Strategic Responses to Carbon Policies and Biased Beliefs: Evidence From a Firm Managers' Survey

Sébastien Houde (HEC Lausanne)
with Kenza Benhima (HEC Lausanne, CEPR), Andreas Fuster (EPFL, CEPR), and Heiner Mikosch (KOF-ETH)

October 15^{th} 2025

ifo Lunch Seminar, Munich

Roadmap

Motivation & Contribution

Model

Identification via Survey Scenarios

Survey Implementation

Results: Strategic Interaction Parameters

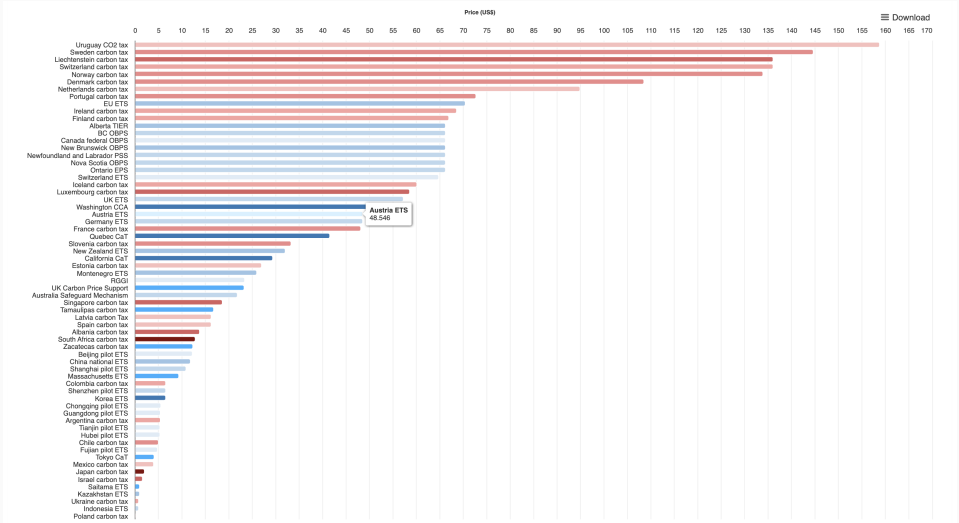
Results: Biased Beliefs

Information counterfactuals

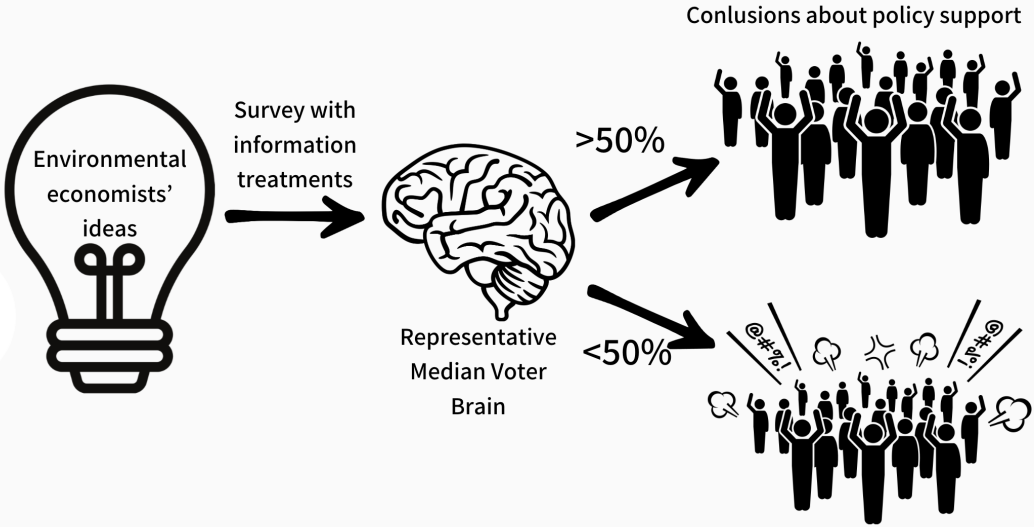
Motivation & Contribution

Status: Adoption of Environmental Economists' Best Idea Ever

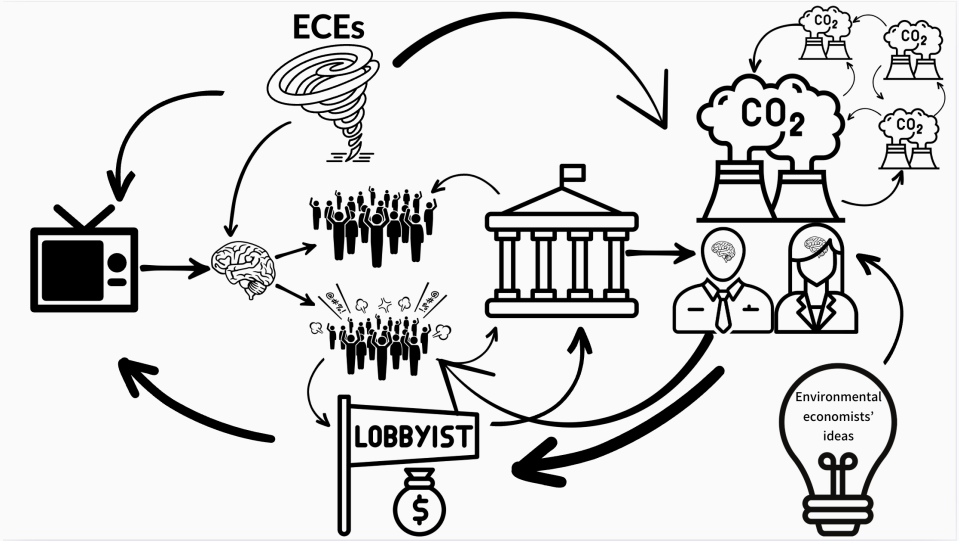
Increase from 23% in 2024 to 28% in 2025. (Source: World Bank Carbon Pricing Dashboard)



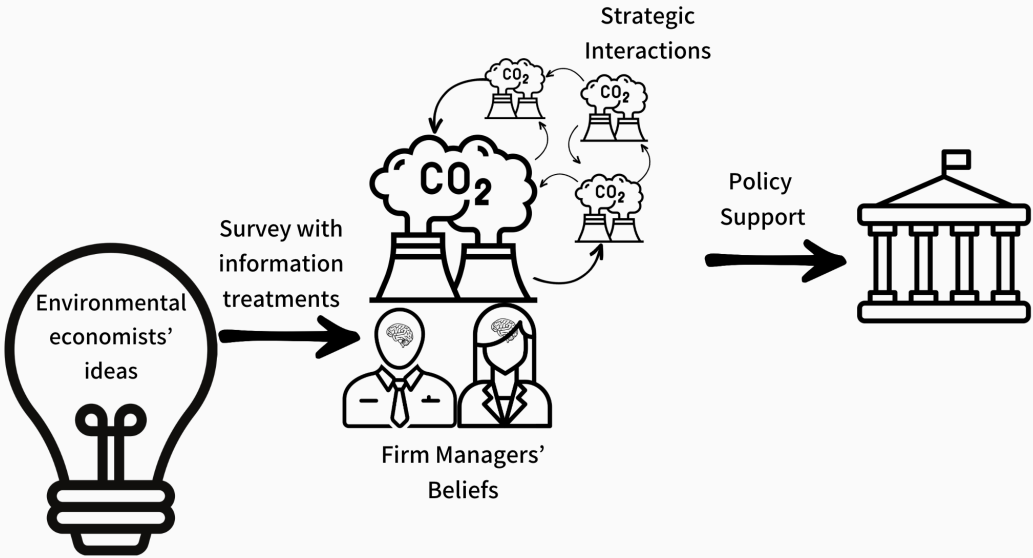
Motivation: Recent Literature



Motivation: What we would like to know



Motivation: This Project



Motivation I

Why should we care about firms' strategic interactions and biased beliefs in response to carbon pricing policies?

- Firm managers' **beliefs** about abatement costs impact their responses.
- **Hypothesis:** Firms' responses to carbon pricing along different margins (output, abatement, prices) are **strategic** $\rightarrow$ depends on responses of others.
- Firm managers' **beliefs** about how other firms will respond thus impact their own responses.
- **Policy support** for climate policies/reforms is thus determined by (biased) beliefs and intensity of strategic interactions.

Motivation II

Why should we care about survey evidence?

- **Ex ante analyses** of carbon tax reform are hard, imprecise, and long to carry out.
  - Rely on production function estimation (not easy to do well)
  - Challenges regarding internal and external validity: require a credible natural experiment that mimics the impact of the proposed reform.
  - Data-intensive but firm-level data are often outdated (released with 2-3 years lag).
- **Survey instruments** can be an alternative/complementary approach to estimate production function, policy support, and the anticipated impact of a reform.
  - It is fast and easy to deploy
  - Transparent estimation
  - It can be used to precisely focus on a proposed policy reform.

Goals of this project

- **Our 1^{st} goal**: Using a firm managers' survey to estimate sufficient statistics that allow for conducting **ex ante** policy analysis.
  - For firm managers: important to capture potential strategic interactions.
- **Our 2^{nd} goal**: Address one important challenge with such an approach: Firm managers' **beliefs might be biased.**
  - The role of the biased beliefs must then be accounted for.
- **Our 3^{rd} goal**: Illustrate how our approach for the context of **carbon pricing reform**, and how it can translate into political support.
  - We need to be better and faster to understand the costs and benefits of environmental policies.

What we do

1. Shows how sectoral & aggregate strategic interactions determine firms' response to a (change in) carbon price.
2. Propose a new identification strategy via **survey scenarios** that allow us to estimate **firm-specific** primitives of the model.
   - Strategic interaction parameters
   - Biased beliefs and priors
   - Profits, policy support function... (for later)
3. Conduct policy simulations of alternative carbon tax reforms under information counterfactuals and simulate firms' responses.

Contributions

1. **Application**: Surveys with firm managers' responses to carbon pricing/environmental policies
   - Firm managers and re-allocation risks (Martin et al. 2014)
   - Using firm surveys to study environmental policies (OECD 2016)
   - Carbon pricing and inflation expectations (Hensel, Mangiante, and Moretti 2024)
2. **Methodological**: Using surveys to estimate firms' production functions, strategic interactions, and/or recover beliefs
   - Coibion, Gorodnichenko, and Kumar 2018
   - Keiller, Paula, and Van Reenen 2024
   - Afrouzi 2024
   - Mikosch et al. 2024

Preview of Results

- Proof-of-concept validated
  - It was a challenging survey, but firm managers made the effort.
- Strategic interactions matter
  - Strong strategic substitutabilities within-sector
  - Weak strategic substitutabilities across sectors
- Pessimistic beliefs about others/rest of the economy
  - Implies overly pessimistic public signals
- In progress: "Debiasing" public signals changes firms' prospects
  - It makes them more optimistic about their abatement costs
  - It makes them more optimistic about others (but that affects them negatively, because of strategic substitutabilities)

Model

A Stylized Model

Details

- **Representative Household**
  - Utility from C and disutility from L: $U = \frac{C^{1-\gamma}}{1-\gamma} - \phi^{-1}\frac{L^{1+\eta}}{1+\eta}$.
  - C is aggregated (w CES) across sectors (ϵ^c) and varieties (ρ^c); and
  - L is aggregated (w CES) across sectors (χ) and varieties (ψ);
- **Firms** (monopolistic competitors within sector)
  - Technology: $Q_{in} = [(1+\beta_{in})L_{in}]^{1/1+\beta_{in}}$ with $\beta_{in} > 0$.
  - Emissions: $E_{in} = \phi_{in}Q_{in}$;
  - Marginal abatement costs: $a(\phi_{in}) = \frac{\kappa_{in}}{2}\left(1 - \frac{\phi_{in}}{\bar{\phi}_{in}}\right)^2$.
- **Equilibrium Outcomes**: output: q_{in}, price: p_{in}, abatement: $a(\phi_{in})$, profits: Π_{in}.

Key assumption (medium run): Quantity chosen with incomplete info about abatement costs and strategies of others (think of capacity constraints and labor market frictions).

Macro-founded Estimating Equation

We show that the output response of firm i in sector n, denoted q_{in}, to a change in carbon price (or other cost shocks), denoted τ_{in}, take the following form:

$$q_{in} = \underbrace{\alpha_{in}^{a}\,\mathbb{E}_{in}(q)}_{\text{economy}} + \underbrace{\alpha_{in}^{s}\,\mathbb{E}_{in}(q_n)}_{\text{sector}} - \underbrace{\mathbb{E}_{in}(\sigma_{in})\,\tau_{in}}_{\text{tax channel}}.$$

Where

- $\mathbb{E}_{in}(q)$: firm i beliefs about change in aggregate output
- $\mathbb{E}_{in}(q_n)$: firm i beliefs about change in sector n output
- α_{in}^{a}: Strategic response to aggregate output (typically > 0).
- α_{in}^{s}: Strategic response to sectoral output (typically < 0).
- $\mathbb{E}_{in}(\sigma_{in})$: Sufficient statistic that captures the direct impact of the carbon tax.

▸ Intuition ▸ Parameters

Role of biased beliefs

Let's define

- q: true aggregate impact
- q_n: true sectoral impact
- σ_{in}: true abatement cost parameter
- $E_{in}(q) - q$: biased beliefs about aggregate impact
- $E_{in}(q_n) - q_n$: biased beliefs about sectoral impact
- $E_{in}(\sigma_{in}) - \sigma_{in}$: biased beliefs about own abatement cost parameters

Our estimating equation becomes:

$$q_{in} = \alpha_{in}^{a}\left[q + (E_{in}(q) - q)\right] + \alpha_{in}^{s}\left[q_n + (E_{in}(q_n) - q_n)\right] - \left[\sigma_{in} + (E_{in}(\sigma_{in}) - \sigma_{in})\right]\tau_{in}$$

$\Rightarrow$ We can simulate counterfactuals about q_{in} accounting for the role of biased beliefs and show how strategic interaction parameters magnify biased beliefs.

Information Structure

- **Private firm signal:**

$$x_{in}^f = \underbrace{\sigma^a + \sigma_n^s + \sigma_{in}^f}_{\sigma_{in}} + e_{in}^f,$$

$$\text{with } \sigma_{in}^f \sim \mathcal{N}\big(0, (\kappa_f)^{-1}\big), \text{ and } e_{in}^f \sim \mathcal{N}\big(0, (\pi_f)^{-1}\big).$$

- **Public sector signal:**

$$E_n^s[\sigma_n^s] = \sigma_n^s + e_n^s, \text{ with } e_n^s \sim \mathcal{N}\big(0, (\pi_s)^{-1}\big),$$

- **Public aggregate signal:**

$$E^a[\sigma^a] = \sigma^a + e^a, \text{ with } e^a \sim \mathcal{N}\big(0, (\pi_a)^{-1}\big).$$

All four shocks e^a, e_n^s, σ_{in}^f, and e_{in}^f are assumed to be mutually independent.

Model solution

Proposition

Under some mild assumptions (Assumptions),

$$\begin{pmatrix} q_{in} \\ E_{in}(q_n) \\ E_{in}(q) \end{pmatrix} = \begin{pmatrix} \mathcal{Q}^{(1)} & \mathcal{Q}^{(2)} & \mathcal{Q}^{(3)} \\ \mathcal{Q}^{s(1)} & \mathcal{Q}^{s(2)} & 0 \\ \mathcal{Q}^{a(1)} & 0 & 0 \end{pmatrix} \cdot \begin{pmatrix} \tau \\ \tau_n - \tau \\ \tau_{in} - \tau_n \end{pmatrix}$$

with $\mathcal{Q}^k = A^k(\Theta_{in})S_{in}$, $k = \{(1),(2),(3),s(1),s(2),a(1)\}$, where Θ_{in} is the set of parameters (α parameters and information parameters) and $S_{in} = (E^a(\sigma^a), E^n(\sigma_n^s), s_{in}^f)'$ is the vector of signals.

Key result: Firm-specific, sector-specific, and economy-wide carbon tax have different effects. Will matter for identification.

Identification via Survey Scenarios

Identification of Strategic Interaction Parameters

We want to recover the firm-level vector: $\left(\alpha^{a}_{in}, \alpha^{s}_{in}, \mathbb{E}_{in}(\sigma_{in})\right)$.

Three parameters to identify, it is enough to generate three independent observations of the vector $(q_{in}, E_{in}(q), E_{in}(q_n), \tau_{in})'$:

$$\begin{pmatrix} q_{in,1} \\ q_{in,2} \\ q_{in,3} \end{pmatrix} = \underbrace{\begin{pmatrix} E_{in}(q_1) & E_{in}(q_{n,1}) & \tau_{in,1} \\ E_{in}(q_2) & E_{in}(q_{n,2}) & \tau_{in,2} \\ E_{in}(q_3) & E_{in}(q_{n,3}) & \tau_{in,3} \end{pmatrix}}_{P_{in}} \cdot \begin{pmatrix} \alpha^{a}_{in} \\ \alpha^{s}_{in} \\ E_{in}(\sigma_{in}) \end{pmatrix}$$

P_{in} is invertible with independent tax scenarios $(\tau_{in,1}, \tau_{in,2}, \tau_{in,3})$ and corresponding elicitation of $(q_{in,\#}, E_{in}(q_{\#}), E_{in}(q_{n,\#}))$ for each scenario $\#$

$\Rightarrow \left(\alpha^{a}_{in}, \alpha^{s}_{in}, \mathbb{E}_{in}(\sigma_{in})\right)$ is identified.

Three independent carbon tax scenarios

Scenarios (randomized tax level $x\%$):

1. National tax: $\tau_{in,1} = \tau = x\%$ (all sectors).
2. Sectoral tax: $\tau_{in,2} = \tau_n = x\%$ (respondent's sector only).
3. Firm-specific tax: $\tau_{in,3} = \tau_{in} = x\%$ (respondent only).

Elicit in each scenario:

1. Own q_{in}, sectoral q_n (others in same sector), and aggregate output q.
2. Own q_{in} and sectoral q_n output.
3. Own q_{in} output only.

Three independent carbon tax scenarios

In matrix notation:

$$\begin{pmatrix} q_{in,1} \\ q_{in,2} \\ q_{in,3} \end{pmatrix} = \underbrace{\begin{pmatrix} E_{in}(q_1) & E_{in}(q_{n,1}) & \tau_{in,1} \\ 0 & E_{in}(q_{n,2}) & \tau_{in,2} \\ 0 & 0 & \tau_{in,3} \end{pmatrix}}_{P_{in} \text{ is now invertible}} \cdot \begin{pmatrix} \alpha_{in}^{a} \\ \alpha_{in}^{s} \\ E_{in}(\sigma_{in}) \end{pmatrix}$$

where

1. National tax: $\tau_{in,1} = \tau = x\%$ imposed on all firms.
2. Sectoral tax: $\tau_{in,2} = \tau_n = x\%$ imposed on respondent's sector only.
3. Firm-specific tax: $\tau_{in,3} = \tau_{in} = x\%$ imposed on respondent only (equivalent to removing an exemption).

Example

By how many percent will annual production volume be lower or higher in 2028 (i.e., in the medium run) due to the tax, compared to a situation in which there is no additional tax?

- Scenario 1: The CHF CO2 tax is levied on all firms **in Switzerland**.
  - Impact on Switzerland's volume of produced services and goods (measured at current sales prices):
  - Impact on your competitors' volume [...]
  - Impact on your firm's volume [...]
- Scenario 2: The CHF CO2 tax is levied only on firms **in your sector**.
  - Impact on your competitors' volume [...]
  - Impact on your firm's volume [...]
- Scenario 3: The CHF CO2 tax is levied only on **your firm**.
  - Impact on your firm's volume [...]

Good to know

Survey Implementation

Design overview

Details

Online survey with Swiss firm managers

1. **Module 1**: Elicit firm characteristics to *construct a firm-specific signal about the cost burden of a carbon tax*
   - Goal: Provide firm-specific signal about σ_{in}.
2. **Module 2**: Elicitation of output responses, vector $(E_{in}(q), E_{in}(q_n), q_{in})$ to carbon tax scenarios (national/sector/firm).
   - We also elicit price responses, $(E_{in}(p), E_{in}(p_n), p_{in})$ for all scenarios.
   - We elicit responses for labor, energy, and profit for the national tax scenario only.
     - Input to future information treatments: part 2 of the project,
3. **Module 3**: Elicitation of a policy support function
4. **Module 4**: Manager characteristics

Deployment

- Pre-registration (AEA RCT Registry with pre-analysis plan) in early June 2025.
- Survey invitation sent in June 2025
  - 3 reminders in June-July
  - Close on August 31st 2025
- Recruitment of firm managers via KOF's firm panel + Orbis
- Representative sample of N=27k with oversampling of large firms
  - We will use survey weights to compute aggregate responses and beliefs
- Response rate:
  - N=27k managers were invited
  - N=2924 started the survey
  - N=1369 completed the survey
  - N=951 complete and usable answers to the carbon tax scenarios (estimation sample)

▸ Firms ▸ Managers ▸ Sectors

Results: Strategic Interaction Parameters

Reduced-form evidence: Own response to different tax levels

We did a between-subject randomization in the tax level to assess scope sensitivity.

Own firm response to a national tax	Tax Level (CHF/Ton CO_2) 100	300	Difference
Δ Energy Cost (%)	7.98	23.59	-15.61***
Δ Ouput (%)	-0.98	-2.22	1.24***
Δ Price (%)	2.51	2.54	-0.03
Δ Energy Consumption (%)†	-0.84	-1.21	0.37
Δ FTE (%)	-0.88	-1.43	0.55**
Δ Profits (%)	-1.84	-2.93	1.09***
Observations	480	461	941

†Price elasticity of -0.1 and -0.05, for the tax levels 100 and 300, respectively.

Reduced-form evidence: Own response vs beliefs about others

Differences between **own firm's response** versus impact on **others in the same sector**, or **national impact** for a nation-wide carbon tax.

	Own	Other	Nat	Other – Own	Nat – Own
Δ Output (%)	-1.58	-1.70	-2.47	-0.11	-0.88***

Firms are more pessimistic about others than about themselves.

Reduced-form evidence: Own response across tax scenarios (scope)

Differences between scenarios of **own firm's response**.

	National Tax	Sectoral Tax	Firm-Specific Tax	Nat – Sector	Nat – Firm
Output	-1.58	-1.78	-3.03	0.20	1.45***

Firms believe that a firm-specific tax is the worst scenario. Indicates the presence of strategic substitutabilities.

Reminder: Strategic interaction parameters are recovered by solving:

$$\begin{pmatrix} q_{in,1} \\ q_{in,2} \\ q_{in,3} \end{pmatrix} = \begin{pmatrix} E_{in}(q_1) & E_{in}(q_{n,1}) & \tau_{in,1} \\ 0 & E_{in}(q_{n,2}) & \tau_{in,2} \\ 0 & 0 & \tau_{in,3} \end{pmatrix} \cdot \begin{pmatrix} \alpha_{in}^{a} \\ \alpha_{in}^{s} \\ E_{in}(\sigma_{in}) \end{pmatrix}$$

Strategic interaction parameters: output response

Price responses

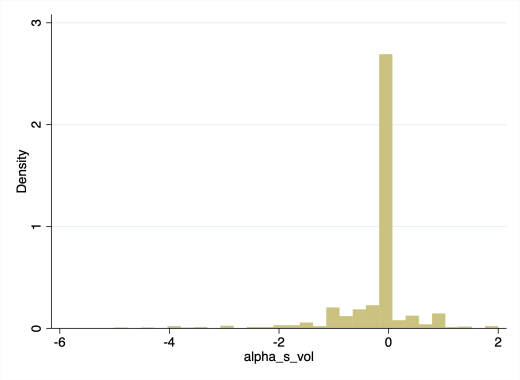
We estimate the firm-level vector: $\left(\alpha^a_{in}, \alpha^s_{in}, \mathbb{E}_{in}(\sigma_{in})\right)$ for the output response.

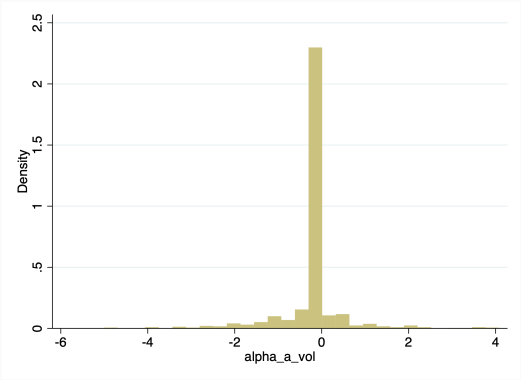
	Mean	Median	P25	P75
Policy elasticity $E_{in}(\sigma_{in})$	-1.76	0	-3	0
Sectoral-level strategic α^s_{in}	-.19	0	-.08	0
Aggregate-level strategic α^a_{in}	-.11	0	0	0

Take-aways:

- Strategic interactions matter but only for some managers.
  - 65% are not strategic in the sectoral dimension.
  - 66% are not strategic in the aggregate dimension.
- As predicted: strong substituabilities within-sector
- Weak substituabilities across sectors (see heterogeneity next)

Distribution of sectoral strategic interaction parameters: α_{in}^{s} and α_{in}^{a}





Heterogeneity: $\alpha_{in}^{s} = \mathrm{f}(\mathrm{Observables})$ More

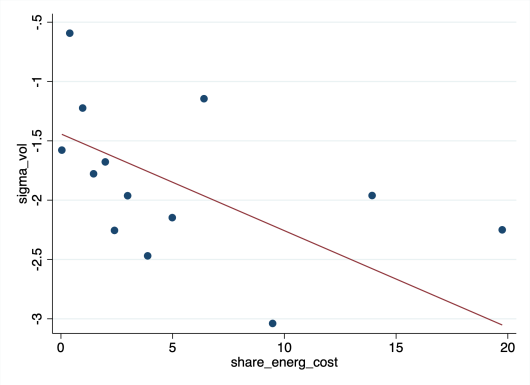
	Spec I	Spec II	Spec III	Spec IV	Spec V
Full-time employees	-0.008	-0.009	-0.008		-0.007
Turnover	**0.000*****	**0.000*****	0.000		0.000
Export share		**0.002****	**0.002****		**0.002****
Intensity compet. (binary)		**-0.137*****	**-0.130*****		**-0.128*****
Only Swiss compet. (binary)		**0.115****	**0.113****		**0.114****
Manufacturing–Machine (binary)		-0.059	-0.077		-0.078
Share of energy cost			**-0.010****		**-0.010****
Uses electricity (binary)			0.080		0.082
Uses fossil (binary)			**-0.148*****		**-0.142*****
CO_2 emissions			-0.000		-0.000
CEO, Director, CFO (binary)				0.060	0.054
Manager: years in role				0.001	0.001
Manager: male (binary)				**-0.160*****	**-0.142****
Master or PhD (binary)				0.031	-0.002
Survey duration (minutes)				0.000	0.000
Observations	906	890	889	894	876
Adj. R-squared	-0.001	0.012	0.027	-0.000	0.025

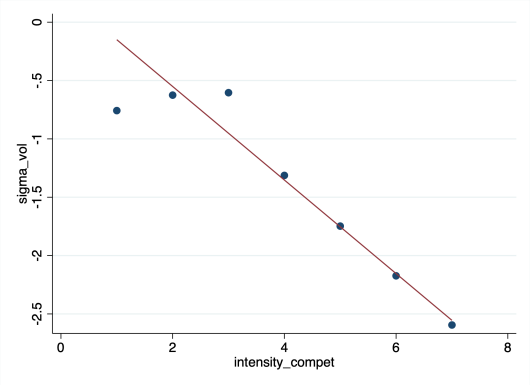
Heterogeneity: $\alpha_{in}^{a} = \mathrm{f}(\mathrm{Observables})$ More

	Spec I	Spec II	Spec III	Spec IV	Spec V
Full-time employees	0.007	0.008	0.009		0.010
Turnover	0.000	**0.000***	-0.000		-0.000
Export share		0.001	0.001		0.001
Intensity compet. (binary)		-0.065	-0.059		-0.055
Only Swiss compet. (binary)		**0.120****	**0.127****		**0.130****
Manufacturing–Machine (binary)		-0.007	-0.012		-0.011
Share of energy cost			0.000		-0.000
Uses electricity (binary)			0.147		0.149
Uses fossil (binary)			**-0.146*****		**-0.141****
CO_2 emissions			0.001		0.001
CEO, Director, CFO (binary)				0.039	0.043
Manager: years in role				-0.002	-0.001
Manager: male (binary)				**-0.126****	**-0.107****
Master or PhD (binary)				-0.005	-0.025
Survey duration (min)				-0.000	-0.000
Observations	906	890	889	894	876
Adj. R-squared	-0.001	0.002	0.008	-0.002	0.005

Policy Elasticity vs Energy Intensity and Intensity of Competition

More





Results: Biased Beliefs

Illustration: biased beliefs amplify strategic interactions

Strategic substitutability + pessimistic beliefs $\rightarrow q_{in}^{Unbiased} < q_{in}^{Biased}$

$$q_{in}^{Biased} = \alpha_{in}^{a} \cdot q + \alpha_{in}^{s} \left[q_n + (E_{in}(q_n) - q_n) \right] - \sigma_{in}\tau_{in}$$

$$q_{in}^{Unbiased} = \alpha_{in}^{a} \cdot q + \alpha_{in}^{s} \cdot q_n - \sigma_{in}\tau_{in}$$

- $q_{in}^{Biased} =$ **-2%**
- $\alpha_{in}^{s} =$ -0.5 $< 0 \rightarrow$ Strategic substitutability
- $E_{in}(q_n) =$ -5%
- $q_n =$ -3%
- $E_{in}(q_n) - q_n = -2\% < 0 \rightarrow$ Pessimistic beliefs about others
- $\alpha_{in}^{s} \cdot (E_{in}(q_n) - q_n) = 1\%$
- $q_{in}^{Biased} = q_{in}^{Unbiased} + 1\%$
- $q_{in}^{Unbiased}$ **= -3%**

Individual-specific biased beliefs

- National output change for scenario 1 (Sc.1): $(E_{in}(q) - q)$
  - where $q = \sum_i q_{in}$.
- Sectoral output change for scenario 1 (Sc.1): $(E_{in}(q_{n,1}) - q_{n,1})$
  - where $q_{n,1} = \sum_{i \in n} q_{in,1}$.
- Sectoral output change for scenario 2 (Sc.2): $(E_{in}(q_{n,2}) - q_{n,2})$
  - where $q_{n,2} = \sum_{i \in n} q_{in,2}$.

	Tax 100-300 CHF/CO_2			
	Mean	**Median**	P25	P75
Δ Output (%) (Sc.1)	**-1.67**	**0.00**	-3.00	0.00
Bias national (Sc.1): $(E_{in}(q) - q)$	**-0.96**	**-0.02**	-3.02	1.98
Bias Sector (Sc.1): $(E_{in}(q_{n,1}) - q_{n,1})$	**-0.17**	**0.36**	-1.75	2.25
Bias Sector (Sc.2) : $(E_{in}(q_{n,2}) - q_{n,2})$	**-0.31**	**0.62**	-2.00	2.04

Second Takeaways

1. Quantities responses are subject to strategic responses for some managers.
2. Firm managers are most strategic with respect to the responses of firms in their sector.
3. Pessimistic beliefs about the impact on others.

Information counterfactuals

Role of biased beliefs – Simplified information structure

- **Hypothesis 1.** We assume a simple information structure about σ_{in}:
  - Elasticity σ_{in} has an aggregate, sectoral, and idiosyncratic component:

$$\sigma_{in} = \sigma^a + \sigma^s_n + \sigma^f_{in}$$
$$\text{with } \sigma^f_{in} \sim N(0, (\kappa^f)^{-1})$$

- **Hypothesis 2.** There are commonly shared priors on the aggregate and sectoral components:

$$E^a(\sigma^a) = \sigma^a + e^a, \qquad E^s_n(\sigma^s_n) = \sigma^s_n + e^s_n$$
$$\text{with } e^a \sim N(0, (\pi^a)^{-1}) \text{ and } e^s_n \sim N(0, (\pi^s)^{-1})$$

  - Note: σ_{in} is also a signal on σ^a and σ^s_n.
- **Hypothesis 3.** Firms observe σ_{in} perfectly, so that $E_{in}(\sigma_{in}) = \sigma_{in}$.

Role of biased beliefs: Implications of Hypotheses 1-3

- **H3.** $\rightarrow$

$$q_{in} = \alpha_{in}^{a}\left[q + (E_{in}(q) - q)\right] + \alpha_{in}^{s}\left[q_n + (E_{in}(q_n) - q_n)\right] - \sigma_{in}\tau_{in}$$

- **H1., H2., H3.** $\rightarrow$

  The equilibrium aggregate output is then given by:

$$q = \frac{1}{1-\alpha^a-\alpha^s}\left[\alpha^a\left(\underbrace{\bar{E}(q)-q}_{\text{Aggregate bias}}\right) + \alpha^s\left(\underbrace{\bar{E}(q_n)-q}_{\text{Sectoral bias}}\right) - \underbrace{\sigma^a}_{\text{Average of } \sigma_{in}}\tau\right]$$

  Removing the biases (setting $\bar{E}(q) - q = \bar{E}(q_n) - q = 0$) has a negative impact on q, because of strategic substitutability (α^a and α^s are negative on average)

  However, we assume that σ_{in} is observed by firms (**H3**).

Role of biased beliefs: Relaxing Hypothesis 3

- **Without H3.** $\rightarrow$

$$q_{in} = \alpha^a_{in}\left[q + (E_{in}(q) - q)\right] + \alpha^s_{in}\left[q_n + (E_{in}(q_n) - q_n)\right] - \left[\sigma_{in} + (E_{in}(\sigma_{in}) - \sigma_{in})\right]\tau_{in}$$

- **H1., H2.** $\rightarrow$
  The equilibrium aggregate output is then given by:

$$q = \frac{1}{1-\alpha^a-\alpha^s}\left[\alpha^a\left(\underbrace{\bar{E}(q) - q}_{\text{Aggregate bias}}\right) + \alpha^s\left(\underbrace{\bar{E}(q_n) - q}_{\text{Sectoral bias}}\right) - \left(\underbrace{\bar{E}(\sigma_{in}) - \sigma^a}_{\text{Error on } \sigma}\right) - \sigma^a\tau\right]$$

  What can we say about $\bar{E}(\sigma_{in}) - \sigma^a$**?**

Output response as a function of the signals

Given the information structure, the output response is of the form:

$$q_{in} = -\left(\gamma_{in}^{a} E^{a}(\sigma^{a}) + \gamma_{in}^{s} E_{n}^{s}(\sigma_{n}^{s}) + \gamma_{in}^{f} x_{in}^{f}\right)\tau \tag{1}$$

where γ_{in}^{a}, γ_{in}^{s}, and γ_{in}^{f} are function of the *deep* parameters:

- the prior means (σ^{a}, σ_{n}^{s});
- the signal precisions (π_{a}, π_{s}, π_{f}, κ_{f}); and
- strategic interaction parameters (α_{in}^{a}, α_{in}^{s}).

Other quantities as function of the signals

Aggregate quantities:

$$q = -\left(\gamma^a E^a(\sigma^a) + \gamma^f \sigma^a\right)\tau$$

Biased beliefs about aggregate quantities:

$$\bar{E}(\sigma_{in}) - \sigma^a = \frac{-(1-\delta^f)}{\gamma^f(1-\delta^a)}(\bar{E}(q) - q)$$

- If firms are too pessimistic about the aggregate output, it implies that they are also too pessimistic about their own abatement costs on average. This is due to overly pessimistic public signals. Unbiasing σ can then increase q through that channel.
- How to back out $\bar{E}(\sigma_{in}) - \sigma^a$? We need to identify the information structure (ML: in progress).

Takeaways & Next Steps

1. Strategic interactions and biased beliefs with respect to carbon pricing matter.
2. Information frictions amplify strategic responses.
3. Survey instrument permits *policy-relevant counterfactuals*.

Next:

- Back-out prior beliefs and information structure.
- More counterfactuals and policy simulations.
- Merge to registry/admin firm data; validation exercises.
- Follow-up with households and firm managers surveys to create treatments.

Thank you!

Comments and suggestions:

sebastien.houde@unil.ch

References

- Afrouzi, Hassan (2024). **"Strategic inattention, inflation dynamics, and the nonneutrality of money".** In: *Journal of Political Economy* 132.10, pp. 3378–3420.
- Coibion, Olivier, Yuriy Gorodnichenko, and Saten Kumar (2018). **"How Do Firms Form Their Expectations? New Survey Evidence".** In: *American Economic Review* 108.9, pp. 2671–2713.
- Hensel, Jannik, Giacomo Mangiante, and Luca Moretti (Oct. 2024). **"Carbon pricing and inflation expectations: Evidence from France".** In: *Journal of Monetary Economics* 147, p. 103593.

References ii

- Keiller, Agnes Norris, Áureo de Paula, and John Van Reenen (2024). **Production Function Estimation Using Subjective Expectations Data.** Tech. rep. NBER Working Paper 32725. National Bureau of Economic Research.
- Martin, Ralf et al. (2014). **"Industry Compensation under Relocation Risk: A Firm-Level Analysis of the EU Emissions Trading Scheme".** In: *American Economic Review* 104.8, pp. 2482–2508.
- Mikosch, Heiner et al. (2024). **"Uncertainty and Information Acquisition: Evidence from Firms and Households".** In: *American Economic Journal: Macroeconomics* 16.2, pp. 375–405.
- OECD (2016). **Firm Surveys Relating Environmental Policies, Environmental Performance and Innovation.** OECD Environment Working Paper No. 96.

Backup

Assumptions for Proposition 1

Back

Assumption 1: Orders of magnitude

- Let α_{in} be firm-level strategic parameters, α_n sectoral averages, and α the aggregate average.
- Products of deviations such as $(\alpha_{in} - \alpha_n)(\alpha_{in} - \alpha)'$ and $(\alpha_{in} - \alpha)(\alpha_n - \alpha)'$ are small relative to $|\alpha|$.

Assumption 2: Independence

- Firm-level shocks and taxes are independent of firm-level structural parameters.
- Sector-level shocks and taxes are independent of sector-level structural parameters.

Assumption 3: Invertibility

- The matrix summarizing strategic interactions is invertible.
- Ensures existence and uniqueness of a linear equilibrium solution.

Economic Intuition Behind the Assumptions

Back

1. **Orders of magnitude**

   - Firms and sectors can differ, but heterogeneity is "small".
   - Interaction terms involving deviations from the mean are second-order.
     $\Rightarrow$ We can approximate behavior using average parameters.

2. **Independence**

   - Who receives high/low taxes or shocks is not systematically related to their type.
   - Eliminates covariance terms between shocks/taxes and structural parameters.
     $\Rightarrow$ Linear firm-level rules aggregate to sector and aggregate levels.

3. **Invertibility**

   - Best responses form a linear system that can be solved uniquely.
     $\Rightarrow$ Small changes in taxes lead to well-defined changes in all firms' outputs.

Households

Back

Representative household utility:

$$U = \frac{C^{1-\gamma}}{1-\gamma} - \phi^{-1}\frac{L^{1+\eta}}{1+\eta}$$

$\Rightarrow$ CES across sectors (ϵ^c) and varieties (ρ^c); labor aggregator with elasticities χ, ψ.

- Demand: $C_{in} = C\left(\frac{P_n}{P}\right)^{-\epsilon^c}\left(\frac{P_{in}}{P_n}\right)^{-\rho^c}$.
- Labor supply to firm: $L_{in} = L\left(\frac{W_n}{W}\right)^{1/\chi}\left(\frac{W_{in}}{W_n}\right)^{1/\psi}$.

Firms

Back

Maximize expected profits with tax τ_{in} per-ton of emissions.

$$E_{in}\Pi_{in} = E_{in}\left\{P_{in}Q_{in} - W_{in}L_{in} - tax_{in}E_{in} - \frac{\kappa_{in}}{2}\left(1 - \frac{\phi_{in}}{\bar{\phi}_{in}}\right)^2 Q_{in}\right\} \tag{2}$$

Timing

1. Choose L_{in} (hence Q_{in}) before observing the strategies of others, abatement cost parameters $(\bar{\phi}_{in}, \kappa_{in})$, and setting prices.
2. After choosing Q_{in}, learn abatement cost parameters and set price and abatement.

Key idea

Prices fully adjust after shocks are revealed, but quantities are predetermined.

This generates strategic interactions in quantity setting.

$\Rightarrow$ The survey is designed to determine whether these frictions are empirically relevant.

Strategic interactions: intuition

Back

Key assumption: Quantity chosen with incomplete info about abatement costs and strategies of others.

- **Why?** Production adjustments are costly (think of capacity constraints and labor market frictions).
  - In anticipation of a carbon tax reform, firms need to precommit to a certain production.
- **So what?** Firms anticipate that other firms, and the economy, will do the same.
  - Sophisticated firm managers' expected behavioral responses should account for beliefs about sectoral q_n (sector) and national q (aggregate) output change.
- **Predictions**
  - Strategic substituabilities at the sectoral level, i.e., $\alpha^s < 0$, due to high within-sector elasticities (ρ^c).
  - Strategic complementarities at the aggregate level, i.e., $\alpha^a > 0$, due to low between-sector elasticities (ϵ^c).
  - Less strategic interactions for price responses.

Strategic parameters — signs

Back

$$\alpha^{s}_{in} = \frac{(\psi - \chi)(1 + \beta_n) + (\rho^c)^{-1} - (\epsilon^c)^{-1}}{(\psi(1 + \beta_{in}) + \beta_{in}) + (\rho^c)^{-1}}, \quad \alpha^{a}_{in} = \frac{(\chi - \eta)(1 + \beta) - \gamma + (\epsilon^c)^{-1}}{(\psi(1 + \beta_{in}) + \beta_{in}) + (\rho^c)^{-1}}$$

Typical calibration: $\epsilon^c < 1$ (across-sector complements), $\rho^c > 1$ (within-sector substitutes).

Pricing equation in expectations

$$\mathbb{E}(p_{in}) = \mathbb{E}(w_{in}) - \beta_{in} q_{in} - \mathbb{E}(\tilde{\sigma}_{in})\, \tau_{in}$$

with

$$\mathbb{E}(w_{in}) = \psi q_{in} + (\chi - \psi)\mathbb{E}(q_n) + (\gamma - \chi)\mathbb{E}(q) + \mathbb{E}(p) \ (p = 0).$$

Reduced form:

$$\mathbb{E}(p_{in}) = \kappa^a \mathbb{E}(q) + \kappa^s \mathbb{E}(q_n) + \kappa^f \mathbb{E}(\sigma_{in}) \tau_{in}.$$

Good to Know

Back

Our procedure...

- ...is robust (or can provide bounds) to different types of noisy beliefs, demand effects, and survey-induced measurement errors
- ...can be applied to different outcome variables (investment, labor, energy, prices, and profit)
- ...can be applied to any type of (cost) shock (inflation, energy price shocks, labor shortage, productivity, e.g., disruptive AI)

Good to Know

Back

Our procedure...

- ...is robust (or can provide bounds) to different types of noisy beliefs, demand effects, and survey-induced measurement errors

Why?

$$E_{in}(\sigma_{in}) = q_{in,3}/\tau$$

$$\alpha^{s}_{in} = \frac{q_{in,2} - q_{in,3}}{E_{in}(q_{n,2})}$$

$$\alpha^{a}_{in} = \frac{(q_{in,1} - q_{in,3}) - (q_{in,2} - q_{in,3}) \cdot [E_{in}(q_{n,1})/E_{in}(q_{n,2})]}{E_{in}(q_1)}$$

Module 1 — firm info + CO_2 signal

Back

- Elicit energy cost shares (electricity, gas, oil, heat, other).
- Map to CO_2 via Swiss coefficients $\Rightarrow$ firm-level emissions estimate.
- Convert proposed CHF/ton tax into CHF/year cost increment.
  Imperfect but unbiased signal for σ_{in} (fits identification).

Given how much you reported spending on different energy sources, we estimate that your CO2 emissions associated with the following energy sources, for the year 2024, were:

Electricity	34.720	tons of CO2
Other energy sources	258.614	tons of CO2
Total	293.334	tons of CO2

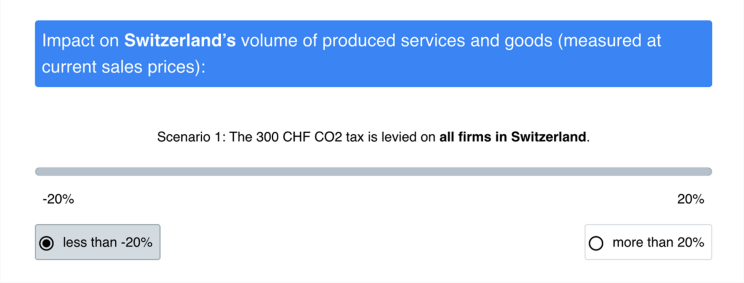
We estimate that an additional CO2 tax of 100 CHF per ton of CO2 would then increase your after-tax energy costs by 29'300 CHF.

Module 2 — scenarios and questions

Back

For each scope (Nat/Sector/Firm) and randomized tax level (Low/High):

- Own: Δq_{in} (% terms).
- Sector peers: Δq_n (%).
- Economy: Δq (%).



**We repeat the exact same procedure for prices: Δp_{in}, Δp_n, and Δp.

Descriptive Statics: Firm Characteristics

Back

	Started	Complete	Restricted 1	**Restricted 2**
Full-time employees	161	92	96	92
Turnover (in million CHF)	151	111	142	148
Export share (%)	12	12	12	13
Intensity compet. (1=above mean)	0.70	0.72	0.72	0.72
Only Swiss compet. (binary)	0.46	0.45	0.44	0.44
Manufacturing-Machine (binary)	0.25	0.37	0.38	0.39
Share of energy cost (%)	6	5	5	4
Uses fossil (binary)	0.66	0.69	0.70	0.69
CO2 emissions (tons CO2eq)	4453	6047	7839	8369
Observations	2,211	1,369	1,027	951

Descriptive Statics: Manager Characteristics

Back

	Started	Complete	Restricted 1	**Restricted 2**
CEO, Director, or CFO (binary)	0.26	0.76	0.76	0.77
Manager's years in firm	18	18	17	17
Manager: male (binary)	0.83	0.84	0.86	0.87
Master or PhD (binary)	0.10	0.30	0.32	0.33
Survey duration (minutes)	-	33	38	38
Observations	2,211	1,369	1,027	951

Summary by (NOGA) sector

Back

NOGA sector	*N*	FTE employees	Export share %	Intensity Compet 1-7	Share energy cost %
A — Agriculture, forestry	34	115	6.00	5.17	6.33
C — Manufacturing	162	142	27.02	5.18	4.57
D — Electricity, gas, steam	5	50	1.20	3.67	7.20
E — Water, sewerage, waste	3	7	51.00	4.33	8.68
F — Construction	82	110	2.11	5.60	3.76
G — Wholesale/retail; motor repairs	70	40	9.14	5.61	3.48
H — Transportation & storage	14	364	21.64	4.40	9.53
I — Accommodation & food services	11	16	10.73	4.55	7.27
J — Information & communication	12	13	18.42	5.25	2.62
K — Financial & insurance	22	60	9.36	5.14	3.74
L — Real estate	34	55	17.56	5.60	1.35
M — Professional, scientific, technical	13	23	0.08	3.62	3.57
N — Administrative & support	133	54	9.08	5.04	3.46
O — Public administration	30	132	6.93	5.74	3.18
P — Education	2	45	0.50	1.00	3.30
Q — Human health & social work	4	56	5.00	4.00	2.80
R — Arts, entertainment & recreation	39	131	3.83	3.70	3.88
S — Other services	13	14	8.38	4.15	4.39
T — Households as employers / own-use	15	180	1.00	3.87	3.87
Missing	235	76	13.58	5.02	5.61
Total	933	92	12.75	5.06	4.45

Strategic interaction parameters: Price response

Back

We also estimate the firm-level vector but using price responses: $\left(\alpha^{a}_{in}, \alpha^{s}_{in}, \mathbb{E}_{in}(\sigma_{in})\right)$ for the output response.

	Mean	Median	P25	P75
Policy elasticity $E_{in}(\sigma_{in})$	1.65	1	0	2
Sectoral-level strategic α^{s}_{in}	.009	0	0	0
Aggregate-level strategic α^{a}_{in}	-.03	0	0	0

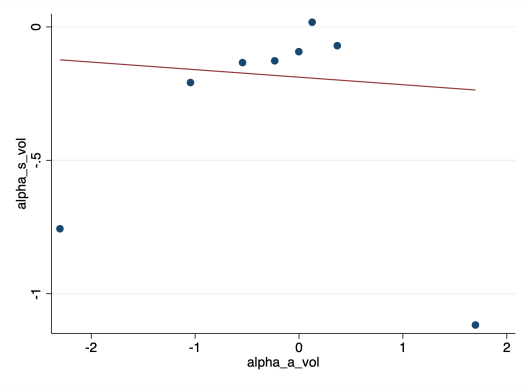
Take-aways:

- **As our model predicts: strategic interactions matter less in the price dimension because prices can adjust quickly.**

Strategic interaction parameters:: sectoral vs aggregate

Back

Bin-scatter plot of the two strategic parameters: y-axis α_{in}^{s}, x-axis α_{in}^{a}.

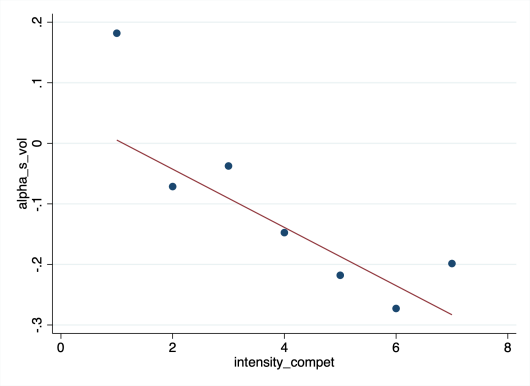


Firm managers that are the most strategic in the sectoral dimension are also the most strategic in the aggregate dimension!

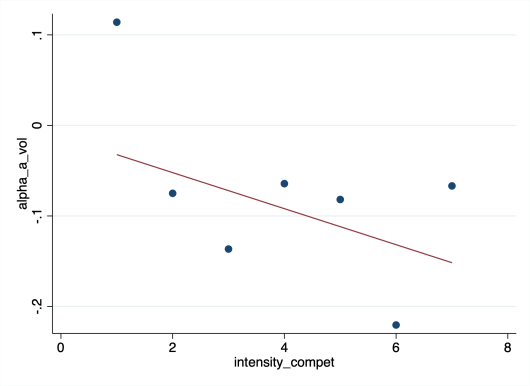
Strategic interaction parameters vs Intensity of competition

Back

We asked each manager to self-report the intensity of competition they face in their sector (1=very little, 7=very intense).



Sectoral strategic parameter for output (α_s) response versus self-reported sectoral

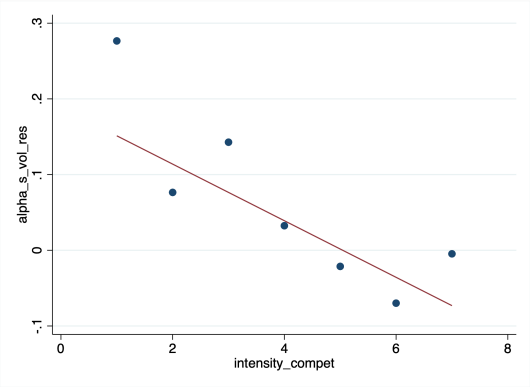


National strategic parameter for output (α_a) response versus self-reported sectoral

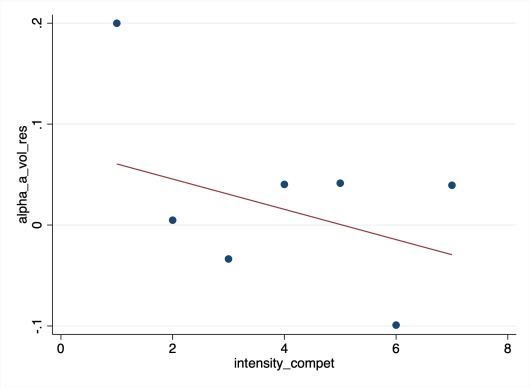
Strategic interaction parameters vs Intensity of competition

Back

- Controlling for **sector fixed effects**
- Nothing changes!
- → Rich within-sector variation.



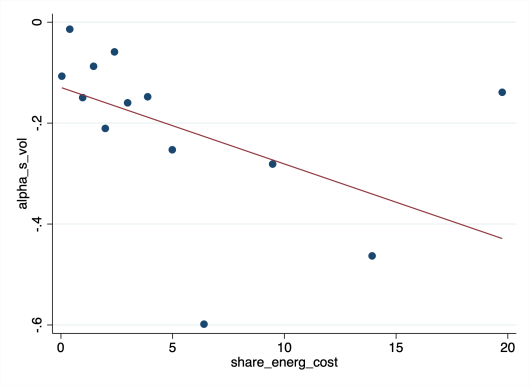
Sectoral strategic parameter for output



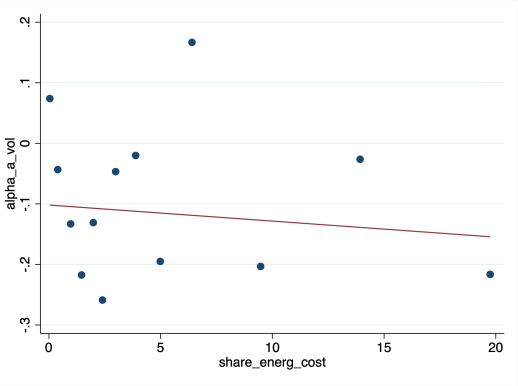
National strategic parameter for output

Strategic interaction parameters vs Energy Intensity

Back



Sectoral strategic parameter for output (α_s) response versus share of energy costs (%)



National strategic parameter for output (α_a) response versus share of energy costs (%)

Regression: $\mathbb{1}\{\alpha_{in}^{s} \neq 0\} = \mathrm{f}(\mathrm{Observables})$ Back

	Spec I	Spec II	Spec III	Spec IV	Spec V
Full-time employees	-0.002	-0.003	-0.003		-0.003
Turnover	**-0.000*****	**-0.000*****	-0.000		-0.000
Export share		**-0.001****	**-0.001***		-0.001
Intense compet. (binary)		**0.156*****	**0.151*****		**0.140*****
Only Swiss compet. (binary)		**-0.059***	-0.058		**-0.065***
Manufacturing–Machine (binary)		-0.042	-0.028		-0.032
Share of energy cost			**0.010*****		**0.010*****
Uses electricity (binary)			-0.092		-0.095
Uses fossil (binary)			**0.065***		0.048
CO_2 emissions			0.000		0.000
CEO, Director, CFO (binary)				-0.033	-0.026
Manager: years in role				0.001	0.001
Manager: male (binary)				**0.103****	**0.093****
Master or PhD (binary)				**-0.102*****	**-0.085****
Survey duration (min)				-0.000	-0.000
Constant	**0.362*****	**0.306*****	**0.301*****	**0.315*****	**0.284*****
Observations	906	890	889	894	876
Adj. R-squared	-0.001	0.023	0.049	0.011	0.053

Regression: $\mathbb{1}\{\alpha_{in}^{a} \neq 0\} = \mathrm{f}(\mathrm{Observables})$ Back

	Spec I	Spec II	Spec III	Spec IV	Spec V
Full-time employees	-0.002	-0.002	-0.004		-0.003
Turnover	**-0.000*****	**-0.000*****	0.000		0.000
Export share		**-0.001***	-0.001		-0.001
Intense compet. (binary)		**0.122*****	**0.113*****		**0.100*****
Only Swiss compet. (binary)		**-0.071****	**-0.070****		**-0.077****
Manufacturing–Machine (binary)		**-0.066****	-0.049		-0.052
Share of energy cost			**0.016*****		**0.016*****
Uses electricity (binary)			-0.115		-0.116
Uses fossil (binary)			**0.083****		**0.064***
CO_2 emissions			-0.001		-0.001
CEO, Director, CFO (binary)				-0.011	0.008
Manager: years in role				0.002	0.001
Manager: male (binary)				**0.117*****	**0.107****
Master or PhD (binary)				**-0.115*****	**-0.092*****
Survey duration (min)				-0.000	-0.000
Constant	**0.336*****	**0.319*****	**0.297*****	**0.255*****	**0.232****
Observations	906	890	889	894	876
Adj. R-squared	-0.001	0.018	0.081	0.017	0.090

Regression: $\mathbb{1}\{\alpha_{in}^{s} \neq 0 \wedge \alpha_{in}^{a} \neq 0\} = \mathrm{f}(\mathrm{Observables})$ Back

	Spec I	Spec II	Spec III	Spec IV	Spec V
Full-time employees	-0.002	-0.002	-0.003		-0.002
Turnover	**-0.000*****	**-0.000*****	0.000		0.000
Export share		**-0.001***	-0.001		-0.001
Intense compet. (binary)		**0.112*****	**0.108*****		**0.097*****
Only Swiss compet. (binary)		-0.050	-0.048		-0.055
Manufacturing–Machine (binary)		-0.042	-0.031		-0.033
Share of energy cost			**0.011*****		**0.011*****
Uses electricity (binary)			-0.042		-0.044
Uses fossil (binary)			0.033		0.018
CO_2 emissions			-0.000		-0.000
CEO, Director, CFO (binary)				-0.007	0.009
Manager: years in role				0.001	0.001
Manager: male (binary)				**0.071***	0.064
Master or PhD (binary)				**-0.101*****	**-0.089*****
Survey duration (min)				-0.000	-0.000
Constant	**0.272*****	**0.241*****	**0.207****	**0.228*****	**0.181***
Observations	906	890	889	894	876
Adj. R-squared	-0.002	0.013	0.040	0.010	0.046

But who are the most strategic? Back

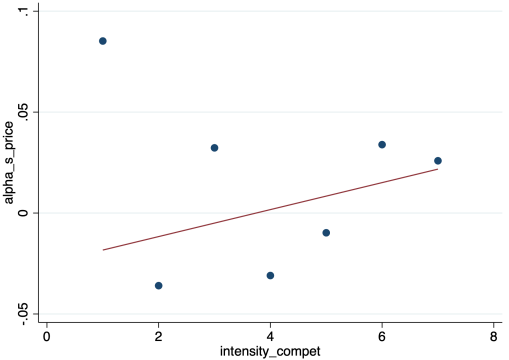
- We define a 0-1 dummy taking the value 1 if the two strategic parameters (α^s,α^a) are jointly at the extremes.

	Spec I	Spec II	Spec III	Spec IV	Spec V
Full-time employees	0.002	0.002	0.002		0.002
Turnover	**-0.000*****	**-0.000*****	-0.000		-0.000
Export share		**-0.001*****	**-0.000*****		**-0.000****
Intensity compet. (binary)		**0.023***	0.022		0.018
Only Swiss compet. (binary)		-0.014	-0.014		-0.017
Manufacturing–Machine (binary)		0.001	0.003		0.001
Share of energy cost			0.001		0.001
Uses electricity (binary)			-0.002		-0.004
Uses fossil (binary)			0.020		0.015
CO_2 emissions			0.000		0.000
CEO, Director, CFO (binary)				-0.005	-0.006
Manager: years in role				0.001	0.001
Manager: male (binary)				**0.042*****	**0.040*****
Master or PhD (binary)				-0.021	-0.019
Survey duration (min)				0.000	0.000
Constant	**0.041*****	**0.036****	0.021	0.005	-0.008

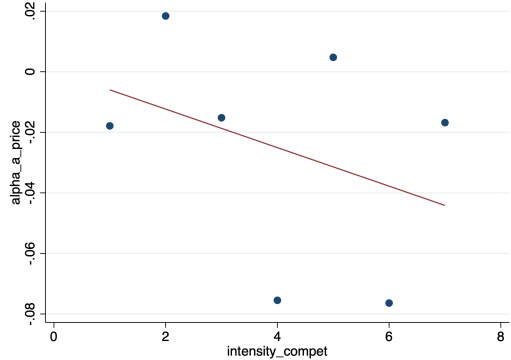
Strategic interaction price parameters vs Intensity of competition

Back

In the price dimension, weaker correlation at the sectoral and aggregate levels, as our model predicts.



Sectoral strategic parameter for price (α_s) response versus self-reported sectoral

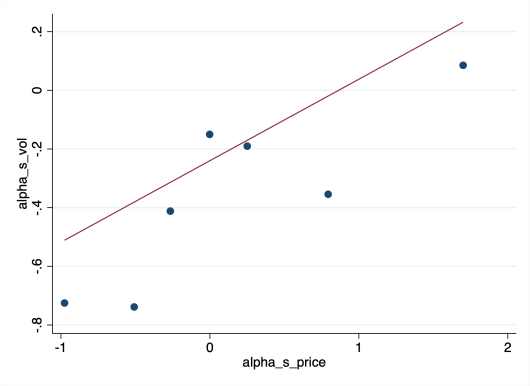


National strategic parameter for price (α_a) response versus self-reported sectoral

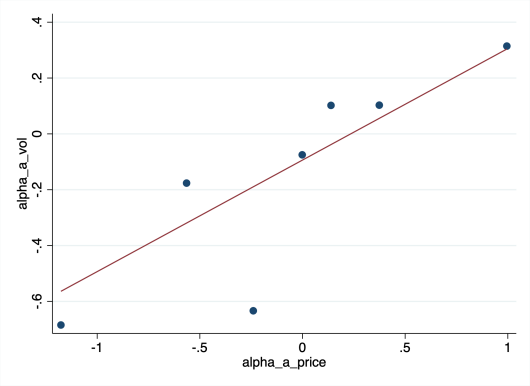
Strategic interaction parameters: price vs output

Back

→ Firm managers who are strategic are also strategic across the output and price dimensions.



Sectoral strategic parameter (α_s) for output vs price

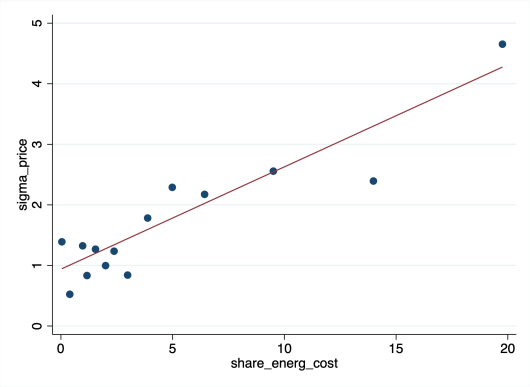


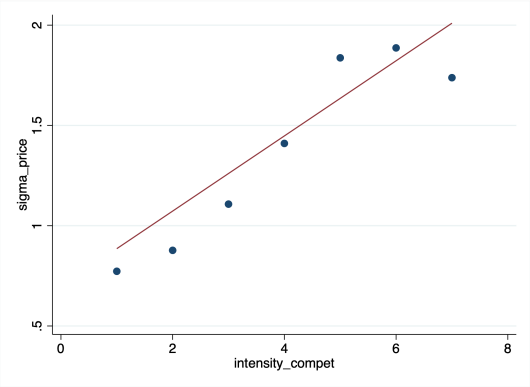
National strategic parameter (α_a) for output vs price

Policy Elasticity (price) vs Energy Intensity and Intensity of Competition

Back

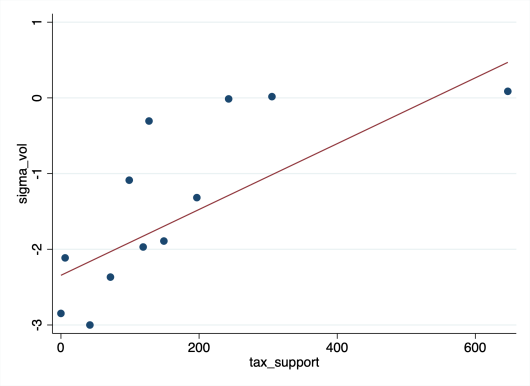
No ex ante prediction on this, but interesting to see:



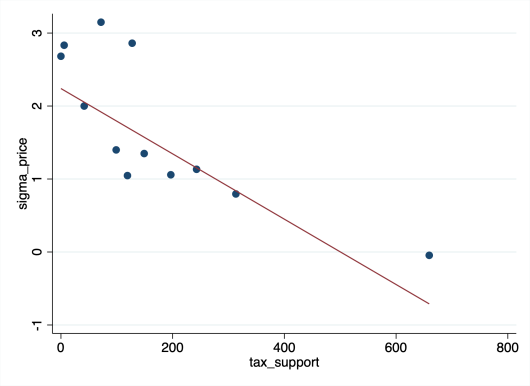


Policy Elasticity (output and price) vs Carbon tax support

Back



Policy Elasticity (σ) for Output Response



Policy Elasticity (σ) for Price Response

Solution structure

$$q_{in} = (A^a_{in}\xi_{in})\tau + (A^s_{in}\xi_{in})\tau_n + (A^f_{in}\xi_{in})\tau_{in}$$

$$\mathbb{E}_{in}(q_n) = (B^a_n\xi_{in})\tau + (B^s_n\xi_{in})\tau_n, \quad \mathbb{E}_{in}(q) = (C^a\xi_{in})\tau.$$

Aggregate tax affects both $\mathbb{E}(q)$ and $\mathbb{E}(q_n)$; sectoral tax affects $\mathbb{E}(q_n)$ only.

Perfect information benchmark

$$q_{in} = -(\sigma_{in} + \tilde{\alpha}^{s}_{in}\sigma_{n} + \tilde{\alpha}^{a}_{in}\sigma)\,\tau^{a} - (\sigma_{in} + \tilde{\alpha}^{s}_{in}\sigma_{n})\,\tau^{s}_{n} - \sigma_{in}\,\tau^{f}_{in}.$$

Complements magnify response to common components τ^{a}, τ^{s}_{n}.

Signals and posteriors

Aggregate prior: $E^a(\sigma^a) = \sigma^a + \bar{e}^a$; Sector prior: $E^s_n(\sigma^s_n) = \sigma^s_n + \bar{e}^s_n$.

- Biases $\bar{e}^a, \bar{e}^s_n$ combine prior mis-spec and signal noise.
- Weights $\tilde{\delta}^a, \tilde{\delta}^s, \tilde{\delta}^x$ pinned by dispersion ratios.

Expectation–realization gaps

$$\bar{E}(q) - q = -\gamma^f(1 - \tilde{\delta}^a)\bar{e}^a, \qquad \bar{E}_n(q_n) - q_n = -\gamma_n^f(1 - \tilde{\delta}^a - \tilde{\delta}^s)(\bar{e}^a + \bar{e}_n^s).$$

Use to diagnose directional belief biases by scope.

Identifying $\tilde{\delta}$'s

Within-sector dispersion ratios:

$$\frac{\mathbb{V}(\mathbb{E}_{in}(q) - \bar{E}_n(q))}{\mathbb{V}(q_{in} - q_n)} = (\tilde{\delta}^a)^2, \quad \frac{\mathbb{V}(\mathbb{E}_{in}(q_n) - \bar{E}_n(q_n))}{\mathbb{V}(q_{in} - q_n)} = (\tilde{\delta}^a + \tilde{\delta}^s)^2.$$

Recovering γ^f

Use sectoral noise vs signal:

$$\frac{\mathbb{V}[\bar{E}_n(q) - \bar{E}(q)]}{\mathbb{V}[\tilde{\delta}^a(q_{in} - q_n)]} = \Big(\frac{\pi^s}{\kappa^f + \pi^f}\Big)^2 \Rightarrow \text{infer noise-to-signal of sector prior,}$$

then

$$\frac{\mathbb{V}[\bar{E}_n(q) - \bar{E}(q)]}{\mathbb{V}[(1-\alpha^s)(\tilde{\delta}^a(q_n - q) - \{\bar{E}_n(q) - \bar{E}(q)\})]} = (\gamma^f)^2\Big(\frac{\pi^s}{\kappa^s + \pi^s}\Big)^2.$$

Profit-based support

Linearized: $\Pi(\tau, \theta_{in}) \approx \Pi(\tau_0, \theta_{in}) + \tilde{\Pi}(\theta_{in})(\tau - \tau_0)$. With preference term $f(\tau) = \lambda^1 \tau - \frac{\lambda^2}{2}\tau^2$, FOC gives

$$\tau_{in}^{opt} = \frac{\tilde{\Pi}(\theta_{in}) + \lambda^1}{\lambda^2}.$$

Identify λ^2 using Q1/Q2 shift and scenario-specific $\tilde{\Pi}$.

Experimenter demand effects

If $\widehat{\tilde{\Pi}} = \tilde{\Pi} + \alpha^{\pi}$ and $\widehat{\tau^{opt}} = \tau^{opt} + \alpha^{\tau}$:

$$\widehat{\lambda^2} = \frac{\tilde{\Pi}(2) + \alpha^{\pi}}{\tau^{opt}(1) - \tau^{opt}(2)}.$$

Bias in $\tilde{\Pi}$ matters; bias in τ^{opt} cancels.

Plan: calibrate/measure α^{π} via embedded vignette.

Questionnaire wording — sector vs aggregate

- Define "your sector" precisely (NACE-2) in the survey header.
- For aggregate questions, remind: "all firms in Switzerland across all sectors".

Attrition detail

CONSORT-style diagram (contacted $\rightarrow$ started $\rightarrow$ passed attention $\rightarrow$ completed).

[TODO: Insert numbers once fielded]

Heterogeneity cuts (backup)

- By energy intensity deciles.
- By exposure to international competition.
- By firm size (employment bins).

Notation table (backup)

q_{in}	firm output (log deviation)
q_n, q	sector and aggregate outputs
α^s, α^a	strategic interaction parameters
σ_{in}	climate-related marginal-cost elasticity
τ_{in}	carbon tax component (firm/sector/agg)
$\tilde{\delta}^a, \tilde{\delta}^s, \tilde{\delta}^x$	signal weights
κ, π	precisions (fundamental/signal)