Strategic Managers with Noisy Beliefs: Evidence from Carbon Pricing

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Abstract

We study how strategic interactions and noisy beliefs shape managers' expectations about the impacts of a given macroeconomic shock in a general equilibrium setting. We propose a novel identification strategy based on a survey instrument designed to recover primitives governing firm managers' strategic interactions and beliefs. We apply our approach to the context of carbon pricing reform in Switzerland and find that a CHF 100 per ton carbon tax increase is expected to reduce output by 1.14% over a short- to medium-run horizon; that firms hold overly pessimistic beliefs about the economy-wide impact of carbon pricing; and that quantity setting tends to exhibit strategic substitutabilities, dampening the impact of noisy beliefs. Information counterfactuals show that removing the excess pessimism from aggregate public signals would reduce the expected output decline by about 40%, and by 30% when we take strategic substitutabilities into account.

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1 Introduction

This paper examines how strategic interactions and noisy beliefs shape managers' expectations about the impacts of a given macroeconomic shock (e.g. a technology shock, an energy price shock, or a policy reform). The central premise is simple. A manager contemplating the impacts of a macroeconomic shock must form expectations not only about the direct impact on their own firm, but also about the general-equilibrium response of competitors and demand conditions. These general-equilibrium effects can be summarized as a strategic game in which firms' optimal quantity choices depend, in part, on beliefs about others' choices. As a consequence, the expected impacts of a shock are jointly determined by (i) beliefs about the firm's direct shock elasticity, (ii) beliefs about other firms' elasticity, and (iii) the intensity and sign of strategic interactions. Beliefs about the economy-wide elasticity can influence firms' beliefs about their own elasticity but also about other firms' elasticity. In turn, strategic interactions shape how managers' pessimistic or optimistic beliefs about the economy translate into firm-level expectations. Whether equilibrium outcomes are strategic complements or substitutes, strategic interactions amplify or dampen noisy beliefs, respectively.

Empirically, assessing these mechanisms through ex-ante analyses based solely on observational data poses several challenges. It typically requires strong identifying variation, rich firm-level data (often released with substantial lags), and structural assumptions about production technologies and market structure. As a result, it is often difficult, if not impossible, to provide timely evidence to policymakers about the expected impacts of an upcoming change in economic conditions or a policy reform. We propose an approach that aims to circumvent these challenges. We develop a novel survey-based identification strategy designed to recover firm-specific primitives governing firm managers' strategic interactions and noisy beliefs in a general equilibrium setting. Crucially, our approach yields a set of sufficient statistics that requires minimal assumptions about the production structure of the economy, allowing us to conduct counterfactual policy simulations.

We apply our approach to the context of carbon pricing reform in Switzerland, a timely and highly debated topic. Our identification strategy to recover firm-specific primitives is built around three scenarios that vary the scope of a carbon tax reform. Namely, managers need to form expectations about the impacts of an economy-wide, sector-wide, and firm-specific carbon pricing scheme over a short-

to medium-run horizon (3 years). In addition, we need to elicit managers' own planned production impact, and, for some but not all scenarios, expectation of sectoral production impact, and expectation of aggregate production impact (with natural restrictions for the sectoral and firm-specific scenarios).[1] Our design allows us to identify: (i) the relevant tax semi-elasticity (beliefs about the quantity impact of carbon pricing); (ii) strategic interaction parameters capturing how a firm's own quantity choices respond to expected sectoral and aggregate changes; and (iii) noisy beliefs about the policy's sectoral and aggregate production impacts.

Our main findings can be summarized as follows. First, the survey-based identification strategy is feasible in practice: managers respond meaningfully to the scenarios, allowing us to recover firm-specific primitives. Second, managers perceive sizable output costs of carbon taxation: in our baseline scenario, a CHF 100/ton increase in the carbon tax is associated with an expected decline in aggregate output of around 1.14% after three years. Third, we find evidence of *overly pessimistic beliefs* about how the rest of the economy responds to the tax, compared to the average firms' beliefs about their own impact. This evidence suggests that firms receive excessively negative signals about the aggregate cost elasticity. Last, but not least, we find strong strategic substitutabilities in quantity setting, especially at the sectoral level: most managers expect that stronger activity by other firms in their sector lowers their own optimal production response, consistent with competitive interactions within sectors. In turn, strategic substitutabilities *dampen* the impact of their pessimistic beliefs about carbon pricing on their own outcomes.

Motivated by this evidence, we enrich the model with an information structure where firms observe some private signal of their own elasticity, and public signals about the aggregate and sectoral elasticity that can be driven respectively by aggregate and sectoral noise. We show that firms' overly pessimistic beliefs about the aggregate effect of the carbon tax come from the public signal on the aggregate elasticity that is too pessimistic. This pessimistic public signal leads firms to be also excessively pessimistic about their own elasticity. We use our data to identify the parameters that characterize firms' prior beliefs. Our estimation of prior beliefs,

[1] Although this is not formally required for the identification, we also provide respondents with a firm-specific, noisy but unbiased signal about the implied tax burden based on self-reported energy expenditure shares and Swiss-specific emissions coefficients. This signal is consistent with our assumed information structure and helps managers map a CHF/ton CO_2 policy into firm-level costs.

then, allows us to perform *information counterfactuals* that quantify how firms' intended responses would change if aggregate and sectoral noise were removed while keeping the underlying information structure otherwise unchanged. We find that removing noise in the aggregate public signal would reduce the expected fall in the firms' output by 30% on average. If we ignore the dampening effect of strategic substitutabilities, that number increases to 40%. The aggregate public signal, which we can interpret as the general public "sentiment" on the costs of decarbonizing, contributes in a non-negligible way to firms' beliefs about the impact of carbon pricing.

Our paper contributes to a growing literature that uses survey data to recover firms' structural primitives that are otherwise difficult to identify from observational data. For instance, Keiller et al. (2024) demonstrate how carefully designed survey instruments can be used to estimate production-function parameters and adjustment frictions at the firm level. Coibion et al. (2021) show how firms' expectations can be exploited to study strategic interactions in price setting, highlighting the role of higher-order beliefs in firms' decisions. Closest to our approach, Afrouzi (2024) shows that survey scenarios can identify strategic complementarities in price setting by eliciting higher-order beliefs. We build on and extend this method by designing survey scenarios that vary the scope of a policy shock to jointly identify firm-specific cost elasticities and strategic interaction parameters.

Our methodology also provides results that relate to a large literature on strategic interactions in quantity setting. Standard models of Cournot competition imply strategic substitutability (Bulow et al., 1985; Vives, 1999), while macroeconomic models featuring aggregate demand externalities or network production can generate complementarities (Cooper and John, 1988; Benhabib and Farmer, 1994; Farmer, 1999). These complementarities typically amplify the impact of noisy information (Benhabib et al., 2015; Angeletos and La'O, 2013).[2] Existing work assumes the sign of strategic interactions. We provide direct survey-based firm-level evidence that quantity setting is characterized by strategic substitutability, especially at the sectoral and, to a lesser extent, at the aggregate level. We are the first to document this "zero-sum thinking" at the firm level. As a consequence, pessimistic beliefs about aggregate responses to carbon pricing dampen–rather

[2]Strategic interaction parameters also shape the use of information, with complementarities leading to an under-use of private signals and substitutabilities leading to an under-use of public information (Morris and Shin, 2002; Angeletos and Pavan, 2007).

than amplify–firms' own pessimistic responses. This mechanism highlights a previously undocumented channel through which information frictions interact with competitive forces to shape firms' expectations about policy reforms.

We also contribute to an emerging literature that shows that support for carbon pricing is shaped by (mis-)perceptions about its costs, distributional incidence, and macroeconomic effects, and that correcting these beliefs can substantially increase policy support (Carattini et al., 2018; Beiser-McGrath and Bernauer, 2019; Kallbekken and Sælen, 2011; Andre et al., 2024). While this work focuses primarily on households, much less is known about firms' beliefs about carbon pricing and how these beliefs interact with strategic considerations. Our paper contributes by measuring firm-level expectations about carbon pricing and showing how aggregate belief distortions shape firms' expected real responses.

Finally, our paper contributes to a growing literature that uses surveys of firm managers to study the economic and political economy implications of environmental policies. Martin et al. (2014) show that firms' perceived relocation risks under carbon regulation shape their responses and policy positions. Hensel et al. (2024) demonstrate that carbon pricing affects firms' and households' inflation expectations, pointing to a potentially important macroeconomic expectations channel. More broadly, OECD (2016) has emphasized the value of firm surveys as a tool to study environmental policies when administrative or balance-sheet data are unavailable or released with long lags. Our contribution is to use survey-based scenarios to go beyond eliciting firm managers' opinions and expectations about future environmental policies. Our approach allows us to estimate structural parameters that permit us to conduct counterfactual policy simulations about the effects of carbon pricing along multiple margins and at different levels of aggregation. This approach allows us not only to document firms' perceived costs of carbon pricing but also to quantify how aggregate beliefs and strategic interactions shape firms' intended responses, providing a bridge between micro-level survey evidence and general-equilibrium analyses of environmental policy.

2 The Model

We lay out a simple one-period model to illustrate the impact of carbon pricing on firms' decisions. We introduce carbon policies as a carbon tax. Firms know

the tax, but they decide how much to produce before they know how the tax impacts their costs. Firms can reduce their carbon emissions through a carbon abatement technology or by reducing production (equivalently, labor). We show that the equilibrium decisions of the firms boil down to a game between firms with strategic interactions. We then pinpoint the parameters that we need to identify, and design an identification strategy based on a firm questionnaire.

2.1 Representative household

There is a representative household with utility

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

where C is a consumption bundle that depends on the consumption of imperfectly substitutable goods from different sectors: $C = \left(\sum_n C_n^{\frac{1-\epsilon^c}{\epsilon^c}}\right)^{\frac{\epsilon^c}{1-\epsilon^c}}$, where each sector-specific consumption C_n is itself a bundle of different consumption varieties C_{in} within the sector $C_n = \left(\sum_i C_{in}^{\frac{1-\rho^c}{\rho^c}}\right)^{\frac{\rho^c}{1-\rho^c}}$. L is a function of the labor supplied to the different sectors: $L = (\sum_n L_n^{1+\chi})^{\frac{1}{1+\chi}}$, where each sector-specific labor supply L_n is a function of the labor supplied to the firms producing individual varieties: $L_n = \left(\sum_i L_{in}^{1+\psi}\right)^{\frac{1}{1+\psi}}$. The budget constraint faced by the household is

$$\sum_n \sum_i P_{in} C_{in} = \sum_n \sum_i W_{in} L_{in} \tag{2}$$

where P_{in} is the price of variety i in sector n, W_{in} is the wage paid by the firm producing good i in sector n.

The household's optimal choices imply

$$\phi^{-1} C^{\gamma} L^{\eta} = \frac{W}{P} \tag{3}$$

$$C_n = C \left(\frac{P_n}{P} \right)^{-\epsilon^c} \tag{4}$$

$$C_{in} = C_n \left(\frac{P_{in}}{P_n} \right)^{-\rho^c} \tag{5}$$

$$L_n = L \left(\frac{W_n}{W} \right)^{1/\chi} \tag{6}$$

$$L_{in} = L_n \left(\frac{W_{in}}{W_n} \right)^{1/\psi} \tag{7}$$

$$\tag{8}$$

where P, P_n, W and W_n are price aggregators defined as $P = \left(\sum_n P_n^{1-\epsilon^c}\right)^{\frac{1}{1-\epsilon^c}}$, $P_n = \left(\sum_i P_{in}^{1-\rho^c}\right)^{\frac{1}{1-\rho^c}}$, $W = \left(\sum_n W_n^{1+1/\chi}\right)^{\frac{1}{1+1/\chi}}$, and $W_n = \left(\sum_i W_{in}^{1+1/\psi}\right)^{\frac{1}{1+1/\psi}}$.

2.2 Firms

Consider firm i in sector n. Its production function is

$$Q_{in} = [(1 + \beta_{in}) L_{in}]^{\frac{1}{1+\beta_{in}}} \tag{9}$$

where $\beta_{in} > 0$ is a firm-specific return-to-scale parameter.

We assume for simplicity that carbon emissions are proportional to output, so that

$$E_{in} = \phi_{in} Q_{in} \tag{10}$$

ϕ_{in} is the firm-specific carbon-intensity of production. One can think of this carbon-intensity as arising for instance from the firm-specific energy mix that combines dirty and green energy sources. This parameter is endogenous, as firms can lower their carbon intensity if they pay the abatement cost

$$\frac{\kappa_{in}}{2} \left(1 - \frac{\phi_{in}}{\bar{\phi}_{in}} \right)^2 Q_{in}.$$

$\bar{\phi}_{in}$ is the business-as-usual carbon intensity, that is, the carbon-intensity that would hold in the absence of abatement effort. κ_{in} is a parameter that reflects

how costly it is for that firm to decarbonize its production. This cost can be thought of for instance as the cost of switching from a brown energy source to a green energy source, which requires some investment from the firm. The cost is quadratic in the carbon intensity and is proportional to total production. Firms are imperfectly informed about both $\bar{\phi}_{in}$ and κ_{in}, which means that they ignore both their business-as-usual carbon intensity and how much it would cost them to decrease it. The firm faces a tax tax_{in} per unit of carbon emission.

Timing and information At the beginning of the period, the firm decides how much labor to hire (equivalently, how much to produce). At that stage, the firm knows its own tax tax_{in} and the distribution of the tax within its own sector and in the firms' population, as well as the distribution of the preference and technolopgy parameters. However, the firm does not observes the business-as-usual carbon-intensity $\bar{\phi}_{in}$ and the cost parameter κ_{in}, nor their distribution within their sector or in the firms' population. Prices and abatement efforts are set at the end of period, after the firm learns about $\bar{\phi}_{in}$ and κ_{in} and their distribution.

Firm's decisions The firm behaves monopolistically within its sector. Its expected profits are

$$E_{in}\Pi_{in} = E_{in}\left\{P_{in}Q_{in} - W_{in}L_{in} - tax_{in}E_{in} - \frac{\kappa_{in}}{2}\left(1 - \frac{\phi_{in}}{\bar{\phi}_{in}}\right)^2 Q_{in}\right\} \tag{11}$$

For a given tax tax_{in}, the firm maximizes its profits (11) with respect to production Q_{in} and abatement effort ϕ_{in}, subject to the demand for its product (5), its production technology (9) and its emission technology (10).

According to our timing assumption, firms know the parameters of the abatement technology when they decide their abatement effort ϕ_{in}. As a result, the marginal abatement cost must be equal to the carbon tax:

$$tax_{in} = \frac{\kappa_{in}}{\bar{\phi}_{in}}\left(1 - \frac{\phi_{in}}{\bar{\phi}_{in}}\right) \tag{12}$$

When deciding their production Q_{in}, the firms do not know the parameters of the abatement technology yet. Taking into account the abatement efforts of the firm, the optimal level of production is then set so that the markup is constant in expectations:

$$E_{in}(P_{in}) = E_{in}\left\{\frac{\rho^c}{\rho^c - 1}\left(W_{in}Q_{in}^{\beta_{in}} + tax_{in}\bar{\phi}_{in}\left(1 - \frac{tax_{in}\bar{\phi}_{in}}{2\kappa_{in}}\right)\right)\right\} \tag{13}$$

2.3 Equilibrium

The consumption of variety i in sector n should be equal to the production of variety i in sector n:

$$C_{in} = Q_{in} \tag{14}$$

2.4 Strategic interactions in quantity setting

We have assumed that the firm has to make quantity decisions before the uncertainty on decarbonization parameters is resolved, while prices fully adjust after. This assumption will give us strategic interactions in quantity setting.

We log-linearize the model around the firm-specific baseline tax level $tax_{in} = \overline{tax}_{in}$, that we assume to be close to zero. We denote the log-deviations from the baseline by lower-case letters and denote by $\tau_{in} = tax_{in} - \overline{tax}_{in}$ the deviation of the tax from its baseline level, in euros say.

The firm must then set its production so that her markup does not deviate from its optimal level in expectations, and the price follows (13). The firm behavior can be approximated as follows:

$$E_{in}\left\{p_{in} - (w_{in} + \beta_{in} q_{in}) - \tilde{\sigma}_{in}\tau_{in}\right\} = 0 \tag{15}$$

where $\tilde{\sigma}_{in} = \frac{\bar{\phi}_{in}}{\bar{W}_{in}\bar{Q}_{in}^{\beta_{in}}}$ is the semi-elasticity of the marginal cost to τ_{in}, with $\bar{W}_{in}$, $\bar{Q}_{in}$ the baseline wage and output. Output increases the marginal cost through a decreasing-return-to-scale channel, which depends on the curvature of the production function parameter β_{in}. The carbon tax τ_{in} increases the marginal cost because it works as a tax on production.

Given our timing assumptions, the firm makes production decisions before observing market prices and before observing abatement cost parameters. But, to make a decision on output, the firm must infer the potential drivers of the inverse of the product wage $p_{in} - w_{in}$, and the price tax-elasticity $\tilde{\sigma}_{in}$, as implied by Equation (16):

$$q_{in} = \frac{1}{\beta_{in}}\left\{E_{in}(p_{in} - w_{in}) - E_{in}(\tilde{\sigma}_{in})\tau_{in}\right\} \tag{16}$$

The product wage can be decomposed as follows:

$$p_{in} - w_{in} = (p_{in} - p_n) + (p_n - p) - (w_{in} - w_n) - (w_n - w) - (w - p) \tag{17}$$

It depends on the variety's relative price, within its sector, and on the relative price of the sector within the aggregate economy. These will depend respectively on the supply of the variety relative to the sectoral supply, and on the supply of the sector relative to the aggregate supply. The product wage also depends on the wage, which has an individual, sectoral and aggregate component. These will depend respectively on the individual, sectoral and aggregate input demand.

Using the optimal output (16) and the product wage expression (17), and combining with the consumption demand and labor supply equations (3)-(7), the equilibrium relations (14), and the production function (9), we obtain the following log-linear approximation of the optimal individual output:

$$q_{in} = \alpha^a_{in} E_{in}(q) + \alpha^s_{in} E_{in}(q_n) - E_{in}(\sigma_{in})\tau_{in} + \omega \tag{18}$$

with $\sigma_{in} = \tilde{\sigma}_{in}/[\psi(1+\beta_{in}) + (\rho^c)^{-1} + \beta_{in}]$ and where α^s_{in} and α^a_{in} are the strategic complementarity parameters at the sectoral and aggregate levels:

$$\alpha^s_{in} = \frac{(\psi-\chi)(1+\beta_n)+(\rho^c)^{-1}-(\epsilon^c)^{-1}}{(\psi(1+\beta_n)+\beta_{in})+(\rho^c)^{-1}}$$
$$\alpha^a_{in} = \frac{(\chi-\eta)(1+\beta)-\gamma+(\epsilon^c)^{-1}}{(\psi(1+\beta_{in})+\beta_{in})+(\rho^c)^{-1}}$$

where β_n and β are respectively the sectoral and economy-wide averages of β_{in}. The constant term $\omega = [(\psi-\chi)Cov(\beta_{in}-\beta_n, q_{in}-q_n) + \chi Cov(\beta_n-\beta, q_n-q)]$ is negligible under some mild assumptions, as we will show later.

Note that there are two strategic interaction parameters: α^a describes strategic interactions between sectors, while α^s describes strategic interactions within a sector. These parameters depend on the degree of competition in the product markets (governed by the elasticities of substitution ϵ^c and ρ^c) and in the input markets (governed by γ, η, ψ and χ). Moreover, the strength of the decreasing marginal returns (governed by β) also matters. Since the elasticity of substitution between sectors ϵ^c tends to be small ($\epsilon^c < 1$), α^a is typically positive, which means strategic complementarities between sectors are more likely. On the other hand, since the elasticity of substitution within sectors, i.e., across varieties, tends to be large ($\rho^c > 1$), α^s is typically negative, reflecting strategic substitutabilities between competing firms in the same sector.

2.5 Information structure

So far, our assumptions about the information structure were minimal. We simply assume that the carbon taxes τ_{in} and strategic interaction parameters α^a_{in} and α^s_{in}

are known to all firms, but firms are uncertain about the tax-related elasticities σ_{in}. We now formalize the information structure about σ_{in}.

Let σ_{in}^f, σ_n^s and σ^a be some firm-level, sectoral and aggregate stochastic components of σ_{in}:

$$\sigma_{in} = \sigma^a + \sigma_n^s + \sigma_{in}^f$$

We assume that σ^a, σ_n^s and σ_{in}^f are Gaussian and mutually independent: $\sigma^a \sim \mathcal{N}(E^a(\sigma^a), \pi_a^{-1})$, $\sigma_n^s \sim \mathcal{N}(E_n^s(\sigma_n^s), \pi_s^{-1})$, $\sigma_{in}^f \sim \mathcal{N}(0, \kappa_f^{-1})$, where the sectoral average of σ_{in}^f and the economy-wide average of σ_n^s are equal to zero. $E^a(\sigma^a)$ and $E_n^s(\sigma_n^s)$ are respectively the common priors about the economy-wide and sectoral components σ^a and σ_n^s, and π_a and π_s are the precisions of these priors. This constitutes the public information about σ^a and σ_n^s.

These aggregate and sectoral priors can be decomposed into the fundamental and some noise:

$$\begin{aligned} E^a(\sigma^a) &= \sigma^a + e^a \\ E_n^s(\sigma_n^s) &= \sigma_n^s + e_n^s \end{aligned}$$

with e^a and e_n^s follow the distributions $e^a \sim N(0, (\pi^a)^{-1})$ and $e_n^s \sim N(0, (\pi_n^s)^{-1})$.

We additionally assume that, before making a production decision, firm i observes an individual signal on the firm-level elasticity σ_{in},

$$s_{in}^f = \sigma_{in} + e_{in}^f = \sigma^a + \sigma_n^s + \sigma_{in}^f + e_{in}^f$$

with $e_{in}^f \sim N(0, (\pi^f)^{-1})$ averaging out to zero at the sectoral and aggregate level. It is natural to assume that firms observe their elasticity σ_{in} imperfectly, but that there is no systematic aggregate or sectoral noise in that signal. Conditional on this private signal, some firms may overestimate or underestimate their elasticity, but on average they observe it correctly.

2.6 Model solution

The information structure defined in the previous sub-section, and the firm's optimal decision (18), are enough to derive the equilibrium quantities chosen by the firm.

In order to further characterize the solution, we make the following assumption:

Assumption 1 (Orders of magnitude) *Define $\alpha_{in} = (\alpha_{in}^a, \alpha_{in}^s)'$. Let α_n and α be the sectoral and economy-wide average of α_{in}. We assume that $|(\alpha_{in} - \alpha_n)(\alpha_{in} - \alpha_n)'|$ is small compared to $|\alpha_n|$, and $|(\alpha_n - \alpha)(\alpha_n - \alpha)'|$ is small compared to $|\alpha|$.*

We also make some independence assumption, namely, that firm-specific shocks and taxes are independent from firm-specific parameters and that sector-specific shocks and taxes are independent from sector-specific parameters (see Assumption 2 in Appendix A). These two assumptions ensure that any linear solution at the firm-level involving firm-level parameters can be linearly aggregated at the sector and aggregate level using sectoral and aggregate parameters. We also make some invertibility assumption that ensures the existence of a unique linear solution (see Assumption 3 in Appendix A).

Proposition 1 *Under Assumptions 1, 2 and 3 (see Appendix A for the latter two), we can show that* $\omega = 0$*, and that the equilibrium solution for* q_{in} *is of the form*

$$q_{in} = \mathcal{Q}^{(1)}(\Theta_{in}, S_{in})\tau + \mathcal{Q}^{(2)}(\Theta_{in}, S_{in})(\tau_n - \tau) + \mathcal{Q}^{(3)}(\Theta_{in}, S_{in})(\tau_{in} - \tau_n) \tag{19}$$

where τ *and* τ_n *are the economy-wide and sectoral averages of* τ_{in} *and* $\Theta_{in} = \{\theta^{\alpha}, \theta^{info}\}$*, with* $\theta^{\alpha} = \{\alpha_{in}, \alpha_n, \alpha\}$ *the set of strategic interaction parameters,* $\theta^{info} = \{\pi^a, \pi^s, \pi^f, \kappa^f\}$ *the set of information parameters, and* $S_{in} = (E^a(\sigma^a), E^s_n(\sigma^s_n), s^f_{in})'$ *the vector of signals. More specifically, the solution is linear in the signals, as* $\mathcal{Q}^{(j)}(\Theta_{in}, S_{in}) = A^{(j)}(\Theta_{in})S_{in}$*, for* $j = 1, 2, 3$*.*

Additionally, the equilibrium solution for firm's expectations is of the form

$$\begin{aligned} E_{in}(q_n) &= \mathcal{Q}^{s(1)}(\Theta_{in}, S_{in})\tau + \mathcal{Q}^{s(2)}(\Theta_{in}, S_{in})(\tau_n - \tau) \\ E_{in}(q) &= \mathcal{Q}^{a(1)}(\Theta_{in}, S_{in})\tau \end{aligned} \tag{20}$$

which is also linear in the signals: $\mathcal{Q}^{k(j)}(\Theta_{in}, S_{in}) = A^{k(j)}(\Theta_{in})S_{in}$*, for* $(j, k) = (1, s), (2, s), (1, a)$*.*

See proof in Appendix A. This proposition has two important implications. First, the proposition shows that the equilibrium output and expectations depend only on the strategic interaction parameters, the information parameters, and the signals. To perform counterfactual analysis, we thus need to identify these parameters.

Second, while the aggregate tax τ affects not only the expectation about the whole economy, but also the expectation about the sector, the sector-specific tax $\tau_n - \tau$ affects only the expectation about the sector. Besides, the firm-specific tax $\tau_{in} - \tau_n$ does not affect the expected aggregate and sectoral production, while it

affects individual production. This result is quite general. It hinges only on the linearity of the model and on the fact that the tax is common knowledge. But it will be important for our identification strategy.

2.6.1 Noisy beliefs and strategic interactions

We define "noisy beliefs" as a situation where firms have erroneous expectation about the sectoral and aggregate elasticities on average, that is, $\bar{E}_n(\sigma_n) \neq \sigma_n$ or $\bar{E}(\sigma) \neq \sigma$, where $\bar{E}_n(\sigma_n)$ is the sectoral average of $E_{in}(\sigma_n)$ and $\bar{E}(\sigma)$ is the economy-wide average. As we will see, this implies that firms are also, on average, mistaken about their own elasticity, that is, $\bar{E}(\sigma_{in}) \neq \sigma$. It also leads to situations where $\bar{E}_n(q_n) \neq q_n$, $\bar{E}_n(q) \neq q$, $\bar{E}(q_n) \neq q_n$ or $\bar{E}(q) \neq q$, that is, where the average responses about aggregate or sectoral expected output differ from the actual aggregate or sectoral outputs, computed as the aggregate or sectoral averages of the firms' responses about their own production.

This has consequences on the expected impact of the carbon tax, since we can write Equation (18) as

$$q_{in} = \alpha^a_{in}\left[q + (E_{in}(q) - q)\right] + \alpha^s_{in}\left[q_n + (E_{in}(q_n) - q_n)\right] - \left[\sigma_{in} + (E_{in}(\sigma_{in}) - \sigma_{in})\right]\tau_{in} \tag{21}$$

Taking the economy-wide averages, we obtain

$$q = \frac{1}{1-\alpha^a-\alpha^s}\left[\alpha^a\left(\bar{E}(q) - q\right) + \alpha^s\left(\bar{E}(q_n) - q\right) - \left(\bar{E}(\sigma_{in}) - \sigma^a\right)\tau - \sigma^a\tau\right] \tag{22}$$

An aggregate error on the elasticity $\bar{E}(\sigma_{in}) - \sigma^a$, but also on aggregate production $\bar{E}(q) - q$, or on sectoral production $\bar{E}(q_n) - q$, affects the firms' response. The impact of these errors depends on the strategic interaction parameters α^a and α^s.

The purpose of the following section is to identify the relevant statistics to perform "information counterfactuals". In particular, we would like to estimate the impact of the errors on aggregate output. More specificaly, the experiment we would like to conduct is to remove the sectoral and aggregate noise:

Definition 2 (Removing noise) *Removing noise consists in changing the information set of the firms so that there is no aggregate or sectoral noise, that is, replacing S_{in} with $\tilde{S}_{in} = (\sigma^a, \sigma^s_n, s^f_{in})'$, but without changing the information structure.*

In this experiment, we assume that the aggregate and sectoral signals are without noise, but firms still consider these signals as potentially biased. This is equivalent to setting $e^a = e^s_n = 0$. We show below that this amounts to removing the aggregate and sectoral errors about aggregate and sectoral output.

3 Identification Strategy

Here we discuss how to identify the firms' beliefs about the elasticities $E_{in}(\sigma_{in})$ and the degree of strategic complementarities α^a_{in} and α^s_{in}. We then discuss how we can go further and identify the firms' information about the firm-level, sectoral and aggregate elasticity, as well as the true aggregate elasticity σ^a.

3.1 Strategic interactions and firm-level elasticities

Suppose that we want to identify the firms' beliefs about the elasticities $E_{in}(\sigma_{in})$ and the degree of strategic complementarities α^a_{in} and α^s_{in}, or in other words, the vector $(\alpha^a_{in}, \alpha^s_{in}, E_{in}(\sigma_{in}))'$. Equation (18) suggests that this is possible if we generate variations in policies, firm-level quantities, and firm-level expectations about aggregate and sectoral quantities, namely in the vector $(q_{in}, E_{in}(q), E_{in}(q_n), \tau_{in})'$. On the other hand, Proposition 1 suggests that, conditional on the parameters and signals (Θ_{in} and S_{in}), variations in $(q_{in}, E_{in}(q), E_{in}(q_n))'$ are driven by variations in $(\tau, \tau_n - \tau, \tau_{in} - \tau_n)'$. We thus can produce observations of $(q_{in}, E_{in}(q), E_{in}(q_n), \tau_{in})'$ through survey questions where firms are provided with different scenarios on $(\tau, \tau_n - \tau, \tau_{in} - \tau_n)'$.

Because there are three parameters to identify, it is enough to generate three independent observations of the vector $(q_{in}, E_{in}(q), E_{in}(q_n), \tau_{in})'$. In that case, we can write

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

where the 1, 2 and 3 subscripts correspond to three distinct scenarios. Provided

that P_{in} is invertible, we can recover $(\alpha_{in}^a, \alpha_{in}^s, E_{in}(\sigma_{in}))'$ as follows:

$$\begin{pmatrix} \alpha_{in}^a \\ \alpha_{in}^s \\ E_{in}(\sigma_{in}) \end{pmatrix} = P_{in}^{-1} \begin{pmatrix} q_{in,1} \\ q_{in,2} \\ q_{in,3} \end{pmatrix}$$

Therefore, the parameters are identified if and only if P_{in} is invertible.

According to Proposition 1, we can write P_{in} as the product of two matrices:

$$P_{in} = \underbrace{\begin{pmatrix} \tau_1 & \tau_{n,1} - \tau_1 & \tau_{in,1} - \tau_{n,1} \\ \tau_2 & \tau_{n,2} - \tau_2 & \tau_{in,2} - \tau_{n,2} \\ \tau_3 & \tau_{n,3} - \tau_3 & \tau_{in,3} - \tau_{n,3} \end{pmatrix}}_{T_{in}} \underbrace{\begin{pmatrix} \mathcal{Q}^{a(1)} & \mathcal{Q}^{s(1)} & 1 \\ 0 & \mathcal{Q}^{s(2)} & 1 \\ 0 & 0 & 1 \end{pmatrix}}_{D_{in}}$$

T_{in} is the set of alternative scenarios on the different tax components (aggregate, sector-specific and firm-specific), and D_{in} is the set of elasticities of expected aggregate and sectoral quantities, and of the individual tax to these tax components. P_{in} is invertible if and only if both T_{in} and D_{in} are invertible. D_{in} is an upper-triangular matrix invertible as long as $\mathcal{Q}^{a(1)}$ and $\mathcal{Q}^{s(2)}$ are different from zero. This is a mild assumption. Intuitively, this requires that firms believe that an economy-wide tax will have some impact on the economy in general and that a sectoral tax will have an impact on their sector.

T_{in} describes the set of tax scenarios that are provided to firms. It is invertible if we set for instance:

$$T_{in} = \begin{pmatrix} x & 0 & 0 \\ 0 & x & 0 \\ 0 & 0 & x \end{pmatrix}$$

τ_{in} is defined as the deviation of the tax from its baseline level. This amounts to presenting firms with the following three scenarios: (1) an x increase in the economy-wide tax; (2) an x increase in the tax in the sector where the firm operates (but not in the rest of the economy); (3) an x increase in the tax that applies to the firm (but not to the rest of the economy, including the sector where the firm operates). In each of these scenarios, we ask firms about their own production, the production in their sector, and aggregate production.

Note that with these scenarios, we ensure that P_{in} is upper-triangular, with

non-zero diagonal elements:

$$P_{in} = \begin{pmatrix} E_{in}(q_1) & E_{in}(q_{n,1}) & x \\ 0 & E_{in}(q_{n,2}) & x \\ 0 & 0 & x \end{pmatrix} \tag{23}$$

which ensures invertibility.

Discussion What is key here? We need (i) three independent scenarios on the different tax levels (individual, sectoral and aggregate) (T_{in} is invertible), and (ii) that these different tax levels drive independent responses of the three right-hand-side variables in Equation (18) (D_{in} is invertible). Regarding (i), the fact that we consider firm-level, sector-level and aggregate scenarios of the tax provides naturally independent scenarios. Regarding (ii), the three variables that we consider (expected aggregate and sectoral productions and the tax) are independent because the three variables are affected differently by the three scenarios. Naturally, aggregate, sectoral and firm-level variables are affected differently by aggregate, sectoral and firm-level taxes.

This identification strategy is different from the one implemented by Afrouzi (2024), who uses survey questions to identify the degree of strategic complementarity in price setting. Transposing to our firms' quantity decisions, it would amount to identify the parameters of a version of Equation (18) that abstract from the sectoral level, using the following question: "Suppose that you get news that the general level of the carbon policy went up by x in the economy:

(a) By what percentage do you think aggregate production would change?

(b) By what percentage would your firm change its production level?

(c) By what percentage would your firm change its production level if aggregate production did not change at all in response to this news?"

This generates variations in $(q_{in}, E_{in}(q), \tau_{in})$ that help identify the parameters $\bar{\alpha}^a_{in}$ and $E_{in}(\sigma_{in})$:

$$\begin{pmatrix} \bar{\alpha}^a_{in} \\ E_{in}(\sigma_{in}) \end{pmatrix} = \begin{pmatrix} E_{in}(q_1) & x \\ 0 & x \end{pmatrix}^{-1} \begin{pmatrix} q_{in,1} \\ q_{in,2} \end{pmatrix}$$

where $E_{in}(q_1)$ is the answer to (a), $q_{in,1}$ is the answer to (b) and $q_{in,2}$ is the answer to (c).

Contrary to us, Afrouzi would consider only one policy scenario and would generate variations by artificially shutting down some channels, here $E_{in}(q_2) = 0$. His approach is close to ours, but the advantage of our approach is that it is more natural and allows a better control of the environment. For instance, it is not clear what firms infer from the assumption $E_{in}(q_2) = 0$.

3.2 Higher-order expectations and noisy beliefs

Here we examine what the firms' answers regarding q_{in}, $E_{in}(q_n)$ and $E_{in}(q)$ tell us about the firms' information structure and possibly noisy beliefs. Throughout this section, we consider an economy-wide tax policy ($\tau_{in} = \tau_n = \tau$). The quantity responses we use here are therefore those of scenario 1.

Identifying noisy beliefs using higher-order expectations The presence of private information enables us to use higher-order beliefs to identify the presence of "noisy priors" about the aggregate and sectoral elasticity. For illustration, consider individual output q_{in}, which, according to Proposition 1, is of the form

$$q_{in} = -\left(\gamma^a_{in} E^a(\sigma^a) + \gamma^s_{in} E^s_n(\sigma^s_n) + \gamma^f_{in} s^f_{in}\right)\tau \tag{24}$$

The γ parameters are positive and are functions of the deep parameters of the model. Simply put, the output response is a linear combination of the firm's signals.[3] Among these signals, two are common knowledge ($E^a(\sigma^a)$ and $E^s_n(\sigma^s_n)$) and one is private (s^f_{in}). When summing these individual quantities across firms, the private signals sum to the fundamental value of the aggregate elasticity σ^a:

$$q = -\left(\gamma^a E^a(\sigma^a) + \gamma^f \sigma^a\right)\tau \tag{25}$$

When forming an expectation of this quantity (a higher-order belief), firms must not only forecast the part that they know, $E^a(\sigma^a)$ (because it is public information), but also the part that they don't know, σ^a (because it arises from the others'

[3]This corresponds to the solution (19) with $\tau_n - \tau = 0$, $\tau_{in} - \tau_n = 0$, and $\mathcal{Q}^{(1)} = A^{(1)} S_{in}$ with $A^{(1)} = (-\gamma^a_{in}, -\gamma^s_{in}, -\gamma^f_{in})'$. In Appendix C, we derive closed-form expressions of γ^a_{in}, γ^s_{in} and γ^f_{in} under the same set of assumptions as Proposition 1, as well as the aggregate and sectoral versions (25) and (27) below.

private information). As a consequence, the error on q is driven by the error on σ^a, but only to the extent that q depends on the firms' private information ($\gamma^f \neq 0$):

$$E_{in}(q) - q = -\gamma^f [E_{in}(\sigma^a) - \sigma^a]\tau$$

The aggregate error is then

$$\bar{E}(q) - q = -\gamma^f [\bar{E}(\sigma^a) - \sigma^a]\tau = -\gamma^f (1 - \delta^a) e^a \tau \tag{26}$$

where we used $E_{in}(\sigma^a) = (1-\delta^a)E^a(\sigma^a) - \delta^a E_n^s(\sigma_n^s) + \delta^a s_{in}^f$, with $\delta^a = (\pi^a)^{-1}/[(\pi^a)^{-1} + (\pi^s)^{-1} + (\kappa^f)^{-1} + (\pi^f)^{-1}]$ the weight put by the firm on the private signal when forecasting the aggregate elasticity (see Appendix B). Noise in the public signal about the aggregate elasticity e^a drives the error on the response of aggregate output. Excessive pessimism regarding this response would reveal a prior about the aggregate elasticity that is too high ($e^a > 0$).

Similarly, summing (24) within a given sector, we can show that sectoral output is:

$$q_n = -\left(\gamma_n^a E^a(\sigma^a) + \gamma_n^s E_n^s(\sigma_n^s) + \gamma_n^f (\sigma^a + \sigma_n^s)\right)\tau \tag{27}$$

In this expression, both the sectoral and aggregate component of the elasticity are unknown and need to be estimated by the firm. The expectation error can then be expressed as a function of the errors on both the aggregate and sectoral components:

$$E_{in}(q_n) - q_n = -\gamma_n^f [E_{in}(\sigma^a) - \sigma^a + E_{in}(\sigma_n^s) - \sigma_n^s]\tau$$

The aggregate error on sectoral output is then

$$\bar{E}(q_n) - q = -\gamma^f (1 - \delta^a - \delta^s) e^a \tau \tag{28}$$

where we used $E_{in}(\sigma_n^s) = -\delta^s E^a(\sigma^a) + (1-\delta^s)E_n^s(\sigma_n^s) + \delta^s s_{in}^f$, with $\delta^s = (\pi^s)^{-1}/[(\pi^a)^{-1} + (\pi^s)^{-1} + (\kappa^f)^{-1} + (\pi^f)^{-1}]$ the weight put by the firm on the private signal when forecasting the sector-specific elasticity (see Appendix B). The aggregate noise e^a also drives the aggregate error on the sectoral output, but to a smaller extent.

The noise in the public signal, e^a, drives the aggregate errors on quantities (aggregate and sectoral), and it thus moves the firms' aggregate output decisions through the interaction parameters α^a and α^s, as Equation (22) shows. This noise also drives the aggregate error on the firms' elasticity, which also matters

for aggregate quantities, as that same equation shows. To understand, note that firms combine the public signal $E^a(\sigma^a)$ with the other signals to infer their own elasticity:

$$E_{in}(\sigma_{in}) = (1-\delta^f)\left[E^a(\sigma^a) + E^s_n(\sigma^s_n)\right] + \delta^f s^f_{in}$$

with $\delta^f = [(\pi^a)^{-1} + (\pi^s)^{-1} + (\kappa^f)^{-1}]/[(\pi^a)^{-1} + (\pi^s)^{-1} + (\kappa^f)^{-1} + (\pi^f)^{-1}]$ (see Appendix B). As a result, the aggregate error on σ_{in} is

$$\bar{E}(\sigma_{in}) - \sigma^a = (1-\delta^f)e^a \tag{29}$$

which also depends on e^a. The aggregate errors on quantities thus inform us on the aggregate error firms make on their own elasticity. If firms underestimate aggregate output ($\bar{E}(q) - q < 0$), it indicates that they get an overly pessimistic public signal on the aggregate elasticity ($e^a > 0$), which implies that they will also be over-pessimistic about their own elasticity on average ($\bar{E}(\sigma_{in}) - \sigma^a > 0$).

As a result of removing noise, $e^a = 0$, so the aggregate errors vanish, and aggregate output only reflects the aggregate elasticity, as stated in the following proposition:

Proposition 3 (Counterfactual output) *When unbiasing signals as described in Definition 2, the errors vanish: $\bar{E}(q) - q = \bar{E}(q_n) - q = \bar{E}(\sigma_{in}) - \sigma^a = 0$, and aggregate output is*

$$q^{unbiased} = \frac{-\sigma^a \tau}{1 - \alpha^a - \alpha^s} \tag{30}$$

The wedge between the noisy and noiseless output depends only on the aggregate errors:

$$q^{noisy} - q^{noiseless} = \frac{1}{1-\alpha^a-\alpha^s}\left(\alpha^a\left(\bar{E}(q) - q\right) + \alpha^s\left(\bar{E}(q_n) - q\right) - \left(\bar{E}(\sigma_{in}) - \sigma^a\right)\tau\right) \tag{31}$$

This result derives directly from noting that $\bar{E}(q) - q = \bar{E}(q_n) - q = \bar{E}(\sigma_{in}) - \sigma^a = 0$ when $e^a = 0$, and from Equation (22).

An immediate test of the presence of noisy beliefs is therefore a mean equality test of $\bar{E}(q) = q$ or $\bar{E}(q_n) = q$, which would indicate the sign of e^a. We can then estimate $q^{noisy} - q^{noiseless}$. To do so, one needs estimates of the strategic interaction parameters α^a and α^s, which can be estimated using the approach described above, and of the output errors $\bar{E}(q) - q$ and $\bar{E}(q_n) - q$, which come directly from our survey data, and of the elasticity error $\bar{E}(\sigma_{in}) - \sigma^a$. To estimate the latter, we need to identify the information structure, which we can do by targeting moments in the data.

4 Data

4.1 Survey Implementation

We conduct a survey with firm managers using information about the universe of firms in Switzerland.[4] To recruit firm managers, we created a representative sample of firms with oversampling of large firms using three sources: the KOF's firm panel of Swiss firms, the universe of Swiss firms in Orbis, and a small list of firms that have already participated in a survey and accepted to be contacted again. Further details on the sampling strategy can be found in Appendix E. On June 17^{th}, 2025, we sent the first email invitation with a link to our online survey to 27k firms for which we had contact information. We sent three reminders from June to August, and closed the survey on August 31^{st} 2025. Our survey consisted of an online questionnaire with three main modules.

Firm characteristics In the first module, we elicited firms' characteristics, which we used to explore heterogeneity. We asked for information about number of employees, location of their headquarters, sector of activity, turnover, and export share. We also asked about their perception of competition intensity (1 to 7 scale), whether their main competitors are located in Switzerland or abroad, beliefs about their carbon intensity relative to other firms, and whether their firm was exempted of the Swiss carbon tax, participated in the federal program for voluntary reductions in CO_2 emissions, or participated in the Swiss emission trading system.

Carbon tax scenarios The second module is the core of the survey. We presented three carbon tax scenarios, the same for each manager, which map exactly into the three scenarios required for our identification strategy outlined in Section 3. Namely, we vary the scope of the tax to a national, sectoral, or firm-specific tax, denoted by $\tau_{in,1}$, $\tau_{in,2}$, and $\tau_{in,3}$, respectively. For each tax scenario, we ask managers about what they believed would be the expected impacts of such a tax on other- and own-firm outcomes. Specifically, we elicit the change in own production, the quantity $q_{in,s}$, where the subscript s corresponds to a given scenario; the

[4]The survey and pre-analysis plan were pre-registered on the AEA RCT Registry on June 13^{th}, 2025 (RCT-ID: AEARCTR-0013609). The ETH Zurich Ethics Commission approved the study in June 2024 (EK-2024-N-196).

change in production for other firms in firm'i own sector n, the quantity $E_{in}(q_{n,s})$; and the aggregate change in production, the quantity $E_{in}(q_s)$. For the firm-specific tax scenario (i.e., $s = 3$), we only elicit $q_{in,3}$ as we assume that the firm is small relative to the rest of the sector and economy. We also assume that for the sectoral tax scenario (i.e., $s = 2$), the aggregate impact is negligible; we thus only elicit $q_{in,2}$ and $E_{in}(q_{n,2})$. With this elicitation procedure, we obtain the following system of equations:

$$\begin{pmatrix} q_{in,1} \\ q_{in,2} \\ q_{in,3} \end{pmatrix} = \begin{pmatrix} E_{in}(q_1) & E_{in}(q_{n,1}) & \tau_{in,1} \\ 0 & E_{in}(q_{n,2}) & \tau_{in,2} \\ 0 & 0 & \tau_{in,3} \end{pmatrix} \cdot \begin{pmatrix} \alpha^a_{in} \\ \alpha^s_{in} \\ E_{in}(\sigma_{in}) \end{pmatrix}, \tag{32}$$

which we can use to recover the vector of parameters $\{\alpha^a_{in}, \alpha^s_{in}, E_{in}(\sigma_{in})\}$ for each firm manager.

In our analysis, we focus on production outcomes over the medium-term, which we fix at three years. But we also elicited firm managers' expected impacts on final prices for all three scenarios and over the same time horizon,[5] and impacts on labor, energy use, and profits, but for only the national tax scenario (i.e., $s = 1$). Finally, note that in all scenarios, we randomize the level of the tax (100 versus 300 CHF per ton of CO_2) across subjects, which we kept constant across scenarios (i.e., within respondent).[6]

A crucial element of this module is that, in a preamble to the scenario questions, we devise a procedure to help managers think through the tax burden of a carbon tax reform by providing an estimate of the CO_2 emissions of their firm and the to total tax burden of a given carbon tax. To implement this procedure, we ask about the firm's total costs, the share of energy operating costs, and the shares of different energy sources in energy costs. Using this information, we use Swiss-specific energy prices and CO_2 coefficients for each energy source to estimate the

[5]Note that our model is developed to study the role of strategic interactions and biased beliefs on production decisions. Our assumptions about the information structure, in particular the timing of the information shocks, are important for the identification. For pricing decisions, the timing might be different, and thus Equation (18) is only consistent with pricing decisions under a particular assumption regarding the timing of information shocks.

[6]The current carbon tax in Switzerland, which applies on fossil thermal fuels is currently at 120 CHF/ton of CO_2. Note that Ecoplan and INFRAS (2024) recommended a high estimate of 430 CHF per ton of CO_2 for the social cost of carbon to be used by the Swiss federal government, which aligns with our high-tax scenario.

total CO_2 emissions of the firms associated with direct fossil fuel consumption. We then use this information to inform managers about how a carbon tax of a specific level (expressed in CHF/ton of CO_2) translates into an additional tax burden (expressed in CHF/year).

Formally, we can think of this procedure as providing a private firm-specific signal about the climate policy-related elasticity that we want to estimate, the quantity σ_{in}. Note that the signal is noisy but does not contain systematic aggregate or sectoral noise, and thus respects the information structure needed for the identification.

Manager characteristics In the third survey module, we elicited managers' characteristics. We focus on a few demographics (gender, age, education), as well as role and years in the firm. We also asked about what they considered the ideal level of a carbon tax to be that they would support.

4.2 Attrition and Estimating Sample

From the 27k firms we contacted, 4116 managers opened the survey link, 2356 started but did not complete the survey, and 1408 proceeded until the end of the survey. Among those who completed the survey, 1145 answered the scenario questions on the impact of a carbon tax on production. These managers are our estimating sample. Note that some managers (N=95) completed only some of the questions for the different scenarios but still proceeded until the end of the survey.

Among the managers who did not complete the survey (N=2708), 20% dropped after answering only a few questions related to their main sector of activity or number of employees, and another 20% dropped during the carbon tax scenario questions.

In Table 1, we compare the samples along different characteristics. For our main analysis, we focus on managers who completed the survey and provided complete answers to the scenario questions regarding production impacts.

4.3 Descriptive Statistics

In Table 2, we report the mean outcomes for all the different impacts we elicited for a national carbon tax reform. Each manager was presented with scenarios

for a tax of 100 CHF/tCO_2 or 300 CHF/tCO_2. Note that this variation is not required for our main identification of strategic interaction parameters or prior beliefs. However, we use this between-subject variation to first show that managers are sensitive to the level of the carbon tax, providing a first indication that they pay close attention when completing the survey. We expect that a larger tax should induce larger expected impacts. This is what we find.

The first row of the table corresponds to the increase in energy costs resulting from the carbon tax we presented to managers. The 100 CHF/tCO_2 tax translates into a 7.88% increase in energy cost on average, and the 300 CHF/tCO_2 tax has an impact that is three times larger, as expected. Managers expect a reduction in their firm's output of about -1.47% for the lower tax, and a decrease of -2.42%—a difference that is statistically significant (p-value=0.01). Managers expect to pass these costs to consumers, as for both tax levels, managers report that they will increase the price of their main final product by 2.70% to 2.99%. They also expect to lower their energy consumption, a reduction of -1.26% and -1.40% for the low and high tax levels, respectively. Combining both tax levels (first column), the elasticity of energy consumption with respect to the carbon tax is -0.08 (-1.33/16.01). This is in line with short-run elasticities of firms' energy use with respect to energy costs. The impacts on labor and profits are negative. They are larger, and statistically different at the higher tax level compared to the lower tax level.

Next, we investigate how managers responded to the scope of the carbon tax reform across the three scenarios we presented to each of them. As shown in Table 5 (Panel A), managers report larger, i.e., more negative, impacts from a carbon pricing scheme that targets only their firm, versus their sector, or the whole economy. For a national scheme, managers expect a reduction in output of -1.14%, on average, which decreases to -1.53% for a sectoral scheme, and to -2.37% for firm-specific tax. Note that for all those estimates, we have normalized the impact for a 100 CHF/tCO_2 tax.[7]

Finally, we also investigate variation in managers' beliefs about the impact of carbon tax reform on their own output versus other firms' output. Remember that, for a national carbon tax, we elicit, in addition to the change in their own production, what they believe the change in production across the whole economy

[7]To do so, we have divided the expected impacts of managers that received the 300 CHF/tCO_2 tax by three.

and in their sector will be. In Table 5 (Panel B), we show that managers more pessimistic higher-order beliefs, on average, especially about the aggregate impacts. The average firm's reduction in output is less pronounced than the (average) expected impact on the whole economy. Managers thus systematically believe that the economy, and to a lesser extent their sector, would be hit harder than what they collectively report about the impact on their own firm.

5 Strategic Interaction and Noisy Beliefs

We now turn to the estimation of the strategic interaction parameters and noisy beliefs. For the estimation, we focus on a sample of managers who completed the survey and provided answers to all scenario questions pertaining to the output response to the different carbon tax reforms.

5.1 Strategic Interaction Parameters

We use the system of equations (32) to recover the vector of parameters $\{\alpha^a_{in}, \alpha^s_{in}, E_{in}(\sigma_{in})\}$, one for each manager who responded to the survey. Figure 1 presents the distribution of the three parameters. We observe a mode at zero, especially for the two strategic interaction parameters, and their means are both negative, as shown in Table 9. Output responses are thus strategic substitutes, on average. These averages, however, mask important variations across the distribution. To see this, consider Figure 2, which is a binned scatter plot showing the joint distribution of α^a_{in} and α^s_{in}. There are two important takeaways.

First, the distribution of the sectoral strategic parameter spans mostly negative values, unlike the distribution of the aggregate strategic parameters, which has support that ranges from negative to positive values. Strategic interactions at the sectoral level are thus clearly strategic substitutes. At the aggregate level, it is ambiguous. For some managers, aggregate output is a strategic complement; for others, it is a strategic substitute.

Second, the correlation between the two parameters shows that the intensity of strategic interactions is strongly correlated across both dimensions. Large negative or positive values of α^a_{in} arise at the tail of the distribution of α^s_{in}. This means that managers who are strategic about how they believe other firms in their sector would respond are also strategic about the change in aggregate output.

We further document heterogeneity patterns by correlating the parameters with observables. Figure 3 shows binned scatter plots that represent the correlation between the strategic parameters and the intensity of competition and energy intensity. The sectoral strategic interaction parameter shows a strong correlation with both variables. Managers who perceive more intense competition from other firms in their sector and are more energy-intensive are more likely to respond strategically by considering the output responses of other firms. But only for firms in their sector. At the aggregate level, the correlations are weaker.

We formally test these correlations using regressions of the strategic parameters on a large set of observables collected in the survey. Results are presented in Table 12. In Column I, the dependent variable is the parameter α^s_{in}, whereas in Column II, the dependent variable is a dummy variable that takes a value of 1 if the parameter α^s_{in} is non-zero. Similarly, columns III and IV are for the dependent variable α^a_{in} and a dummy variable indicating whether α^a_{in} is nonzero. We find that among all observables, competition-related variables, such as the self-reported intensity of competition variable, export shares, and whether competitors are only Swiss, are strongly correlated with both strategic parameters. Higher exposure to a carbon tax, which is captured by a high share of energy cost in total costs, and the use of fossil fuels are also correlated.

5.2 Noisy Beliefs

How accurate are managers' beliefs about the impacts of carbon pricing on other firms? To answer this question, we compute aggregate errors (national or sectoral). First, we construct the relevant realized aggregate output change by summing all the managers' estimates of own output change. We then define the manager's error as the difference between the manager's expectations for the impact on others and the realized aggregate impact. For instance, in the scenario for the national carbon tax, the realized aggregate output change is

$$q \;=\; \sum_i q_{in},$$

so the corresponding error is made by manager i is:

$$\varepsilon_{in} \;=\; E_{in}(q) - q.$$

Similarly, for the scenario with a carbon tax in sector n, the realized sectoral output change is

$$q_{n,s} \;=\; \sum_{i \in n} q_{in,s},$$

and the sectoral error is defined as

$$\varepsilon^{s}_{in}(n) \;=\; E_{in}(q_{n,s}) - q_{n,s}.$$

Finally, aggregate errors are assessed by averaging these errors across observations and evaluating whether the mean error differs from zero. In calculating q and $q_{n,s}$, one important question is whether we have a representative sample such that these quantities truly represent the whole economy and its sector, respectively. Re-weigthing could change the value of these aggregate quantities and impact the aggregate errors we report.

In Table 9, we report results using inverse probability weighting to obtain a representative sample by firm size. In the appendix, we provide more details on our approach and also provide additional results based on alternative weighting methodologies. Our main results are qualitatively the same. Managers tend to have noisy beliefs as they overestimate the impact on others compared to the true aggregate impacts. This is particularly evident for the national impact of a carbon tax. Managers are overly pessimistic about the aggregate impact compared to what they believe about their own impact. In simple terms, every manager believes that their firm will be less affected, on average, than the rest of the economy.

As for the strategic parameters, we can also explore patterns of heterogeneity in these errors. In Table 13, we report regressions where the dependent variable is a manager error, either at the national or sectoral level for the national tax scenario, and the regressors are the set of observables we collected. We also report results (Columns II and IV) using a dependent variable that is a dummy equal to 1 if the manager has pessimistic beliefs. Overall, there are a few variables that are strongly correlated with the managers' error, except for the variable that identifies whether a firm has only Swiss competitors, and firm size. The positive coefficient suggests that large firms, and firms that have only Swiss competitors are less likely to hold pessimistic beliefs.

6 Counterfactual Analysis

So far, we have documented the strategic interaction parameters and the aggregate errors. We have found that firms hold excessively pessimistic beliefs about the aggregate impact of the carbon tax, and that quantity setting features strategic substitutabilities. According to our discussion in Section 3, pessimistic beliefs about the aggregate economy imply that firms hold pessimistic beliefs about the tax elasticity σ_{in}. We can therefore expect the noiseless expected output to be higher than the noisy one, although strategic substitutabilities should mitigate the consequences of removing noise.

However, to estimate the noiseless output, we need first to identify the information parameters, which we can do by targeting moments in the data.

6.1 Fitted moments and information parameter estimates

The estimation targets a set of moments capturing average expectations, average errors, and selected second moments that are not mechanically affected by heterogeneity in the belief parameters α^a and α^s.

Table 14 reports targeted and untargeted moments in the data and in the model. We minimize the sum of the squared distance between the theoretical and empirical moments. All moments are weighted with an equal weight of one, except the average expected output in scenario 1 $\bar{E}(q)^{sc.1}$, on which we put a weight of 5, because it will be the main object of our counterfactual exercise. Overall, the model performs well in reproducing the targeted moments. In particular, it closely matches the variance of expectations about aggregate output in scenario 1, the variance of firms' own outcomes in scenario 3, and the covariance between the two. It also captures reasonably well the average expectations about the firms' own outcomes and the average errors in scenario 1, and the average expectations about the firms' own outcomes in scenario 3.

However, the model tends to underestimate the error on the aggregate outcome $(\bar{E}(q) - q)^{sc.1}$ and overestimate the error on the sectoral outcome $(\bar{E}(q_n) - q)^{sc.1}$. In our model, the error on the sectoral and aggregate outcomes are very similar. This is because the sectoral prior concerns the sectoral component of the elasticity. Since the sectoral elasticity has an aggregate component, the error on the aggregate elasticity translates into an error on the sectoral elasticity, no matter how precise

is the sectoral prior. In a variant of the model, we assume that the sectoral prior concerns the sectoral elasticity as a whole. In that case, if the sectoral prior is precise, then a small error at the sectoral level becomes compatible with a large error at the aggregate level, and the model fits the sectoral errors better, while the main results remain unchanged.

Importantly, note that the model also delivers a reasonable fit for untargeted moments. Although not explicitly targeted in the estimation, the average expectations about the firms' own outcomes in scenario 2 is broadly in line with its empirical counterpart. However, the average error on the sectoral outcomes in scenario 2 is lower in the data than in the model. This is consistent with the model also missing the sectoral error in scenario 1, as discussed above.

Table 15 reports the estimated structural parameters. The estimation implies a large aggregate noise component, reflected in a high value of e^a. At the same time, the sectoral signal is estimated to be substantially more precise than both the aggregate signal and private signals, as indicated by the relative magnitudes of π^s, π^a, and π^f. Finally, the ratio of the standard deviation of individual-level forecast uncertainty to sectoral uncertainty is large, highlighting the central role of individual heterogeneity in driving variation in the true σ_{in}.

6.2 Removing Noise

We can now quantify the role of noisy beliefs in shaping equilibrium expectations. Thanks to our estimation,we can now compute the average error the firms make on their own elasticity $\bar{E}(\sigma_{in}) - \sigma^a$ and replace in Equation (31). We also replace the errors on quantities $\bar{E}(q) - q$ and $\bar{E}(q_n) - q$ using the model-consistent values so that our counterfactual remains consistent with our estimation.[8]

Table 16 reports the average noisy output, the average noiseless output, the difference between the two and the contribution of each component to this difference. The expected fall in output at the firm level drops from 1.25% to 0.88%, which amounts to a 0.37% difference. The direct, partial-equilibrium effect through the removal of noise in the expectations of the firm's own elasticity σ_{in} is quite large, which reflects the large estimated aggregate noise component.. The firms decrease their expected elasticity expectation by 0.67 on average, which corresponds to one third of their average noisy expectation (2.22). This contributes to a 0.50% de-

[8]Using the empirical errors do not significantly affect the results.

cline in their expected quantity outcome. Noisy expectations about aggregate and sectoral outcomes, $\bar{E}(q) - q$ and $\bar{E}(q_n) - q$, contribute to limiting the equilibrium impact of removing noise, but their effect is quantitatively small. In total, the firms have a more optimistic outlook: their expected output is 0.37% higher on average, which corresponds to 30% of the decline in output that is expected by firms under noisy beliefs.

Aggregate noise therefore accounts for a sizable share of the expected drop in output. Interestingly, noise e^a accounts for two thirds of the public prior on the aggregate elasticity, so that, according to that signal, the elasticity is 3.48, while the estimated true σ^a is equal to 1.16. The impact of that noise on the firms' expectations is mitigated because they have access to other signals (the sectoral and private signals). However, what our analysis shows is that public information on the costs of carbon taxation are extremely pessimistic, reflecting a very negative global sentiment about the economic impact of carbon policies.

7 Conclusion

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8 Tables and Figures

Table 1: Descriptive Statistics: Means by Subsample

	Incomplete	End of Survey	Complete
Panel A: Firm characteristics			
Full-time employees	175	92	93
Turnover (million)	199	110	131
Export share (%)	5	12	12
Intense compet. (binary)	0.68	0.72	0.72
Only Swiss compet. (binary)	0.48	0.45	0.43
Manufacturing–Machine (binary)	0.46	0.50	0.50
Share of energy cost (%)	2	5	5
Uses electricity (binary)	0.90	0.94	0.95
Uses fossil (binary)	0.61	0.69	0.70
CO_2 emissions (tons CO_2eq)	1963	5893	7092
Own CO_2 more than others	0.00	0.03	0.04
Sector CO_2 more than others	0.00	0.12	0.13
Panel B: Manager characteristics			
CEO, Director, CFO (binary)	0.00	0.76	0.76
Manager: years in role	17	18	17
Manager: male (binary)	0.67	0.84	0.86
Master or PhD (binary)	0.00	0.30	0.31
Survey duration (minutes)	–	33	37
Observations	2708	1408	1145

Entries are means; missing values excluded. Turnover shown in millions.

Table 2: Mean Outcomes Across Tax Levels

Own firm response to a national tax	Tax Level (CHF/Ton CO_2) All	100	300	$\Delta_{100-300}$	p-val
Δ Energy Cost (%)	16.01	8.11	24.11	-16.00	0.00
Δ Output (%)	-1.94	-1.47	-2.42	0.95	0.01
Δ Price (%)	2.84	2.70	2.99	-0.29	0.36
Δ Energy Consumption (%)	-1.33	-1.26	-1.40	0.14	0.64
Δ FTE (%)	-1.51	-1.27	-1.75	0.48	0.10
Δ Profits (%)	-2.85	-2.41	-3.31	0.90	0.01
Observations	1145	580	565	1145	–

Table 3: Mean Outcomes Across Tax Levels: Reweighted # Firms

Own firm response to a national tax	Tax Level (CHF/Ton CO_2) All	100	300	$\Delta_{100-300}$	p-val
Δ Energy Cost (%)	17.59	7.99	24.74	-16.75	< 0.01
Δ Output (%)	-1.69	-0.98	-2.21	1.23	0.09
Δ Price (%)	3.14	2.16	3.88	-1.72	0.01
Δ Energy Consumption (%)[2]	-0.95	-1.04	-0.89	-0.16	0.79
Δ FTE (%)	-0.95	-0.67	-1.16	0.49	0.39
Δ Profits (%)	-2.50	-1.70	-3.10	1.41	0.03
Observations	1145	580	565	1145	–

Table 4: Mean Outcomes Across Tax Levels: Reweighted FTE

Own firm response to a national tax	Tax Level (CHF/Ton CO_2) All	100	300	$\Delta_{100-300}$	p-val
Δ Energy Cost (%)	17.70	8.02	25.09	-17.07	< 0.01
Δ Output (%)	-1.70	-1.14	-2.13	0.98	0.18
Δ Price (%)	3.16	2.32	3.80	-1.48	0.02
Δ Energy Consumption (%)[2]	-0.95	-1.06	-0.88	-0.18	0.77
Δ FTE (%)	-0.92	-0.71	-1.08	0.37	0.50
Δ Profits (%)	-2.50	-1.79	-3.05	1.26	0.05
Observations	1145	580	565	1145	–

Table 5: Own Output Response and Beliefs About Responses Across Groups and Scenarios (Unweighted)

Panel A: Own Output Across Tax Scenarios					
	National Tax	Sectoral Tax	Firm Tax	Nat – Sector	Nat – Firm
Δ Output (%)	-1.14	-1.53	-2.37	0.39^{*}	1.23^{***}
$\mathbf{1}\{\Delta \text{ Output} < 0\}$	0.48	0.48	0.51	.	.
$\mathbf{1}\{\Delta \text{ Output} = 0\}$	0.36	0.38	0.36	.	.
$\mathbf{1}\{\Delta \text{ Output} > 0\}$	0.16	0.14	0.13	.	.
Panel B: Own Output vs Beliefs About Others (National Tax)					
	Own Firm	Firms in Sector	Aggregate Impact	Sector – Own	Agg – Own
Δ Output (%)	-1.14	-1.32	-1.85	-0.18	-0.71^{***}
$\mathbf{1}\{\Delta \text{ Output} < 0\}$	0.48	0.51	0.60	.	.
$\mathbf{1}\{\Delta \text{ Output} = 0\}$	0.36	0.33	0.26	.	.
$\mathbf{1}\{\Delta \text{ Output} > 0\}$	0.16	0.16	0.14	.	.

Table 6: Own Output Response and Beliefs About Responses Across Groups and Scenarios (Reweighted # firms)

Panel A: Own Output Across Tax Scenarios					
	National Tax	Sectoral Tax	Firm Tax	Nat – Sector	Nat – Firm
Δ Output (%)	-.8422489	-1.171605	-1.55155	.329356	.7093008
$\mathbf{1}\{\Delta \text{ Output} < 0\}$	.3991554	.4155007	.4381748	.	.
$\mathbf{1}\{\Delta \text{ Output} = 0\}$	.4061957	.4177116	.3980072	.	.
$\mathbf{1}\{\Delta \text{ Output} > 0\}$	.1946489	.1667878	.163818	.	.
Panel B: Own Output vs Beliefs About Others (National Tax)					
	Own Firm	Firms in Sector	Aggregate Impact	Sector – Own	Agg – Own
Δ Output (%)	-.8422489	-1.057408	-1.5009	-.2151591	-.6586514
$\mathbf{1}\{\Delta \text{ Output} < 0\}$	.3991554	.4557433	.532555	.	.
$\mathbf{1}\{\Delta \text{ Output} = 0\}$	.4061957	.3708493	.2894327	.	.
$\mathbf{1}\{\Delta \text{ Output} > 0\}$	.1946489	.1734074	.1780124	.	.

Table 7: Own Output Response and Beliefs About Responses Across Groups and Scenarios (Reweighted FTE)

Panel A: Own Output Across Tax Scenarios					
	National Tax	Sectoral Tax	Firm Tax	Nat – Sector	Nat – Firm
Δ Output (%)	-.8965758	-1.227855	-1.664688	.3312793	.768112
Panel B: Own Output vs Beliefs About Others (National Tax)					
	Own Firm	Firms in Sector	Aggregate Impact	Sector – Own	Agg – Own
Δ Output (%)	-.8965758	-1.114509	-1.561595	-.2179332	-.6650187

Table 8: OUTDATED Policy Elasticity, Strategic Interaction, and Aggregate Errors (means unweighted)

	Mean	Median	P25	P75
Panel A: Policy Elasticity and Strategic Interaction (Re-weighted)				
Policy elasticity $E_{in}(\sigma_{in})$	-2.209394	-.3333333	-3.5	0
Sectoral-level strategic α^s_{in}	-.1809757	0	-.1380952	0
Aggregate-level strategic α^a_{in}	-.1205706	0	0	0
Panel B: Noisy Beliefs for Aggregate and Sectoral Outcomes				
Δ Output (%) (Sc.1)	-1.15	0.00	-2.00	0.00
Error nat. w. HK (Sc1)	-1.14	-0.26	-2.60	0.74
Error nat. w. HK level (Sc1)	-0.98	-0.10	-2.44	0.90
Error nat. w. HK hybrid (Sc1)	-1.15	-0.27	-2.60	0.73
Error nat. w. KB (Sc1)	-0.85	0.03	-2.30	1.03
Error nat. w. KB. hybrid (Sc1)	-1.76	-0.88	-3.21	0.12
Error sec. w. HK (Sc1)	-0.56	0.11	-1.66	0.99
Error sec. w. HK level (Sc1)	-0.58	0.39	-1.57	0.93
Error sec. w. KB (Sc1)	-0.14	0.36	-1.31	1.72
Error sec. w. HK (Sc2)	-0.45	0.29	-1.48	1.43
Error sec. w. HK level (Sc2)	-0.53	0.46	-1.76	1.15
Error sec. w. KB (Sc2)	0.01	0.76	-1.13	1.82

Note: To compute the noisy beliefs, the quantities q, $q_{n,1}$, and $q_{n,2}$ are a weighted sum of the firms' own responses, where the weights replicate the distribution of firm size in the Swiss economy.

Table 9: Vshare: Policy Elasticity, Strategic Interaction, and Aggregate Errors (means unweighted)

	Mean	Median	Share < 0	Share > 0
Panel A: Policy Elasticity and Strategic Interaction				
Policy elasticity $E_{in}(\sigma_{in})$	-2.21	-0.33	0.50	0.13
Sectoral-level strategic α^s_{in}	-0.18	0.00	0.27	0.11
Aggregate-level strategic α^a_{in}	-0.12	0.00	0.24	0.12
Panel B: Noisy Beliefs for Aggregate and Sectoral Outcomes				
Δ Output (%) (Sc.1)	-1.15	0.00	0.47	0.16
Error nat. w. HK (Sc1)	-1.14	-0.26	0.53	0.47
Error nat. w. HK level (Sc1)	-0.98	-0.10	0.53	0.47
Error nat. w. HK hybrid (Sc1)	-1.15	-0.27	0.53	0.47
Error nat. w. KB (Sc1)	-0.85	0.03	0.44	0.56
Error nat. w. KB. hybrid (Sc1)	-0.73	0.15	0.44	0.56
Error sec. w. HK (Sc1)	-0.56	0.11	0.45	0.55
Error sec. w. HK level (Sc1)	-0.58	0.39	0.44	0.56
Error sec. w. KB (Sc1)	-0.14	0.36	0.36	0.64
Error sec. w. HK (Sc2)	-0.45	0.29	0.42	0.58
Error sec. w. HK level (Sc2)	-0.53	0.46	0.46	0.54
Error sec. w. KB (Sc2)	0.01	0.76	0.37	0.63

Note: To compute the noisy beliefs, the quantities q, $q_{n,1}$, and $q_{n,2}$ are a weighted sum of the firms' own responses, where the weights replicate the distribution of firm size in the Swiss economy.

Table 10: Policy Elasticity, Strategic Interaction, and Aggregate Errors (means reweighted # firms)

	Mean	Median	Share < 0	Share > 0
Panel A: Policy Elasticity and Strategic Interaction (Re-weighted)				
Policy elasticity $E_{in}(\sigma_{in})$	-1.60	0.00	0.44	0.16
Sectoral-level strategic α^s_{in}	-0.16	0.00	0.25	0.09
Aggregate-level strategic α^a_{in}	-0.08	0.00	0.23	0.12
Panel B: Noisy Beliefs for Aggregate and Sectoral Outcomes				
Δ Output (%) (Sc.1)	-0.81	0.00	0.40	0.19
Error nat. w. HK (Sc1)	-0.70	0.40	0.45	0.55
Error nat. w. HK level (Sc1)	-0.54	0.56	0.45	0.55
Error nat. w. HK hybrid (Sc1)	-0.71	0.40	0.45	0.55
Error nat. w. KB (Sc1)	-0.41	0.70	0.40	0.60
Error nat. w. KB. hybrid (Sc1)	-0.29	0.82	0.40	0.60
Error sec. w. HK (Sc1)	-0.29	0.11	0.43	0.57
Error sec. w. HK level (Sc1)	-0.18	0.39	0.38	0.62
Error sec. w. KB (Sc1)	-0.05	0.36	0.36	0.64
Error sec. w. HK (Sc2)	-0.32	0.29	0.39	0.61
Error sec. w. HK level (Sc2)	-0.21	0.51	0.46	0.54
Error sec. w. KB (Sc2)	-0.04	0.76	0.36	0.64

Note: To compute the noisy beliefs, the quantities q, $q_{n,1}$, and $q_{n,2}$ are a weighted sum of the firms' own responses, where the weights replicate the distribution of firm size in the Swiss economy.

Table 11: Policy Elasticity, Strategic Interaction, and Aggregate Errors (means reweighted FTE)

	Mean	Median	P25	P75
Panel A: Policy Elasticity and Strategic Interaction (Re-weighted)				
Policy elasticity $E_{in}(\sigma_{in})$	-1.71	0.00	-3.33	0.00
Sectoral-level strategic α^s_{in}	-0.16	0.00	-0.05	0.00
Aggregate-level strategic α^a_{in}	-0.09	0.00	0.00	0.00
Panel B: Noisy Beliefs for Aggregate and Sectoral Outcomes				
Δ Output (%) (Sc.1)	-0.88	0.00	0.41	0.19
Error nat. w. HK (Sc1)	-0.78	0.07	0.46	0.54
Error nat. w. HK level (Sc1)	-0.62	0.23	0.46	0.54
Error nat. w. HK hybrid (Sc1)	-0.78	0.07	0.46	0.54
Error nat. w. KB (Sc1)	-0.49	0.36	0.40	0.60
Error nat. w. KB. hybrid (Sc1)	-0.37	0.48	0.40	0.60
Error sec. w. HK (Sc1)	-0.31	0.11	0.42	0.58
Error sec. w. HK level (Sc1)	-0.19	0.39	0.38	0.62
Error sec. w. KB (Sc1)	-0.08	0.36	0.36	0.64
Error sec. w. HK (Sc2)	-0.33	0.29	0.38	0.62
Error sec. w. HK level (Sc2)	-0.22	0.51	0.44	0.56
Error sec. w. KB (Sc2)	-0.06	0.76	0.37	0.63

Note: To compute the noisy beliefs, the quantities q, $q_{n,1}$, and $q_{n,2}$ are a weighted sum of the firms' own responses, where the weights replicate the distribution of firm size in the Swiss economy.

Table 12: Heterogeneity: Strategic Interaction and Policy Elasticity Parameters

Dependent Variable	α^s_{in} (I)	$1\{\alpha^s_{in} \neq 0\}$ (II)	α^a_{in} (III)	$1\{\alpha^a_{in} \neq 0\}$ (IV)	σ_{in} (V)	$1\{\sigma_{in} \neq 0\}$ (VI)
Full-time employees (,00000)	0.328	-5.748	10.997*	-6.104	45.436	-4.370
	(6.539)	(3.841)	(6.037)	(4.486)	(41.730)	(4.739)
Turnover (billions)	0.031	-0.025	-0.059	0.028	0.388	0.056***
	(0.036)	(0.027)	(0.045)	(0.043)	(0.566)	(0.020)
Export share	0.002***	-0.001	0.001	-0.001	0.001	0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.007)	(0.001)
Intensity compet. (bin.)	-0.137***	0.130***	-0.010	0.095***	-1.091***	0.153***
	(0.047)	(0.034)	(0.052)	(0.033)	(0.306)	(0.035)
Only Swiss compet. (bin.)	0.103*	-0.040	0.099*	-0.056*	0.966**	-0.093***
	(0.054)	(0.035)	(0.058)	(0.033)	(0.386)	(0.033)
Manufacturing-Machine (bin.)	-0.023	0.010	-0.084	-0.013	0.066	0.002
	(0.053)	(0.033)	(0.056)	(0.032)	(0.358)	(0.032)
Share of energy cost	-0.010**	0.011***	-0.002	0.017***	-0.006	0.014***
	(0.004)	(0.003)	(0.005)	(0.003)	(0.051)	(0.003)
Uses electricity (bin.)	0.062	-0.086	0.097	-0.104	-1.051*	-0.099
	(0.152)	(0.078)	(0.103)	(0.074)	(0.586)	(0.068)
Uses fossil (bin.)	-0.131***	0.038	-0.147***	0.049	-1.170***	0.141***
	(0.050)	(0.034)	(0.050)	(0.033)	(0.305)	(0.034)
CO2 emissions (millions)	-0.407	0.291	0.886	-0.496	-5.730	-0.795***
	(0.525)	(0.402)	(0.655)	(0.634)	(8.284)	(0.293)
Own CO2 more others (bin.)	0.227*	-0.054	-0.170	0.123	-0.892	-0.088
	(0.116)	(0.090)	(0.109)	(0.089)	(1.000)	(0.082)
Sector CO2 more others (bin.)	-0.141*	0.061	0.025	0.019	-0.933	0.064
	(0.078)	(0.051)	(0.068)	(0.050)	(0.567)	(0.047)
CEO, Director, CFO (bin.)	0.055	-0.015	0.003	0.007	-0.674*	-0.019
	(0.066)	(0.040)	(0.054)	(0.038)	(0.393)	(0.039)
Manager: years in role	0.001	-0.000	-0.000	0.001	0.032**	-0.001
	(0.002)	(0.001)	(0.002)	(0.001)	(0.015)	(0.001)
Manager: male (bin.)	-0.152***	0.101**	-0.090*	0.109***	-0.136	0.157***
	(0.057)	(0.044)	(0.047)	(0.041)	(0.446)	(0.046)
Master or PhD (bin.)	-0.036	-0.076**	0.023	-0.082**	-0.000	-0.141***
	(0.053)	(0.034)	(0.052)	(0.033)	(0.341)	(0.035)
Survey duration (min)	-0.000	-0.000	-0.000	-0.000	-0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	933	933	933	933	933	933
Adj. R-squared	0.026	0.048	0.007	0.086	0.035	0.126

Note: The intensity of competition variable is a dummy variable that takes a value of one if a manager reported facing an above-average degree of competition from firms in the same sector.

Table 13: Heterogeneity: Aggregate Errors

Dependent Variable	$E_{in}(q) - q$	$1\{(E_{in}(q) - q) < 0\}$	$E_{in}(q_{n,1}) - q_{n,1}$	$1\{(E_{in}(q_{n,1}) - q_{n,1}) < 0\}$
	(I)	(II)	(III)	(IV)
Full-time employees (,00000)	98.103***	-11.422***	93.743***	-10.425***
	(33.009)	(2.845)	(35.654)	(3.161)
Turnover (billions)	-0.016	0.035	-0.124	0.064
	(0.234)	(0.044)	(0.399)	(0.044)
Export share	-0.019	0.013	0.829	-0.192**
	(0.667)	(0.098)	(0.549)	(0.079)
Intense compet. (bin.)	-0.343	0.116**	-0.167	0.053
	(0.431)	(0.046)	(0.418)	(0.045)
Only Swiss compet. (bin.)	1.223***	-0.122***	1.407***	-0.155***
	(0.403)	(0.046)	(0.437)	(0.046)
Manufacturing-Machine (bin.)	0.789**	-0.078*	0.794*	0.027
	(0.371)	(0.041)	(0.417)	(0.041)
Share of energy cost	0.018	0.006**	0.027	0.007**
	(0.026)	(0.003)	(0.035)	(0.003)
Uses electricity (bin.)	-1.871**	0.078	-2.059	0.074
	(0.924)	(0.070)	(1.568)	(0.079)
Uses fossil (bin.)	-0.673	0.096**	-0.362	0.039
	(0.418)	(0.045)	(0.489)	(0.045)
CO2 emissions (millions)	0.145	-0.404	1.451	-0.810
	(3.402)	(0.644)	(5.893)	(0.661)
Own CO2 more others (bin.)	-0.550	-0.064	-1.139	0.006
	(0.886)	(0.105)	(0.896)	(0.104)
Sector CO2 more others (bin.)	-0.499	0.026	-0.881*	0.068
	(0.429)	(0.061)	(0.452)	(0.065)
CEO, Director, CFO (bin.)	0.260	-0.018	0.254	0.064
	(0.418)	(0.052)	(0.410)	(0.049)
Manager: years in role	0.011	-0.001	0.011	-0.002
	(0.017)	(0.002)	(0.013)	(0.002)
Manager: male (bin.)	0.915*	-0.134**	1.235**	-0.107
	(0.514)	(0.068)	(0.504)	(0.067)
Master or PhD (bin.)	0.054	-0.062	0.538	-0.093**
	(0.412)	(0.046)	(0.438)	(0.043)
Survey duration (min)	-0.000	0.000	0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Observations	1067	1067	1067	1067
Adj. R-squared	0.050	0.062	0.062	0.067

Note: The intensity of competition variable is a dummy variable that takes a value of one if a manager reported facing an above average degree of competition from firms in the same sector.

Table 14: Fitted moments: data and model

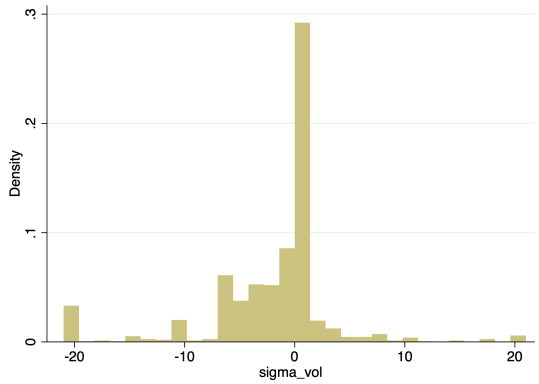
Targeted moments	**Model**	**Data**
$\bar{E}(q)^{sc.1}$	-1.25	-1.14
$(\bar{E}(q)-q)^{sc.1}$	-0.55	-0.75
$(\bar{E}(q_n)-q)^{sc.1}$	-0.54	-0.21
$\bar{E}(q)^{sc.3}$	-1.82	-2.22
$V(E_{in}(q)^{sc.1})$	0.48	0.54
$Cov(E_{in}(q)^{sc.1}, q_{in}^{sc.3})$	0.86	0.80
$V(q_{in}^{sc.3})$	1.71	1.73
Untargeted moments	**Model**	**Data**
$\bar{E}(q)^{sc.2}$	-1.52	-1.46
$(\bar{E}(q_n)-q)^{sc.2}$	-0.60	-0.10

Table 15: Estimated parameters

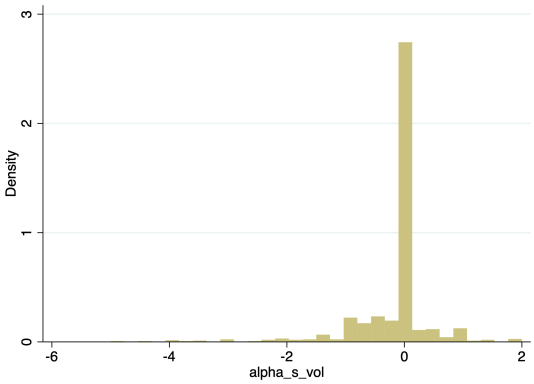
σ^a	e^a	π^a	π^s	π^f	$\frac{\text{std}(\sigma_{in}^f)}{\text{std}(\sigma_n^s)}$
1.16	**2.32**	0.004	**0.70**	0.009	**5**

Table 16: Output effect correction – Decomposition (in p.p.)

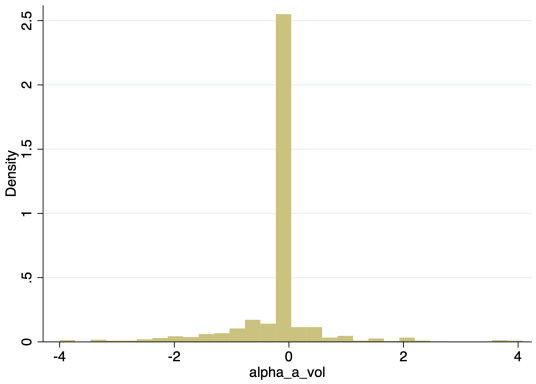
q^{noisy}	-1.25
$q^{noiseless}$	-0.88
$q^{noiseless} - q^{noisy}$	*0.37*
$\bar{E}(q) - q$	-0.55
Contribution of $\bar{E}(q) - q$	*-0.05*
$\bar{E}(q_n) - q$	-0.54
Contribution of $\bar{E}(q_n) - q$	*-0.08*
$\bar{E}(\sigma_{in}) - \sigma^a$	0.67
Contribution of $\bar{E}(\sigma_{in}) - \sigma^a$	*0.50*



(a) Policy elasticity



(b) Sectoral-level strategic



(c) Aggregate-level strategic

Figure 1: Distributions of structural parameters.

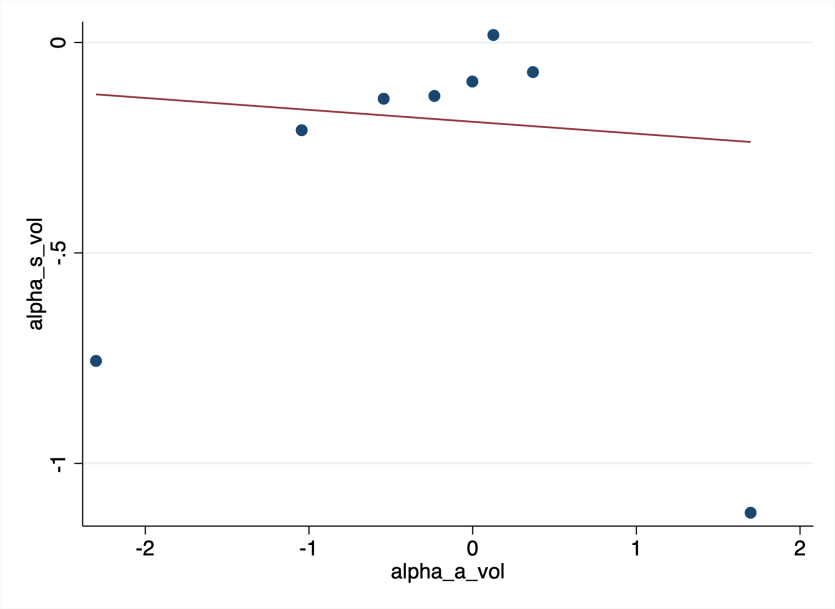
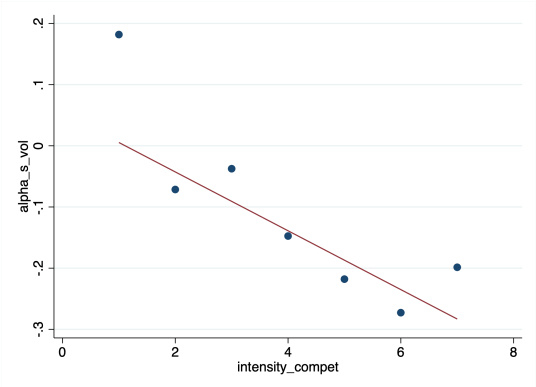
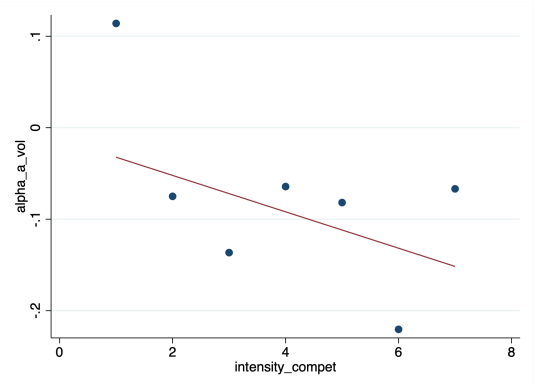


Figure 2: Strategic interaction parameters:: sectoral vs aggregate

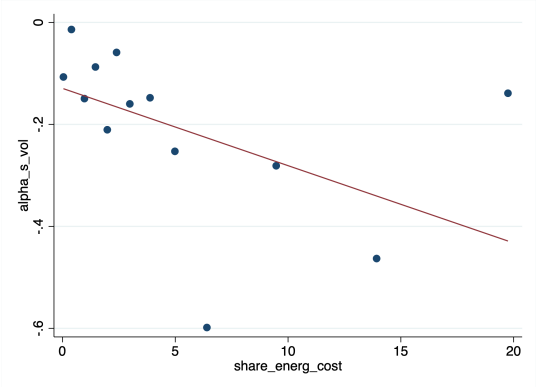
Notes: Firm managers that are the most strategic in the sectoral dimension are also the most strategic in the aggregate dimension



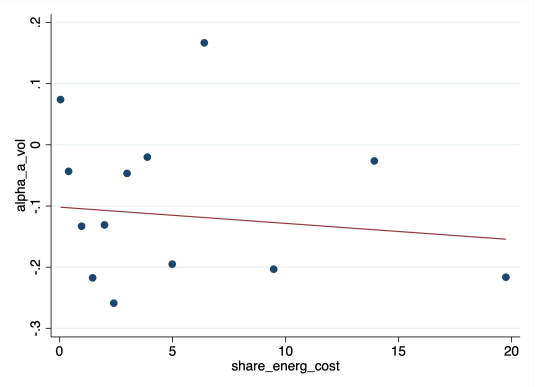
(a) Sectoral strategic parameter for output (α_s) vs. self-reported sectoral competition



(b) National strategic parameter for output (α_a) vs. self-reported sectoral competition



(c) Sectoral strategic parameter for output (α_s) vs. share of energy costs (%)



(d) National strategic parameter for output (α_a) vs. share of energy costs (%)

Figure 3: Strategic interaction parameters versus intensity of competition and energy intensity.

A Proof of Proposition 1

We guess and verify that the solution is of the form

$$q_{in} = (A_{in}^{(1)} S_{in})\tau + (A_{in}^{(2)} S_{in})(\tau_n - \tau) + (A_{in}^{(3)} S_{in})(\tau_{in} - \tau_n) \tag{33}$$

with $A_{in}^{(j)} = A^{(j)}(\Theta_{in})$, for $j = 1, 2, 3$.

Define $A_n^{(1)}$, $A_n^{(2)}$ and $A_n^{(3)}$ as the sector averages of $A_{in}^{(1)}$, $A_{in}^{(2)}$ and $A_{in}^{(3)}$, and $A_n^{(1)}$, $A^{(2)}$ and $A^{(3)}$ as the economy-wide averages.

We define ξ_{in} as the vector of underlying shocks: $\xi_{in} = (\sigma_n^a, e^a, \sigma_n^s, e_n^s, \sigma_{in}^f, e_{in}^f)'$. Note that

$$S_{in} = H\xi_{in} \tag{34}$$

with

$$H = \begin{pmatrix} 1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 & 1 & 0 \end{pmatrix}$$

Then our guess can be rewritten as a function of shocks:

$$q_{in} = (A_{in}^{(1)} H\xi_{in})\tau + (A_{in}^{(2)} H\xi_{in})(\tau_n - \tau) + (A_{in}^{(3)} H\xi_{in})(\tau_{in} - \tau_n) \tag{35}$$

Define Id as the 6×6 identity matrix, and Id^s and Id^a as the identity matrices that select only sectoral and aggregate shocks:

$$Id^s = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

$$Id^a = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

Denote $\xi_n = Id^s \xi_{in}$ and $\xi = Id^a \xi_{in}$ the vectors of shocks that select only the sectoral and aggregate shocks.

Lemma 1 (Expectations) *The rational expectation of ξ_{in} by firm i of sector n is given by*

$$E_{in}(\xi_{in}) = KS_{in}$$

where K is a 6×3 matrix.

Proof. We apply the standard information extraction formula with linear signals and normal shocks. See Appendix B for details. ■

We assume the following independence assumption:

Assumption 2 (Independence) *The firm-specific shocks and parameters are independent: for $j = 1, 2, 3$, we have*

$$\frac{1}{N^n}\sum_i (A_{in}^{(j)} - A_n^{(j)})H(\xi_{in} - \xi_n)(\tau_{in} - \tau_n) = 0$$

$$\frac{1}{N^n}\sum_i (A_{in}^{(j)} - A_n^{(j)})H(\xi_{in} - \xi_n) = 0$$

$$\frac{1}{N^n}\sum_i (A_{in}^{(j)} - A_n^{(j)})(\tau_{in} - \tau_n) = 0$$

$$\frac{1}{N^n}\sum_i (\xi_{in} - \xi_n)(\tau_{in} - \tau_n) = 0$$

The sector-specific shocks and parameters are independent: for $j = 1, 2$, we have

$$\frac{1}{N}\sum_n (A_n^{(j)} - A^{(j)})H(\xi_n - \xi)(\tau_n - \tau) = 0$$

$$\frac{1}{N}\sum_n (A_n^{(j)} - A^{(j)})H(\xi_n - \xi) = 0$$

$$\frac{1}{N}\sum_n (A_n^{(j)} - A^{(j)})(\tau_n - \tau) = 0$$

$$\frac{1}{N}\sum_n (\xi_n - \xi)(\tau_n - \tau) = 0$$

We first establish the following lemma:

Lemma 2 (Sectoral and Economy-wide averages) *Under Assumption 2,*

$$\frac{1}{N^n}\sum_i (A^{(3)}_{in} H\xi_{in})(\tau_{in}-\tau_n) = 0$$
$$\frac{1}{N^n}\sum_i (A^{(2)}_{in} H\xi_{in})(\tau_n-\tau) = (A^{(2)}_n H\xi_n)(\tau_n-\tau)$$
$$\frac{1}{N^n}\sum_i (A^{(1)}_{in} H\xi_{in})\tau = (A^{(1)}_n H\xi_n)\tau$$
$$\frac{1}{N}\sum_n (A^{(2)}_n H\xi_n)(\tau_n-\tau) = 0$$
$$\frac{1}{N}\sum_n (A^{(1)}_n H\xi_n)\tau = (A^{(1)} H\xi)\tau$$

Proof. We use the decomposition $A^l_{in} = (A^l_{in} - A^l_n) + A^l_n$ $A^l_n = (A^l_n - A^l) + A^l$, for $l = a, s, f$, $\xi_{in} = (\xi_{in} - \xi_n) + \xi_n$ and $\xi_n = (\xi_n - \xi) + \xi$, replace in the above averages, and use Assumption 2, as well as the definitions of τ, $(\tau_n - \tau)$, $(\tau_{in} - \tau_n)$, A^l_n and A^l, for $l = a, s, f$. ■

We additionally assume that the following assumption is satisfied:

Assumption 3 (Invertibility) *$Id - \alpha^s Id^s KH - \alpha^a Id^a KH$ and $Id - \alpha^s_n Id^s KH$ are invertible.*

Guess and verify Now we verify that our guess is correct.

Suppose that Equation (33) is true, then, under Assumption 2,

$$q_n = (A^{(1)}_n H\xi_n)\tau + (A^{(2)}_n H\xi_n)(\tau_n - \tau)$$
$$q = (A^{(1)} H\xi)\tau$$

Where we used Lemma 2. We then replace $\xi_n = Id^s \xi_{in}$ and $\xi = Id^a \xi_{in}$:

$$q_n = (A^{(1)}_n HId^s \xi_{in})\tau + (A^{(2)}_n HId^s \xi_{in})(\tau_n - \tau)$$
$$q = (A^{(1)} HId^a \xi_{in})\tau$$

We now take expectation and use the linearity of expectations:

$$E_{in}(q_n) = (A^{(1)}_n HId^s E_{in}(\xi_{in}))\tau + (A^{(2)}_n HId^s E_{in}(\xi_{in}))(\tau_n - \tau)$$
$$E_{in}(q) = (A^{(1)} HId^a E_{in}(\xi_{in}))\tau$$

Using Lemma 2, we obtain

$$E_{in}(q_n) = (A_n^{(1)} HId^s KS_{in})\tau + (A_n^{(2)} HId^s KS_{in})(\tau_n - \tau) \tag{36}$$

$$E_{in}(q) = (A^{(1)} HId^a KS_{in})\tau \tag{37}$$

Note also that $\sigma_{in} = X\xi_{in}$ with $X = (1, 0, 1, 0, 1, 0)$. Therefore, using similar steps, we can show

$$E_{in}(\sigma_{in}) = XKS_{in} \tag{38}$$

Now, we replace $E_{in}(q_n)$, $E_{in}(q)$ and $E_{in}(\sigma_{in})$ in Equation (18) using Equations (36), (37) and (38) and obtain

$$\begin{aligned} q_{in} &= \alpha_{in}^a (A^{(1)} HId^a KS_{in})\tau + \alpha_{in}^s \left[(A_n^{(1)} HId^s KS_{in})\tau + (A_n^{(2)} HId^s KS_{in})(\tau_n - \tau)\right] - XKS_{in}(\tau_{in} - \tau_n) \\ &= \left[\alpha_{in}^a (A^{(1)} HId^a K) + \alpha_{in}^s (A_n^{(1)} HId^s K) - XK\right] S_{in}\tau \\ &+ \left[\alpha_{in}^s (A_n^{(2)} HId^s K) - XKH\right] S_{in}(\tau_n - \tau) \\ &- XKS_{in}(\tau_{in} - \tau_n) \end{aligned} \tag{39}$$

Identifying each element in our guess (33) and in Equation (39), we obtain

$$A_{in}^{(1)} = \alpha_{in}^a (A^{(1)} HId^a K) + \alpha_{in}^s (A_n^{(1)} HId^s K) - XK \tag{40}$$

$$A_{in}^{(2)} = \alpha_{in}^s (A_n^{(2)} HId^s K) - XK \tag{41}$$

$$A_{in}^{(3)} = -XK \tag{42}$$

$A_{in}^{(3)}$ is explicitly defined. To find the solution for $A_{in}^{(2)}$, we solve first for $A_n^{(2)}$ by taking the sectoral average of Equation (41):

$$\begin{aligned} & A_n^{(2)} = \alpha_n^s (A_n^{(2)} HId^s K) - XK \\ \Leftrightarrow\ & A_n^{(2)} (Id - \alpha_n^s HId^s K) = -XK \\ \Leftrightarrow\ & A_n^{(2)} = -XK(Id - \alpha_n^s HId^s K)^{-1} \end{aligned} \tag{43}$$

where we used Assumption 3. Equation (43) gives us a solution for $A_n^{(2)}$. Then $A_{in}^{(2)}$ is simply obtained by replacing $A_n^{(2)}$ in Equation (41).

To find the solution for $A_{in}^{(1)}$, we solve first for $A^{(1)}$ by taking the economy-wide average of Equation (40):

$$\begin{aligned} & A^{(1)} = \alpha^a (A^{(1)} HId^a K) + \alpha^s (A^{(1)} HId^s K) - XK \\ \Leftrightarrow\ & A^{(1)} (Id - \alpha^s HId^s K - \alpha^a HId^a K) = -XK \\ \Leftrightarrow\ & A^{(1)} = -XK(Id - \alpha^s HId^s K - \alpha^a HId^a K)^{-1} \end{aligned} \tag{44}$$

where we used Assumptions 1 and 3. We use Assumption 1 to approximate $\frac{1}{N}\sum_{n=1}^{N}\alpha_n^s A_n^{(1)} \simeq \alpha^s A^{(1)}$. Indeed,

$$\begin{aligned}
A_{in}^{(1)} =& A^{(1)}(\Theta_{in}) = A^{(1)}(\theta_{in}^{\alpha}, \theta^{info}) \\
\simeq& A^{(1)} + (\alpha_{in}^a - \alpha_n^a)\frac{\partial A^{(1)}}{\partial(\alpha_{in}^a - \alpha_n^a)} + (\alpha_{in}^s - \alpha_n^s)\frac{\partial A^{(1)}}{\partial(\alpha_{in}^s - \alpha_n^s)} \\
&+ (\alpha^a - \alpha_n^a)\frac{\partial A^{(1)}}{\partial(\alpha^a - \alpha_n^a)} + (\alpha^s - \alpha_n^s)\frac{\partial A^{(1)}}{\partial(\alpha^s - \alpha_n^s)}
\end{aligned}$$

where $A^{(1)}$ is the value of $A^{(1)}(\Theta_{in})$ when $\alpha_{in} = \alpha_n = \alpha$, with α the economy-wide average of α_{in}. Therefore, $A_n^{(1)}$, the sectoral average of $A_{in}^{(1)}$ can be approximated as

$$A_n^{(1)} \simeq A^{(1)} + (\alpha^a - \alpha_n^a)\frac{\partial A^{(1)}}{\partial(\alpha^a - \alpha_n^a)} + (\alpha^s - \alpha_n^s)\frac{\partial A^{(1)}}{\partial(\alpha^s - \alpha_n^s)}$$

As a result,

$$\begin{aligned}
\frac{1}{N}\sum_{n=1}^{N}\alpha_n^s A_n^{(1)} =& \frac{1}{N}\sum_{n=1}^{N}\alpha^s A_n^{(1)} + \frac{1}{N}\sum_{n=1}^{N}(\alpha_n^s - \alpha^s)A_n^{(1)} \\
=& \alpha^s A^{(1)} + \underbrace{\frac{1}{N}\sum_{n=1}^{N}(\alpha_n^s - \alpha^s)A^{(1)}}_{=0} + \frac{1}{N}\sum_{n=1}^{N}(\alpha_n^s - \alpha^s)(A_n^{(1)} - A^{(1)}) \\
\simeq& \alpha^s A^{(1)} + \frac{1}{N}\sum_{n=1}^{N}(\alpha_n^s - \alpha^s)\left((\alpha^a - \alpha_n^a)\frac{\partial A^{(1)}}{\partial(\alpha^a - \alpha_n^a)} + (\alpha^s - \alpha_n^s)\frac{\partial A^{(1)}}{\partial(\alpha^s - \alpha_n^s)}\right) \\
\simeq& \alpha^s A^{(1)}
\end{aligned}$$

where the last line is a direct consequence of Assumption 1. This enables us to aggregate equation (40) into the simple linear expression (44).

Equation (44) then gives us a solution for $A^{(1)}$. To find $A_n^{(1)}$, we use the sectoral average of Equation (40):

$$\begin{aligned}
& A_n^{(1)} = \alpha_n^a(A^{(1)}HId^aK) + \alpha_n^s(A_n^{(1)}HId^sK) - XK \\
\Leftrightarrow\ & A_n^{(1)}(Id - \alpha_n^s HId^sK) = \alpha_n^a(A^{(1)}HId^aK) - XK \\
\Leftrightarrow\ & A_n^{(1)} = \left[\alpha_n^a(A^{(1)}HId^aK) - XK\right](Id - \alpha_n^s HId^sK)^{-1} \qquad (45)
\end{aligned}$$

where we used Assumption 3. Equation (45) gives us a solution for $A_n^{(1)}$. Then $A_{in}^{(1)}$ is simply obtained by replacing $A^{(1)}$ and $A_n^{(1)}$ in Equation (40).

Combining Equations (40) to (45), we can show that the solution for $(A_{in}^{(1)}, A_{in}^{(2)}, A_{in}^{(3)})$ is

$$\begin{aligned}
A_{in}^{(1)} &= -XK\left[Id + \alpha_n^a(Id - \alpha^s HId^s K - \alpha_n^a HId^a K)^{-1} Id^a K\right]\left[Id + \alpha_{in}^s(Id - \alpha_n^s HId^s K)^{-1} Id^s K\right] \\
&\quad - XK(\alpha_{in}^a - \alpha_n^a)(Id - \alpha^s HId^s K - \alpha_n^a HId^a K)^{-1} Id^a K \\
A_{in}^{(2)} &= -XK\left[Id + \alpha_{in}^s(Id - \alpha_n^s HId^s K)^{-1} Id^s K\right] \\
A_{in}^{(3)} &= -XK
\end{aligned} \tag{46}$$

This satisfies our guess and provides an explicit solution for Equation (33).

Then, Equation (19) can be derived, with $\mathcal{Q}^{(j)}(\Theta_{in}, S_{in}) = A^{(j)}(\Theta_{in})S_{in}$, $j = 1, 2, 3$, with $A^{(j)}(\Theta_{in}) = A_{in}^{(j)}$, as defined in (46).

Equations (20) can be obtained by aggregating Equation (33) at the sectoral and aggregate levels, using Assumption 2:

$$\begin{aligned}
q_n &= (A_n^{(1)} H\xi_n)\tau + (A_n^{(2)}\xi_n)(\tau_n - \tau) \\
q &= (A^{(1)} H\xi)\tau
\end{aligned}$$

We take expectations:

$$\begin{aligned}
E_{in}(q_n) &= A_n^{(1)} HE_{in}(\xi_n)\tau + A_n^{(2)} HE_{in}(\xi_n)(\tau_n - \tau) \\
E_{in}(q) &= A^{(1)} HE_{in}(\xi)\tau
\end{aligned}$$

We then use Lemma 1 to replace the expectations in the right-hand side:

$$\begin{aligned}
E_{in}(q_n) &= A_n^{(1)} Id^s HKS_{in}\tau + A_n^{(2)} Id^s HKS_{in}(\tau_n - \tau) \\
E_{in}(q) &= A^{(1)} Id^a HKS_{in}\tau
\end{aligned}$$

We thus have

$$\begin{aligned}
E_{in}(q_n) &= A_n^{s(1)} S_{in}\tau + A_n^{s(2)} S_{in}(\tau_n - \tau) \\
E_{in}(q) &= A^{a(1)} S_{in}\tau
\end{aligned}$$

with

$$\begin{aligned}
A_n^{s(1)} &= A_n^{(1)} Id^s HK \\
A_n^{s(2)} &= A_n^{(2)} Id^s HK \\
A^{a(1)} &= A^{(1)} Id^a HK
\end{aligned} \tag{47}$$

Therefore, Equations (20) are satisfied, with $\mathcal{Q}^{k(j)}(\Theta_{in}, S_{in}) = A^{k(j)}(\Theta_{in})S_{in}$, for $(j, k) = (1, s), (2, s), (1, a)$, with $A^{s(1)}(\Theta_{in}) = A_n^{s(1)}$, $A^{s(2)}(\Theta_{in}) = A_n^{s(2)}$ and $A^{a(1)}(\Theta_{in}) = A^{a(1)}$ as defined in (47).

B Signal extraction

We are looking for the firm's expectation about the components of the elasticity conditional on the signals $S_{in} = (E^a(\sigma^a), E^s_n(\sigma^s_n), s^f_{in})'$. We use the formulas:

$$\begin{aligned}
E_{in}(\sigma^a) &= E\left(\sigma^a | E^a(\sigma^a), E^s_n(\sigma^s_n)\right) + \delta^a \left[s^f_{in} - E\left(s^f_{in} | E^a(\sigma^a), E^s_n(\sigma^s_n)\right)\right] \\
E_{in}(\sigma^s_n) &= E\left(\sigma^s_n | E^a(\sigma^a), E^s_n(\sigma^s_n)\right) + \delta^s \left[s^f_{in} - E\left(s^f_{in} | E^a(\sigma^a), E^s_n(\sigma^s_n)\right)\right] \\
E_{in}(\sigma^f_{in}) &= E\left(\sigma^f_{in} | E^a(\sigma^a), E^s_n(\sigma^s_n)\right) + \delta^x \left[s^f_{in} - E\left(s^f_{in} | E^a(\sigma^a), E^s_n(\sigma^s_n)\right)\right]
\end{aligned}$$

with

$$\begin{aligned}
\delta^a &= \frac{Cov\left(s^f_{in} - E\left(s^f_{in} | E^a(\sigma^a), E^s_n(\sigma^s_n)\right), \sigma^a - E\left(\sigma^a | E^a(\sigma^a), E^s_n(\sigma^s_n)\right)\right)}{V\left(s^f_{in} - E\left(s^f_{in} | E^a(\sigma^a), E^s_n(\sigma^s_n)\right)\right)} \\
\delta^s &= \frac{Cov\left(s^f_{in} - E\left(s^f_{in} | E^a(\sigma^a), E^s_n(\sigma^s_n)\right), \sigma^s_n - E\left(\sigma^n_s | E^a(\sigma^a), E^s_n(\sigma^s_n)\right)\right)}{V\left(s^f_{in} - E\left(s^f_{in} | E^a(\sigma^a), E^s_n(\sigma^s_n)\right)\right)} \\
\delta^x &= \frac{Cov\left(s^f_{in} - E\left(s^f_{in} | E^a(\sigma^a), E^s_n(\sigma^s_n)\right), \sigma^f_{in} - E\left(\sigma^f_{in} | E^a(\sigma^a), E^s_n(\sigma^s_n)\right)\right)}{V\left(s^f_{in} - E\left(s^f_{in} | E^a(\sigma^a), E^s_n(\sigma^s_n)\right)\right)}
\end{aligned}$$

We have

$$\begin{aligned}
E\left(\sigma^a | E^a(\sigma^a), E^s_n(\sigma^s_n)\right) &= E^a(\sigma^a) \\
E\left(\sigma^s_n | E^a(\sigma^a), E^s_n(\sigma^s_n)\right) &= E^s_n(\sigma^s_n) \\
E\left(\sigma^f_{in} | E^a(\sigma^a), E^s_n(\sigma^s_n)\right) &= 0 \\
s^f_{in} - E\left(s^f_{in} | E^a(\sigma^a), E^s_n(\sigma^s_n)\right) &= s^f_{in} - E^a(\sigma^a) - E^s_n(\sigma^s_n) = \sigma^f_{in} + e^f_{in} - e^a - e^s_n \\
\sigma^a - E\left(\sigma^a | E^a(\sigma^a), E^s_n(\sigma^s_n)\right) &= -e^a \\
\sigma^s_n - E\left(\sigma^s_n | E^a(\sigma^a), E^s_n(\sigma^s_n)\right) &= -e^s_n \\
\sigma^f_{in} - E\left(\sigma^f_{in} | E^a(\sigma^a), E^s_n(\sigma^s_n)\right) &= \sigma^f_{in}
\end{aligned}$$

Therefore,

$$
\begin{aligned}
&V\left(s_{in}^f - E\left(s_{in}^f | E^a(\sigma^a), E_n^s(\sigma_n^s)\right)\right) = (\pi^a)^{-1} + (\pi^s)^{-1} + (\pi^f)^{-1} + (\kappa^f)^{-1} \\
&Cov\left(s_{in}^f - E\left(s_{in}^f | E^a(\sigma^a), E_n^s(\sigma_n^s)\right), \sigma^a - E\left(\sigma^a | E^a(\sigma^a), E_n^s(\sigma_n^s)\right)\right) = (\pi^a)^{-1} \\
&Cov\left(s_{in}^f - E\left(s_{in}^f | E^a(\sigma^a), E_n^s(\sigma_n^s)\right), \sigma_n^s - E\left(\sigma_n^s | E^a(\sigma^a), E_n^s(\sigma_n^s)\right)\right) = (\pi^s)^{-1} \\
&Cov\left(s_{in}^f - E\left(s_{in}^f | E^a(\sigma^a), E_n^s(\sigma_n^s)\right), \sigma_{in}^f - E\left(\sigma_{in}^f | E^a(\sigma^a), E_n^s(\sigma_n^s)\right)\right) = (\kappa^f)^{-1}
\end{aligned}
$$

As a result, the signal-extraction formulas become

$$
\begin{aligned}
E_{in}(\sigma^a) &= (1-\delta^a)E^a(\sigma^a) - \delta^a E_n^s(\sigma_n^s) + \delta^a s_{in}^f \\
E_{in}(\sigma_n^s) &= -\delta^s E^a(\sigma^a) + (1-\delta^s)E_n^s(\sigma_n^s) + \delta^s s_{in}^f \\
E_{in}(\sigma_{in}^f) &= -\delta^x E^a(\sigma^a) - \delta^x E_n^s(\sigma_n^s) + \delta^x s_{in}^f
\end{aligned} \tag{48}
$$

with

$$
\begin{aligned}
\delta^a &= \frac{(\pi^a)^{-1}}{(\pi^a)^{-1} + (\pi^s)^{-1} + (\pi^f)^{-1} + (\kappa^f)^{-1}} \\
\delta^s &= \frac{(\pi^s)^{-1}}{(\pi^a)^{-1} + (\pi^s)^{-1} + (\pi^f)^{-1} + (\kappa^f)^{-1}} \\
\delta^x &= \frac{(\kappa^f)^{-1}}{(\pi^a)^{-1} + (\pi^s)^{-1} + (\pi^f)^{-1} + (\kappa^f)^{-1}}
\end{aligned} \tag{49}
$$

As a consequence, the expected individual elasticity is

$$
\begin{aligned}
E_{in}(\sigma_{in}) &= E_{in}(\sigma^a) + E_{in}(\sigma_n^s) + E_{in}(\sigma_{in}^f) \\
&= (1-\delta^f)\left[E^a(\sigma^a) + E_n^s(\sigma_n^s)\right] + \delta^f s_{in}^f
\end{aligned} \tag{50}
$$

with $\delta^f = \delta^a + \delta^s + \delta^x$.

Noting that

$$
\begin{aligned}
E_{in}(e^a) &= E^a(\sigma^a) - E_{in}(\sigma^a) \\
E_{in}(e_n^s) &= E_n^s(\sigma_n^s) - E_{in}(\sigma_n^s) \\
E_{in}(e_{in}^f) &= s_{in}^f - E_{in}(\sigma_n^s) - E_{in}(\sigma^a) - E_{in}(\sigma_{in}^f)
\end{aligned}
$$

we can derive the full solution for K in Lemma 1:

$$K = \begin{pmatrix} (1-\delta^a) & -\delta^a & \delta^a \\ \delta^a & \delta^a & -\delta^a \\ -\delta^s & (1-\delta^s) & \delta^s \\ \delta^s & \delta^s & -\delta^s \\ -\delta^x & -\delta^x & \delta^x \\ -(1-\delta^a-\delta^s-\delta^x) & -(1-\delta^a-\delta^s-\delta^x) & (1-\delta^a-\delta^s-\delta^x) \end{pmatrix} \tag{51}$$

C Closed-form solution for an economy-wide tax

Proposition 1 implies that the solution for q_{in}, in the case of an economy-wide tax, is of the form displayed in Equation (24). We derive here closed-form expressions for γ^a_{in}, γ^s_{in} and γ^f_{in}.

Assuming that Assumption 2 holds, and aggregating at the sector and aggregate level implies that the expressions (27) and (25) hold for output at the sector and aggregate level. Taking expectations, and using the solution for expectations (48), we obtain

$$\begin{aligned}
E_{in}(q_n) &= -\left(\gamma^a_n E^a(\sigma^a) + \gamma^s_n E^s_n(\sigma^s_n) + \gamma^f_n (E_{in}(\sigma^a) + E_{in}(\sigma^s_n))\right)\tau \\
&= -\left(\gamma^a_n E^a(\sigma^a) + \gamma^s_n E^s_n(\sigma^s_n) + \gamma^f_n ((1-\delta^a-\delta^s)(E^a(\sigma^a) + E^s_n(\sigma^s_n)) + (\delta^a+\delta^s)s^f_{in})\right)\tau \\
&= -\left((\gamma^a_n + \gamma^f_n(1-\delta^a-\delta^s))E^a(\sigma^a) + (\gamma^s_n + \gamma^f_n(1-\delta^a-\delta^s))E^s_n(\sigma^s_n) + \gamma^f_n(\delta^a+\delta^s)s^f_{in}\right)\tau \\
E_{in}(q) &= -\left(\gamma^a E^a(\sigma^a) + \gamma^f E_{in}(\sigma^a)\right)\tau \\
&= -\left(\gamma^a E^a(\sigma^a) + \gamma^f [(1-\delta^a)E^a(\sigma^a) - \delta^a E^s_n(\sigma^s_n) + \delta^a s^f_{in}]\right)\tau \\
&= -\left((\gamma^a + \gamma^f(1-\delta^a))E^a(\sigma^a) - \gamma^f \delta^a E^s_n(\sigma^s_n) + \gamma^f \delta^a s^f_{in}\right)\tau
\end{aligned}$$

Using these expressions, along with (50), we can substitute the terms in Equation

(18) and obtain:

$$\begin{aligned}
q_{in} =& -\alpha_{in}^{a}\left((\gamma^{a}+\gamma^{f}(1-\delta^{a}))E^{a}(\sigma^{a})-\gamma^{f}\delta^{a}E_{n}^{s}(\sigma_{n}^{s})+\gamma^{f}\delta^{a}s_{in}^{f}\right)\tau \\
& -\alpha_{in}^{s}\left((\gamma_{n}^{a}+\gamma_{n}^{f}(1-\delta^{a}-\delta^{s}))E^{a}(\sigma^{a})+(\gamma_{n}^{s}+\gamma_{n}^{f}(1-\delta^{a}-\delta^{s}))E_{n}^{s}(\sigma_{n}^{s})+\gamma_{n}^{f}(\delta^{a}+\delta^{s})s_{in}^{f}\right)\tau \\
& -\left((1-\delta^{f})\left[E^{a}(\sigma^{a})+E_{n}^{s}(\sigma_{n}^{s})\right]+\delta^{f}s_{in}^{f}\right)\tau \\
=& -\left(\alpha_{in}^{a}(\gamma^{a}+\gamma^{f}(1-\delta^{a}))+\alpha_{in}^{s}(\gamma_{n}^{a}+\gamma_{n}^{f}(1-\delta^{a}-\delta^{s}))+1-\delta^{f}\right)E^{a}(\sigma^{a})\tau \\
& -\left(-\alpha_{in}^{a}\gamma^{f}\delta^{a}+\alpha_{in}^{s}(\gamma_{n}^{s}+\gamma_{n}^{f}(1-\delta^{a}-\delta^{s}))+1-\delta^{f}\right)E_{n}^{s}(\sigma_{n}^{s})\tau \\
& -\left(\alpha_{in}^{a}\gamma^{f}\delta^{a}+\alpha_{in}^{s}\gamma_{n}^{f}(\delta^{a}+\delta^{s})+\delta^{f}\right)s_{in}^{f}\tau
\end{aligned}$$

Identifying the coefficients across the above expressions and (24), we obtain:

$$\begin{aligned}
\gamma_{in}^{a} =& \alpha_{in}^{a}(\gamma^{a}+\gamma^{f}(1-\delta^{a}))+\alpha_{in}^{s}(\gamma_{n}^{a}+\gamma_{n}^{f}(1-\delta^{a}-\delta^{s}))+1-\delta^{f} \\
\gamma_{in}^{s} =& -\alpha_{in}^{a}\gamma^{f}\delta^{a}+\alpha_{in}^{s}(\gamma_{n}^{s}+\gamma_{n}^{f}(1-\delta^{a}-\delta^{s}))+1-\delta^{f} \\
\gamma_{in}^{f} =& \alpha_{in}^{a}\gamma^{f}\delta^{a}+\alpha_{in}^{s}\gamma_{n}^{f}(\delta^{a}+\delta^{s})+\delta^{f}
\end{aligned} \tag{52}$$

These equations can be aggregated at the sector level:

$$\begin{aligned}
\gamma_{n}^{a} =& \alpha_{n}^{a}(\gamma^{a}+\gamma^{f}(1-\delta^{a}))+\alpha_{n}^{s}(\gamma_{n}^{a}+\gamma_{n}^{f}(1-\delta^{a}-\delta^{s}))+1-\delta^{f} \\
\gamma_{n}^{s} =& -\alpha_{n}^{a}\gamma^{f}\delta^{a}+\alpha_{n}^{s}(\gamma_{n}^{s}+\gamma_{n}^{f}(1-\delta^{a}-\delta^{s}))+1-\delta^{f} \\
\gamma_{n}^{f} =& \alpha_{n}^{a}\gamma^{f}\delta^{a}+\alpha_{n}^{s}\gamma_{n}^{f}(\delta^{a}+\delta^{s})+\delta^{f}
\end{aligned} \tag{53}$$

Under Assumption 1, we can approximate:

$$\begin{aligned}
\frac{1}{N}\sum_{n=1}^{N}\alpha_{n}^{s}\gamma_{n}^{a} &\simeq \alpha^{s}\gamma^{a} \\
\frac{1}{N}\sum_{n=1}^{N}\alpha_{n}^{s}\gamma_{n}^{s} &\simeq \alpha^{s}\gamma^{s} \\
\frac{1}{N}\sum_{n=1}^{N}\alpha_{n}^{s}\gamma_{n}^{f} &\simeq \alpha^{s}\gamma^{f}
\end{aligned}$$

To show this, we follow the same steps as in the proof of Proposition 1. As a result, the sectoral equations can be aggregated as follows:

$$\begin{aligned}
\gamma^{a} =& \alpha^{a}(\gamma^{a}+\gamma^{f}(1-\delta^{a}))+\alpha^{s}(\gamma^{a}+\gamma^{f}(1-\delta^{a}-\delta^{s}))+1-\delta^{f} \\
\gamma^{s} =& -\alpha^{a}\gamma^{f}\delta^{a}+\alpha^{s}(\gamma^{s}+\gamma^{f}(1-\delta^{a}-\delta^{s}))+1-\delta^{f} \\
\gamma^{f} =& \alpha^{a}\gamma^{f}\delta^{a}+\alpha^{s}\gamma^{f}(\delta^{a}+\delta^{s})+\delta^{f}
\end{aligned} \tag{54}$$

After some further manipulation of these equations, we can show that

$$\begin{aligned}\gamma^a + \gamma^f =& \frac{1}{1-\alpha^a-\alpha^s}\\ \gamma^s + \gamma^f =& \frac{1}{1-\alpha^s}\\ \gamma^f =& \frac{\delta^f}{1-\alpha^a\delta^a-\alpha^s(\delta^a+\delta^f)}\end{aligned} \tag{55}$$

Plugging these values back into the sectoral equations (53), and after rearranging, we obtain:

$$\begin{aligned}\gamma^a_n + \gamma^f_n =& \gamma^a + \gamma^f + \frac{\alpha^a_n - \alpha^a + \alpha^s_n - \alpha^s}{[1-\alpha^s_n][1-\alpha^a-\alpha^s]}\\ \gamma^s_n + \gamma^f_n =& \gamma^s + \gamma^f + \frac{\alpha^s_n - \alpha^s}{(1-\alpha^s)(1-\alpha^s_n)}\\ \gamma^f_n =& \gamma^f + \frac{(\alpha^a_n-\alpha^a)\delta^a + (\alpha^s_n-\alpha^s)(\delta^a+\delta^s)}{[1-\alpha^s_n(\delta^a+\delta^s)][1-\alpha^a\delta^a-\alpha^s(\delta^a+\delta^f)]}\delta^f\end{aligned}$$

This can be approximated at the first order around $\alpha_{in} = \alpha_n = \alpha$ to

$$\begin{aligned}\gamma^a_n + \gamma^f_n - (\gamma^a + \gamma^f) \simeq& \frac{\alpha^a_n - \alpha^a + \alpha^s_n - \alpha^s}{[1-\alpha^s][1-\alpha^a-\alpha^s]}\\ \gamma^s_n + \gamma^f_n - (\gamma^s + \gamma^f) \simeq& \frac{\alpha^s_n - \alpha^s}{(1-\alpha^s)^2}\\ \gamma^f_n - \gamma^f \simeq& \frac{(\alpha^a_n-\alpha^a)\delta^a + (\alpha^s_n-\alpha^s)(\delta^a+\delta^s)}{1-\alpha^s(\delta^a+\delta^s)}\gamma^f\end{aligned} \tag{56}$$

Then, plugging into the individual equations (52), rearranging, and neglecting higher-order terms, we obtain:

$$\begin{aligned}\gamma^a_{in} + \gamma^f_{in} - (\gamma^a_n + \gamma^f_n) =& \frac{\alpha^a_{in} - \alpha^a_n + \alpha^s_{in} - \alpha^s_n}{1-\alpha^a-\alpha^s}\\ \gamma^s_{in} + \gamma^f_{in} - (\gamma^s_n + \gamma^f_n) =& \frac{\alpha^s_{in} - \alpha^s_n}{1-\alpha^s}\\ \gamma^f_{in} - \gamma^f_n \simeq& \left[(\alpha^a_{in}-\alpha^a_n)\delta^a + (\alpha^s_{in}-\alpha^s_n)(\delta^a+\delta^s)\right]\gamma^f\end{aligned} \tag{57}$$

D Proof of Proposition ??

We prove point 1 of the proposition by noting that

$$\begin{aligned}
E_{in}(q) - \bar{E}_n(q) &= -\gamma^f \left(E_{in}(\sigma^a + \sigma^s_n) - \bar{E}_n(\sigma^a + \sigma^s_n) \right) \tau \\
&= -\gamma^f \delta^a (\sigma^f_{in} + e^f_{in}) \tau \\
E_{in}(q_n) - \bar{E}_n(q_n) &= -\gamma^f_n \left(E_{in}(\sigma^a + \sigma^s_n) - \bar{E}_n(\sigma^a + \sigma^s_n) \right) \tau \\
&= -\gamma^f_n (\delta^a + \delta^s)(\sigma^f_{in} + e^f_{in}) \tau \\
&= -\gamma^f (\delta^a + \delta^s)(\sigma^f_{in} + e^f_{in}) \tau - (\gamma^f_n - \gamma^f)(\delta^a + \delta^s)(\sigma^f_{in} + e^f_{in}) \tau \\
&\simeq -\gamma^f (\delta^a + \delta^s)(\sigma^f_{in} + e^f_{in}) \tau
\end{aligned}$$

where the last line is a linear approximation in γ^f_n and $\sigma^f_{in} + e^f_{in}$ around their economy-wide average, which are equal respectively to γ^f and 0. Point 1 is obtained by taking the relative variance of $E_{in}(q_n) - \bar{E}_n(q_n)$ and $E_{in}(q) - \bar{E}_n(q)$.

We prove point 2 by additionally noting that

$$E_{in}(\sigma_{in}) - \bar{E}_n(\sigma_{in}) = \delta^f (\sigma^f_{in} + e^f_{in})$$

Point 2 is obtained by taking the variance of $E_{in}(\sigma_{in}) - \bar{E}_n(\sigma_{in})$ relative to the variance of $E_{in}(q) - \bar{E}_n(q)$, taking Equation **??** into account.

We prove point 3 by first noting that

$$\begin{aligned}
q &= -\left((\gamma^a + \gamma^f)(\sigma^a + e^a) - \gamma^f e^a \right) \tau \\
\bar{E}(q) &= -\left((\gamma^a + \gamma^f)(\sigma^a + e^a) - \gamma^f \delta^a e^a \right) \tau
\end{aligned}$$

These two expressions imply that

$$\begin{aligned}
-\frac{1}{(1-\delta^a)\tau} \left(\bar{E}(q) - q \right) &= \gamma^f e^a \\
\frac{1 - \alpha^a - \alpha^s}{(1-\delta^a)\tau} \left(\delta^a q - \bar{E}(q) \right) &= \sigma^a + e^a
\end{aligned}$$

where we used the solution for $\gamma^a + \gamma^f$ in (55) to derive the last expression. $\sigma^a + e^a$ and $\gamma^f e^a$ can therefore be recovered from observables, but, at this stage, we cannot disentangle γ^f from e^a.

We then compute $q_n - q$:

$$\begin{aligned} q_n - q &= \left(\left(\gamma_n^a + \gamma_n^f - \gamma^a - \gamma^f\right)\sigma^a + \left(\gamma_n^a - \gamma^a\right)e^a + \left(\gamma_n^s + \gamma_n^f\right)\sigma_n^s + \gamma_n^s e_n^s\right)\tau \\ &= \left(\underbrace{\left(\gamma_n^a + \gamma_n^f - \gamma^a - \gamma^f\right)\left(\sigma^a + e^a\right) + \frac{\gamma_n^f - \gamma^f}{\gamma^f}(\gamma^f e^a)}_{\text{Computable}} + \left(\gamma_n^s + \gamma_n^f\right)\sigma_n^s + \gamma_n^s e_n^s\right)\tau \end{aligned}$$

The sector-specific part of sectoral production is not only a function of the sector-specific shocks, but also of the aggregate shocks, to the extent that the sector-level parameters differ from the aggregate parameters. We can however compute the part that is due to aggregate shocks, because we know $\sigma^a + e^a$ and $\gamma^f e^a$, as explained above, and because we can infer the deviations of the sectoral parameters from their aggregate mean, using (56). We thus define

$$\widetilde{q_n - q} = q_n - q - \left[\left(\gamma_n^a + \gamma_n^f - \gamma^a - \gamma^f\right)\left(\sigma^a + e^a\right) + \frac{\gamma_n^f - \gamma^f}{\gamma^f}(\gamma^f e^a)\right]\tau \tag{58}$$

We have

$$\begin{aligned} \widetilde{q_n - q} &= \left(\left(\gamma_n^s + \gamma_n^f\right)\sigma_n^s + \gamma_n^s e_n^s\right)\tau \\ &\simeq \left(\left(\gamma^s + \gamma^f\right)\sigma_n^s + \gamma^s e_n^s\right)\tau \\ &\simeq \left(\frac{1}{1-\alpha^s}\sigma_n^s + \left(\frac{1}{1-\alpha^s} - \gamma^f\right)e_n^s\right)\tau \end{aligned}$$

where the third line is a linear approximation in γ_n^s, γ_n^f and σ_n^s and e_n^s around their economy-wide average, which are equal respectively to γ^s, γ^f, 0 and 0, and the last line makes use of the solutions for the γ parameters (55).

Now note also the following:

$$\begin{aligned} \bar{E}_n(q) - \bar{E}(q) &= -\gamma^f\left(\bar{E}_n(\sigma^a) - \bar{E}(\sigma^a)\right)\tau \\ &= \gamma^f \delta^a e_n^s \tau \\ \bar{E}_n(\sigma_{in}) - \bar{E}(\sigma_{in}) &= \left(\sigma_n^s + \left(1 - \delta^f\right)e_n^s\right)\tau \\ &= \left(\sigma_n^s + \left(1 - \gamma^f(1 - \alpha^a\delta^a - \alpha^s(\delta^a + \delta^s))\right)e_n^s\right)\tau \end{aligned}$$

$$
\begin{aligned}
&\frac{V\left((1-\alpha^s)(\widetilde{q_n-q})\right)-V\left(\bar{E}_n(\sigma_{in})-\bar{E}(\sigma_{in})\right)}{V\left(\frac{1}{\delta^a}\left(\bar{E}_n(q)-\bar{E}(q)\right)\right)}\\
&=\frac{\left(\left(1-\gamma^f(1-\alpha^s)\right)^2-\left(1-\gamma^f[1-\alpha^a\delta^a-\alpha^s(\delta^a+\delta^s)]\right)^2\right)(\pi^s)^{-2}\tau^2}{(\gamma^f)^2(\pi^s)^{-2}\tau^2}\\
&=\frac{\left(\left(1-\gamma^f(1-\alpha^s)\right)^2-\left(1-\gamma^f[1-\alpha^a\delta^a-\alpha^s(\delta^a+\delta^s)]\right)^2\right)}{(\gamma^f)^2}\\
&=\left(\left((\gamma^f)^{-1}-(1-\alpha^s)\right)^2-\left((\gamma^f)^{-1}-[1-\alpha^a\delta^a-\alpha^s(\delta^a+\delta^s)]\right)^2\right)\\
&=2(\gamma^f)^{-1}\left[\alpha^s-\alpha^a\delta^a-\alpha^s(\delta^a+\delta^s)\right]+(1-\alpha^s)^2-(1-\alpha^a\delta^a-\alpha^s(\delta^a+\delta^s))^2
\end{aligned}
$$

This yields point 3.

E Firm Population and Survey Sample

E.1 Firm Population

Our firm survey covers the entire Swiss economy, with the exception of (i) the Italian- and Romansh-speaking regions, and (ii) sectors outside the market economy—specifically, Sectors O (Public Administration and Defence; Compulsory Social Security), P (Education), T (Activities of Households as Employers; Undifferentiated Goods- and Services-Producing Activities of Households for Own Use), and U (Activities of Extraterritorial Organisations and Bodies).

Table 17 presents company population numbers from the Business and Enterprise Register (BER) maintained by the Swiss Federal Statistical Office, disaggregated by employee size class and economic sector, according to letter codes in the Swiss General Classification of Economic Activities (NOGA). The NOGA classification corresponds to the Statistical Classification of Economic Activities (NACE) used in the European Community.[9]

[9]Companies located in the Italian- and Romansh-speaking regions account for only 6% of all companies in the BER.

Table 17: Active Companies (French- and German-speaking Switzerland)

	A	B	C	D	E	F	G	H	I
Micro (1–9)	49163 (8.38%)	112 (0.02%)	29682 (5.06%)	563 (0.10%)	1163 (0.20%)	39266 (6.70%)	59557 (10.16%)	10732 (1.83%)	21109 (3.60%)
Small (10–49)	1003 (0.17%)	94 (0.02%)	6491 (1.11%)	150 (0.03%)	315 (0.05%)	6385 (1.09%)	7558 (1.29%)	1520 (0.26%)	4919 (0.84%)
Medium (50–249)	65 (0.01%)	15 (0.00%)	1822 (0.31%)	69 (0.01%)	72 (0.01%)	793 (0.14%)	1051 (0.18%)	395 (0.07%)	498 (0.08%)
Large (250+)	2 (0.00%)	2 (0.00%)	381 (0.06%)	34 (0.01%)	5 (0.00%)	84 (0.01%)	202 (0.03%)	119 (0.02%)	62 (0.01%)
Total	50233 (8.57%)	223 (0.04%)	38376 (6.54%)	816 (0.14%)	1555 (0.27%)	46528 (7.93%)	68368 (11.66%)	12766 (2.18%)	26588 (4.53%)

	J	K	L	M	N	Q	R	S	Total
Micro (1–9)	23543 (4.01%)	14527 (2.48%)	18873 (3.22%)	95054 (16.21%)	21455 (3.66%)	65682 (11.20%)	23899 (4.08%)	50259 (8.57%)	524639 (89.46%)
Small (10–49)	2179 (0.37%)	1581 (0.27%)	976 (0.17%)	5935 (1.01%)	2685 (0.46%)	4919 (0.84%)	1346 (0.23%)	2560 (0.44%)	50616 (8.63%)
Medium (50–249)	450 (0.08%)	399 (0.07%)	117 (0.02%)	730 (0.12%)	731 (0.12%)	1657 (0.28%)	194 (0.03%)	325 (0.06%)	9383 (1.60%)
Large (250+)	73 (0.01%)	114 (0.02%)	10 (0.00%)	109 (0.02%)	152 (0.03%)	419 (0.07%)	32 (0.01%)	29 (0.00%)	1829 (0.31%)
Total	26245 (4.48%)	16621 (2.83%)	19976 (3.41%)	101828 (17.36%)	25023 (4.27%)	72677 (12.39%)	25471 (4.34%)	53173 (9.07%)	586467 (100.00%)

Note: The table displays the number of active companies and their percentage shares (in parentheses) in the German- and French-speaking regions of Switzerland, disaggregated by NOGA letter sector and employee size class, as recorded in the Business and Enterprise Register of the Swiss Federal Statistical Office. Sectors O, P, T, and U are excluded. Shares are relative to the grand total of 586,467 companies.

E.2 Address Sampling

We construct our company survey sample from three sources: the Orbis company database (Moody's Analytics, 2025), the firm panel maintained by the KOF Swiss Economic Institute at ETH Zurich (KOF Swiss Economic Institute, 2025), and an address panel obtained from a survey conducted by us in the year 2023 (Benhima et al., 2024). All three sources are used exclusively to obtain contact e-mail addresses for firms, stratified by sector and company size.[10] The three address panels are presented in the following sections.

E.3 Orbis Address Panel

The Orbis database provides one of the most comprehensive collections of firm-level contact e-mails in Switzerland. We draw our address sample from Orbis using stratified sampling, based on the population benchmarks shown in Table 17.

Rather than applying purely proportional stratified sampling, we intentionally oversample larger firms and selected sectors. Regards sector oversampling: for each company size stratum in Sectors C (Manufacturing), D (Energy Supply), E (Water Supply; Sewerage; Waste Management and Remediation), F (Construction), G (Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles), and H (Transportation and Storage), the number of contact e-mails is doubled relative to the values in Table 17. With regard to oversampling of larger firms: in order to achieve the target distribution across firm size categories in the unified address panel (see Section E.6), and taking into account the availability of companies in the other two panels (see Sections E.4 and E.5), we needed to sample from the Orbis address database 16,129 micro companies (66.9% of all sampled Orbis companies, as compared to micro companies accounting for 89.5% of all companies in the population), 3,700 small companies (15.4% vs. 8.6%), 2,407 medium-sized companies (10.0% vs. 1.6%), and 1,838 large companies (7.7% vs. 0.3%).

The rationale behind the oversampling strategy is as follows: A larger number of observation units is allocated to those strata of the company population that contribute more heavily to the overall aggregation, either due to their high number

[10] Other firm-level information included in these sources is not used in our analysis. To ensure consistency, all relevant company information is collected directly through the survey.

of employees or high value added. As a result, these strata, which are important for the aggregate, are more accurately captured, reducing the expected sampling error, i.e., the deviation of the survey aggregates from the unobserved population aggregate, which would have been obtained had the entire population been surveyed. Furthermore, the decision to oversample the Sectors C to H is motivated by the expectation that these sectors are more likely to exhibit pronounced effects in response to the climate shock scenario, along with higher within-stratum variability among firms, relative to other sectors. For other sectors, by contrast, we anticipate the effects to be rather small or even zero, and the cross-company variance to be relatively low. Since higher variance implies a larger expected sampling error, ceteris paribus, it justifies a proportionally larger sample size for these high-variance cells. Notably, during the aggregation of survey results, the over- and undersampling is corrected by reweighting firms according to population statistics.

E.4 KOF Address Panel

The KOF Business Tendency Surveys are conducted monthly or quarterly among Swiss firms across a broad range of sectors (KOF Swiss Economic Institute, 2025). For our study, KOF kindly provided access to the address panel underlying the following sectoral surveys: manufacturing, construction, general services, wholesale services, banking, financial, and insurance services, and project engineering services. Table 18 presents the number of companies in this address panel, disaggregated by firm size and sector.

Table 18: KOF Gross Sample

	C	F	G	H	J	K	L	M	N	Q	R	S	Total
Micro (0–9)	138 (4.36%)	180 (5.69%)	106 (3.35%)	25 (0.79%)	86 (2.72%)	51 (1.61%)	31 (0.98%)	194 (6.13%)	42 (1.33%)	51 (1.61%)	31 (0.98%)	12 (0.38%)	947 (29.93%)
Small (10–49)	368 (11.63%)	380 (12.01%)	144 (4.55%)	31 (0.98%)	75 (2.37%)	73 (2.31%)	31 (0.98%)	194 (6.13%)	48 (1.52%)	53 (1.68%)	18 (0.57%)	13 (0.41%)	1428 (45.13%)
Medium (50–249)	204 (6.45%)	129 (4.08%)	73 (2.31%)	26 (0.82%)	32 (1.01%)	39 (1.23%)	10 (0.32%)	40 (1.26%)	22 (0.70%)	59 (1.86%)	6 (0.19%)	6 (0.19%)	646 (20.42%)
Large (250+)	58 (1.83%)	18 (0.57%)	6 (0.19%)	8 (0.25%)	8 (0.25%)	11 (0.35%)	1 (0.03%)	8 (0.25%)	6 (0.19%)	17 (0.54%)	1 (0.03%)	1 (0.03%)	143 (4.52%)
Total	768 (24.27%)	707 (22.35%)	329 (10.40%)	90 (2.84%)	201 (6.35%)	174 (5.50%)	73 (2.31%)	436 (13.78%)	118 (3.73%)	180 (5.69%)	56 (1.77%)	32 (1.01%)	3164 (100.00%)

Note: The table presents the number of company contacts in the KOF address panel available for our survey, along with their corresponding percentage shares (in parentheses), disaggregated by NOGA sector letter and firm size class. Shares are calculated relative to the total sample of 3,164 firms.

E.5 Address Panel from 2023 Survey

Between June and August 2023, we conducted a survey on energy prices and firm decision-making among Swiss firms (Benhima et al., 2024). The survey sample was drawn from the BER using stratified random sampling based on the size-sector distribution of the BER firm population. Firms were randomly selected within each stratum to ensure representative coverage. A total of 353 respondents registered for future survey participation. In line with the criteria outlined in Section E.1, we exclude Italian-speaking respondents and respondents from Sectors O, P, T, and U. Further, we exclude certain legal types: cooperatives, clubs, foundations, public-law institutions, public corporation (administration), public corporation (enterprise). Table 19 presents the size-sector distribution of the remaining 276 contacts.

Table 19: 2023 Survey Gross Sample

	C	D	E	F	G	H	I	J
Micro (1–9)	6 (2.17%)	1 (0.36%)	1 (0.36%)	14 (5.07%)	22 (7.97%)	3 (1.09%)	4 (1.45%)	10 (3.62%)
Small (10–49)	20 (7.25%)	0 (0.00%)	0 (0.00%)	13 (4.71%)	17 (6.16%)	5 (1.81%)	4 (1.45%)	9 (3.26%)
Medium (50–249)	10 (3.62%)	1 (0.36%)	0 (0.00%)	7 (2.54%)	4 (1.45%)	0 (0.00%)	1 (0.36%)	1 (0.36%)
Large (250+)	10 (3.62%)	2 (0.72%)	0 (0.00%)	2 (0.72%)	2 (0.72%)	0 (0.00%)	0 (0.00%)	1 (0.36%)
Total	46 (16.67%)	4 (1.45%)	1 (0.36%)	36 (13.04%)	45 (16.30%)	8 (2.90%)	9 (3.26%)	21 (7.61%)

	K	L	M	N	Q	S	R	Total
Micro (1–9)	7 (2.54%)	4 (1.45%)	28 (10.14%)	6 (2.17%)	9 (3.26%)	3 (1.09%)	0 (0.00%)	118 (42.75%)
Small (10–49)	5 (1.81%)	0 (0.00%)	20 (7.25%)	3 (1.09%)	3 (1.09%)	1 (0.36%)	0 (0.00%)	100 (36.23%)
Medium (50–249)	1 (0.36%)	0 (0.00%)	3 (1.09%)	2 (0.72%)	2 (0.72%)	0 (0.00%)	1 (0.36%)	32 (11.59%)
Large (250+)	1 (0.36%)	1 (0.36%)	1 (0.36%)	2 (0.72%)	4 (1.45%)	0 (0.00%)	0 (0.00%)	26 (9.42%)
Total	14 (5.07%)	5 (1.81%)	52 (18.84%)	13 (4.71%)	18 (6.52%)	4 (1.45%)	1 (0.36%)	276 (100.00%)

Note: The table presents the number of company contacts available from a previous survey, along with their corresponding percentage shares (in parentheses), disaggregated by NOGA sector letter and firm size class. Shares are calculated relative to the total sample of 276 firms.

E.6 Total Gross Sample

The total gross sample, comprising the combined address panels, includes approximately 26,900 companies. In addition, we contacted 100 companies known to participate in the Swiss Emissions Trading System (ETS). The overall sample size of approximately 27,000 was determined by the sending capacity of the KOF survey e-mail distribution system, which permits 9,000 e-mails per day (i.e., 10,000 minus 1,000 reserved for other communications), and by our objective to complete distribution within three days.

Of the total gross sample, 16,900 are micro-enterprises (62.8%), 5,000 are small enterprises (18.6%), 3,000 are medium-sized enterprises (11.2%), and 2,000 are large enterprises (7.4%). These figures were determined a priori to ensure the oversampling of companies larger than micro-enterprises (see Section E.3).

E.7 Recruitment

Recruitment was conducted via an e-mail invitation sent on behalf of ETH Zurich, EPFL, and the University of Lausanne. The e-mail included a secure direct link to the online survey, as well as a link to a login page where respondents can access the survey using a password provided in the invitation. The initial e-mail was send out on June 17-19, 2025, with follow-up reminders sent on June 25-27.

The invitation e-mail was sent in German, French, or English, depending on the language context. For recipients in the KOF and the 2023 survey address panels, the language corresponded to the preference previously indicated by the survey contact. For recipients in the ORBIS address panel, the language corresponded to the primary language of the region in which the firm is located. Additionally, for firms in the KOF and 2023 survey panels, the e-mail included personalized salutations addressed to the identified contact person. In contrast, for firms in the ORBIS sample—where e-mail addresses typically refer to general company inboxes—a generic salutation was used.

The invitation e-mail maintained a neutral, professional tone and includes a brief explanation of the survey's general purpose. All participants were offered exclusive access to a summary report of the survey results. The message was

signed by all authors of the study and includes links to their respective university websites.