Robust Bounds for Welfare Analysis

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- Decisions for [environmental] regulation require weighing welfare costs vs benefits

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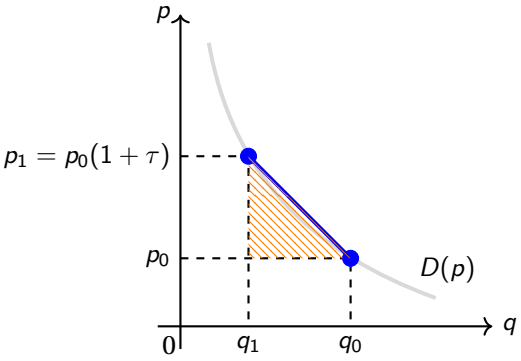
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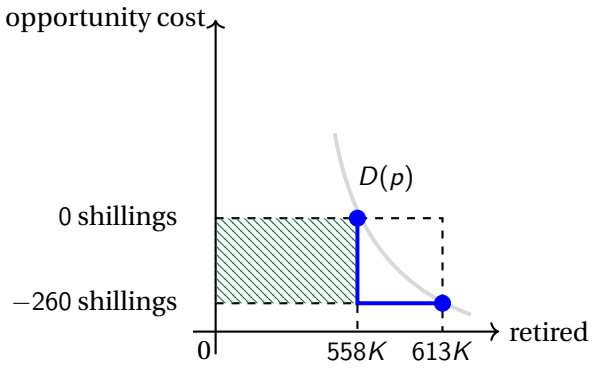
  $\rightsquigarrow$ **Is there a more principled way to engage with assumptions & evaluate welfare?**

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; sssume 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.
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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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- 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)

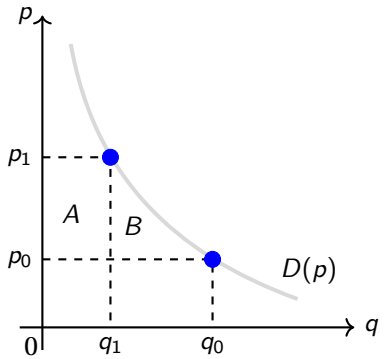
Related literature

- **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)?



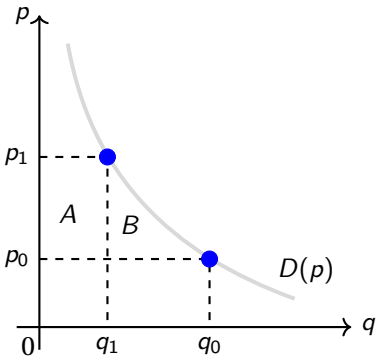
- **Main challenge:** $D(p)$ isn't observed.
- With $D(p)$, change in CS is equal to

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

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

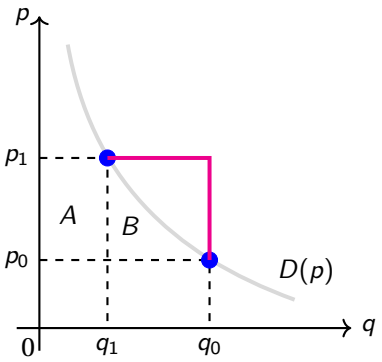
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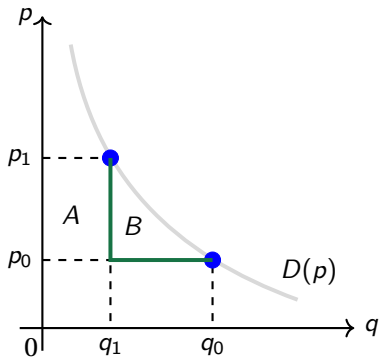


- An upper bound on area B is

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

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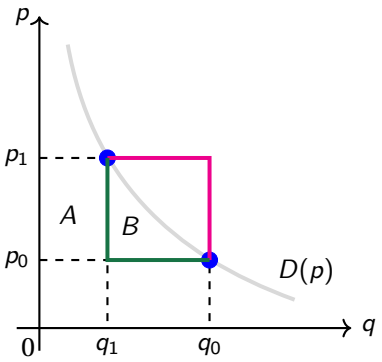
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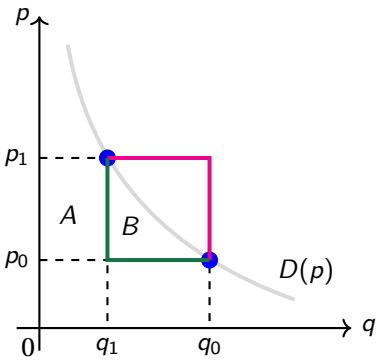
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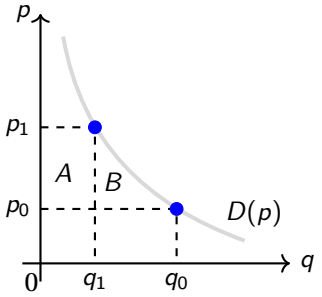
- These bounds are attained only when the **elasticity is equal to 0 or $-\infty$**.

Basic model

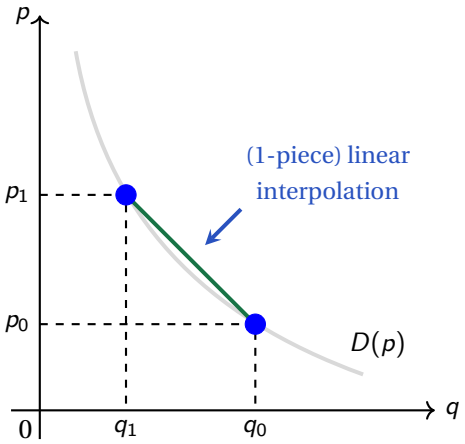
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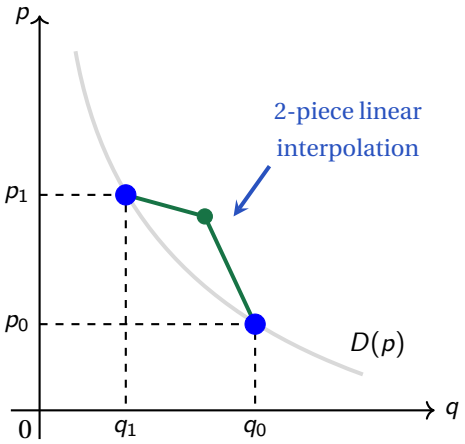
We assume that elasticity between (p_0, q_0) and (p_1, q_1) lie in the interval $[\underline{\varepsilon}, \overline{\varepsilon}] \subset \mathbb{R}_{\leq 0}$.

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

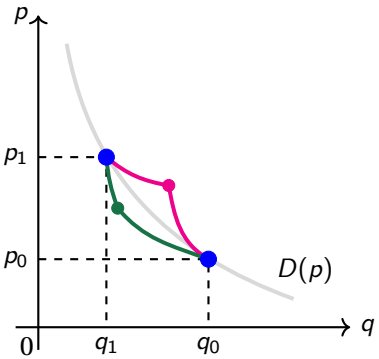




Welfare bounds for basic model

Theorem 1 (welfare bounds)**.**

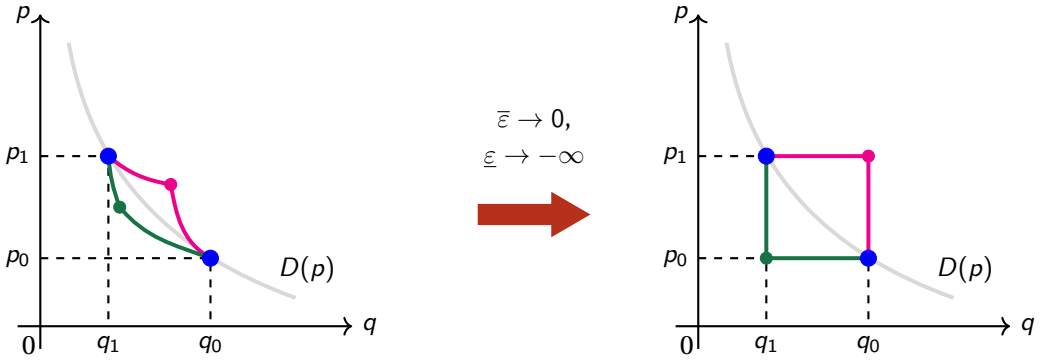
The upper and lower bounds for the change in consumer surplus are attained by **2-piece CES interpolations**. Proof



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



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

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

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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).

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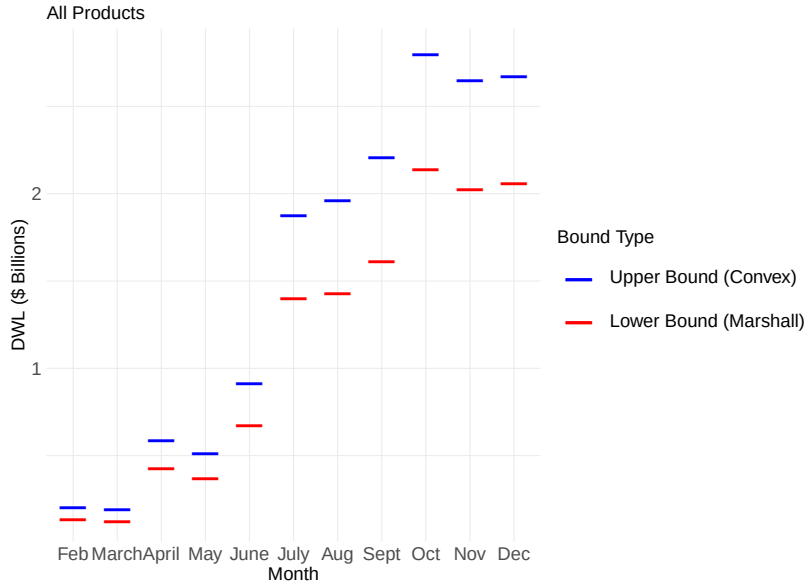
(A1) decreasing elasticity: a *CES* interpolation; $D(p) = \theta_1 p^{-\theta_2}$

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



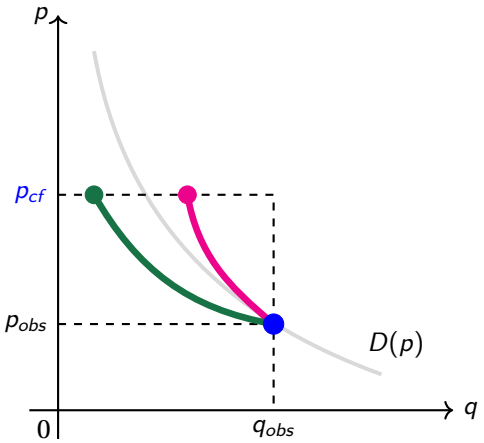
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- The tariff revenue gained over 2018 is **$15.6 billion**.
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- **Question:** Can we tighten these bounds?
  - **Yes**, if impose stronger assumptions on curvature.
  - **Yes** if we can bound elasticities.

(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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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.

  $\rightsquigarrow$ Estimated CARE elasticity of -0.35.
  - Assume non-CARE elasticity is -0.14 (Auffhammer and Rubin, 2018).

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- **Welfare estimates:**

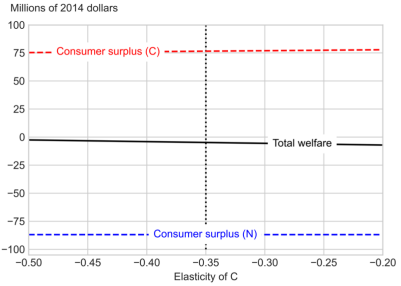
CARE:	+ \$5.3M
Non-CARE:	− \$3.1M
Admin Costs:	− \$7.0M
Net:	− \$4.8M

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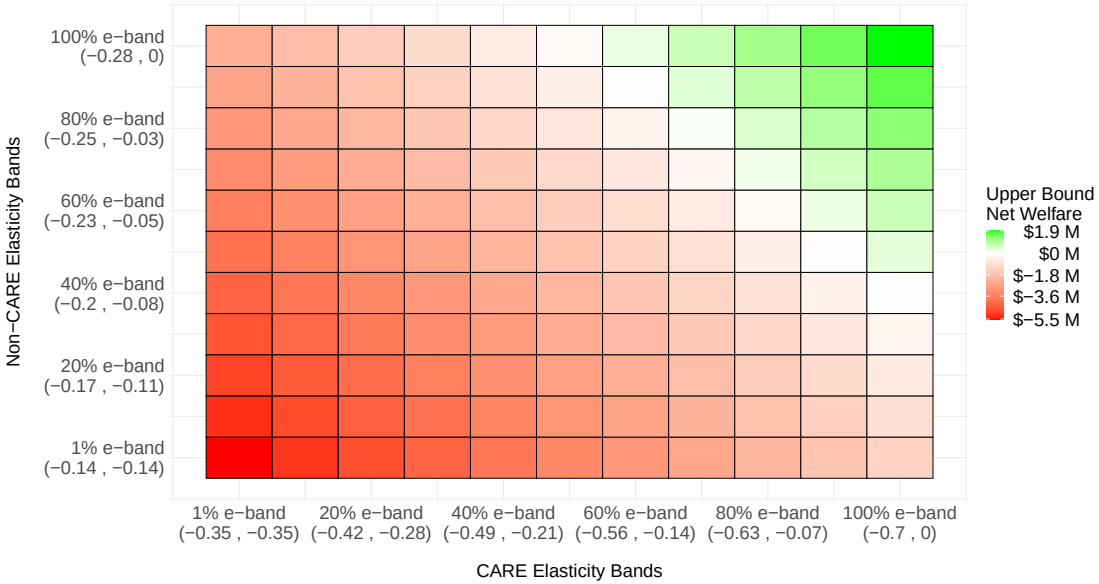
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- **Welfare estimates:**

CARE:	$+$ \$5.3M
Non-CARE:	$-$ \$3.1M
Admin Costs:	$-$ \$7.0M
Net:	$-$ \$4.8M



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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- **#3.** Our bounds are "adversarial."

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: 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

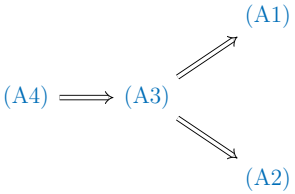
(A4) Concave demand

(A5) ρ-concave demand

(A6) Convex demand

(A7) Log-convex demand

(A8) ρ-convex demand



and



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!

References

Allen, Roy and John Rehbeck, "Counterfactual and welfare analysis with an approximate model," *arXiv preprint arXiv:2009.03379*, 2020.

Amiti, Mary, Stephen J. Redding, and David E. Weinstein, "The Impact of the 2018 Tariffs on Prices and Welfare," *Journal of Economic Perspectives*, 2019, *33* (4), 187–210.

Anderson, Simon P. and Régis Renault, "Efficiency and Surplus Bounds in Cournot Competition," *Journal of Economic Theory*, 2003, *113* (2), 253–264.

Andreyeva, Tatiana, Michael W. Long, and Kelly D. Brownell, "The Impact of Food Prices on Consumption: A Systematic Review of Research on the Price Elasticity of Demand for Food," *American Journal of Public Health*, 2010, *100* (2), 216–222.

Auffhammer, Maximilian and Edward Rubin, "Natural Gas Price Elasticities and Optimal Cost Recovery Under Consumer Heterogeneity: Evidence From 300 Million Natural Gas Bills," *Working paper*, 2018.

References

Bagnoli, Mark and Ted Bergstrom, "Log-Concave Probability and Its Applications," *Economic Theory*, 2005, *26* (2), 445–469.

Bulow, Jeremy and John Roberts, "The Simple Economics of Optimal Auctions," *Journal of Political Economy*, 1989, *97* (5), 1060–1090.

Caplin, Andrew and Barry Nalebuff, "Aggregation and Imperfect Competition: On the Existence of Equilibrium," *Econometrica*, 1991, *59* (1), 25–59.

__ **and** __ , "Aggregation and Social Choice: A Mean Voter Theorem," *Econometrica*, 1991, *59* (1), 1–23.

Chetty, Raj, "Sufficient Statistics for Welfare Analysis: A Bridge Between Structural and Reduced-Form Methods," *Annual Review of Economics*, 2009, *1* (1), 451–488.

Condorelli, Daniele and Balázs Szentes, "Surplus Bounds in Cournot Monopoly and Competition," *Working paper*, 2020.

References

Diewert, W Erwin, "Harberger's welfare indicator and revealed preference theory," *The American Economic Review*, 1976, *66* (1), 143–152.

Feldstein, Martin, "Tax Avoidance and the Deadweight Loss of the Income Tax," *Review of Economics and Statistics*, 1999, *81* (4), 674–680.

Finkelstein, Amy and Nathaniel Hendren, "Welfare Analysis Meets Causal Inference," *Journal of Economic Perspectives*, 2020, *34* (4), 146–67.

Giesecke, Matthias and Philipp Jäger, "Pension incentives and labor supply: Evidence from the introduction of universal old-age assistance in the UK," *Journal of Public Economics*, 2021, *203*, 104516.

Hahn, Robert W. and Robert D. Metcalfe, "Efficiency and Equity Impacts of Energy Subsidies," *American Economic Review*, 2021, *111* (5), 1658–88.

Harberger, Arnold C., "Monopoly and Resource Allocation," *American Economic Review: Papers & Proceedings*, 1954, *44* (2), 77–87.

References

__ , "The Measurement of Waste," *American Economic Review: Papers & Proceedings*, 1964, *54* (3), 58–76.

Hausman, Jerry A., "Exact Consumer's Surplus and Deadweight Loss," *American Economic Review*, 1981, *71* (4), 662–676.

Hausman, Jerry A and Timothy F Bresnahan, *5. Valuation of New Goods under Perfect and Imperfect Competition*, University of Chicago Press, 2008.

Hendren, Nathaniel and Ben Sprung-Keyser, "A Unified Welfare Analysis of Government Policies," *Quarterly Journal of Economics*, 2020, *135* (3), 1209–1318.

Johari, Ramesh and John N. Tsitsiklis, "Efficiency Loss in Cournot Games," *Working paper*, 2005.

Kalouptsidi, Myrto, Paul T. Scott, and Eduardo Souza-Rodrigues, "Identification of Counterfactuals in Dynamic Discrete Choice Models," *Quantitative Economics*, 2021, *12* (2), 351–403.

Kleven, Henrik J., "Sufficient Statistics Revisited," *Annual Review of Economics*, 2021, *13*.

References

Kremer, Michael and Christopher M. Snyder, "Preventives Versus Treatments," *Quarterly Journal of Economics*, 2015, *130* (3), 1167–1239.

Krugman, Paul R., "Increasing Returns, Monopolistic Competition, and International Trade," *Journal of International Economics*, 1979, *9* (4), 469–479.

Manski, Charles F, "Econometrics for decision making: Building foundations sketched by Haavelmo and Wald," *Econometrica*, 2021, *89* (6), 2827–2853.

Marshall, Alfred, *Principles of Economics*, London, UK: Macmillan and Co., 1890.

Myerson, Roger B., "Optimal Auction Design," *Mathematics of Operations Research*, 1981, *6* (1), 58–73.

Robinson, Joan, *The Economics of Imperfect Competition*, London, UK: Macmillan, 1933.

Rosen, J. B., "Existence and Uniqueness of Equilibrium Points for Concave N-person Games," *Econometrica*, 1965, pp. 520–534.

References

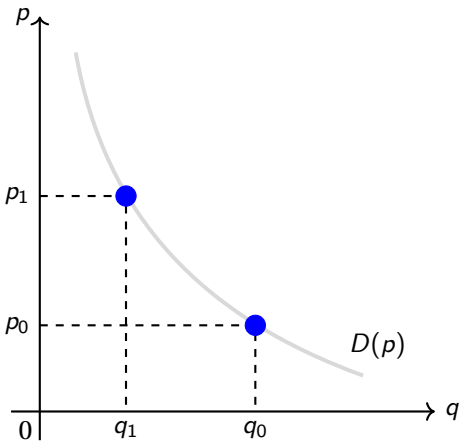
Szidarovszky, Ferenc and Sidney Yakowitz, "A New Proof of the existence and uniqueness of the Cournot equilibrium," *International Economic Review*, 1977, *18* (3), 787–789.

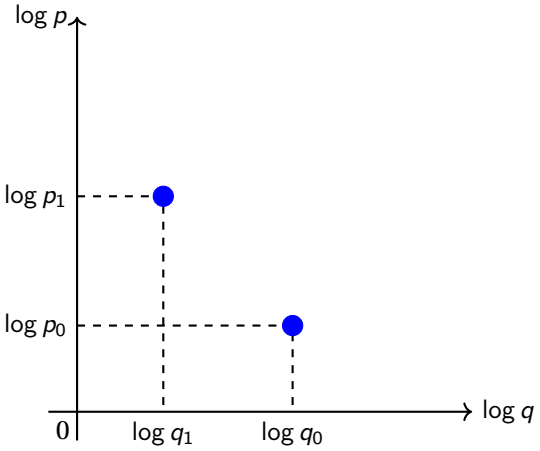
Tsitsiklis, John N. and Yunjian Xu, "Efficiency Loss in a Cournot Oligopoly with Convex Market Demand," *Journal of Mathematical Economics*, 2014, *53*, 46–58.

Varian, Hal R., "The Nonparametric Approach to Demand Analysis," *Econometrica*, 1982, pp. 945–973.

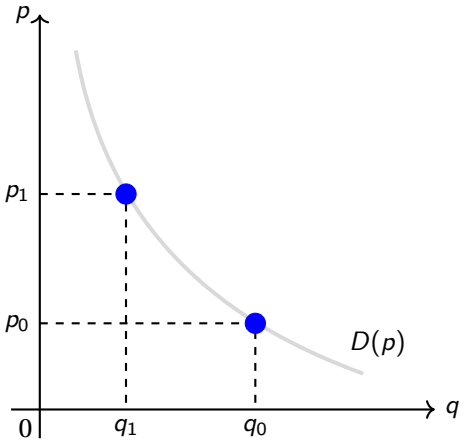
__ , "Price Discrimination and Social Welfare," *American Economic Review*, 1985, *75* (4), 870–875.

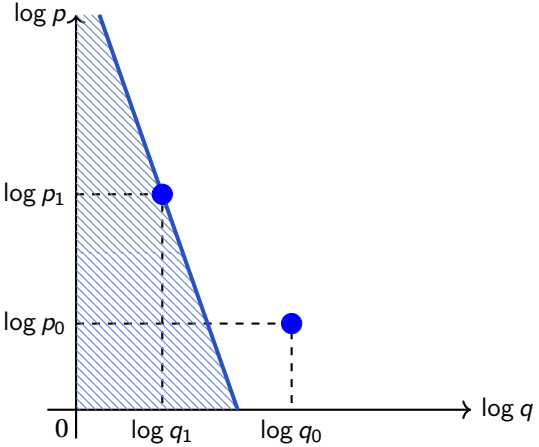
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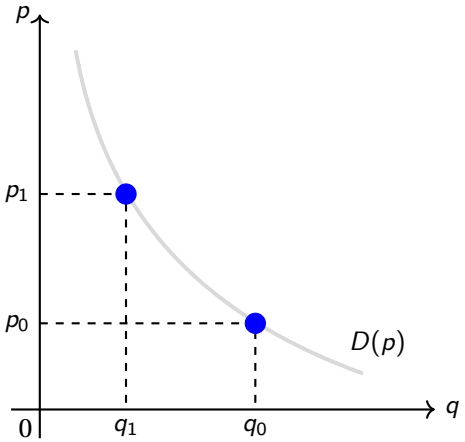


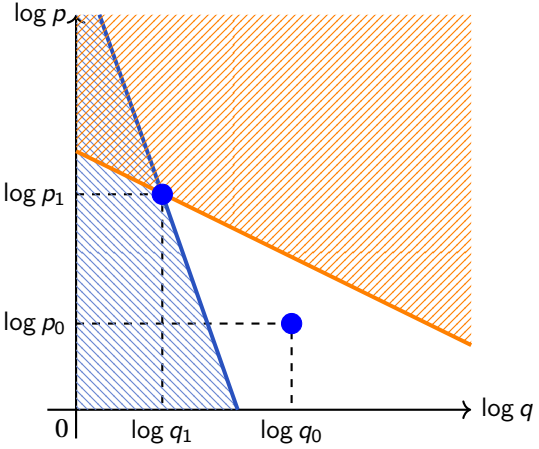
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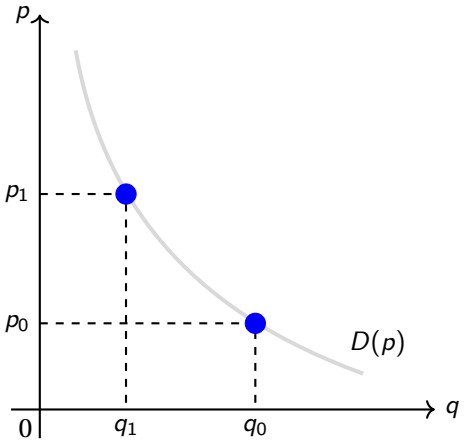


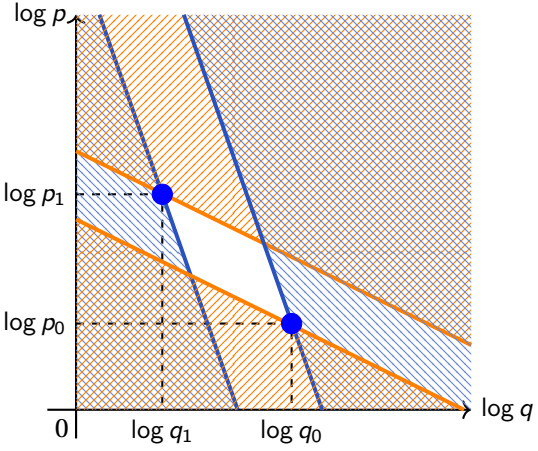
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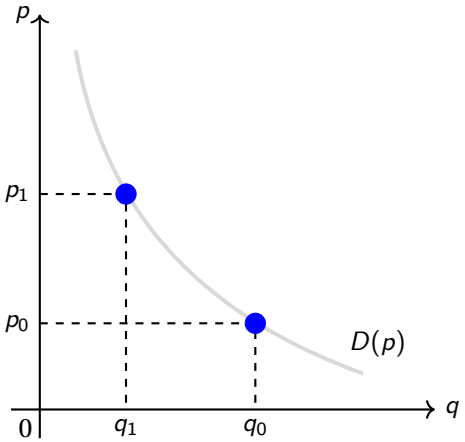


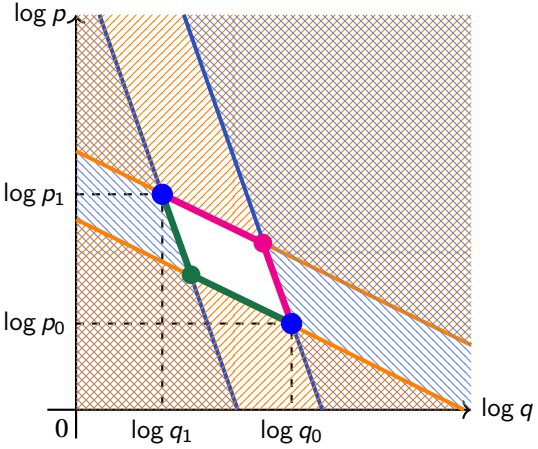
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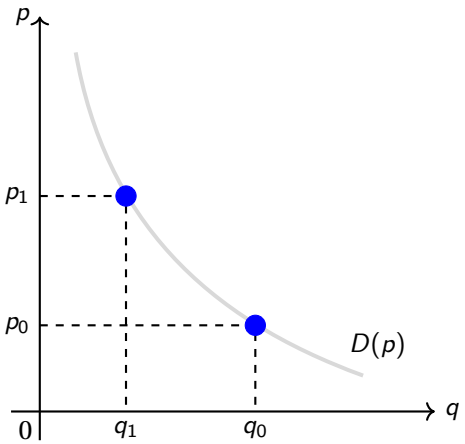


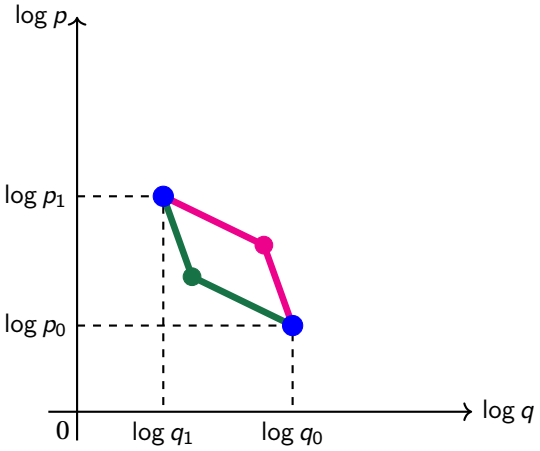
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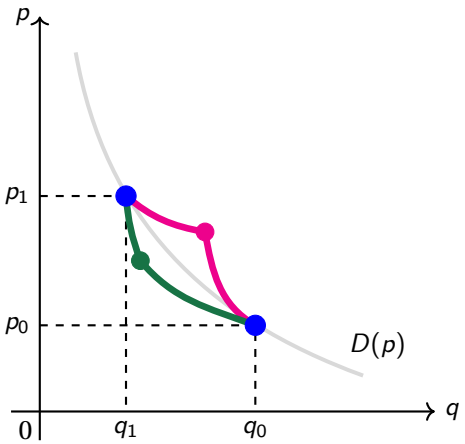


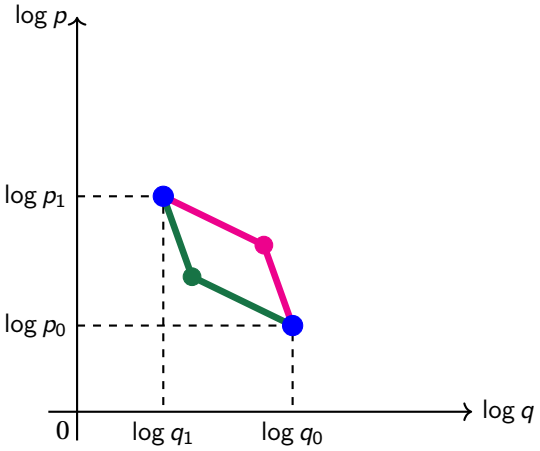
Geometric derivation of welfare bounds





Geometric derivation of welfare bounds





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.

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

Back

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

