Induced Technological Change and Energy Efficiency Improvements

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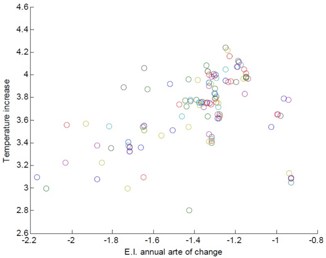
Motivation

determinants of CO_2 emissions: 1. population 2. income 3. energy intensity 4. carbon intensity of energy



We build a model with endogenous energy efficiency improvement and calibrate it with patent data

Summary

- demand for energy is shifted down by innovations in energy intensive sectors
  1000 additional patents -> 0.5% decline in energy use
- innovative activity is determined by
  - energy expenditure (elasticity coefficient: 0.3)
  - stock of past patents (elast. coeff.: 0.65 (domestic), 0.18 (foreign))
- Balanced Growth Path:
  - the level of innovative activity depends on the the growth rate of energy generation cost.
  - energy share is not affected by a level increase in energy price

Production

- Final good produced using energy intensive good, $\tilde{x}$, and non-energy-intensive good, $\tilde{z}$

$$y = (\tilde{x}^{\rho} + \tilde{z}^{\rho})^{\frac{1}{\rho}} \tag{1}$$

- $\tilde{x}$ composed of continuum of intermediate goods i which require labour, l_i and energy x_i:

$$\tilde{x} = \left(\int_{-\infty}^{A} \left((\theta^{q} x_q)^{\alpha} l_q^{1-\alpha} \right)^{\sigma} dq \right)^{\frac{1}{\sigma}}$$

- intermediate goods for $\tilde{z}$ require labour input, z_i.

$$\tilde{z} = \left(\int_{0}^{1} (B_i z_i)^{\sigma} di \right)^{\frac{1}{\sigma}}$$

Energy-Intensive Intermediate goods

Supplied by monopolist, who solves

$$V\left(A_i, k_i\right) = \max_{x_i, l_i} \left\{ p_i \left(A_i x_i\right)^{\alpha} l_i^{1-\alpha} - c x_i - w l_i - m_i + \beta V\left(A_i', k_i'\right) \right\}$$

subject to

$$\left(A_i x_i\right)^{\alpha} l_i^{1-\alpha} = \frac{p_i^{\frac{-\sigma}{1-\sigma}}}{\int_0^1 p_j^{\frac{-\sigma}{1-\sigma}} dj} p_i^{-1} \left(p_{\tilde{x}} \tilde{x}\right)$$

Flow of innovation:

$$P = aR\left(R^{\phi_1 - 1} K^{\phi_2}\right)$$

$$A' = \theta^{\left(P + \sigma P^f\right)} A$$

Results - theory

Proposition 1 Innovative activity in energy-intensive sector depends on energy expenditure

$$\log(P) = \phi_1 \log(cx) - \phi_1 \log(w)$$

$$+\phi_2 \log(K_t) + constant$$

Proposition 2 Innovations in energy-intensive sector shifts down Marshalian demand for energy

$$\Delta \log(x) = \Delta \log(y) - \left(1 + \frac{\alpha\rho}{1-\rho}\right) \Delta \log(c)$$

$$-\frac{(1-\alpha)\rho}{1-\rho} \Delta \log(w) + \frac{\alpha\rho}{1-\rho} \log(\theta) \left(P + \sigma P^f\right)$$

Flow of patents

	Granted EPO			
	(1)	(2)	(3)	(4)
energy expenditure	1.523***	0.532***	0.363***	**0.378*****
own knowledge		0.655***	0.656***	**0.656*****
foreign knowledge		0.182***	0.180***	**0.179*****
GDP per capita			0.787***	0.786***
policy index				0.0192**

Flow of patents

	Granted EPO		
	aggregate	industry	household
	(1)	(2)	(3)
energy expenditure	**0.363*** **	**0.222*** **	**0.156**
own knowledge	0.656***	0.666***	0.442***
foreign knowledge	0.180***	0.207***	0.385***
GDP per capita	0.787***	0.874***	1.996***

Change in Energy demand:

	Granted EPO			
	total		industry	household
	(1)	(2)	(3)	(5)
GDP growth	0.499***	0.494***	0.499***	0.503***
Price growth	-0.0953**	-0.102***	-0.0949**	-0.104***
total patents [1k]	**-0.0052***	-0.00011	-0.0054*	-0.162
patents flow X stock		-0.00322		

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Balanced Growth Path (no spillovers)

$$\Delta \log \left(\hat{A}\right) = \Delta \log (c) + \frac{1-\alpha}{\alpha} \Delta \log (B)$$

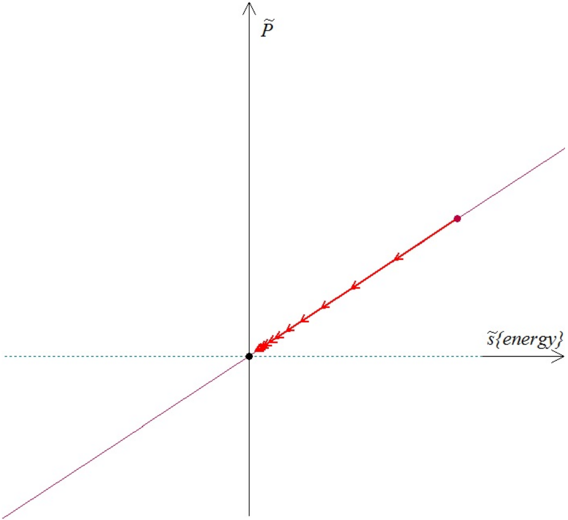
$$\Delta \log \left(\hat{A}\right) = \log (\varphi) \left(\hat{P} + \sigma P^{f}\right)$$

$$\log \left(\hat{P}\right) = \phi_1 \log \left(\hat{R}\right) + constant$$

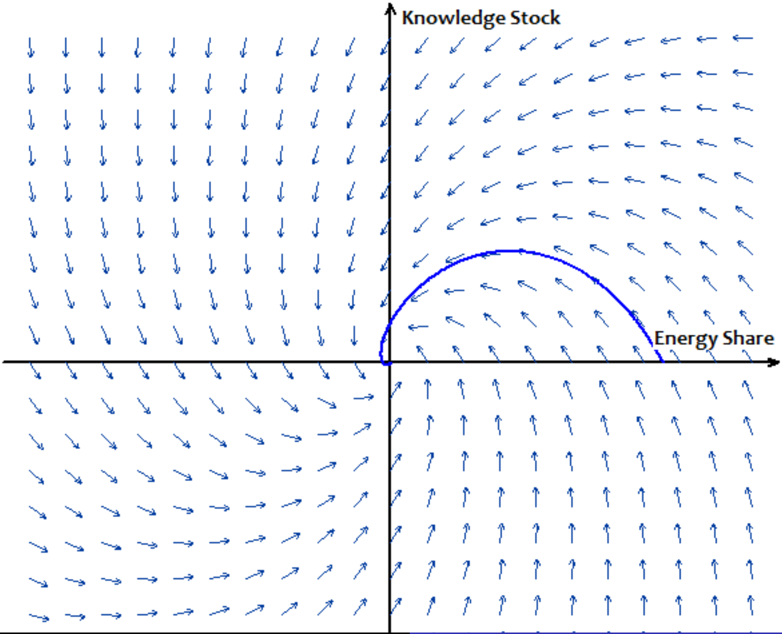
$$\log \left(\hat{R}\right) = \log \left(\frac{\hat{s}_{energy}}{\frac{1}{\mu} - \hat{s}_{energy}}\right) + \log \left(L - \hat{R}\right) + constant$$

Proposition 3 BGP energy share depends on the *growth* of energy price and growth in non-energy sector.

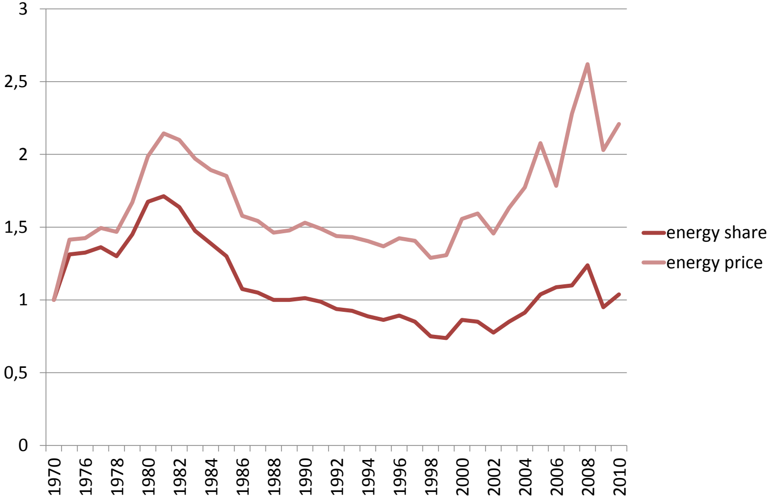
Neighborhood of the balanced growth path (no spillovers)



Neighborhood of the balanced growth path



US energy shares and prices



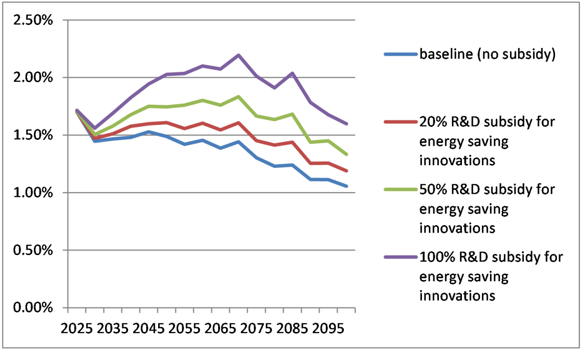
Integration into IAMs

- 2 estimated equations provide a technology module which can be implemented in an integrated assessment model

1. (first equation) information on the energy expenditure growth predicted by the IAM and initial flow of patents allows to predict the growth in production of patents
2. (second equation) use this to predict growth of energy efficiency and update the knowledge stock available to the country in future periods.

- The module allows to evaluate effect of carbon taxes and R&D subsidy on energy efficiency.

Integration into IAMs



ACKNOWLEDGMENT

ENTRACTE

ADVANCE
Advanced Model Development and **Validation** for the **Improved Analysis** of **Costs** and **Impacts** of **Mitigation Policies**

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Thanks!