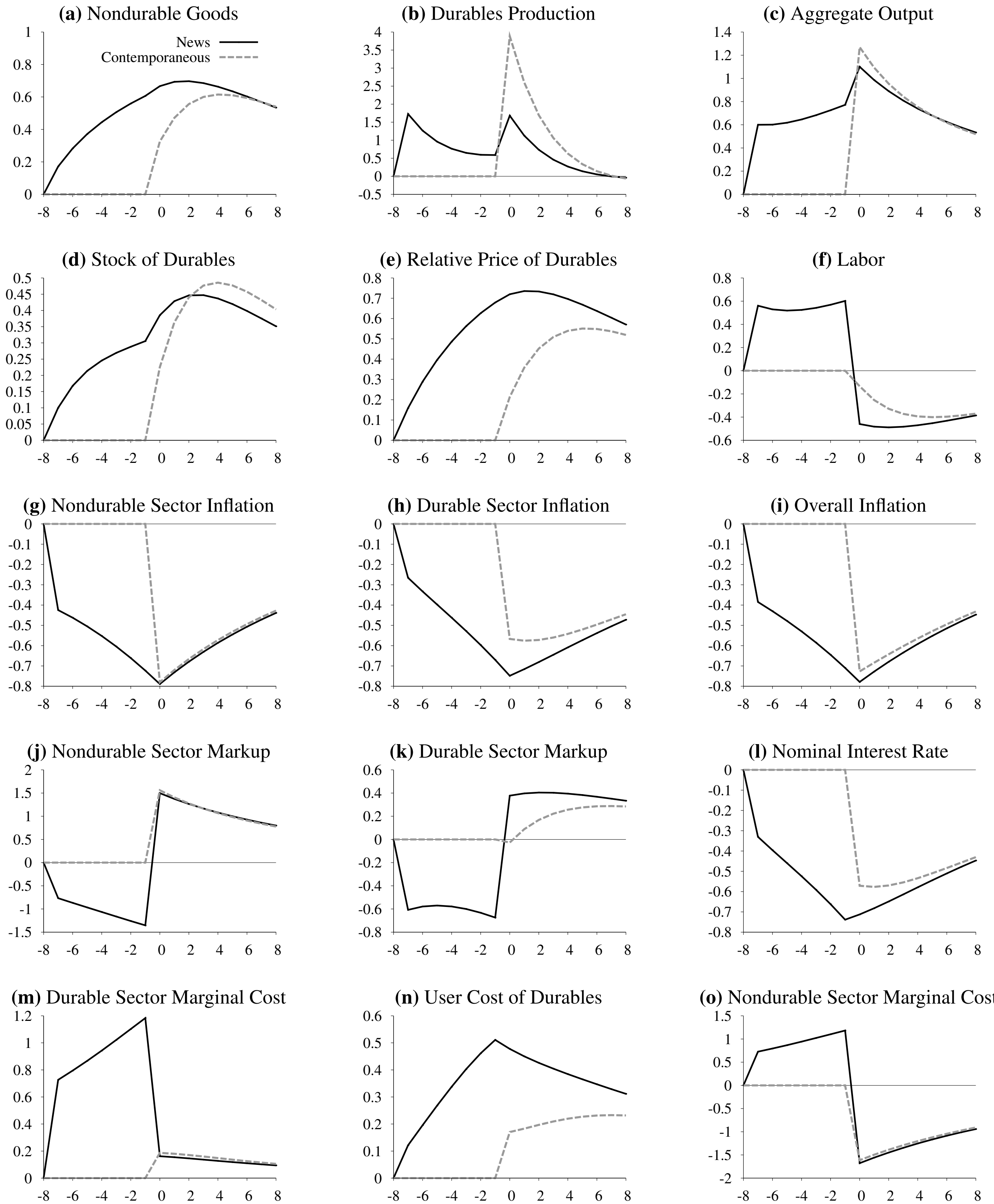
This subsection presents impulse-responses to the model's shocks. In order to concentrate exclusively on the effects of a particular shock, the correlations between the shocks are set to zero so that an impulse to one shock do not spill over to any of the other shocks. Simulations of the model with correlated shocks gives qualitatively similar results, but are harder to interpret.

Figure 3 presents impulse-responses for: (a) a nondurable sector news shock received at time $t = -7$, and so coming into effect at $t = 0$; and (b) a nondurable sector contemporaneous shock received at $t = 0$.

Both shocks are positive one standard deviation events, and the responses are expressed as percentage deviations from steady state. The first item of note is that from time $t = 0$ forward, the effects for the two shocks are qualitatively similar, particular for aggregate output and overall inflation. However, under a news shock, variables move in advance of the realization of the shock at $t = 0$. Of particular interest is the fact that a nondurable sector news shocks leads to a boom in economic activity, manifested in both sectors, and so in employment and aggregate output. Observing a positive response of macroeconomic variables to a news shock is an important component of the Pigou cycle literature. The dynamics following a news shock are determined by three factors. First, the news shock makes households feel wealthier and so, all else the same, they would like to consume more nondurables, durables and leisure, the last of which implies lower labor. However, to accommodate increased output requires *more* labor which means that the real wage must increase to entice households to provide that labor. This increase in the real wage necessarily increases firms' marginal costs. Second, the news shock implies that, in the future, the marginal cost of producing nondurables will be lower. Owing to the nominal rigidities, intermediate goods firms are forward-looking and set their current price (if they are able to adjust it) based on current and future expected marginal costs. Consequently, nondurable intermediate goods producers start lowering their prices in advance of the news shock realization; see Figure 3g. Third, the dynamics of durables depends on the behavior of the relative price of durables which is determined by the interplay of the decisions made by both households and firms. Households' purchases of durables also have a forward-looking element owing to their relatively long lives. If, as in Figure 3e, the relative price of durables rises quickly, then households will buy up durables *before* its price has risen too much. In this case, the steep rise in the price of durables prior to the realization of the news shock at $t = 0$ leads to a durable sector boom. As will be seen later, monetary policy also plays an important role in generating Pigou cycles.

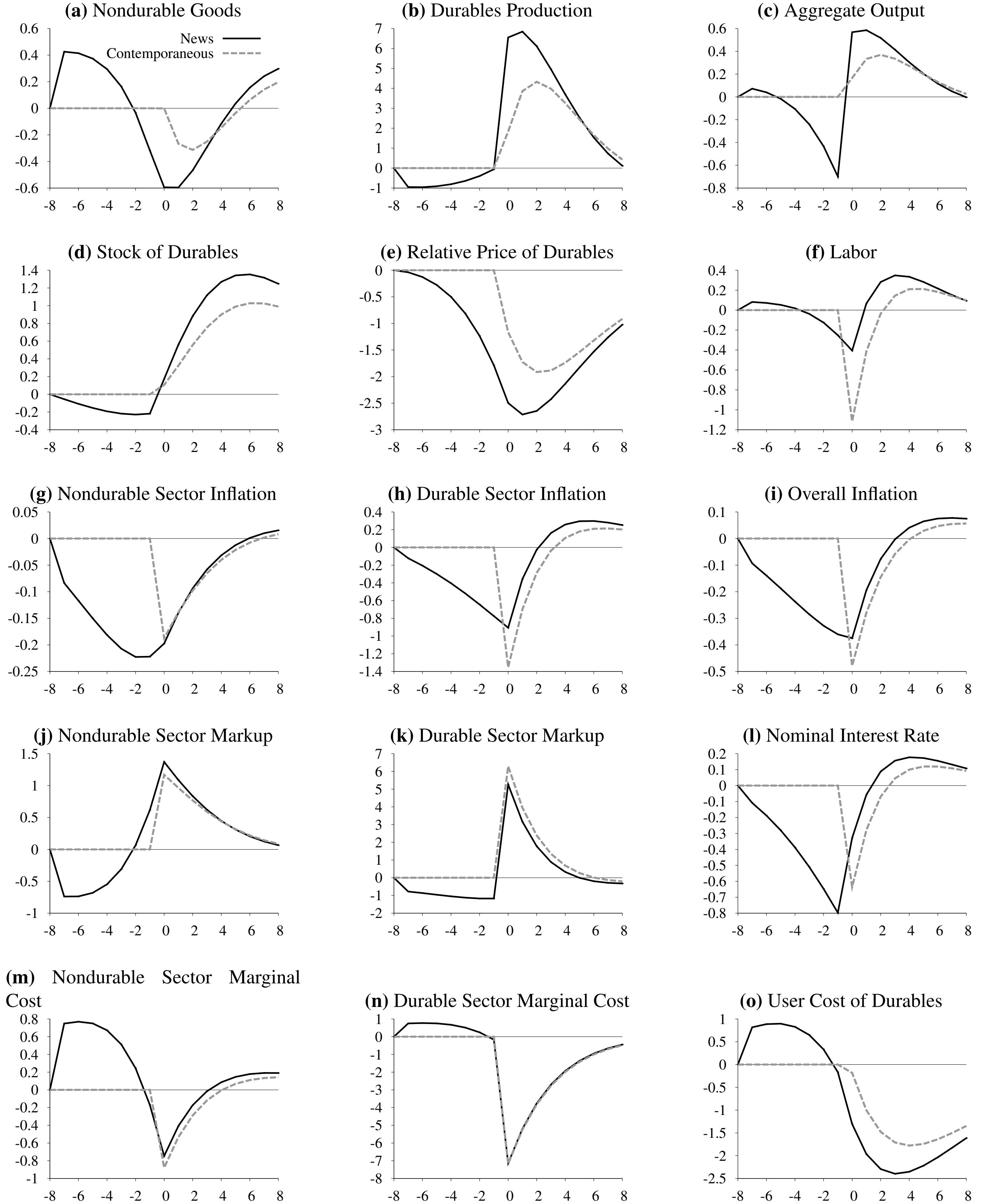
The effects of a durable sector news shock and contemporaneous shock are presented in Figure 4. Again, the news shock is observed at $t = -7$ and realized at $t = 0$ while the contemporaneous shock occurs at $t = 0$. As above, the shocks are positive, one standard deviation events. Concentrating on the effects of the news shock, while the nondurable sector booms immediately, the durable sector does not. In fact, until the realization of the shock at $t = 0$, durable sector output is below steady state. As with the nondurable news shock, the behavior of the relative price of durables is key to the response of the

Figure 3: Responses to Nondurable Good Sector Shocks



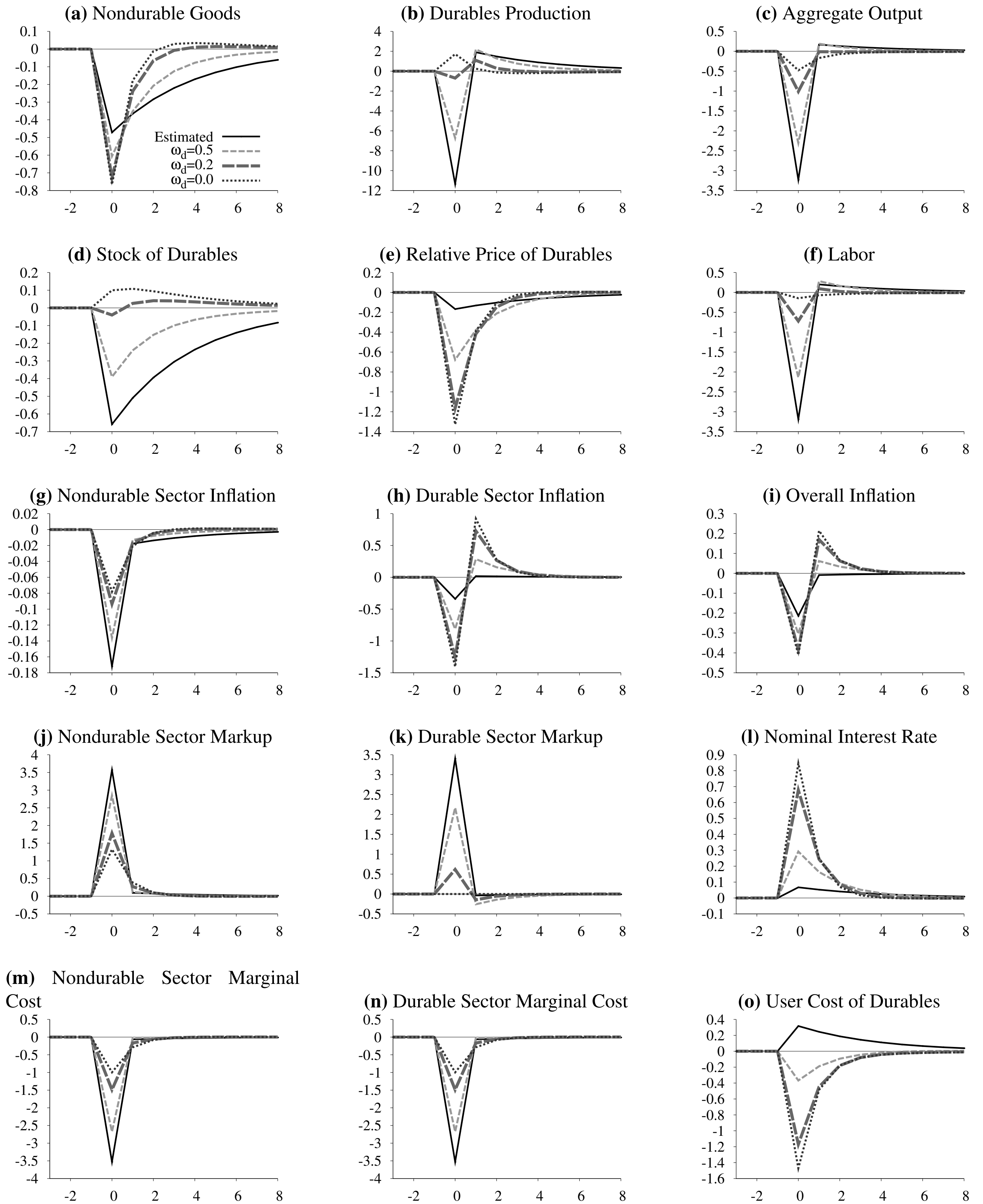
Notes: The nondurable sector news shock is a shock to total factor productivity that is revealed at time $t = -7$ that will take effect at $t = 0$. The contemporaneous shock is also a shock to total factor productivity except it is revealed at $t = 0$ and takes effect at $t = 0$.

Figure 4: Responses to Durable Good Sector Shocks



Notes: The durable sector news shock is a shock to total factor productivity that is revealed at time $t = -7$ that will take effect at $t = 0$. The contemporaneous shock is also a shock to total factor productivity except it is revealed at $t = 0$ and takes effect at $t = 0$.

Figure 5: Responses to a Monetary Policy Shock



Notes: The shock is a positive monetary policy shock occurring at time $t = 0$. Results are presented for varying degrees of durable sector price rigidities: estimated (an average duration between price re-optimizations of 3.67 quarters), $\omega_d = 0.5$ (average duration, 2 quarters), $\omega_d = .2$ (average duration, 1.25 quarters) and $\omega_d = 0$ (average duration, 1 quarter or perfectly flexible prices).

durable sector. In this case, the relative price of durables *falls* in the periods prior to the realization of the news shock, leading households to delay their purchases of durables. Households can afford to put off their purchases of durables since the stock of durables responds more modestly than purchases of new durables. As a result, there is a durable sector bust prior to the realization of the shock. Similar results are obtained in Beaudry and Portier (2004).

Finally, the responses to a monetary policy shock can be found in Figure 5. This shock corresponds to a positive innovation to the interest rate rule, Eq. (18) – that is, a tightening of monetary policy. The solid line presents the responses under the estimated parameter values. To understand these results, it is perhaps easiest to first consider what happens under perfectly flexible durables prices (the dotted line). Perfectly flexible durables prices corresponds to the case in which ω_d, the non-reoptimization probability, equals zero. Tighter monetary policy reduces inflation in both sectors. When durables prices are flexible, the price of durables falls sharply, as does the relative price of durables. This sharp fall in the relative price of durables encourages consumers to purchase more durables, partly offsetting the effect of tighter monetary policy. At the same time, purchases of nondurables falls. The net result is what has come to be termed the *comovement problem* whereby a monetary policy shock leads to *opposite* movements in durables and nondurables. The data, on the other hand, point to positive comovement between the two sectors following such a shock; see Erceg and Levin (2006). Return now to the estimated parameter values (solid line). The estimated price non-reoptimization probability in the durable goods sector is 0.7272 which corresponds to an average duration between price reoptimizations of 3.67 quarters. The durable sector nominal rigidities now imply a more modest fall in inflation in that sector. As a result, the fall in the relative price of durables is much smaller than when durables prices are flexible. The fall in the relative price of durables is no longer sufficient to offset the contractionary effects of the monetary policy shock and durables purchases fall on impact, as does that of nondurables. Thus, on impact, the estimated model exhibits positive comovement between durables and nondurables. In subsequent periods, the relative price of durables is rising, leading households to increase their durables purchases above steady state while that of nondurables remains below its steady state level. In other words, the estimated model presents a partial resolution of the comovement problem.

Figure 5 also presents results for intermediate degrees of durable sector nominal rigidities. The short dashed line sets $\omega_d = 0.5$ which corresponds to an average duration between price reoptimizations of 2 quarters while the long dashed line sets $\omega_d = 0.2$ (a duration of 1.25 quarters). Only for $\omega_d = 0$ – which implies an average duration between price reoptimizations of 1 quarter, meaning perfectly flexible durables prices – does the comovement problem appear. In other words, only when durables prices are (nearly) flexible does the comovement problem arise.

The results in Figure 5 fit nicely with those in Sterk (2010). His model without credit frictions also exhibits the comovement problem when durables prices are flexible. He likewise finds that modest degrees of nominal rigidities in the durables sector lead to positive comovement at the time of the shock, and that as the degree of rigidity increases, so does the number of quarters with a positive comovement between durables and nondurables. One interesting difference is that for 3 or 4 quarters of durable sector price stickiness, Sterk finds that the nominal interest rate actually *falls* following a monetary policy shock. In contrast, in Figure 5l the nominal interest rate uniformly rises, even for the estimated degree of durable sector price rigidity which corresponds to an average duration between price reoptimization of 3.67 quarters.

In light of results in the literature concerning the comovement problem, it is natural to ask what features in the model ameliorate this problem.[6] Figure 6 shows that our partial resolution of the comovement problem is insensitive to a wide range of elasticities of substitution between durables and nondurables, holding the degree of durable goods price rigidity at its estimated value. Most papers that address the comovement problem, starting with Barsky, House, and Kimball (2007), assume a Cobb-Douglas aggregator over durables and nondurables. Figure 7 presents results for $\eta = 0.9999$ – that is, very close to the Cobb-Douglas case – and varies the degree of durable sector price rigidity. Comparing Figure 5 with Figure 7 shows that increasing the elasticity of substitution between durables and nondurables means that the comovement problem manifests itself for a larger range of durable sector price stickiness. Our benchmark estimate of this elasticity implies that durables and nondurables are complements in utility. In other words, the two are not very good substitutes, and the household tends to prefer that increases in nondurables consumption be accompanied by increases in durables consumption.[7]

[6]We also considered policy rules that target inflation more or less strongly, as well as rules that target output more or less strongly. Qualitatively, the results are similar to those presented in Figure 5.

[7]There is no particularly compelling reason to think that this elasticity should be equal to one; an elasticity different from one is quite consistent with balanced growth, for example. It should also be kept in mind that the estimated elasticity, 0.3673, is larger than that used by Beaudry and Portier (2004) in their early work on Pigou cycles.

Figure 6: Responses to a Monetary Policy Shock: Different Elasticities of Substitution

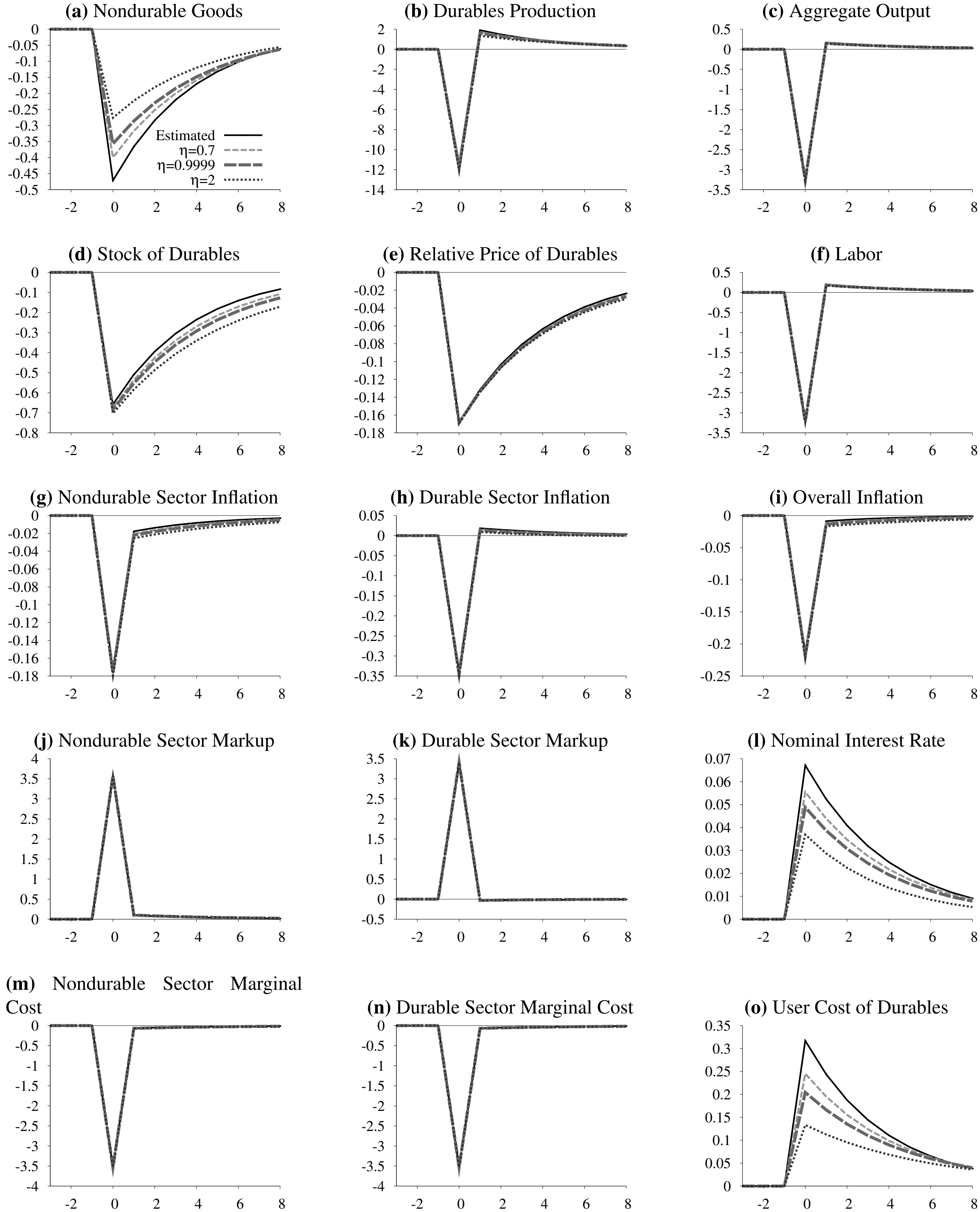
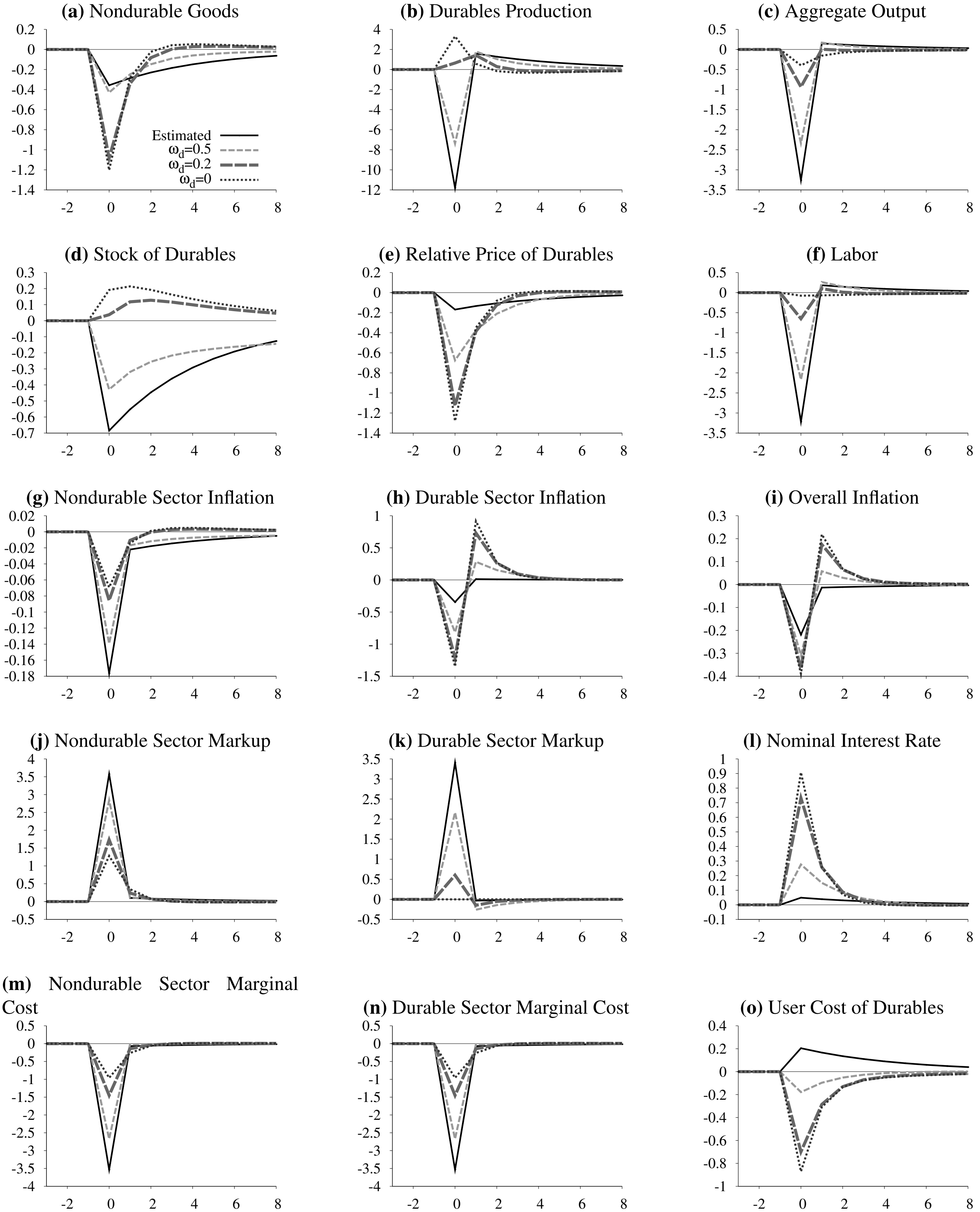


Figure 7: Responses to a Monetary Policy Shock: Higher Elasticity of Substitution ($\eta = 0.9999$), Varying Degrees of Durable Sector Nominal Rigidity



4 The Sources of Pigou Cycles

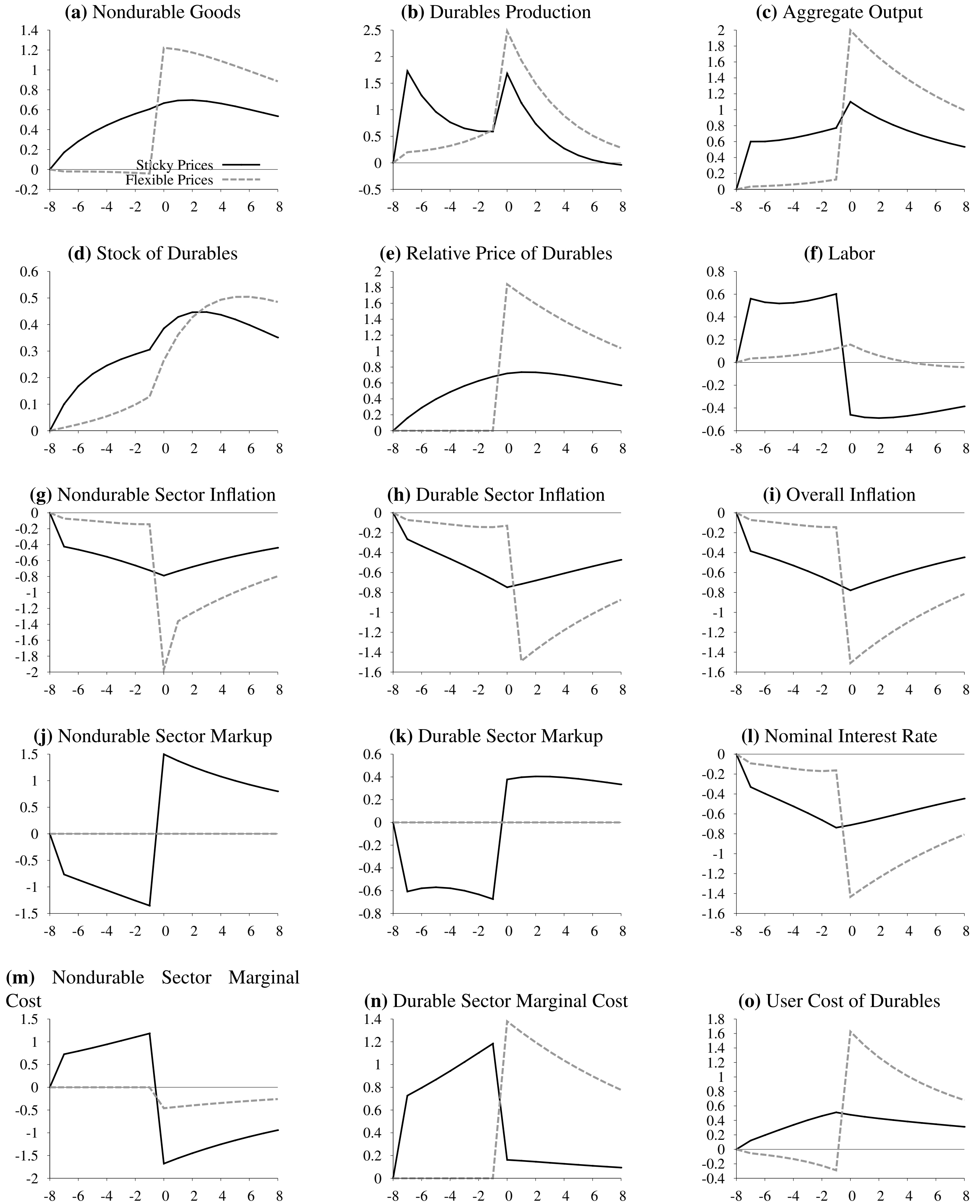
As seen in Figure 3, Pigou cycles develop in response to nondurable sector news shocks (but not durable sector news shocks, as reported in Figure 4). What model features account for the Pigou cycles? This section assesses the roles of nominal rigidities, monetary policy, and money-in-the-utility function.

4.1 Nominal Rigidities

Figure 8 traces out impulse-responses following a nondurable sector news shock for the benchmark estimated model, and for a version of the model that allows prices to be fully flexible (by setting the non-reoptimization probabilities, ω_c and ω_d, to zero). Flexible prices mute the response of nondurables production: it is essentially zero until the shock is realized. As previously discussed, With sticky prices, nondurable intermediate good producers are forward-looking, setting their prices based on current and expected future marginal costs. Since the news shock implies a fall in future marginal costs, with sticky prices the price of nondurables starts falling immediately. Under flexible prices, the decline in the price of nondurables is quite modest leading up to the shock, then falls sharply; see Figure 8g which plots nondurable sector inflation. The earlier discussion of the effects of news shocks pointed out that the relative price of durables was key to the dynamics of durables output. Under flexible prices, the relative price of durables does not change until the realization of the news shock. Since households foresee a future increase in this relative price, they purchase durables in the periods leading up to the realization of the shock. Price stickiness serves two roles in the model. First, it induces more forward-looking behavior among firms in their pricing decisions, leading to larger movements in the price of nondurables in the periods leading up to the realization of the shock, thus leading to a greater nondurable sector output response. Second, price stickiness leads to an increase in the relative price of durables upon receipt of the news shock which leads to a heightened response of durable sector output. As discussed earlier, households buy more durables when they foresee a rise in the relative price of durables. Under both flexible and sticky prices, the price of durables rises; the only difference is that under sticky prices the rise is more gradual than with flexible prices which sees a sharp rise in the relative price of durables when the news shock takes effect.

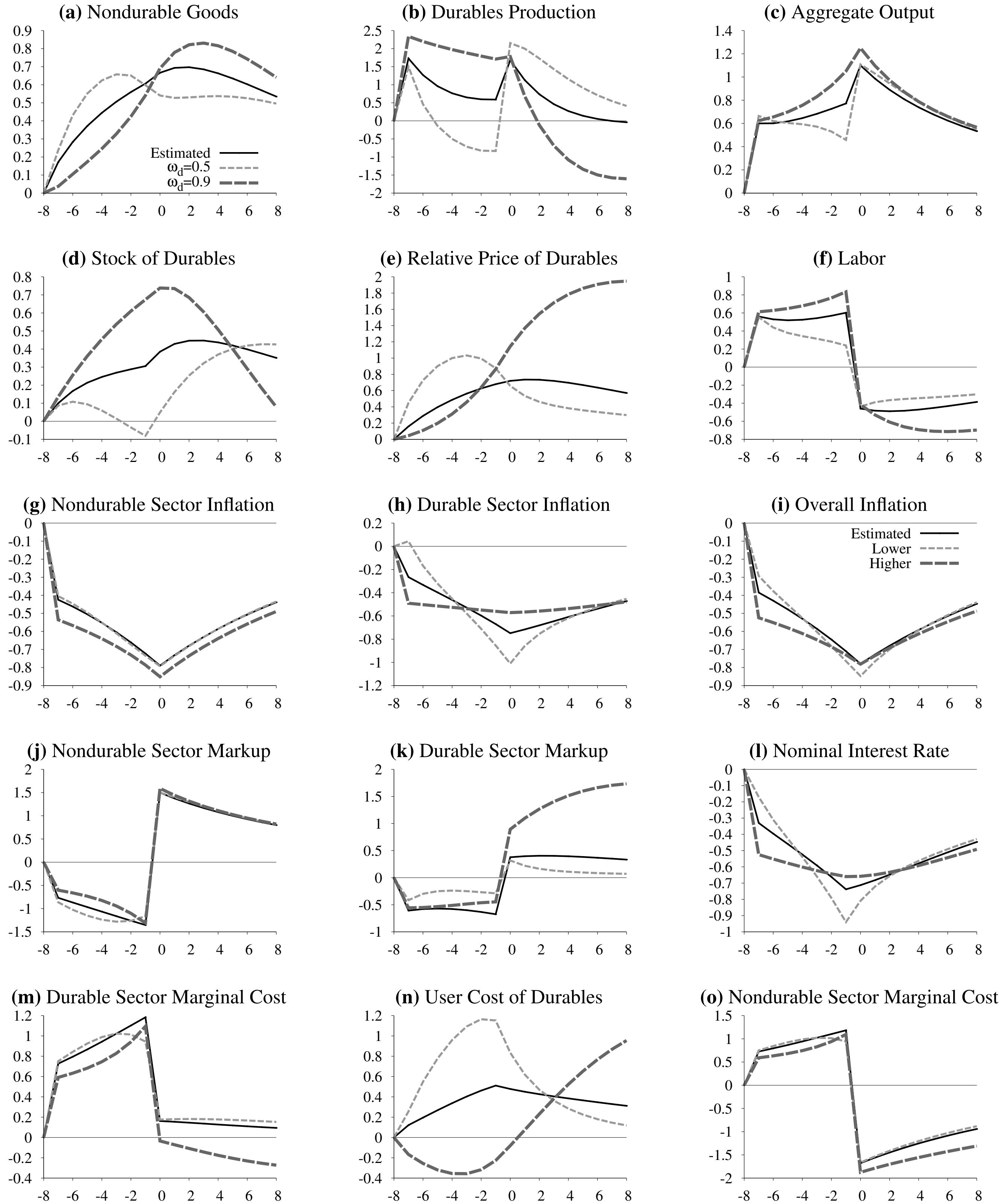
Figure 9 gives the responses to a nondurable sector news shock for different degrees of durable sector

Figure 8: Responses to Nondurable Good Sector News Shock With and Without Nominal Rigidities



Notes: A nondurable sector news shock is a shock to total factor productivity that is revealed at time $t = -7$ that will take effect at $t = 0$.

Figure 9: Responses to Nondurable Good Sector News Shock: Various Durable Sector Nominal Rigidities



Notes: A nondurable sector news shock is a shock to total factor productivity that is revealed at time $t = -7$ that will take effect at $t = 0$.

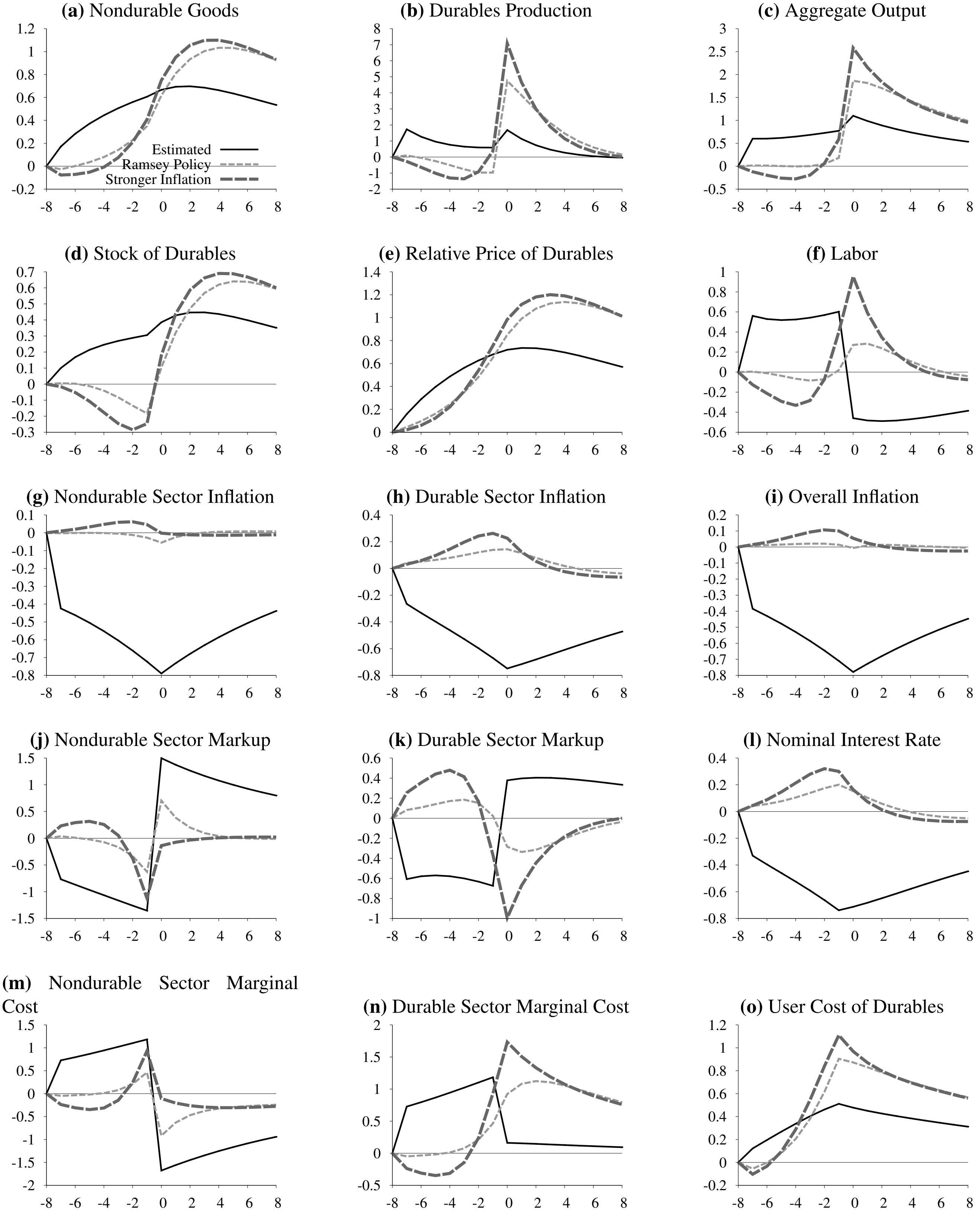
price rigidity, holding nondurable sector price rigidity at its estimated value. In particular, this figure considers less durable sector price rigidity ($\omega_d = 0.5$) and more ($\omega_d = 0.9$); the estimated value of ω_d is 0.7272. While greater durable sector price stickiness continues to lead to Pigou cycles, Figure 9 shows that with lower durable sector price rigidity, the model does not generate Pigou cycles. Specifically, for $\omega_d = 0.5$, there is an initial boom in durable sector output, followed by a bust in the 5 quarters immediately prior to the realization of the news shock. This dynamic is, once again, a consequence of the movements in the relative price of durables. In this case, the relative price rises sharply, plateaus 3 or 4 quarters before the realization of the shock, then falls. In anticipation of this path for the relative price of durables, households initially increase their purchases of durables before they become quite expensive. Later, households are willing to hold off on their purchases of durables since they foresee that the relative price will soon fall.

4.2 Monetary Policy

Rather than the estimated interest rate rule, suppose that monetary policy is conducted according to the precepts of the Ramsey rule introduced in Section 2.5.2. Figure 10 compares the responses to a nondurable sector news shock in the benchmark model with those obtained under the Ramsey-optimal policy. The key result is that the Ramsey-optimal policy does not lead to Pigou cycles. In particular, immediately upon receipt of the news, nondurable production falls slightly while that of durables rises somewhat. In subsequent periods, nondurable output rises above its steady state level while durable sector output falls below. Overall output stays very close to its steady state value until the shock takes effect at which point it rises sharply.

To explain why the Ramsey policy does not generate Pigou cycles, it is necessary to reexamine some implications of the Ramsey policy. Recall that the Ramsey problem seeks to maximize expected lifetime utility of the representative agent, subject to private optimization conditions and constraints. The distortions associated with monopoly pricing have already been offset through a production subsidy. The other important distortion is that associated with variation in the within-sector relative prices of intermediate goods (that is, among nondurable intermediate goods, and among durable intermediate goods). Since non-reoptimizing firms index their prices to the average rate of inflation, these within-sector relative

Figure 10: Responses to Nondurable Good Sector News Shock Under Alternative Monetary Policy Rules



Notes: "Estimated" refers to a Taylor rule with a coefficients on inflation $\rho_\pi = 1.4615$ and output $\rho_y = 0.3870$. The Ramsey policy is as described in Section 2.5.2. "Stronger Inflation" corresponds to an interest rate rule with $\rho_\pi = 3$ and $\rho_y = 0$.

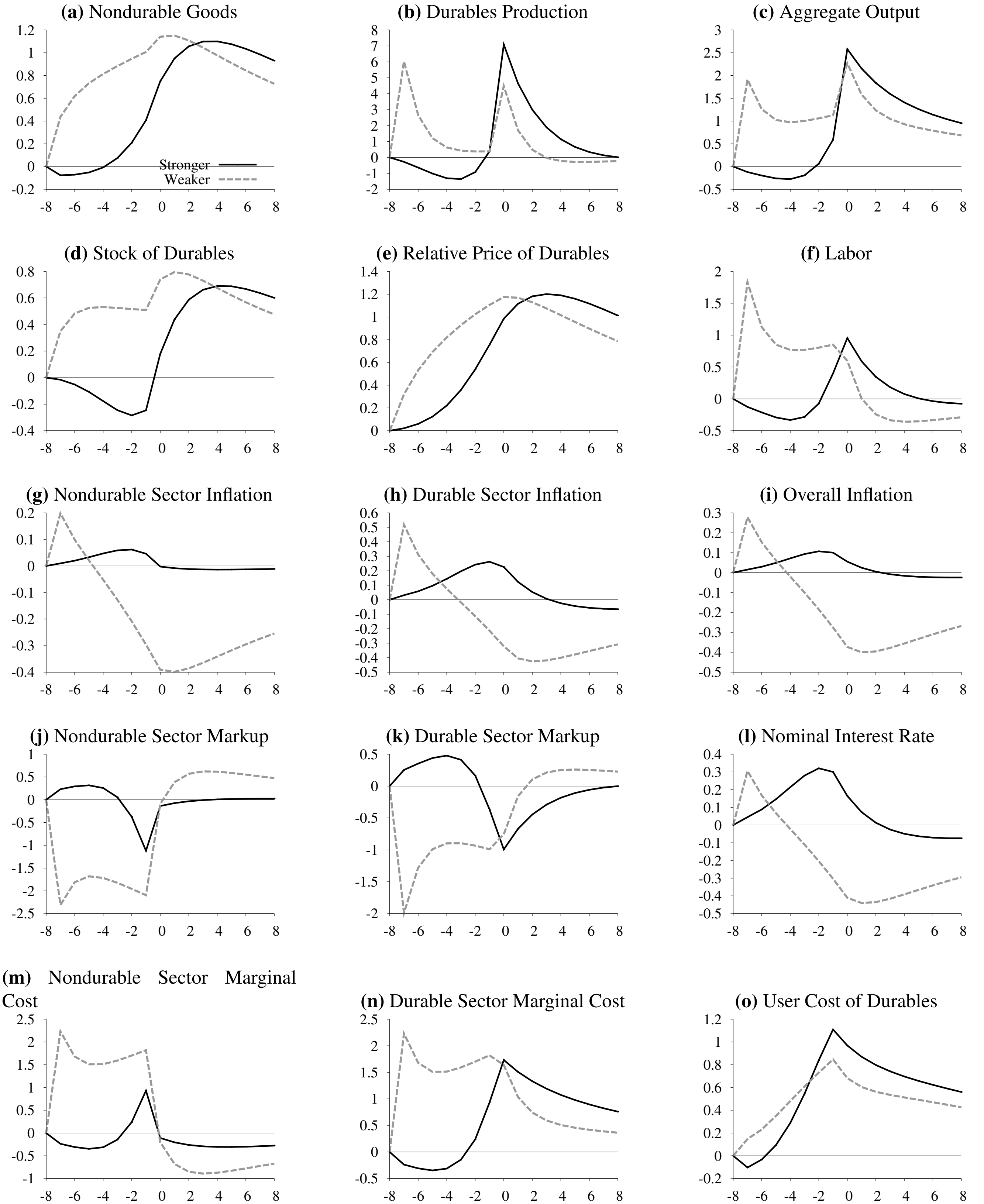
price distortions would be minimized by keeping sectoral inflation at its steady state value. Figures 10g and 10h show that the Ramsey policy does, in fact, keep sectoral inflation rates near their steady state levels. Owing to the different inflation responses, the Ramsey policy implies a more gradual increase in the relative price of durables than is seen under the estimated policy rule. Accordingly, under the Ramsey policy households put off their purchases of durables until the realization of the news shock when they also increase their purchases of nondurables. (Recall that durables and nondurables are complements in utility.) The Ramsey policy also calls for a more contractionary monetary policy as reflected in either the nominal interest rate, or the real rate (which can be inferred from the behavior of the nominal interest rate and inflation).

Further evidence that it is the response of sectoral inflation rates that are behind the Pigou cycle results of the estimate model can be garnered by looking at a monetary policy that more strongly targets inflation. Specifically, the parameter on inflation, ρ_π, is set to 3 (compared to 1.4615 in the estimated model) while that on output, ρ_y, is set to zero (as opposed to 0.3870). Under this policy, inflation in both sectors rises above steady state, although not by as much as these inflation rates fall below steady state under the estimated policy. Compared to the estimated policy, the relative price of durables rises more gradually and the nondurable sector news shock actually results in a bust in both sectors. Under the strong inflation targeting rule, the nominal and real interest rates rise more than under either the Ramsey or estimated policies. In other words, contractionary monetary policy also plays a role in the dynamics in this case. Under strong inflation targeting, this contractionary policy results in a fall in aggregate output.

To further drive home the point concerning the importance of the sectoral inflation rates, Figure 11 presents impulse responses for the strong inflation target described above ($\rho_y = 0$ and $\rho_\pi = 3$) as well as a weak inflation target ($\rho_y = 0$ and $\rho_\pi = 1.1$). The weak inflation targeting rule allows for greater inflation variation both at the sectoral and aggregate levels. Of particular interest is the observation that with the weak inflation target, the relative price of durables rises quickly upon receipt of the nondurable news shock. As emphasized earlier, it is this rapid rise that leads to a boom in durable sector output as households purchase durables in advance of the rise in their relative price.

Figure 12 considers two other monetary policy rules: one that more strongly targets output ($\rho_\pi = 3$ and $\rho_y = 1$), the other that weakly targets output ($\rho_\pi = 3$ and $\rho_y = 0$). The stronger output targeting rule

Figure 11: Responses to Nondurable Good Sector News Shock with Different Weights on Inflation in the Interest Rate Rule



Notes: In both cases, the coefficient on output is $\rho_y = 0$. "Stronger" corresponds to a coefficient on inflation of $\rho_\pi = 3$; "Weaker" sets $\rho_\pi = 1.1$

dampens the response of output to the news shock, and allows for greater movements in inflation. As a result, the relative price of durables rises faster under the strong output targeting rule than under the weak targeting rule. Once more, households build up their stock of durables in advance of the rapid rise in the relative price of durables implied by the strong output targeting rule.

The results of the experiments in this subsection are summarized in Figure 13. To generate this figure, the model was solved for a variety of different combinations of (ρ_y, ρ_π), the parameters governing the responses to output and inflation, respectively, in the interest rate rule. All other parameters were kept at their estimated values. Parameter combinations that lead to Pigou cycles are contained in the shaded region in Figure 13. The larger is the weight on output, the larger must the weight on inflation be to avoid Pigou cycles. For example, when the weight on output is 0, Pigou cycles do not occur when the weight on inflation is 1.5 or higher. When the weight on output is 0.2, the weight on inflation must be greater than 2.5 to avoid Pigou cycles. Recall that the estimated parameters are $\rho_y = 0.3870$ and $\rho_\pi = 1.4615$ which are well within the region leading to Pigou cycles.

4.3 Cash-in-advance Constraint

To evaluate the role played by money-in-the-utility function, suppose that money demand is motivated instead by a cash-in-advance constraint. Replace preferences by

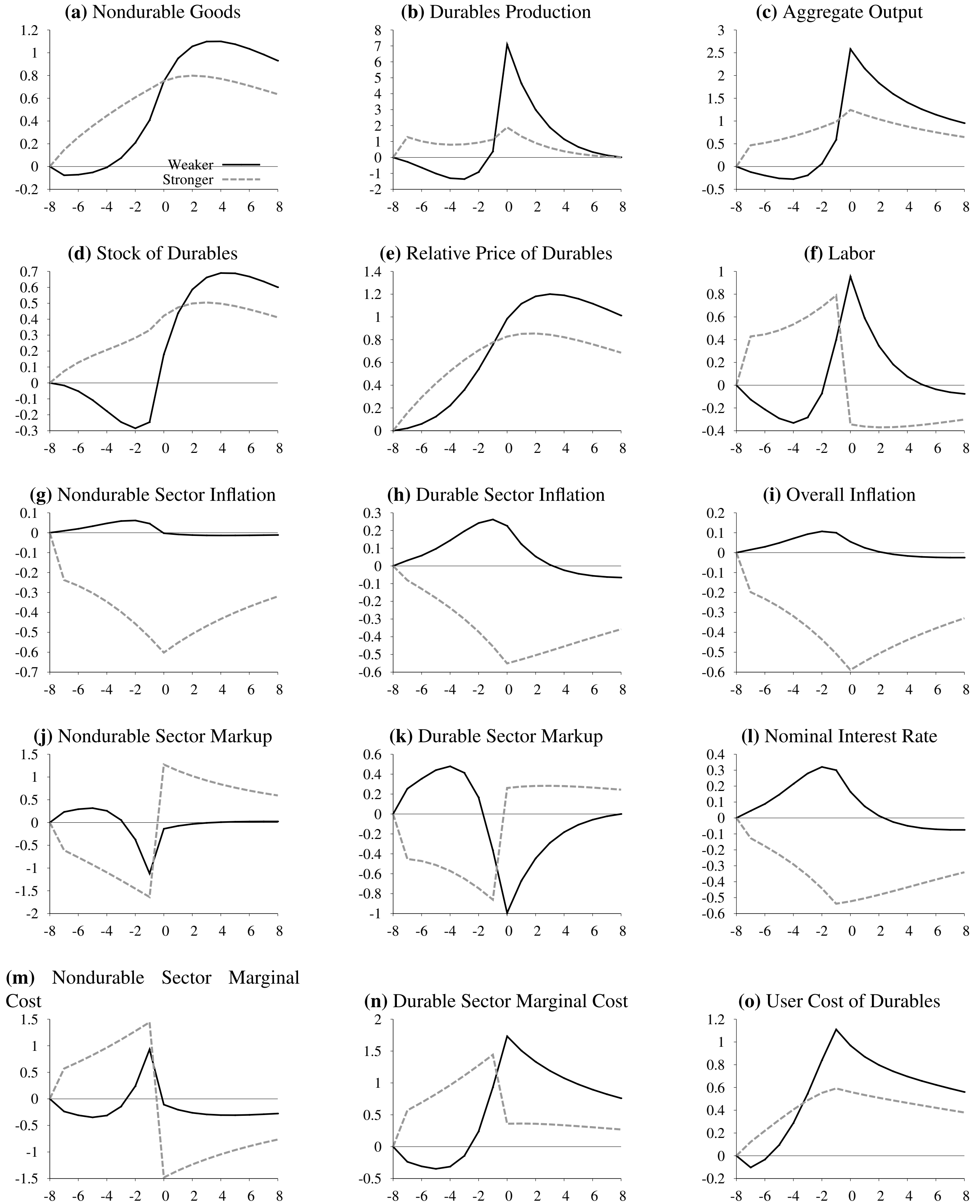
$$E_0 \sum_{t=0}^{\infty} \beta^t U\left(C_t, D_t, N_t\right), \quad 0 < \beta < 1 \tag{24}$$

where U is as in Eq. (2) except for the omission of the real balances. In addition, the household now faces a cash-in-advance constraint that applies to purchases of both durables and nondurables:

$$P_{ct} C_t + P_{dt} \left[D_t - (1-\delta) D_{t-1}\right] \leq M_{t-1}. \tag{25}$$

Estimates of the cash-in-advance model are presented in Table 3. The estimates are broadly similar to those obtained for the benchmark model. The parameters governing total factor productivity – the news and contemporaneous shocks – are very similar across the two estimations. The cash-in-advance estimates exhibit a lesser degree of nominal rigidities in both sectors, as well as larger policy reaction

Figure 12: Responses to Nondurable Good Sector News Shock with Different Weights on Output in the Interest Rate Rule

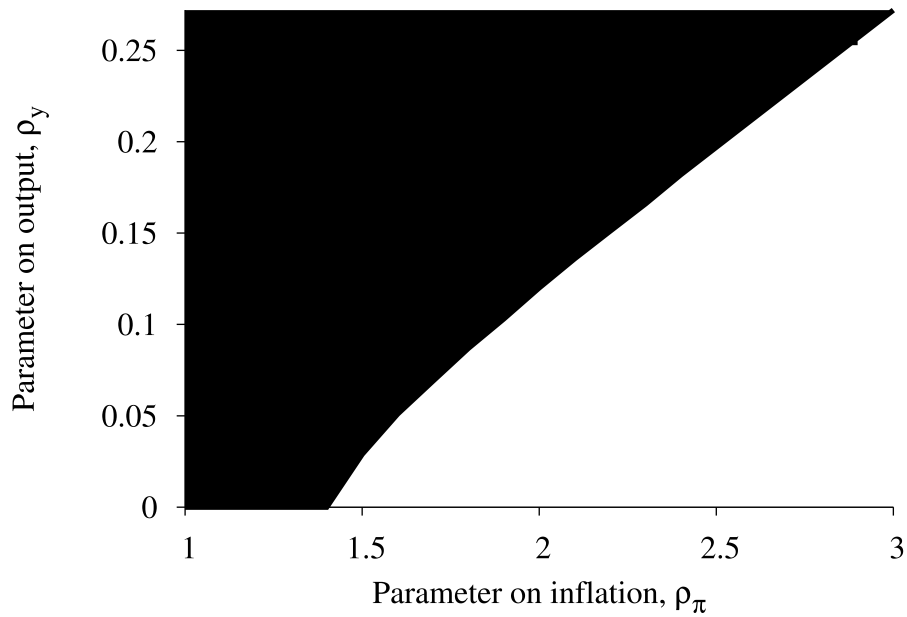


Notes: In both cases, the coefficient on inflation is $\rho_\pi = 3$. "Stronger" sets $\rho_y = 1$ while "Weaker" corresponds to $\rho_y = 0$.

Table 3: Estimation Results: Model with Cash-in-advance

Parameter	Description	Prior Distribution			Posterior Distribution		
		Type	Mean	Std. Dev.	Mean	90% interval	
η	elasticity of substitution between nondurables and durables	gamma	0.2	0.05	0.2264	0.1653	0.3009
ω_c	nominal rigidity in nondurable sector	beta	0.75	0.1	0.8006	0.7800	0.8184
ω_d	nominal rigidity in durable sector	beta	0.75	0.1	0.6868	0.6659	0.7116
ρ_y	policy reaction to output	gamma	0.5	0.05	0.4467	0.4088	0.5058
ρ_π	policy reaction to inflation	gamma	1.5	0.1	1.6645	1.5823	1.7715
ρ_c	persistence of shocks in nondurable sector	beta	0.7	0.05	0.9308	0.9277	0.9328
ρ_d	persistence of shocks in durable sector	beta	0.7	0.05	0.8707	0.8297	0.9265
Standard deviations:							
$\sigma_{\xi c}$	nondurable sector news shock	gamma	0.05	0.025	0.0196	0.0178	0.0210
$\sigma_{\zeta c}$	nondurable sector contemporaneous shock	gamma	0.05	0.025	0.0185	0.0168	0.0201
$\sigma_{\xi d}$	durable sector news shock	gamma	0.05	0.025	0.0560	0.0457	0.0698
$\sigma_{\zeta d}$	durable sector contemporaneous shock	gamma	0.05	0.025	0.0573	0.0512	0.0658
σ_e	monetary shock	gamma	0.01	0.005	0.0185	0.0167	0.0211
Shock correlations:							
$\sigma_{\xi c \zeta c}$	nondurable news, nondurable contemporaneous	normal	0.0	0.3	−0.6126	−0.6853	−0.5524
$\sigma_{\xi c \xi d}$	nondurable news, durable news	normal	0.0	0.3	−0.6441	−0.7047	−0.5312
$\sigma_{\xi c \zeta d}$	nondurable news, durable contemporaneous	normal	0.0	0.3	−0.0505	−0.1569	0.0556
$\sigma_{\xi ce}$	nondurable news, monetary	normal	0.0	0.3	0.0862	0.0003	0.1728
$\sigma_{\zeta c \xi d}$	nondurable contemporaneous, durable news	normal	0.0	0.3	0.4612	0.3989	0.5561
$\sigma_{\zeta c \zeta d}$	nondurable contemporaneous, durable contemporaneous	normal	0.0	0.3	−0.6032	−0.6566	−0.5047
$\sigma_{\zeta ce}$	nondurable contemporaneous, monetary	normal	0.0	0.3	−0.0945	−0.2097	−0.0010
$\sigma_{\xi d \zeta d}$	durable news, durable contemporaneous	normal	0.0	0.3	−0.0323	−0.1379	0.1113
$\sigma_{\xi de}$	durable news, monetary	normal	0.0	0.3	−0.0401	−0.1293	0.0647
$\sigma_{\zeta de}$	durable contemporaneous, monetary	normal	0.0	0.3	0.0334	−0.0601	0.1697
log data density	−2614.46						

Figure 13: Policy parameter region that results in Pigou cycles

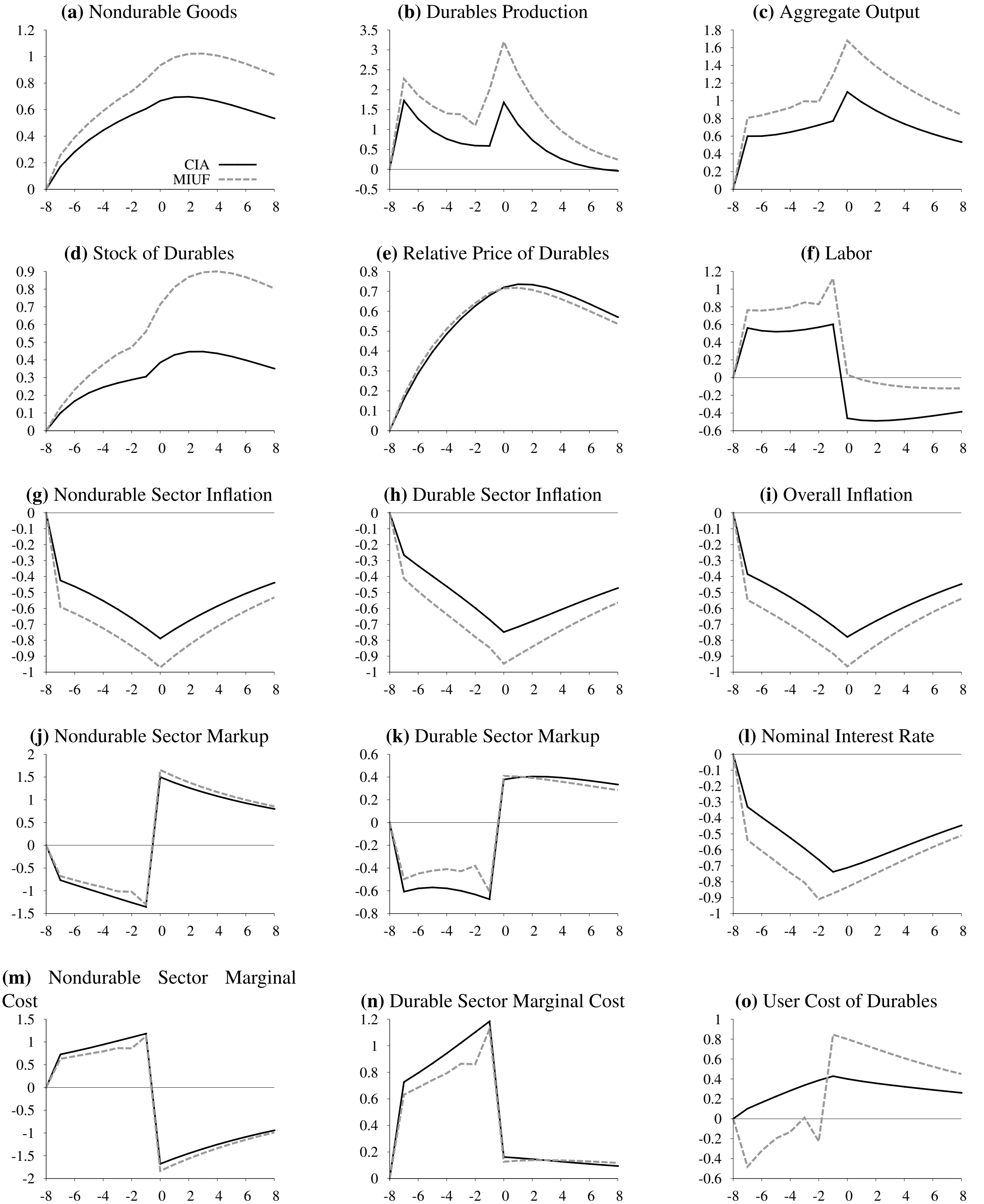


Note: Pigou cycles occur in the shaded region.

parameters to both output and inflation. Overall, though, the estimates are broadly similar.

Figure 14 presents impulse-responses for a nondurable sector news shock for both the estimated cash-in-advance model as well as the benchmark money-in-the-utility-function model. Overall, the responses of the cash-in-advance model are qualitatively similar to those obtained with money-in-the-utility function, although the responses of most variables are dampened relative to the benchmark model.

Figure 14: Responses to Nondurable Sector News Shock: Money-in-the-Utility Function (MIUF) compared to Cash-in-advance (CIA)



Notes: A nondurable sector news shock is a shock to total factor productivity that is revealed at time $t = -7$ that will take effect at $t = 0$.

5 Historical Simulations

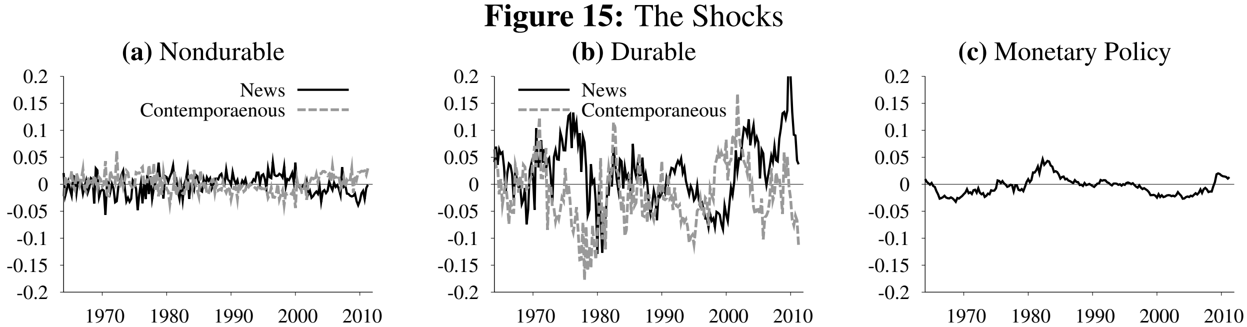
The task in this section is to evaluate the historical contribution of the shocks in the model. The actual shocks are presented in Figure 15. Although it may be difficult to see, the shocks have correlation patterns similar to those estimated in Table 2. In particular, the shocks to the nondurable sector are fairly strongly negatively correlated as are the two news shocks as well as the two contemporaneous shocks.

By construction, when all five shocks are in play, the model replicates the dependent variables exactly. Here, attention is focused on aggregate output. To assess the contributions of various shocks, one or more shocks are zeroed out for a simulation. Comparing the actual path of output with that predicted when a shock is zero gives the contribution of that particular shock. These results are summarized in Figure 16.

To start, the contributions of the durable sector shocks are quite modest. To see this, consider the durable sector news shock. Figure 16a shows that the model's prediction for the path of output when this shock is zero is very close to actual output, indicating that the contribution of the durable sector news shock is small. Similarly, Figure 16d shows that excluding the contemporaneous durable sector shock has little effect. Not surprisingly, Figure 16g shows that the joint contribution of the durable sector shocks is similarly modest.

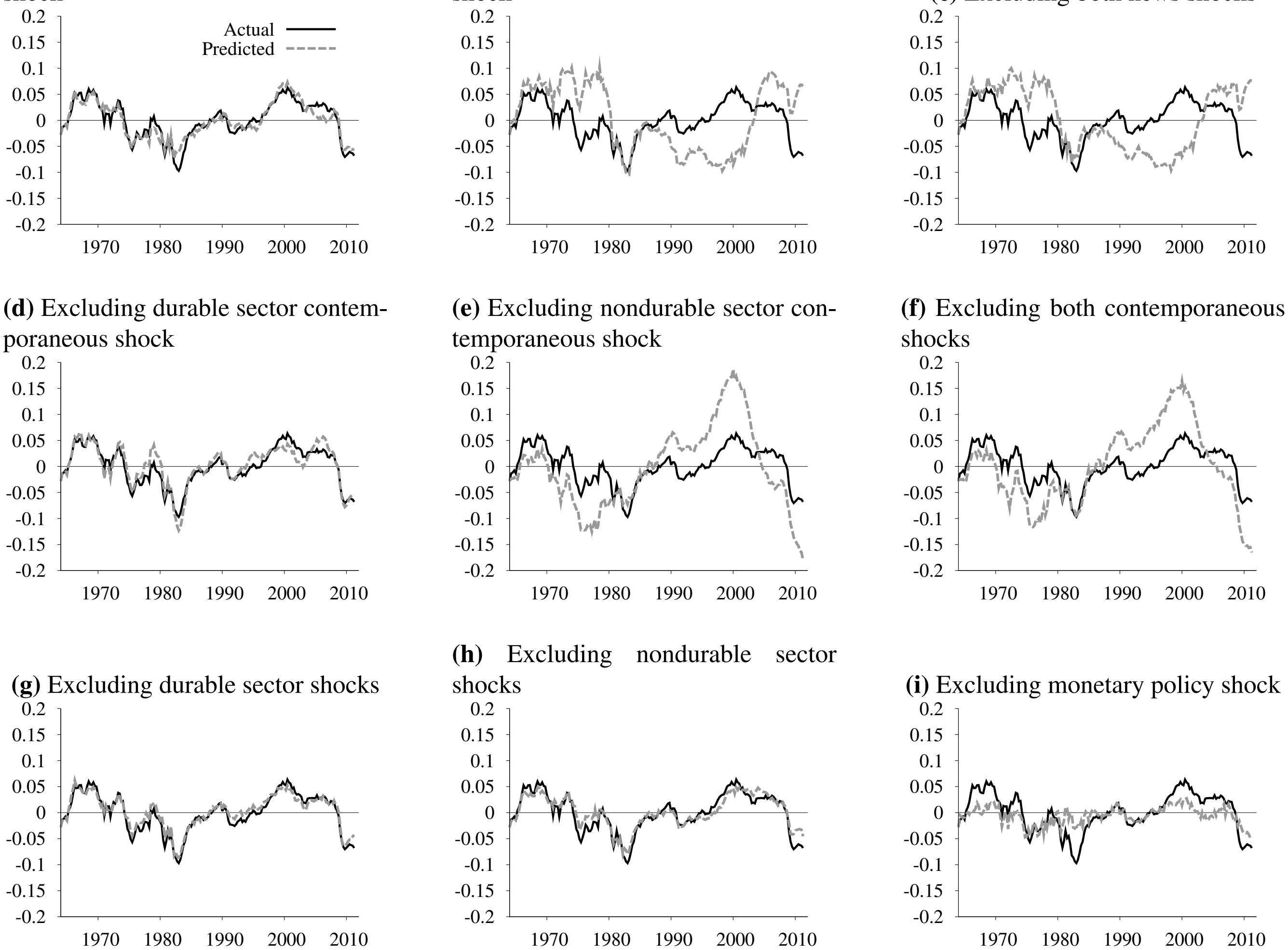
Individually, the nondurable sector shocks have rather substantial effects on the path of output. Simulating the model without the nondurable sector news shock, presented in Figure 16b, shows substantial deviations from actual output. Likewise, Figure 16e reveals that the nondurable sector contemporaneous shock likewise has large effects on output. However, the joint contribution of the nondurable sector shocks is far more modest owing to the negative correlation between (the innovations to) these two

Figure 15: The Shocks



Notes: The shocks correspond to what Dynare refers to as "smoothed shocks" which use all the information in the sample (as opposed to using only information based on past information only).

Figure 16: Model Simulations of Deviations of Output from Trend Using Historical Shock Series



(a) Excluding durable sector news shock

(b) Excluding nondurable sector news shock

(c) Excluding both news shocks

(d) Excluding durable sector contemporaneous shock

(e) Excluding nondurable sector contemporaneous shock

(f) Excluding both contemporaneous shocks

(g) Excluding durable sector shocks

(h) Excluding nondurable sector shocks

(i) Excluding monetary policy shock

Notes: If all the shocks are included, the model simulations replicate actual output exactly, by construction. "Predicted" gives the model's prediction for detrended output when one or more of the shocks is set to zero. The effect of a particular shock can, then, be gauged by the difference between actual and predicted.

shocks; see Figure 16h. Broadly speaking, the nondurable sector news shock pushed output down over the 1970s, boosted output from the mid-1980s through the early 2000s at which point its influence once more became negative. An opposite pattern is observed with respect to the nondurable sector contemporaneous shock.

The effects of monetary policy shocks can be found in Figure 16i. While the effects of the monetary policy shocks are smaller than either of the nondurable sector shocks, their effects are larger than the joint contribution of the nondurable sector shocks. In the late 1960s and early 1970s, monetary policy shocks raised output. These shocks pushed output down in the early- to mid-1980s. Between 1995 and 2005, monetary shocks again boosted output. Since then, monetary policy shocks have exerted a negative influence.

Viewed through the lens of this model, the events from 2008 through 2011, the financial crisis period, can be interpreted as follows. Monetary policy shocks had a negative influence on output. While nondurable sector news shocks pushed output down, nondurable sector contemporaneous shocks raised output. The net effect of these latter two shocks was to depress output somewhat. While the individual effects of the durable sector shocks is small, their net effect on output was also negative. In other words, shocks to the durable and nondurable sectors as well as monetary policy all contributed to below average output performance over 2008–11.

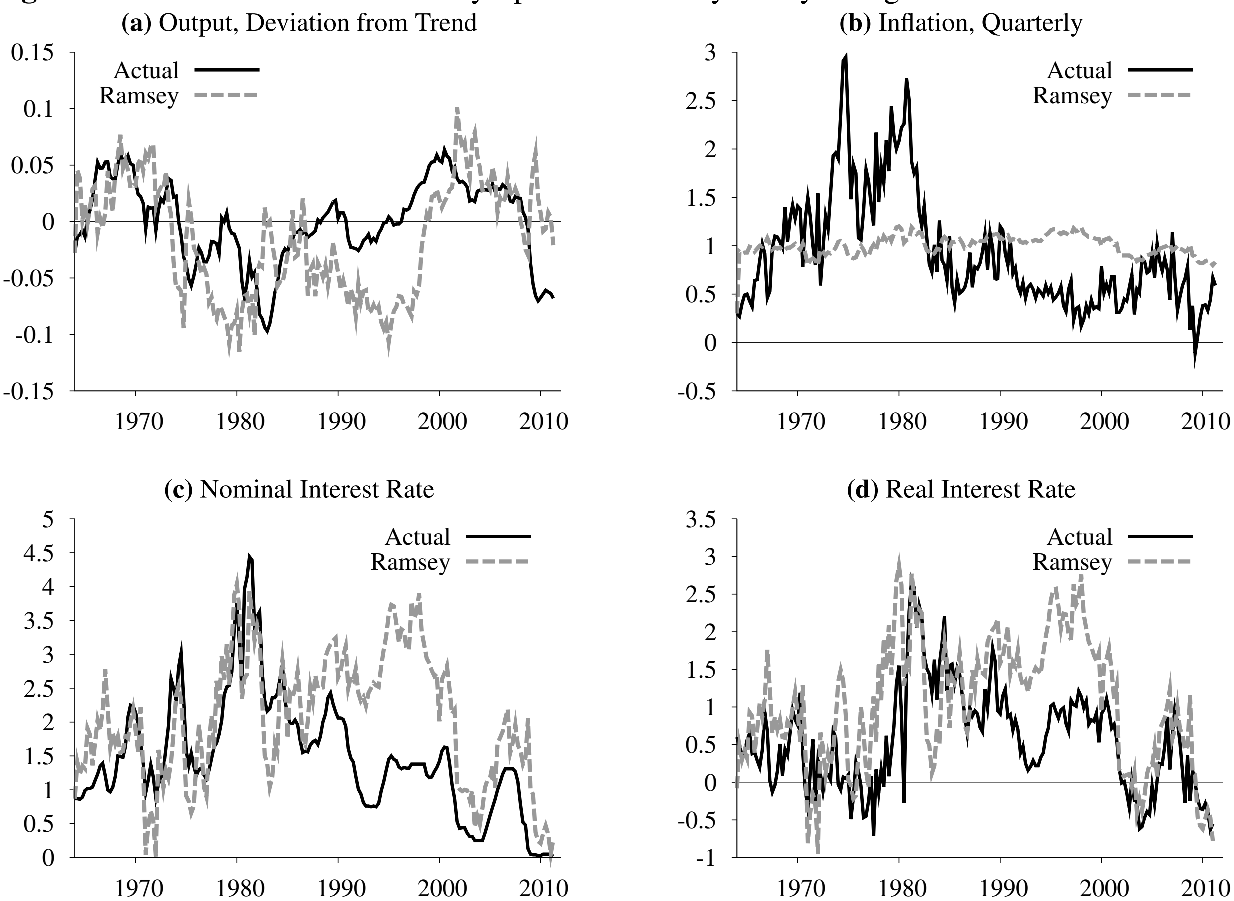
History According to the Ramsey-optimal Policy

What would U.S. economic performance have looked like if the Ramsey-optimal policy had been in place over our sample period? To answer this question, the model is simulated using the decision rules obtained from solving the model under the Ramsey-optimal policy, imposing the structural shocks, news and contemporaneous shocks to sectoral total factor productivity, obtained from the benchmark model estimation.

The most striking feature of these simulations is that the Ramsey policy implies a much smoother inflation rate than was actually the case.[8] This result is clearly driven by the fact that the Ramsey policy seeks to keep the variance of within-sector price dispersion low. In particular, it avoids the large run-up

[8]That the Ramsey-optimal policy does not deliver negative – much less zero inflation – is an artifact of having required that the Ramsey policy deliver inflation that is, on average, the same as was observed in the U.S.

Figure 17: Simulations of the Ramsey-optimal Monetary Policy Using Historical Structural Shocks



Notes: The historical shocks are Dynare's so-called "smoothed shocks" and were retrieved after estimating the model. The model was then simulated using decision rules obtained for the Ramsey-optimal policy, imposing the structural shocks (that is, excluding the monetary policy shock) in inflation seen in the 1970s, but also delivers somewhat higher inflation though the 1990s. That the Ramsey policy allows for movements in output that are of a similar magnitude to those seen in the data reflects the fact that the Ramsey policy largely accommodates the effects of the total factor productivity shocks. In particular, the behavior of output is *not* driven by the fact that the Ramsey policy simulations omit the monetary policy shock: comparing Figure 17a with Figure 16i shows that simulated output is clearly different; and looking at the timing of the monetary policy shocks in Figure 15c shows that they do not line up with movements in output in Figure 17a. The Ramsey policy implies a boom until the early 1970s, a bust from the mid-1970s through to the mid-1980s and from the late 1980s to the late 1990s, and finally a boom in the new millennium. Of particular note is that the Ramsey policy manages to avoid the bust associated with the financial crisis period. According to our model, the financial crisis can be attributed to suboptimal monetary policy.

How does the Ramsey policy manage to keep inflation so steady? Evidently, the nominal interest rate is not a particularly good metric since during the 1970s, the nominal interest rate under the Ramsey policy differs little from what was observed. In fact it is really only after the mid-1980s that the actual and simulated nominal interest rates substantially differ. The real interest rate tells a different story. The Ramsey-optimal policy sees much larger real rates in the 1970s when actual inflation rose precipitously. The real rate under the Ramsey policy is also substantially above actual through the 1990s which has the effect of pushing output under the Ramsey policy below actual.

6 Conclusion

This paper estimated a two sector new Keynesian model with both news shocks and contemporaneous shocks to total factor productivity to the two sectors, durables and nondurables. The degree of price rigidity in the two sectors was estimated as were the parameters in the interest rate rule characterizing monetary policy, the elasticity of substitution between durables and nondurables, and the shock processes. The estimated model generates a boom in economic activity in response to a nondurable sector news shock; that is, the model exhibits Pigou cycles. Alternative monetary policies, including the Ramsey-optimal policy, do not generate Pigou cycles. Whether or not Pigou cycles occur depends on how rapidly the relative price of durables rises; when it rises quickly, households run up their purchases of durables prior to the peak response of the relative price of durables. Such a quick increase in the price of durables occurs when the central bank does not place a sufficiently large weight on inflation in its interest rate rule. The Ramsey-optimal policy keeps sectoral inflation rates close to their steady state values to avoid large within-sector price dispersion, and so moderates the increase in the relative price of durables. Qualitatively, interest rate rules with a large coefficient on inflation operate much like the Ramsey policy, avoiding the boom in durable sector output following a nondurable news shock.

The estimated model also presents a partial resolution to the comovement problem. In the data, a contractionary monetary policy shock leads to a bust in both the durable and nondurable sectors. Many models have difficulty replicating this dynamic. For example, in our model, when durables prices are perfectly flexible, the relative price of durables falls sharply following such a monetary policy shock. This decline in the relative price of durables is enough to entice households to increase their purchases of durables, offsetting the contraction art effect of the monetary policy shock. It was shown that even a moderate degree of durable sector price rigidity is sufficient to moderate the decline in the relative price of durables. Durable output then declines, as does that of nondurables. Key to this result is the elasticity of substitution between durables and durables. Its estimated value implies that durables and nondurables are compliments in utility. For larger elasticities of substitution (in the literature addressing the comovement problem, an elasticity of one is common), the comovement problem develops for a wider range of durable sector price rigidity. However, there is no reason to prefer an elasticity of one. Indeed, Beaudry and Portier (2004) assumed a smaller elasticity than we estimated.

A historical decomposition of the effects of the model's shocks on output was presented. According to the model, durable sector shocks had little impact on output. While the news and contemporaneous nondurable shocks individually have considerable effects on output, their joint contribution is more modest. Monetary policy shocks have, at times, had large consequences for output. The recent financial crisis period was attributed chiefly to monetary policy shocks and the net effect of the nondurable sector shocks. When the model is simulated under the Ramsey-optimal policy, the deleterious output effects of the financial crisis period are avoided, suggesting that suboptimal monetary policy may have been the root cause of this episode.

A Data Sources

With the following exceptions, all data were downloaded from the Bureau of Economic Analysis's web site, http://www.bea.gov/iTable/iTable.cfm?ReqID=9&step=1: the Federal funds rate was obtained from the Board of Governors of the Federal Reserve System, and the 16+ population from the U.S. Census Bureau. More details on the data sources are contained in Table 4. Manipulations of the data are summarized in Table 5.

Total sectoral hours are computed as the product of sectoral employment and average hours worked in that sector. Sectoral average labor productivity is calculated as sectoral output divided by total sectoral hours. Sectoral average labor productivity is detended by running a linear regression of the logarithm of sectoral average labor productivity against a time trend. Output is similarly detrended.

Table 4: Data Sources

Mnemonic	Description
GCN	nominal personal consumption of non-durable goods
GCS	nominal personal consumption of service
GCD	nominal personal consumption of durable goods
GDP	nominal gross domestic product
PDGDP	price index for GDP
PDGCN	price index for the personal consumption of non-durable goods
PDGCS	price index for the personal consumption of service
PDGCD	price index for the personal consumption of durable goods
P16	population above 16 years old

Table 5: Matching the Data to the Model

Description	Variable	Calculation
Aggregate output	Y_t	(GDP/PGDP)/P16
Nondurable output	Y_{ct}	(GCN/PDGCN+GCS/PDGCS)/P16
Durable output	Y_{dt}	(GCD/PDGCD)/P16
Inflation rate		log(PDGDP$_t$/PDGDP$_{t-1}$)
Interest rate		Federal funds rate

B Summary of Equations Describing the Model Equilibrium

$$\upsilon N_t^{\sigma} = U_c\left(C_t, D_t, N_t, \frac{M_t}{P_t}\right)\hat{W}_t/\hat{P}_{ct}$$

$$q_t U_c\left(C_t, D_t, N_t, \frac{M_t}{P_t}\right) = U_d\left(C_t, D_t, N_t, \frac{M_t}{P_t}\right) + \beta E_t\left\{q_{t+1}U_c\left(C_{t+1}, D_{t+1}, N_{t+1}, \frac{M_{t+1}}{P_{t+1}}\right)(1-\delta)\right\}$$

$$U_c\left(C_t, D_t, N_t, \frac{M_t}{P_t}\right) = \beta E_t\left\{R_t \frac{U_c\left(C_{t+1}, D_{t+1}, N_{t+1}, \frac{M_{t+1}}{P_{t+1}}\right)}{\pi_{c,t+1}}\right\}$$

$$U_c\left(C_t, D_t, N_t, \frac{M_t}{P_t}\right) = \beta E_t\left\{\frac{U_c\left(C_{t+1}, D_{t+1}, N_{t+1}, \frac{M_{t+1}}{P_{t+1}}\right)}{\pi_{c,t+1}}\right\} + \chi \hat{P}_{ct}\hat{M}_t^{-\mu}$$

$$P1_{j,t} = \omega_j \beta\left(\frac{\pi_{t+1}}{\pi}\right)^{\varepsilon_j} P1_{j,t+1} + U_c(C_t, D_t, N_t) MC_{j,t} Y_{j,t} \hat{P}_{j,t}^{\varepsilon_j}/\hat{P}_{c,t}$$

$$P2_{j,t} = \omega_j \beta\left(\frac{\pi_{t+1}}{\pi}\right)^{\varepsilon_j - 1} P2_{j,t+1} + U_c(C_t, D_t, N_t) Y_{j,t} \hat{P}_{j,t}^{\varepsilon_j}/\hat{P}_{c,t}$$

$$\hat{P}_{j,t}^{*} = \frac{P1_{j,t}}{P2_{j,t}}$$

$$\hat{P}_{j,t} = \left[(1-\omega_j)(\hat{P}_{j,t}^{*})^{1-\varepsilon_j} + \omega_j(\hat{P}_{j,t-1}\pi/\pi_t)^{1-\varepsilon_j}\right]^{\frac{1}{1-\varepsilon_j}}$$

$$MC_{j,t} = \frac{\hat{W}_t}{A_{j,t}}$$

$$(\hat{P}_{c,t}C_t + \hat{P}_{d,t}I_t)/(C_t + I_t) = 1$$

$$A_{c,t}N_{c,t} = s_{c,t}C_t$$

$$A_{d,t}N_{d,t} = s_{d,t}(D_t - (1-\delta)D_{t-1})$$

$$s_{j,t} = (1-\omega_j)\left(\frac{\hat{P}_{j,t}^{*}}{\hat{P}_{j,t}}\right)^{-\varepsilon_j} + \omega_j\left(\frac{\pi}{\pi_{j,t}}\right)^{-\varepsilon_j} s_{j,t-1}$$

$$N_t = N_{c,t} + N_{d,t}$$

$$I_t = D_t - (1-\delta)D_{t-1}$$

$$Y_t = C_t + q_t I_t$$

$$q_t = \hat{P}_{d,t}/\hat{P}_{c,t}$$

$$\ln(A_{j,t}) = \rho_j \ln(A_{j,t-1}) + \varepsilon_{j,t-p} + \zeta_{j,t}$$

$$\ln(R_t) = \ln R^{*} + \rho_{\pi}(\ln \pi_t - \ln \pi) + \rho_y(\ln Y_t - \ln Y) + e_t$$

Notes:

1. $P1_{j,t}$ and $P2_{j,t}$ denote the numerator and the denominator of Eq. (14) in recursive form respectively;

2. Nominal variables are normalized by dividing the aggregate price P_t, that is, $\hat{M}_t = M_t/P_t$, $\hat{W}_t = W_t/P_t$, $\hat{P}_{j,t} = P_{j,t}/P_t$, $\hat{P}^*_{j,t} = P^*_{j,t}/P_t$.

C Estimates using Alternative Priors

Table 6: Estimation Results with Alternative Priors on Price Stickiness

Parameter	Description	Prior Distribution			Posterior Distribution		
		Type	Mean	Std. Dev.	Mean	90% interval	
η	elasticity of substitution between nondurables and durables	gamma	0.2	0.05	0.3232	0.2121	0.4124
ω_c	nominal rigidity in nondurable sector	beta	0.5	0.1	0.8141	0.8014	0.8247
ω_d	nominal rigidity in durable sector	beta	0.5	0.1	0.7087	0.6809	0.7382
ρ_y	policy reaction to output	gamma	0.5	0.05	0.4038	0.3464	0.4484
ρ_π	policy reaction to inflation	gamma	1.5	0.1	1.4321	1.3408	1.5351
ρ_c	persistence of shocks in nondurable sector	beta	0.7	0.05	0.9310	0.9291	0.9327
ρ_d	persistence of shocks in durable sector	beta	0.7	0.05	0.7386	0.7033	0.7725
Standard deviations:							
$\sigma_{\xi c}$	nondurable sector news shock	gamma	0.05	0.025	0.0185	0.0168	0.0200
$\sigma_{\zeta c}$	nondurable sector contemporaneous shock	gamma	0.05	0.025	0.0171	0.0158	0.0186
$\sigma_{\xi d}$	durable sector news shock	gamma	0.05	0.025	0.0637	0.0557	0.0731
$\sigma_{\zeta d}$	durable sector contemporaneous shock	gamma	0.05	0.025	0.0601	0.0514	0.0659
σ_e	monetary shock	gamma	0.01	0.005	0.0165	0.0147	0.0184
Shock correlations:							
$\sigma_{\xi c\zeta c}$	nondurable news, nondurable contemporaneous	normal	0.0	0.3	−0.6234	−0.6971	−0.5450
$\sigma_{\xi c\xi d}$	nondurable news, durable news	normal	0.0	0.3	−0.6493	−0.7142	−0.5843
$\sigma_{\xi c\zeta d}$	nondurable news, durable contemporaneous	normal	0.0	0.3	−0.1310	−0.2435	−0.0162
$\sigma_{\xi ce}$	nondurable news, monetary	normal	0.0	0.3	0.0296	−0.0869	0.1311
$\sigma_{\zeta c\xi d}$	nondurable contemporaneous, durable news	normal	0.0	0.3	0.5009	0.4313	0.5846
$\sigma_{\zeta c\zeta d}$	nondurable contemporaneous, durable contemporaneous	normal	0.0	0.3	−0.3687	−0.4546	−0.2330
$\sigma_{\zeta ce}$	nondurable contemporaneous, monetary	normal	0.0	0.3	−0.0623	−0.1631	0.0408
$\sigma_{\xi d\zeta d}$	durable news, durable contemporaneous	normal	0.0	0.3	−0.0347	−0.1944	0.1048
$\sigma_{\xi de}$	durable news, monetary	normal	0.0	0.3	0.0044	−0.1105	0.0983
$\sigma_{\zeta de}$	durable contemporaneous, monetary	normal	0.0	0.3	−0.0969	−0.2043	0.0298
log data density	−2518.14						

Table 7: Estimation Results with Alternative Priors on Monetary Policy Rule Parameters

Parameter	Description	Prior Distribution			Posterior Distribution		
		Type	Mean	Std. Dev.	Mean	90% interval	
η	elasticity of substitution between nondurables and durables	gamma	0.2	0.05	0.3360	0.2349	0.4246
ω_c	nominal rigidity in nondurable sector	beta	0.75	0.1	0.8166	0.8067	0.8244
ω_d	nominal rigidity in durable sector	beta	0.75	0.1	0.7318	0.7095	0.7632
ρ_y	policy reaction to output	gamma	0.35	0.05	0.3515	0.2779	0.4217
ρ_π	policy reaction to inflation	gamma	1.75	0.1	1.5040	1.3611	1.6417
ρ_c	persistence of shocks in nondurable sector	beta	0.7	0.05	0.9312	0.9292	0.9328
ρ_d	persistence of shocks in durable sector	beta	0.7	0.05	0.7321	0.6881	0.7622
Standard deviations:							
$\sigma_{\xi c}$	nondurable sector news shock	gamma	0.05	0.025	0.0188	0.0161	0.0206
$\sigma_{\zeta c}$	nondurable sector contemporaneous shock	gamma	0.05	0.025	0.0183	0.0156	0.0204
$\sigma_{\xi d}$	durable sector news shock	gamma	0.05	0.025	0.0630	0.0535	0.0733
$\sigma_{\zeta d}$	durable sector contemporaneous shock	gamma	0.05	0.025	0.0631	0.0552	0.0710
σ_e	monetary shock	gamma	0.01	0.005	0.0151	0.0126	0.0171
Shock correlations:							
$\sigma_{\xi c\zeta c}$	nondurable news, nondurable contemporaneous	normal	0.0	0.3	−0.5678	−0.6436	−0.4962
$\sigma_{\xi c\xi d}$	nondurable news, durable news	normal	0.0	0.3	−0.6359	−0.6980	−0.5705
$\sigma_{\xi c\zeta d}$	nondurable news, durable contemporaneous	normal	0.0	0.3	−0.1097	−0.2161	−0.0042
$\sigma_{\xi ce}$	nondurable news, monetary	normal	0.0	0.3	0.0813	−0.0142	0.1989
$\sigma_{\zeta c\xi d}$	nondurable contemporaneous, durable news	normal	0.0	0.3	0.4759	0.4124	0.6160
$\sigma_{\zeta c\zeta d}$	nondurable contemporaneous, durable contemporaneous	normal	0.0	0.3	−0.3818	−0.4666	−0.3084
$\sigma_{\zeta ce}$	nondurable contemporaneous, monetary	normal	0.0	0.3	−0.0625	−0.1664	0.0609
$\sigma_{\xi d\zeta d}$	durable news, durable contemporaneous	normal	0.0	0.3	−0.0628	−0.1986	0.0591
$\sigma_{\xi de}$	durable news, monetary	normal	0.0	0.3	−0.0808	−0.1855	0.0118
$\sigma_{\zeta de}$	durable contemporaneous, monetary	normal	0.0	0.3	−0.0635	−0.1983	0.0352
log data density	−2524.70						

Table 8: Estimation Results with Alternative Priors on Persistence of Technology Shock

Parameter	Description	Prior Distribution			Posterior Distribution		
		Type	Mean	Std. Dev.	Mean	90% interval	
η	elasticity of substitution between nondurables and durables	gamma	0.2	0.05	0.3951	0.2959	0.5127
ω_c	nominal rigidity in nondurable sector	beta	0.75	0.1	0.8597	0.8416	0.8715
ω_d	nominal rigidity in durable sector	beta	0.75	0.1	0.6896	0.6474	0.7265
ρ_y	policy reaction to output	gamma	0.5	0.05	0.4027	0.3428	0.4661
ρ_π	policy reaction to inflation	gamma	1.5	0.1	1.2757	1.1830	1.3795
ρ_c	persistence of shocks in nondurable sector	beta	0.7	0.1	0.9948	0.9932	0.9960
ρ_d	persistence of shocks in durable sector	beta	0.7	0.1	0.7971	0.7405	0.8546
Standard deviations:							
$\sigma_{\xi c}$	nondurable sector news shock	gamma	0.05	0.025	0.0117	0.0111	0.0128
$\sigma_{\zeta c}$	nondurable sector contemporaneous shock	gamma	0.05	0.025	0.0106	0.0097	0.0113
$\sigma_{\xi d}$	durable sector news shock	gamma	0.05	0.025	0.0505	0.0418	0.0598
$\sigma_{\zeta d}$	durable sector contemporaneous shock	gamma	0.05	0.025	0.0527	0.0435	0.0591
σ_e	monetary shock	gamma	0.01	0.005	0.0166	0.0143	0.0190
Shock correlations:							
$\sigma_{\xi c\zeta c}$	nondurable news, nondurable contemporaneous	normal	0.0	0.3	−0.8231	−0.8835	−0.7457
$\sigma_{\xi c\xi d}$	nondurable news, durable news	normal	0.0	0.3	−0.3976	−0.5027	−0.3000
$\sigma_{\xi c\zeta d}$	nondurable news, durable contemporaneous	normal	0.0	0.3	−0.1294	−0.2154	−0.0435
$\sigma_{\xi ce}$	nondurable news, monetary	normal	0.0	0.3	0.0607	−0.0252	0.1359
$\sigma_{\zeta c\xi d}$	nondurable contemporaneous, durable news	normal	0.0	0.3	0.3199	0.2276	0.4134
$\sigma_{\zeta c\zeta d}$	nondurable contemporaneous, durable contemporaneous	normal	0.0	0.3	−0.1996	−0.3440	−0.0824
$\sigma_{\zeta ce}$	nondurable contemporaneous, monetary	normal	0.0	0.3	−0.0652	−0.1596	0.0137
$\sigma_{\xi d\zeta d}$	durable news, durable contemporaneous	normal	0.0	0.3	−0.0127	−0.1388	0.1180
$\sigma_{\xi de}$	durable news, monetary	normal	0.0	0.3	0.0104	−0.0787	0.1262
$\sigma_{\zeta de}$	durable contemporaneous, monetary	normal	0.0	0.3	−0.1043	−0.2236	−0.0115
log data density	−2603.47						

Table 9: Estimation Results with Alternative Priors on Shocks

Parameter	Description	Prior Distribution			Posterior Distribution		
		Type	Mean	Std. Dev.	Mean	90% interval	
η	elasticity of substitution between nondurables and durables	gamma	0.2	0.05	0.3546	0.2640	0.4758
ω_c	nominal rigidity in nondurable sector	beta	0.75	0.1	0.8141	0.8033	0.8279
ω_d	nominal rigidity in durable sector	beta	0.75	0.1	0.7227	0.6985	0.7453
ρ_y	policy reaction to output	gamma	0.5	0.05	0.3973	0.3380	0.4624
ρ_π	policy reaction to inflation	gamma	1.5	0.1	1.4441	1.3531	1.5348
ρ_c	persistence of shocks in nondurable sector	beta	0.7	0.05	0.9310	0.9289	0.9327
ρ_d	persistence of shocks in durable sector	beta	0.7	0.05	0.7429	0.7156	0.7800
Standard deviations:							
$\sigma_{\xi c}$	nondurable sector news shock	gamma	0.05	0.025	0.0178	0.0161	0.0196
$\sigma_{\zeta c}$	nondurable sector contemporaneous shock	gamma	0.01	0.025	0.0174	0.0155	0.0200
$\sigma_{\xi d}$	durable sector news shock	gamma	0.05	0.025	0.0644	0.0543	0.0717
$\sigma_{\zeta d}$	durable sector contemporaneous shock	gamma	0.01	0.025	0.0631	0.0533	0.0704
σ_e	monetary shock	gamma	0.01	0.005	0.0167	0.0147	0.0188
Shock correlations:							
$\sigma_{\xi c \zeta c}$	nondurable news, nondurable contemporaneous	normal	0.0	0.3	−0.5873	−0.6887	−0.4845
$\sigma_{\xi c \xi d}$	nondurable news, durable news	normal	0.0	0.3	−0.6345	−0.7123	−0.5390
$\sigma_{\xi c \zeta d}$	nondurable news, durable contemporaneous	normal	0.0	0.3	−0.1166	−0.1964	−0.0214
$\sigma_{\xi ce}$	nondurable news, monetary	normal	0.0	0.3	0.0616	−0.0354	0.1610
$\sigma_{\zeta c \xi d}$	nondurable contemporaneous, durable news	normal	0.0	0.3	0.4768	0.3669	0.5516
$\sigma_{\zeta c \zeta d}$	nondurable contemporaneous, durable contemporaneous	normal	0.0	0.3	−0.3921	−0.4805	−0.3215
$\sigma_{\zeta ce}$	nondurable contemporaneous, monetary	normal	0.0	0.3	−0.0723	−0.1905	0.0274
$\sigma_{\xi d \zeta d}$	durable news, durable contemporaneous	normal	0.0	0.3	−0.0468	−0.1435	0.0610
$\sigma_{\xi de}$	durable news, monetary	normal	0.0	0.3	−0.0413	−0.1506	0.0538
$\sigma_{\zeta de}$	durable contemporaneous, monetary	normal	0.0	0.3	−0.0935	−0.2381	0.0242
log data density	−2523.72						

Table 10: Estimation Results with Alternative Priors on Shocks

Parameter	Description	Prior Distribution			Posterior Distribution		
		Type	Mean	Std. Dev.	Mean	90% interval	
η	elasticity of substitution between nondurables and durables	gamma	0.2	0.05	0.3643	0.2351	0.4659
ω_c	nominal rigidity in nondurable sector	beta	0.75	0.1	0.8143	0.8025	0.8281
ω_d	nominal rigidity in durable sector	beta	0.75	0.1	0.7189	0.6880	0.7460
ρ_y	policy reaction to output	gamma	0.5	0.05	0.4158	0.3508	0.4648
ρ_π	policy reaction to inflation	gamma	1.5	0.1	1.4613	1.3716	1.5390
ρ_c	persistence of shocks in nondurable sector	beta	0.7	0.05	0.9311	0.9288	0.9327
ρ_d	persistence of shocks in durable sector	beta	0.7	0.05	0.7389	0.7010	0.7797
Standard deviations:							
$\sigma_{\xi c}$	nondurable sector news shock	gamma	0.01	0.025	0.0178	0.0163	0.0193
$\sigma_{\zeta c}$	nondurable sector contemporaneous shock	gamma	0.05	0.025	0.0171	0.0156	0.0189
$\sigma_{\xi d}$	durable sector news shock	gamma	0.01	0.025	0.0632	0.0540	0.0722
$\sigma_{\zeta d}$	durable sector contemporaneous shock	gamma	0.05	0.025	0.0627	0.0537	0.0697
σ_e	monetary shock	gamma	0.01	0.005	0.0170	0.0148	0.0189
Shock correlations:							
$\sigma_{\xi c \zeta c}$	nondurable news, nondurable contemporaneous	normal	0.0	0.3	−0.5986	−0.6683	−0.5055
$\sigma_{\xi c \xi d}$	nondurable news, durable news	normal	0.0	0.3	−0.6294	−0.6979	−0.5257
$\sigma_{\xi c \zeta d}$	nondurable news, durable contemporaneous	normal	0.0	0.3	−0.1292	−0.2325	−0.0291
$\sigma_{\xi ce}$	nondurable news, monetary	normal	0.0	0.3	0.0604	−0.0224	0.1536
$\sigma_{\zeta c \xi d}$	nondurable contemporaneous, durable news	normal	0.0	0.3	0.4887	0.4107	0.5735
$\sigma_{\zeta c \zeta d}$	nondurable contemporaneous, durable contemporaneous	normal	0.0	0.3	−0.3753	−0.4577	−0.2878
$\sigma_{\zeta ce}$	nondurable contemporaneous, monetary	normal	0.0	0.3	−0.0746	−0.2257	0.0303
$\sigma_{\xi d \zeta d}$	durable news, durable contemporaneous	normal	0.0	0.3	−0.0729	−0.1971	0.0818
$\sigma_{\xi de}$	durable news, monetary	normal	0.0	0.3	−0.0002	−0.0829	0.0929
$\sigma_{\zeta de}$	durable contemporaneous, monetary	normal	0.0	0.3	−0.0799	−0.1898	0.0223
log data density	−2524.07						

Table 11: Estimation Results with Alternative Priors on Elasticity of Substitution between Nondurable and Durable Goods

Parameter	Description	Prior Distribution			Posterior Distribution		
		Type	Mean	Std. Dev.	Mean	90% interval	
η	elasticity of substitution between nondurables and durables	uniform	0.99	0.5	0.8510	0.7084	0.9982
ω_c	nominal rigidity in nondurable sector	beta	0.75	0.1	0.8179	0.8077	0.8301
ω_d	nominal rigidity in durable sector	beta	0.75	0.1	0.7313	0.7114	0.7517
ρ_y	policy reaction to output	gamma	0.5	0.05	0.4258	0.3607	0.4741
ρ_π	policy reaction to inflation	gamma	1.5	0.1	1.4486	1.3356	1.5488
ρ_c	persistence of shocks in nondurable sector	beta	0.7	0.05	0.9312	0.9294	0.9327
ρ_d	persistence of shocks in durable sector	beta	0.7	0.05	0.8169	0.7914	0.8495
Standard deviations:							
$\sigma_{\xi c}$	nondurable sector news shock	gamma	0.05	0.025	0.0179	0.0165	0.0195
$\sigma_{\zeta c}$	nondurable sector contemporaneous shock	gamma	0.05	0.025	0.0165	0.0151	0.0183
$\sigma_{\xi d}$	durable sector news shock	gamma	0.05	0.025	0.0594	0.0536	0.0669
$\sigma_{\zeta d}$	durable sector contemporaneous shock	gamma	0.05	0.025	0.0587	0.0524	0.0652
σ_e	monetary shock	gamma	0.01	0.005	0.0181	0.0151	0.0207
Shock correlations:							
$\sigma_{\xi c\zeta c}$	nondurable news, nondurable contemporaneous	normal	0.0	0.3	−0.5669	−0.6939	−0.4915
$\sigma_{\xi c\xi d}$	nondurable news, durable news	normal	0.0	0.3	−0.5786	−0.6725	−0.4784
$\sigma_{\xi c\zeta d}$	nondurable news, durable contemporaneous	normal	0.0	0.3	−0.1450	−0.2772	−0.0403
$\sigma_{\xi ce}$	nondurable news, monetary	normal	0.0	0.3	0.0314	−0.0663	0.1074
$\sigma_{\zeta c\xi d}$	nondurable contemporaneous, durable news	normal	0.0	0.3	0.4643	0.3642	0.5914
$\sigma_{\zeta c\zeta d}$	nondurable contemporaneous, durable contemporaneous	normal	0.0	0.3	−0.4286	−0.5099	−0.3245
$\sigma_{\zeta ce}$	nondurable contemporaneous, monetary	normal	0.0	0.3	−0.0869	−0.1852	−0.0053
$\sigma_{\xi d\zeta d}$	durable news, durable contemporaneous	normal	0.0	0.3	−0.1184	−0.2512	0.0015
$\sigma_{\xi de}$	durable news, monetary	normal	0.0	0.3	−0.1023	−0.2324	0.0050
$\sigma_{\zeta de}$	durable contemporaneous, monetary	normal	0.0	0.3	0.0571	−0.0301	0.1703
log data density	−2538.18						

References

An, Sungbae and Frank Schorfheide. 2007. "Bayesian Analysis of DSGE Models." *Econometric Reviews* 26 (2-4):113–172.

Barksy, Robert B. and Eric R. Sims. forthcoming. "Information, Animal Spirits, and the Meaning of Innovations in Consumer Confidence." *American Economic Review* .

Barsky, Robert, Christopher L. House, and Miles Kimball. 2007. "Sticky Price Models and Durable Goods." *American Economic Review* 97 (3):984–998.

Beaudry, Paul and Franck Portier. 2004. "An Exploration Into Pigou's Theory of Cycles." *Journal of Monetary Economics* 51 (6):1183–1216.

———. 2007. "When Can Changes in Expectations Cause Business Cycle Fluctuations in Neo-classical Settings?" *Journal of Economic Theory* 135 (1):458–477.

Bils, Mark and Peter J. Klenow. 2004. "Some Evidence on the Importance of Sticky Prices." *Journal of Political Economy* 112 (5):947–985.

Bouakez, Hafedh, Emanuela Cardia, and Francisco J. Ruge-Murcia. 2011. "Durable Goods, Inter-sectoral Linkages and Monetary Policy." *Journal of Economic Dynamics and Control* 35 (5):730–745.

Calvo, Guillermo. 1983. "Staggered Prices in a Utility Maximizing Framework." *Journal of Monetary Economics* 12 (3):383–398.

Carlstrom, Charles T. and Timothy S. Fuerst. 2006. "Co-Movement in Sticky Price Models with Durable Goods." Working Paper 06-14, Federal Reserve Bank of Cleveland.

Chari, V. V., Patrick J. Kehoe, and Ellen R. McGrattan. 2000. "Sticky Price Models of the Business Cycle: Can the Contract Multiplier Solve the Persistence Problem?" *Econometrica* 68 (5):1151–1179.

Christiano, Lawrence, Cosmin Ilut, Roberto Motto, and Massimo Rostagno. 2008. "Monetary Policy and Stock Market Boom-Bust Cycles." *European Central Bank Working Paper No. 955* .

Clarida, Richard, Jordi Galí, and Mark Gertler. 2000. "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory." *Quarterly Journal of Economics* CXV (1):147–180.

Den Haan, Wouter J. and Georg Kaltenbrunner. 2009. "Anticipated growth and business cycles in matching models." *Journal of Monetary Economics* 56 (3):309–327.

Den Haan, Wouter J. and Matija Lozej. 2011. "Pigou Cycles in Closed and Open Economies with Matching Frictions." In *NBER International Seminar on Macroeconomics 2010*, edited by Richard Clarida and Francesco Giavazzi. University of Chicago Press, 193–233.

Erceg, Christopher and Andrew Levin. 2006. "Optimal Monetary Policy with Durable Consumption Goods." *Journal of Monetary Economics* 53 (7):1341–1359.

Gortz, Christoph and John Tsoukalas. 2011. "News and Financial Intermediation in Aggregate Fluctuations." Mimeo, University of Nottingham and University of Glasgow.

Hamilton, James D. 1994. "State-space Models." In *Handbook of Econometrics, Volume IV*, edited by R. F. Engle and D. L. McFadden. Amsterdam: Elsevier Science, 3039–3080.

Ireland, Peter N. 2001. "Sticky-Price Models of the Business Cycle: Specification and Stability." *Journal of Monetary Economics* 47 (1):3–18.

Jaimovich, Nir and Sergio Rebelo. 2009. "Can News About the Future Drive the Business Cycle?" *American Economic Review* 99 (4):1097–1118.

Kahn, Aubhik, Robert G. King, and Alexander L. Wolman. 2003. "Optimal Monetary Policy." *Review of Economic Studies* 10 (4):825–860.

Khan, Hashmat and John Tsoukalas. 2011. "The Quantitative Importance of News Shocks in Estimated DSGE Models." Mimeo, Carleton University and University of Nottingham.

Kobayashi, Keiichiro and Kengo Nutahara. 2010. "Nominal Rigidities, News-Driven Business Cycles, and Monetary Policy." *The B.E. Journal of Macroeconomics* 10 (1):Article 24.

Leeper, Eric M., Todd B. Walker, and Shu-Chun Susan Yang. 2011. "Foresight and Information Flows." Mimeo, Indiana University.

Levin, Andrew T., Alexei Onatski, John C. Williams, and Noah Williams. 2006. "Monetary Policy Under Uncertainty in Micro-Founded Macroeconometric Models." In *NBER Macroeconomics Annual 2005*, edited by Mark Gertler and Kenneth Rogoff. MIT Press, Cambridge, 229–287.

Lubik, Thomas and Frank Schorfheide. 2006. "A Bayesian Look at the New Open Economy Macroeconomics." In *NBER Macroeconomics Annual 2005*. National Bureau of Economic Research, 313–382.

Lubik, Thomas A. and Frank Schorfheide. 2004. "Testing for Indeterminacy: An Application to U.S. Monetary Policy." *American Economic Review* 94 (1):190–217.

Rabanal, Pau and Juan F. Rubio-Ramirez. 2005. "Comparing New Keynesian models of the business cycle: A Bayesian approach." *Journal of Monetary Economics* 52 (6):1151–1166.

Rotemberg, Julio and Michael Woodford. 1992. "Oligopolistic Pricing and the Effects of Aggregate Demand on Economic Activity." *Journal of Political Economy* 100 (6):1153–1207.

———. 1997. "An Optimization-Based Econometric Framework for the Evaluation of Monetary Policy." In *NBER Macroeconomics Annual 1997*, edited by Ben Bernanke and Julio J. Rotemberg. Cambridge and London: MIT Press, 297–346.

Schmitt-Grohé, Stephanie and Martín Uribe. 2004. "Optimal Fiscal and Monetary Policy under Sticky Prices." *Journal of Economic Theory* 114 (2):198–230.

———. 2010. "What's News in Business Cycles." Mimeo, Columbia University.

Schorfheide, Frank. 2000. "Loss function-based evaluation of DSGE models." *Journal of Applied Econometrics* 15 (6):645–670.

Siu, Henry E. 2004. "Optimal Fiscal and Monetary Policy with Sticky Prices." *Journal of Monetary Economics* 51 (3):575–607.

Smets, Frank and Raf Wouters. 2003. "An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area." *Journal of the European Economic Association* 1 (5):1123–1175.

Smets, Frank and Rafael Wouters. 2007. "Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach." *American Economic Review* 97 (3):586–606.

Sterk, Vincent. 2010. "Credit Frictions and the Comovement Between Durable and Nondurable Consumption." *Journal of Monetary Economics* 57 (2):217–225.

Taylor, John B. 1993. "Discretion Versus Policy Rules in Practice." *Carnegie-Rochester Series on Public*

Policy 39 (1):195–214.

———. 1999. “Staggered Price and Wage Setting in Macroeconomics.” In *Handbook of Macroeconomics*, edited by J. B. Taylor and M. Woodford. North-Holland, Amsterdam, New York, 1009–1050.