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

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PRELIMINARY AND INCOMPLETE
In 2007 the Research and Statistics Division moved into production an estimated DSGE model, called FRB/EDO, for use in addressing both quotidian and *ad hoc* policy questions.

- This model serves as a complement to FRB/US.

- Quotidian questions currently addressed by the model include the generation of an alternative model forecast.

- Going forward other uses of the model are anticipated.

- In this paper, we use this model, which was developed as a general-purpose, policy-oriented DSGE model, to examine the sources of recent fluctuations in residential investment.
Outline of the presentation

- Describe the FRB/EDO (Estimated Dynamic Optimization-based) model.
  - Emphasize the features of the model that differ from the Christiano-Eichenbaum-Evans/Smets-Wouters models.

- Discuss briefly the estimation of the model.

- Turn to the analysis on residential investment fluctuations.
  - Document the role of different model shocks in accounting for fluctuations in residential investment and other key variables.
  - Examine the paths of residential investment and other key variables under alternative monetary policies.
Our model is more disaggregated than most closed-economy models.

The model has two production sectors:
- A slow-growing goods producing sector, $X^{slw}$; and,
- A fast-growing goods producing sector, $X^{fst}$.

The model has multiple expenditure aggregates:
- Expenditures on consumer nondurable goods and non-housing services, $E^{cnn}$;
- Expenditures on consumer durable goods, $E^{cd}$;
- Expenditures on residential capital, $E^r$;
- Expenditures on non-residential capital, $E^{nr}$; and,
- Public, net-foreign demand, $E^{exog}$. 
Why do we disaggregate production?

- U.S. NIPA data are *not* consistent with a one-sector growth model.
  - There are sizable differences in long-run real growth rates across NIPA categories with large trends in relative prices.
  - But nominal growth rates are broadly similar across NIPA categories.

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A two-sector growth model implies:

- Differential real growth rates and inflation rates across sectors.
- The same nominal growth rate across sectors.

When

$$X_{slw} = (K_{slw}^{t})^{\alpha} (Z_{ntrl}^{t} L_{slw}^{t})^{1-\alpha}$$

and

$$X_{fst} = (K_{fst}^{t})^{\alpha} (Z_{ntrl}^{t} Z_{fst}^{t} L_{fst}^{t})^{1-\alpha}$$

(\text{where } \ln Z_{t}^{s} = \ln Z_{t-1}^{s} + \ln \Gamma_{s}^{s} + \gamma_{t}^{s}, \ s = \text{ntrl, fst}), \ we \ have:\

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<th>Sector</th>
<th>Real Gr. ((\Gamma_{*}^{x,s}))</th>
<th>Price Ch. ((\Pi_{*}^{p,s}))</th>
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<td>Slow</td>
<td>(\Gamma_{<em>}^{z,ntrl} (\Gamma_{z,fst}^{</em>})^{\alpha})</td>
<td>(\Pi_{*}^{p,slw})</td>
<td>(\Pi_{<em>}^{p,slw} \Gamma_{</em>} (\Gamma_{*}^{z,fst})^{\alpha})</td>
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<td>Fast</td>
<td>(\Gamma_{*}^{z,ntrl} \Gamma_{z,fst}^{z})</td>
<td>(\Pi_{<em>}^{p,slw} (\Gamma_{</em>}^{z,fst})^{\alpha-1})</td>
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When \( X_{slw} \) and \( X_{fst} \) are given by:

\[
X_{slw} = (K_{slw})^\alpha (Z_{slw}^{ntrl} L_{slw})^{1-\alpha} \quad \text{and} \quad X_{fst} = (K_{fst})^\alpha (Z_{fst}^{ntrl} Z_{fst}^{fst} L_{fst})^{1-\alpha}
\]

(where \( \ln Z_t^s = \ln Z_{t-1}^s + \ln \Gamma_{*,z,s}^z + \gamma_{t,s}^z \), \( s = ntrl, fst \)), we have:

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<tr>
<th>Sector</th>
<th>Real Gr. ((\Gamma_{*,x,s}^x))</th>
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Long-run properties of a two-sector growth model

- A two-sector growth model implies:
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  - The same nominal growth rate across sectors.

When \( X_{slw}^t = (K_{slw}^t)^\alpha (Z_{ntrl}^t L_{slw}^t)^{1-\alpha} \) and \( X_{fst}^t = (K_{fst}^t)^\alpha (Z_{ntrl}^t Z_{fst}^t L_{fst}^t)^{1-\alpha} \) (where \( \ln Z_t^s = \ln Z_{t-1}^s + \ln \Gamma_{*,s}^z + \gamma_{t,s}^z s = ntrl, fst \)), we have:

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- Differential real growth rates and inflation rates across sectors.
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(\text{where} \ ln Z_{t}^{s} = ln Z_{t-1}^{s} + \ln \Gamma_{s}^{*}, s = ntrl, fst), \ we \ have:

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Why do we further disaggregate expenditures?

- Different expenditure categories have different cyclical properties.
  - Consumer durables and residential investment tend to lead business cycles; non-residential *fixed* investment tends to lag.
  - Consumer durables and residential investment may be more responsive to monetary policy.

- Policy-makers are concerned with movements in detailed aggregates.

- Growth accounting requires that the (latent) capital stock series used in the model’s production functions correspond to conventional definitions of productive capital.
Model features

- **Nominal rigidities:**
  - Sticky prices and sticky wages, where both lagged inflation and steady-state inflation determine adjustment costs.

- **Real rigidities:**
  - Habit formation in consumption;
  - Adjustment costs to investment;
  - Adjustment costs to cross-sectoral factor movements; and,
  - Variable utilization of non-residential capital.
Household preferences

- Utility is defined over leisure and the following goods:
  - Consumer non-durable goods and non-housing services, $E_{t}^{cnn}$;
  - Consumer durable capital stock, $K_{t}^{cd}$; and,
  - Residential capital stock, $K_{t}^{r}$.

- Within-period utility is:

$$\varsigma^{cnn} \Xi^{cnn}_{t} \ln \left( E_{t}^{cnn} (i) - h^{cnn} E_{t-1}^{cnn} (i) \right) + \varsigma^{cd} \Xi^{cd}_{t} \ln \left( K_{t}^{cd} (i) - h^{cd} K_{t-1}^{cd} (i) \right)$$

$$+ \varsigma^{r} \Xi^{r}_{t} \ln \left( K_{t}^{r} (i) - h^{r} K_{t-1}^{r} (i) \right) - \varsigma^{l} \Xi^{l}_{t} \left( L_{t}^{slw} (i) + L_{t}^{fst} (i) \right)^{1+\nu}$$

- $\Xi^{cnn}_{t}$, $\Xi^{cd}_{t}$, $\Xi^{r}_{t}$, and $\Xi^{l}_{t}$, are persistent preference shocks.
Capital evolution processes

- The economy possesses multiple capital stocks:
  - Non-residential capital, $K_{nr}^r$;
  - Residential capital stock, $K^r_t$; and,
  - Consumer durable capital stock, $K_{cd}^t$.

- Investment incurs adjustment costs; e.g., res. capital evolves:

\[
K_{t+1}^r(k) = (1 - \delta^r)K_t^r(k) + A_t^r E_t^r(k) \\
- \frac{100 \cdot \chi^r}{2} \left[ \frac{E_t^r(k) - E_{t-1}^r(k) \Gamma_{t}^{x,slw}}{K_t^r} \right]^2 K_t^r
\]

- $A_t^r$ is a transitory, but persistent, capex. “efficiency” shock.

- Non-residential and consumer durables capital evolve similarly.
Intermediate goods producing firms and households face convex adjustment costs in altering their prices and nominal wages.

Adjustment costs depend on both lagged and steady-state inflation.

The log-linearized price Phillips curves are:

\[ \pi_{t}^{p,s} = \frac{\eta^{p,s}}{1 + \beta \eta^{p,s}} \cdot \pi_{t-1}^{p,s} + \frac{\beta}{1 + \beta \eta^{p,s}} \cdot E_{t} \pi_{t+1}^{p,s} \]

\[ - \frac{1}{1 + \beta \eta^{p,s}} \cdot \frac{1}{100 \cdot \chi^{p,s} (\Pi_{*}^{p,s})^{2}} (\Theta_{*}^{x,s} - 1) m_{c,t}^{s} - \theta_{t}^{x,s} . \]

The log-linearized wage Phillips curves take a similar form.
The log-linearized monetary policy rule is:

\[ r_t = \phi^r \cdot r_{t-1} + (1 - \phi^r) \cdot \bar{r}_t + \epsilon_t. \]

The target nominal interest rate, \( \bar{r}_t \), is:

\[ \bar{r}_t = \phi^{l_{total}} \cdot l_{total} + \phi^{\Delta l_{total}} \cdot \Delta l_{total} + \phi^{\pi_{gdp}} \cdot \pi_{gdp} + \phi^{\Delta \pi_{gdp}} \cdot \Delta \pi_{gdp}. \]

where \( l_{total} \) = Total hours and \( \pi_{gdp} \) = GDP price inflation.

Total hours are the sum of hours in the slow and fast sectors of the economy.

GDP price inflation is consistent with the NIPAs; that is, it is a Tornquists index.
Utility maximization by households (and cost minimization by capital owners) implies:

- Non-durables & non-housing services consumption demand, consumer durables demand, residential capital goods demand.
- Labor supply (i.e., wage Phillips curves).

Cost minimization by firms (and capital owners) implies:

- Economy-wide labor demand.
- Non-residential capital goods demand.

Profit-maximization by firms implies:

- Aggregate supply for goods (i.e., price Phillips curves).
- The monetary authority follows an interest rate feedback rule.
- Public and foreign demand evolve exogenously.
The model is estimated with Bayesian techniques using 12 data series:

**Real variables**
- GDP
- NDS (ex. housing) consumption
- Durables consumption
- Residential investment
- Non-residential investment
- Hours in the NFB sector

**Wages and prices**
- Real comp. per hour in the NFB sector
- GDP deflator
- NDS (ex. housing) consumption deflator
- Non-residential investment goods deflator

**Financial market**
- Yield on the 10-yr. Treasury (coupon-basis)

**Monetary policy**
- Federal funds rate

All other (latent) model variables are estimated as part of the Kalman-filter routine.

The estimation period 1984q3 to 2007q2.
The model assumes 14 exogenous structural shocks

**Technology shocks**
- Sector-neutral TFP
- Sector-specific TFP

**Mark-up shocks**
- Slow sector prices over m.c.
- Fast sector prices over m.c.

**Preference shocks**
- Labor supply
- Durables consumption
- Housing services consumption
- NDS (ex. housing) consumption

**Capex. efficiency shocks**
- Non-residential investment
- Residential investment
- Consumer durables

**Demand shock**
- Exog. public, net-foreign demand

**Term prem./Unexpl. bond price shock**
- 10-yr Treasury rate

**Monetary policy shock**
- Federal funds rate

Later we will group shocks into AS curve shocks and IS curve shocks, while the monetary policy shock will remain alone.
Estimation overview (2)

The model assumes 14 exogenous structural shocks

| Technology shocks | • Sector-neutral TFP
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Key estimation results

- **Nominal rigidities:**
  - Nominal rigidities are important with prices more sticky than wages.
  - In both the wage and price Phillips curves, the weight on the lead of inflation is larger than on the lag.

- **Real rigidities:**
  - Habit formation for NDS (ex. housing) consumption is large.
  - Habit formation for the service flow from consumer durables and residential capital is lower but the data is not informative.
  - Adjustment costs are important for explaining the dynamics of residential and non-residential investment spending.
  - Adjustment costs in the movement of labor between the two production sectors are important for aggregate comovement.

- Most of the structural shocks follow persistent processes.
Main questions for this paper

- What are the fundamental determinants of business-cycle fluctuations in residential investment?

- Are the sources of fluctuations in residential investment different from the sources for real GDP, hours, and GDP price inflation fluctuations?

- How important was monetary policy as a factor driving residential investment fluctuations over the past two decades, as well as more recently?

  - We consider both the systematic and non-systematic components of monetary policy.
Related research: Identified VAR models

- Del Negro & Otrok (2007) use a FAVAR model to examine the influence of monetary policy shocks on house prices.
  - Monetary policy shocks have little influence on the national component of the 2001 to 2005 house price appreciation.

- Fisher & Quayyum (2006) use a VAR to examine the influence of monetary policy shocks on residential investment.
  - Monetary policy innovations play only a very small role in explaining the 2001 to 2005 surge in spending.
  - Technology shocks from the late 1990s (via wealth) account for most of the surge.

- Because Del Negro & Otrok and Fisher & Quayyum both use non-structural approaches, they cannot consider the role of the systematic component of monetary policy.
Taylor (2007) uses a reduced-form, single-equation model linking housing starts to the funds rate to consider the influence of monetary policy shocks.

- Monetary policy shocks are the difference between the actual funds rate and that implied by the classic (1.5,0.5) Taylor rule.

- In this case monetary policy shocks are large and found to play a key role in the surge in residential investment.

- Taylor does not consider the role of the systematic component of monetary policy.
Iacoviello & Neri (2007) develop a two-sector DSGE model to examine the influence of monetary policy, technology, and preferences shocks on house prices and investment.

- Their production disaggregation is between housing and non-housing PDFP.

- Their modeling of housing is richer (e.g., includes a collateral channel, land). However, our modeling of the rest of the economy is more detailed.

- The estimation period is 1965q1 to 2006q4.

- Monetary policy shocks have a non-trivial influence on the run up in house prices and residential investment spending.

Iacoviello & Neri do not consider the role of the systematic component of monetary policy.
Fluctuations in macroeconomic variables

- Fluctuations in all variables in the model are driven by our 14 structural shocks.

- Deviations from steady-state of any variable can be attributed to innovations in these 14 shocks.

- As discussed model shocks are grouped into AS curve shocks and IS curve shocks; the monetary policy shock remains alone.

- We report the sources of fluctuations over time as well as the variance decomposition over the full sample.
  - We first consider residential investment growth.
  - We then consider other key macroeconomic variables (real GDP growth, hours, and GDP price inflation).
Sources of fluctuations in residential investment

Legend: Solid, black - Total deviation from trend; Dashed, blue - Deviation due to type of shock.

Aggregate supply shocks

Intertemporal IS curve shocks

Monetary policy shocks

Forecast-error variance decomposition

<table>
<thead>
<tr>
<th>Horizon</th>
<th>1-quarter</th>
<th>4-quarter</th>
<th>8-quarter</th>
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<td>Aggregate Supply</td>
<td>0.15</td>
<td>0.18</td>
<td>0.66</td>
</tr>
<tr>
<td>Intertemporal IS curve</td>
<td>0.85</td>
<td>0.80</td>
<td>0.33</td>
</tr>
<tr>
<td>Monetary Policy</td>
<td>0.00</td>
<td>0.01</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Legend: Solid, black - Total deviation from trend; Dashed, blue - Deviation due to type of shock.
Sources of fluctuations in real GDP

Aggregate supply shocks

Intertemporal IS curve shocks

Monetary policy shocks

Forecast-error variance decomposition

Legend: Solid, black - Total deviation from trend; Dashed, blue - Deviation due to type of shock.
Sources of fluctuations in hours

Aggregate supply shocks

Percentage points

Intertemporal IS curve shocks

Percentage points

Monetary policy shocks

Percentage points

Forecast-error variance decomposition

<table>
<thead>
<tr>
<th></th>
<th>1-quarter</th>
<th>4-quarter</th>
<th>8-quarter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate Supply</td>
<td>0.07</td>
<td>0.02</td>
<td>0.03</td>
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<tr>
<td>Intertemporal IS curve</td>
<td>0.88</td>
<td>0.90</td>
<td>0.90</td>
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<tr>
<td>Monetary Policy</td>
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<td>0.06</td>
<td>0.07</td>
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</tbody>
</table>

Legend: Solid, black - Total deviation from trend; Dashed, blue - Deviation due to type of shock.
Sources of fluctuations in GDP price inflation

Legend: Solid, black - Total deviation from trend; Dashed, blue - Deviation due to type of shock.

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Aggregate Supply</th>
<th>Intertemporal IS curve</th>
<th>Monetary Policy</th>
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<tbody>
<tr>
<td>1-quarter</td>
<td>0.91</td>
<td>0.09</td>
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<tr>
<td>4-quarter</td>
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<td>0.01</td>
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<tr>
<td>8-quarter</td>
<td>0.72</td>
<td>0.27</td>
<td>0.01</td>
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</tbody>
</table>

Legend: Solid, black - Total deviation from trend; Dashed, blue - Deviation due to type of shock.
## Forecast error variance decompositions for key variables

<table>
<thead>
<tr>
<th>Type of shock</th>
<th>Horizon (quarter)</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>1</td>
<td>4</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td><strong>Res. investment growth</strong></td>
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<td>Real GDP growth</td>
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<td></td>
</tr>
<tr>
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<td>0.01</td>
</tr>
<tr>
<td><strong>Hours</strong></td>
<td>Hours</td>
<td>GDP price inflation</td>
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Business-cycle fluctuations in residential investment appear to be driven by innovations to the intertemporal IS curve.

The sources of fluctuations in residential investment growth differ from those for real GDP growth, hours, and GDP price inflation.

Monetary policy shocks—i.e., deviations of interest rates from the model’s estimated feedback rule—have had only a minor influence on recent fluctuations in residential investment.

That said, they have not had absolutely no influence.
Recall: Sources of fluctuations in residential investment

Legend: Solid, black - Total deviation from trend; Dashed, blue - Deviation due to type of shock.

Forecast-error variance decomposition

<table>
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<tr>
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Edge, Kiley, Laforte
Sources of Fluctuations in Residential Investment...
Effects of monetary policy innovations

Legend: Solid, black - Data; Dashed, red - Counterfactual with no monetary policy innov.
The role of monetary policy shocks

- Monetary policy shocks boosted residential investment growth only a couple of percentage points over 2002 to 2005.
  - Relatively speaking this boost is small.

- Monetary policy shocks had little impact on GDP price inflation over the expansion but a notable influence on hours.

- Had monetary policy not deviated from the model’s interest rate rule:
  - Monetary policy tightening would have started in late 2003;
  - Hours per capita would have been $\frac{1}{2}$ to $\frac{3}{4}$ percentage points lower over the post-2001 recovery and expansion; and,
  - The unemployment rate would have peaked at 6.6 percent, 0.3 percentage point higher than its realized peak.
The FRB/US model also finds that monetary policy shocks account for little of the recent movements in residential investment.

In addition, had monetary policy not deviated from the model’s interest rate rule:

- The unemployment rate would have peaked at 6.8 percent; 0.5 percentage point higher than its realized peak.
Residential investment, absent policy shocks

Legend: Solid, black - Data; Dashed, blue - FRB/EDO; Dotted, red - FRB/US.

Billions of 2000 chain-weighted dollars

Legend: Solid, black - Data; Dashed, blue - FRB/EDO; Dotted, red - FRB/US.

Edge, Kiley, Laforte
Sources of Fluctuations in Residential Investment...
Comparison to results reported in related research

- Comparison to Taylor (2007).
  - The monetary policy shocks used in Taylor’s analysis are substantially larger those implied by our model.
  - Housing starts may be more sensitive to the funds rate due to Taylor’s estimation period of 1959q2 to 2007q2.

- Comparison to Iacoviello & Neri (2007).
  - Monetary policy may be deemed a greater contributor to cycles due to the estimation period of 1965q1 to 2006q4.

- Comparison to Del Negro & Otrok (2007) and Fisher & Quayyum (2006). These studies:
  - Use similar sample periods to ours; and
  - Reach broadly similar conclusions (though we do not attribute residential investment fluctuations to AS curve shocks).
Aside: Transmission of monetary policy in FRB/EDO

Legend: Dashed, blue - FRB/EDO model; Dotted, red - FRB/US model.
How important is the systematic component of monetary policy in inducing fluctuations in residential investment?

Would alternative monetary policy rules have implied more modest fluctuations in residential investment?

We answer these questions recognizing the Federal Reserve’s legislated mandate of full employment and price stability.
We compare the systematic component of the monetary policy rule we estimate to optimized simple rules.

Our simple rules are of the form

\[ \Delta r_t = \phi_{\pi,gdp} \cdot \pi_{t}^{p,gdp} + \phi_{l,total} \cdot l_{t}^{total}.\]

We choose \( \phi_{\pi,gdp} \) and \( \phi_{l,total} \) in this rule to minimize

\[ \mathcal{L} = \text{Var}(\pi_{t}^{p,gdp}) + \omega \cdot \text{Var}(l_{t}^{total}) \text{ for } \omega \in [0, 5] \]

subject to (i) all model equations and (ii) \( \text{Var}(r_t) \) not exceeding \( \text{Var}(r) \) over history.

This implies a policy frontier with each point corresponding to a value of \( \omega \).
The efficient policy frontier

![Graph showing the relationship between the variance of hours per capita and the variance of GDP price inflation. The graph is labeled with axes for variance of hours per capita and variance of GDP price inflation. The title of the graph is not visible.]
The efficient policy frontier

![Graph showing the efficient policy frontier with variance of hours per capita on the x-axis and variance of GDP price inflation on the y-axis. The graph includes a line that curves downward from left to right, indicating a trade-off between the two variables. A point labeled "Values at the posterior mode" is marked on the line.]
The efficient policy frontier

![Graph showing the relationship between variance of hours per capita and variance of GDP price inflation. The graph includes points marked as values at the posterior mode and values at hours stabilizing policy.](image-url)
The efficient policy frontier

Variance of hours per capita

Variance of GDP price inflation

Values at the posterior mode

Values at hours stabilizing policy

Values at inflation stabilizing policy
Outcomes under alternative monetary policy rules (1)

Legend: Solid, black - Actual policy (no innov.); Dashed, blue - Hours-stabilizing policy (no innov.);
Dotted, red - Inflation-stabilizing policy (no innov.)

Nominal federal funds rate

GDP price index

Hours per capita

Residential investment

Legend: Solid, black - Actual policy (no innov.); Dashed, blue - Hours-stabilizing policy (no innov.);
Dotted, red - Inflation-stabilizing policy (no innov.)

Sources of Fluctuations in Residential Investment...
The paths of residential investment under the alternative policies that we consider are little different from under the estimated rule.

Thus, to the extent that the Federal Reserve faces a mandate of full employment and price stability:

- The systematic component of monetary policy does not appear to have driven recent movements in residential investment.
Monetary policy has had only modest effects on the recent path of residential investment.

Fluctuations in residential investment are mainly driven by IS curve shocks.

Understanding these IS shocks and their propagation will likely highlight directions for future model development.