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Measuring Leakage Risk †

Meredith Fowlie (UC Berkeley), Mar Reguant (Northwestern), Stephen Ryan (University of Texas Austin)

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Motivation

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- The global nature of the climate change problem creates challenges for regional climate change policies.
- Policy-induced increases in firms' operating costs can cause emissions 'leakage' into less stringently regulated jurisdictions.
- Researchers are exploring policy design alternatives to mitigate this emissions leakage.

Leakage mitigation

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- Economists have shown how output-based allocation of emissions allowances can – in theory– be used to mitigate emissions leakage in a regional GHG emissions trading program (e.g., Fischer and Fox (2007); Fowlie, Reguant, and Ryan (2016)).
- Policy makers in California, Europe, and elsewhere are putting this theory into practice.
- Allowance allocation updating comes at a cost, so it is important that output-based allocation updating is targeted judiciously.

Leakage mitigation in practice

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- Efficient targeting of leakage mitigating subsidies requires policy makers to identify industries facing high leakage risk during the policy implementation phase.
- Emissions leakage mitigation comprises an important component of California's landmark Greenhouse Gas Emissions Trading Program.
- Our analysis aims to inform the process by which policy makers assess leakage risk and target emissions leakage mitigation.

Our objectives

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1. Develop an analytical framework to inform the design of emissions leakage risk metrics and associated leakage mitigating subsidies.
2. Estimate key parameters that determine the extent to which *international* emissions leakage could manifest.
3. Use these empirical estimates to calibrate intuitive measures of leakage risk and output-based leakage mitigation.

Our scope

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- Two companion studies focus on *intra-national*, inter-state emissions leakage (the primary leakage channel in some sectors).
- International market transfers could be significant in industries where international imports and exports play an important role.
- We use our framework to assess the potential for *international* emissions leakage to jurisdictions outside the United States.

Conceptual framework

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The report develops a conceptual framework useful for:

- Identifying the key factors that determine the extent to which leakage could occur in a given industry.
- Demonstrating how output-based updating can be used to mitigate leakage.
- Deriving an intuitive measure of leakage risk and leakage mitigation.

Provide only a brief overview in this short presentation. More details can be found in our report.

Key concepts

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- **Emissions leakage** refers to change in emissions in outside jurisdictions that is caused by the introduction of a regional emissions regulation.
- **Market transfer rate:** measures the change in production levels in outside jurisdictions associated with a policy-induced change in production at regulated entities.
- **Output-based leakage rate** can be expressed as the market transfer rate multiplied by the marginal emissions rate among outside/unregulated producers:

$$\text{unregulated emissions rate} \times \frac{\text{change in unregulated production}}{\text{change in regulated production}}$$

Key intuition

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- Emissions leakage occurs when the policy-induced increase in operating costs causes regulated producers to lose market share to un/less regulated rivals.
- Allocating allowances on the basis of output confers an *implicit production subsidy* which offsets some share of compliance cost impacts, thus reducing/eliminating market transfer.
- Intuitively, the size of this implicit production subsidy (measured in terms of free allowances) should reflect the output-based emissions leakage rate.

Estimation overview

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- The conceptual framework focuses our attention on the market transfer rate as a key determinant of emissions leakage and output-based subsidies.
- Using rich transaction and and establishment-level data, we estimate elasticities of imports, exports, and domestic production with respect to domestic energy costs (controlling for other factors such as labor costs and foreign energy costs).
- With these estimates in hand, we can calibrate an upper-bound estimate of the industry-specific market transfer rate (focusing on international transfers).

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Table 1: Relevant Data Sets

Data Set	Main Variables	Level Aggregation	Years	Notes
Longitudinal Firm Trade Transactions Database (LFTTD)	Value of transaction, product HS code, U.S. firm in trade, port of entry/exit, country of origin/ destination	Transaction	1993–2011	Restricted
Census of Manufacturers (CMF)	Value of shipments, value and quantity of electricity purchased, value of primary fuels purchased, wages, input costs, capital intensity	Establishment-Year	1997, 2002, 2007, 2012	Restricted
Annual Survey of Manufacturers (ASM)	Same as CMF	Establishment-Year	1993–2012 (excluding CMF years)	Restricted
Longitudinal Business Database (LBD)	Establishment-to-firm linkage	Establishment-Year	1993–2012	Restricted
Manufacturing Energy Consumption Survey (MECS)	Primary energy consumption by fuel type	Industry-Region-Year	1998, 2002, 2006, 2010	Public
State Energy Data System (SEDS)	Primary energy price by fuel type	State-Year	1993–2012	Public
Enerdata Global Energy Data	Foreign electricity and natural gas prices	Country-Year	1989–2011	Proprietary
IEA Energy Prices and Taxes	Foreign electricity and natural gas prices	Country-Year	1989–2011	Proprietary

Source: Own elaboration.

Key variables

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Outcome variables (measured in $2010 USD):

- Annual value of domestic shipments
- Annual value of imports
- Annual value of exports

Explanatory variables:

- Weighted average annual domestic energy prices (industry-specific)
- Weighted average annual foreign energy prices (industry-specific)
- Energy intensity (energy costs as a share of total input costs).
- Emissions intensity (metric tons of CO_2/MMBtu and /$ shipments.
- Weighted average annual labor costs (industry-specific)
- California value share (industry-specific)
- Capital share (industry-specific)

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- We estimate the changes in outcomes (domestic production, imports, and exports) associated with changes in relative energy-related operating costs, controlling for other factors (e.g. foreign energy prices, labor costs).
- Regression analysis yields elasticity measures, which can be interpreted as the percentage change in an outcome associated with a percent change in energy-related operating costs (controlling for other factors).
  Estimating equation
- These elasticities vary systematically with industry characteristics (i.e., energy intensity, capital intensity).

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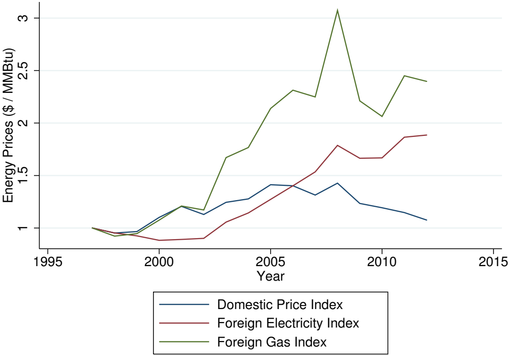
Many empirical challenges!

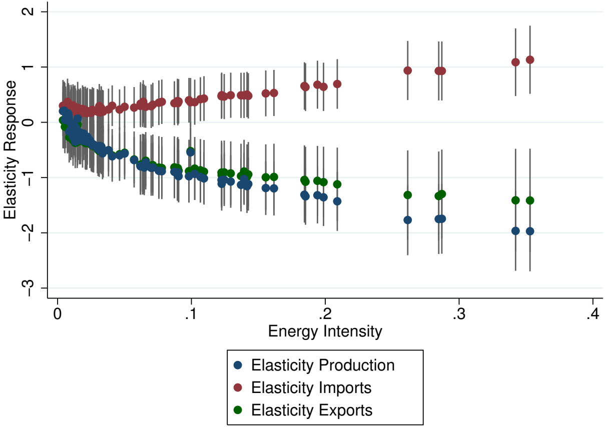
- Economic theory yields clear predictions but not specific instructions about how to specify estimating equations.
- Policy-induced changes in relative operating costs are one of many factors driving outcomes.
- Energy prices, product prices, production quantities, trade volumes are determined at the same time.
- We observe import and export flows but not global production.
- We do not observe domestic carbon price variation during our study period.

Variation in energy costs over time



This figure summarizes variation in weighted average domestic energy prices, foreign natural gas prices, and foreign electricity prices over time.

Coefficient estimates along energy intensity



This figure displays estimated elasticities calibrated to each industry along with 95 percent confidence intervals.

Sensitivity analysis

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- Economic theory does not provide clear direction when specifying the particular forms of the relationships between determining factors and outcomes.
- To assess the robustness of our results, we estimate close to 600 specifications using the full sample of data covering 98 industries. Robustness
- The report summarizes the interquartile range of our estimates across the full suite of specifications.

Carbon price impacts?

With some additional assumptions, we can use our elasticity estimates to 'simulate' the effect of a carbon price on domestic production, imports, exports.

1. Calculate the potential effect of a given carbon price (measured in $ per metric ton CO_2) on energy input costs using industry-specific carbon intensities.
2. Express this simulated energy price increase as a percent of industry-specific domestic energy costs.
3. Multiply by corresponding domestic production, import, and export elasticity estimates to assess potential impact of this carbon price on outcomes.

Estimated impact of \$10 per metric ton CO_2 price on domestic production values

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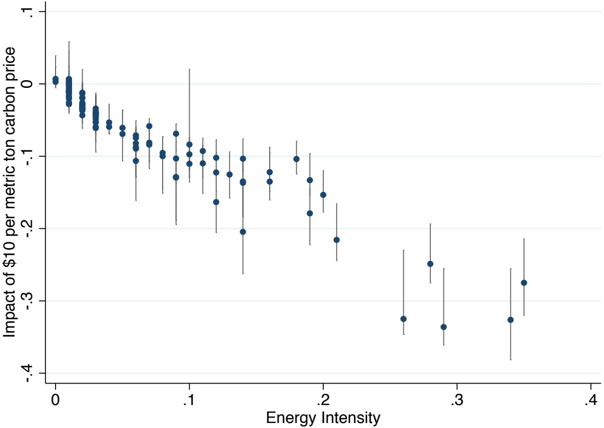

Industries ordered according to energy intensity. Vertical axis measures percentage change in annual domestic production values. Bars show interquartile range across 192 specifications.

Estimated impact of \$10 per metric ton CO_2 price on exports

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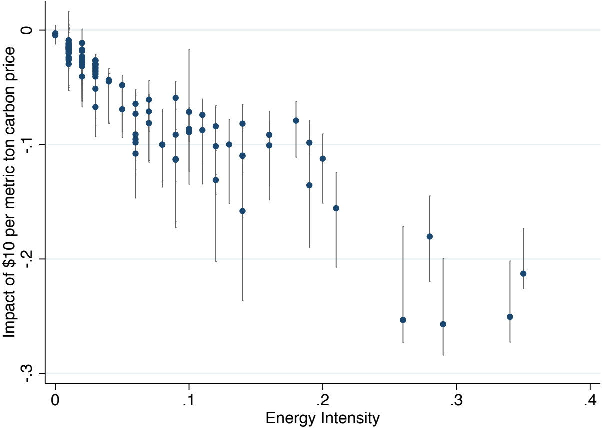

Industries ordered according to energy intensity. Vertical axis measures percentage change in annual export values. Bars show interquartile range across 192 specifications.

Estimated impact of \$10 per metric ton CO_2 price on imports

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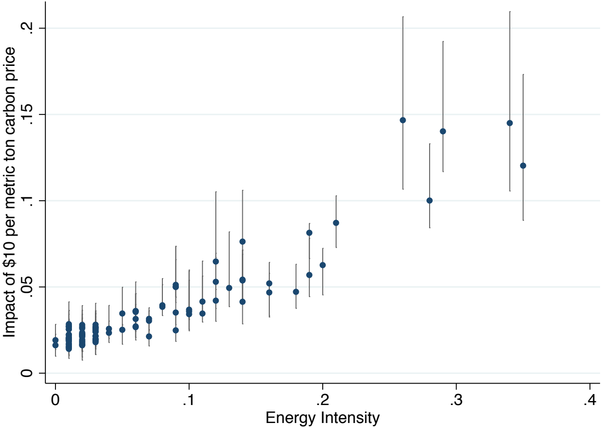

Industries ordered according to energy intensity. Vertical axis measures percentage change in annual export values. Bars show interquartile range across 192 specifications.

Emissions leakage rates?

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- In principle, these elasticity estimates (together with estimates of baseline domestic production, import, and export volumes) can be used to calibrate industry-specific measures of market transfer rates.
- Market-transfer rates, in combination with estimates of the marginal emissions intensity of foreign production, can be used to calibrate output-based leakage rates:

$$\text{foreign emissions rate} \times \frac{\text{increase in imports} + \text{decrease in exports}}{\text{change in domestic production}}$$

- The report highlights several caveats and considerations; calibrated market-transfer rates should be interpreted with care.

Heat map of market transfer rates

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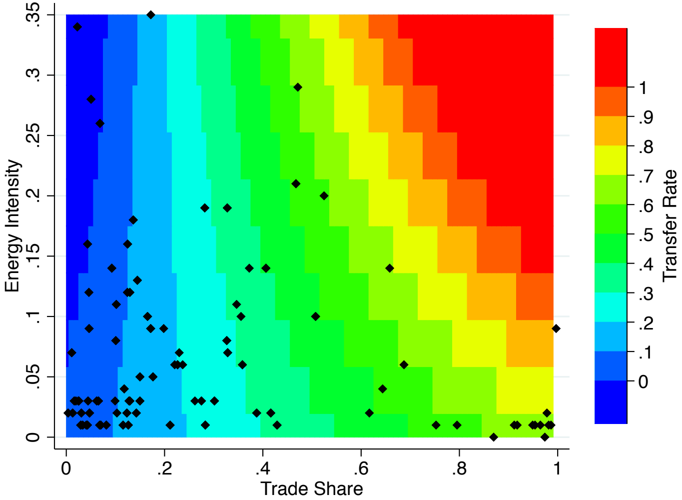

Market transfer rates in context

- This calibration exercise generates an approximate upper bound on national rates of potential market transfer.
- On average, our upper bound estimate of market transfer rates fall below 20 percent for many industries.
- The product of the market-transfer rate and the corresponding foreign emissions rate would provide a theoretically consistent and empirically calibrated output-based measure of emissions leakage potential.
- An important caveat is that estimates are noisy and capture relatively short-run impacts.

Summary of estimation results

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- Estimated elasticities capture the responsiveness of domestic production and trade flows to recent changes in relative energy costs.
- For the median industry, a 10 percent increase in domestic energy prices is associated with reductions in export values in the range of 3 to 9 percent and increases in import values in the range of 2 to 4 percent.
- Industries with higher energy intensities have systematically larger responses across all three outcome variables.

Summary of calibration results

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- Estimates imply that a domestic carbon tax of $10 per metric ton (and no output-based allocation updating) is associated with reductions in export values on the order of 6 percent or smaller for most industries.
- For cement, lime, industrial gas, wet corn milling, nitrogen fertilizer, iron and steel industries, we estimate negative impacts on export volumes of 20 percent or greater.
- Increases in imports estimated in the range of 4 percent or less for most industries; estimated impacts exceed 11 percent in cement, lime, and industrial gas industries.
- Estimated upper bound on market transfer rates fall at or below 20 percent for most industries.

Caveats and conclusions

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- These results are most accurately interpreted in the context of a regulation that increases *domestic* energy costs on international import and export flows, respectively.
- Under the California Cap-and-Trade Program, our findings are most relevant for those industries in which California producers comprise a majority of exports (or California manufacturers demand the majority of imports of a manufacturing input).
- Two companion studies investigate intra-national, inter-state movements of production outputs and inputs.

Estimation framework

The general form of the specifications we estimate:

$$\ln(y_{it}) = \alpha_0 + f(p^d_{it}, p^f_{it}, X_{it}; \beta) + \gamma \ln(w_{it}) + \phi_i + \eta_{st} + \varepsilon_{it},$$

where,

i = 6-digit NAICS index,

t = year index,

y_{it} = aggregate outcome for industry i in year t,

p^d_{it} = domestic energy price,

p^f_{it} = foreign energy price (a vector of foreign electricity and gas prices),

X_{it} = Industry characteristics other than energy intensity (e.g., capital intensity)

w_{it} = domestic wage,

ϕ_i = 3-digit NAICS fixed effects,

η_{st} = year by sector (2-digit NAICS) fixed effects.

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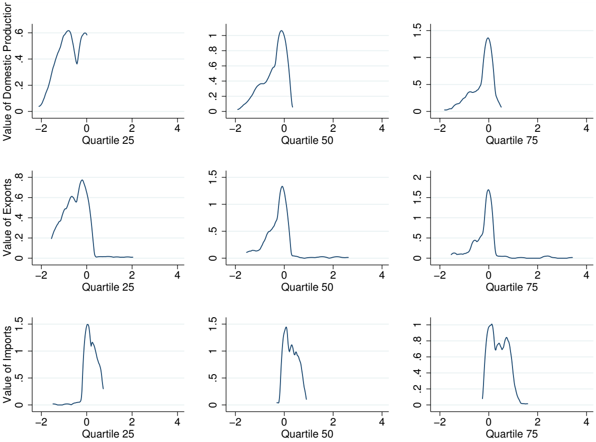
Elasticity estimates across the full suite of specifications

Supplemental



This figure displays the density plots of the 25th, median, and 75th percentile estimates of elasticities across 192 different specifications. Back to main2.