Prospectus Proposal

Emmanuel Murray Leclair

Thesis Commitee

David Rivers (Main Advisor)

Salvador Navarro

Sergio Ocampo Diaz

October 1st, 2021

Energy Inputs in the Production Function: Evidence from India

Just put it in the prev. slide
waste of time to have a slide for this
(you present last, keep that in mind)

Motivation - Bigger Picture

- Need to reduce greenhouse emission efficiently.
- Externality → classical econ theory advocates carbon tax.
  - Implemented through **proportional** taxes on polluting inputs.

Add space \bigskip

~~Q1:~~ How should we optimally tax polluting inputs like fossil fuels? // Can we do better than carbon pricing?

New line

↳ Is this a sub-bullet?

▶ Answer depends on firms energy choices

↳ Use this as lead up to your Q.

This Paper :

~~Q2)~~ Q1) How do energy inputs enter firms' production function?

1. Document ~~salient~~ features of plant-level fuel usage in industry (37% of global emissions, Worell, Bertstein, Roy, Price and Harnisch, 2009) why blue? use gray or black
   \smallskip
   - Corner solutions in fuel usage .... } Non-standard
   - Switching between fuel sets across periods .... } Non-standard

   use purple

   Space here \medskip
2. Identify and estimate production model with flexible energy input choices.
   \smallskip
   - Switching between fuels set related to productivity.

     Kind of obvious statement. What do you mean?
   - Cleaner fuels are more productive/energy efficient.

I don't like this trasparency. Either show it or hide it.

This Paper

Q2: How do energy inputs enter firms' production function?

1. Document salient features of plant-level fuel usage in industry (37% of global emissions, Worell, Bertstein, Roy, Price and Harnisch, 2009)
   - Corner solutions in fuel usage ....
   - Switching between fuel sets across periods ....

   Non-standard
2. Identify and estimate production model with flexible energy input choices.
   - Switching between fuels set related to productivity.
   - Cleaner fuels are more productive/energy efficient.

Contribution

ugly blue

Energy Substitution in industry Wiertzema, Ahman and Harvey (2018), Luh et al. (2020), Lechtenbohmer et al.(2016), Joskow and Mishkin (1977), Aktinson and Halvorsen (1976)

space

- I allow for fairly general energy input substitution patterns ~~that go beyond canonical assumptions~~.
  - **Intensive Margin:** Energy Tasks } what does this mean?
  - **Extensive Margin:** Discrete fuel set choice

Cite what you are using to extend

Acemoglu Aghion Restrepo

Longer space

Factor-~~augmenting~~ productivity specific? Doraszelski and Jaumandreu (2018), Hassler (2012), Demirer (2020)

space

- I identify and estimate plant-level endogenous energy and fuel-augmenting productivity without relying on markovian assumptions for productivity.

Are you building on something?

Data :

- Indian Survey of industries (ASI) : 2009-2016
  - Panel of all Indian manufacturing plants with at least 100 workers and a sample of plants with more than 10 workers (∼ 300,000 observations)
  - Standard production function inputs
  - Energy inputs: Coal, Oil, Natural Gas and Electricity
    - Convert to equivalent energy units (million british thermal units - mmBtu)
    - How energy (mmBtu) gets used depends on technology/productivity.
      1. *Electric arc furnaces vs. Coal-powered furnace*
      2. *Quality*

New line or sub-bullet

indent out

space here

space

Indian plants use ~~very~~ pollution-intensive energy

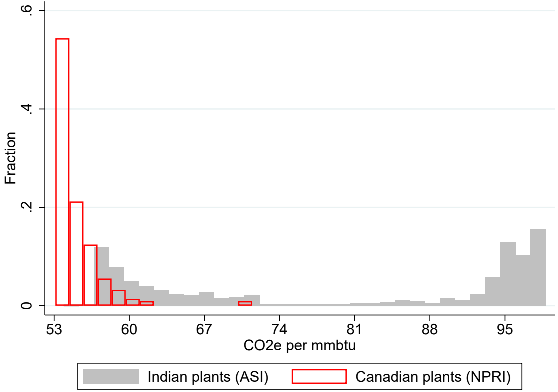


Figure: Pollution Intensity of Energy - Cement manufacturing

- Many Indian plants primarily use coal (right-end cluster)
- Switching from coal to gas → ~~large~~ contributor es to manufacturing clean-up in dev. economies (Rehfeldt et al. 2020)

Horrible blue

- Natural gas cleanest energy in India

Space
Perhaps due to \rightmargin

Plants in narrowly defined industries use different fuel mixes

~~Table:~~ Casting of Steel and Iron

	Percentage
Oil, Electricity	50.75 %
Coal, Oil, Electricity	27.44 %
Oil, Gas, Electricity	11.61 %
Other	8.92 %

Make it larger
don't use float

~~Table:~~ Cement

	Percentage
Oil, Electricity	40.06 %
Coal, Oil, Electricity	49.53 %
Other	10.09 %

Add the missing row

40% of plants switch between energy mixes at least once

use "S" so that numbers are centered on decimal

	Adds New Fuel (%)	Drops Existing Fuel (%)
No	58.5	60.4
Yes	41.5	39.6
~~Total~~	~~100.0~~	~~100.0~~

what info does this give?

~~Table:~~ Number of unique plants that **add** and **drop** a fuel (Balanced Panel)

Model - single plant

Put this here.

- **Outer production:** standard CES in K, L, M, E with Hicks-neutral technology z

  $Y = zF(K, L, M, E)$ kap, labor, energy — Too much notation say what they are

- **Inner production:** discrete set of $\mathcal{M}$ complement energy tasks (ω) to produce E

  Space here

  - $\mathcal{F}$: set of fuels available.
  - fuels $e_f(\omega) \in \mathcal{F}$ are perfect substitutes at task-level but feature different **task-specific productivity** $\psi_f(\omega)$ (Acemoglu and Restrepo, 2021)

    ↳ The blue.

    Result from opt.

  - $p(\omega) = \min_{f\in\mathcal{F}} \left\{\frac{p_f}{\psi_f(\omega)}\right\}$
  - task-level technologies aggregate to average fuel productivity. $\Gamma_f(\mathbf{p}_{\mathcal{F}}, \mathbf{\Psi})$ This isn't enough

you should write that in opt:

$E = \sum \Gamma_f(p_{\mathcal{F}}, \Psi) \cdot f$ or e_f

Details

Consider splitting and giving more detail on inner step → We can discuss

Full Model - ~~definition and timeline~~

new bullet

- Plants produce differentiated products and engage in monopolistic competition. Each year, production decisions are made according to the following timeline:

t — t+1

Observe $\mathcal{F}_t$, Ψ_t, $\{p_{ft}\}_{f \in \mathcal{F}_t}$

Solve allocation of fuels to energy tasks. Get $p_e(\Psi, \mathcal{F}_t)$

Observe Input prices p_{mt}, r_t, w_t, z_t

Choose Static inputs M_t, E_t

Choose Dynamic inputs $\mathcal{F}_{t+1}, L_{t+1}, K_{t+1}$

Energy Tasks (Inner Nest)

Outer Nest

Bold? Adjustment Costs { :

- Fixed cost κ_f for each fuel f in $\mathcal{F}_{t+1}$ that wasn't in $\mathcal{F}_t$.

sub-bullet ?

- ~~More productive plants are more likely to expand the fuel set.~~

Identification

\hfill \beamerbutton{

Move here

- Observe fuel quantities e_{fit} (inner nest) but not E_{it} (outer nest).

Space

Under optimality, it is true that energy spending equals total fuel spending:

$$p_{eit}E_{it} = \sum_f p_{fit}e_{fit} \tag{1}$$

what does this mean?

Structural variation in expenditure shares between a flexible input and energy recovers E_{it} (Grieco et al. 2016):

Use same format as in other cites

$$\frac{E_{it}}{\bar{E}} = \left(\frac{p_{eit}E_{it}}{p_{mit}M_{it}}\right)^{\frac{\sigma}{\sigma-1}} \left(\frac{\alpha_m}{\alpha_e}\right)^{\frac{\sigma}{\sigma-1}} \frac{M_{it}}{\bar{M}} \tag{2}$$

Details

PFE Estimation results (selected industries)

what does this mean?

Production Function?

Larger font

~~Table: Production Function Estimation (selected industries)~~

	Cement	Steel & Iron	Casting of Metals
Elast. of sub between plants: $\hat{\rho}$	3.86	9.93	7.06
	[3.67,4.11]	[7.55,15.11]	[5.34,11.69]
Elast. of sub between factors: $\hat{\sigma}$	6.93	3.19	3.96
	[5.99,8.33]	[2.41,5.26]	[2.79,7.82]
Labor coef: $\hat{\alpha}_l$	0.29	0.10	0.20
	[0.27,0.30]	[0.08,0.12]	[0.17,0.24]
Capital coef: $\hat{\alpha}_k$	0.04	0.02	0.03
	[0.03,0.04]	[0.02,0.03]	[0.02,0.04]
Materials coef: $\hat{\alpha}_m$	0.51	0.80	0.69
	[0.51,0.52]	[0.77,0.82]	[0.65,0.73]
Energy coef: $\hat{\alpha}_e$	0.16	0.07	0.08
	[0.16,0.17]	[0.07,0.08]	[0.08,0.08]
Returns to Scale: $\hat{\nu}$	1.17	1.13	1.16
	[1.14,1.21]	[1.07,1.19]	[1.09,1.24]
N	25,518	8,698	6,170

Bootstrap 95% confidence interval in bracket (499 reps)

→ Keep font
Make IC gray

too many numbers

What do you want to highlight?

This slide doesn't work

↳ Center! hopefully to decimal

Estimating Equation   Average Elasticities

~~Evidence that fuel switching across years isn't random~~

3 ~~1.~~ Plants that added a fuel to their mix were more productive in the previous year.

~~Table:~~ Marginal effects, probability of adding fuel (current year)

	(1) Any fuels	(2) Natural Gas	(3) Coal
Lagged log(TPF)	0.011^{***}	0.006^{***}	0.0036^{***}
	(0.0012)	(0.00073)	(0.00057)
N	102,951	102,951	102,951

Standard errors in parentheses

$^{*}\ p < 0.05$, $^{**}\ p < 0.01$, $^{***}\ p < 0.001$

-tive of strategic (non-random) fuel switching

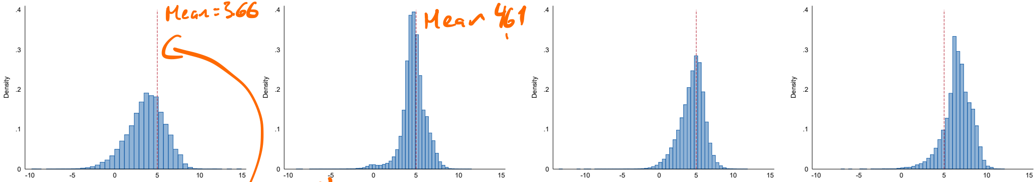
TFP computation

Distribution of $\ln \hat{\Gamma}_{fit}$

▸ Fuel-augmenting prod computation

average fuel productivity ($\ln \hat{\Gamma}_{fit}$)

Left-skewed distribution ~~means~~ higher productivity → Natural Gas is ~~on average~~ more productive.



(a) Natural Gas
(Mean: 3.66)

can you get it onto graph

(b) Electricity
(Mean: 4.61)

(c) Oil
(Mean: 4.34)

(d) Coal
(Mean: 6.47) → why bold

~~Figure: Distribution of average fuel productivity~~

Identification (in progress)

use words, then math

How do you read this?

1. $\Gamma_{fit} : (\psi_{fit}(\omega), p_{fit}) \in \mathbb{R}^M \rightarrow \mathbb{R}$

   Space

   - Distribution of fuel-by-task productivity $\psi_f(\omega)$ can theoretically be recovered under parametric distributional assumption (Fréchet) using simulated GMM. Details

Space

2. Fixed fuel adoption costs κ_f.

Missing a slide telling us what you will do with model after estimation (and how)

Overview of thesis plan

I would rather have you fit the following slides into this one

1. *Energy Inputs in the Production Function: Evidence from India* (JMP)
2. *Optimal Environmental Taxes on Energy Inputs*
3. *Asymmetric Environmental Regulation and Carbon Leakage* (Summer Paper)

Overview of thesis plan

1. *Energy Inputs in the Production Function: Evidence from India* (JMP)
2. *Optimal Environmental Taxes on Energy Inputs*
   - ~~I use estimates of the first chapter to study the~~ optimal design of environmental ~~taxes in the Indian Context~~. space Say thing about estimates verbally. space
     - Relative tax rate between different inputs (departure from carbon pricing). ▸ Details
     - Optimal transportation price of Natural Gas across proximity of plants to pipeline networks. ▸ Details
3. *Asymmetric Environmental Regulation and Carbon Leakage* (Summer Paper)

Overview of thesis plan

1. *Energy Inputs in the Production Function: Evidence from India* (JMP)
2. *Optimal Environmental Taxes on Energy Inputs*
3. *Asymmetric Environmental Regulation and Carbon Leakage* (Summer Paper)
   - Model where plants compete across location and are subject to different environmental regulation.
   - I estimate the model with Canadian plants and find little evidence of carbon leakage between Canadian provinces as a result of the 2008 BC carbon tax.

Fuel-Augmenting Productivity

With production function parameters, I get an estimate of normalized effective energy: $\frac{E_{it}}{\bar{E}}$, which I use to recover (inverse) fuel-augmenting productivity

$$e_{fit} = E_{it}\Gamma_{fit} \tag{3}$$

$$\widehat{\bar{E}\Gamma_{fit}} = e_{fit}\left(\frac{\bar{E}}{E_{it}}\right) \tag{4}$$

I decompose Γ_{fit} between a scale component $\exp(1/\gamma_{it})$ and a relative fuel productivity component $\tilde{\Gamma}_{fit}$ such that

$$\widehat{\bar{E}\Gamma_{fit}} \equiv \bar{E}\underbrace{\frac{\Gamma_{fit}}{\sum_f \Gamma_{fit}}}_{\tilde{\Gamma}_{fit}}\underbrace{\sum_f \Gamma_{fit}}_{\exp(1/\gamma_{it})} \tag{5}$$

Back to main

Assumption on distribution of fuel-by-task productivity

known to the plant but unknown to the economist

$$P(\psi_f(\omega) \leq w) = e^{-T_f w^{-\theta}} \tag{6}$$

Then, the probability that fuel f is chosen for task ω is given by:

$$\tau_f(\omega) = P\Big(\frac{p_f}{\psi_f(\omega)} = \min_{f \in \mathcal{F}} \Big\{\frac{p_f}{\psi_f(\omega)}\Big\}\Big) = \frac{(T_f p_f^{-\theta})^{|\mathcal{F}|}}{\prod_{j \neq f}^{|\mathcal{F}|}(T_f p_f^{-\theta} + T_j p_j^{-\theta})} = \tau_f \tag{7}$$

And the probability that fuel f is used for m tasks follows a binomial distribution by the symmetry of tasks:

$$P_r(M\mathcal{T}_f = m) = \binom{M}{m} \tau_f^m (1 - \tau_f)^{M-m} \tag{8}$$

Algorithm

Back to main

Algorithm to recover the distribution of fuel-by-task productivity

Algorithm 1 Estimation of $\{T_f\}_{f=1}^{F}, \theta, M$ by Simulated Method of Moments (SMM)

For each plant-year, I observe Γ_{fit}

1: Set guess for $\hat{\Theta} = \{\hat{T}_f\}_{f=1}^{F}, \hat{\theta}, \hat{M}$
2: For each plant-year, draw ψ_f M times for each $f \in \mathcal{F}_{it}$
3: Compute allocation of fuels to task
4: Get number of tasks $(M\mathcal{T}_f)$ and associated productivity (ψ_f) for chosen fuels
5: Compute $\Gamma_{fit}(model) = \sum_{i=1}^{M\mathcal{T}_{fit}} \psi_{fit}^{-1}$
6: Repeat 1-5 S times

Iterate 1-6 until $\hat{\Theta}$ minimizes $||\hat{m}(\Gamma_{fit}|\Theta) - m(\Gamma_{fit})||$ for some moments

Back to main

Production for a single plant

Adaptation of Acemoglu and Restrepo (2021) to study energy substitution. Production for a single plant:

$$\frac{Y}{\bar{Y}} = e^z\left(\alpha_k\left(\frac{K}{\bar{K}}\right)^{\frac{\sigma-1}{\sigma}} + \alpha_l\left(\frac{L}{\bar{L}}\right)^{\frac{\sigma-1}{\sigma}} + \alpha_m\left(\frac{M}{\bar{M}}\right)^{\frac{\sigma-1}{\sigma}} + \alpha_e\left(\frac{E}{\bar{E}}\right)^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\nu\sigma}{\sigma-1}} \tag{9}$$

$$\frac{E}{\mathcal{M}} = \min\{\tau(\omega) : \omega \in [0,1]\} \tag{10}$$

$$\tau(\omega) = \sum_{f\in\mathcal{F}} \psi_f(\omega) e_f(\omega) \tag{11}$$

Energy-task model within a standard CES in capital, labor, intermediates and Energy.

- Example of energy tasks: oil for transportation, electricity for heating the plant and coal for industrial melting.

Implications Back to main

Implications

Energy task prices:

$$p(\omega) = \min\left\{\frac{p_1}{\psi_1(\omega)}, ..., \frac{p_F}{\psi_F(\omega)}\right\} \tag{12}$$

demand for fuel in task ω:

$$e_f(\omega) = \frac{E}{M}\psi_f(\omega)^{-1} \tag{13}$$

More productive fuel means less fuel quantity needed to produce one unit of energy $\rightarrow$ **more energy efficient.**

▸ Task Aggregation ▸ Back to main

Aggregation across tasks

Let $\mathcal{T}(p_{\mathcal{F}})_f$ be the set of tasks performed by fuel f. Then, conditional fuel demand is

$$e_f = \int_{\mathcal{T}_f} e_f(\omega) d\omega = E \frac{1}{M} \int_{\mathcal{T}_f} \psi_f(\omega)^{-1} \tag{14}$$

$$= E\Gamma_f \tag{15}$$

Γ_f relate to the inverse of factor-augmenting productivity for fuel f. This is very flexible because it can be 0 if fuel f is not chosen for any of the tasks ($\mathcal{T}_f = 0$) while it can represent total fuel productivity if fuel f is chosen for all tasks ($\mathcal{T}_f = 1$). Back to main

Main Identification Goal and challenge

I would like to recover fuel-augmenting productivity Γ_{fit} and study how they change with variation in fuel prices through market-based environmental policy. However, I face an identification challenge:

$$e_{fit} = E_{it}\Gamma_{fit} \tag{16}$$

$$= f(\mathbf{p_{it}}, \theta)\frac{\Gamma_{fit}}{\exp(z_{it})} \tag{17}$$

Think of a plant using only fuel f. I cannot in principle separately identify the scale of fuel-augmenting productivity from the TFP term z_{it} because I don't observe E_{it}.

Back to main

Estimating Equation

I can plug the optimal choice of $E_{it}/\bar{E}$ as a function of expenditure shares and the normalized quantity of intermediates back into the CES production function and get an estimating equation for all production function parameters in log revenues with two restrictions:

$$\ln R_{it} = \ln \tfrac{\rho}{\rho-1} + \ln \left[\tfrac{P_{mit} M_{it}}{\nu} \left(1 + \tfrac{\alpha_k}{\alpha_m} \left(\tfrac{K_{it}/\bar{K}}{M_{it}/\bar{M}} \right)^{\frac{\sigma-1}{\sigma}} + \tfrac{\alpha_l}{\alpha_m} \left(\tfrac{L_{it}/\bar{L}}{M_{it}/\bar{M}} \right)^{\frac{\sigma-1}{\sigma}} \right) + p_{eit} E_{it} \right] + u_{it}$$

s.t.

$$\overline{P_e E} / \overline{P_m M} = \frac{\alpha_e}{\alpha_m} \tag{18}$$

$$\alpha_k + \alpha_l + \alpha_m + \alpha_e = 1 \tag{19}$$

Back to main

Average output Elasticities (Selected industries)

Output elasticity with respect to specific factors are defined as:

$$\hat{\epsilon}_{it,yj} = \frac{\hat{\alpha}_j (x_{jit}/\bar{x}_j)^{\frac{\rho-1}{\rho}}}{\sum_j \hat{\alpha}_j (x_{jit}/\bar{x}_j)^{\frac{\rho-1}{\rho}}} \tag{20}$$

Table: Average Output Elasticities

	Cement	Steel & Iron	Casting of Metal
$\bar{\epsilon}_{y,l}$	0.27	0.11	0.21
$\bar{\epsilon}_{y,k}$	0.05	0.03	0.04
$\bar{\epsilon}_{y,m}$	0.46	0.74	0.64
$\bar{\epsilon}_{y,e}$	0.22	0.11	0.11

Back to main

Total-Factor Productivity estimate

- I follow De Loecker (2011) to get an estimate of hicks-neutral productivity $\exp(z_{it})$ by deflating revenues with year/indsutry dummies.
- I decompose fuel-augmenting productivity into a scale component $\exp(\gamma_{it})$ and a relative fuel productivity component. Then, following Doraszelski and Jaumandreu (2018), I multiply the scale component by $\epsilon_{it,ye}$ to get it in units of output.

(log) TFP is then calculated as follows:

$$\ln TFP_{it} = z_{it} + \epsilon_{it,ye}\gamma_{it} \tag{21}$$

Back to main

Optimal Policy - relative tax on energy inputs

Benchmark: carbon tax

$$ghg = \sum_f \gamma_f e_f \implies \frac{\tau_f}{\tau_k} = \frac{\gamma_f}{\gamma_k} \tag{22}$$

What I expect to find:

- Lower relative tax rate on cleaner fuels than carbon tax (e.g. natural gas). Why?
  - presence of fixed adoption costs means taxes must be low enough on cleaner fuels to incentive adoption.
  - When cleaner fuels are more productive, additional energy efficiency gains from incentivizing their adoption.

Back to main

Optimal Policy- relative price of natural gas across districts

- Natural Gas is very costly to transport
  - High-pressure steel pipelines to keep it gasified.
- Large variation in price of natural gas based on location of plants relative to existing pipeline networks and source of gas.
  - 80% of natural gas pipelines owned by government corporation (GAIL)
  - Petroleum and Natural Gas Regulatory Board (PNGRB) sets transportation price jointly with GAIL.

In November 2020, PNGRB announced that it would increase transportation cost of natural gas by 20-30% for plants near source and equivalently decrease it for plants far from source.

Back to main