

The Heterogeneous Impacts of Firm Upgrading on Energy Intensity

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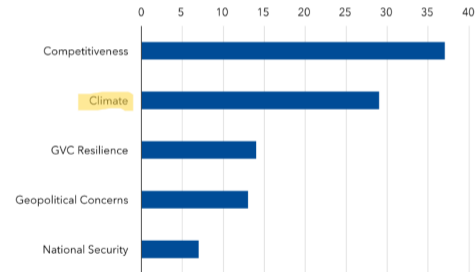
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Distortive industrial policy drivers

New industrial policy measures are increasingly driven by climate mitigation, supply chain resilience and security.

Share of distortive industrial policy measures by motive
(percent)



Source: Evenett and others (2024); IMF staff calculations.
Note: Cumulative stock of measures for 2023. For measures with multiple motives, each motive is given equal weight.

- **Theoretically**, ambiguous effects between trade and firm-level emission
 - Trade \Rightarrow technology upgrading \Rightarrow **lower** emission intensity (Forslid et al., 2018)
 - Trade \Rightarrow change in product-mix \Rightarrow **higher** emission intensity (Barrows and Ollivier, 2018)
- **Empirically**, causality it not easy to establish
 - Empirical estimates are usually based on cross-sections (Batrakova and Davies, 2012; Holladay, 2016; Forslid et al., 2018; Barrows and Ollivier, 2018)
 - \Rightarrow Selection bias
- **What Did We Do?**
 - Construct a panel of firm-level emissions that captures their upgrading process

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- **What Did We Do?**
 - Construct a firm-level complexity index that captures firms' upgrading process
 - Provide a novel measure of trade-related upgrading and export complexity
 - Explore the channels through which trade might help speed up the green transition

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- **What Did We Do?**
 - Construct a firm-level complexity index that captures firms' upgrading process
 - Provide causal evidence on trade-induced upgrading and energy intensity
 - Explore other policy options that might help speed up the green transition

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- **What Did We Find?**

- Causal link: \uparrow Foreign import demand \Rightarrow \uparrow growth of firm's complexity
- Upgrading reduces energy intensity, heterogeneity matters!
 - Small firms experience a notable decrease in energy intensity when they upgrade
 - Big firms' improvement in energy efficiency is not significant
- Financial constraints hinders energy efficiency improvement
 - Small firms: hinder improvements in energy efficiency during the upgrading process
 - Big firms: financial constraints increase energy intensity, can be mitigated by upgrading
- Can firms finance upgrading by charging a higher markup?
 - Small firms: No
 - Big firms: Yes

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Data and Measurements

- Annual **firm-level** survey data from *Valstybės Duomenų Agentūra*, 2000-2015
 - 1995-2019, **balance sheet** and **income statement**
 - Number of firms: 81% (LLC); employment: 91% (LLC)
- Annual **product-level** data from *Lietuvos Respublikos Muitinė*, 2000-2015
 - Both **import and export**
 - **Firm-product(HS8)–source/destination**
- Annual **global product-level** trade data from CEPII’s BACI database
 - Bilateral trade flows for 200 countries at the HS6 product level (5000 products)
- Atlas of Economic Complexity from Harvard Growth Lab
 - **Product complexity** and **country complexity**

- Verhoogen (2023), firms' upgrading process benefits from
 - Firms that they trade with
 - Countries that they trade with
- Utilizing our data, for exporters

$$\text{UFCl}_{i,t}^{\text{EX}} \equiv \sum_c \sum_j w_{c,t}^{\text{EX}} s_{ijc,t}^{\text{EX}} \text{Complexity}_{j,t}$$

- $\text{Complexity}_{j,t}$: product-level complexity index
- $s_{ijc,t}^{\text{EX}}$: firm i 's export share of product j to country c
- $w_{c,t}^{\text{EX}} \equiv \frac{\text{Complexity}_{c,t}}{\frac{1}{C} \sum_c \text{Complexity}_{c,t}}$: relative complexity of the country c

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Table: Summary Statistics

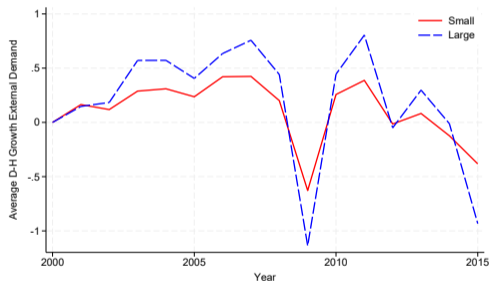
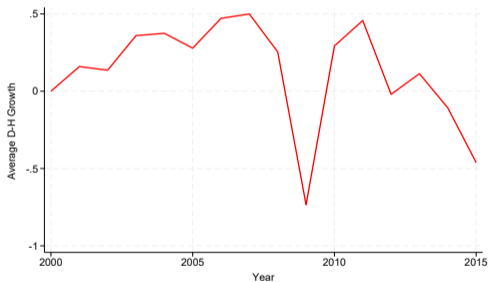
	Mean	Median	Std. Dev.	Small (mean)	Large (mean)
Revenue	1170496.03	103921.50	11243539.42	470017.12	11115233.09
Employment	19.1125	5	132.42	8.08962	175.606
Export	1302561.63	66948	8568029.59	474027.42	5002895.98
Exporter products	10.28	3	25.53	1	24
Expenditure on Energy	47177.41	1660	1205280.38	14943.58	504778.47
Cost of Sales	929668.44	55812	9563562	367302.19	8913612.00
Total Debt	477288.7	39881.5	4528501	223423	4081241
log(TFP)	2.55	2.58	0.71	2.60	2.20
Markup	1.11	1.07	0.18	1.11	1.12
UFCI ^{EX}	57.79	16.71	113.30	43.65	116.89
Δ UFCI ^{EX}	0.03	0.01	0.71	0.02	0.05

Note: Descriptive statistics are computed over the 569,540 firm-year observations corresponding to 96,299 firms observed between 2000 and 2015. Revenue corresponds to total sales revenue. Employment is the average number of employees within a year. Total debt is the sum of current liabilities and long-term debt. Export refers to the total export value at the firm level. Expenditure on energy is the sum of expenditure on fuel, electricity, and energy. Cost of sales refers to the total costs of goods sold. Log(TFP) and markup are estimated based on the translog production function.

Empirical Strategy

- **Idea:** *construct* weighted average foreign import demand (ΔED) in countries that LT tends to sell to
 - Leaving LTs own export out
 - Instrumenting these measures with base-year weighted average shocks
- **Identification:** shift-share design (SSIV) as in [Borusyak et al. \(2022\)](#)
 - Robustness: panel IV strategy as in [Barrows and Ollivier \(2021\)](#)

Figure: Growth Rate of External Demand Over Time and Size



Baseline Results

First Stage: Impacts of External Demand (ΔED) on Complexity ($\Delta UFCI$)

Shift-share IV (SSIV) & Panel IV

Table: SSIV

Dependent variable	$\Delta UFCI$	$\Delta UFCI$	$\Delta UFCI$
ΔED	0.0914** (0.0444)	0.0968** (0.0431)	0.101*** (0.0375)
IMP share ^{EU15} _{t-1}		✓	
EXP share ^{EU15} _{t-1}		✓	
Δ IMP share ^{EU15} _{t-1}			✓
Δ EXP share ^{EU15} _{t-1}			✓
Year FE	✓	✓	✓
Year \times Industry FE	✓	✓	✓
Observations	43,574	43,359	40,275
LM statistic	119.382	80.648	65.779
Wald F statistic	155.693	124.584	103.916
Hansen J statistic	0	0	0

Table: Panel IV

Dependent variable	$\Delta UFCI$	$\Delta UFCI$	$\Delta UFCI$
ΔED	0.0156** (0.00726)	0.0179** (0.00761)	0.0232*** (0.00768)
IMP share ^{EU15} _{t-1}		-0.00980 (0.0108)	
EXP share ^{EU15} _{t-1}		0.0294* (0.0151)	
Δ IMP share ^{EU15} _{t-1}			-0.00185 (0.00885)
Δ EXP share ^{EU15} _{t-1}			0.00953 (0.0121)
Firm FE	✓	✓	✓
Year FE	✓	✓	✓
Year \times Industry FE	✓	✓	✓
Observations	52,500	41,585	33,267
Method	2SLS	2SLS	2SLS
IV	Z_firm	Z_firm	Z_firm

Table: Upgrading and Energy Intensity

Dependent variable	ΔEI_y	ΔEI_y	ΔEI_y
ΔUFCI_{SSIV}	-0.00519*** (0.00161)	-0.00609*** (0.00186)	-0.00478** (0.00205)
$\text{IMP Share}_{t-1}^{EU15}$		0.00677 (0.0185)	
$\text{EXP Share}_{t-1}^{EU15}$		-0.00363 (0.0243)	
$\Delta\text{IMP Share}_{t-1}^{EU15}$			0.0158 (0.0172)
$\Delta\text{EXP Share}_{t-1}^{EU15}$			0.0515** (0.0220)
Firm FE	✓	✓	✓
Year FE	✓	✓	✓
Year \times Industry FE	✓	✓	✓
Observations	68,728	42,055	33,462
R-squared	0.153	0.134	0.131

Note: ΔEI_y stands for the Davis-Haltiwanger growth rate of firm-level expenditure of gas, fuel, and electricity over sales.

Table: Upgrading and Energy Intensity: Small Firms

Dependent variable	ΔEI_y	ΔEI_y	ΔEI_y
ΔUFCI_{SSIV}	-0.00553*** (0.00224)	-0.00849*** (0.00276)	-0.00726** (0.00321)
Controls; Firm, Year, Year \times Industry FE	✓	✓	✓
Observations	53,715	29,691	22,624
R-squared	0.175	0.154	0.149
Firm Size	Small	Small	Small

Table: Upgrading and Energy Intensity: Big Firms

Dependent variable	ΔEI_y	ΔEI_y	ΔEI_y
ΔUFCI_{SSIV}	-0.00307 (0.00237)	-0.00222 (0.00256)	-0.00122 (0.00265)
Controls; Firm, Year, Year \times Industry FE	✓	✓	✓
Observations	14,345	11,928	10,472
R-squared	0.181	0.179	0.184
Firm Size	Large	Large	Large

Extensions

- **Financial constraints:** measured by **Fin Ratio**
 - Captures firm's debt servicing burden
 - **Sum of amortization and interest payments of debt over firm sales**
 - Other financing cost ratios as robustness checks
- **Markups**, following **Ding et al. (2024)**
 - Production function approach as in **De Loecker and Warzynski (2012)**
 - Two-step method as in **Olley and Pakes (1996)** and identification as in **Ackerberg et al. (2015)**
 - Local projection as in **Jorda (2005)**

Table: Upgrading, Energy Intensity, Financing Friction: Small Firms

Columns	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variable	ΔEI_y	ΔEI_y	ΔEI_y	ΔEI_y	ΔEI_y	ΔEI_y	ΔEI_y
$\Delta UFCI_{SSIV}$	-0.0060***	-0.0092***			-0.0089**		
Fin Ratio	0.0086	0.0138	0.0135	0.0135	-0.0092	-0.0102	-0.0100
$\Delta UFCI_{SSIV} \times \text{Fin Ratio}$	0.0200**	0.0228	0.0230	0.0231	0.0478**	0.0484**	0.0483**
Controls; Firm, Year, Year \times Industry FE	✓	✓	✓	✓	✓	✓	✓
Observations	53,114	29,615	29,615	29,615	22,584	22,584	22,584
R-squared	0.175	0.156	0.156	0.156	0.152	0.153	0.153
Firm Size	Small	Small	Small	Small	Small	Small	Small

Table: Upgrading, Energy Intensity, Financing Friction: Big Firms

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Dependent variable	ΔEI_y	ΔEI_y	ΔEI_y	ΔEI_y	ΔEI_y	ΔEI_y	ΔEI_y
$\Delta UFCI_{SSIV}$	-0.0016	-0.0012			-0.0003		
Fin Ratio	0.0885***	0.0904**	0.0901**	0.0900**	0.1071**	0.1065*	0.1057*
$\Delta UFCI_{SSIV} \times \text{Fin Ratio}$	-0.0137**	-0.0105**	-0.0106**	-0.0106**	-0.0122**	-0.0123**	-0.0122**
Controls; Firm, Year, Year \times Industry FE	✓	✓	✓	✓	✓	✓	✓
Observations	14,303	11,904	11,904	10,449	10,449	10,449	10,449
R-squared	0.182	0.182	0.182	0.182	0.186	0.186	0.187
Firm Size	Big	Big	Big	Big	Big	Big	Big

Figure: Small Firms

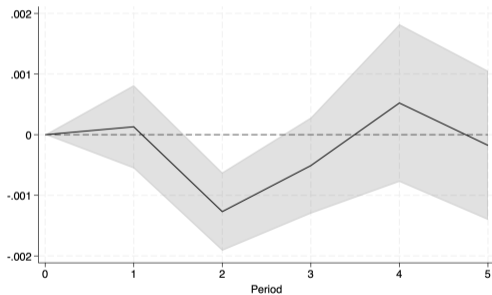
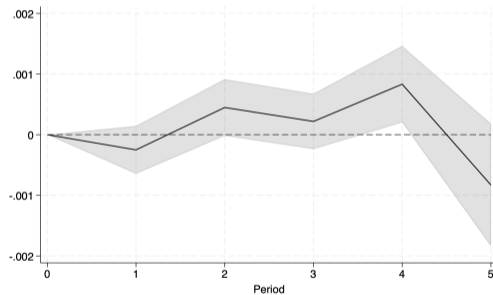


Figure: Big Firms



Conclusions

- **What Did We Do?**

- Firm-level complexity index , causal analysis, and explore market mechanisms

- **What Did We Learn?**

- ↑ Foreign import demand ⇒ ↑ growth of firm's complexity

- Upgrading improves energy efficiency with heterogeneous impacts

- **Policy Implications**

- Need governmental policies to induce firm upgrading and energy transition

- Support for small firms in their upgrading efforts

- Mitigation of financial frictions that hinder energy efficiency gains

- Promotion of well-functioning input market and free trade

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