Energy Efficient Technology and Vintage Capital in Chinese Industries

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Abstract

By incorporating energy-saving through both technology-embodied investment, embodied and disembodied technical change into a dynamic stochastic general equilibrium (DSGE) model with heterogeneous investment, this paper identifies avenues through which firms adjust to rising energy prices. Using Chinese firm-level data from 1997-2004, we estimate a set of stylized facts regarding how firms of various ownership types respond to energy price changes. We then use these stylized facts to recover key parameters in the DSGE model through indirect inference. The results show that within Chinese industry, in response to rising energy prices, state-owned enterprises, domestic non-state enterprises, and foreign-funded enterprises employ significantly different means to achieve their energy efficiency. Such differences can be substantially explained by government policy affecting energy pricing and the cost of investment finance across firms of different ownership types.

Motivation

- Many studies on energy consumption treat firms as "block box", with unspecified channels to achieve energy efficiency
  - Reduced-form analysis usually regresses energy intensity on energy prices, investment/vintage capital, ownership, technology and other variables
  - It is hard to identify and disentangle various channels, because
    - investment and technology are interconnected, in the case of energy-saving technology embodied in machines and equipments
    - data on vintage capital and technology are not directly available
- This paper identifies various channels through which Chinese industrial firms achieve energy efficiency
  - Construct and estimate a structural model, which is able to replicate stylized facts observed from data

Main Takaways

- Vintage capital or investment embedded with energy-efficient technology plays a crucial role in achieving energy efficiency in Chinese industrial firms
  - state-owned enterprises rely on vintage capital most, followed bydomestic non-state-owned enterprises, and foreign-funded firms rely on vintage capital least
- Embodied and disembodied technologies are another two critical channels through which firms achieve their energy efficiency
  - the model with both embodied and disembodied technologies fit the data best
  - state-owned enterprises rely on embodied technology more than domestic non-state-owned enterprises and foreign-funded firms
  - all three types of firms equally rely on disembodied technology

Data

- A unbalanced panel from Above Scale dataset, collected by National Bureau of Statistics of China
- It provides firm-level energy consumptions, energy prices and economic/financial variables
- 10,837 osbervations from 1997-2004, with
  - 51% state-owned enterprises (SOEs)
  - 38% domestic non-state-owned enterprises (NSOEs)
  - 11% foreign-funded firms (FFEs)

Facts

- Regression 1: Energy intensity responding to energy

$$\ln(En/Y)_t = \beta_0 + \beta_1 \ln P_t + \beta_2 \ln P_{t-1} + \beta_3 \ln P_{t-2} + \beta_4 \ln P_{t-3} + \beta_5 \ln P_{t-4} + \text{controls} + \epsilon$$

- Regression 2: Energy intensity responding to the vintage structure

$$\ln(En/Y)_t = \alpha_0 + \alpha_1 \ln P_t + \alpha_2 \ln(NVFA/OVFA)_t + \alpha \cdot \text{ lag energy prices} + \text{controls} + \nu$$

- Regression 3: vintage structure $NVFA/OVFA$ responding

$$\ln(NVFA/OVFA)_t = \gamma_0 + \gamma_1 \cdot \text{average enery prices} + \text{controls} + \varepsilon$$

  - OVFA: original value of fixed assets; NVFA: net value of fixed assets
  - the higher $NVFA/OVFA$, the younger age structure of a firm's capital stock

- Right panels of Tables 1-3 report regressions for SOEs, NSOEs and FFEs
- SOEs: robust price-investment mechanism; SOEs invest in energy-saving capital goods when energy prices rise
- NSOEs: investment helps firms reduce energy intensity, however NSOEs' investment do not reponse to energy prices
- FFEs: little evidence on the price-investment mechanism

Model and Estimation

- In a dynamic stochastic general equilibrium model, we introduces:
  - putty-clay investment or vintage capital: capital's energy efficiency is optimally chosen by firms in response to energy prices change
  - embodied and disembodied technologies: autonomous change and energy-price induced innovation
- Estimating parameteres in the model
  - key structural parameters are estimated via indirect inference method
  - the estimated model is able to replicate the stylized facts observed from the data

- In Tables 1-3, we compare the estimated structural model with data for three types of firms
  - The left panels of Tables 1-3 report the regression coefficients from the estimated model
  - The right panels of Tables 1-3 report the regression coefficients directly obtained from the firm-level data
- Our model successfully reproduce the stylized facts for SOEs, NSOEs and FFEs

- Table 1: Compare model with data: SOEs

	Model					SOEs				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
		1-year	2-year	3-year	4-year		1-year	2-year	3-year	4-year
Regression 1: Energy intensity responding to energy prices										
P^e_t	−0.405	−0.277	−0.278	−0.278	−0.279	−0.389	−0.304	−0.325	−0.313	−0.304
P^e_{t-1}		−0.238	−0.159	−0.160	−0.159		−0.206	−0.147	−0.159	−0.126
P^e_{t-2}			−0.145	−0.093	−0.094			−0.141	−0.087	−0.129
P^e_{t-3}				−0.095	−0.061				−0.111	−0.066
P^e_{t-4}					−0.064					−0.081
Regression 2: Energy intensity responding to the vintage structure $NVFA/OVFA$										
P^e_t	−0.403	−0.277	−0.282	−0.299	−0.315	−0.387	−0.303	−0.323	−0.324	−0.318
$\frac{NVFA}{OVFA}$	−0.143	−0.145	−0.132	−0.114	−0.096	−0.125	−0.108	−0.148	−0.128	−0.132
Lagged P^e		−0.237	−0.298	−0.328	−0.344		−0.205	−0.285	−0.339	−0.379
Regression 3: vintage structure $NVFA/OVFA$ responding to energy prices										
Lagged P^e	−0.002	−0.003	0.015	0.048	0.090	0.012	0.013	0.031	0.040	0.059

- Table 2: Compare model with data: NSOEs

	Model					NSOEs				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
		1-year	2-year	3-year	4-year		1-year	2-year	3-year	4-year
Regression 1: energy intensity responding to energy prices										
P^e_t	−0.448	−0.322	−0.323	−0.323	−0.324	−0.441	−0.339	−0.351	−0.330	−0.315
P^e_{t-1}		−0.233	−0.147	−0.148	−0.148		−0.217	−0.121	−0.119	−0.074
P^e_{t-2}			−0.158	−0.094	−0.095			−0.178	−0.134	−0.137
P^e_{t-3}				−0.118	−0.069				−0.163	−0.141
P^e_{t-4}					−0.089					−0.048
Regression 2: Energy intensity responding to vintage structure $NVFA/OVFA$										
P^e_t	−0.445	−0.321	−0.323	−0.336	−0.351	−0.440	−0.337	−0.341	−0.320	−0.309
$\frac{NVFA}{OVFA}$	−0.144	−0.148	−0.142	−0.131	−0.118	−0.106	−0.160	−0.180	−0.227	−0.215
Lagged P^e		−0.233	−0.303	−0.344	−0.372		−0.217	−0.305	−0.422	−0.408
Regression 3: vintage structure $NVFA/OVFA$ responding to lagged energy prices										
Lagged P^e	−0.007	−0.012	−0.001	0.025	0.062	0.010	0	0	0	0

- Table 3: Compare model with data: FFEs

	Model					FFEs				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
		1-year	2-year	3-year	4-year		1-year	2-year	3-year	4-year
Regression 1: Energy intensity responding to energy prices										
P^e_t	−0.519	−0.387	−0.388	−0.388	−0.389	−0.525	−0.425	−0.404	−0.360	−0.467
P^e_{t-1}		−0.224	−0.147	−0.147	−0.147		−0.221	−0.135	−0.126	0
P^e_{t-2}			−0.130	−0.078	−0.079			−0.155	−0.095	0
P^e_{t-3}				−0.088	−0.052				−0.179	−0.134
P^e_{t-4}					−0.061					−0.089
Regression 2: Energy intensity responding to vintage structure $NVFA/OVFA$										
P^e_t	−0.516	−0.387	−0.392	−0.408	−0.424	−0.525	−0.425	−0.401	−0.349	−0.415
$\frac{NVFA}{OVFA}$	−0.055	−0.056	−0.055	−0.052	−0.049	0	0	0	0	0
Lagged P^e		−0.223	−0.274	−0.297	−0.310		−0.222	−0.292	−0.403	−0.343
Regression 3: Vintage structure $NVFA/OVFA$ responding to lagged energy price										
Lagged P^e	−0.007	−0.011	0.002	0.028	0.065	0	0	0	0	0

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