Geopolitical Oil Price Risk and Economic Fluctuations

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INTRODUCTION

- Heightened interest in the effects of geopolitical risks
  - Particularly for risks connected with supply of energy (Global access to Russian oil; Israel-Iran conflict; disruptions of oil shipments)
- Even the possibility of geopolitical events disrupting oil production can raise uncertainty and affect the economy
- Deep-rooted belief that increases in oil price uncertainty driven by geopolitical events have large adverse effects

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- Literature has focused on the oil price uncertainty arising from geopolitical events (i.e., the outcome of the shock)
- We explicitly model the downside risk to oil production inherent in these events (i.e., the underlying shock)
- Develop a DSGE model of the global economy
  - Oil production sector and oil storage
  - Endogenously determined oil prices and uncertainty
  - Macro and oil production disasters of stochastic length that occur with time-varying probabilities

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KEY RESULTS

1. Shocks to the probability of an oil production disaster have modest effects on the oil market and real activity
2. Downside risk is very different from volatility shocks
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OUTLINE

1. Our empirical measure of oil price uncertainty
2. Description and fit of the calibrated DSGE model
3. Effects of oil disaster probability shocks

Measuring Oil Price Uncertainty

- Conditional volatility in the real price of oil:

$$\mathcal{U}_t^{p_o} \equiv \sqrt{E_t[(\ln(p_{t+1}^o/p_t^o) - E_t[\ln(p_{t+1}^o/p_t^o)])^2]}$$

  - Estimate based on FAVAR from Jurado et al. (2015)
- Benefits of this measure:
  - Strips out predictable variation in the growth rate
  - Maps cleanly into our DSGE model
  - Longer sample than measures based on options

▸ Real Oil Price

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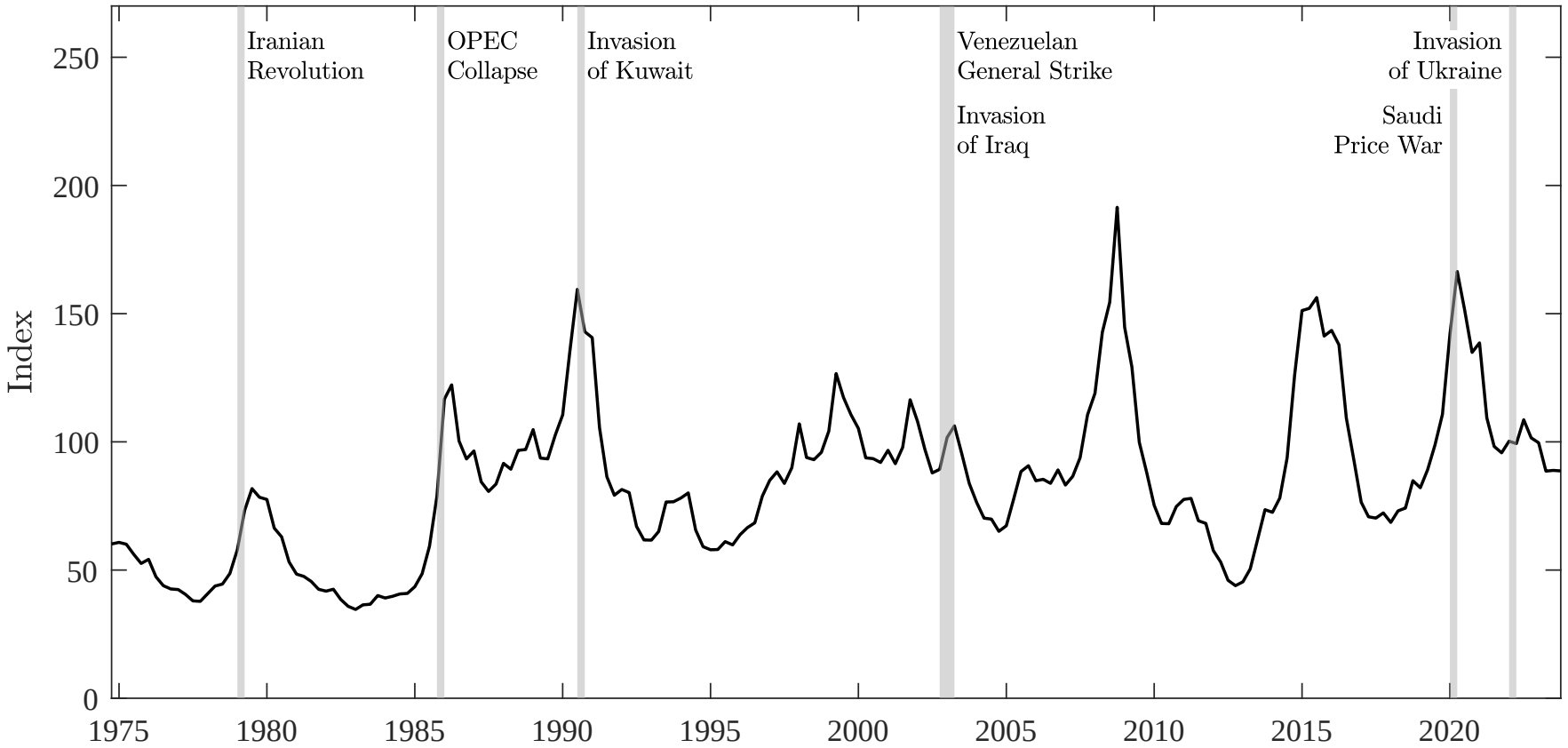
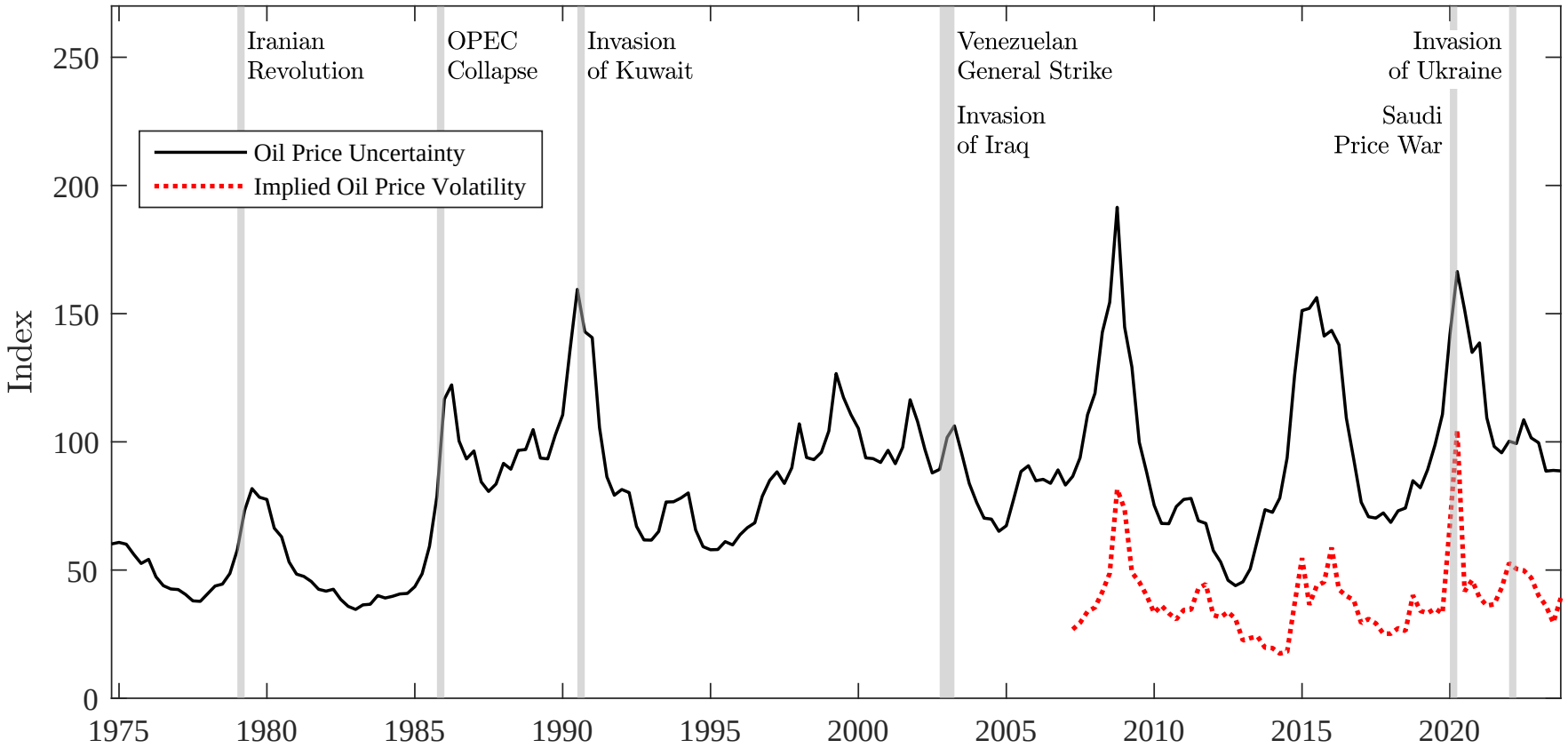
Oil Price Uncertainty, 1974Q4-2023Q4



- Not all geopolitical events increase oil price uncertainty and some spikes are mostly driven by macro events

OIL PRICE UNCERTAINTY, 1974Q4-2023Q4



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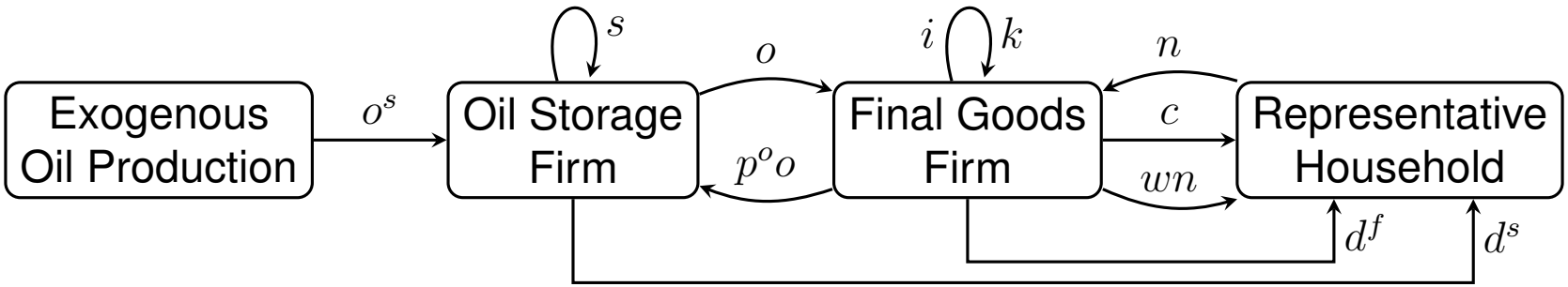
Sketch of the DSGE Model



- Stochastic growth model with exogenous oil production
- Oil storage firm holds unused production as inventories
- Oil is an intermediate input of the final goods firm
- Representative household with Epstein-Zin preferences
- Two types of disasters with time-varying probabilities:
  - Oil production (geopolitical risk)
  - Output (macroeconomic risk)

▸ More

GEOPOLITICAL OIL PRODUCTION DISASTERS

- Oil production:

$$o_t^s = \underbrace{a_t^o}_{\substack{\text{Permanent} \\ \text{Component}}} \times \underbrace{e_t}_{\substack{\text{Transitory} \\ \text{Component}}}$$

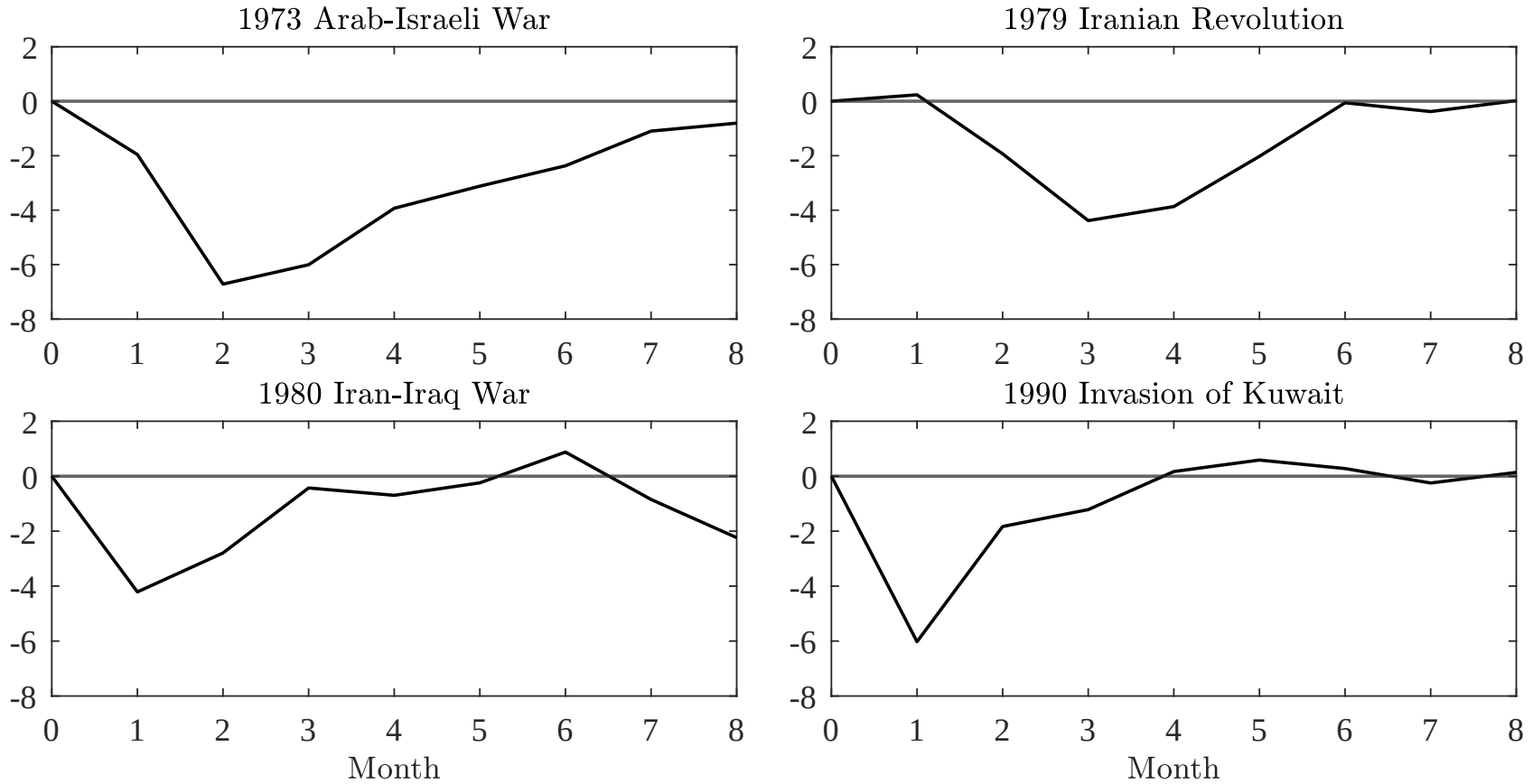
- Permanent component is cointegrated with productivity:

$$a_t^o = \kappa_0 g_t^{\kappa_1} \epsilon_{t-1}^{\kappa_2} a_{t-1}^o \exp(\sigma_{go} \varepsilon_{go,t}), \quad \epsilon_t = a_t / a_t^o$$

- Transitory component captures geopolitical disruptions:

$$\ln e_t = \ln \bar{e} - \zeta_e (v_t^e - \bar{\pi}_1^e),$$
$$\Pr(v_{t+1}^e = 1 | v_t^e = 0) = p_t^e, \quad \Pr(v_{t+1}^e = 1 | v_t^e = 1) = \bar{q}^e$$
$$\ln p_t^e = (1 - \rho_p^e) \ln \bar{p}^e + \rho_p^e \ln p_{t-1}^e + \sigma_p^e \varepsilon_{p,t}^e$$

Major Geopolitical Events



- Size (ζ_e): 5% drop in global production
- Average Frequency ($\bar{p}^e$): Every 12.5 years
- Average Duration ($\bar{q}^e$): 3 quarters

Data and Targeted Moments

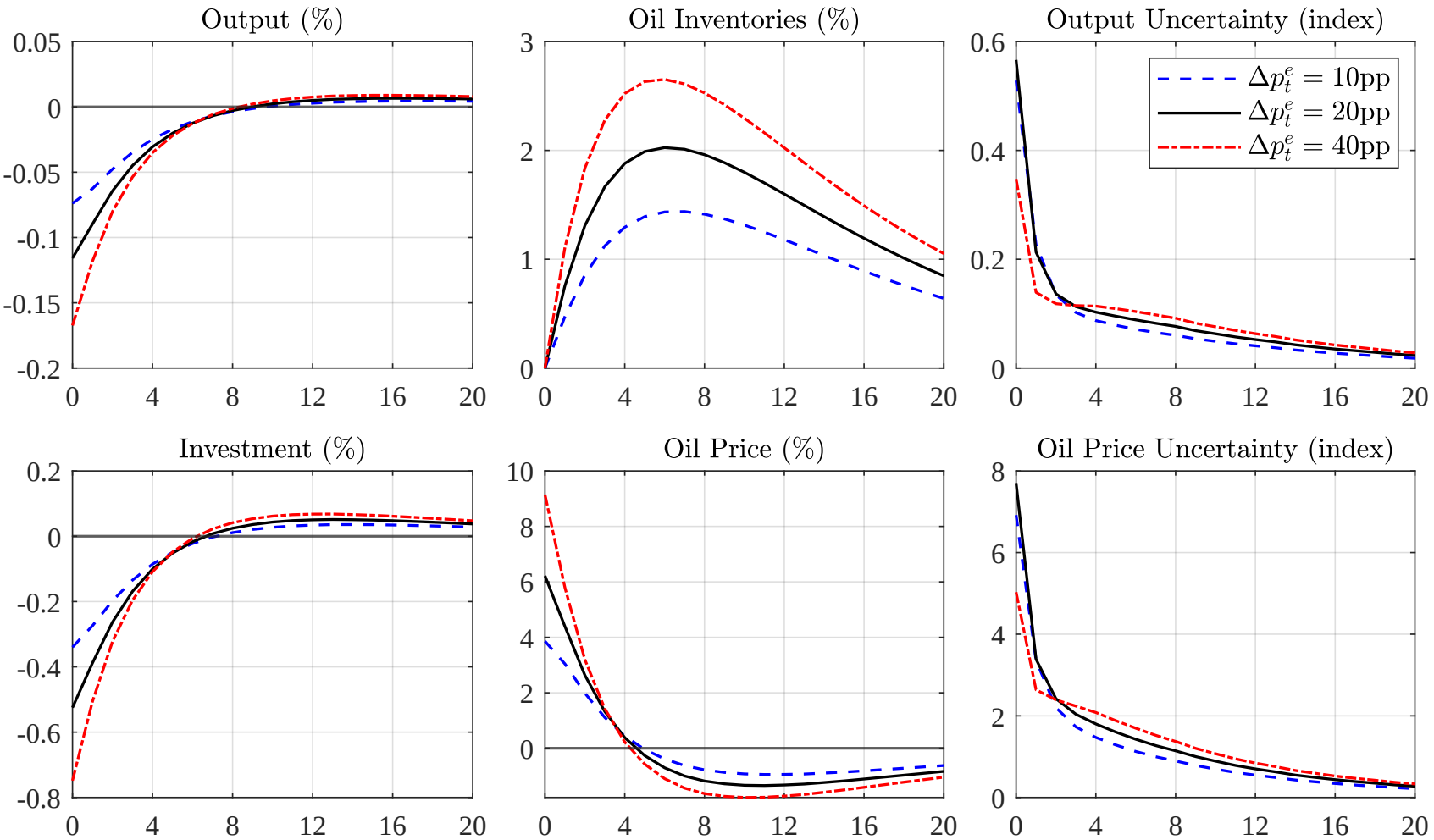
Moment	Data	Model	Moment	Data	Model
$E(\Delta y)$	0.39	0.39	$SD(\Delta o^s)$	2.01	2.14
$E(s/o)$	0.97	0.97	$SD(\Delta p^o)$	14.39	14.27
$E(p^o o/y)$	0.045	0.046	$SD(r^{ex})$	8.29	5.55
$E(r^{ex})$	2.18	2.11	$SD(\mathcal{U}_y)$	14.51	15.61
$E(r)$	0.22	0.20	$SD(\mathcal{U}_{p^o})$	29.95	30.49
$SD(\Delta y)$	0.74	0.87	$AC(\mathcal{U}_y)$	0.87	0.81
$SD(\Delta i)$	1.95	1.92	$AC(\mathcal{U}_{p^o})$	0.93	0.82

Notes: $SD(\mathcal{U}_y)$ and $SD(\mathcal{U}_{p^o})$ have been normalized by $SD(\Delta y)$ and $SD(\Delta p^o)$, respectively, to be consistent with the normalization in Jurado et al. (2015).

- Sample is quarterly from 1975Q1 to 2019Q4
- Model moments: $10{,}000$ simulations of 180 periods
- Model closely matches moments related to oil market dynamics, real activity, asset prices, and uncertainty
- Also closely matches several untargeted moments

▸ Calibration ▸ Solution Method

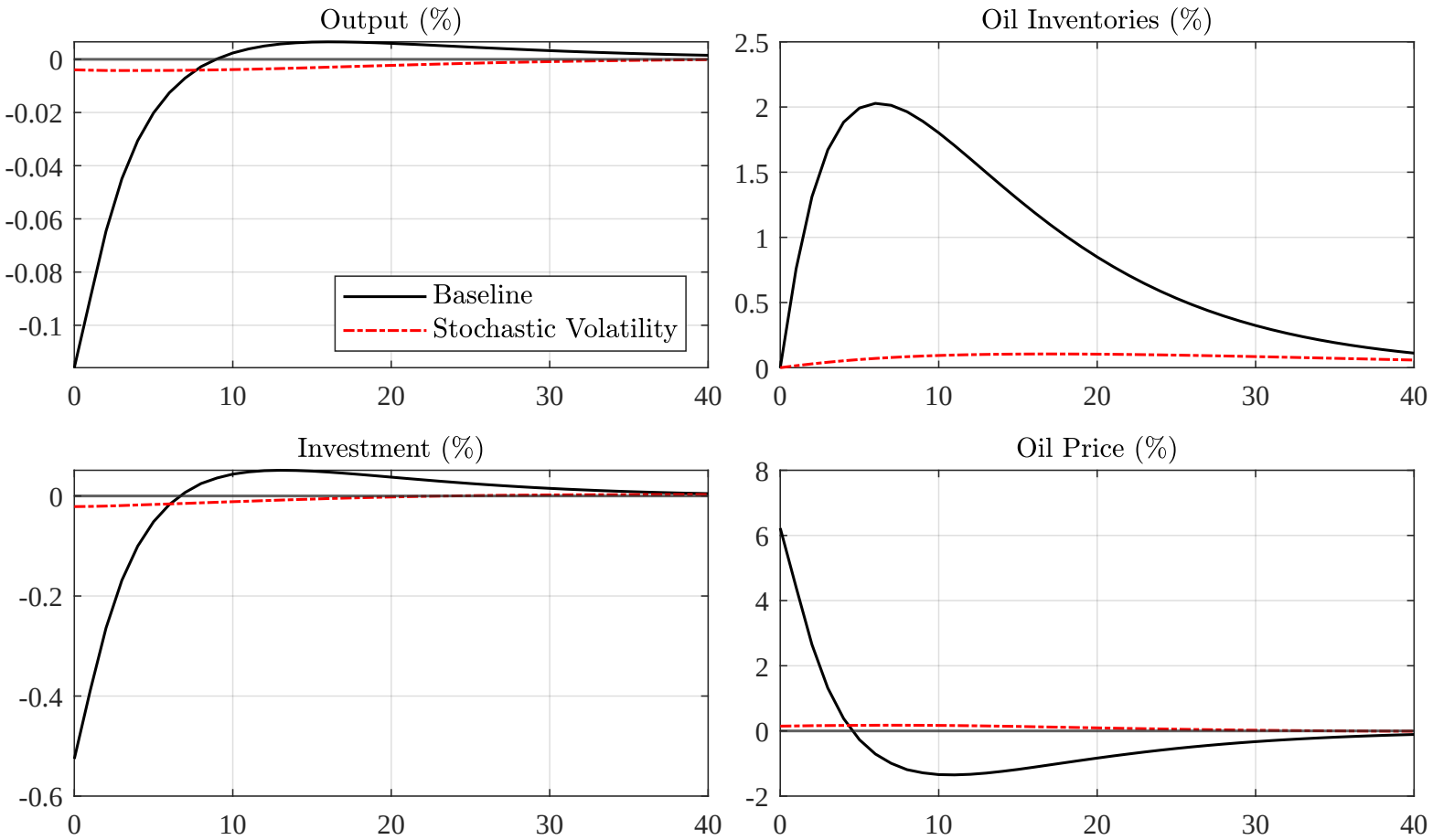
Oil Disaster Probability Shock



Notes: Responses in deviations from the baseline. Assumes no disasters are realized.

▸ Oil Disaster Realization ▸ Role of Storage

Oil Production Uncertainty Shocks



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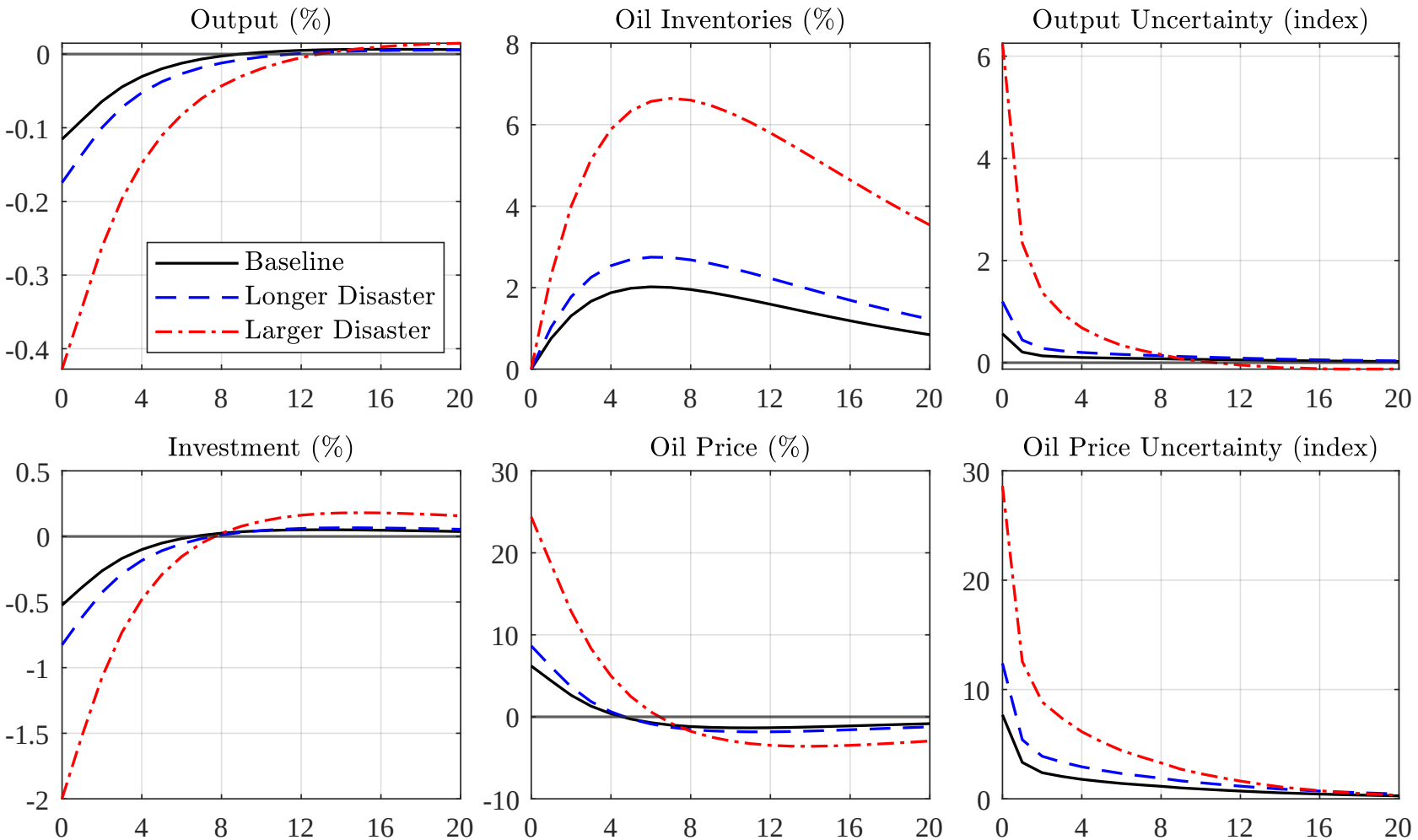
▸ Macro Volatility Shock

Alternative Disaster Specifications

- Oil market may have been concerned about a much larger or longer lasting disaster than the average realized oil production disaster observed in the data
- Alternative oil production disaster specifications:
  - Longer disasters: 10 quarters vs. 3 quarters
  - Larger disasters: 20% drop vs. 5% drop (e.g., cessation of oil supply in the Persian Gulf)

20pp Oil Disaster Probability Shock



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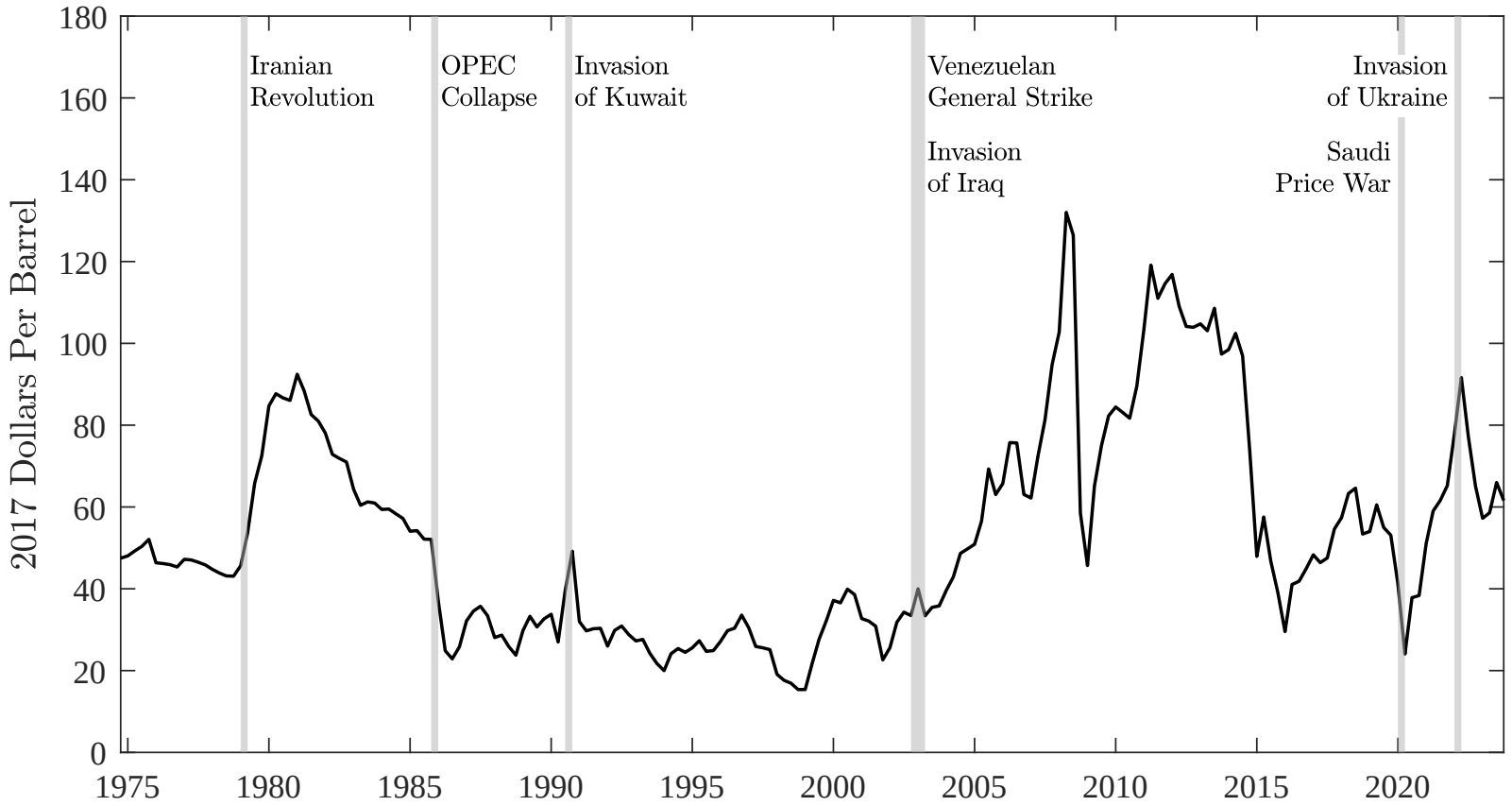
Conclusion

- There is considerable interest in understanding the economic effects of geopolitical risk in oil markets
- We developed a model of the global economy with:
  - Oil production sector and oil storage
  - Macro disasters and oil production disasters
  - Endogenous oil prices and oil price uncertainty
- Notwithstanding the attention geopolitical events in oil markets have attracted, we find that geopolitical oil price risk is unlikely to generate sizable recessionary effects

Additional Slides

Real Oil Price, 1974Q4-2023Q4



Notes: U.S. refiners' acquisition cost for imported oil scaled by the GDP deflator

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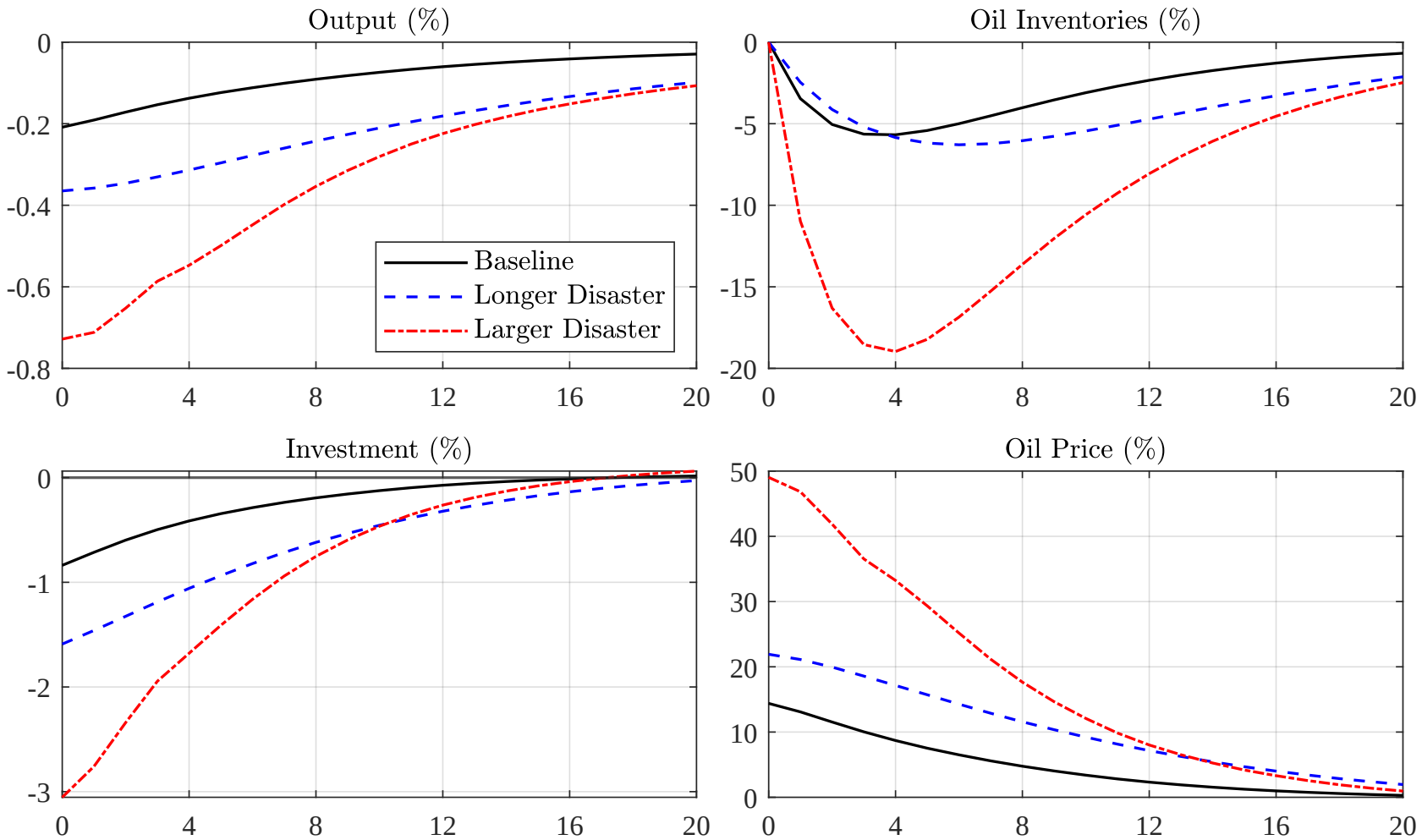
Oil Disaster Realization



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SOLUTION METHOD

- Model contains 7 state variables and 6 shocks
- Disaster risk prevents perturbation methods
- Solve the model using policy function iteration:
  - Piecewise linear interpolation of policy functions
  - Rouwenhorst method for numerical iteration
- State space contains over $300{,}000$ nodes and $40{,}000$ possible shock realizations
- Programmed in Fortran and parallelized with MPI
- Solved on a cluster with over $10{,}000$ cores

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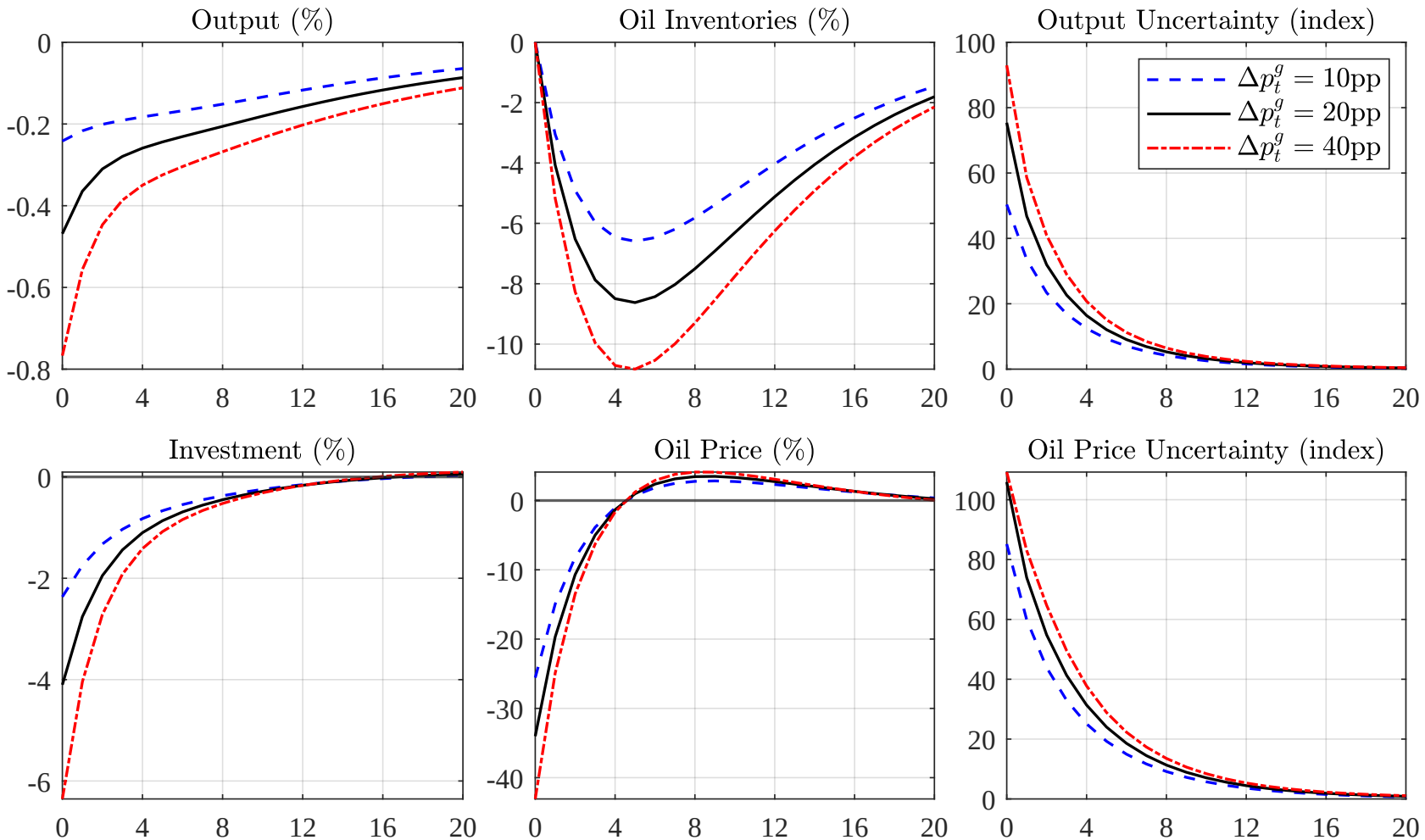
Macro Disaster Probability Shock



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Decomposition of Key Volatilities

		Model		
Moment	Data	Baseline	No Output Disaster Risk	No Output Disaster Risk or Oil Production Disaster Risk
$SD(\Delta y)$	0.74	0.87	0.65	0.64
$SD(\Delta i)$	1.95	1.92	1.26	1.23
$SD(\mathcal{U}_y)$	14.51	15.61	0.30	0.14
$SD(\mathcal{U}_{p^o})$	29.95	30.49	4.98	2.01

Notes: $SD(\mathcal{U}_y)$ and $SD(\mathcal{U}_{p^o})$ have been normalized by $SD(\Delta y)$ and $SD(\Delta p^o)$, respectively, to be consistent with the normalization in Jurado et al. (2015).

- Output disaster risk a major driver of oil price uncertainty
- Oil production disaster risk is not a major driver of fluctuations in output uncertainty or macro aggregates

Irreversible Investment (1/3)

Bernanke (1983):

- Partial equilibrium model of firm investment
- Investment is irreversible
- Two types of capital that differ by energy efficiency
- Exogenous uncertainty about the long-run oil price
- Uncertainty creates incentive to delay investment

IRREVERSIBLE INVESTMENT (2/3)

- Challenging to extend the Bernanke framework to a general equilibrium setting while maintaining tractability
- Atkeson and Kehoe (1999) introduce a model that incorporates some key features into a DSGE model
- Continuum of capital goods indexed by energy efficiency
- Model implies that oil consumption does not respond on impact to changes in the price of oil
  - Permits aggregation across capital types
- Model also assumes price of oil is exogenous

IRREVERSIBLE INVESTMENT (3/3)

- Endogenous oil prices are crucial for our analysis
- Oil inventories must adjust each period to clear oil market
  - Suppose there is an oil supply shock
  - If oil consumption does not respond, oil inventories must change to clear the market
  - Leads to counterfactual oil inventory moments
- Removing the assumption of predetermined oil consumption prohibits aggregation across capital types
- We do not use the Atkeson and Kehoe framework, but our model still generates macro responses that are consistent with models of irreversible investment
  - Risk averse agents are reluctant to invest given the limited substitutability between capital and oil

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EMPIRICAL IMPLICATIONS

- VAR models with GARCH errors: Uncertainty shocks are squared level shocks (Elder and Serletis, 2010)
  Our Model: Level and uncertainty shocks are different; Oil price changes do not always increase uncertainty
- VAR models with SV: Oil price uncertainty shocks are independent of oil price level shocks (Jo, 2014)
  Our Model: Oil price uncertainty is endogenous and may be driven by the same shocks as the price of oil
- Recursive VAR models: Uncertainty predetermined or macro aggregates predetermined (Gao et al., 2022)
  Our Model: All variables simultaneously determined

Seemingly robust evidence that oil price uncertainty shocks substantially lower real activity must be viewed with caution

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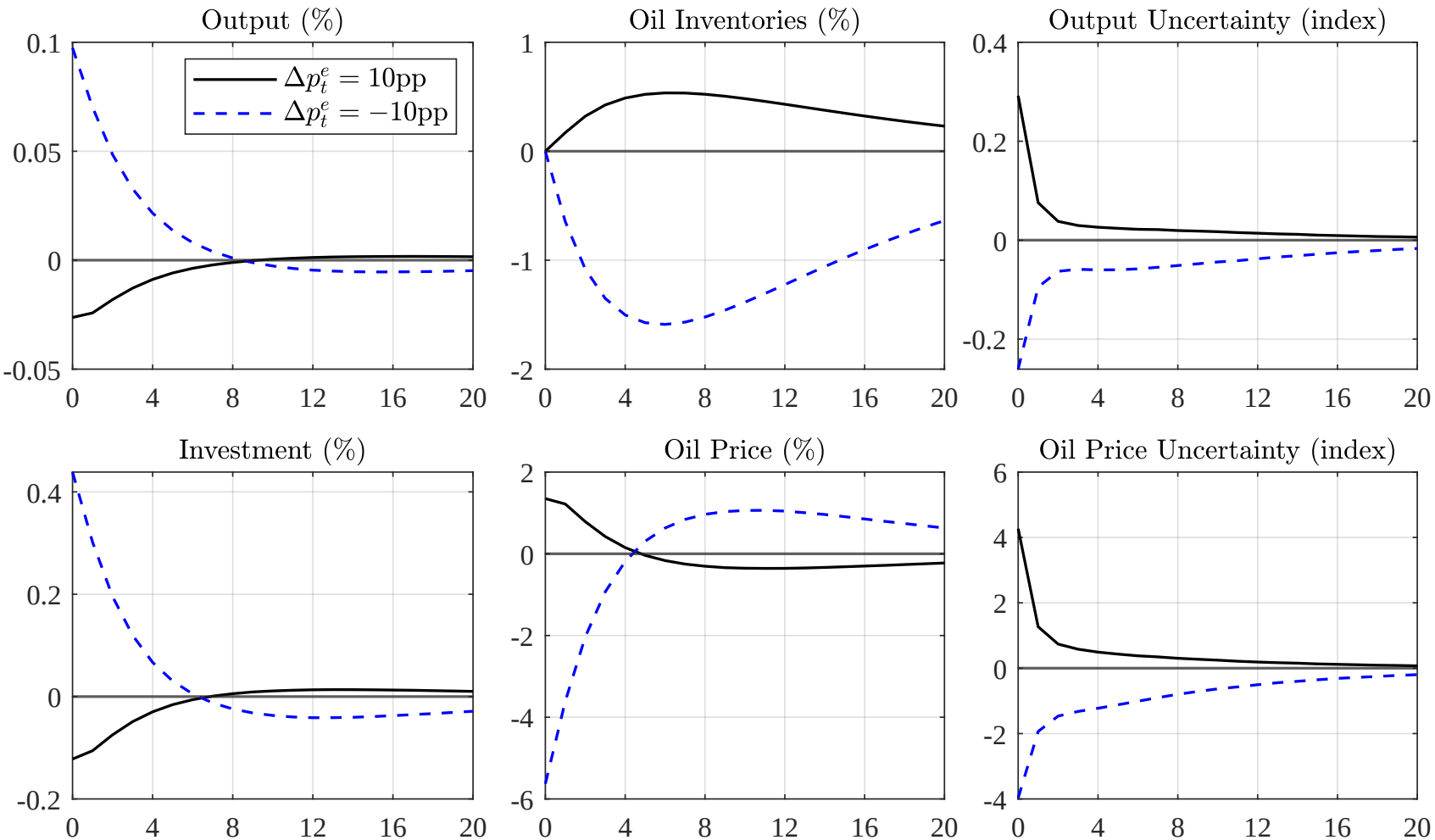

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QUARTERLY CALIBRATION (1/2)

- Assume the world economy resembles the U.S. economy
- Provides a useful benchmark and a natural starting point for studying the role of downside risk in the global economy

Parameter	Value	Target
Discount Factor (β)	0.997	$E(r)$
Risk Aversion (γ)	10	Gao et al. (2022), Croce (2014)
Intertemporal Elasticity (ψ)	2	Gao et al. (2022), Croce (2014)
Frisch Labor Supply Elasticity (η^{λ})	2	Peterman (2016), Basu and Bundick (2017)
Capital-Oil Elasticity (σ)	0.105	$SD(\Delta p^o)$
Capital Depreciation Rate (δ)	0.025	Depreciation on fixed assets and durables
Capital-Oil Share of Production (ξ)	0.4043	Avg. labor share of income
Investment Adjustment Cost (ν)	3.3	$SD(\Delta i)$
Oil Storage Cost (ω)	0.025	Casassus et al. (2018), Gao et al. (2022)
Average Growth Rate ($\bar{g}$)	1.0043	$E(\Delta y)$
Firm Leverage (ϑ)	0.9	$SD(r^{ex})$
Elasticity of Oil Supply to TFP (κ_1)	0	Newell and Prest (2019)
Oil Supply Adj. Speed to TFP (κ_2)	0.05	Half life of 3.5 years

Quarterly Calibration (2/2)

Parameter	Value	Target
Growth Shock SD (σ_g)	0.0095	$SD(\Delta y)$
Oil Production Growth Shock SD (σ_{go})	0.011	$SD(\Delta o^s)$
Growth Disaster Size (ζ_g)	0.018	$E(r^{ex})$
Probability of Entering Growth Disaster ($\bar{p}_g$)	0.005	Occurs on average every 50 years
Probability of Exiting Growth Disaster ($\bar{q}_g$)	0.9	Gourio (2012)
Growth Disaster Probability Persistence (ρ_{pg})	0.8	$AC(\mathcal{U}_y)$
Growth Disaster Probability SD (σ_{pg})	0.9	$SD(\mathcal{U}_y)$
Oil Production Disaster Size (ζ_e)	0.05	Avg. peak decline in oil disasters
Probability of Entering Oil Disaster ($\bar{p}_e$)	0.02	Avg. frequency of oil disasters
Probability of Exiting Oil Disaster ($\bar{q}_e$)	0.67	Avg. duration of oil disasters
Oil Disaster Probability Persistence (ρ_{pe})	0.9	$AC(\mathcal{U}_{p^o})$
Oil Disaster Probability SD (σ_{pe})	1.4	$SD(\mathcal{U}_{p^o})$

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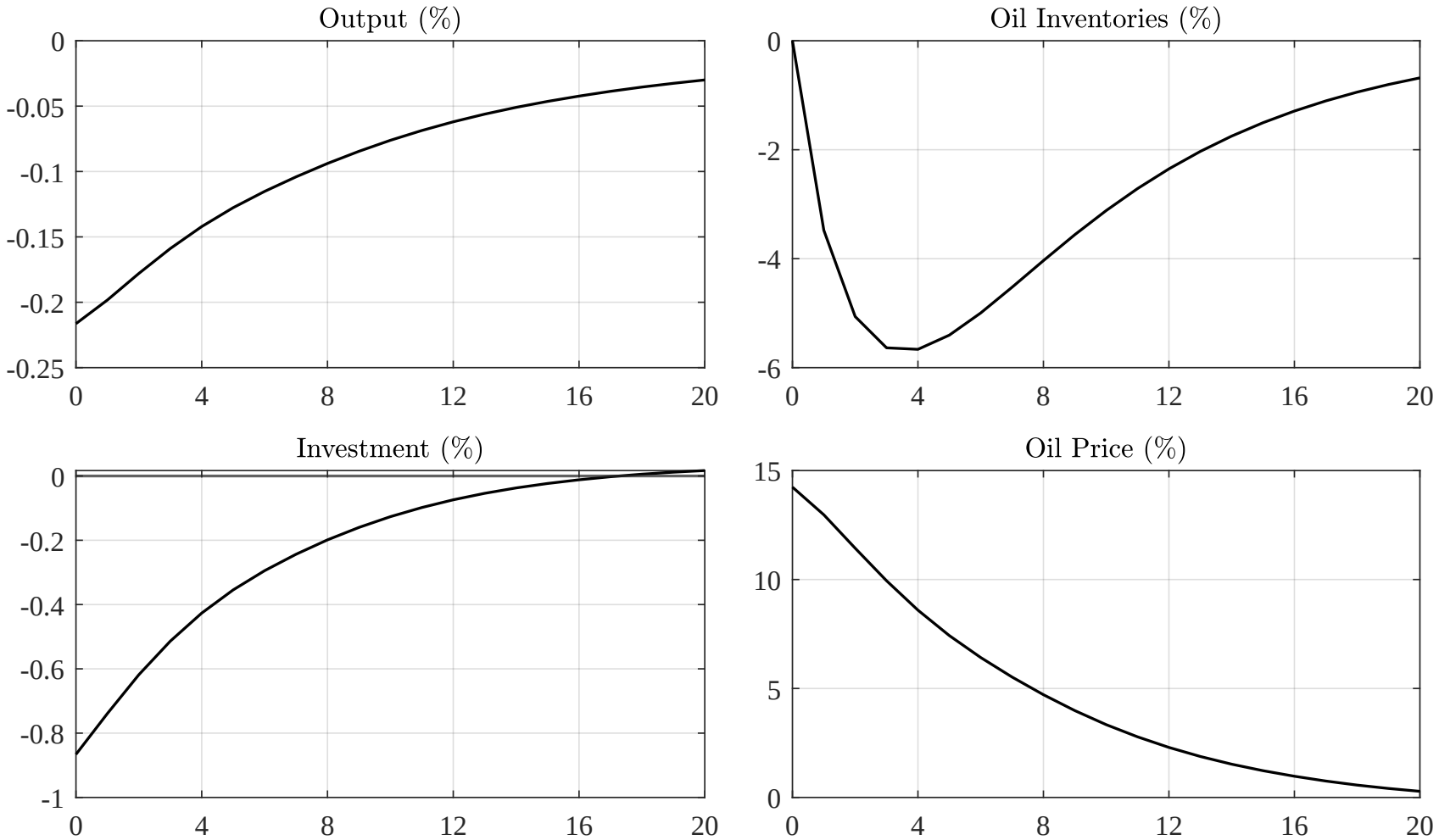
Oil Disaster Realization



Notes: Responses in deviations from the baseline. Disaster occurs in period 0.

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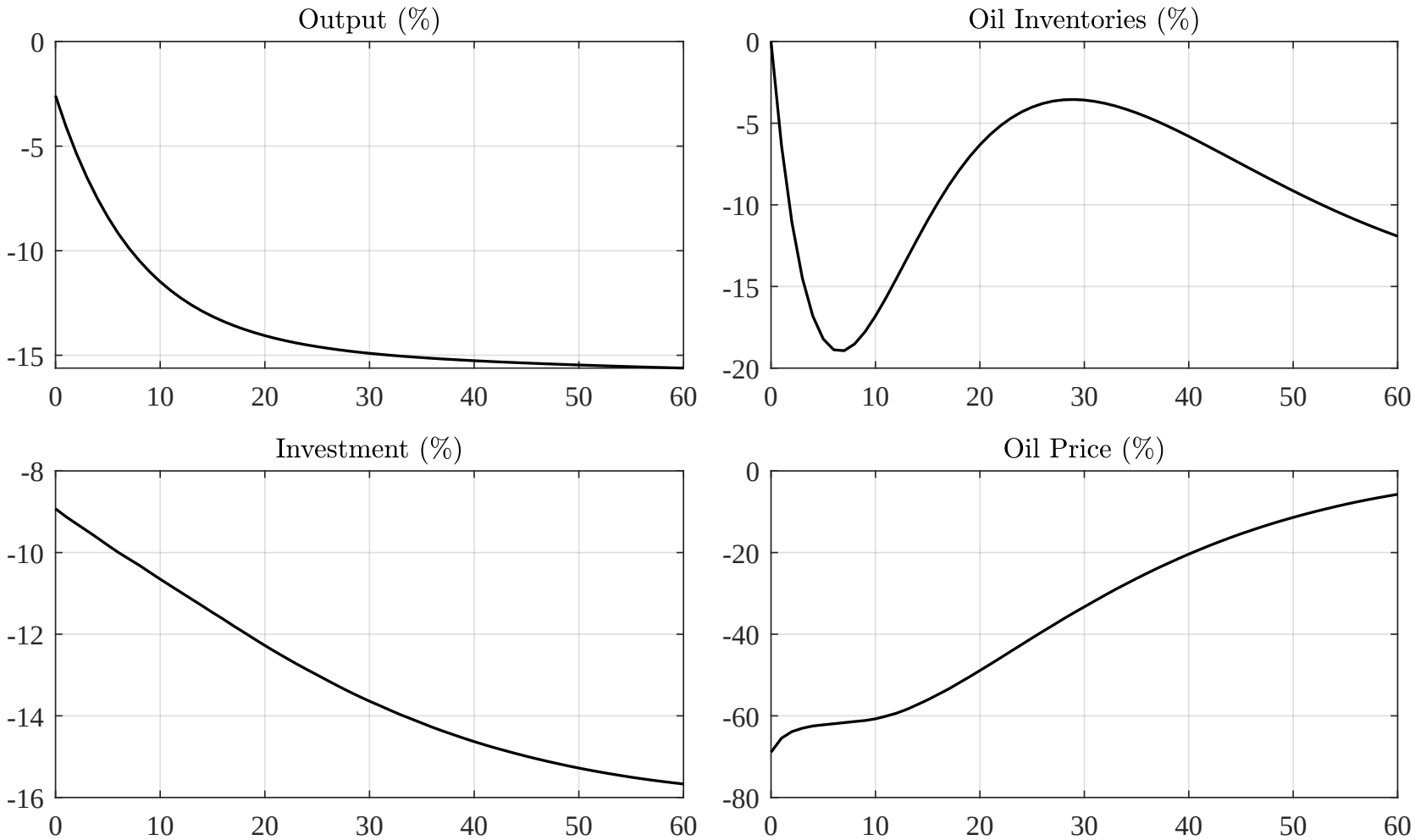
Macro Disaster Realization



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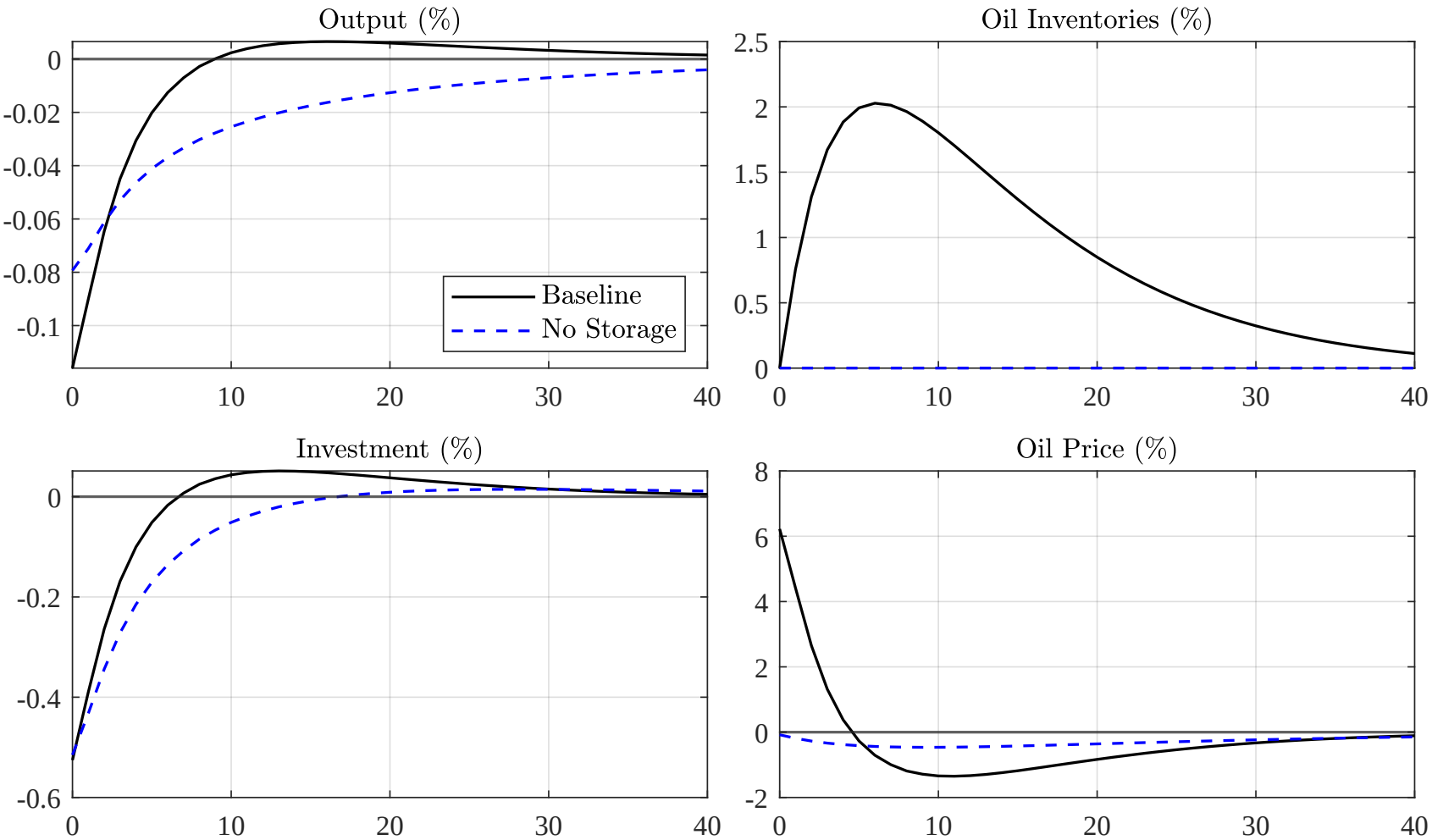
Role of Oil Storage: Oil Risk



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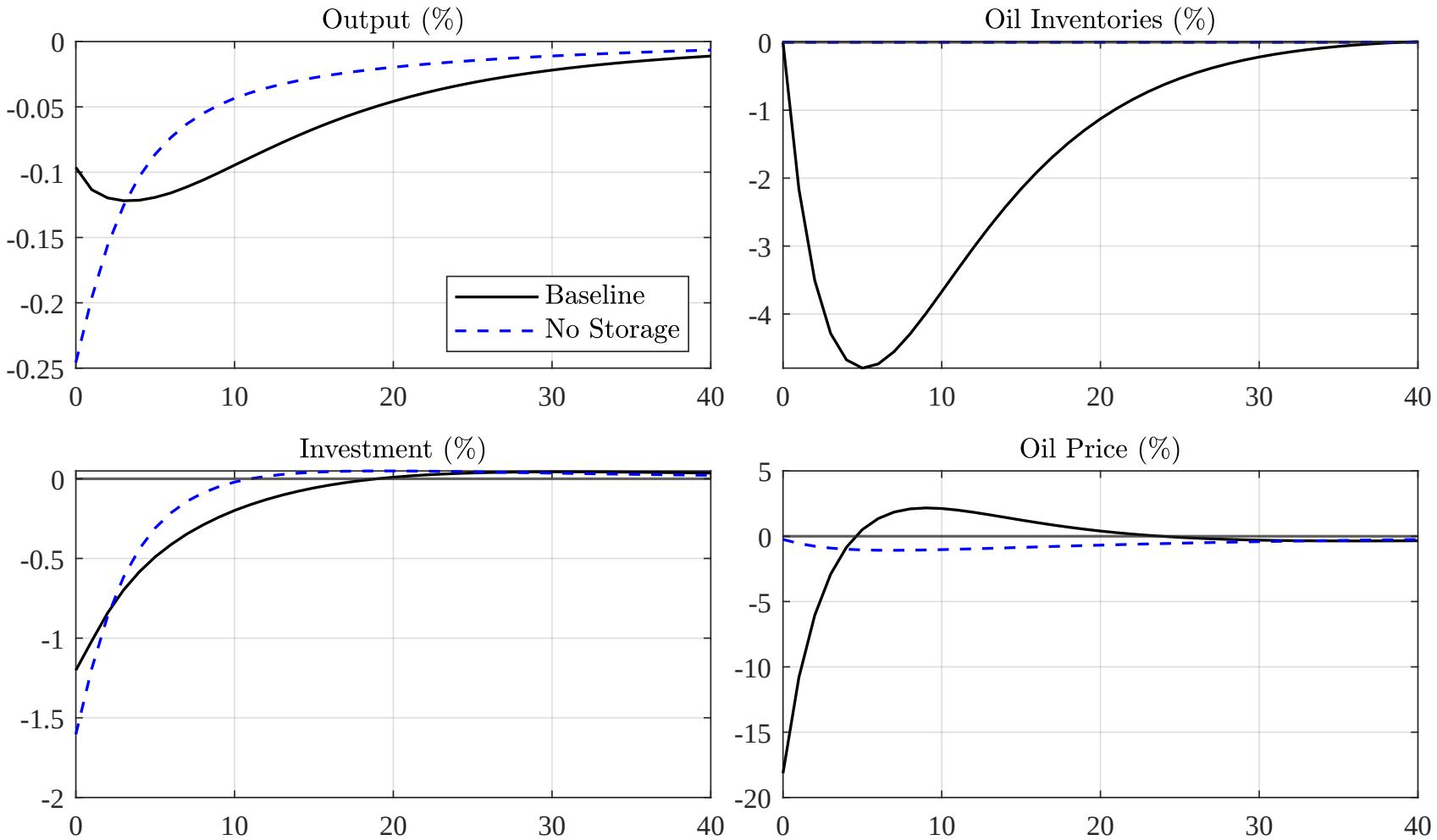
Role of Oil Storage: Macro Risk



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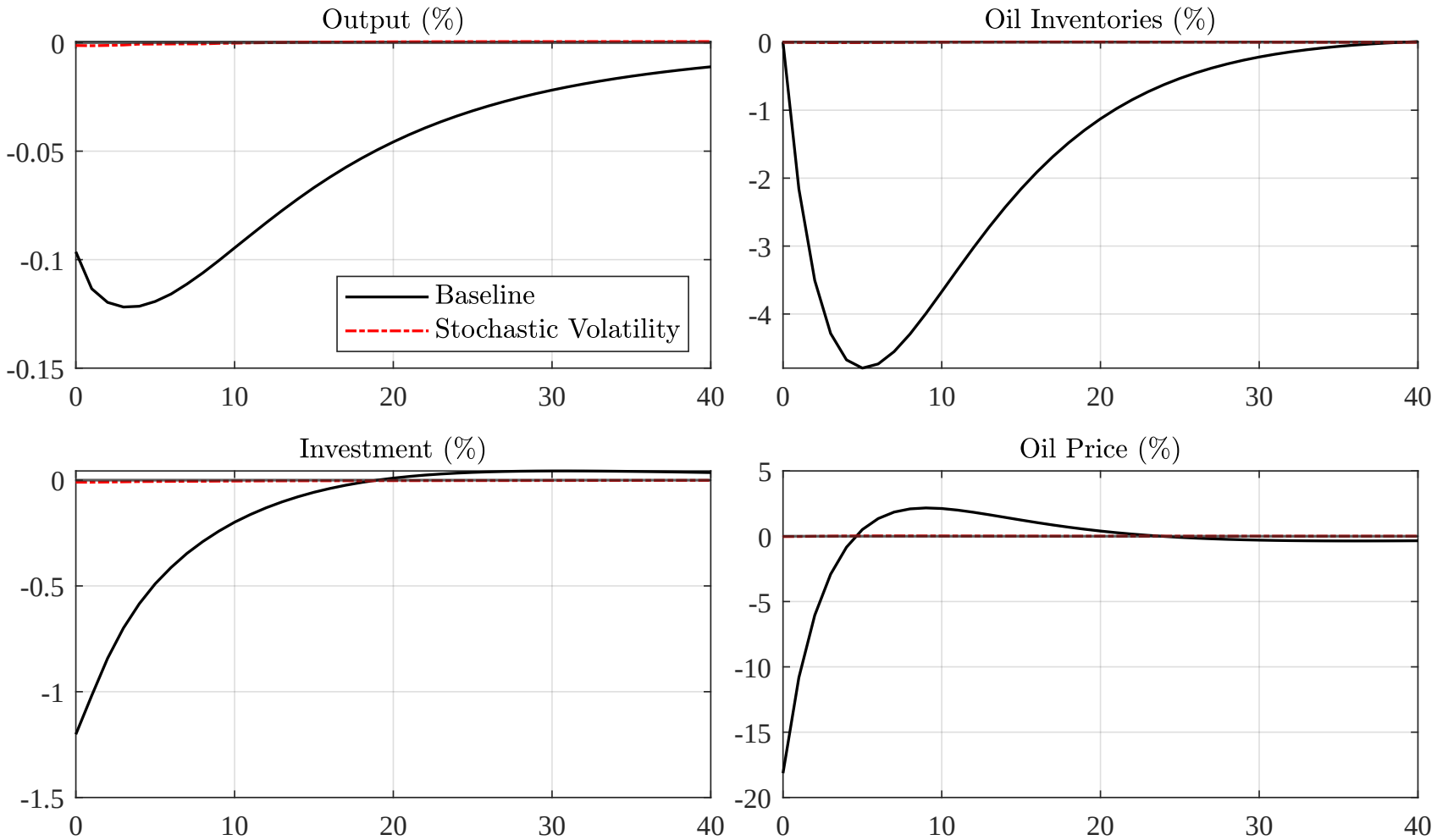
GROWTH SV SHOCK



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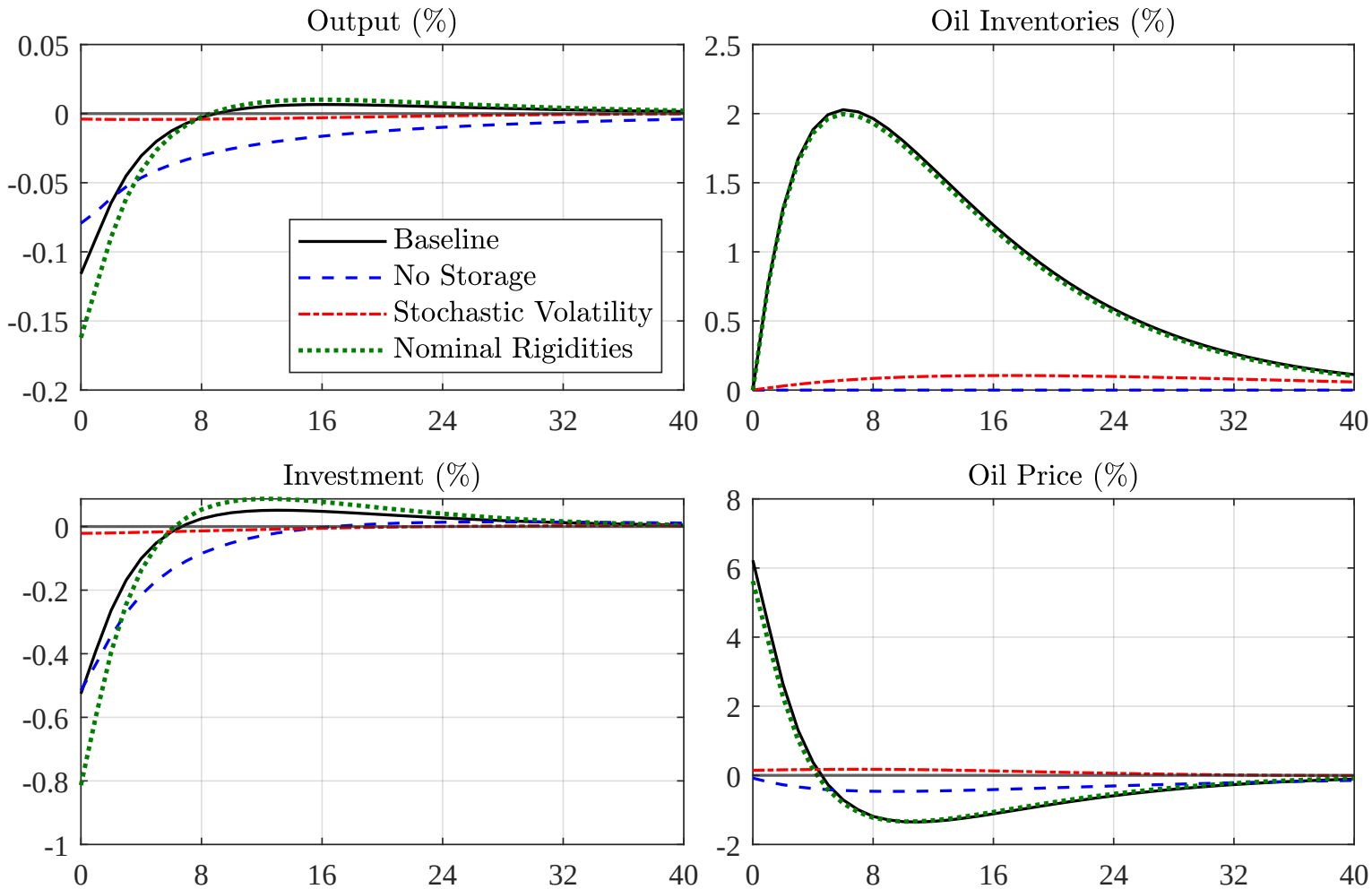
NOMINAL RIGIDITIES, STORAGE AND SV



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