The Sources of Fluctuations in Residential Investment: A View from a Policy-Oriented DSGE Model of the U.S. Economy *

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Abstract

This paper analyzes fluctuations in residential investment using an estimated DSGE model of the U.S. economy designed to analyze policy questions and to produce forecasts on a regular basis. Importantly, the model is more detailed in its treatment of domestic spending and production decisions than most other models, allowing consideration of questions related to the housing sector and other macroecnomic developments. Our analysis examines the importance of various structural factors in determining the course of residential investment in the United States over the past two decades. We focus especially on developments in the last ten years, and examine in detail the relationship between monetary policy actions and residential investment within our model.

JEL classification: C51; E32; E52; O41.

Keywords: Residential Investment, Housing, Monetary Policy

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1 Introduction

We have previously presented an estimated dynamic, stochastic, general-equilibrium model of the U.S. economy designed to analyze policy questions and contribute to the forecast work at the Federal Reserve Board (Edge, Kiley, and Laforte (2007, 2008a, 2008b)). This research examines how our Estimated, Dynamic, Optimization-based model, FRB/EDO, interprets fluctuations in residential investment over the last two decades. We focus on three questions:

- What are the fundamental determinants of business-cycle fluctuations in residential investment?
- Are the sources of fluctuations in residential investment at business-cycle frequencies different, at least to some extent, than the sources of fluctuations in GDP, hours per capita, and inflation?
- How important is monetary policy as a factor driving residential investment over the past two decades, as well as more recently?

We think each of these questions is particularly important in the current environment. Residential investment has contracted sharply over the past year-and-a-half. A decomposition of this decline into the separate influences of structural factors – such as productivity movements, preference (e.g., demand) shifts, and interest rates – provides information on the likely future course of the housing market and the setting of monetary policy. Moreover, our analysis sheds some light on the degree to which the strength of residential investment from 2002 to 2005 may have reflected monetary policy decisions, a topic of several recent pieces of research.

The Edo model is particularly well-suited to answer this set of questions. The model's general equilibrium approach and rich sectoral detail allow consideration of movements in residential investment, broader measures of economic activity (such as GDP and aggregate hours), and inflation; its New-Keynesian structure embeds a central role for monetary policy; and its empirical approach ensures that it can provide a reasonable characterization of the sources of fluctuations over history. This combination of features is relatively unique among existing DSGE models.

The remainder of this paper is divided into five sections. The first summarizes some related recent research. The second discusses the structure of the FRB/EDO model. The next examines the sources of fluctuations in residential investment according to Edo and compares these sources to those driving GDP, hours, and inflation. The fourth section examines the role of monetary policy innovations in accounting for the realized paths of key macroeconomic variables, both over the past two decades and during the recent run-up and subsequent decline in housing; we also compare our analysis to results from the FRB/US model, a large structural macroeconomic model used at the Federal Reserve Board since 1996 with different structural characteristics from our DSGE model. A concluding section provides some thoughts for future research.

2 Related Research

A number of recent pieces have examined the rise and subsequent decline of residential investment in the United States over the past ten years. We highlight the previous studies most closely related to our focus.

Del Negro and Otrok (2005) and Fisher and Quayyam (2006) examine the impact of monetary policy innovations on house prices and residential investment, respectively, using plausible identifying restrictions in reduced-form vector-autoregression (VAR) models. Both studies attribute only a small portion of the run-up in these housing market indicators through 2005 to monetary policy. Our use of a structural model allows us to widen our study to examine the broader economic implications of monetary policy in both the early 1990s and early 2000s. We are also able to extend our analysis through the first half of 2007.

Iacoviello and Neri (2007) consider similar questions in a dynamic, stochastic, general equilibrium model with many features that are similar to the Edo model. Their model contains a collateral channel for housing wealth that is absent from Edo; they also model house prices. However, their model contains less detail on other components of expenditure (e.g., consumer durables are lumped with other components of consumption, and their measure of GDP ignores inventory investment, government expenditure, and net exports); they also model less detail on inflation (e.g., our model contains measures of consumer expenditure inflation, capital goods inflation, and GDP inflation, whereas their model considers only nonfarm business inflation). We suspect that a fairly detailed treatment of inflation and GDP is most appropriate for questions analyzing monetary policy, as policymakers appear concerned with economic activity overall – not the subset of activity that is both modeled and measured by Iacoviello and Neri (2007).

With respect to findings, Iacoviello and Neri (2007) attribute a sizeable portion of the run-up in residential investment following 2002 to monetary policy shocks. However, this finding appears to reflect, in part, their estimation strategy. In particular, they estimate their model over the period from 1965 to the present. As a result, their model views monetary policy as more erratic and hence as a larger contributor to the business cycle than would models that focus on the U.S. economy since the early 1980s, as does Edo. (We estimate the Edo model from late 1984 to the present, arguably a period with a more stable monetary policy; other aspects of the economy may have also been more stable during our sample period).

Leamer (2007) suggests that monetary policy contributed significantly to housing fluctuations recently. His analysis is neither based on a structural model nor on transparent identification assumptions (a hallmark of the other research discussed previously). He suggests that monetary policy performed very poorly recently but well in the early 1990s.

Taylor (2007) also suggests that monetary policy did not perform especially well in the most recent period. But his analysis is much more impressionistic that that of the other research we have reviewed, except perhaps that of Leamer (2007). Nonetheless, two points are worth highlighting. First, Taylor calls for analysis using a structural model with firm microeconomic foundations, but follows a reduced-form approach in his own analysis; our research addresses his call for a structural approach. Second, Taylor views the path of the federal funds rate from 2002 through 2005 as the result of very large deviations from the "normal" policy rule. We will find smaller deviations in our examination in section 5. It is important to note that Taylor's view reagrading deivations from the monetary policy rule is simply assumed; it is not based on an estimated rule consistent with FOMC behavior over the past two decades. The policy rule in Edo is estimated and tracks the federal funds rate data very well.

3 Model Overview and Motivation

The EDO model contains a detailed description of domestic production and expenditures decisions. The heart of the model is a two-sector production structure. In particular, we assume the economy consists of a consumption goods and an investment goods sector. We discuss the motivation for this basic structure in detail in Edge, Kiley, and Laforte (2007, 2008a).

Figure 1 provides a graphical overview of the economy described by our model. The model possesses two final goods: slow-growing "CBI" goods—so called because *most* of these goods are used for consumption (C) and because they are produced by the business and institutions (BI) sector—and fast-growing "KB" goods—so called because these goods are used for capital (K) accumulation and are produced by the business (B) sector. The goods are produced in two stages by intermediate- and then final-goods producing firms (shown in the center of the figure). On the model's demand-side, there are four components of spending (each shown in a box surrounding the producers in the figure): consumer non-durable goods and services (sold to households), consumer durable goods, residential capital goods, and non-residential capital goods. Consumer non-durable goods and services and residential capital goods are purchased (by households and residential capital goods owners, respectively) from the first of economy's two final goods producing sectors, while consumer durable goods and non-residential capital goods are purchased (by consumer durable and residential capital goods owners, respectively) from the second sector. We "decentralize" the economy by assuming that residential capital and consumer durables capital are rented to households while non-residential capital is rented to firms. In addition to consuming the non-durable goods and services that they purchase, households supply labor to the intermediate goods-producing firms in both sectors of the economy.

The canonical DSGE models of Christiano et al. [2005] and Smets and Wouters [2004b] did not address differences in trend growth rates between investment and consumption spending aggregates and trending relative price measures that drive our choice of a two-sector structure, although an earlier literature—less closely tied to business cycle fluctuations in the data—did explore the multi-sector structure underlying U.S. growth and fluctuations.[1] Subsequent richly-specified models with close ties to the data have adopted a multi-sector growth structure, including Altig et al. [2004], Edge, Laubach, and Williams [2003], and DiCecio [2005]; our model shares features with the latter two of these models.

The disaggregation of production (aggregate supply) leads naturally to some disaggregation of expenditures (aggregate demand). We move beyond a model with just two categories of (private domestic) final spending and disaggregate along the four categories of private expenditure mentioned earlier: consumer non-durable goods and non-housing services, consumer durable goods, residential investment, and non-residential investment. This rich disaggregation is central to our analysis of residential investment. Many previous models have lumped residential investment with other types of investment. Of course, important exceptions exist – most notably Iacoveillo

[1]See for examples, Greenwood et. al [1997], Greenwood et. al [2000], Whelan [2003], and Fisher [2006].

and Neri (2007), as discussed earlier.

This remainder of this section provides an overview of the decisions made by each of the agents in our economy. Given some of the broad similarities between our model and others, our presentation is selective.

3.1 The Final Goods Producers' Problem

The economy produces two final goods and services: slow-growing "consumption" goods and services, X_t^{cbi}, and fast-growing "capital" goods, X_t^{kb}. These final goods are produced by aggregating (according to a Dixit-Stiglitz technology) an infinite number of sector-specific differentiated intermediate inputs, $X_t^s(j)$ for $s = cbi, kb$, distributed over the unit interval. The representative firm in each of the consumption and capital goods producing sectors chooses the optimal level of each intermediate input, taking as given the prices for each of the differentiated intermediate inputs, $P_t^s(j)$, to solve the cost-minimization problem:

$$\min_{\{X_t^s(j)\}_{j=0}^1} \int_0^1 P_t^s(j) X_t^s(j) dj \text{ subject to } \left(\int_0^1 \left(X_t^s(j)\right)^{\frac{\Theta_t^{x,s}-1}{\Theta_t^{x,s}}} dj \right)^{\frac{\Theta_t^{x,s}}{\Theta_t^{x,s}-1}} \geq X_t^s, \text{ for } s = cbi, kb. \tag{1}$$

The term $\Theta_t^{x,s}$ is the stochastic elasticity of substitution between the differentiated intermediate goods inputs used in the production of the consumption or capital goods sectors. Letting $\theta_t^{x,s} \equiv \ln \Theta_t^{x,s} - \ln \Theta_*^{x,s}$ denote the log-deviation of $\Theta_t^{x,s}$ from its steady-state value of $\Theta_*^{x,s}$, we assume that

$$\theta_t^{x,s} = \epsilon_t^{\theta,x,s}, \text{ for } s = cbi, kb, \tag{2}$$

where $\epsilon_t^{\theta,x,s}$ is an i.i.d. shock process. A stochastic elasticity of substitution introduces transitory markup shocks into the pricing decisions of intermediate-goods producers.

3.2 The Intermediate Goods Producers' Problem

The intermediate goods entering each final goods technology are produced by aggregating (according to a Dixit-Stiglitz technology) an infinite number of differentiated labor inputs, $L_t^s(j)$ for $s = cbi, kb$, distributed over the unit interval and combining this aggregate labor input (via a Cobb-Douglas production function) with utilized non-residential capital, $K_t^{u,nr,s}$. Each intermediate-good producing firm effectively solves three problems: two factor-input cost-minimization problems (over differentiated labor inputs and the aggregate labor and capital) and one price-setting profit-maximization problem.

In its first cost-minimization problem, an intermediate goods producing firm chooses the optimal level of each type of differential labor input, taking as given the wages for each of the differentiated types of labor, $W_t^s(i)$, to solve:

$$\min_{\{L_t^s(i,j)\}_{i=0}^1} \int_0^1 W_t^s(i) L_t^s(i,j) di \text{ subject to } \left(\int_0^1 \left(L_t^s(i,j)\right)^{\frac{\Theta_t^l - 1}{\Theta_t^l}} di \right)^{\frac{\Theta_t^l}{\Theta_t^l - 1}} \geq L_t^s(j), \text{ for } s = cbi, kb. \quad (3)$$

The term Θ_t^l is the stochastic elasticity of substitution between the differentiated labor inputs. Letting $\theta_t^l \equiv \ln \Theta_t^l - \ln \Theta_*^l$ denote the log-deviation of Θ_t^l from its steady-state value of Θ_*^l, we assume that

$$\theta_t^l = \epsilon_t^{\theta,l} \quad (4)$$

where $\epsilon_t^{\theta,l}$ is an i.i.d. shock process.

In its second cost-minimization problem, an intermediate-goods producing firm chooses the optimal levels of aggregated labor input and utilized capital, taking as given the wage, W_t^s, for aggregated labor, L_t^s (which is generated by the cost function derived the previous problem), and the rental rate, $R_t^{nr,s}$, on utilized capital, $K_t^{u,nr,s}$, to solve:

$$\min_{\left\{L_t^s(j), K_t^{u,nr,s}(j)\right\}} W_t^s L_t^s(j) + R_t^{nr,s} K_t^{u,nr,s}(j)$$
$$\text{subject to } \left(Z_t^m Z_t^s L_t^s(j)\right)^{1-\alpha} \left(K_t^{u,nr,s}(j)\right)^{\alpha} \geq X_t^s(j), \text{ for } s = cbi, kb, \text{ but } Z_t^{cbi} \equiv 1. \quad (5)$$

The parameter α is the elasticity of output with respect to capital, while the Z_t variables denote the level of productivity. The level of productivity has two components. The first, Z_t^m, is common to both sectors and thus represents the level of economy-wide technology. The second, Z_t^s, is sector specific; we normalize Z_t^{cbi} to one, while Z_t^{kb} is not restricted.

The exogenous productivity terms contain a unit root, that is, they exhibit permanent movements in their levels. We assume that the stochastic processes Z_t^m and Z_t^{kb} evolve according to

$$\ln Z_t^n - \ln Z_{t-1}^n = \ln \Gamma_t^{z,n} = \ln\left(\Gamma_*^{z,n} \cdot \exp[\gamma_t^{z,n}]\right) = \ln \Gamma_*^{z,n} + \gamma_t^{z,n}, \; n = kb, m \tag{6}$$

where $\Gamma_*^{z,n}$ and $\gamma_t^{z,n}$ are the steady-state and stochastic components of $\Gamma_t^{z,n}$. The stochastic component $\gamma_t^{z,n}$ is assumed to evolve according to

$$\gamma_t^{z,n} = \rho^{z,n}\gamma_{t-1}^{z,n} + \epsilon_t^{z,n}, \; n = kb, m. \tag{7}$$

where $\epsilon_t^{z,n}$ is an i.i.d shock process, and $\rho^{z,n}$ represents the persistence of $\gamma_t^{z,n}$ to a shock. It is the presence of capital-specific technological progress that allows the model to generate differential trend growth rates in the economy's two production sectors. In line with historical experience, we assume a more rapid rate of technological progress in capital goods production by calibrating $\Gamma_*^{z,kb} > 1$, where (as is the case for all model variables) an asterisk on a variable denotes its steady-state value.

In its price-setting problem (or profit-maximization), an intermediate goods producing firm chooses its optimal nominal price and the quantity it will supply consistent with that price. In doing so it takes as given the marginal cost, $MC_t^s(j)$, of producing a unit of output, $X_t^s(j)$, the aggregate price level for its sector, P_t^s, and households' valuation of a unit of nominal profits income in each period, which is given by $\Lambda_t^{cnn}/P_t^{cbi}$ where Λ_t^{cnn} denotes the marginal utility of non-durables and non-housing services consumption. Specifically, firms solve:

$$\max_{\{P_t^s(j),X_t^s(j),X_t^s(j)\}_{t=0}^{\infty}} \mathcal{E}_0 \sum_{t=0}^{\infty} \beta^t \frac{\Lambda_t^{cnn}}{P_t^{cbi}} \{P_t^s(j)X_t^s(j) - MC_t^s(j)X_t^s(j)$$
$$- \frac{100 \cdot \chi^p}{2} \left(\frac{P_t^s(j)}{P_{t-1}^s(j)} - \eta^p \Pi_{t-1}^{p,s} - (1-\eta^p)\Pi_*^{p,s} \right)^2 P_t^s X_t^s \Bigg\}$$

subject to $X_\tau^s(j) = (P_\tau^s(j)/P_\tau^s)^{-\Theta_\tau^{x,s}} X_\tau^s$ for $\tau = 0, 1, ..., \infty$ and $s = cbi, kb$. (8)

The profit function reflects price-setting adjustment costs (the size which depend on the parameter χ^p and the lagged and steady-state inflation rate). The constraint against which the firm maximizes its profits is the demand curve it faces for its differentiated good, which derives from the final goods producing firm's cost-minimization problem. This type of price-setting decision delivers a new-Keynesian Phillips curve. Because adjustment costs potentially depend upon lagged inflation, the Phillips curve can take the "hybrid" form in which inflation is linked to its own lead and lag as well as marginal cost.

3.3 The Capital Owners' Problem

We now shift from producers' decisions to spending decisions (that is, those by agents encircling our producers in Figure 1). Non-residential capital owners choose investment in non-residential capital, E_t^{nr}, the stock of non-residential capital, K_t^{nr} (which is linked to the investment decision via the capital accumulation identity), and the amount and utilization of non-residential capital in each production sector, $K_t^{nr,cbi}$, U_t^{cbi}, $K_t^{nr,kb}$, and U_t^{kb}. (Recall, that the firm's choice variables in equation 5 is utilized capital $K_t^{u,nr,s} = U_t^s K_t^{nr,s}$.) The mathematical representation of this decision is described by the following maximization problem (in which capital owners take as given the rental rate on non-residential capital, R_t^{nr}, the price of non-residential capital goods, P_t^{kb}, and households' valuation of nominal capital income in each period,

$\Lambda_t^{cnn}/P_t^{cbi}$):

$$\max_{\{E_t^{nr}(k),K_{t+1}^{nr}(k),K_t^{nr,cbi}(k),K_t^{nr,kb}(k)U_t^{cbi}(k),U_t^{kb}(k)\}_{t=0}^{\infty}}$$

$$\mathcal{E}_0 \sum_{t=0}^{\infty} \beta^t \frac{\Lambda_t^{cnn}}{P_t^{cbi}} \Big\{ R_t^{nr} U_t^{cbi}(k) K_t^{nr,cbi}(k) + R_t^{nr} U_t^{kb}(k) K_t^{nr,kb}(k) - P_t^{kb} E_t^{nr}(k)$$

$$-\kappa \left(\frac{U_t^{cbi}(k)^{1+\psi} - 1}{1+\psi} \right) P_t^{kb} K_t^{nr,cbi} - \kappa \left(\frac{U_t^{kb}(k)^{1+\psi} - 1}{1+\psi} \right) P_t^{kb} K_t^{nr,kb} \Big\}$$

subject to

$$K_{\tau+1}^{nr}(k) = (1-\delta^{nr}) K_\tau^{nr}(k) + A_\tau^{nr} E_\tau^{nr}(k) - \frac{100 \cdot \chi^{nr}}{2} \left(\frac{E_\tau^{nr}(k) - E_{\tau-1}^{nr}(k) \Gamma_t^{y,kb}}{K_\tau^{nr}} \right)^2 K_\tau^{nr} \text{ and}$$

$$K_\tau^{nr,cbi}(k) + K_\tau^{nr,kb}(k) = K_\tau^{nr}(k) \text{ for } \tau = 0, 1, ..., \infty. \tag{9}$$

The parameter δ^{nr} in the capital-accumulation constraint denotes the depreciation rate for non-residential capital, while the parameter χ^{nr} governs how quickly investment adjustment costs increase when $(E_\tau^{nr}(k) - E_{\tau-1}^{nr}(k)\Gamma_t^{y,kb})$ rises above zero. The variable A_t^{nr} is a stochastic element affecting the efficiency of non-residential investment in the capital-accumulation process. Letting $a_t^{nr} \equiv \ln A_t^{nr}$ denote the log-deviation of A_t^{nr} from its steady-state value of unity, we assume that:

$$a_t^{nr} = \rho^{a,nr} a_{t-1}^{nr} + \epsilon_t^{a,nr}. \tag{10}$$

Higher rates of utilization incur a cost (reflected in the last two terms in the capital owner's profit function). We assume that $\kappa = R_*^{nr}/P_*^{kb}$, which implies that utilization is unity in the steady-state.

The problems solved by the consumer durables and residential capital owners are slightly simpler than the non-residential capital owner's problems. Since utilization rates are not variable for these types of capital, their owners make only investment and capital accumulation decisions. Taking as given the rental rate on consumer durables capital, R_t^{cd}, the price of consumer-durable goods, P_t^{kb}, and households' valuation of nominal capital income, $\Lambda_t^{cnn}/P_t^{cbi}$, the capital owner chooses investment in consumer durables, I_t^{cd}, and its implied capital stock, K_t^{cd}, to solve:

$$\max_{\{E_t^{cd}(k),K_{t+1}^{cd}(k)\}_{t=0}^{\infty}} \mathcal{E}_0 \sum_{t=0}^{\infty} \beta^t \frac{\Lambda_t^{cnn}}{P_t^{cbi}} \left\{ R_t^{cd} K_t^{cd}(k) - P_t^{kb} E_t^{cd}(k) \right\}$$

subject to

$$K_{\tau+1}^{cd}(k) = (1-\delta^{cd}) K_\tau^{cd}(k) + A_\tau^{cd} E_\tau^{cd}(k) - \frac{100 \cdot \chi^{cd}}{2} \left(\frac{E_\tau^{cd}(k) - E_{\tau-1}^{cd}(k)\Gamma_\tau^{x,kb}}{K_\tau^{cd}} \right)^2 K_\tau^{cd}$$

for $\tau = 0, 1, ..., \infty.$ (11)

The residential capital owner's decision is analogous:

$$\max_{\{E_t^{r}(k),K_{t+1}^{r}(k)\}_{t=0}^{\infty}} \mathcal{E}_0 \sum_{t=0}^{\infty} \beta^t \frac{\Lambda_t^{cnn}}{P_t^{cbi}} \left\{ R_t^{r} K_t^{r}(k) - P_t^{cbi} E_t^{r}(k) \right\}$$

subject to

$$K_{\tau+1}^{r}(k) = (1-\delta^{r}) K_\tau^{r}(k) + A_\tau^{r} E_\tau^{r}(k) - \frac{100 \cdot \chi^{r}}{2} \left(\frac{E_\tau^{r}(k) - E_{\tau-1}^{r}(k)\Gamma_\tau^{x,cbi}}{K_\tau^{cd}} \right)^2 K_\tau^{cd}$$

for $\tau = 0, 1, ..., \infty.$ (12)

The notation for the consumer durables and residential capital stock problems parallels that of non-residential capital. In particular, the capital-efficiency shocks, A_t^{cd} and A_t^r, follow an autoregression process similar to that given in equation (10).

3.4 The Households' Problem

The final group of private agents in the model are households who make both expenditures and labor-supply decisions. Households derive utility from four sources: their purchases of the consumer non-durable goods and non-housing services, the flow of services from their rental of consumer-durable capital, the flow of services from their rental of residential capital, and their leisure time, which is equal to what remains of their time endowment after labor is supplied to the market. Preferences are separable over all arguments of the utility function. The utility that households derive from the three components of goods and services consumption is influenced by the habit stock for each of these consumption components, a feature that has been shown to be important for consumption dynamics in similar models. A household's habit stock for its consumption of non-durable goods and non-housing services is equal to a factor h^{cnn} multiplied by its consumption last period E^{cnn}_{t-1}. Its habit stock for the other components of consumption is defined similarly.

Each household chooses its purchases of consumer non-durable goods and services, E^{cnn}_t, the quantities of residential and consumer durable capital it wishes to rent, K^r_t and K^{cd}_t, its holdings of bonds, B_t, its wage for each sector, W^{cbi}_t and W^{kb}_t, and supply of labor consistent with each wage, L^{cbi}_t and L^{kb}_t. This decision is made subject to the household's budget constraint, which reflects the costs of adjusting wages and the mix of labor supplied to each sector, as well as the demand curve it faces for its differentiated labor. Specifically, the ith household solves:

$$\max_{\left\{E^{cnn}_t(i),K^{cd}_t(i),K^r_t(i),\{W^s_t(i),L^s_t(i)\}_{s=cbi,kb},B_{t+1}(i)\right\}^{\infty}_{t=0}}$$

$$\mathcal{E}_0\sum_{t=0}^{\infty}\beta^t\Big\{\varsigma^{cnn}\Xi^{cnn}_t\ln(E^{cnn}_t(i)-h^{cnn}E^{cnn}_{t-1}(i))+\varsigma^{cd}\Xi^{cd}_t\ln(K^{cd}_t(i)-h^{cd}K^{cd}_{t-1}(i))$$
$$+\varsigma^r\Xi^r_t\ln(K^r_t(i)-h^rK^r_{t-1}(i))-\varsigma^l\Xi^l_t\frac{(L^{cbi}_t(i)+L^{kb}_t(i))^{1+\nu}}{1+\nu}\Big\}.$$

subject to

$$R^{-1}_\tau B_{\tau+1}(i)=B_\tau(i)+\sum_{s=cbi,kb}W^s_\tau(i)L^s_\tau(i)+\mathit{Capital\ and\ Profits\ Income}_\tau(i)-P^{cbi}_\tau E^{cnn}_\tau(i)$$
$$-R^{cd}_\tau K^{cd}_\tau(i)-R^r_\tau K^r_\tau(i)-\sum_{s=cbi,kb}\frac{100\cdot\chi^w}{2}\left(\frac{W^s_\tau(j)}{W^s_{\tau-1}(j)}-\eta^w\Pi^{w,s}_{\tau-1}-(1-\eta^w)\Pi^w_*\right)^2W^s_\tau L^s_\tau$$
$$-\frac{100\cdot\chi^l}{2}\left(\frac{L^{cbi}_*\cdot W^{cbi}_\tau}{L^{cbi}_*+L^{kb}_*}+\frac{L^{kb}_*\cdot W^{kb}_\tau}{L^{cbi}_*+L^{kb}_*}\right)\left(\frac{L^{cbi}_\tau(i)}{L^{kb}_\tau(i)}-\eta^l\frac{L^{cbi}_{\tau-1}}{L^{kb}_{\tau-1}}-(1-\eta^l)\frac{L^{cbi}_*}{L^{kb}_*}\right)^2\frac{L^{kb}_\tau}{L^{cbi}_\tau}.$$
$$L^{cbi}_\tau(i)=\left(W^{cbi}_\tau(i)/W^{cbi}_\tau\right)^{-\Theta^{l,cbi}_\tau}L^{cbi}_\tau,\text{ and }L^{kb}_\tau(i)=\left(W^{kb}_\tau(i)/W^{kb}_\tau\right)^{-\Theta^{l,kb}_\tau}L^{kb}_\tau,$$
$$\text{for }\tau=0,1,...,\infty. \tag{13}$$

In the utility function the parameter β is the household's discount factor, ν denotes its inverse labor supply elasticity, while ς^{cnn}, ς^{cd}, ς^r, and ς^l are scale parameter that tie down the ratios between the household's consumption components. The stationary, unit-mean, stochastic variables Ξ^{cnn}_t, Ξ^{cd}_t, Ξ^r_t, and Ξ^l_t represent aggregate shocks to the household's utility of its consumption components and its disutility of labor. Letting

$\xi_t^x \equiv \ln \Xi_t^x - \ln \Xi_*^x$ denote the log-deviation of Ξ_t^x from its steady-state value of Ξ_*^x, we assume that

$$\xi_t^x = \rho^{\xi,x}\xi_{t-1}^x + \epsilon_t^{\xi,x}, \qquad x = cnn, cd, r, l. \tag{14}$$

The variable $\epsilon_t^{\xi,x}$ is an i.i.d. shock process, and $\rho^{\xi,x}$ represents the persistence of Ξ_t^x away from steady-state following a shock to equation (14). The household's budget constraint reflects wage setting adjustment costs, which depend on the parameter χ^w and the lagged and steady-state wage inflation rate, and the costs in changing the mix of labor supplied to each sector, which depend on the parameter χ^l. The costs incurred by households when the mix of labor input across sectors changes may be important for sectoral comovements, a point we briefly return to when discussing our parameter estimates.

3.5 Monetary Authority

We now turn to the last important agent in our model, the monetary authority. It sets monetary policy in accordance with an Taylor-type interest-rate feedback rule. Policymakers smoothly adjust the actual interest rate R_t to its target level $\bar{R}_t$

$$R_t = (R_{t-1})^{\phi^r} \left(\bar{R}_t\right)^{1-\phi^r} \exp\left[\epsilon_t^r\right], \tag{15}$$

where the parameter ϕ^r reflects the degree of interest rate smoothing, while ϵ_t^r represents a monetary policy shock. The central bank's target nominal interest rate, $\bar{R}_t$ depends on hours per capita relative to their steady-state level, $\frac{L_t^{cbi}+L_t^{kb}}{L_*^{cbi}+L_*^{kb}(i)}$, the growth rate of hours per capita, $\frac{L_t^{cbi}+L_t^{kb}}{L_{t-1}^{cbi}+L_{t-1}^{kb}}$, GDP inflation relative to target, $\Pi_*^{p,gdp}/\Pi_t^{p,gdp}$, and the acceleration of GDP inflation, $\Pi_t^{p,gdp}/\Pi_{t-1}^{p,gdp}$:

$$\bar{R}_t = \left(\frac{L_t^{cbi}+L_t^{kb}}{L_*^{cbi}+L_*^{kb}(i)}\right)^{\phi^L} \left(\frac{L_t^{cbi}+L_t^{kb}}{L_{t-1}^{cbi}+L_{t-1}^{kb}}\right)^{\phi^{\Delta L}} \left(\frac{\Pi_t^{p,gdp}}{\Pi_*^{p,gdp}}\right)^{\phi^{\pi,gdp}} \left(\frac{\Pi_t^{p,gdp}}{\Pi_{t-1}^{p,gdp}}\right)^{\phi^{\Delta\pi,gdp}} R_*. \tag{16}$$

In equation (16), R_* denotes the economy's steady-state nominal interest rate and ϕ^L, $\phi^{\Delta L}$, $\phi^{\pi,gdp}$, and $\phi^{\Delta\pi,gdp}$ denote the weights in the feedback rule. [2]

3.6 Summary of Model Specification

Our brief presentation of the model highlights several important points. First, although our model considers production and expenditure decisions in a bit more detail, it shares many similar features with other DSGE models in the literature, such as, imperfect competition, nominal price and wage rigidities, and real frictions like adjustment costs and habit-persistence. The rich specification of structural shocks (to productivity, preferences, capital efficiency, and mark-ups) and adjustment costs allows our model to be brought to the data with some chance of finding empirical validation.[3]

3.7 Estimation Strategy

The empirical implementation of the model takes a log-linear approximation to the first-order conditions and constraints that describe the economy's equilibrium, casts this resulting system in its state-space representation for the set of (in our case 12) observable variables, uses the Kalman filter to evaluate the likelihood of the observed variables, and forms the posterior distribution of the parameters of interest by combining the likelihood function with a joint density characterizing some prior beliefs. Since we do not have a closed-form solution of the posterior, we rely on Markov-Chain Monte Carlo (MCMC) methods.

[2]GDP growth equals the Divisia (share-weighted) aggregate of final spending in the economy; to a first approximation, this definition of GDP growth is equivalent to how it is defined in the U.S. NIPA. See Edge, Kiley, and Laforte (2007) for the complete model.

[3]Interestingly, a common criticism of large econometric models like the FRB/US has been their reliance on adjustment costs; DSGE models similar to that herein have increasingly relied on similar mechanisms when required to fit macroeconomic data, which may be a cause for concern regarding the "structural" interpretation of such models.

The model is estimated using 12 data series over the sample period from 1984:Q4 to 2007:Q2. The series, each from the Bureau of Economic Analysis's National Income and Product Accounts except where noted, are: Nominal gross domestic product; Nominal consumption expenditure on non-durables and services excluding housing services; Nominal consumption expenditure on durables; Nominal residential investment expenditure; Nominal business investment expenditure, which equals nominal gross private domestic investment minus nominal residential investment; GDP price inflation; Inflation for consumer non-durables and non-housing services; Inflation for consumer durables; Hours, which equals hours of all persons in the non-farm business sector from the Bureau of Labor Statistics;[4] Wage inflation, which equals compensation per hour in the non-farm business sector from the Bureau of Labor Statistics; the federal funds rate, from the Federal Reserve Board; and the nominal yield on the Ten-Year Treasury Note, our measure of the long-term interest rate.

Our implementation adds measurement error processes to the likelihood implied by the model for all of the observed series used in estimation except the nominal interest rate series. Our companion piece presents estimates of the model's parameters and properties in detail. Previous research (Edge, Kiley, and Laforte (2007, 2008a)) has presented detailed estimation results; the corresponding information used in the current analysis is available upon request.

4 Sources of fluctuations in residential investment

Within Edo, fluctuations in all economic variables are driven by fourteen structural shocks. For our purposes, it is most convenient to summarize these shocks into three broad categories:

[4]We scale up this measure of hours by the ratio of nominal spending in our model to nominal non-farm business sector output in order to model a level of hours more appropriate for the total economy.

- Aggregate supply shocks: This category consists of shocks to technology, labor supply (e.g., the preference for leisure), and price markups.
- Intertemporal IS curve shocks: This category consists of shocks to preferences and capital accumulation technologies (both if which affect the intertemporal Euler equations for the components of household and business demand), autonomous demand, and the slope of the term structure.
- A monetary policy shock

This classification maps (indirectly) the sources of fluctuations into aggregate demand (IS and monetary policy shocks) and aggregate supply in a manner familiar from textbook treatments. However, this mapping is imprecise: for example, technology shocks have significant effects on demand, and demand shocks influence the (short-run) productive potential of the economy through their effect on capital accumulation.

Table 1 presents the forecast-error-variance decomposition for growth of residential investment at various (quarterly) horizons, divided into the three broad categories. These statistics indicate how much of the variance in the forecast error for growth at each horizon is attributable to each category of shock. It is clear from the table that short-run fluctuations in residential investment are overwhelmingly driven by shifts in the IS curve (column 2); aggregate supply shocks contribute the most to the forecast error variance at medium-to-long horizons (column 1). Within the IS curve category, the most important shock contributing to the forecast error variance is the shock to the marginal efficiency of residential investment – that is, shifts in the first-order condition determining residential investment.

Figures 2 and 3 provide a historical decomposition of the percent change in residential investment from a year earlier relative to its trend; the decomposition attributes deviations from trend to the structural shocks. As shown in figure 2, the downturn in residential investment in the early 1990s and recently are entirely declines relative to the long-run trend. According to figure 3, nearly all of the fluctuations relative to trend come from shifts in the IS curve (the middle panel). Aggregate supply shocks

Table 1: Forecast-Error-Variance Decomposition - Growth in Residential Investment

Horizon	Type of Shock Aggregate supply	 Intertemporal IS curve	 Monetary policy
One Quarter	0.15	0.85	0.00
Four Quarter	0.18	0.80	0.01
Eight Quarter	0.66	0.33	0.01

Note: Each row contains the fraction of the forecast-error variance accounted for by each category of shock. Rows may not sum to 100 due to rounding.

(the upper panel) generate lower-frequency fluctuations. Finally, monetary policy shocks the lower panel contribute relatively little to the wide swings in the growth of residential investment. We will return to the role of monetary policy in the third section.

The role of our structural shocks in driving residential investment is a bit hard to interpret out-of-context. We provide similar decompositions for real GDP growth, hours per capita, and GDP price inflation for comparison purposes in tables 2, 3, and 4 and in figures 4 to 9.

For GDP, aggregate supply shocks are the most important contributor to the forecast error variance at all frequencies (table 2, column 1). Nonetheless, shifts in the IS curve have important cyclical effects, as is apparent in the sources of deviations of GDP growth from trend in figure 5; of particular note is the sharp drag on GDP growth exhibited by shifts in the IS curve at the start of the 1990s and 2000s that is, at the start of the two recessions in our sample period.

For hours per capita, shifts in the IS curve dominate the cyclical movements (table 3 and figures 6 and 7). The figures make it quite clear that the drops in hours per capita in the recessions seen over the sample period are largely due to shifts in the

Table 2: Forecast-Error-Variance Decomposition - Growth in Real GDP

	Type of Shock		
Horizon	Aggregate supply	Intertemporal IS curve	Monetary policy
One Quarter	0.76	0.22	0.01
Four Quarter	0.89	0.11	0.01
Eight Quarter	0.97	0.03	0.00

Note: Each row contains the fraction of the forecast-error variance accounted for by each category of shock. Rows may not sum to 100 due to rounding.

IS curve.

Aggregate supply shocks are a very important factor for fluctuations in GDP price inflation (table 4, column 1 and figures 8 and 9). The bottom two panels of figure 7 reveal only a slow-moving and persistent effect of shifts in the IS curve and monetary policy shocks on inflation; the low-frequency effect of IS curve shocks on inflation is apparent in their role in the forecast error variance decomposition at long horizons. The small effect of IS curve errors in the short run and the more important effect in the long run is consistent with the relatively flat Phillips curve effect in response to IS curve shocks.

5 The role of monetary policy

The variance decompositions and decomposition of historical fluctuations in residential investment do not suggest a large role for monetary policy. This finding seems to conflict with arguments by some economists that monetary policy was an important factor in recent fluctuations in residential investment.

In this section, we examine the interaction between monetary policy and residen-

Table 3: Forecast-Error-Variance Decomposition - Hours Per Capita

	Type of Shock		
Horizon	Aggregate supply	Intertemporal IS curve	Monetary policy
One Quarter	0.07	0.88	0.05
Four Quarter	0.02	0.90	0.06
Eight Quarter	0.03	0.90	0.07

Note: Each row contains the fraction of the forecast-error variance accounted for by each category of shock. Rows may not sum to 100 due to rounding.

Table 4: Forecast-Error-Variance Decomposition - GDP Price Inflation

	Type of Shock		
Horizon	Aggregate supply	Intertemporal IS curve	Monetary policy
One Quarter	0.91	0.09	0.01
Four Quarter	0.74	0.24	0.01
Eight Quarter	0.72	0.27	0.01

Note: Each row contains the fraction of the forecast-error variance accounted for by each category of shock. Rows may not sum to 100 due to rounding.

tial investment in more detail. In the first subsection, we take the estimated rule in the FRB/EDO model as given, and examine how shocks to monetary policy have influenced residential investment and the economy more generally; this analysis is very similar to some of the previous research summarized in section 2. The next subsection considers how residential investment, and the economy more generally, may have behaved over the past two decades if monetary policy actions had acted optimally given the structure of the FRB/EDO model.

5.1 Monetary policy shocks

Figure 10 provides some perspective on the role of monetary policy in fluctuations of residential investment. The upper panel presents the contribution of monetary policy shocks to the four-quarter change in residential investment (the dotted blue line) – the same information shown on the lower panel of figure 3, but without the data on residential investment. The primary change from figure 3 is a change in scale – a change that makes it apparent that monetary policy shocks have played a role in housing fluctuations, albeit a modest one relative to the overall size of movements in residential investment. Most recently, monetary policymakers set the federal funds rate below the level implied by the estimated rule: the deviation was modest beginning in 1999, turned very briefly positive in 2000, and then moved more notably below the prescriptions of the rule beginning in the fourth quarter of 2001; policy remained below the level consistent with no deviations from the policy rule until the middle of 2005. But the cumulative deviation was modest. As a result, the cumulative contribution of monetary policy shocks to residential investment from the fourth quarter of 2001 to the middle of 2005 was only 4 percent of the level of residential investment. Given the size of swings in residential investment, this contribution to the rise in residential investment from the end of 2001 is pretty small.

However, an examination of residential investment in isolation does not provide any context. In particular, the upper panel of figure 10 gives no context regarding the setting of monetary policy over this period and its interaction with other economic variables. Edo provides a coherent framework for considering this question, as its detailed general-equilibrium structure allows analysis of residential investment, GDP, inflation, the labor market, and monetary policy within a single model based on clear micro-foundations.

Within Edo, monetary policy is governed by an estimated nominal interest rate rule linking the federal funds rate to its own lag and current and lagged readings on GDP growth and GDP price inflation. The second panel of figure 10 presents the data on the federal funds rate (solid, black line) and the simulated value that would have prevailed with no monetary policy shocks (the dashed, red line). The model explains movements in the federal funds rate quite well. This suggests that monetary policy shocks may have played only a small role in cyclical fluctuations, because most movements in the federal funds rate are systematic policy responses, not policy shocks. Nonetheless, as noted above, the funds rate was consistently below the prescriptions of the estimated policy rule for most of the period from 1999 to 2005. Of course, much of this period was one of a weak labor market, with a recession in 2001 and only slowly recovery in the labor market after 2001. One hypothesis is that monetary policy was looser during this period in order to prevent a more pronounced deterioration in the labor market.

The bottom two panels offer some support to this interpretation. As indicated, monetary policy shocks have only small effects on GDP price inflation and hours per capita according to Edo, because monetary policy, as summarized by the federal funds rate, is well characterized as a systematic response to movements in inflation and the labor market. However, it is quite clear from the bottom panel of figure 10 that hours per capita would have been much lower over 2001 to 2005 absent accomodative monetary policy. From the end of 2001 to the end of 2005, Edo estimates that hours per capita would have been 0.5 to 0.75 percentage points lower in the absence of settings of the federal funds rate below the prescriptions of the policy rule. This additional labor market slack is considerable: For example, a percentage point movement in hours per capita translates, roughly, to 0.4 percentage points on the unemployment rate. Therefore, Edo suggests that the unemployment rate would have peaked at 6.6 percentage points in 2003, 0.3 percentage points higher than the realized peak in the unemployment rate.

The data appear consistent with two hypotheses. First, discretionary monetary policy actions, in the sense of deviations from typical historical practice as summarized by Edo's estimated policy rule, contributed only modestly to the runup in residential investment through 2005. And second, this contribution may have been motivated by a desire to curb the deterioration in the labor market during this period.

Our relatively sanguine interpretation of policy actions during this period is quite different than that of Leamer (2007) and Taylor (2007), who view the setting of the federal funds rate in recent years as a major contributor to the runup in residential investment and a significant policy mistake. These authors reach different conclusions for reasons that are readily apparent from their analysis. Leamer (2007) does not examine monetary policy shocks or consider a structural model; rather, his analysis is stylistic and relies on his assertion that the low level of the federal funds rate in the early 2000s was excessively stimulative. His analysis does not examines a structural model that jointly considers monetary policy, inflation, the labor market, and residential investment. Taylor (2007) considers a calibrated monetary policy rule that fits the data poorly; as a result, he estimates large policy shocks after 2001. And Taylor (2007) does not consider a general equilibrium model; in fact, he concludes that a structural investigation like that we conduct is required to satisfactorily examine these questions. In summary, we find the analyses of Leamer (2007) and Taylor (2007) as more loosely connected to the data and reliant of weaker identifying assumptions (as emphasized by these auithors athemselves, who highlight that structural analyses like ours may prove more informative).

5.2 Optimal Monetary Policy

The modest role of monetary policy shocks in economic fluctuations in Edo, including those for residential investment, clearly arises because policy is well characterized as systematic. As a result, it is important to examine the systematic portion of monetary policy in order to consider the effects of policy actions on economic fluctuations. Therefore, we now turn to an analysis of the effects of alternative specifications of policy rules on fluctuations and most especially residential investment.

The estimated version of Edo assumes that policy is governed by a rule of that depends on GDP price inflation, hours per capita, and the lagged funds rate; this form as chosen both because it fits well and because the legislated mandate of the Federal Reserve involves full employment and price stability – objectives measured in the Edo model in terms of price inflation and fluctuations in hours per capita. Our consideration of alternative policy choices will focus on optimal policy choices for an assumed loss function involving the mandated objectives of policymakers. In particular, we will consider how the economy would have evolved, given the estimated structural shocks according to the Edo model, if policymakers had followed policy rules that minimized our chosen objective function.

Specifically, we assume the monetary policy actions are chosen to minimize an objective function (L) consisting of the weighted variances of GDP price inflation and hours per capita

$$Ł = var(\Pi_t^{p,gdp}) + \omega var(L_t^{cbi}(i) + L_t^{kb}(i)), \text{ for } s = cbi, kb, \tag{17}$$

The parameter ω governs the relative weight placed on the variance of hours, and we compute a policy frontier for various values of this parameter. This assumed loss function is not motivated by appeal to the utility function of the representative agent. Rather, we view such a loss function as a reasonable approximation to the mandated objectives of the Federal Reserve; our assumed loss function also has a long history in analyses of monetary policy. As such, the assumed form of the loss function may provide a reasonable guide to understanding the structure of efficient policies that may be followed to achieve full employment and price stability. A comparison of the nature of efficient policies conditional on a loss function like ours to such policies when the loss funcion is given by the representative agent's utility function is an interesting area for future research.

We impose two constraints on the minimization problem of the monetary policymaker. First, the policymaker minimizes the objective function by choosing the parameters ϕ^{L} and $\phi^{\pi,gdp}$ in the policy rule, while the parameters ϕ^{r}, $\phi^{\Delta L}$ and $\phi^{\Delta\pi,gdp}$ are set equal to 1, 0, and 0; this restriction to simple rules has a long history and provides a useful benchmark against which to judge historical policy. (As our analysis is positive, not normative, the restriction to policies consistent with simple rules is more appropriate as more general policies will be highly model-specific; the restriction ϕ^{r} equal to 1 is consistent with the nature of the Edo model, where inertial rules can yield higher welfare, and the general view among analysts that policy is highly inertial.) Second, we only consider policy rules where the variance of the change in the federal funds rate is less than or equal to that found under the baseline policy rule in Edo; this concern for the variance of the funds rate is consistent with interest rate smoothing, perhaps for reasons related to financial stability. (On the latter point, we readily admit that there is no link between financial stability and the variance of the funds rate in our Edo model; this is another area for future research).

Figure 11 presents the efficient policy frontier, given the structure of the Edo model with parameters at their estimated posterior mode and various values for the weight on hours stabilization. The convex shape is familiar, and the variances of inflation and hours lie modestly above the efficient policy frontier under the estimated historical rule, as indicated by the arrow.

Given the efficient simple rules that underly the policy frontier shown in figure 11, we can consider how economic fluctuations would have proceeded if policy had been governed by the efficient rules rather than the estimated rule. This analysis

Table 5: Variances of Macroeconomic Aggregates Under Alternative Policy Rules

	Variable		
Horizon	GDP price inflation	Hours per capita	Residential Investment
Historical Rule	0.27	2.60	10.45
Rule to stabilize hours	0.27	1.24	11.21

Note: Variance of inflation and the growth rate of residential investment measured at quarterly rates.

simply involves replacing the estimated rule with the efficient rule and simulating the model over history given initial conditions and the evolution of the exogenous processes governing fluctuations uncovered through estimation of the model under the estimated rule. We present these results for one of the efficient rules underlying the frontier in figure 11, corresponding to the rule consistent with point A. Point A is the efficient rule that achieves the same variance of inflation as realized over history. Table 5 reports the variances of hours per capita, GDP price inflation, and the growth rate of residential investment. Figure 12 presents the historical data for these series and the federal funds rate along with their simulated evolution under the alternative policy rule (according to the Edo model). These statistics and simulations of alternative histories assume that agents in the economy fully understand and believe that monetary policymakers are committed to the alternative rule.

The rule consistent with point A in figure 11 places a substantial weight on the stabilization of hours per capita. As a result, GDP price inflation has the same variance as under the estimated historical rule (columns 1 and 2), by construction, while the variance of hours per capita is reduced by 50 percent. The variance of residential invvestment is only slightly higher than that under the historical rule. Figure 12 shows that the alternative rule would have stabilized historical movements in hours per capita a great deal, according to Edo. The alternative path of the federal funds rate over history would have looked quite similar to that actually realized – with somewhat greater declines during recessions according to the alternative rule (in order to maintain hours per capita in those periods at higher levels).

The similarity between the path of the funds rate realized historically and that called for by the alternative rule provides some additional support, at least in a heuristic way, to the notion that policy actions during recessions and their immediate aftermath – such as the period in the early 2000s – may have been motivated by efforts to raise employment and hours during those periods. It is of particular note that the alternative policy consistent with point A called for even lower values of the federal funds rate during and immediately following the recession. This seems inconsistent with the impressions of Leamer (2007) and Taylor (2007), who suggest policy was perhaps too stimulative during that period.

5.3 Comparison to results from the FRB/US model

The Edo model is an example of the growing set of models with specifications tightly linked to assumptions regarding preferences and technologies. These micro-founded models have been developed, in part, to address criticisms of the identifying assumptions and econometric techniques used in models like the FRB/US model (e.g., Sims (2002, 2008)). Nonetheless, models like the FRB/US model are designed to provide good reduced-form fits to the data and have substantial currency in policy applications (e.g., Reifschneider, Stockton, and Wilcox (1997)). As a result, results from models like FRB/US provide a useful check on our analysis.

We compare our analysis using the Edo model to similar results from FRB/US along two dimensions:

- Is the response of residential investment and other variables to monetary policy similar in Edo and FRB/US?

- Does the FRB/US model suggest a similar role for monetary policy shocks in the evolution of residential investment over the last ten years?

These questions provide some sense of the plausibility of the results from Edo.

Figure 13 presents impulse responses following a one-standard deviation monetary policy innovation (28 basis points at an annual rate) for the federal funds rate, real GDP, hours, and residential investment in Edo and the FRB/US model. The path for the funds rate is very similar; the initial responses of hours and GDP are larger in Edo than in FRB/US, the responses at one year are very similar in both models, and hours and GDP return to baseline more quickly in Edo than in FRB/US. The responses for residential investment are very similar at one year in both models. However, the response of residential investment is larger at longer horizons in Edo than in FRB/US. This shows that the sensitivity of residential investment to interest rates is higher in the Edo model. As a result, the Edo model will show larger effects of monetary policy shocks on residential investment than the FRB/US model. This suggests that the small role for monetary policy shocks in the recent evolution of residential investment will also arise in the FRB/US model.

Figure 14 shows that this is the case. The figure presents alternative histories of residential investment assuming that monetary policy followed the rules embedded in Edo and FRB/US since 1999 – i.e., that there were no unusually low settings of the federal funds rate during the 2001 recession. It is clear that the FRB/US model does not ascribe a large role to monetary policy innovations in the recent evolution of residential investment.

The comparison of the results from the Edo and FRB/US models suggests that the conclusions herein are robust to alternative structural models that have been specified to provide policy-relevant descriptions of U.S. economic fluctuations.

6 Conclusions

We have examined the nature of fluctuations in residential investment in an estimated dynamic, stochastic, general-equilibrium model with explicit microceconomic foundations – the Edo model. This model is general enough to consider a broad range of questions, as evidenced by the current and previous applications. In particular, the joint modeling of aggregate fluctuations and monetary policy actions at some level of detail allows for interesting investigations of historical fluctuations and policy actions.

We have three primary findings:

- Fluctuations in residential investment are primarily driven by "shifts in demand" – that is, by shocks to the first-order conditions for residential investment and, to a lesser extent, other intertemporal first-order conditions that act as "intertemporal IS curve shocks" – and not by the shocks like aggregate or investment-specific productivity.
- The fluctuations in GDP are more closely related to productivity, but shocks to the intertemporal IS curve are very important. Intertemporal IS curve shocks overwhelmingly dominate cyclical movements in hours.
- Monetary policy has been only a modest factor in movements in residential investment, even recently.

Our findings regarding monetary policy differ from those in Leamer (2007) and Taylor (2007). Both suggest that overly loose monetary policy contributed significantly to the rise in residential investment following 2001. Our conclusion differs because we focus on a structural model. In fact, our results using the DSGE/Edo model are very similar to results from the FRB/US model, which has a different structure.

Our discussion has skipped over some important details that deserve further study.

Edo contains an explicit, utility-based welfare criterion, and it is possible to consider whether the nature of efficient policy according to this metric, rather than the assumed loss function we have analyzed. However, we do have some reservations about these types of welfare calculations. In particular, Edo contains a very rich description of economic dynamics, but only a partial description of the wide range of factors the lead to important welfare effects of fluctuations in inflation and activity; as a result, its welfare calculations may miss important interactions between features that are included in Edo and those that are excluded.

And we have only provided a cursory description of the nature of the intertemporal IS curve shocks that are very important in Edo. A fuller description of the nature of these shocks may supply good clues regarding future model enhancements that may allow us to more fully understand these sources of fluctuations. One likely source of IS curve shocks is developments in financial markets. This area that is very difficult to model in a micro-founded, general-equilibrium manner, but we consider future research in this area to be very important.

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Figure 1: Model Overview

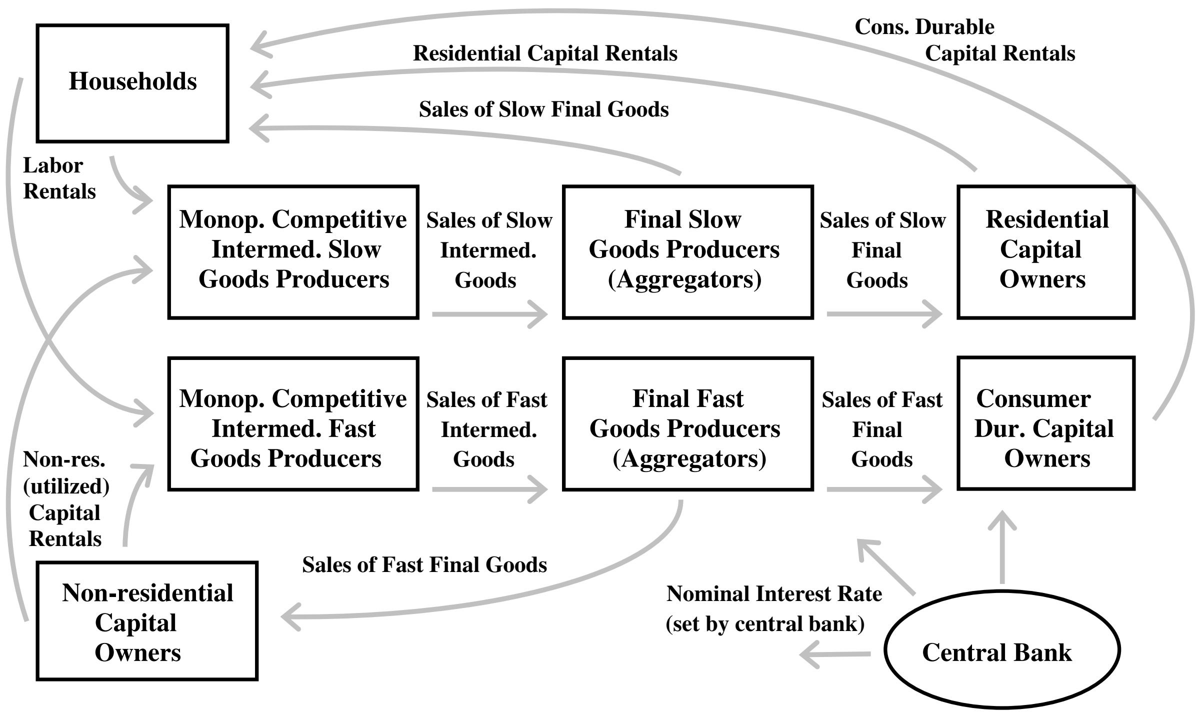
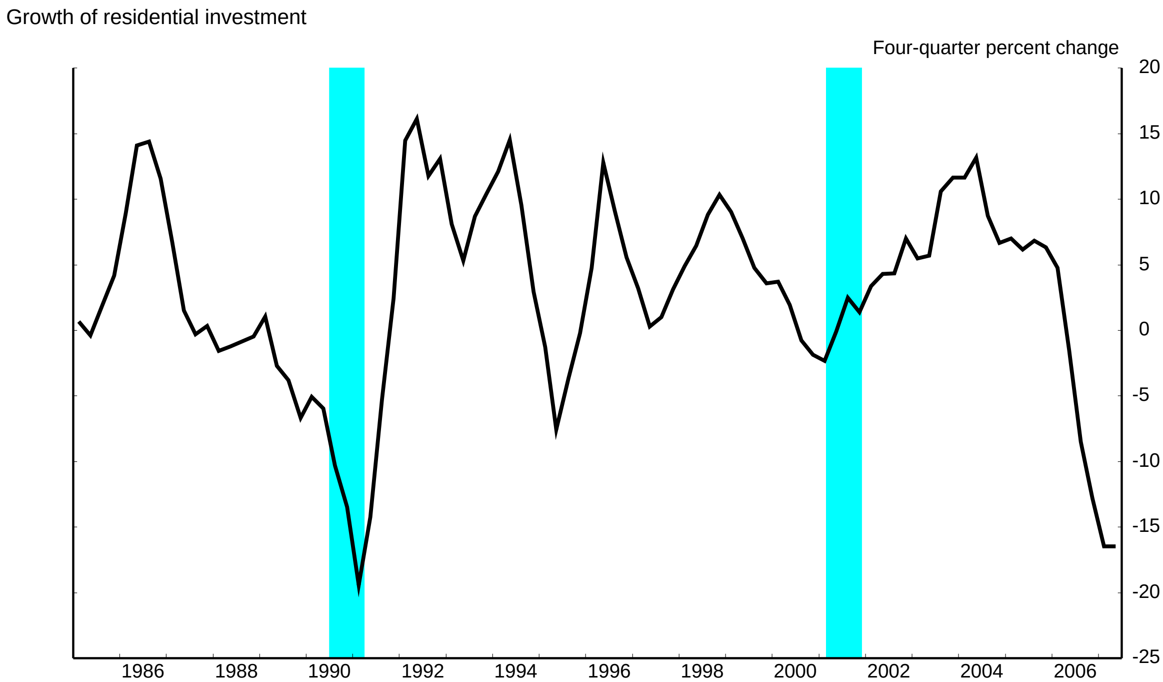


Figure 2
Residential Investment (in chain-weighted 2000 dollars)



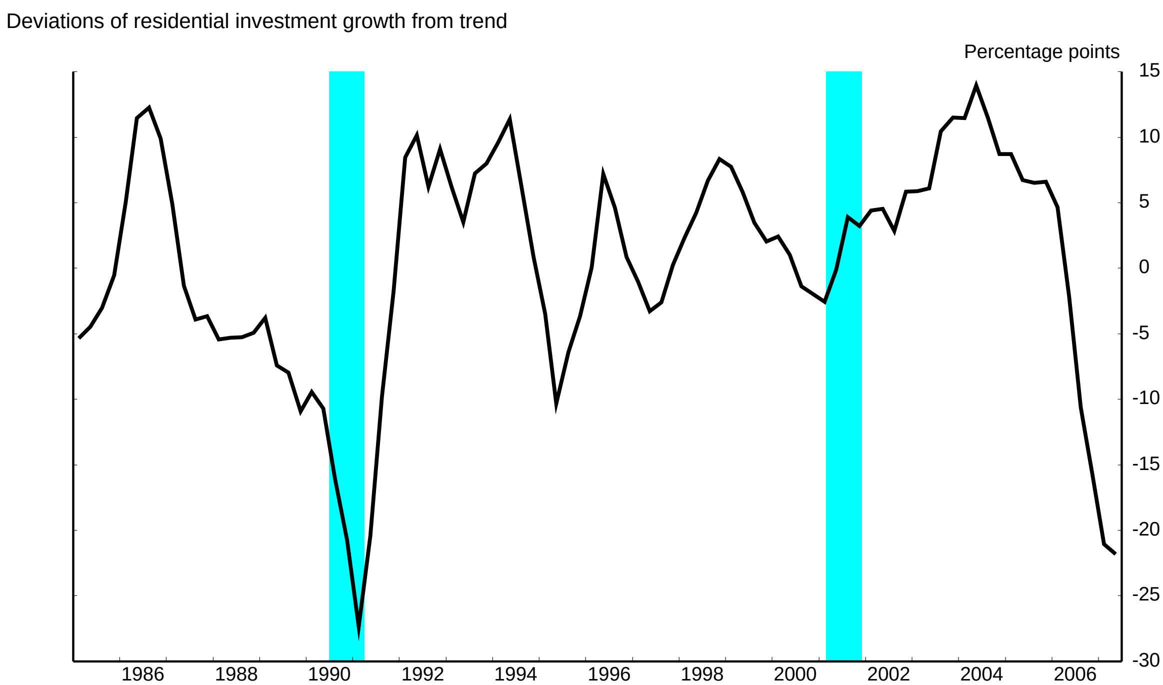
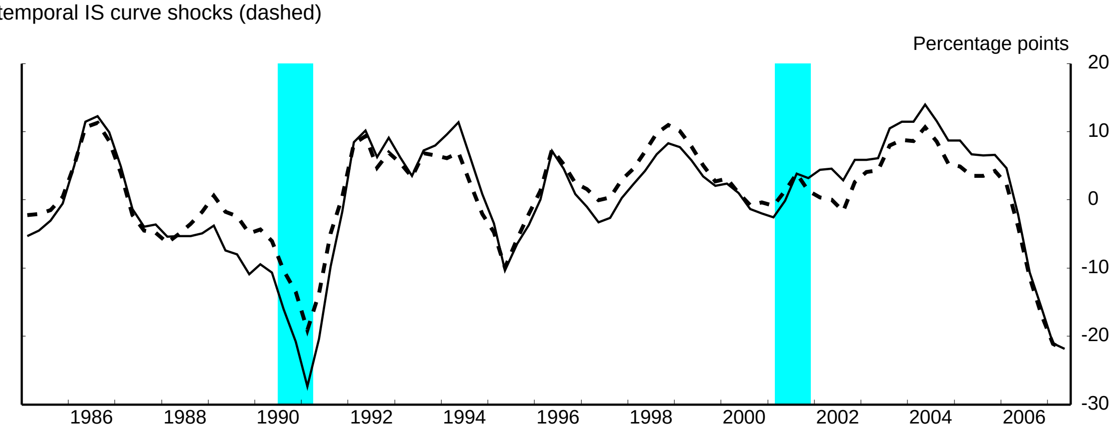


Figure 3
Sources of fluctuations in residential investment

Aggregate supply shocks (dashed)

Intertemporal IS curve shocks (dashed)



Monetary policy shocks (dashed)

Figure 4
Gross domestic product (GDP, in chain-weighted 2000 dollars)

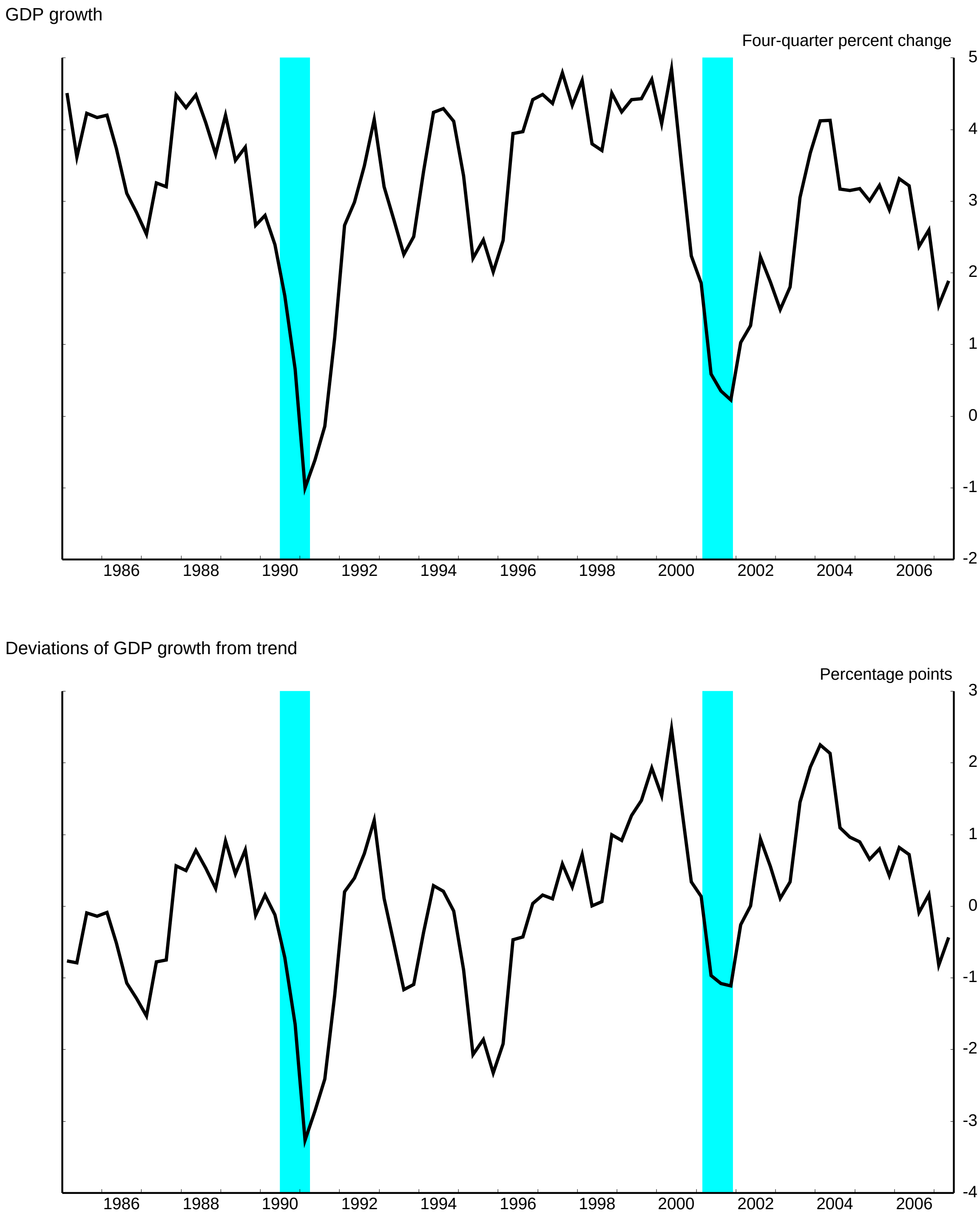
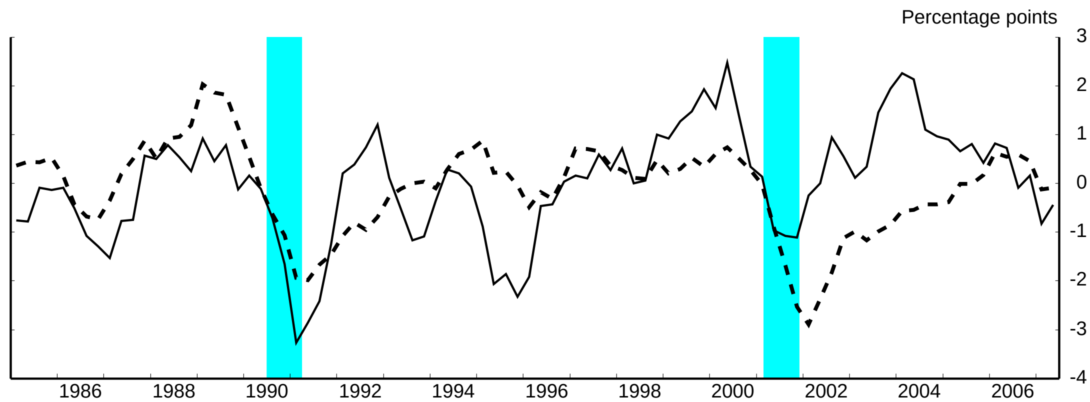


Figure 5
Sources of fluctuations in GDP

Aggregate supply shocks (dashed)

Intertemporal IS curve shocks (dashed)



Monetary policy shocks (dashed)

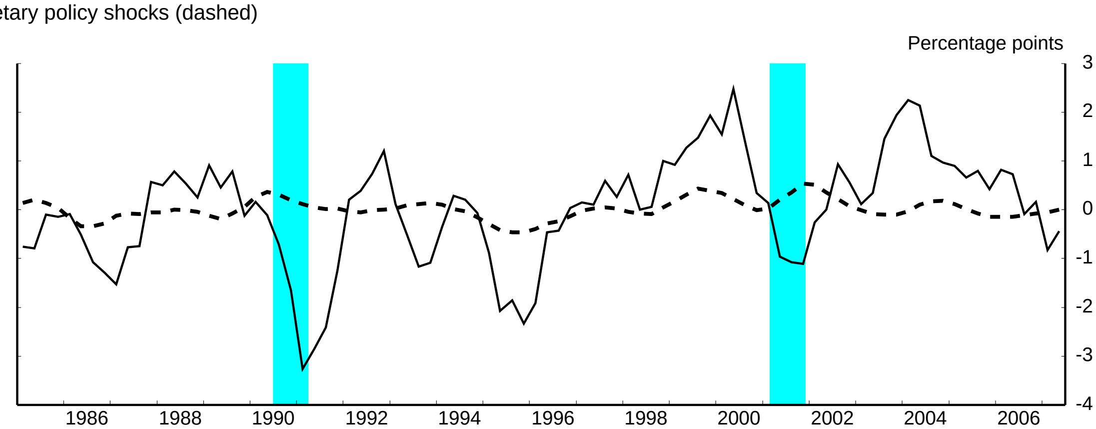


Figure 6
Hours per capita (detrended)

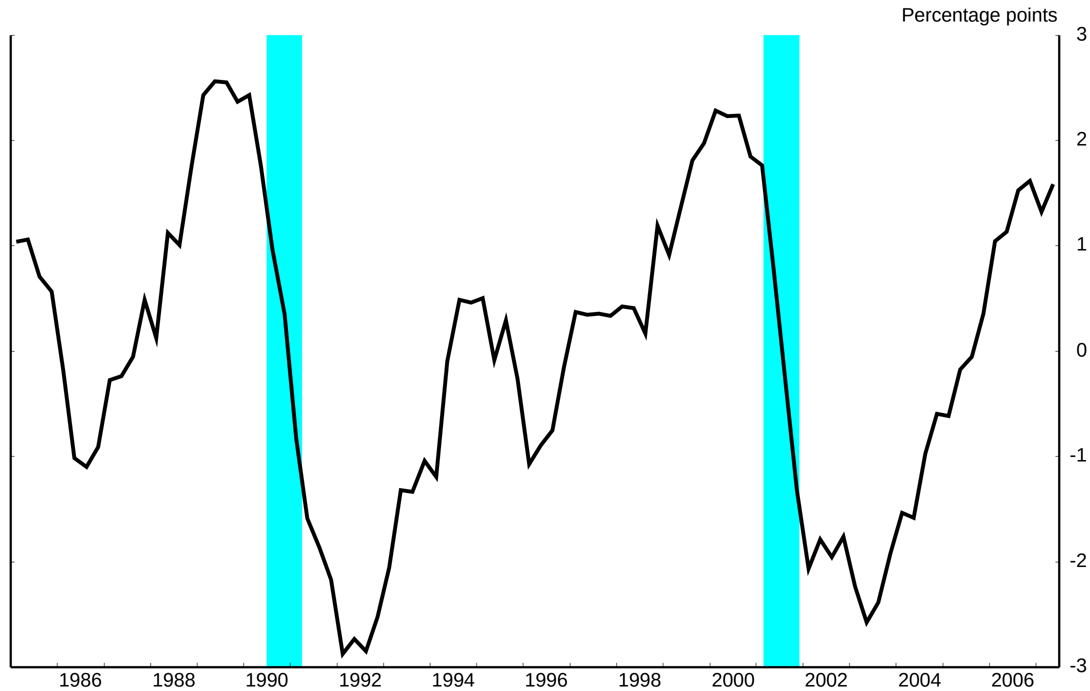
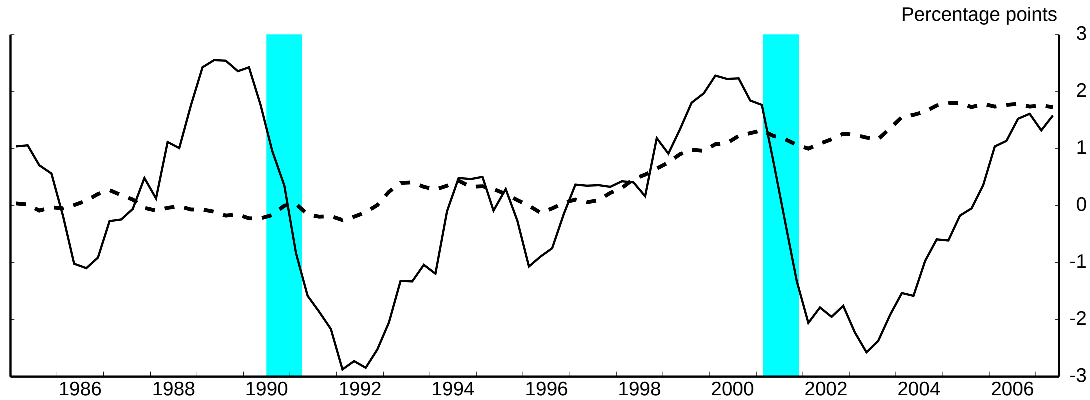
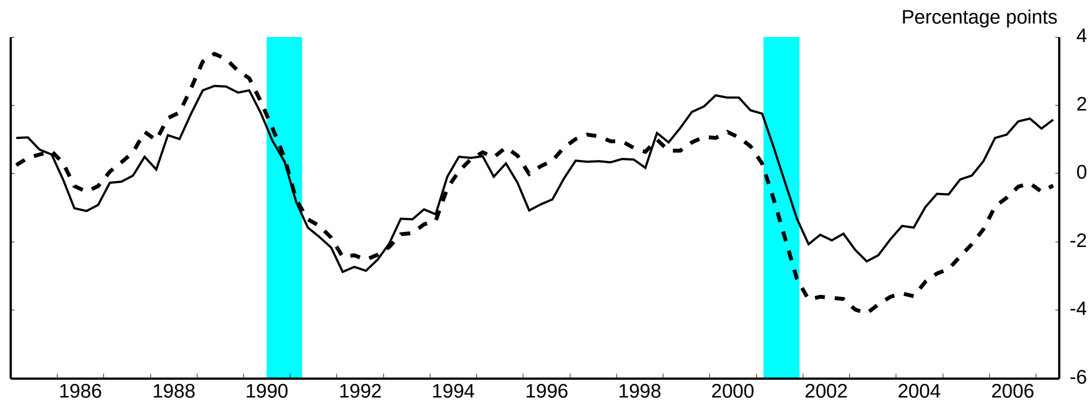


Figure 7
Sources of fluctuations in hour per capita

Aggregate supply shocks (dashed)



Intertemporal IS curve shocks (dashed)



Monetary policy shocks (dashed)

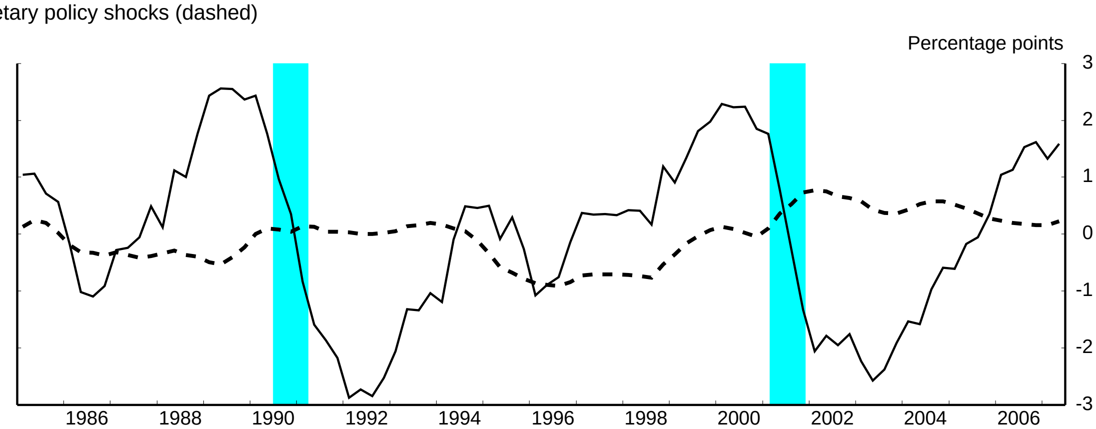
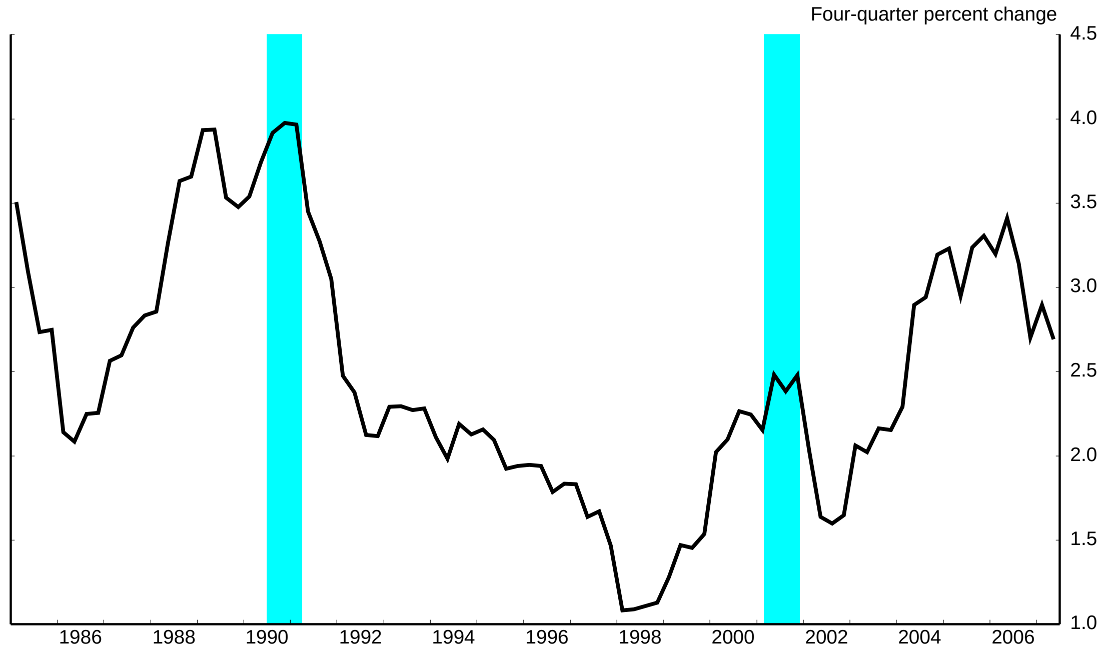


Figure 8
Inflation (GDP price index)

GDP inflation



Deviations of GDP price inflation from trend (four-quarter percent change)

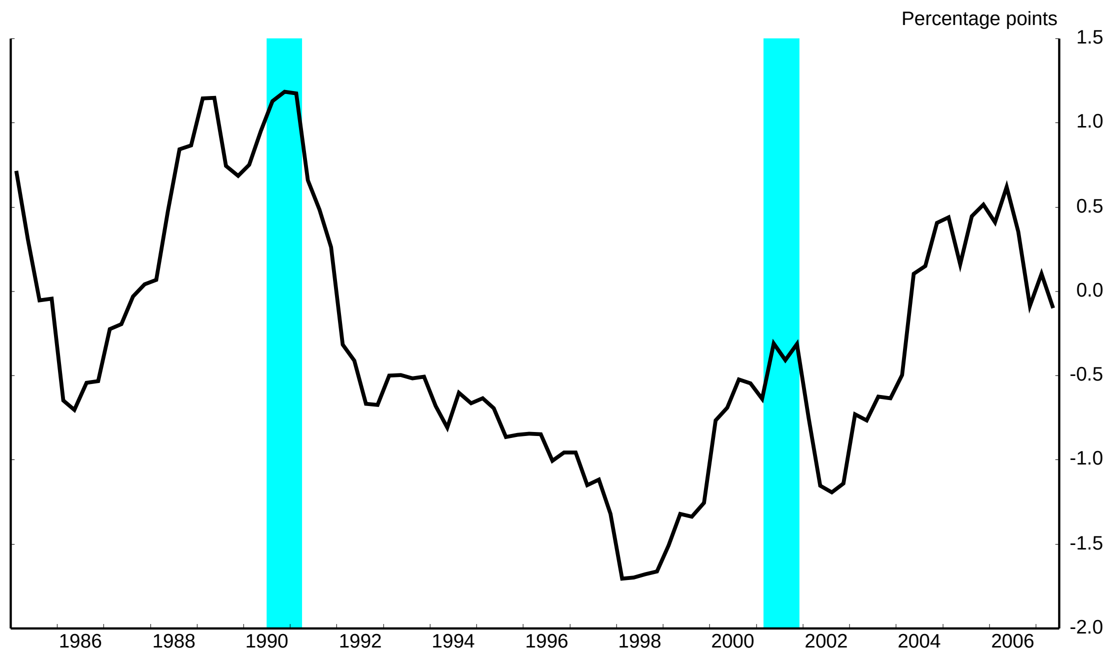
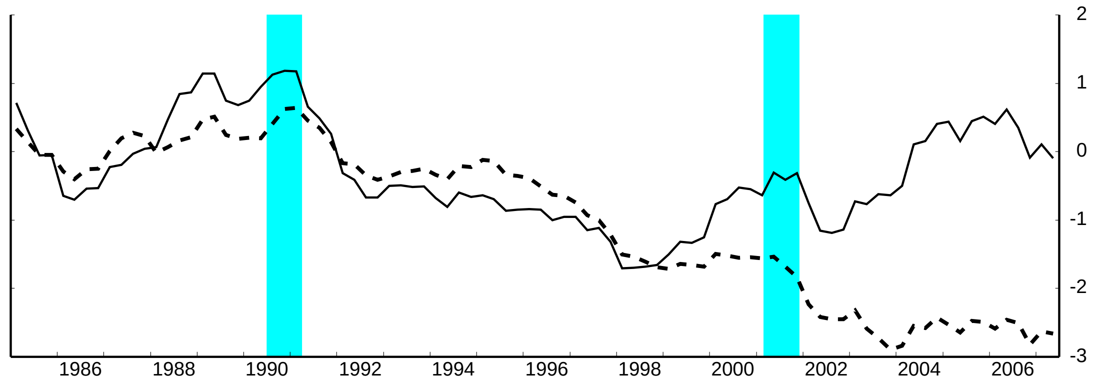
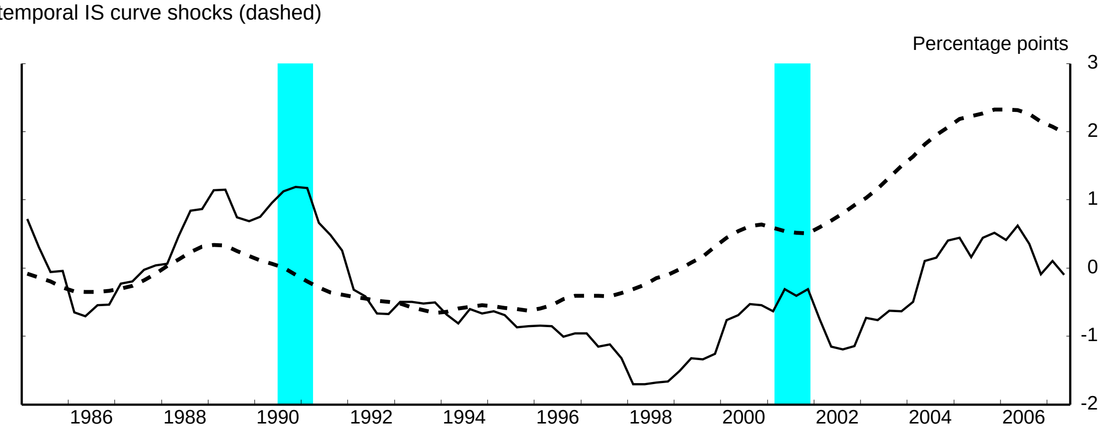


Figure 9
Sources of fluctuations in GDP price inflation

Aggregate supply shocks (dashed)



Intertemporal IS curve shocks (dashed)



Monetary policy shocks (dashed)

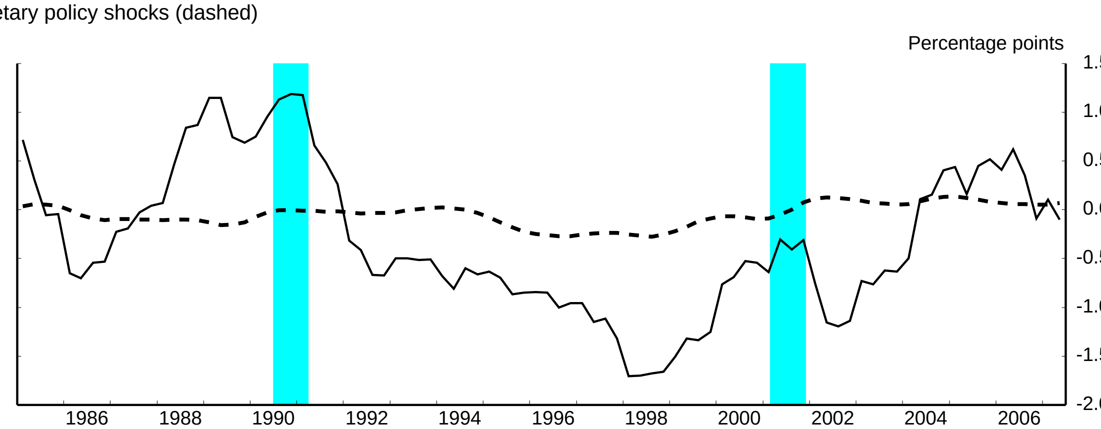
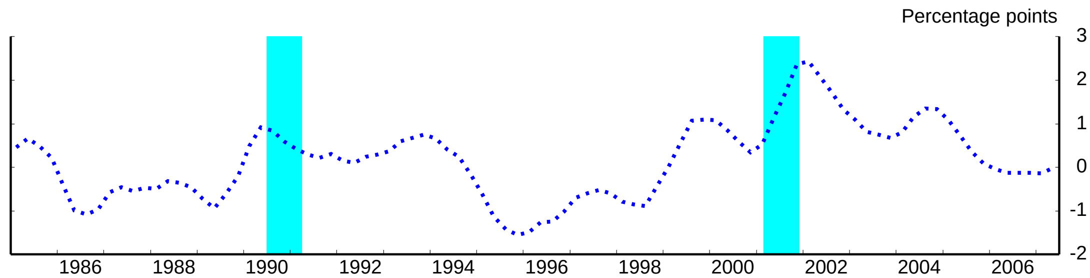
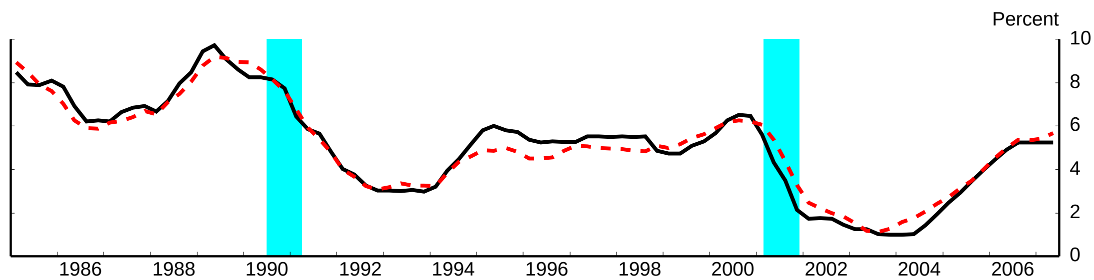


Figure 10: Effects of Monetary Policy Innovations

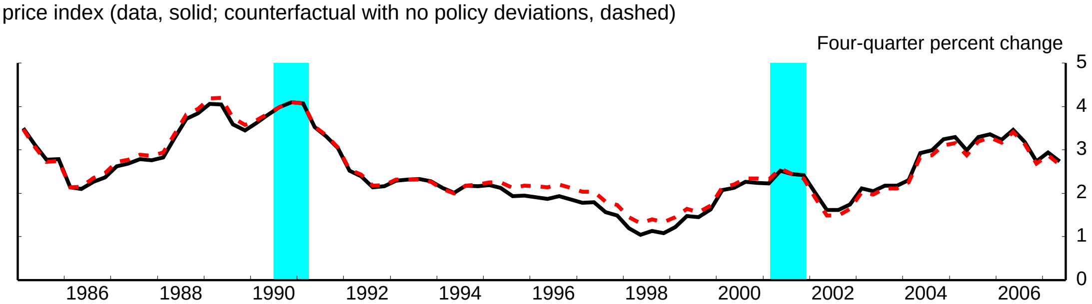
Monetary policy contribution to four-quarter percent change in res. investment (dotted)



Nominal federal funds rate (data, solid; counterfactual with no policy deviations, dashed)



GDP price index (data, solid; counterfactual with no policy deviations, dashed)



Hours per capita (data, solid; counterfactual with no policy deviations, dashed)

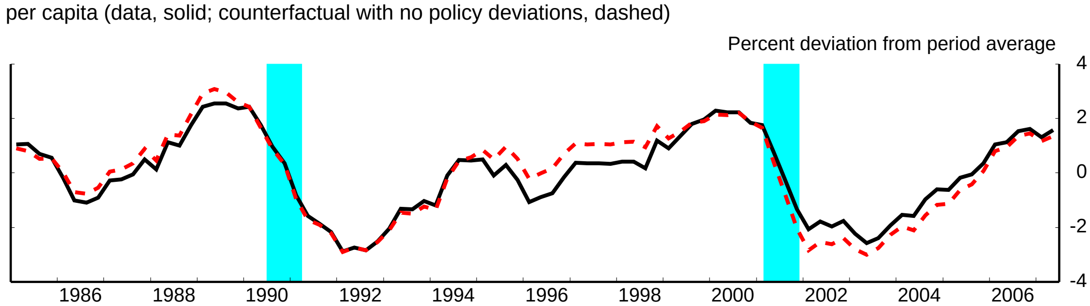


Figure 11: Efficient Policy Frontier

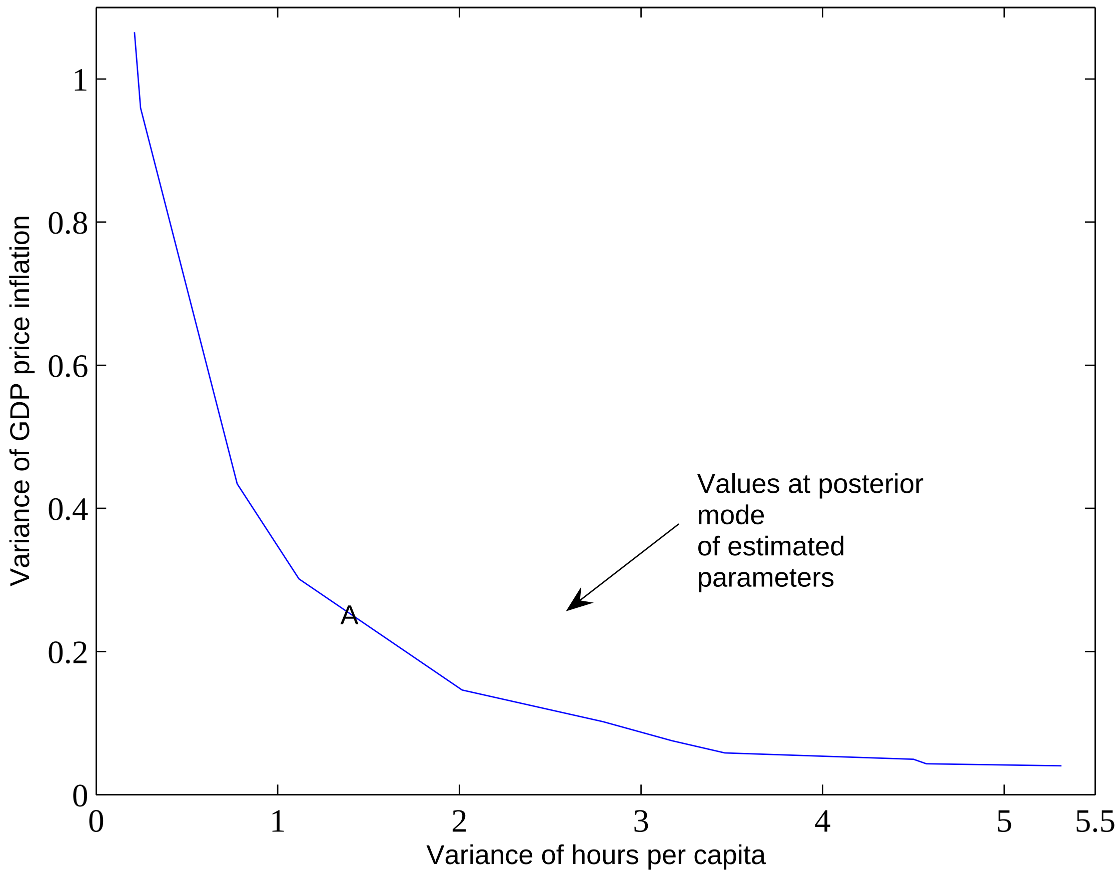
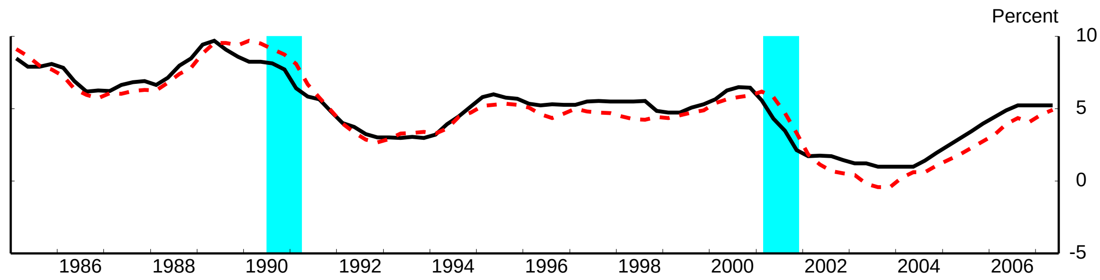
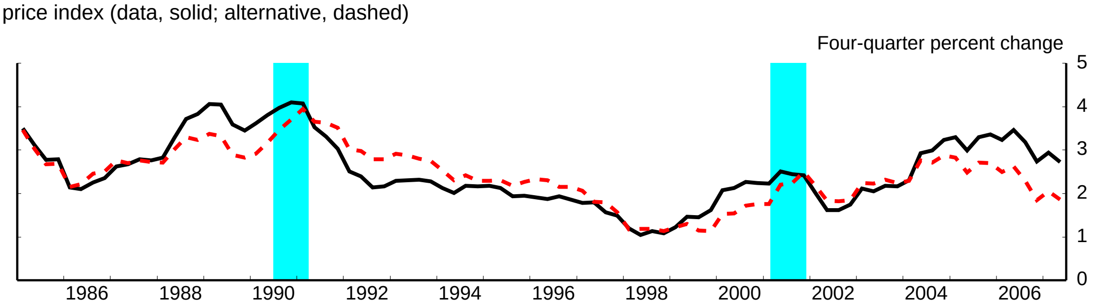


Figure 12: Alternative Histories Under Hours-Stabilizing Monetary Policy

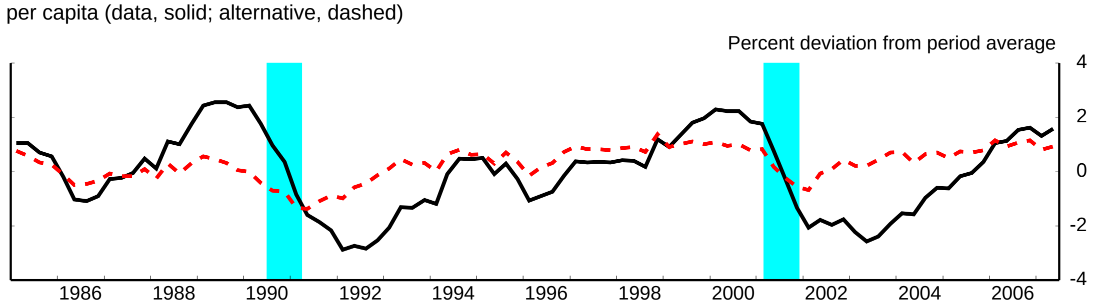
Nominal federal funds rate (data, solid; alternative, dashed)



GDP price index (data, solid; alternative, dashed)



Hours per capita (data, solid; alternative, dashed)



Residential investment (data, solid; alternative, dashed)

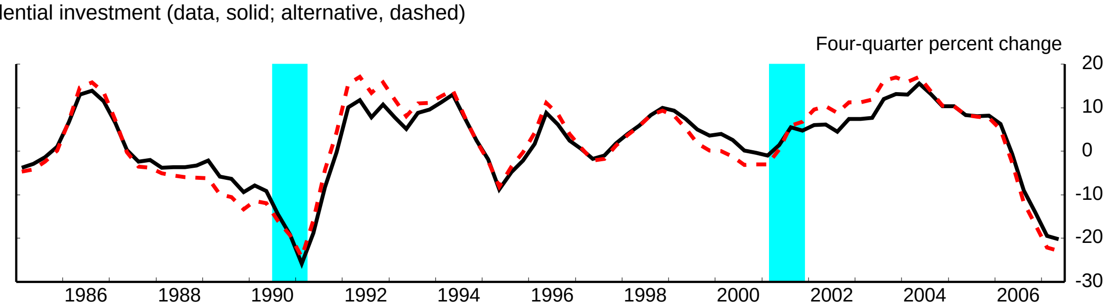


Figure 13
Impulse responses to a monetary policy shock
(solid, DSGE/Edo; dashed, FRB/US model)

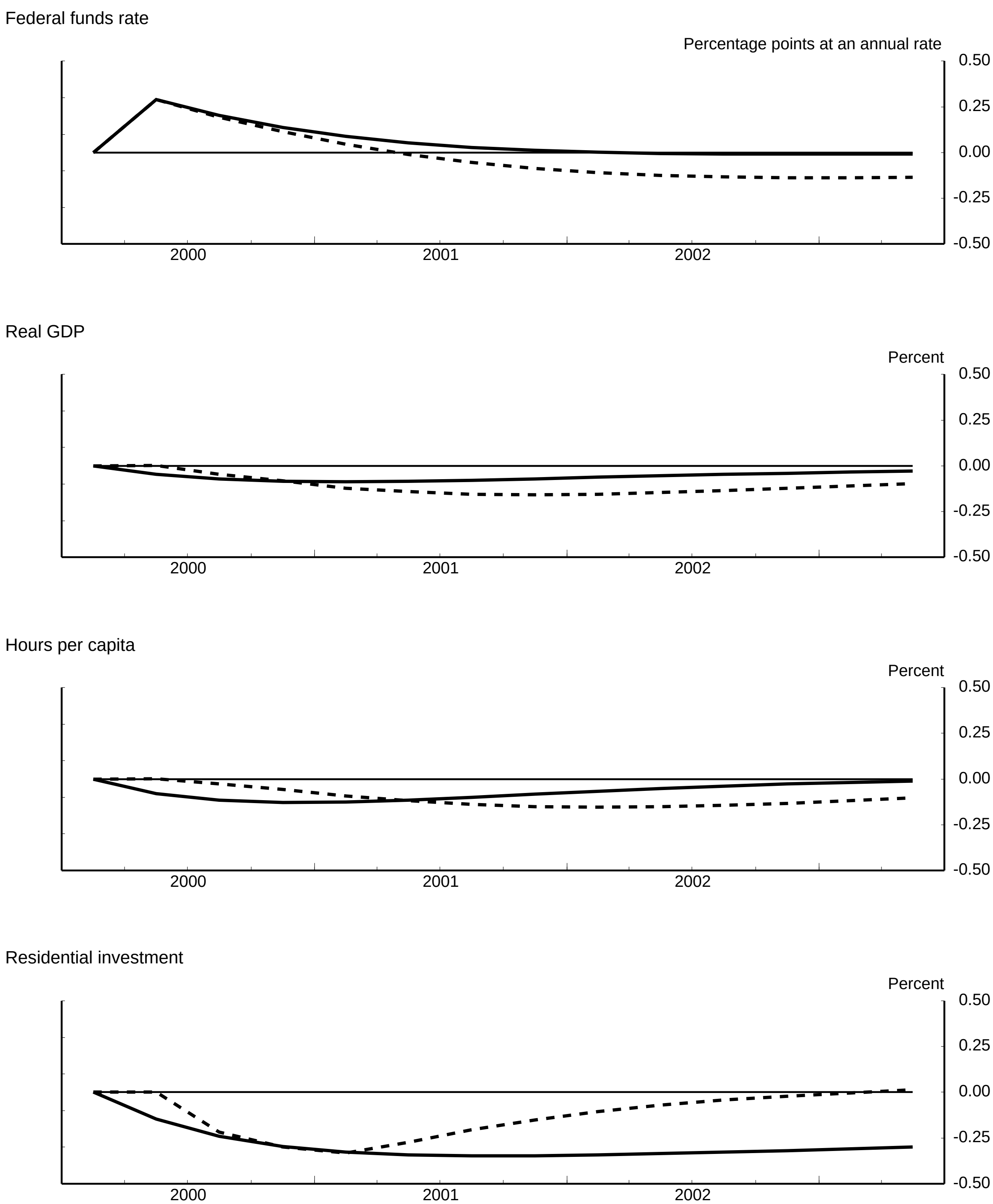


Figure 14
Alternative Paths of Residential Investment Absent Monetary Policy Shocks (post-1998)
(solid, data; dashed, DSGE/Edo model; dotted, FRB/US model