Procyclical Productivity in New Keynesian Models

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Impulse and Propagation Mechanisms

Research Question

- In the data, labor productivity is procyclical conditional on demand shocks. Yet, due to non-increasing returns in labor, models have a difficult time generating it.
- New Keynesian models use a variety of mechanisms such as (1) capital/labor utilization and (2) fixed cost of production to move productivity, but
  - labor productivity still does not move sufficiently (Christiano et al., 2005), and
  - a countercyclical labor share consistent with data is difficult to get (Cantore et al., 2021; Nekarda and Ramey, 2020), due to countercyclical markups.
- We propose a mechanism where productivity is increased as households exert effort to squeeze output out of the economy.
- Our theory shows analytically how this mechanism works and improves a lot the performance of a version of medium-scale DSGE (Christiano et al., 2016).
- We view it as a step forward in aligning the model with data.

Key Ingredients of the Mechanism

- Households care about
  1. the number of varieties (need to be found with search effort), and
  2. the quantity of each variety (need to be purchased with spending).
- Suitably chosen preferences ensure that more spending
  1. increases the number of varieties in the basket (available number of varieties $>$ what a single household can find), and
  2. increases the purchases of each variety.
- Search effort matches with firms' production locations (dealt with a directed search protocol), which determines firms' occupancy rate.
- Since search effort is not measured as an input, higher occupancy rate looks like higher productivity.
- Unlike costly capital/labor utilization models, firms do not pay for this higher productivity.

A Brief Description of the Search Friction

- Each firm, as a variety producer, operates a continuum of locations, each of which has its own preinstalled inputs and identical production technology.

- A directed search protocol coordinates the matches of production locations with search effort in active markets indexed by price and tightness $\{p, q\}$.

- A **CRS** matching function $\psi(J(p,q), D(p,q))$ between firms J and search effort D in each market $\{p, q\}$. Market tightness is defined as $q = \frac{D(p,q)}{J(p,q)}$.

- Matching probabilities per unit of search effort and per firm are $\psi^h(q) \equiv \frac{\psi(J(p,q),D(p,q))}{D(p,q)}$ and

$$\psi^f(q) \equiv \frac{\psi(J(p,q), D(p,q))}{J(p,q)} \qquad \text{(occupancy rate is TFP).}$$

A Glimpse of a Simple Static Model with Exogenous Expenditures and Wages

- Consider a Single Goods Market $\{p, q\}$.
- Household's utility displays love for varieties $\mathcal{I}$ and distaste of search effort d:

$$u\left(\int_0^{\mathcal{I}} c_i^{\frac{1}{\rho}}\, di, d\right) \quad \text{with} \quad \rho > 1.$$

- The varieties found depend on search effort d, and market tightness q:

$$\mathcal{I} = d\ \psi^h(q).$$

- When the only market available has price p, we get the budget constraint with nominal spending e

$$e \geq p \int_0^{\mathcal{I}} c_i\ di = p\ \mathcal{I}\ c.$$

- The household chooses $\mathcal{I}$, d, and $\{c_i\}$ to maximize utility.

Determination of Available Markets (Technical)

- Define an interim object that determines firm problem.
  - Let $\Phi(e, \overline{v})$ as the set of markets or pairs $\{p, q\}$, in which the household attains utility $\overline{v}$ when spending e.
  - $\Phi(e, \overline{v})$ implicitly defines a one-to-one mapping from price p to tightness q that we denote as $\widetilde{q}(e, \overline{v}, p)$.
  - Associated to these markets, the household's optimal purchase of goods for each variety is denoted as $\widetilde{c}(e, \overline{v}, p)$.
- These two objects are what firms take as given when solving their problem.

Firms' Choice

- For firms in each location, output occurs only when households show up. Consequently, the actual output is ψ^f times the potential output.

- Firms take as given nominal wages W, functions $\widetilde{c}(e, \overline{v}, p)$ and $\widetilde{q}(e, \overline{v}, p)$, and a Rotemberg style price adjustment cost $\chi(p)\ e$ to maximize profits:

$$\Omega(e, W, \overline{v}) = \max_{p} \left(p\ \psi^f(\widetilde{q}(e, \overline{v}, p)) - W \right)\ \widetilde{c}(e, \overline{v}, p) - \chi(p)\ e,$$

Equilibrium is a pair $\{P^*, Q^*\}$

- where households optimize

$$\frac{e}{P^*} \cdot (\rho - 1) \cdot \psi^f(Q^*)^{\rho-1} = \zeta \cdot (Q^*)^{1+\nu},$$

  - Households' FOC (for GHH utilitiy) reflects the trade-off between the love for varieties $\psi^f(Q^*)^{\rho-1}$ and the searching distaste $(Q^*)^{1+\nu}$.
- and firms also optimize ($\mathcal{E}(q) \equiv \frac{d \ln \psi^f(q)}{d \ln q}$)

$$\chi_p(P^*)\, P^* = \frac{\rho}{\rho - 1} \left[\frac{W}{P^*\ \psi^f(Q^*)} - \frac{1}{\rho\,(1 - \mathcal{E}(Q^*))} \right].$$

  - The left hand side is the marginal Rotemberg cost of changing the price.
  - The term inside the bracket is marginal cost minus marginal revenue.
  - Marginal cost is the real wage noting that the firm is not fully occupied.
  - Marginal revenue takes into account that an increase in the quantity sold increases productivity via the increase in search effort of households.
- The standard case has full occupancy $\psi^f(Q^*) = 1$ & $\mathcal{E}(Q^*) = 0$. The hhold condition disappears and the firm's optimality condition becomes

$$\chi_p(P^*)\, P^* = \frac{\rho}{\rho - 1} \left[\frac{W}{P^* \ \cdot \ 1} - \frac{1}{\rho\,(1 - \ 0\ )} \right].$$

The Impact of Expenditures e in the New Mechanism

- Perturbation of the equilibrium conditions yields

$$d\ln(\psi^f(Q^*)) = \widetilde{\Psi} \cdot [d\ln(e) - d\ln(P^*)],$$
$$d\ln(P^*) = \widetilde{\kappa} \cdot \left[d\ln(W) - d\ln(P^*) + (\widetilde{\gamma} - 1)\, d\ln(\psi^f(Q^*)) \right].$$

- $(\widetilde{\Psi}, \widetilde{\gamma}, \widetilde{\kappa})$ are functions of deep parameters. They have to satisfy certain restrictions to ensure procyclical markups, inflation and real wages.

- $(\widetilde{\Psi}, \widetilde{\gamma})$ are new.

  - $\widetilde{\Psi}$ captures the elasticity of occupancy rate $\psi^f(Q^*)$ w.r.t. real spending e/P^*,

  - $\widetilde{\gamma}$ captures the elasticity of gross desired markup $\rho\,(1 - \mathcal{E}(Q^*))$ w.r.t. occupancy rate $\psi^f(Q^*)$ (just an algebraic connection).

Putting These Ideas to Work

- We embed this variable number of varieties with the search friction in a version of the ***medium-scale NK model*** in Christiano et al. (2016).
- We see how it performs vis a vis versions of the model w/o this mechanism.
  - We add labor productivity and labor share to the estimation targets.
  - We use Rotemberg instead of Calvo to avoid price dispersion issues and ignore the public sector (for convenience).
- We look at Three Models
  1. **Capital utilization alone**: Like Christiano et al. (2016) that estimates the curvature of utilization costs among many other things.
  2. **Search alone**: Infinite curvature of utilization costs but need to estimate two additional parameters $\widetilde{\Psi}$ and $\widetilde{\gamma}$ (elasticity of TFP w.r.t. real spending and that of desired markup w.r.t. TFP).
  3. **Both capital utilization and search (benchmark)**

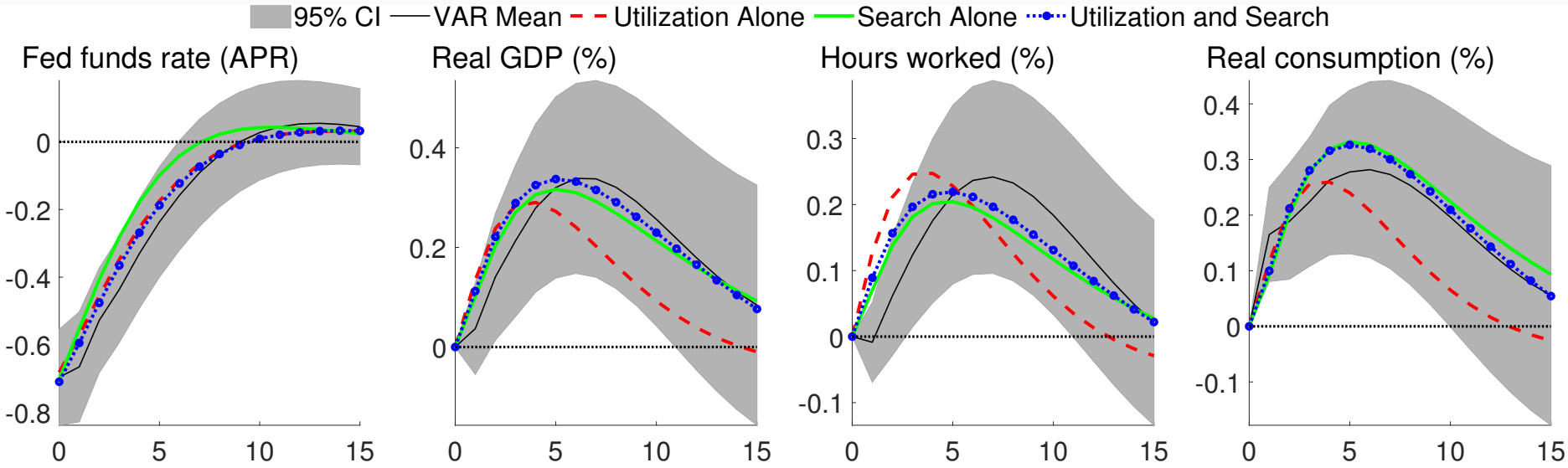
Estimation via Impulse Response Matching

- We estimate 15 parameters in the benchmark model
- to match 11 SVAR impulse responses of
  - real GDP, hours worked, real consumption, real investment, Fed funds rate,
  - capacity utilization, real wage, inflation, relative price of investment,
  - labor productivity, labor share,
- under 3 structural shocks of
  - Fed funds rate,
  - neutral technology,
  - investment-specific technology.

Important Numbers from the Estimation Results

	Capital Util Alone (u)	Search Alone	Both u and Search
Steady-state markup	**0.53**	**0.25**	**0.14**
Fixed cost of production / GDP	**0.39**	**0.14**	**0.03**
Frisch elasticity of labor supply	**9.09**	**1.01**	**1.56**
corr(Markup, GDP | FFR shocks)	**0.06**	**0.76**	**0.96**
Log marginal likelihood	**3.8**	**117.1**	**167.1**
Curvature of capital utilization cost	**0.10**	∞	**0.36**
Elast. of TFP wrt real spending, $\widetilde{\Psi}$	-	**0.42**	**0.39**
Elast. of desired markup wrt TFP, $\widetilde{\gamma}$	-	**0.27**	**0.79**

Selected Results of Impulse Response Matching



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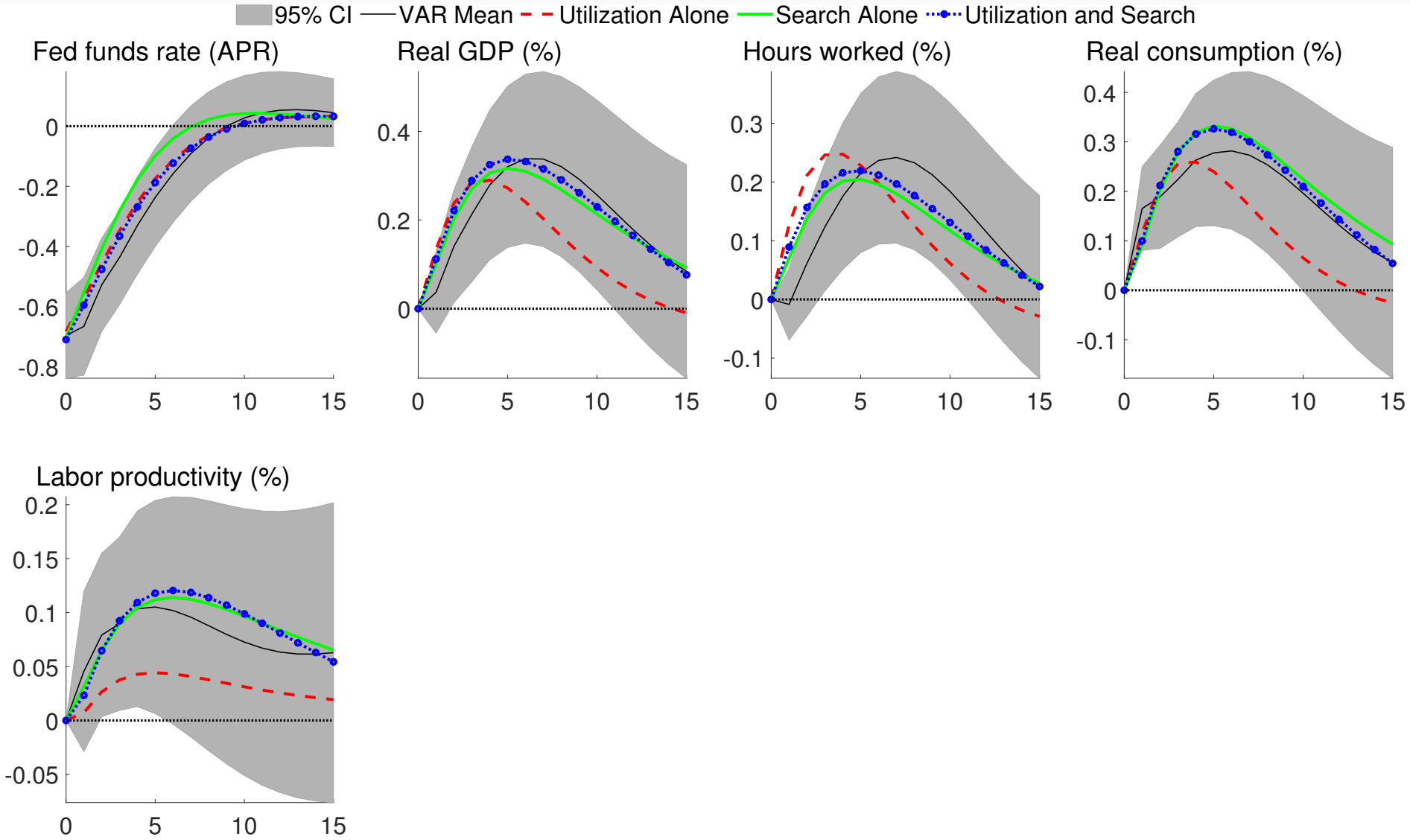

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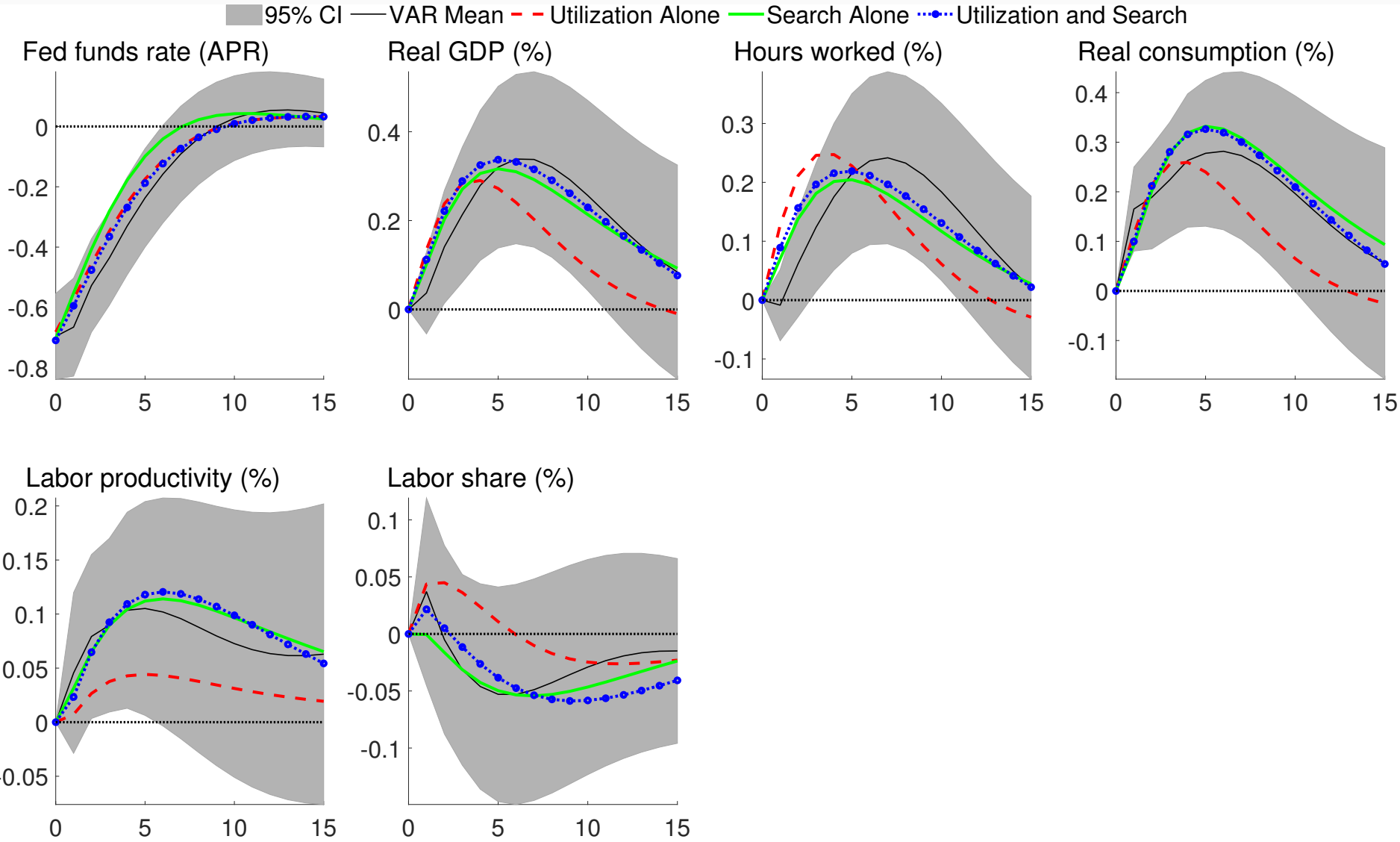

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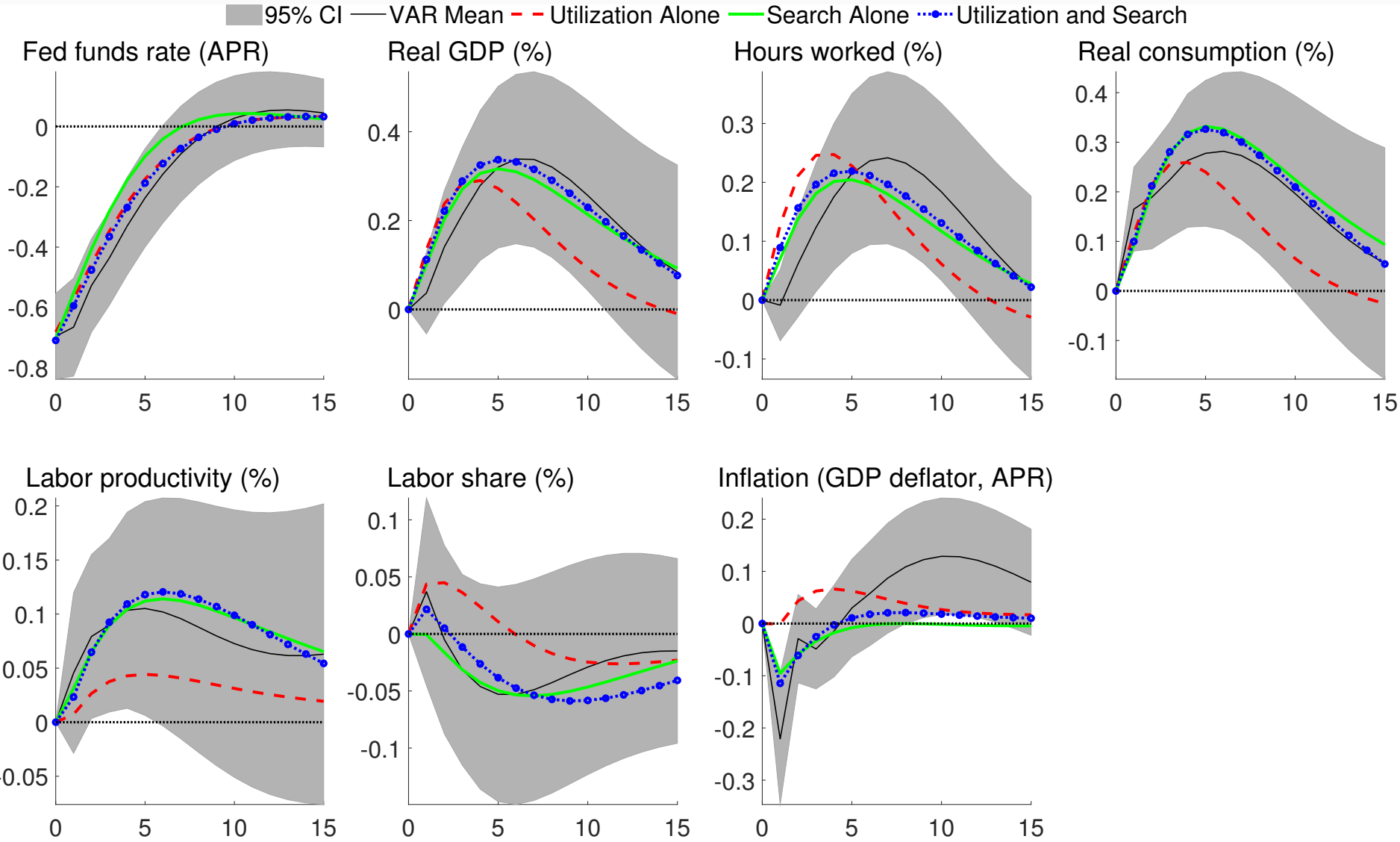

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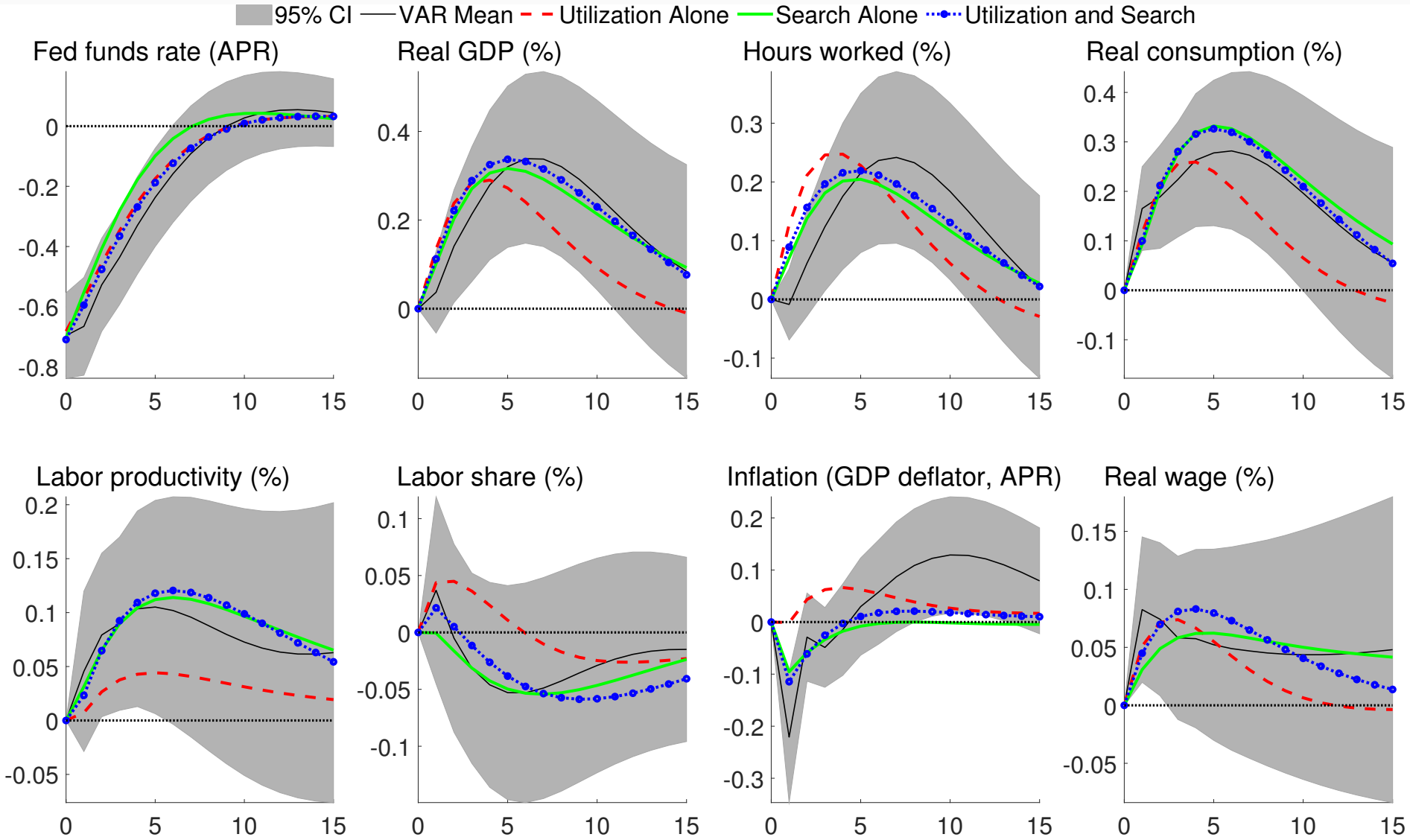

Conclusion

- We propose a new mechanism of procyclical productivity in NK models.
- It is based on the notions that expenditures increase productivity temporarily due to additional search effort of the households.
- We show that the mechanism is easy to implement in a medium-scale DSGE.
- A version of Christiano et al. (2016) with our mechanism either substituting or complementing capital utilization has far superior performance:
    1. St-st markup, fixed cost, and the Frisch elasticity have very reasonable values.
    2. Markups conditional on Federal Funds shocks become procyclical.
    3. Log marginal likelihood has a huge improvement.
    4. Most IRFs, e.g. labor productivity and labor share, fit the data better.
- Hence, we think search frictions in goods markets should be considered as part of the standard ingredients in New Keynesian models.

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