U.S. Shale Boom and International Business Cycles

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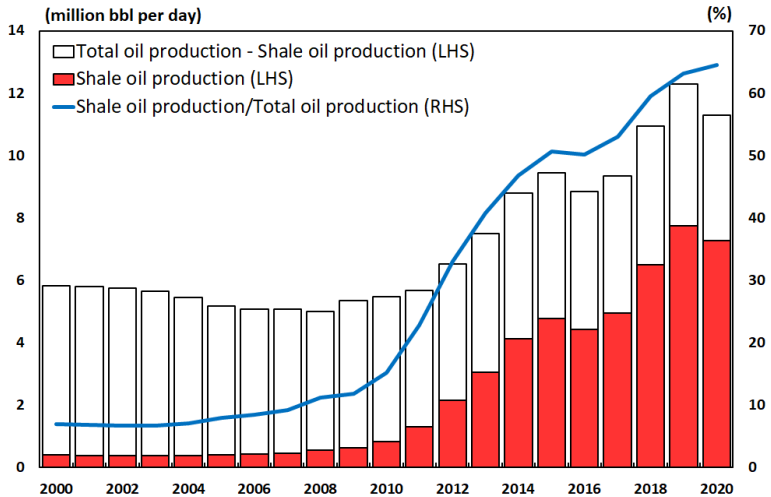
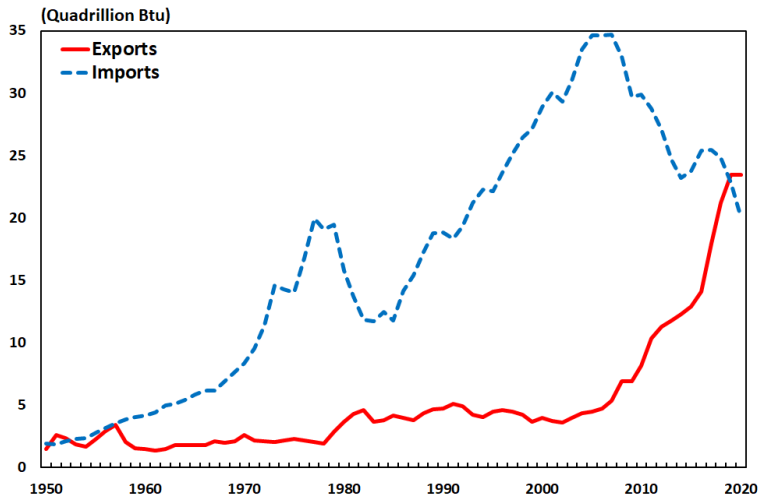
Motivation

- Due to the U.S. shale boom, U.S. energy production has hugely increased and hence U.S. net energy imports have sharply reduced



(a) Shale oil production



(b) Energy exports and imports

Motivation

- Changes in energy trades and prices have been regarded as an important source of economic fluctuation
- The increased U.S. energy production capacity due to shale boom may have significant effects on international business cycles

Illustration

- Before the shale boom
  - U.S. is a major net energy-importing country
  - Positive shocks in the U.S. will lead to a rise in U.S. energy imports for consumption and production
  - Since the U.S. is a large economy, the increased U.S. energy imports will raise energy prices

Illustration

- After the shale boom
  - Since U.S. energy production capacity increases thanks to the shale boom, U.S. is a minor net energy-importing country
  - In response to positive shocks in the U.S., (i) its import demand for energy will increase by less and (ii) Rise in energy prices will be smaller
  - (ii) will have positive influences on output in energy importers
  - (i) & (ii) will adversely affect output in energy exporters

$\Rightarrow$ U.S. output correlation with output in energy importers will be higher, while that with output in energy exporters will be lower

Illustration

- Smaller increase in energy prices will result in a smaller rise in U.S. import prices

$\Rightarrow$ Correlation between terms of trade and output in the U.S. will decline

- Less increased energy imports in the U.S. will bring about a larger rise in its net exports

$\Rightarrow$ Correlation between net exports and output in the U.S. will be greater

Aim

- Providing empirical findings that U.S. international business cycles during the U.S. shale boom period have changed
  - During the shale boom period, comovement between terms of trade and output in the U.S. has become weaker
  - Net exports and output in the U.S. have been more synchronized
  - U.S. output comovement with energy importers has become stronger
  - U.S. output comovement with energy exporters has become weaker

Aim

- Construct a three-country model including the U.S., an energy importer and an energy exporter
  - Show that the model captures the observed variations in U.S. international business cycles across the two periods
  - Investigate the mechanism of how the U.S. shale boom brought about the changes in international business cycles, using impulse responses of the model

Variations in international business cycles after the shale boom

Some definitions

- Pre-shale boom period: Q1 2000 to Q2 2008
- Shale boom period: Q1 2012 to Q3 2019
- Sample countries: 19 major OECD member countries
- Energy Importers: energy consumption $>$ energy production (from the EIA data)
- Energy Exporters: energy consumption $<$ energy production
  - Australia, Canada, Denmark, Mexico and Norway

International business cycles of interest

Consistent with the hypothesis, the U.S. output correlation with terms of trade fell, but that with net exports increased

	Pre-shale boom	Shale boom
U.S. domestic comovement		
Terms of trade and output	**0.483**	**-0.004**
Net exports and output	**-0.306**	**0.053**

International business cycles of interest

Output comvement		
U.S. and Importers		
Austria	0.705	0.800
Belgium	0.815	0.895
France	0.758	0.881
Germany	0.530	0.690
Italy	0.654	0.785
Japan	0.837	0.610
Korea	0.200	0.644
Netherlands	0.574	0.819
New Zealand	0.308	0.747
Portugal	0.485	0.823
Spain	0.679	0.772
Sweden	0.836	0.692
Switzerland	0.659	0.846
U.K.	0.748	0.857
Average	**0.628**	**0.775**
U.S. and Exporters		
Australia	0.436	0.771
Canada	0.826	0.819
Denmark	0.810	0.647
Mexico	0.908	0.819
Norway	0.682	0.412
Average	**0.732**	**0.694**

The model

Overview

- The world economy consists of three countries: U.S. (country A), importer (country B) and exporter (country C)
  - Countries A and B can produce energy, but they cannot produce energy in sufficient quantities to meet domestic demand for energy
  - Country C produces enough energy to meet domestic demand and the other countries' demand for imports of energy

Households

- Utility:

$$U^A = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \frac{\left(C_t^{A^\theta} L_t^{A^{1-\theta}} \right)^{1-\chi}}{1-\chi} \tag{1}$$

- Budget constraint:

$$C_t^A + \mathbb{E}_t \left[Q_{t,t+1} B_{t+1}^A \right] + D_t^A = B_t^A + R_{t-1}^A D_{t-1}^A + W_t^A N_t^A \tag{2}$$

- Aggregate consumption:

$$C_t^A = \left\{ (1-\gamma_0)^{\frac{1}{\eta_0}} C_{NE,t}^{A^{\frac{\eta_0-1}{\eta_0}}} + \gamma_0^{\frac{1}{\eta_0}} C_{E,t}^{A^{\frac{\eta_0-1}{\eta_0}}} \right\}^{\frac{\eta_0}{\eta_0-1}} \tag{3}$$

Households

- Energy consumption:

$$C^A_{E,t} = C^A_{E,A,t} + C^A_{E,C,t} \tag{4}$$

- Imported energy consumption:

$$C^A_{E,C,t} = \gamma C^A_{E,t} \tag{5}$$

- Non-energy consumption:

$$C^A_{NE,t} = \left\{ (1-\gamma_1)^{\frac{1}{\eta_1}} C^{A\,\frac{\eta_1-1}{\eta_1}}_{A,t} + \left(\frac{\gamma_1}{2}\right)^{\frac{1}{\eta_1}} C^{A\,\frac{\eta_1-1}{\eta_1}}_{B,t} + \left(\frac{\gamma_1}{2}\right)^{\frac{1}{\eta_1}} C^{A\,\frac{\eta_1-1}{\eta_1}}_{C,t} \right\}^{\frac{\eta_1}{\eta_1-1}} \tag{6}$$

Firms

- Energy producers: $Y^A_{E,t} = A^A_{E,t} K^{A^{\alpha_E}}_{E,t} N^{A^{1-\alpha_E}}_{E,t}$
- Non-energy producers:
  $Y^A_{NE,t} = A^A_{NE,t} \left\{ (1-a) K^{A^{-\nu}}_{NE,t} + a E^{A^{-\nu}}_t \right\}^{-\frac{\alpha}{\nu}} N^{A^{1-\alpha}}_{NE,t}$
- Imported energy inputs: $E^C_{C,t} = \gamma E^C_t$
- Capital producers:
  $\max_{K^A_{s,t+1}} q^A_{s,t} K^A_{s,t+1} - (1-\delta) q^A_{s,t} K^A_{s,t} - p^A_{s,t} I^A_{s,t+h}$
  s.t. $K^A_{s,t+1} = (1-\delta) K^A_{s,t} + \phi \left(\frac{I^A_{s,t}}{K^A_{s,t}} \right) K^A_{s,t}$

Parameter values

Pre-shale boom period

Definition	Parameter	Values
Discount factor	β	0.99
Depreciation rate of capital	δ	0.025
Coefficient of relative risk aversion	χ	2
Consumption share in utility	θ	0.34
Elasticity of substitution between energy and capital in the non-energy production	$1/(1+\nu)$	0.588
Parameter related to the weight of energy in the non-energy production	a	0.001
Labor share in the non-energy sector	$1-\alpha$	0.66
Labor share in the energy sector in countries A and B	$1-\alpha_E$	0.66
Labor share in the energy sector in country C	$1-\alpha_E^C$	0.675
Weight of energy consumption in aggregate consumption	γ_0	0.05
Elasticity of substitution between energy and non-energy in consumption	η_0	0.3
Fraction of imported energy in energy consumption and energy input in countries A and B	γ	0.79
Weight of imported non-energy in the non-energy consumption in countries A and B	γ_1	0.3795
Weight of imported non-energy in the non-energy consumption in country C	γ_1^C	0.5143
Elasticity of substitution between domestic and foreign non-energy in non-energy consumption	η_1	1.2

Parameter values

- Shale boom period:
  - Average U.S. net energy imports during the shale boom period have decreased by about a third
  - Parameter γ for the U.S., which determines U.S. net energy imports, declines form 0.79 to 0.257
  - γ for the importer is maintained as 0.79
  - Other parameter values are the same as those for the pre-shale boom period

Results

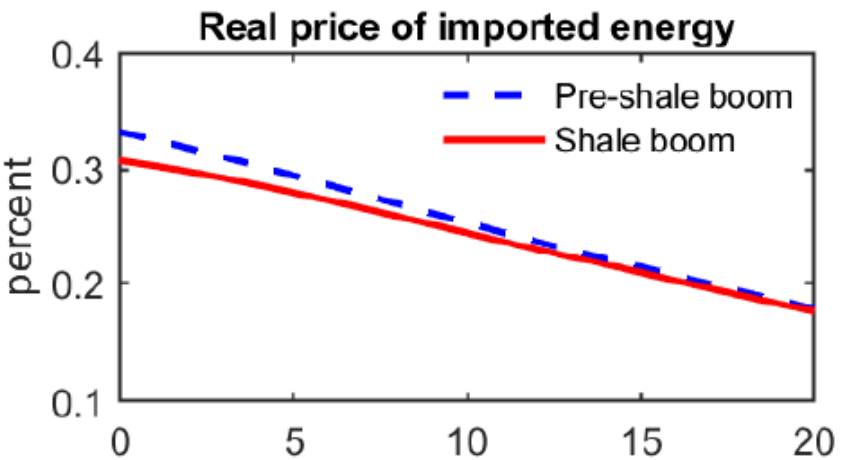
International business cycles

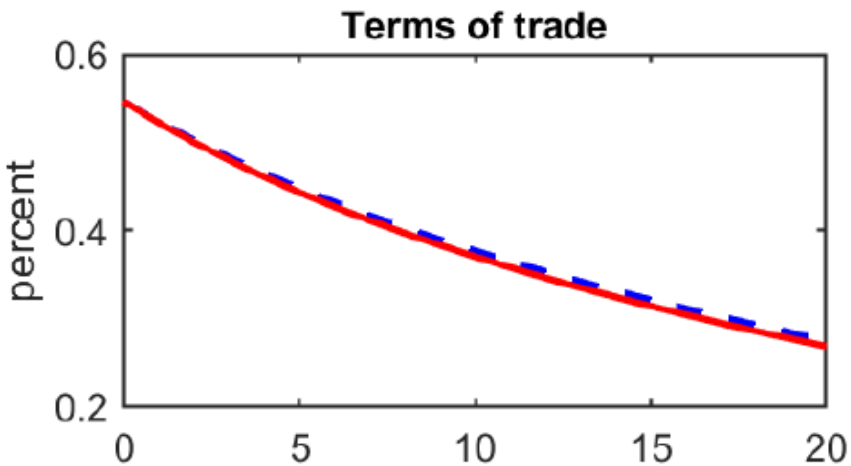
The model does a reasonably good job in capturing the observed variations in international business cycles across the two periods

	Data		Model predictions	
	Pre-shale boom	Shale boom	Pre-shale boom	Shale boom
U.S. domestic comovement				
Terms of trade and output	0.483	-0.004	0.754	0.667
Net exports and output	-0.306	0.053	-0.588	0.061
Output comovement				
U.S. and importer	0.628	0.775	0.348	0.357
U.S. and exporter	0.732	0.694	0.401	0.384

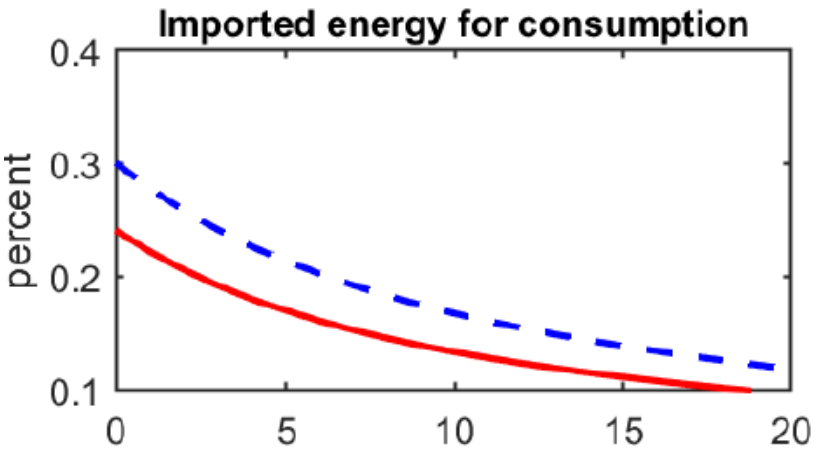
Mechanism

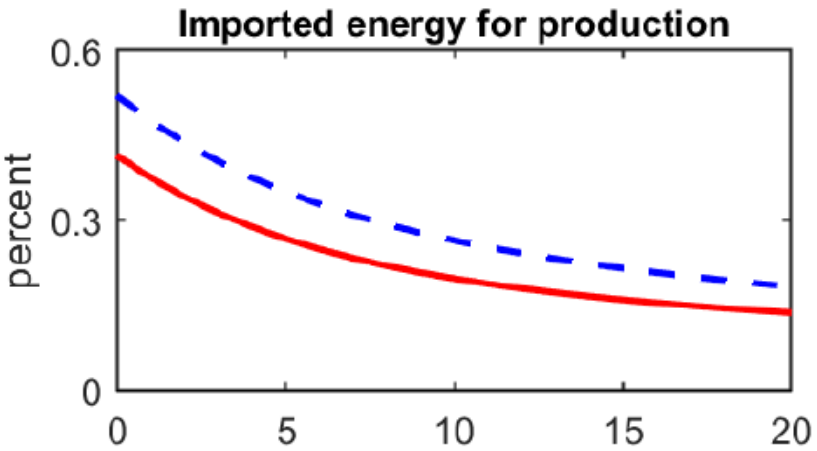
Responses of the U.S. to a positive productivity shock in U.S. non-energy sector

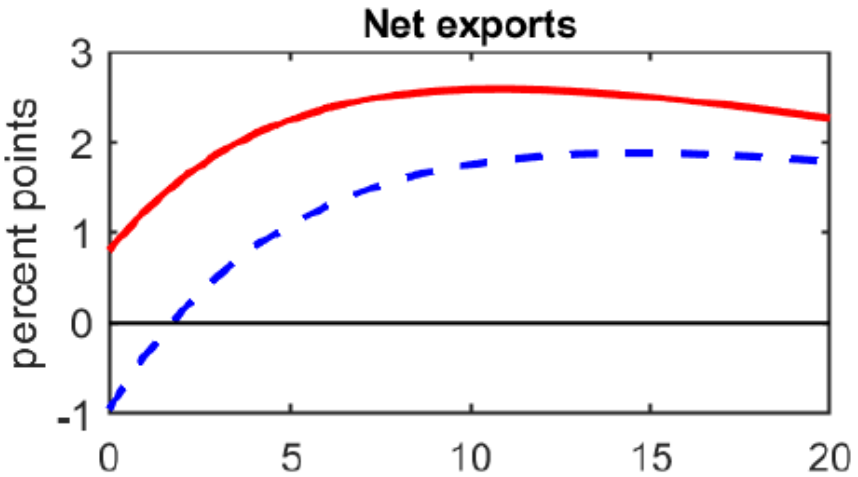




Mechanism

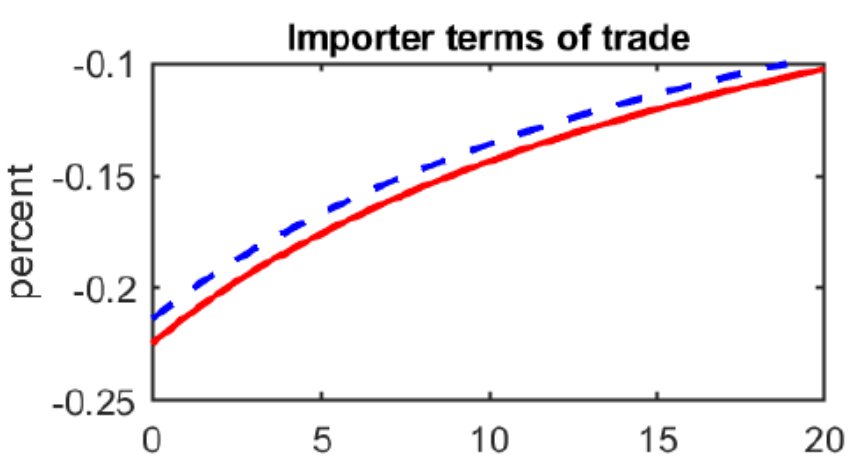

Imported energy for consumption
percent
0.4
0.3
0.2
0.1
0
5
10
15
20

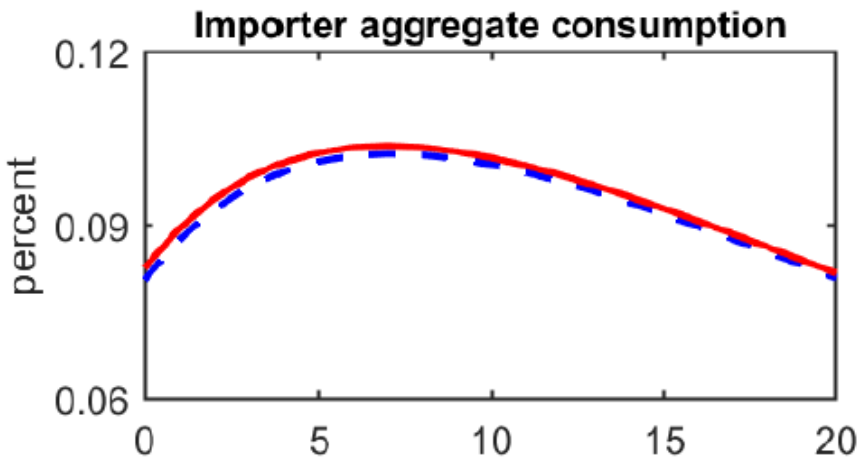

Imported energy for production
percent
0.6
0.3
0
0
5
10
15
20

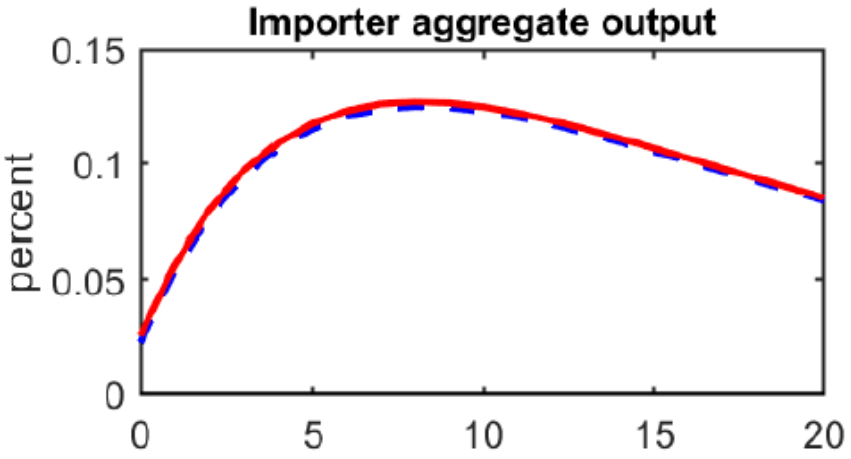

Net exports
percent points
3
2
1
0
-1
0
5
10
15
20

Mechanism

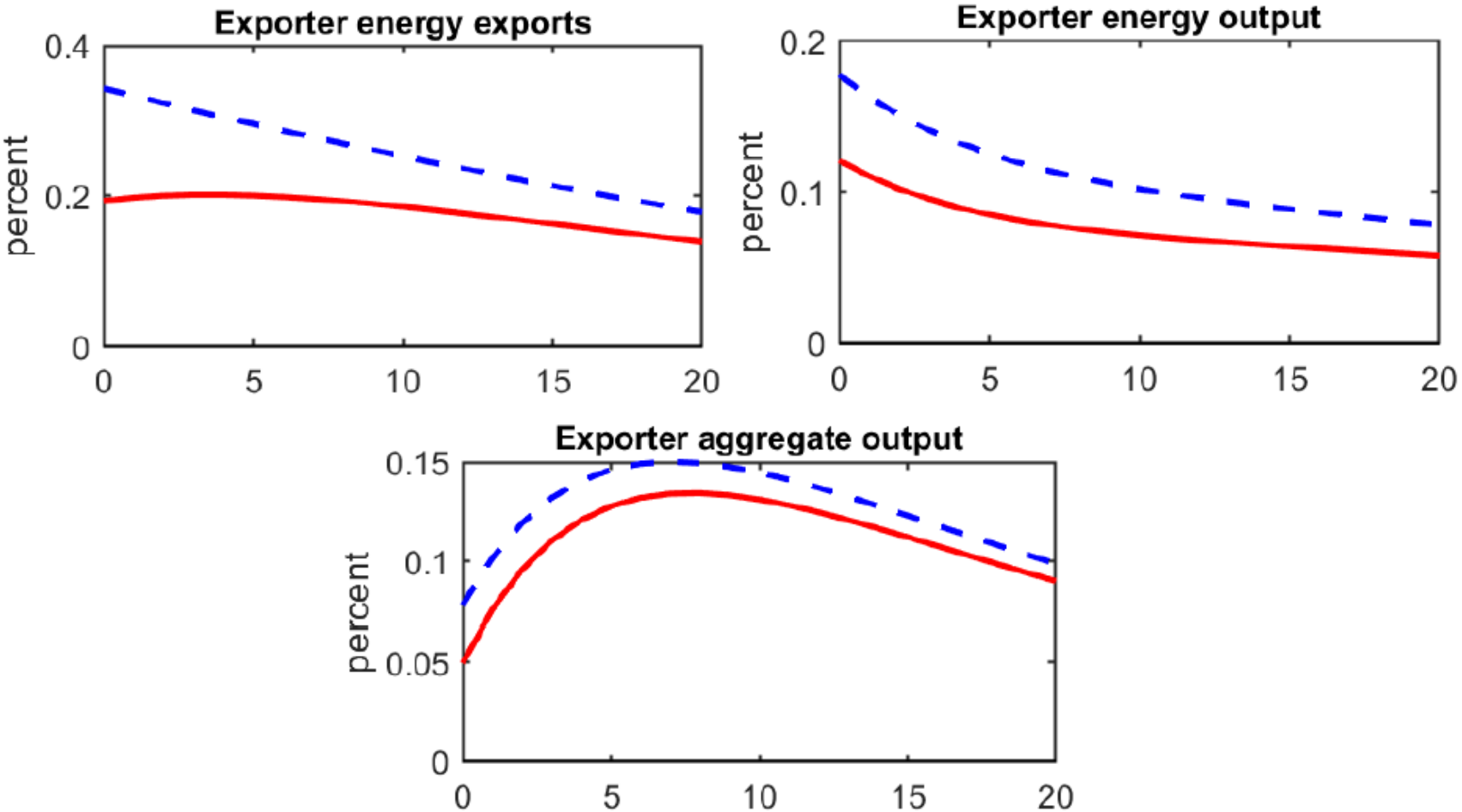
Responses to a positive productivity shock in U.S. non-energy sector







Mechanism


Exporter energy exports
percent
0.4
0.2
0
0
5
10
15
20
Exporter energy output
percent
0.2
0.1
0
0
5
10
15
20
Exporter aggregate output
percent
0.15
0.1
0.05
0
0
5
10
15
20

Results under different assumptions

	Pre-shale boom				Shale boom			
	Y^A, τ^A	Y^A, nx^A	Y^A, Y^B	Y^A, Y^C	Y^A, τ^A	Y^A, nx^A	Y^A, Y^B	Y^A, Y^C
Incomplete markets	0.778	-0.757	0.352	0.402	0.703	0.344	0.360	0.386
Energy shocks	0.681	-0.279	0.351	0.402	0.659	0.041	0.357	0.385
No productivity spillovers	0.737	-0.513	0.348	0.392	0.663	0.136	0.354	0.375
High productivity shock persistence	0.834	-0.112	0.209	0.293	0.740	0.406	0.225	0.273
Low productivity shock persistence	0.735	-0.880	0.359	0.395	0.663	-0.449	0.364	0.382
High elasticity between energy and non-energy	0.740	-0.523	0.352	0.399	0.662	0.093	0.359	0.383
Low elasticity between energy and non-energy	0.764	-0.617	0.346	0.402	0.672	0.038	0.355	0.385
High elasticity between non-energy goods	0.825	0.492	0.285	0.328	0.720	0.595	0.294	0.318
Low elasticity between non-energy goods	0.712	-0.849	0.390	0.450	0.635	-0.727	0.398	0.428
High elasticity between capital and energy	0.752	-0.706	0.349	0.400	0.668	-0.021	0.357	0.382
Low elasticity between capital and energy	0.755	-0.482	0.348	0.401	0.667	0.112	0.357	0.385
High weight of imported non-energy goods	0.706	-0.870	0.383	0.444	0.634	-0.466	0.392	0.424
Low weight of imported non-energy goods	0.845	-0.339	0.309	0.353	0.727	0.292	0.316	0.338

Thank you