Navigating Geopolitical Crises for Energy Security: Evaluating Optimal Subsidy Policies via a Markov Switching DSGE Model

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Motivation

- The recent geopolitical crisis between Russia and Ukraine has highlighted the vulnerability and dependence of European countries on a single energy supplier.
  - Russia, which supplied 34% of the gas consumed by the European Union countries (EU27) plus Great Britain (GB) in 2019.
- This study focuses specifically on the dimension of energy self-sufficiency. →Energy resilience
- Bolstering energy resilience enables countries to improve their capacity to withstand and recover from disruptions from geopolitical conflicts, natural disasters, cyberattacks, or infrastructure failures.

Main results

- A disruption in energy imports causes a significant decrease in output, social welfare, and energy consumption.
- Furthermore, the mere expectation or anticipation of an energy crisis can impact household consumption and saving behavior, making households more conservative.
- By solving a Ramsey planner problem in each economic regime, we find that the optimal subsidy policy should be responsive to positive supply shocks while reducing its responsiveness to positive demand shocks.
- In situations where the probability of an energy supply termination is high, the government should adopt a subsidy policy with lower sensitivity to ongoing economic shocks.

Literature review

DSGE: Heutel (2012); Fischer and Springborn (2011); Punzi (2019); Annicchiarico and Di Dio (2015).

RS: Sims and Zha (2006); Liu et al. (2011); Choi and Hur (2015); Bianchi (2013).

Energy resilience: Jasiunas et al. (2021); Thomas and Kerner (2010); Sharifi and Yamagata (2016); Gatto and Drago (2020a); Gatto and Drago (2020b).

Our focus is to explore how countries can enhance energy resilience in preparation for potential geopolitical conflicts.

Firm I

$$Y_t = A_t K_t^{\alpha_K} E_t^{\alpha_E} L_t^{1-\alpha_K-\alpha_E}. \tag{1}$$

$$\log(A_t) = (1-\rho_A)\log(A) + \rho_A \log(A_{t-1}) + \varepsilon_{A,t}. \tag{2}$$

$$E_t = E^M(s_t) + E_t^D. \tag{3}$$

We categorize energy based solely on its origin - whether it is domestically produced or imported from foreign countries - without differentiation by energy source.

Firm II

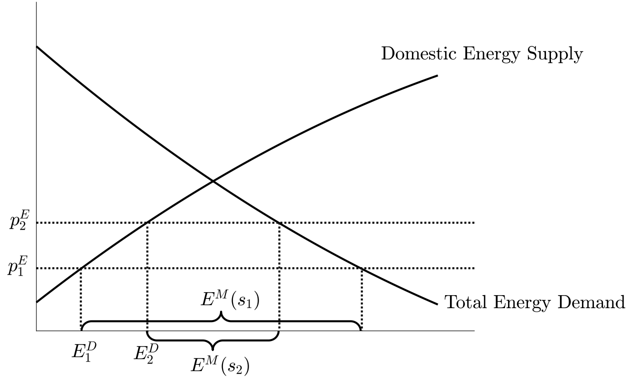

Figure: The demand and supply curves of energy market.

The normal regime: the energy import is E_1^M. The crisis regime: the energy import is E_2^M, with $E_2^M < E_1^M$.

Firm III

The variable $E^M(s_t)$ follows a first-order discrete Markov process with two states, $\{E_1^M, E_2^M\}$. The transition matrix for this process is given by:

$$p = \begin{bmatrix} p_{11} & 1-p_{11} \\ 1-p_{22} & p_{22} \end{bmatrix}. \tag{4}$$

The cost of energy production is:

$$\mathscr{C}(E_t^D) = \phi_1 (E_t^D)^{\phi_2}, \phi_1 > 0, \phi_2 > 1. \tag{5}$$

Househoulds & goods mkts equilibrium

$$\mathbb{E}_{t_0} \sum_{t=t_0}^{\infty} \beta^t a_t \left(\frac{C_t^{1-\sigma_c}}{1-\sigma_c} - \mu_L \frac{L_t^{1+\phi}}{1+\phi} \right). \tag{6}$$

$$\log(a_t) = \rho_a \log(a_{t-1}) + \varepsilon_{A,t}. \tag{7}$$

$$C_t + I_t \leq w_t L_t + r_t K_t + \pi_t - T_t. \tag{8}$$

$$K_{t+1} = (1-\delta_K) K_t + I_t. \tag{9}$$

$$Y_t - p_t^E E_t^M = I_t + C_t + \phi_1 (E_t^D)^{\phi_2}. \tag{10}$$

Table: Parameter values.

Parameters	Value	Description
α_K	0.3	Share of capital in production
α_E	0.1	Share of energy in production
ϕ_1	0.0065	Parameter in cost functions of energy production
ϕ_2	2	Parameter in cost functions of energy production
δ_K	0.025	Capital depreciation rate
ρ	0.01	discount factor rate
σ_C	1	Risk aversion
ϕ	1	Inverse of Frisch elasticity
μ_L	1	Scale of labor disutility
A	1	Steady-state value of TFP level
ρ_A	0.95	TFP shock persistence
σ_A	1	TFP shock standard deviation
ρ_a	0.194	Preference shock persistence
σ_a	1	Preference shock standard deviation

Long-term impacts in the two regimes I

Long-term impacts

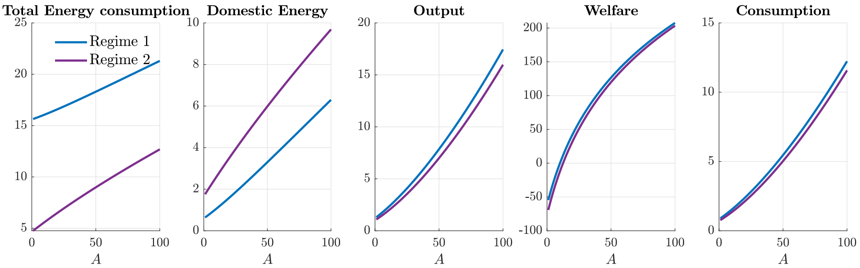

Figure: The long run effects of TFP level in the two regimes.

Short-term impacts

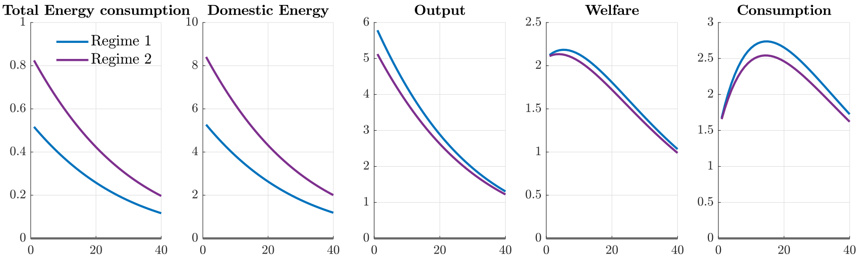

Figure: Regime-specific dynamic responses of energy, social welfare and economic variables to positive TFP shocks. *Notes: The responses are shows in percent.*

Short-term impacts

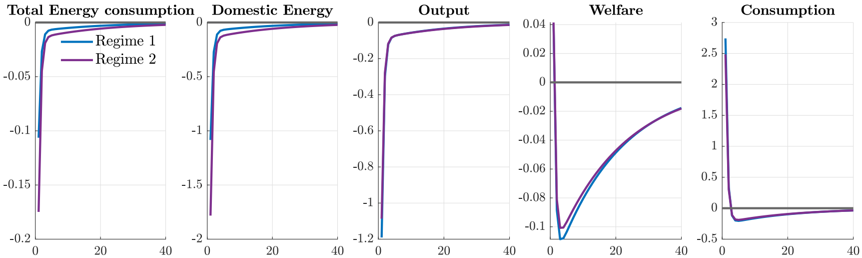

Figure: Regime-specific dynamic responses of energy, social welfare and economic variables to positive preference shocks. *Notes: The responses are shows in percent.*

The importance of transition probability I

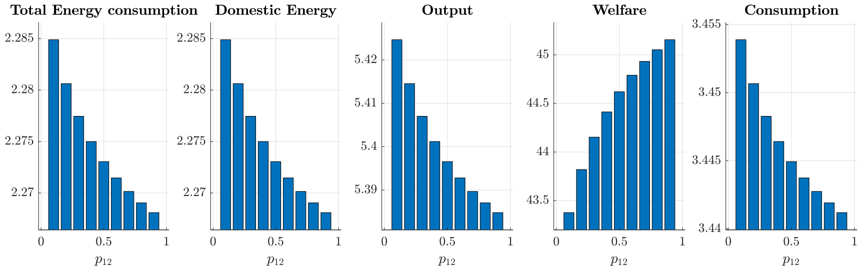

Figure: The accumulated responses of energy, welfare and economic variables to positive TFP shocks with different values of regime-switching probability p_{12}.

The importance of transition probability II

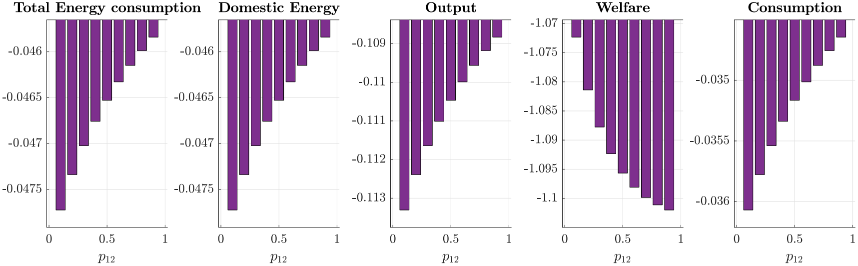

Figure: The accumulated responses of energy, welfare and economic variables to positive preference shocks with different values of regime-switching probability p_{12}.

The importance of transition probability III

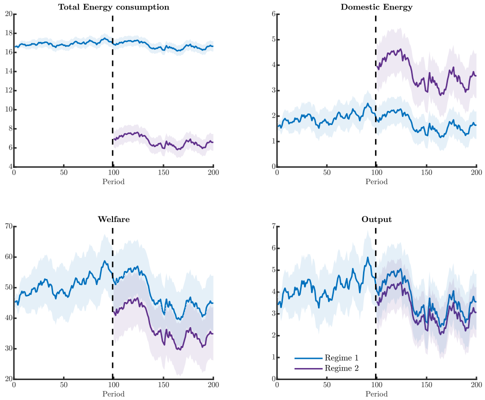

Figure: The simulated series of energy, social welfare, and output. *Notes: The shaped areas are the 95% confidence interval of the series. The regime switches from regime 1 to regime 2 in period 100. The blue lines from period 100 to 200 are the counterfactual paths of the series if the regime does not shift.*

The optimal subsidy policy I

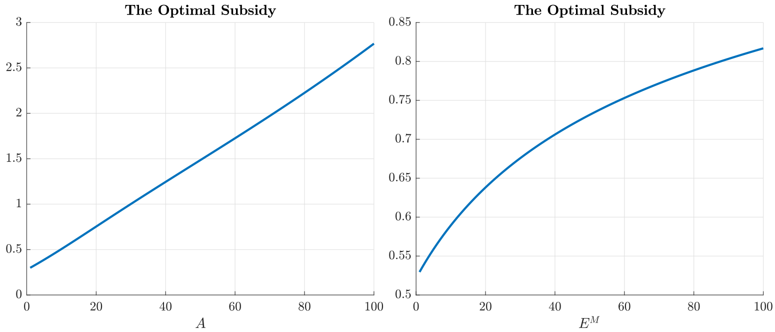

Figure: The steady-state optimal subsidy against the TFP level and imported energy.

The optimal subsidy policy II

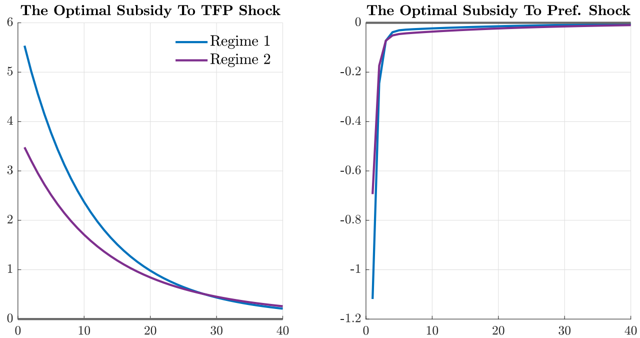

Figure: Regime-specific dynamic response of the optimal subsidy level to positive TFP and preference shocks. *Notes: The responses are shows in percent.*

The optimal subsidy policy III

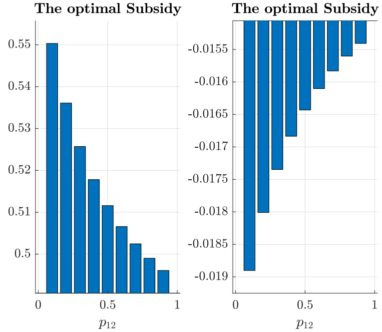

Figure: The accumulated responses of the optimal subsidy levels to positive TFP and preference shocks with different values of regime-switching probability p_{12}.

Conclusion

- An interruption in energy supply from foreign countries leads to a significant reduction in output, social welfare, and energy consumption.
  - During an energy crisis, energy consumption becomes more sensitive to economic shocks in the short run.
  - Household behavior adjusts in response to the anticipation of an energy crisis, mitigating potential negative effects and reducing volatility in energy, output, and household consumption.
- Our findings indicate that a well-designed subsidy policy must take into account the variations in productivity levels and energy imports.
- When the economy faces a significant risk of energy imports disruption, the optimal approach for the government is to select a subsidy policy that is less responsive to current economic shocks.

Thank you!