Robust Bounds for Welfare Analysis

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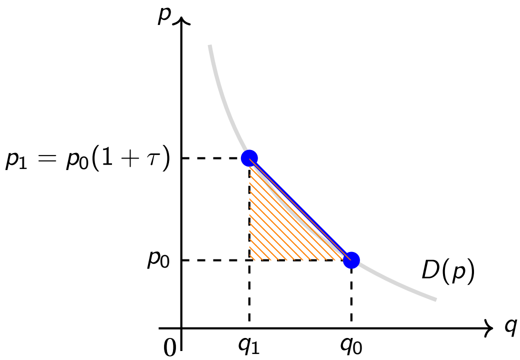
  - Conservative bounds in lieu of assumptions are often extreme.

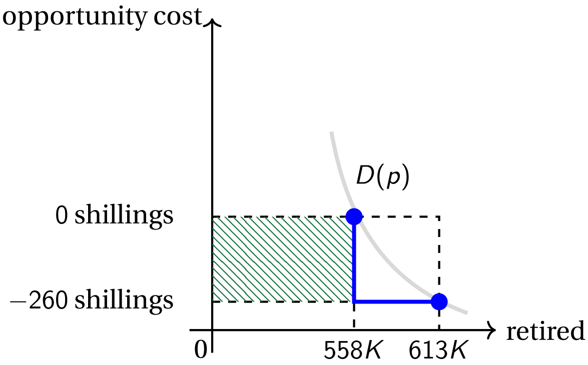
  $\rightsquigarrow$ **Is there a more principled way to engage with assumptions & evaluate welfare?**

Example: Evaluating the deadweight loss of the Trump tariffs



- Amiti, Redding and Weinstein (2019)
- **Setting:** 2018 trade war involved tariffs as high as 30–50%.
- **Question:** What was the DWL?
- **Approach:** Compare monthly prices & quantities by item in 2017 vs. 2018.
- **Method:** Approximate $D(p)$ with a linear curve; integrate under the curve.

Example: Evaluating the MVPF of 1911 U.K. pensions



- Giesecke and Jäger (2021)
- **Setting:** Pensions created for poor 70+ year-olds in 1911.
- **Question:** What is the MVPF of the pension policy?
- **Approach:** MVPF = (WTP for not working) ÷ (cost of pension).
- **Method:** Compute % marginal workers through RD; Assume marginal workers' WTP = 0.

This paper

- Instead of interpolating to get a welfare estimate, we establish **welfare bounds**.
  - These bounds are **robust**: they give the *best-case* and *worst-case* welfare estimates that are consistent with a set of pre-specified economic assumptions.
  - These bounds are also **simple**: we can compute them in closed form.

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- Our bounds are (often) meaningful both in informing the policy question and in distinguishing between assumptions.
  - Our approach facilitates connecting empirical measurements (*e.g.*, LATE) and theoretical primitives (*e.g.*, log-concavity) when evaluating welfare.
- Our bounds shed light on welfare implications of commonly used demand curves.
  - **Example:** CES interpolation yields the *smallest welfare estimate among all possible interpolations*, assuming that the demand curve satisfies Marshall's second law.

This paper

- Our bounds apply directly to settings with:
  (i) exogenous policy shocks/experiments/quasi-experiments;
  (ii) measurements of "price" and "quantity", before and after the policy shock; and
  (iii) interest in effects on consumer surplus (or other welfare measures).

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  - (iii) interest in effects on consumer surplus (or other welfare measures).
- We show how our bounds can be applied to a variety of settings across literatures:
  - #1. deadweight loss of import tariffs; (Amiti, Redding and Weinstein, 2019)
  - #2. marginal excess burden of income taxation; and (Feldstein, 1999)
  - #3. welfare impact of energy subsidies. (Hahn and Metcalfe, 2021)

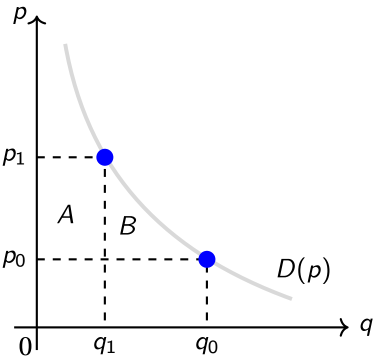
Related literature

- **Price indices.** Diewert (1976); Hausman (1981); Hausman and Bresnahan (2008); Varian (1982, 1985).
- **Sufficient statistics.** Harberger (1954, 1964); Feldstein (1999); Chetty (2009); Hendren and Sprung-Keyser (2020); Finkelstein and Hendren (2020); Kleven (2021).
- **Partial identification for CFs.** Manski (2021); Kalouptsidi et al. (2021); Allen and Rehbeck (2020).
- **Welfare bounds in oligopoly.** Anderson and Renault (2003); Johari and Tsitsiklis (2005); Tsitsiklis and Xu (2014); Kremer and Snyder (2015); Condorelli and Szentes (2020).

Basic model

An analyst observes 2 points on a demand curve: (p_0, q_0) and (p_1, q_1).

Question. What is the change in consumer surplus from (p_0, q_0) to (p_1, q_1)?



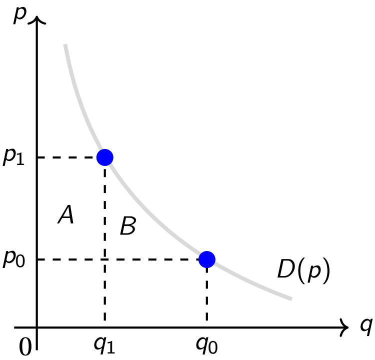
- **Main challenge:** $D(p)$ isn't observed.
- With $D(p)$, change in CS is equal to

$$\underbrace{\text{area } A}_{=(p_1 - p_0)q_1} + \text{area } B = \int_{p_0}^{p_1} D(p)\,\mathrm{d}p.$$

- Equivalently, we want to *bound* area B.

Bounds without additional assumptions

- Using only the fact that the demand curve is decreasing, the analyst can establish bounds on the change in welfare (Varian, 1985).



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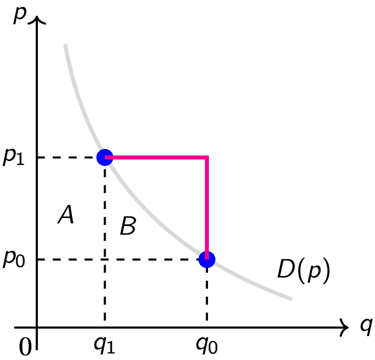

- An upper bound on area B is

$$\text{area } B \leq (p_1 - p_0) \times (q_0 - q_1)\,.$$

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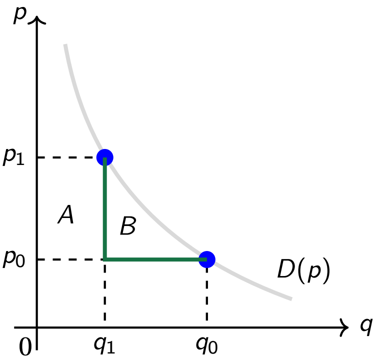

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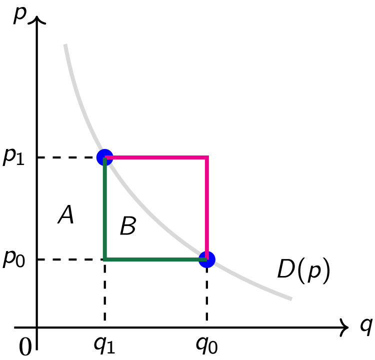

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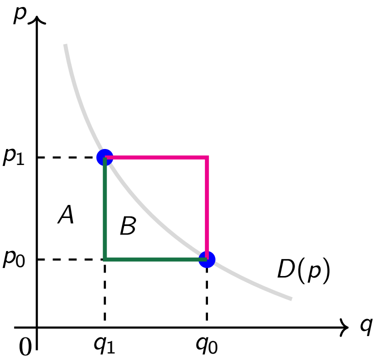

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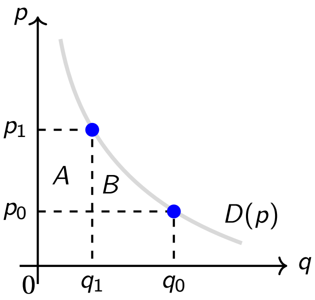
- These bounds are attained only when the **elasticity is equal to 0 or $-\infty$**.

Basic model

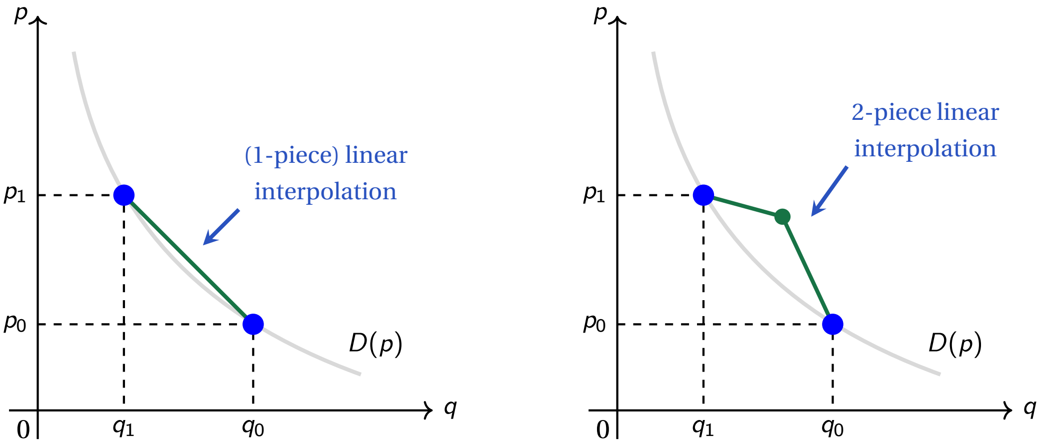
An analyst observes 2 points on a demand curve: (p_0, q_0) and (p_1, q_1).

We assume that elasticity between (p_0, q_0) and (p_1, q_1) lie in the interval $[\underline{\varepsilon}, \overline{\varepsilon}] \subset \mathbb{R}_{\leq 0}$.

Question. What is the change in consumer surplus from (p_0, q_0) to (p_1, q_1)?



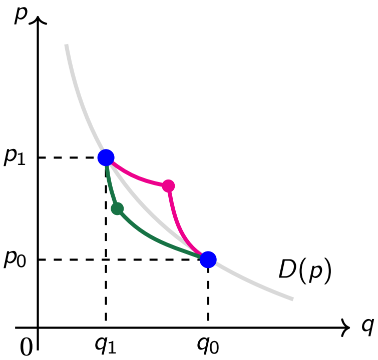
Defining 1-piece and 2-piece interpolations



Welfare bounds for basic model

Theorem 1 (welfare bounds)**.**

The upper and lower bounds for the change in consumer surplus are attained by **2-piece CES interpolations**. Proof



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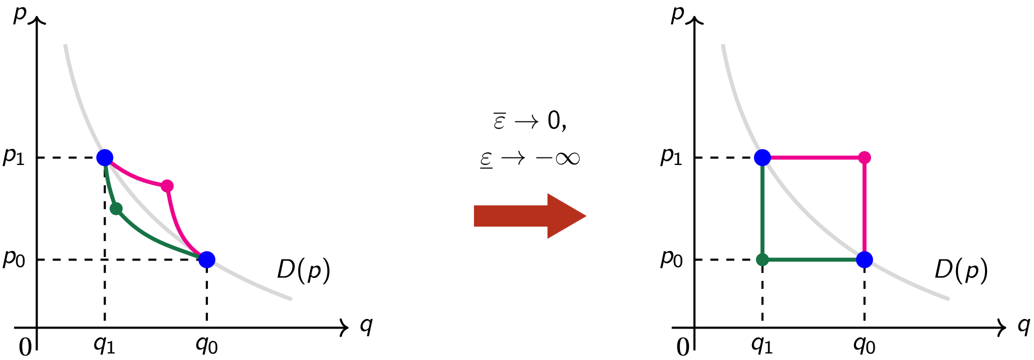

Where do $\underline{\varepsilon}$ and $\overline{\varepsilon}$ come from?

How might you choose an informed elasticity range?

- Institutional knowledge

  $\rightsquigarrow$ If we can reason that elasticities aren't infinite, maybe we can reason a bit more.

- Previous studies

  $\rightsquigarrow$ Andreyeva et al. (2010) summarize elasticities for food and beverage in the U.S. from 160 empirical studies and determine that all lie between -3.18 and -0.01.

- Experimental Evidence

  $\rightsquigarrow$ Local treatment effects can often be interpreted as elasticity estimates.

Extending the basic model

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4. The points (p_0, q_0) and (p_1, q_1) on the demand curve are observed precisely.

   In practice, the analyst might be limited by observational (measurement) error.

Extending the basic model

Our welfare bounds for the basic model rely on a number of modeling choices:

1. *In practice, the analyst might make assumptions about demand curvature.*

   $\Longrightarrow$ We show how **demand curvature** assumptions lead to tighter welfare bounds.

2. *In practice, the analyst might observe more points on the demand curve.*

   $\Longrightarrow$ We show how to **interpolate** with more observations.

3. *In practice, the analyst might observe* p_0, p_1, *and* q_1, *but not* q_0.

   $\Longrightarrow$ We show how to **extrapolate** from fewer observations.

4. *In practice, the analyst might be limited by observational (measurement) error.*

   $\Longrightarrow$ We show how to incorporate **observational error** into welfare bounds.

Theorem 2a. (concave-like assumptions)**.**

The **lower** bound for the change in consumer surplus are attained by:

- **(A1)** **decreasing elasticity:** a *CES* interpolation; $D(p) = \theta_1 p^{-\theta_2}$
- **(A2)** **decreasing MR:** a *constant MR* interpolation; $D(p) = \theta_1 (p - \theta_2)^{-1}$
- **(A3)** **log-concave demand:** an *exponential* interpolation; $D(p) = \theta_1 e^{-\theta_2 p}$
- **(A4)** **concave demand:** a *linear* interpolation; $D(p) = \theta_1 - \theta_2 p$
- **(A5)** **ρ-concave demand:** a ρ-*linear* interpolation. $D(p) = [1 + \rho(\theta_1 - \theta_2 p)]^{1/\rho}$

① Assumptions on demand curvature: combining assumptions

Marshall's second law (decreasing elasticity) + convex demand

Theorem 2a. (concave-like assumptions).

The **lower** bound for the change in consumer surplus are attained by:

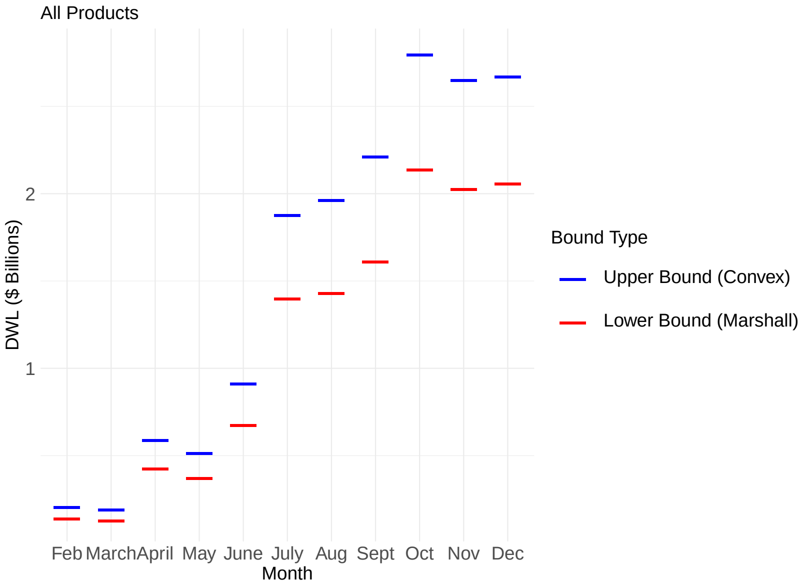
(A1) **decreasing elasticity:** a *CES* interpolation; $D(p) = \theta_1 p^{-\theta_2}$

Theorem 2b. (convex-like assumptions).

The **upper** bound for the change in consumer surplus are attained by:

(A6) **convex demand:** a *linear* interpolation; $D(p) = \theta_1 - \theta_2 p$

Example: Evaluating the Deadweight Loss of the Trump Tariffs



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- The tariff revenue gained over 2018 is **$15.6 billion**.
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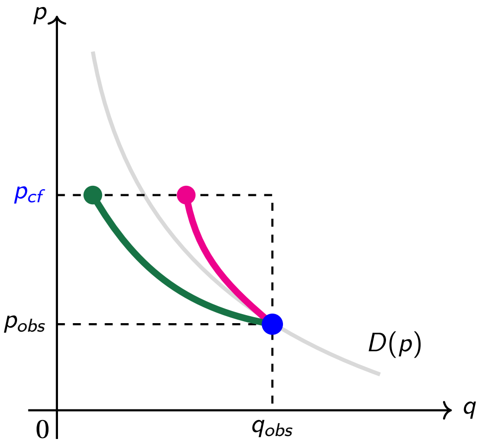
- **Question:** Can we tighten these bounds?
  - **Yes**, if impose stronger assumptions on curvature.
  - **Yes** if we can bound elasticities.

(3) Extrapolating to counterfactual prices (with elasticity bounds)



Overview of applications

#1. Welfare impact of trade tariffs.

#2. Marginal excess burden of income taxation.

#3. **Welfare impact of energy subsidies**.

What is the welfare impact of CARE gas subsidies?

CARE Program:

- **Low income:** 20% discount on gas
  - ⇝ Gas usage ↑
  - ⇝ Consumer surplus ↑
  - ⇝ Climate impact ↓
- **Other households:** Gas price ↑ (given a fixed budget)
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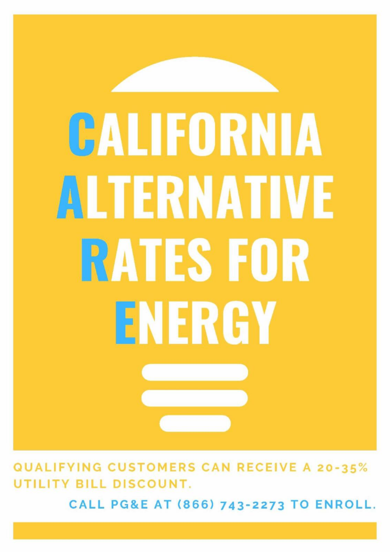

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Question: Is CARE net welfare improving?

Welfare impact of energy subsidies (Hahn and Metcalfe, 2021)

- **Empirical strategy:**
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  - Interpret the LATE as an elasticity:

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- **Modeling assumptions:**
  - The CARE program operates under a fixed budget.

  ⇝ The **counterfactual** "uniform" **price** is pinned down by observed quantities:

$$N_n\left(P_{1n} - P_0\right) Q_{1n} = N_c\left(P_0 - P_{1c}\right) Q_{1c} + A.$$

Welfare impact of energy subsidies (Hahn and Metcalfe, 2021)

- **Empirical strategy:**
  - Estimate a LATE for gas usage in CARE & interpret it as an elasticity:

  ⇝ *How much does gas usage change given a 20% discount in unit price?*

- **Modeling assumptions:**
  - Predict a **counterfactual** "uniform" **price** based on a fixed budget assumption.
  - Assume linear consumer demand.

  ⇝ Linear demand pins down the **counterfactual** "uniform" **quantity**.

Welfare impact of energy subsidies (Hahn and Metcalfe, 2021)

- **Elasticity estimates:**
  - CARE increased consumption 21 therms/month $\rightarrow$ 23 therms/month.
  - $\leadsto$ Estimated CARE elasticity of -0.35.
  - Assume non-CARE elasticity is -0.14 (Auffhammer and Rubin, 2018).

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CARE:	$+$ \$5.3M
Non-CARE:	$-$ \$3.1M
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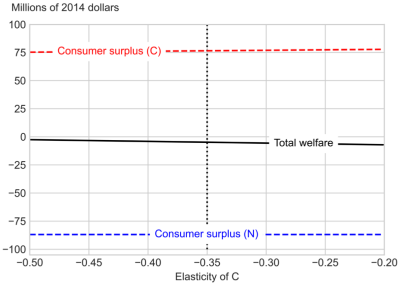
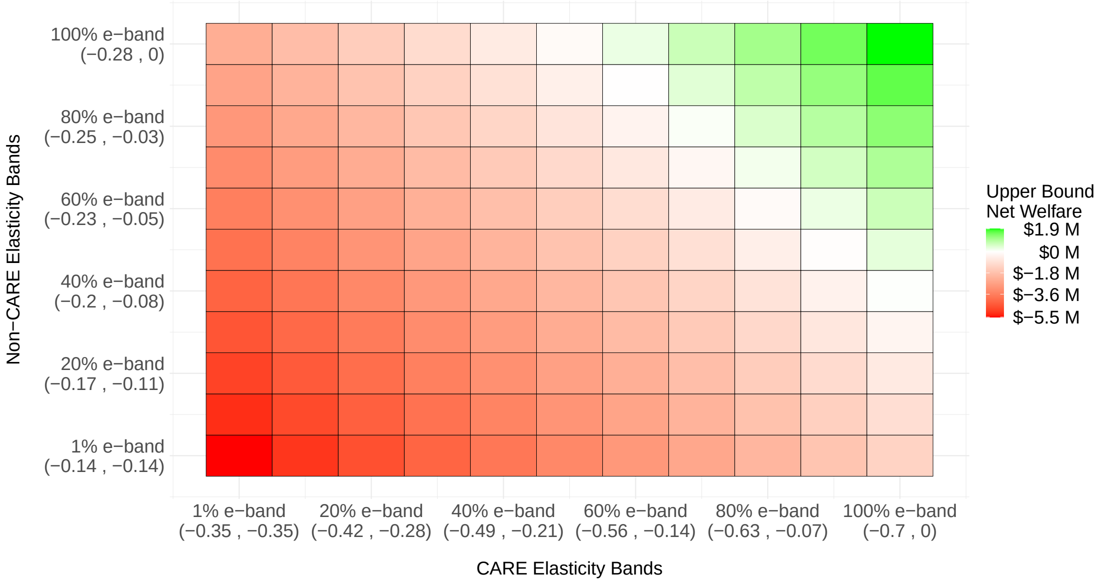


How robust is the negative welfare result?



Discussion

Why might we expect the welfare results to flip?

- **#1.** Before imposing any assumptions, we can test the Varian (box) bounds.
  - ⇝ They are positive! Something must give.
- **#2.** We "observe" p_1, q_1, ϵ_1 and p_0 but not q_0 or ϵ_0.
  - ⇝ Our bounds account for uncertainty in both.
- **#3.** Our bounds are "adversarial."
  - ⇝ They consider *all* feasible demand curves.
  - ⇝ They default to joint uncertainty in ϵ_C and ϵ_N.

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So, how do we interpret these results?

$\rightsquigarrow$ The Hahn–Metcalfe conclusion is pretty robust.

$\rightsquigarrow$ In fact, uncertainty in the non-CARE elasticity is not enough to break their result.

more

Summing up: Welfare beyond ΔCS

- **#1.** Supply works just as well as demand
- **#2.** Can handle heterogeneity + distributional questions
- **#3.** Can handle multiple objectives at once
  - $\rightsquigarrow$ E.g. pareto-weighted consumer surplus + DWL

Summing up: How to use robust bounds

- **#1. Comparing across papers with differing assumptions**
  - Interpret common functional form assumptions as bounds.

    e.g. CES yields the *lowest* DWL from a tax among all demand curves w/ decreasing elasticity.
  - Common functional form assumptions are related through their curvatures.

Relationships between curvature assumptions

(A1) Decreasing elasticity

(A2) Decreasing MR

(A3) Log-concave demand

(A4) Concave demand

(A5) ρ-concave demand

(A6) Convex demand

(A7) Log-convex demand

(A8) ρ-convex demand

$$(A4) \Longrightarrow (A3) \quad \begin{cases} \Longrightarrow (A1) \\ \Longrightarrow (A2) \end{cases} \qquad \text{and} \qquad (A7) \Longrightarrow (A6).$$

Summing up: How to use robust bounds

- **#2. Computing welfare from a (quasi-) experiment**
  - Interpret DiD/RDD/etc. estimates in terms of welfare bounds.
    - ⇝ Bounds are *robust* and *simple* (and often easy to compute).
    - ⇝ Bounds are (often) *informative* without strong parametric assumptions.
  - Tighten bounds with sensible assumptions from an institutional perspective.
    - ⇝ Assumptions on empirical objects being measured (*e.g.*, elasticities)
    - ⇝ Assumptions on theoretical objects used for principled predictions (*e.g.*, curvature).

Summing up: How to use robust bounds

- **#3. Assess the robustness of existing estimates**
  - Use expertise to construct an informative prior on the shape of demand
    - ⇝ What is the range of elasticities previously observed in similar markets?
    - ⇝ What patterns in demand (and supply) are likely to bind?
  - Test the sensitivity of the most important bound
    - ⇝ Does the result hold under box bounds?
    - ⇝ How much uncertainty can the result withstand?

Thank you!

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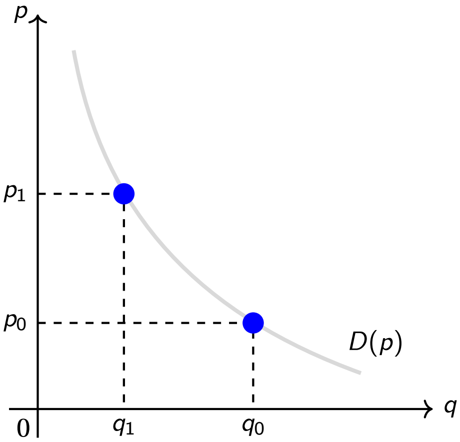
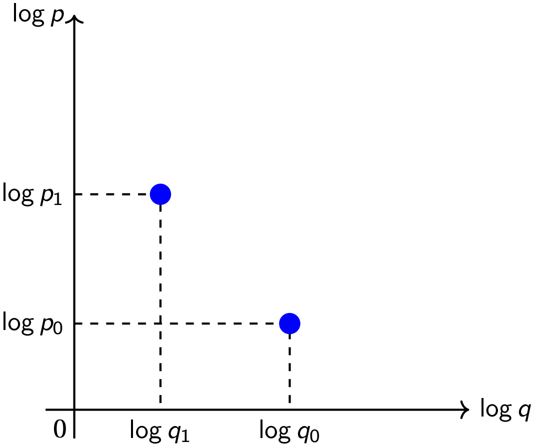
Geometric derivation of welfare bounds





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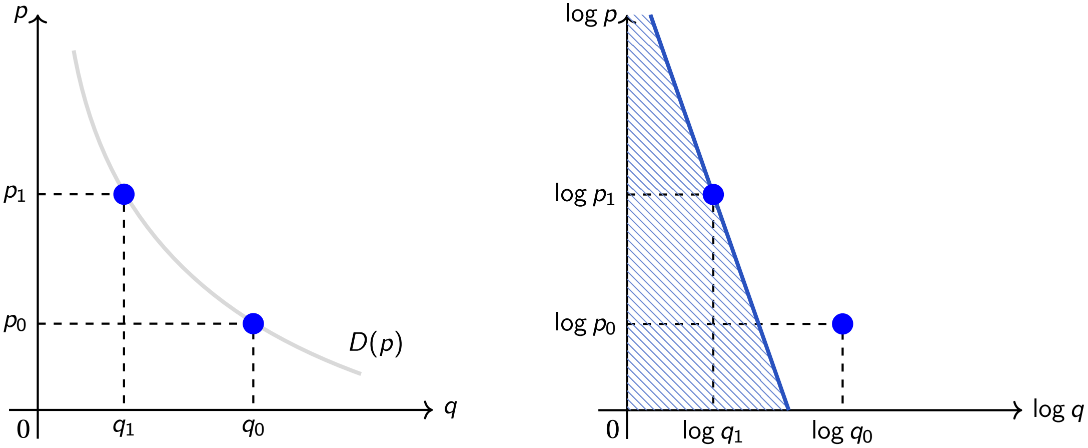

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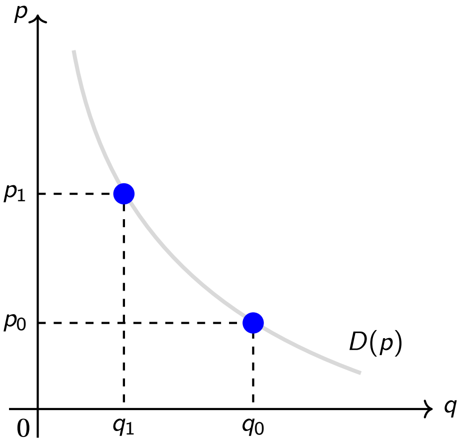

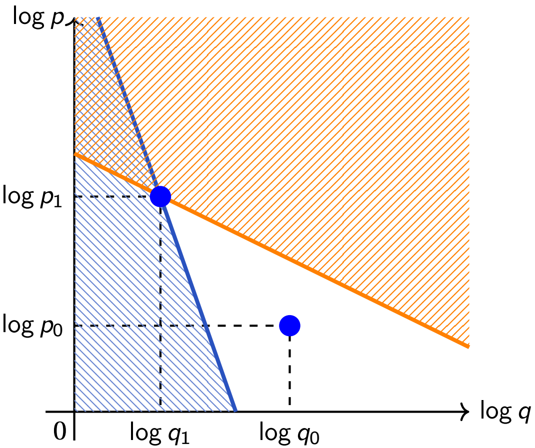

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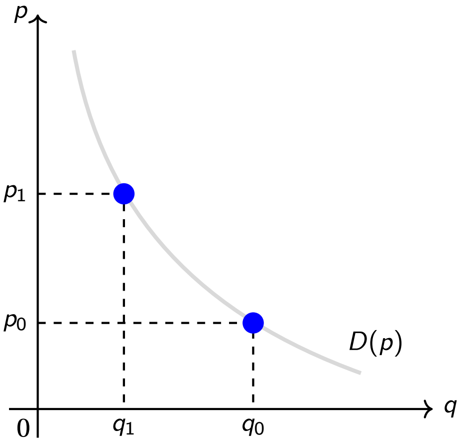

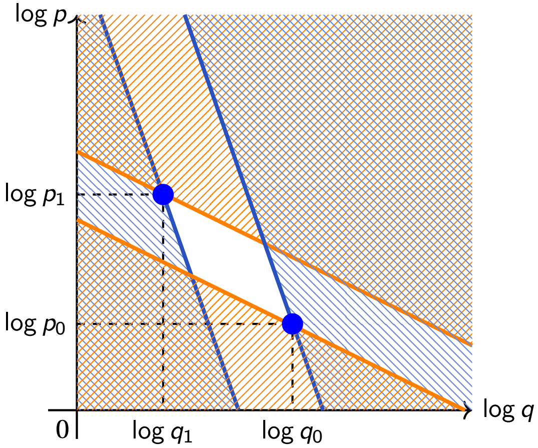

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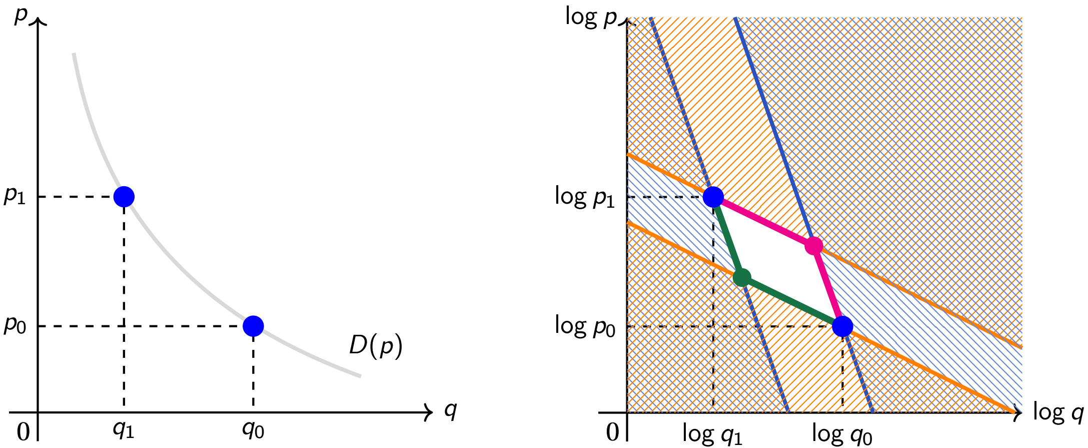

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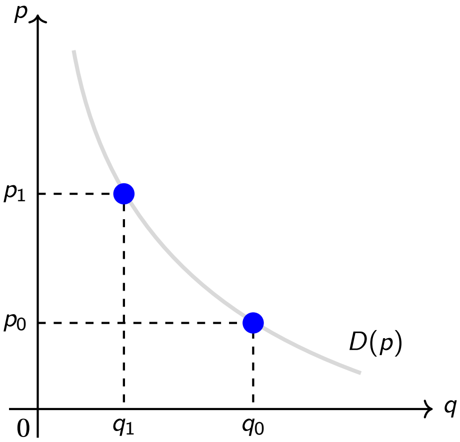

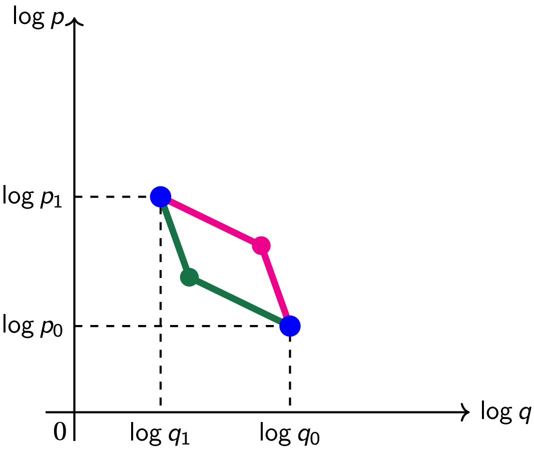

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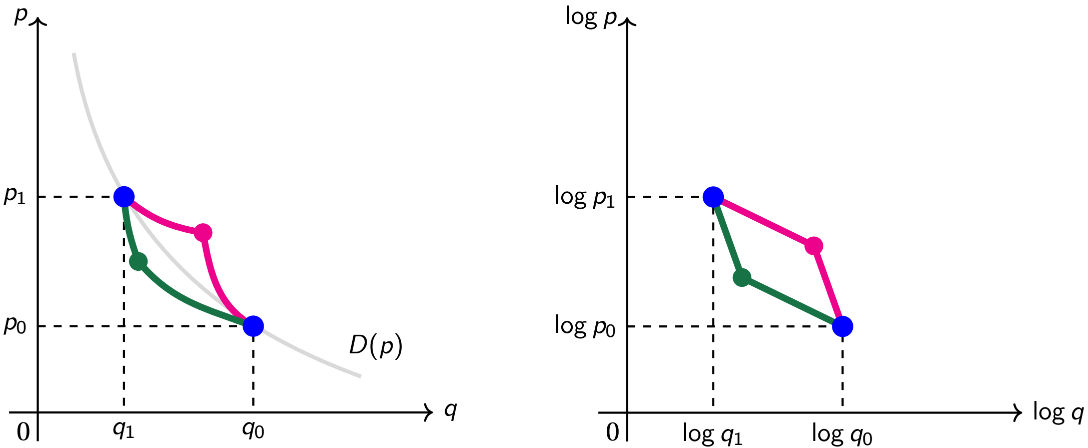

Welfare bounds for basic model

Theorem 1 (welfare bounds)**.**

The upper and lower bounds for the change in consumer surplus are attained by **2-piece CES interpolations**.

- As the geometric proof shows, these bounds can be easily computed.

Welfare bounds for basic model

Theorem 1 (welfare bounds)**.**

The upper and lower bounds for the change in consumer surplus are attained by **2-piece CES interpolations**.

- As the geometric proof shows, these bounds can be easily computed.
- Tighter range of elasticities, $[\underline{\varepsilon}, \overline{\varepsilon}] \implies$ tighter bounds on consumer surplus.
- **Related literature:** "sufficient statistics" approach (Chetty, 2009; Kleven, 2021) maps from *local* elasticity estimates to *local* welfare estimates.

  $\leadsto$ Our approach maps from *global* elasticity bounds to *global* welfare bounds.

Back

How robust is the negative welfare result? 2-D version (Back)