Energy shocks and aggregate fluctuations
Is Decoupling possible ?
WORK IN PROGRESS

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Meeting w/ Professor Uhlig

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Motivation

- How important is energy for economic fluctuations ?
  - Energy – e.g. oil or electricity – is complementary in production
  - Contribute to output growth, inflation, capital deepening ...

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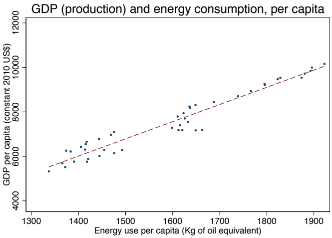
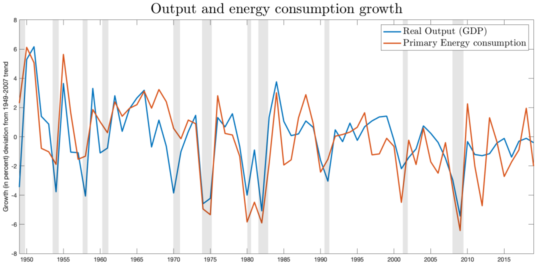
  - … but also to global warming
    – as fossil fuels $\sim 82\%$ of energy consumed
  - … or secular stagnation
    – as global energy production growth declined threefold in 50 years
- Quantitative question :
  - By how much ?
  - Is energy an important driver of business cycles fluctuations ?

Introduction – Motivation

- Real production growth limited by physical constraints.



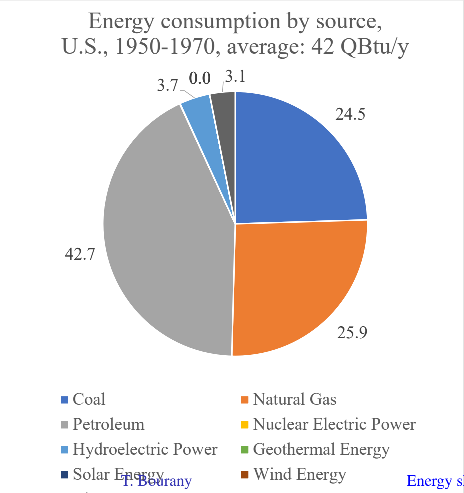


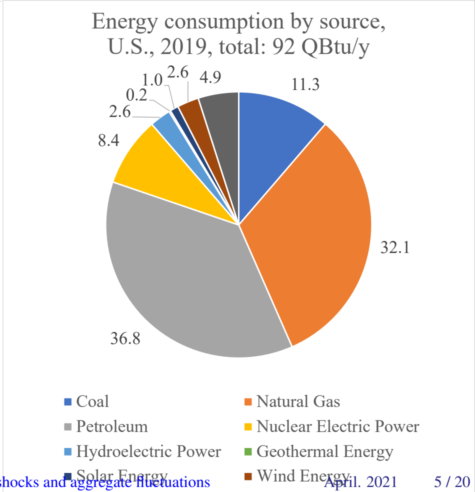
This paper

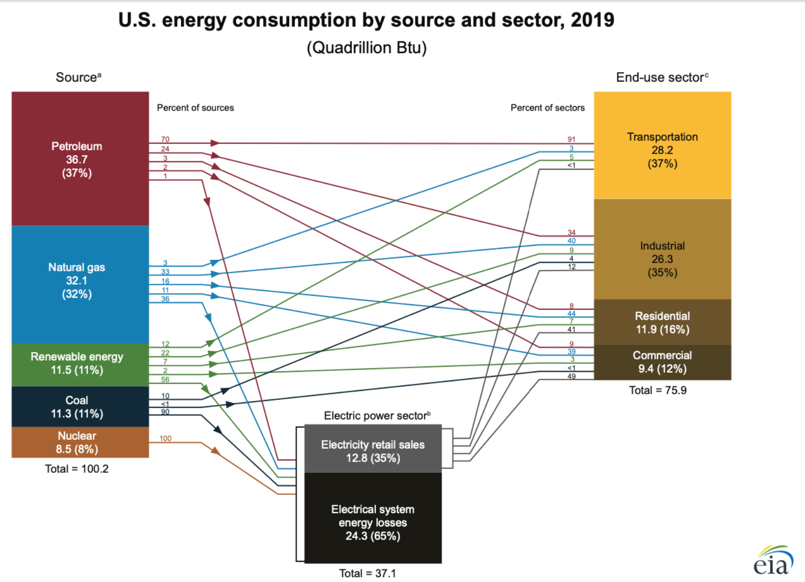
- Try to provide a quantitative answer on the importance of energy
- Theoretical contribution :
  - Energy as a complementary factor and non-linearity in the production process
  - DSGE model with multiple shocks.
  - Potential transmission and spillovers to the rest of the economy
- Empirical contribution :
  - Particle filtering and non-linear estimation methods
- Counterfactuals (if time permits)
  - A long-lasting decline in energy supply
  - A policy to reduce demand for energy

New data - 1

- Energy per sources and large sectors






U.S. energy consumption by source and sector, 2019
(Quadrillion Btu)
Source[a]
Percent of sources
Petroleum
36.7
(37%)
Natural gas
32.1
(32%)
Renewable energy
11.5 (11%)
Coal
11.3 (11%)
Nuclear
8.5 (8%)
Total = 100.2
End-use sector[c]
Percent of sectors
Transportation
28.2
(37%)
Industrial
26.3
(35%)
Residential
11.9 (16%)
Commercial
9.4 (12%)
Total = 75.9
Electric power sector[b]
Electricity retail sales
12.8 (35%)
Electrical system
energy losses
24.3 (65%)
Total = 37.1

Model

- Use the simplest RBC framework, with 2 small differences :
  - Energy as a factor, in a nested CES production, complementary to capital
  - Stochastic energy supply shock, and energy augmenting shocks (in addition to 4 other standard macro shocks)
- Perform a Business Cycle accounting procedure
  - Decompose business cycles in a set of 5 shocks, including energy
- Next steps : introduce different sectors ?

Model - RBC - Production

- Production process :

$$Y = \mathcal{F}(M, L) = Z_t \left[\alpha^{\frac{1}{\varepsilon_y}} M^{\frac{\varepsilon_y - 1}{\varepsilon_y}} + (1 - \alpha)(Z_t^{\ell} L)^{\frac{\varepsilon_y - 1}{\varepsilon_y}} \right]^{\frac{\varepsilon_y}{\varepsilon_y - 1}}$$

$$M = \mathcal{M}(E, K) = \left[\eta^{\frac{1}{\varepsilon_e}} (Z_t^{es} E)^{\frac{\varepsilon_e - 1}{\varepsilon_e}} + (1 - \eta) K^{\frac{\varepsilon_e - 1}{\varepsilon_e}} \right]^{\frac{\varepsilon_e}{\varepsilon_e - 1}}$$

  - Special case : if $\varepsilon_e \to 0$, $\mathcal{M} \sim$ Leontieff, if $\varepsilon_e \to 1$, $\mathcal{M} \sim$ Cobb-Douglas
- Price of energy as marginal product (demand curve) :

$$Q_t^E = \frac{\partial \mathcal{F}(M, L)}{\partial M} \frac{\partial \mathcal{M}(E, K)}{\partial E} = \alpha Y^{1/\varepsilon_y} H^{(1/\varepsilon_e) - (1/\varepsilon_y)} \eta E^{-1/\varepsilon_e}$$

Model – Energy sector - 1

- Energy production problem :
  - Microfunded as in : *"A World Equilibrium Model of the Oil Market", Bornstein, Krusell and Rebelo (2021)*

$$V_0^E = \max_{\{I_t^E, E_t\}} \mathbb{E}_0 \sum_{t=0}^{\infty} \Lambda_t \Big[Q_t^E E_t - I_t^E - \bar{C} \Big(\xi_t^e \frac{E_t}{\mathcal{R}_t^E} \Big)^{\nu} \mathcal{R}_t^E \Big]$$

s.t.

  - Evolution of "Exploration capital" X_t^E

$$K_{t+1}^E = (1-\lambda) K_t^E + \Xi_t^x \Theta \big(I_t^E \big)^{\theta} \big(L^E \big)^{1-\theta}$$

  - Stock of capacity of energy production $\mathcal{C}_t^E$

$$\mathcal{R}_{t+1}^E = \mathcal{R}_t^E - E_t + \lambda X_t^E$$

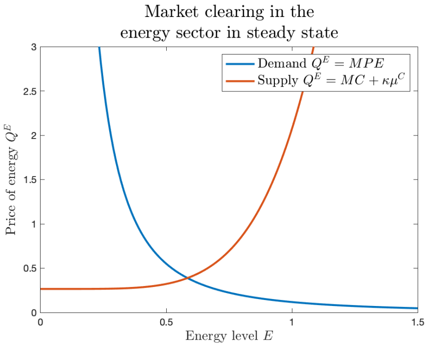
  - Two AR(1) shocks :

$$\log \xi_t^e = \rho \log \xi_t^e + \omega_t^e \qquad\qquad \log \Xi_t^x = \rho \log \Xi_t^x + \omega_t^e$$

Model – Energy sector - 2

- This allows for lags λ in a model *a la Hotelling*
  - FOCs : optimal decisions for $s_t^E = \frac{E_t}{\mathcal{R}_t^E}$ and $\mathcal{C}_t^E$

$$Q_{t+1}^E = \nu \bar{C}(s_{t+1}^E)^{\nu-1} + \mu_{t+1}^{\mathcal{R}}$$
$$\mu_t^{\mathcal{R}} = \mathbb{E}_t\Big[\Lambda_{t+1}\big(Q_{t+1}^E s_{t+1}^E + (1 - s_{t+1}^E)\mu_{t+1}^{\mathcal{R}} - \bar{C}(s_{t+1}^E)^\nu\big)\Big]$$



Model – RBC

- Rest of model : standard RBC :
  - Representative HH with preferences a la *King Plosser Rebelo* + Euler equation

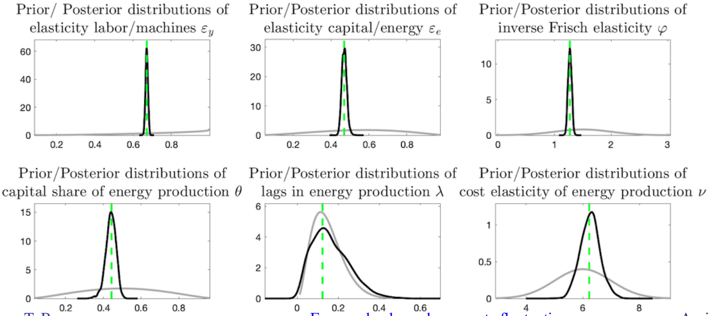
$$U(C,L) = \frac{1}{1-\sigma}\left(C_t^{1-\sigma}\left(1-\psi(1-\sigma)\frac{L^{1+\varphi}}{1+\varphi}\right)^{\sigma} - 1\right)$$

$$\Rightarrow \qquad U(C,L) = \log(C) - \psi\frac{L^{1+\varphi}}{1+\varphi} \qquad \& \quad 1 = \mathbb{E}_t[\Lambda_{t,t+1}(1+r^k_{t+1})]$$

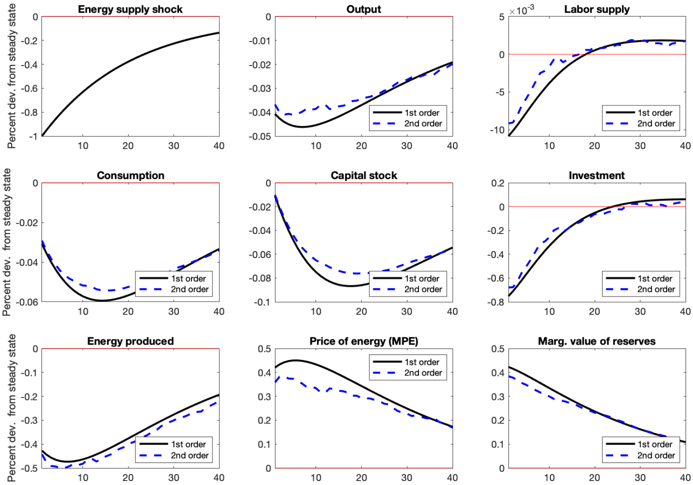
  - LoM for capital and investment with adjustment cost
- Business cycle accounting exercise :
- Set of shocks :
  - TFP shock Z_t and ω^z
  - Labor wedge τ_t^ℓ and ω^ℓ
  - Investment wedge τ_t^i and ω^i
  - Government wedge G_t and ω^g
  - In addition : Energy augmenting technology shock Z_t^{es}

Parameters – Estimation

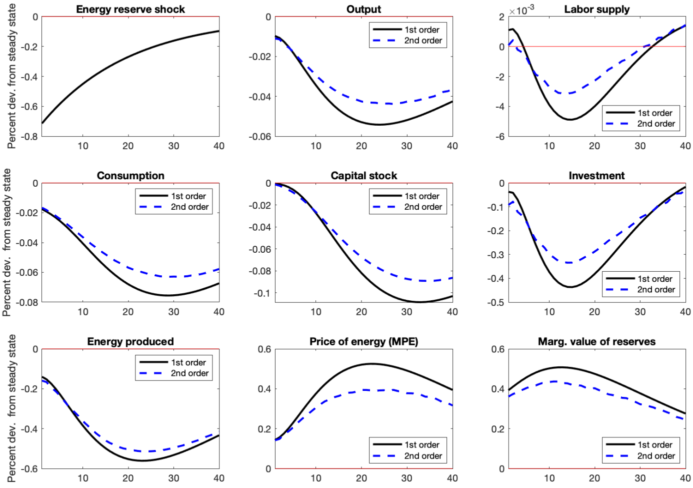
	Parameters	Post. mean
ε_y	Elasticity Machine/Labor	0.671
ε_e	Elasticity Energy/Capital	0.470
φ	Inverse Frisch elasticity	1.272
ν	Cost elasticity of energy production	6.259
θ	Capital intensity of energy	0.4392
λ	Lags in energy production	0.163



Analytics of the model : “pure” supply shock

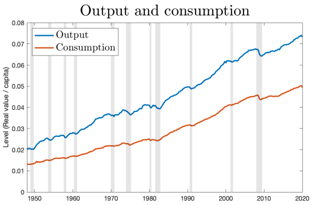


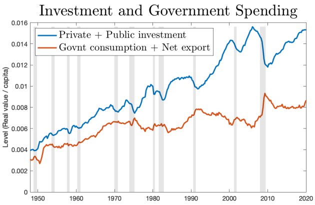
Analytics of the model : reserve shock

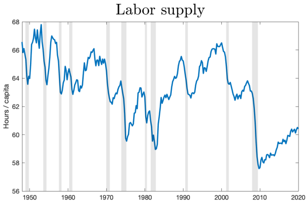


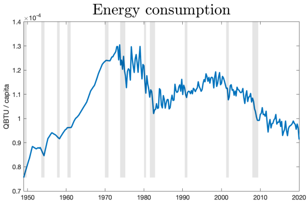
Model – Stationary variance decomposition

Variable	ω_z	ω_ℓ	ω_g	ω_{es}	ω_e	ω_x
Y_t	58.8	24.4	9.9	2.4	2.7	1.8
L_t	13.3	62.2	24.6	0.4	0.3	0.2
E_t	2.4	1.0	1.1	0.8	54.0	40.8
Q_t^E	10.3	4.3	0.7	2.4	46.1	36.2
K_t	48.1	19.9	2.0	7.6	8.7	13.7
I_t	55.1	22.8	2.3	8.5	7.2	4.1
C_t	25.6	10.6	54.9	2.1	3.3	3.4



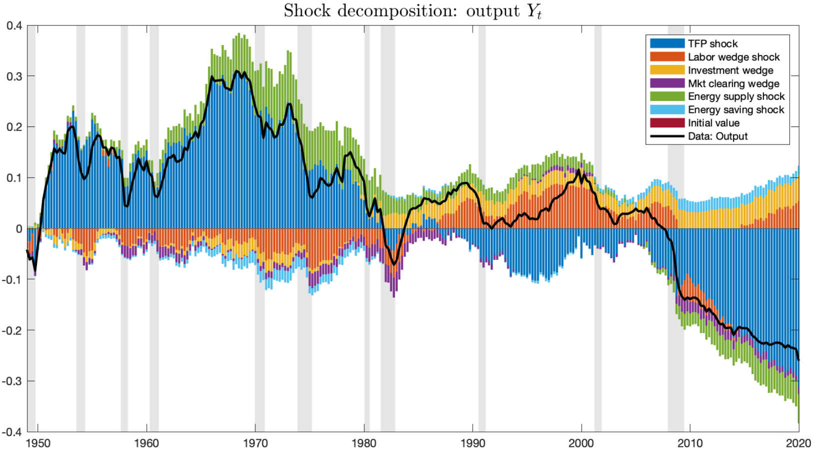




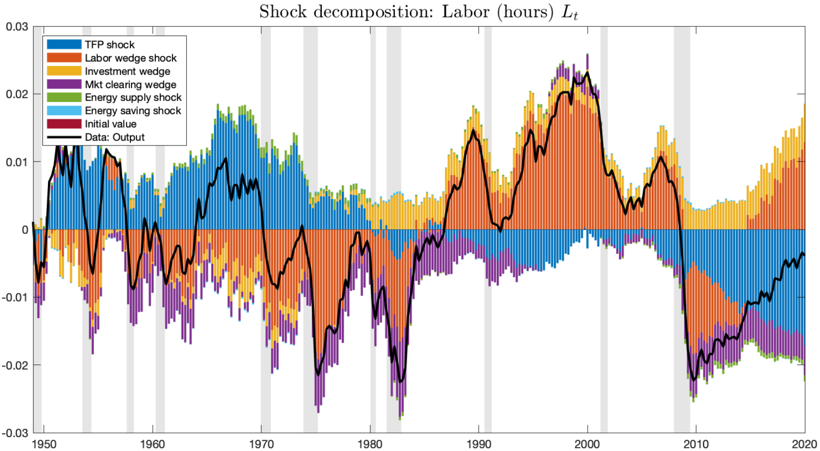


Sample U.S. data 1949 Q1 - 2020 Q1, in level per capita, deflated

Historical shock decomposition - energy supply shocks and output

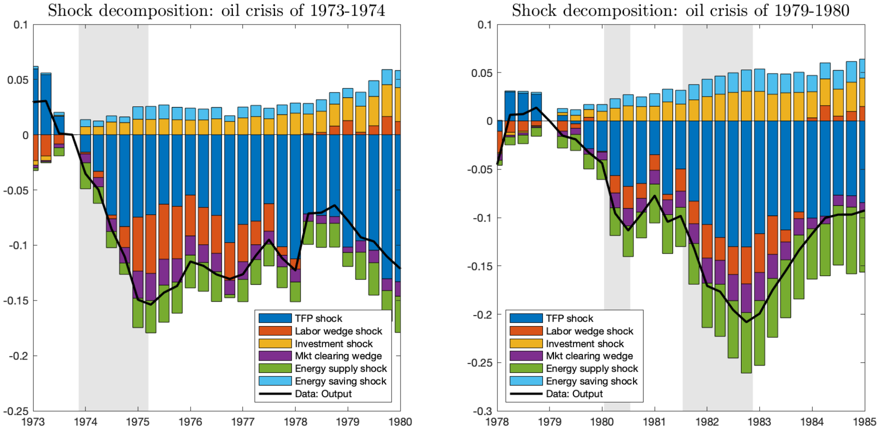


Historical shock decomposition – energy shocks and labor (hours)



Oil Shocks – 1973 vs. 1980

- Case studies



Conclusion and future paths

- How important is energy for economic fluctuations ?
  - With complementarity in production the energy shocks can be amplified
  - ... However, with reallocation toward the energy sector : the effects are smoothed dramatically
- In our quantitative : energy shocks do not seem to matter enormously
- Future plans :
  - Zoom in a particular event (oil shocks of 1973 and 1980)
  - Investigate the reallocation channels ?
  - Decompose economy by sector and the energy sector by sources ?