# Reallocation, productivity and monetary policy in an energy crisis

Boris Chafwehe[1], Andrea Colciago[2] and Romanos Priftis[3]

[1]Bank of England

[2]De Nederlandsche Bank and University of Milano-Bicocca

[3]European Central Bank

Champ Network, 7 April 2025, Osterreichische national bank

Disclaimer: the views expressed here are personal, and do not necessarily represent those of our employers.

# Motivation

- In 2022 global fossil fuel prices started to soar upon Russia's invasion of Ukraine.
- The rise in the relative price of fossil resources may weigh on the economy if firms and households cannot substitute more expensive carbon-intensive energy with greener and cheaper alternatives.
- Factors such as sectoral composition and labor market rigidities are likely to matter for the transmission of supply shocks and their persistence.
- Central banks may need to be more aggressive in their responses in economies where workers are less willing to accept real wage declines or where the weight of energy-intensive sector is larger.

# This paper

- We develop a multi-sector industry dynamic model to study these issues.
- In our model, a shock to the price of fossil resources affects the relative size of the sectors in the economy through changes in productivity and the entry and exit of heterogeneous firms.
- Monetary policy affects these dynamics through its GE effects on firms' revenues and the real wage.
- We estimate the model's parameters through a moments matching technique.

# Model

- Model's key features:
  1. two final good sectors, which we identify as manufacturing and services, that have ex-ante different energy intensities;
  2. firms are heterogeneous in terms of productivity and are subject to endogenous entry and exit;
  3. imperfectly competitive goods and labor markets with nominal rigidities;
  4. two energy sectors, one producing energy with renewables, the other with dirty inputs;
  5. the two types of energy are bundled in a final energy product, used both in production and consumption.

# Preview of results

In the aftermath of an increase in the price of fossil resources our analysis suggests:

- A reallocation of activity from energy-intensive sectors to greener sectors
- An increase in labor productivity, more so in energy-intensive sectors.
- A persistent decrease in the number of active firms through a decrease in the entry rate and an increase in the exit rate.
- A greener production of energy, promoting both a greener production and consumption.

# Mechanism

Increase in the price of the fossil resource

$\Downarrow$

Higher marginal costs in both sectors
more so in manufacturing, which is energy intensive

$\Downarrow$

Higher idiosyncratic productivity required to enter and survive.

$\Downarrow$

Entry is persistently depressed due to higher productivity requirement

# The role of monetary policy

- A monetary policy tightening in response to the fossil price shock generate GE effects that affect productivity through 2 channels:

  1. *Revenue channel*: a higher real rate reduces aggregate demand, which in turn depresses firm revenues $\Rightarrow$ a HIGHER idiosyncratic productivity is required for both survival and market entry.

  2. *Cost channel*: lower demand for final goods reduces the demand for labor, leading to lower labor costs for firms$\Rightarrow$ a LOWER idiosyncratic productivity is required for both survival and market entry.

# A stabilization challenge

- The monetary policy stance alters the relative strength of the revenue and cost channels.
- More anti-inflationary policies depress output to a large extent, but also dampen real wages, leading to a milder increase in productivity in both sectors.
- The smaller productivity boost under tighter policies allows the entry rate to recover more rapidly after the shock in both the services and manufacturing sectors.
- Our results therefore reveal a novel trade-off in monetary policy: balancing the stabilization of aggregate activity on one hand and fostering business dynamism on the other.

# Production of Goods

- 2 ex-ante heterogeneous sectors: manufacturing, the brown good, and services, the green good.
- Production: Cobb Douglas in labor and energy. Manufacturing is energy-intensive.
- final goods is a CES aggregate of the manufacturing goods and service goods.
- Within each sector: Heterogeneous firms with endogenous entry and exit 'a la Melitz (2003), augmented with nominal rigidities as Colciago and Silvestrini (2022).
- Monopolistic competition.
- Rotemberg (1982) pricing.

# Entry and Exit

- Upon entry, firms are assigned a productivity level drawn from a Pareto distribution.
- Firm Entry: if discounted value of future profits is larger than the entry cost, following Bilbiee, Ghironi and Melitz (2012).
- Firm Exit: if period profits are negative.

# Production of Energy

- 2 sectors: Dirty and clean energy.
- Clean energy: Cobb Douglas in labor and renewable resource.
- Dirty energy: Cobb Douglas in labor and fossil resource.
- price of fossil resources is exogenous, supply of renewable is constant.

# Definition: the core good

- Core good is an aggregate of the two sectorial goods $Y_t(g)$ and $Y_t(b)$, denoting aggregate output in the services (green) and manufacturing (brown) sector, respectively:

$$Y_t^{core} = \left( \chi^{\frac{1}{\eta}} Y_t(g)^{\frac{\eta-1}{\eta}} + (1-\chi)^{\frac{1}{\eta}} Y_t(b)^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}} \tag{1}$$

- Both $Y_t(g)$ and $Y_t(b)$ are aggregators of goods produced in the green and brown sectors.

# Definition: energy

- The energy provider bundles clean energy, $E_{C,t}$, and dirty energy, $E_{D,t}$, with the following CES production function:

$$E_t = \left[ \xi^{\frac{1}{\rho}} E_{D,t}^{\frac{\rho-1}{\rho}} + (1-\xi)^{\frac{1}{\rho}} E_{C,t}^{\frac{\rho-1}{\rho}} \right]^{\frac{\rho}{\rho-1}} \tag{2}$$

- $\rho$ is the elasticity of substitution between clean and dirty energy, and $\xi$ their relative weight in the input bundle.
- The variable $E_t$ is the quantity of energy produced at time t that is sold to the market.

# Definition: final good

- The final consumption good is assumed to be a composite between a 'core' good, denoted by $Y_t^{core}$, and energy, denoted by $E_t^H$.

$$Y_t = \left(\omega^{\frac{1}{\tilde{\eta}}}\left(Y_t^{core}\right)^{\frac{\tilde{\eta}-1}{\tilde{\eta}}} + (1-\omega)^{\frac{1}{\tilde{\eta}}}\left(E_t^H\right)^{\frac{\tilde{\eta}-1}{\tilde{\eta}}}\right)^{\frac{\tilde{\eta}}{\tilde{\eta}-1}}, \qquad (3)$$

where the parameter $\omega$ captures the relative importance of the core good compared to energy in the consumption bundle, and the parameter $\tilde{\eta}$ measures the elasticity of substitution between the two goods.

# Demand side

1. Households maximize lifetime utility over Consumption and Hours
2. Provide differentiated labor inputs. Calvo (1982) nominal wage stickiness.
3. Complete markets
4. Households can invest in firms through the stock market;
5. Households invest in entry up to the point where the entry cost equals the discounted value of future profits.

# Monetary Policy

The Central Bank sets the nominal interest rate, $R_t$, according to the following Taylor rule with smoothing:

$$\left(\frac{R_t}{R}\right) = \left[\left(\frac{\pi_t}{\pi}\right)^{\phi_\pi}\left(\frac{Y_t}{Y}\right)^{\phi_Y}\right]^{1-\phi_R}\left(\frac{R_{t-1}}{R}\right)^{\phi_R}, \qquad (4)$$

where variables without time subscript denote steady state values. For simplicity, we assume that the steady state gross inflation rate equals one.

# Key mechanism: productivity cutoff

- to enter the market and to continue production, firms must have an idiosyncratic productivity larger than a threshold $z_t^*$
- the latter, under flexible prices, is given by

$$z_t^c(q) = \frac{\theta^{\frac{\theta}{\theta-1}}}{\theta-1} \frac{1}{Z_t(q)} \left(\frac{w_t}{1-\alpha_q}\right)^{1-\alpha_q} \left(\frac{p_t^E}{\alpha_q}\right)^{\alpha_q} \left(\frac{f_{x,t}}{\rho_t(q)^\theta Y_t(q)}\right)^{\frac{1}{\theta-1}} \tag{5}$$

- $z_t^*$ depends on:
  1. the real wage, $w_t$.
  2. the relative price of energy $p_t^E$.
  3. fixed costs of production, $f^{fix}$
  4. aggregate production, $Y_t^c$
  5. $\alpha_q$ is the parameter on Energy in the CD production function of final good.

# Parameterization

1. *Calibration*: We calibrate a subset of the model's parameters by relying on empirical data and targets from the literature specific to the US economy.

2. *Estimation*: The remaining parameters are estimated by minimizing the difference between twelve unconditional moments derived from US data and their corresponding model-generated moments.
3. To compute the model's moments, we introduce three aggregate shocks: to the price of fossil resources, to aggregate technology, and monetary policy.

# Calibration

Table 1: Calibrated parameters

| Parameter | Description | Value |
|---|---|---|
| *Households and wage setting* | | |
| $\beta$ | discount factor | 0.98 |
| $\phi$ | inverse Frisch elasticity | 4 |
| $\chi$ | share of good $g$ in core good bundle | 0.7 |
| $\eta$ | elasticity of substitution between good $g$ and $b$ | 1.5 |
| $\theta_w$ | elasticity of substitution between labour inputs | 4 |
| *Firms* | | |
| $\alpha_g$ | production share of energy in sector $g$ | 0.017 |
| $\alpha_b$ | production share of energy in sector $b$ | 0.051 |
| $\theta$ | elasticity of substitution between sectoral goods | 3.8 |
| $\psi_0$ | entry cost parameter 1 | 1 |
| $\psi_1$ | entry cost parameter 2 | |
| $\gamma$ | elasticity of entry cost to number of entrants | 1.5 |
| $\delta$ | exit rate | 2.5% |
| $zmin$ | minimum value of idiosyncratic productivity | 1 |
| $\kappa$ | Pareto distribution parameter | 6 |
| *Energy sector* | | |
| $\widetilde{\eta}$ | eos between energy and non-energy in consumption | 0.94 |
| $\omega$ | share of energy in consumption | 0.04 |
| $\rho$ | eos between energy inputs | 1.8 |
| $\xi$ | share of dirty energy in energy bundle | 0.59 |
| $\xi_D$ | labour share, dirty energy sector | 0.5 |
| $\rho_D$ | eos between labour and fossil resource | 0.25 |
| $\xi_C$ | labour share, clean energy sector | 0.5 |
| $\rho_C$ | eos between labour and clean resource | 0.25 |
| *Price and wage stickiness* | | |
| $\alpha^*$ | Calvo wage stickiness | 0.75 |

Notes: Sector $g$ reflects Services. Sector $b$ reflects manufacturing

# Estimation

- The values of the parameters are selected to solve the following minimization problem

$$\min_{\Theta} \left( mom^{DSGE}(\Theta) - mom^{DATA} \right)' \mathbf{W} \left( mom^{DSGE}(\Theta) - mom^{DATA} \right), \tag{6}$$

- where
  1. $\Theta$ is the column vector that contains the parameters to be estimated
  2. $mom^{DATA}$ is a column vector containing the empirical moments
  3. $mom^{DSGE}$ is the vector of the corresponding model-implied moments
  4. we use the identity matrix as the weighting matrix.

# Estimated Parameters

| Parameter | Description | Value |
|---|---|---|
| $\tau$ | Rotemberg price setting | 159.77 |
| $\phi_R$ | Interest rate inertia | 0.81 |
| $\phi_\pi$ | Taylor rule, inflation coefficient | 1.1 |
| $\phi_Y$ | Taylor rule, output coefficient | 0.037 |
| $\rho_{FR}$ | AR coefficient fossil resource price | 0.436 |
| $\rho_Z$ | AR coefficient TFP shock | 0.48 |
| $\sigma_{FR} \times 100$ | Std. dev. fossil resource price | 1.123 |
| $\sigma_Z \times 100$ | Std. dev. TFP shock | 0.073 |
| $\sigma_R \times 100$ | Std. dev. MP shock | 0.163 |

*Notes:* The table reports the value of the parameters chosen to minimise the mean squared deviation of model-implied moments relative to their US counterpart, as described in text.

# Implied moments

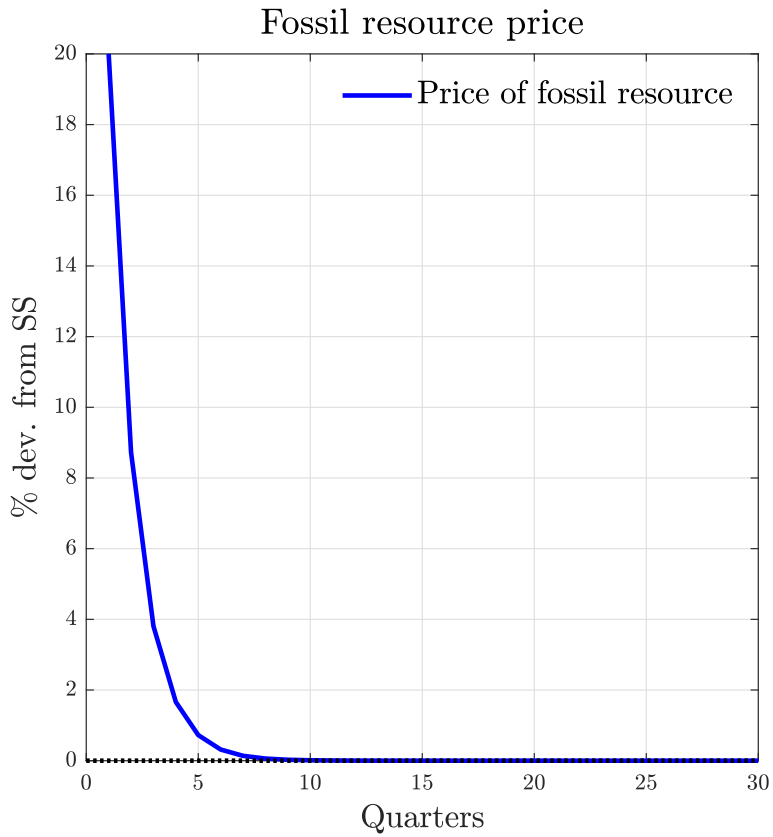
Table 3: Model-implied moments

| | Model | US data |
|---|---|---|
| **Standard deviations** | | |
| Output | 0.989 | 1.057 |
| Inflation | 1.344 | 1.304 |
| Entry rate | 0.053 | 0.336 |
| Exit rate | 0.27 | 0.312 |
| Productivity | 0.905 | 0.853 |
| **Correlation with output** | | |
| Entry rate | 0.556 | 0.484 |
| Exit rate | -0.457 | -0.124 |
| **Auto-correlations** | | |
| Output | 0.642 | 0.876 |
| Inflation | 0.932 | 0.857 |
| Entry rate | 0.814 | 0.941 |
| Exit rate | 0.971 | 0.909 |
| Productivity | 0.978 | 0.739 |

Figure: Empirical and model-implied moments

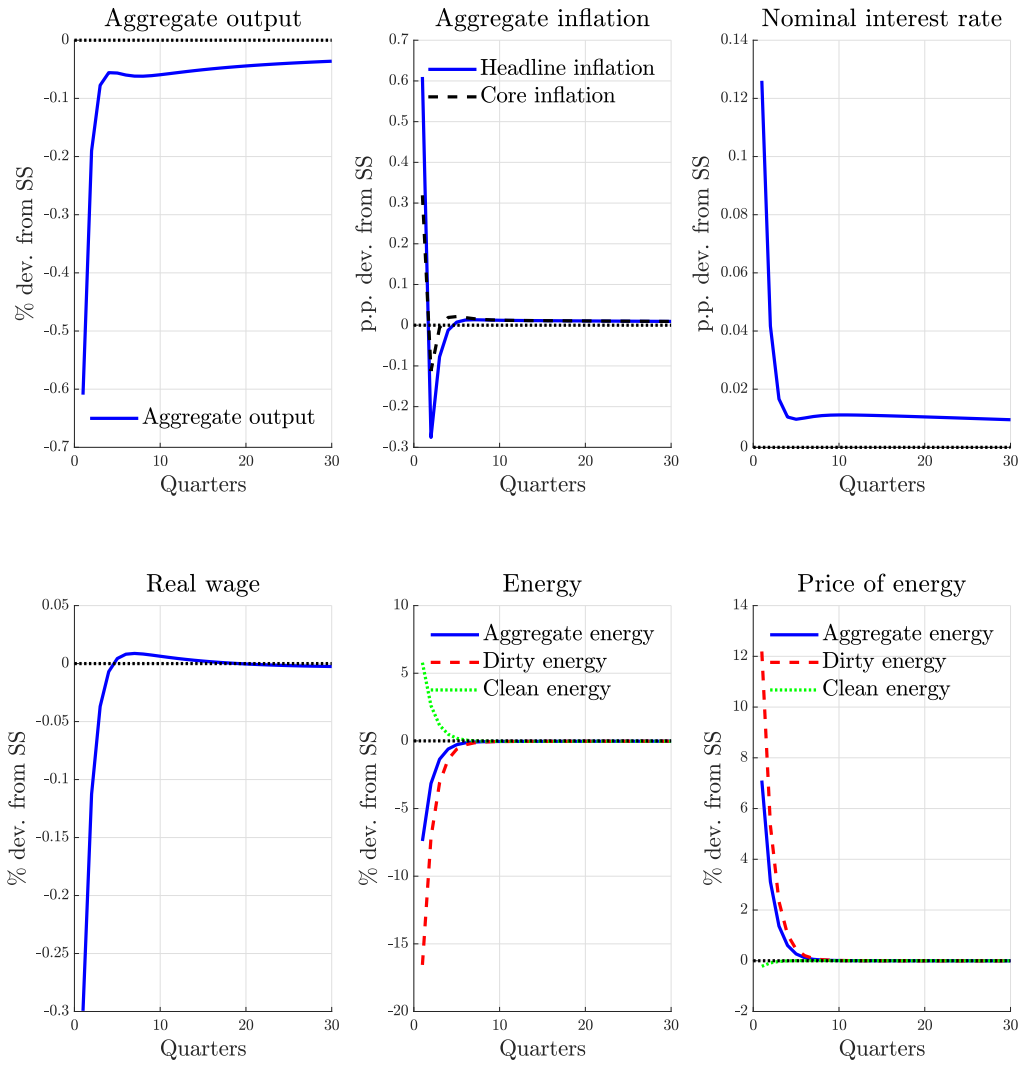
# Increase in price of fossil resource

Figure: Price of fossil resource

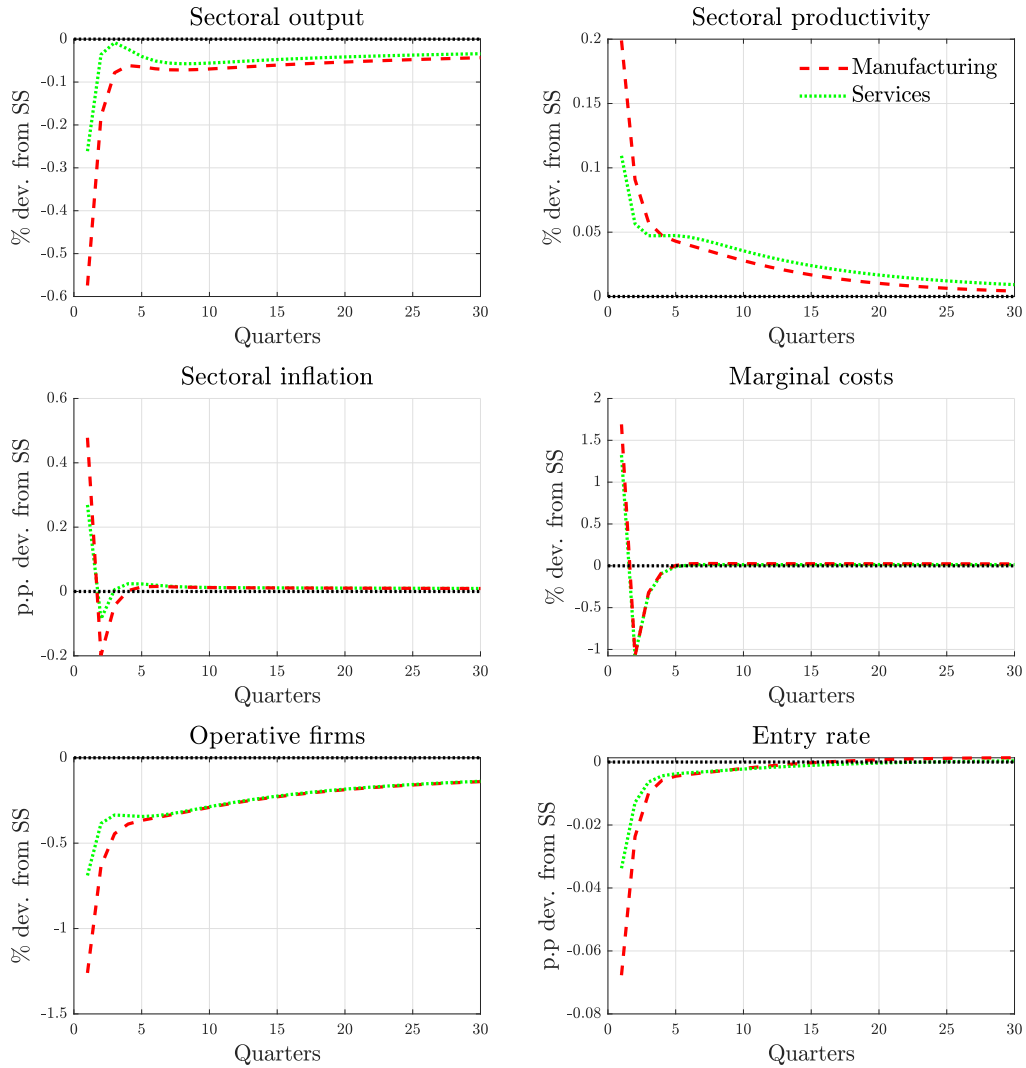



Notes: The price of fossil resources is expressed in percentage deviations from the initial steady state. Time on the horizontal axes is in quarters.

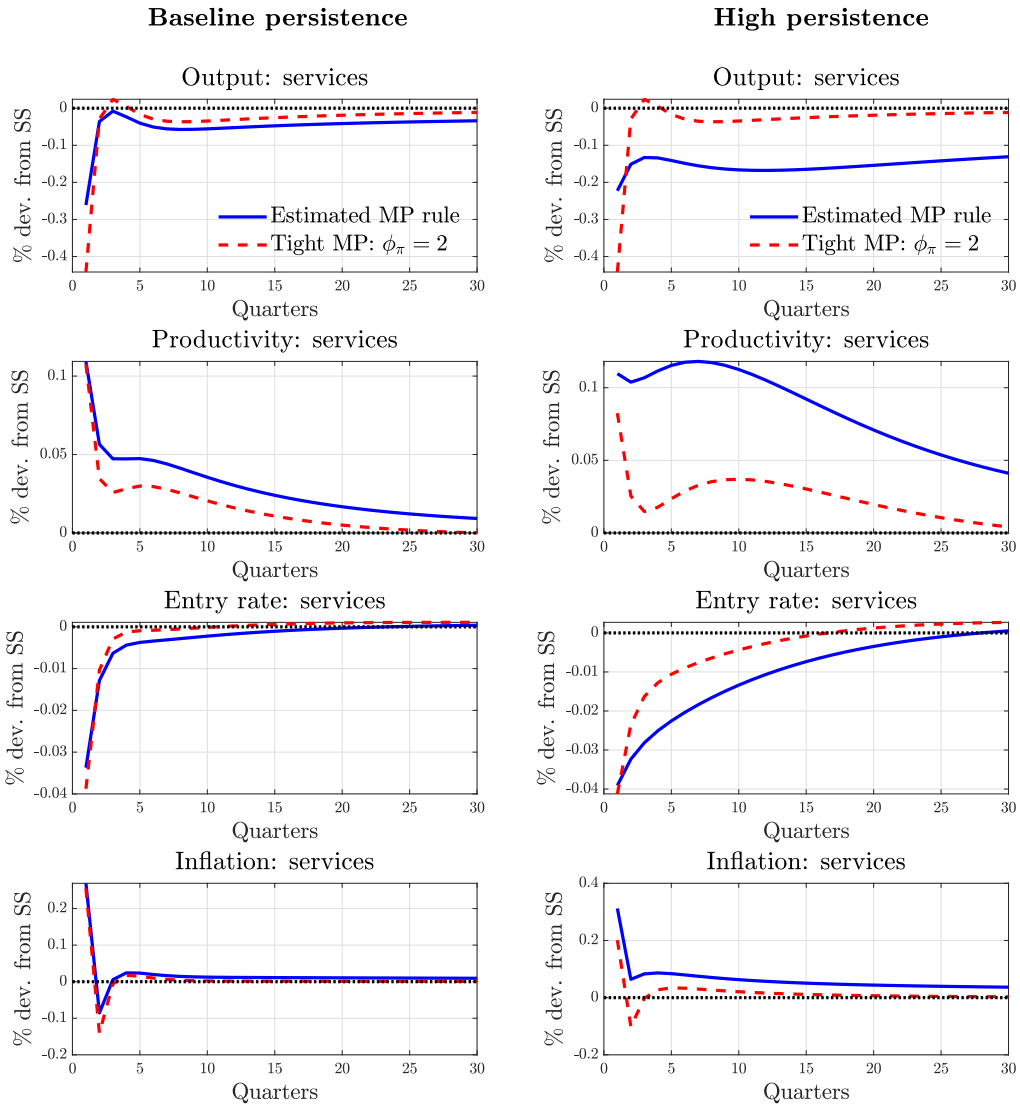
# Response of aggregate variables



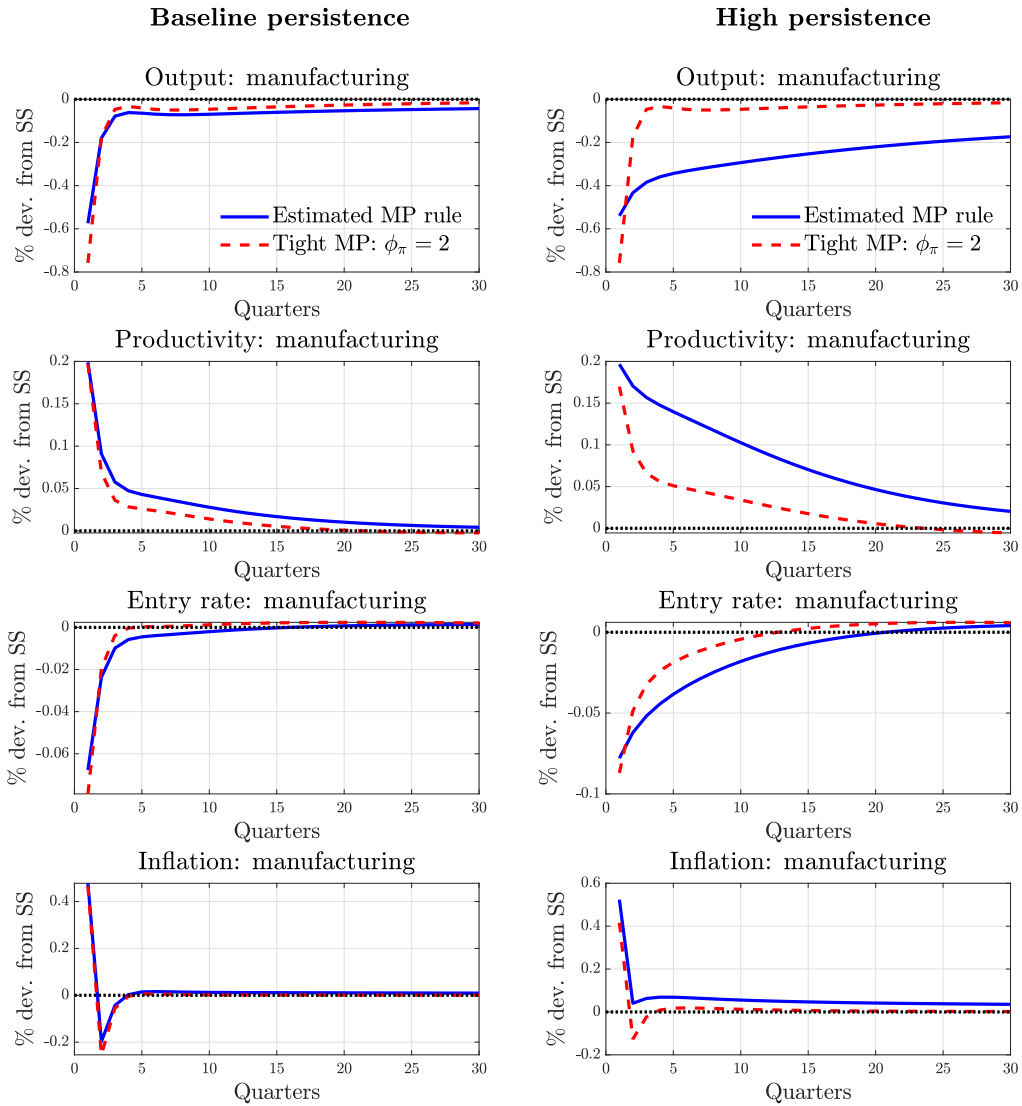
# Response of sectoral variables



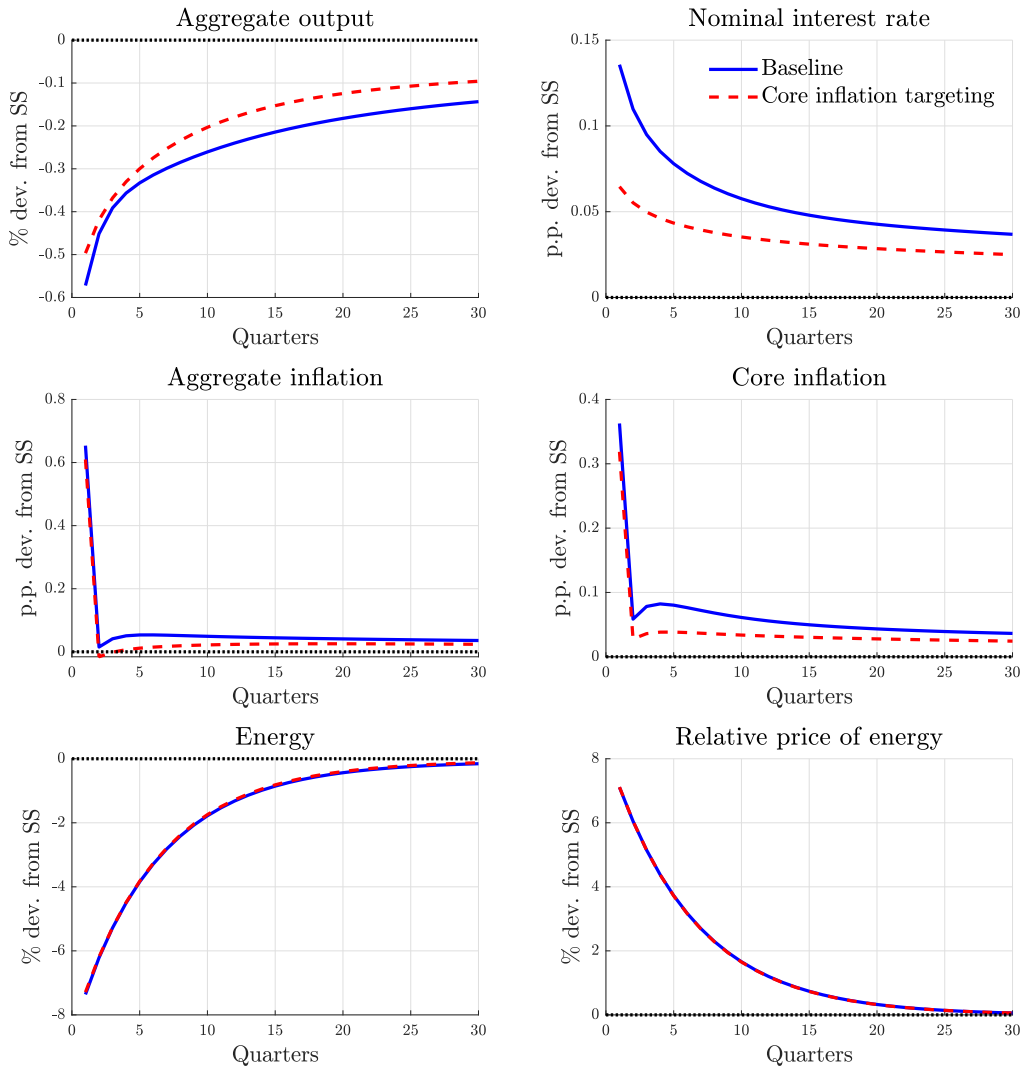
# Shock persistence and monetary policy: services



# Shock persistence and monetary policy: manufacturing



# Targeting core inflation



# Summary

- We provide a multi-sector industry dynamic model with endogenous entry and exit of heterogeneous firms to analyze the short- to medium-term impact of a persistent increase in the price of fossil resources on:
  1. the relative size of sectors;
  2. labor productivity;
  3. Competitiveness.
- The energy price shock triggers a selection and cleansing process. The latter leads to:
  1. higher average productivity in both the manufacturing and service sectors.
  2. contraction in business entry
- A central bank with a strong anti-inflationary stance entails a higher impact cost in terms of output and lower average productivity in response to the shock, but a faster recovery of firms creation.