Knowledge Production Matrix

Predicting The Efficiency Improvement

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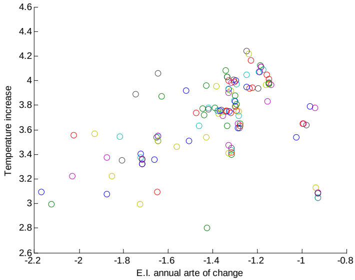
Motivation



determinants of climate change: 1. income 2. energy intensity 3. population 4. carbon intensity of energy

Aim of this work: Assess the drivers and effects of innovation activity related to energy saving technologies.

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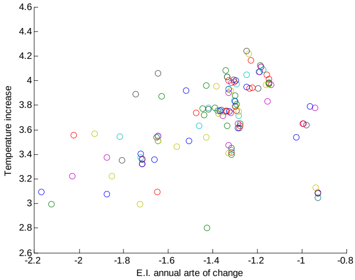

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Contribution

Two strands of literature

1. estimation of ideas production function ((Caballero and Jae (1992), Popp (2002), Porter and Stern (2000), Verdolini and Galeotti (2011))
2. impact of innovation on energy efficiency (Popp (2001) and Sue Wing (2008)

Four contributions

1. theoretical model to show that the effect of innovation inputs (R&D investment) on innovation output (patents) can be quantified relying solely on energy expenditure data.
2. estimate an energy expenditure - energy patents relation for all major economies, with spillovers
3. examine the relation between energy efficiency growth and flow of patents (to reduce cointegration problems)
4. build a simple technology module which can be easily fed into IAMs

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Analytical Framework

theoretical model:

energy expenditure → research investment → flow of new ideas → efficiency improvement

production of innovations

Knowledge production

The Flow of New Knowledge,
novel ideas on energy efficiency improvement

$$P\left(R, k, K\right)$$

Inputs:
R, R&D Investment
k, Knowledge Stock
K, International Knowledge

elasticities:
$\frac{dP}{dR}\frac{R}{P} = \varepsilon_{P,R}$ Decreasing Returns: $\varepsilon_{P,R} < 1$
$\frac{dP}{dk}\frac{k}{P} = \varepsilon_{P,k}$ Intertemporal Spillover $\varepsilon_{P,k} > 0$
$\frac{dP}{dK}\frac{K}{P} = \varepsilon_{P,K}$ International Spillover $\varepsilon_{P,K} > 0$

Knowledge production

Domestic Knowledge Stock

Accumulated Knowledge

$$k_{t+1}(k_t, P_t)$$

Today's novel ideas will also increase domestic knowledge/experience. This knowledge can help to invent new ideas in future (recall $P(R, k, K)$)

P_t, the flow of new knowledge

k_t, domestic knowledge stock

$$\frac{dk_{t+1}}{dP_t}\frac{P_t}{k_{t+1}} = \varepsilon_{k_{t+1}P_t}$$

$$\frac{dk_{t+1}}{dk_t}\frac{k_t}{k_{t+1}} = \varepsilon_{k_{t+1}k_t}$$

Knowledge production

Energy Efficiency

how well we can transform energy into final good

$$A_{t+1}(A_t, P_t)$$

Today's energy effiviency is improved by today's novel ideas to result in higher energy efficiency tomorrow

P_t, the flow of new knowledge

A_t, current energy efficiency

$$\frac{dA_{t+1}}{dP_t}\frac{P_t}{A_{t+1}} = \varepsilon_{A_{t+1}P_t}$$
$$\frac{dA_{t+1}}{dA_t}\frac{A_t}{A_{t+1}} = \varepsilon_{A_{t+1}A_t}$$

Production

Final good produced using energy (E) and other inputs (vector $\mathbf{z}$):

$$y_t \left(A_t E_t, \mathbf{z_t} \right)$$

The planner maximization problem is described with the following Bellman equation:

$$V\left(A, k\right) = \max_{E,\mathbf{z},R} \left\{ y\left(AE, \mathbf{z}\right) - p_E E - \mathbf{p_z z} - R + \beta V\left(A', k'\right) \right\}$$

subject to

$$A' = A'\left(P, A\right),\ P = P\left(R, k, K\right) \text{ and } k' = k'\left(P, k\right)$$

[apostrophe denotes the next period value of the variable]

Solving the model

FOC + manipulation ▶

$$\begin{bmatrix} R_t \\ \frac{dV(A_t,k_t)}{dA_t} A_t \\ \frac{dV(A_t,k_t)}{dk_t} k_t \end{bmatrix} =$$

$$\begin{bmatrix} 0 & \varepsilon_{PR}\varepsilon_{A'P} & \varepsilon_{PR}\varepsilon_{k'P} \\ 1 & \varepsilon_{A'A} & 0 \\ 0 & \varepsilon_{A',P}\varepsilon_{P,k} & \varepsilon_{k',P}\varepsilon_{P,k} + \varepsilon_{k',k} \end{bmatrix} \begin{bmatrix} p_t x_t \\ \beta \frac{dV(A_{t+1},k_{t+1})}{dA_{t+1}} A_{t+1} \\ \beta \frac{dV(A_{t+1},k_{t+1})}{dk_{t+1}} k_{t+1} \end{bmatrix}$$

The research expenditure depends solely on energy expenditure, the current stock of knowledge, the current productivity and the R&D production function

if the elasticities in the matrix in are constant in all periods, then research expenditure, R, is a simple linear function of future energy expenditures.

Solving the model

FOC + manipulation ▶

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Solving the model

Are the elasticities constant? What does endogenous growth models (EGM) suggest?

$$\begin{bmatrix} R_t \\ v_t \\ u_t \end{bmatrix} = \begin{bmatrix} 0 & \varepsilon_{P_t R_t}\varepsilon_{A_{t+1}P_t} & \varepsilon_{P_t R_t}\varepsilon_{k_{t+1}P_t} \\ 1 & \varepsilon_{A_{t+1}A_t} & 0 \\ 0 & \varepsilon_{A_{t+1}P_t}\varepsilon_{P_t,k_t} & \varepsilon_{k_{t+1}P_t}\varepsilon_{P_t k_t} + \varepsilon_{k_{t+1}k_t} \end{bmatrix} \begin{bmatrix} p_{Et}E_t \\ \beta v_{t+1} \\ \beta u_{t+1} \end{bmatrix}$$

- with $P = R^{\phi_1} k^{\phi_2} K^{\phi_3}$(standard in EGM) $\varepsilon_{P_t R_t}$ and $\varepsilon_{P_t k_t}$ are constant
- Since variation in $\varepsilon_{k_{t+1}P_t}$, $\varepsilon_{k_{t+1}k_t}$ and $\varepsilon_{A_{t+1}A_t}$ have very little impact, they are assumed constant
- $\varepsilon_{A_{t+1}P_t}$ depends on a specification (Romer (1989) vs. Caballero and Jaffe (1994))

From knowledge to energy efficiency

We assume the Cabalerro and Jaffe (1994) specification:

$$\Delta \log(A_t) = \log(\theta_h) P_t + \log(\theta_f) fP_t$$

where fP is a flow of foreign patents.

- The specification predicts constant efficiency growth with constant flow of patents - correspond to the pattern observed in the data.
- Then $\varepsilon_{A_{t+1} P_t} = \frac{\log(\theta_h)}{1-2\alpha} P_t$ and

$$\log R_t = c_1 + \frac{1}{1-\phi_1} \log(p_{x,t+1} E_{t+1})$$

Sum up of model results

The prediction of the theoretical model:

$$\log(P_{it}) = \phi_0 \log(p_{Eit+1} E_{it+1}) + \phi_1 \log(k_{it}) + \phi_2 \sum_{j \neq i} w_{ji} \log(k_{jt}) + c_{i1}$$

$$\Delta \log(A_{t+1}) = \psi_1 P_{it} + \psi_2 fP_{it} + c_{i2}$$

where

- P_{it} is a flow of new ideas in country i at time t , fP_{it} is a (weighted) flow of patents in other countries.
- $p_{Eit+1} E_{it+1}$ is energy expenditure,
- k_{it} is a knowledge stock: $\log(k_{it}) = \sum_{s=0}^{t} P_{is}$
- $\sum_{j \neq i} w_{ji} \log(k_{jt})$ is a stock of foreign knowledge,
- A_{it} is a meassure of energy efficiency.

Predicting Efficiency Growth

theoretical models

energy expenditure → research investment → flow of new ideas → efficiency improvement

empirical models

energy expenditure ⟶ flow of new ideas → efficiency improvement

Data

- We construct a proxy for the flow of new innovations, P_{it} using the number of patents applications in one country i in year t.
- The measure on efficiency is the inverse of energy intensity of the economy ($\frac{GDP}{Total\ Energy}$)
- The data on GDP, energy supply and energy prices are taken from stats.OECD.
- The data on patents come from the NBER patents dataset

Flow of patents for country i:

	(1)	(2)	(3)
energy expenditure {t-5}	.860***	.931***	1.039***
own knowledge {t-3}	.0002***	.0003***	.0002***
foreign knowledge {t-3}	.0005**	.0005**	.0004
GDP relative to US {t-5}		-.547	
energy supply patents {t-5}			.137**

Table : The dependent variable is count of patents related to one of demand for energy patent categories. ***, **, * indicate significance of the coefficients at the 1%, 5% and 10% level, respectively. 'Energy supply patents' is a count of patents related to production of energy (such as solar or wind energy patents). All regressions contain full set of country, time and patents category dummy variables. All variables are transformed with a log function. The estimations are obtained using a Maximum Likelihood estimator. The probability distribution assumed is the negative binomial.

Energy demand:

			clustered
	(1)	(2)	(3)
patents count {t-1}	-.00003	-.0001***	-.0001***
foreign patents {t-1}	-.0005***	-.001***	-.001***
$\Delta \log(GDP)$	.4916***	.5303***	.5303***
$\Delta \log(p_E)$	-.0385***	-.0305***	-.0305*
$P_t * TStock$		1.55e-08	1.55e-08
$fP_t * TStock$		2.36e-07***	2.36e-07***

Table : The dependent variable is growth of total primary energy supply. Dependent variables are flow of patents in country i flow, weighted sum of patents invented in other countries (weights are constructed using citation data), growth of GDP, growth of energy price index and interactions between flows of patents and world stock of patents (home plus foreign). Energy, GDP and price data are smoothed using HP filter. ***, **, * indicate significance of the coefficients at the 1%, 5% and 10%. All regressions include country fixed effects. Column (3) reports results for regression with robust standard error.

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 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.

Work ongoing

- from NBER to PATSTAT (more classes, countries, recent data)
- sectoral level separate estimates (transport, residential, industry)
- implementation in WITCH and check against scenario data base

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Thanks!

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