Incidence

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Question: Who bears the burden of environmental taxes?

Theory

The incidence of (environmental) taxation

- Tax incidence is the study of how a tax affects prices and welfare.
- In the case of a Pigouvian tax, we know that the tax increases social welfare (reduces inefficiency).
- But policymakers are still interested in which side of the taxed market bears the burden of the tax.
- Key point: Tax incidence is not a simple accounting exercise. Rather, it is an analytical characterization of equilibrium changes.

Example: Gasoline Taxes

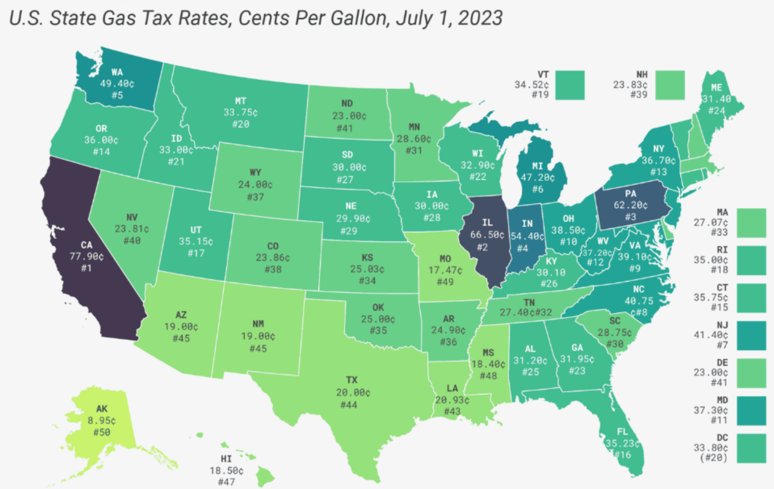
Driving is associated with many externalities:

- local pollution (petroleum)
- national security? (petroleum)
- road damage (all driving)
- accident risk (all driving)
- climate change (petroleum)

The economists' prescription to deal with these externalities is to tax them.

All told, the gas tax should be well above \$2/gallon.

Current State Gasoline Excise Taxes

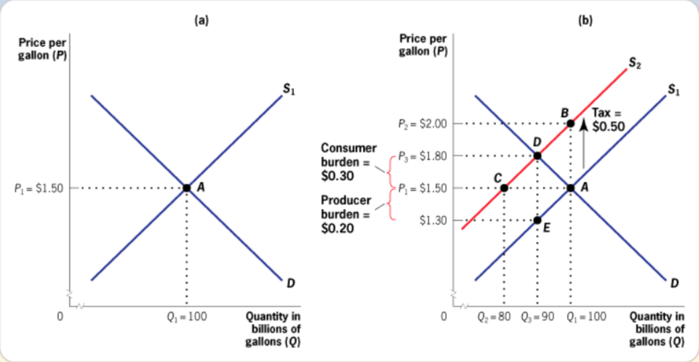


What is the economic incidence of gas taxes?

- Imagine that without taxes, the price at the pump would be $1.50.
- Consider a 50-cent excise tax levied on retailers.
  - For every wholesale gallon a gas station owner buys, it must pay the state $0.50.

Incidence of a tax on retailers

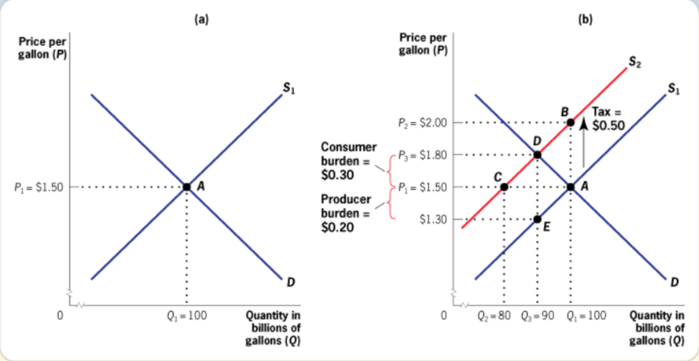
■ FIGURE 19-2



Statistical Burdens Are Not Real Burdens • Panel (a) shows the equilibrium in the gas market before taxation (point *A*). A 50¢ tax levied on gas producers (the statutory burden) in panel (b) leads to a decrease in supply from S_1 to S_2 and to a 30¢ rise in the price of gas from P_1 to P_3 (point *D*). The real burden of the tax is borne primarily by consumers, who pay 30¢ of the tax through higher prices, leaving producers to bear only 20¢ of the tax.

Incidence of a tax on retailers

■ FIGURE 19-2



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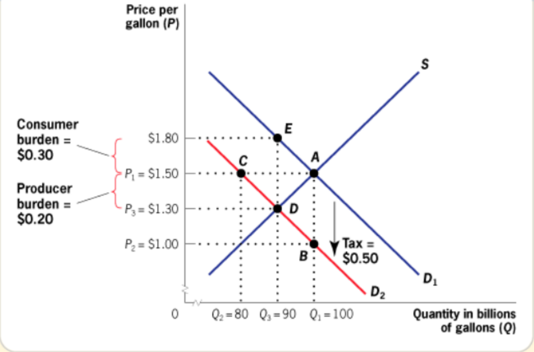
Consumer prices increase by 30 cents after a 50-cent tax ⇒ consumers bear 60% of the economic burden.

What if we taxed drivers instead?

- Now consider a rule change which would shift the statutory burden to consumers.
  - Now drivers, not station owners, cut a check to the state.
- How would this change the incidence of a 50-cent tax?
- Should consumers oppose this change?

Incidence is the same if we tax drivers



The Side of the Market Is Irrelevant • A 50¢ tax levied on gas consumers (the statutory burden) leads to a decrease in demand from D_1 to D_2 and to a 20¢ fall in the price of gas from P_1 to P_3 (with the market moving from the pre-tax equilibrium at point *A* to the post-tax equilibrium at point *D*). The real burden of the tax is borne primarily by consumers, who pay the 50¢ tax to the government but receive an offsetting price reduction of only 20¢; producers bear that 20¢ of the tax.

What *does* determine incidence?

- In this example, price goes up by \$0.30 after a \$0.50 tax.
- This tells us that consumers incur 60% of the economic burden.
  - And therefore producers incur 40%.
- What determines these proportions?
- The following slides from Emmanuel Saez derive an analytical answer.

Partial Equilibrium Tax Incidence

We consider partial equilibrium model with a single good (illustrates well key mechanisms)

Government levies an excise tax on good x

Excise means it is levied on a quantity (gallon, pack, ton, ...). Typically fixed in nominal terms (e.g, $1 per pack)

[ad-valorem tax is a fraction of prices (e.g. 5% sales tax)]

Let p denote the pretax price of x (producer price)

Let $p^c = p + dt$ denote the tax inclusive price of x (consumer price) where dt is the tax per unit

We assume that dt is small and trace out the impact dp and dQ on p and Q using calculus

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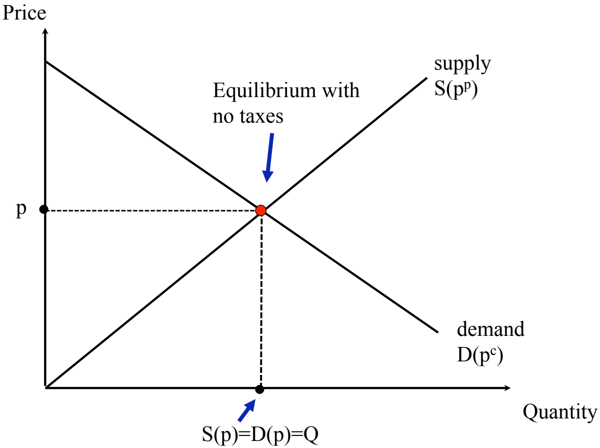
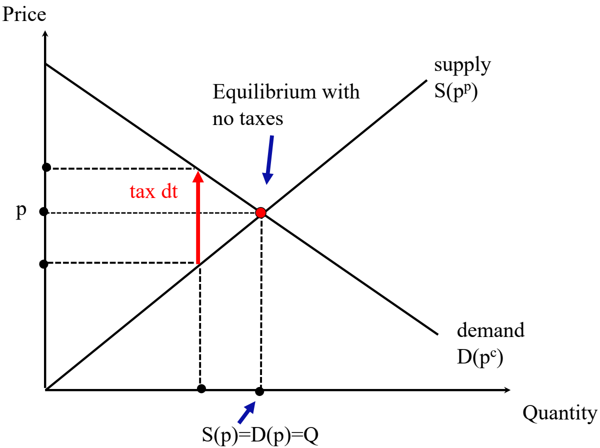

Price
supply
S(pp)
Equilibrium with
no taxes
p
demand
D(pc)
Quantity
S(p)=D(p)=Q


Price
supply
S(p^p)
Equilibrium with
no taxes
tax dt
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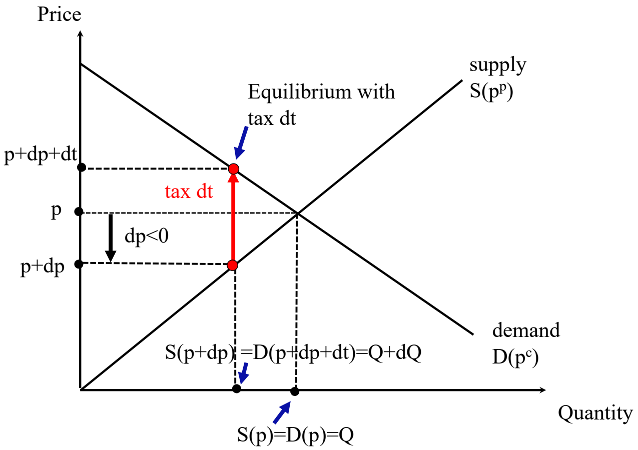
demand
D(p^c)
Quantity
S(p)=D(p)=Q


Price
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p+dp
demand
D(p^c)
S(p+dp) =D(p+dp+dt)=Q+dQ
Quantity
S(p)=D(p)=Q

TAX INCIDENCE

Supply of good x is $S(p)$ increases with producer price $p^p = p$

Demand is $D(p^c)$ decreases with consumer price $p^c = p + dt$

Start from $t = 0$ and no tax equilibrium $S(p) = D(p)$

Effect of a small tax dt on price p:

Change dt generates change dp so that equilibrium holds:

$$S(p + dp) = D(p + dp + dt) \Rightarrow$$

$$S(p) + S'(p)dp = D(p) + D'(p)(dp + dt) \Rightarrow$$

$$S'(p)dp = D'(p)(dp + dt) \Rightarrow$$

$$\frac{dp}{dt} = \frac{D'(p)}{S'(p) - D'(p)}$$

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TAX INCIDENCE FOR SMALL TAX dt

Elasticities useful in economics because they are unit free

Elasticity: percentage change in quantity when price changes by one percent

$\varepsilon_D = \frac{p^c}{D}\frac{dD}{dp^c} = \frac{p^c D'(p^c)}{D(p^c)} < 0$ denotes the price elasticity of demand

$\varepsilon_S = \frac{p}{S}\frac{dS}{dp} = \frac{pS'(p)}{S(p)} > 0$ denotes the price elasticity of supply

$$\frac{dp}{dt} = \frac{D'(p)}{S'(p) - D'(p)} = \frac{pD'(p)/D(p)}{pS'(p)/S(p) - pD'(p)/D(p)} = \frac{\varepsilon_D}{\varepsilon_S - \varepsilon_D}$$

$$-1 \leq \frac{dp}{dt} \leq 0 \quad \text{and} \quad 0 \leq \frac{dp^c}{dt} = 1 + \frac{dp}{dt} \leq 1$$

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Tax incidence depends on elasticities

Buyers' share (increase in price paid per unit of t):

$$\frac{dP^c}{dt} = \frac{\varepsilon_S}{\varepsilon_S - \varepsilon_D} = \frac{\varepsilon_S}{\varepsilon_S + |\varepsilon_D|}.$$

Sellers' share (decrease in net price received per unit of t):

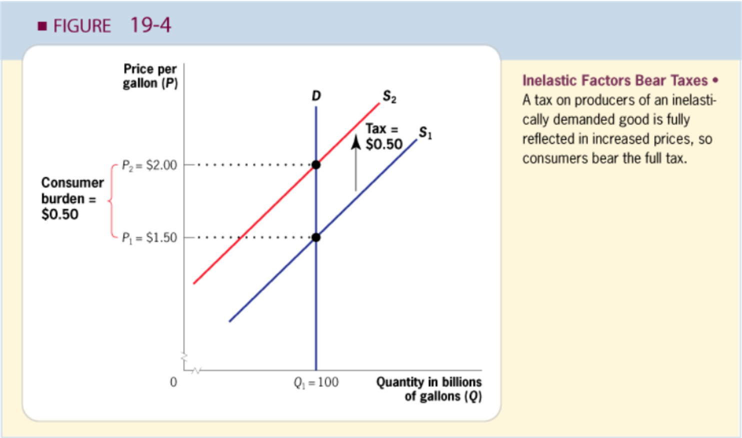
$$-\frac{dP}{dt} = \frac{-\varepsilon_D}{\varepsilon_S - \varepsilon_D} = \frac{|\varepsilon_D|}{\varepsilon_S + |\varepsilon_D|}.$$

Consumers bear the full burden with perfectly inelastic demand ($\varepsilon_D = 0$) or perfectly elastic supply ($\varepsilon_S = \infty$).

Producers bear the full burden with perfectly inelastic supply ($\varepsilon_S = 0$) or perfectly elastic demand ($\varepsilon_D = -\infty$).

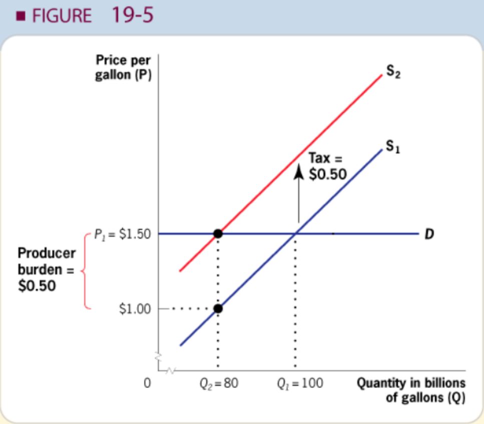
Inelastic factors bear taxes

Perfectly Inelastic Demand



Elastic factors avoid them

Perfectly Elastic Demand

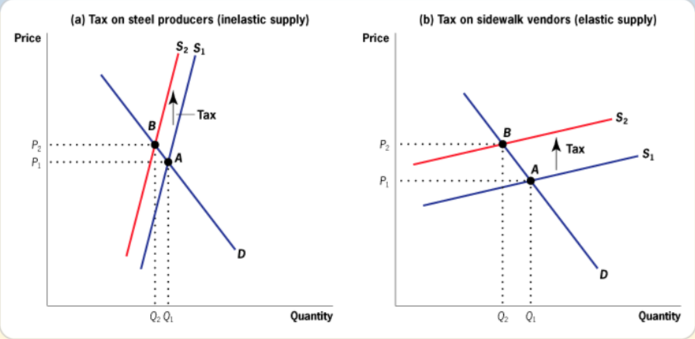


Elastic Factors Avoid Taxes • A tax on producers of a perfectly elastically demanded good cannot be passed along to consumers through an increase in prices, so producers bear the full burden of the tax.

Inelastic factors bear taxes; Elastic factors avoid

Supply Elasticities

■ FIGURE 19-6



Elasticity of Supply Also Matters • A tax on producers of an inelastically supplied good, as in panel (a), leads to a very small rise in prices, so producers bear most of the burden of the tax. An equal-sized tax on producers of an elastically supplied good, as in panel (b), leads to a large rise in prices, so producers bear little of the burden of the tax (and consumers bear most of the burden).

What determines these elasticities?

Demand:

What determines these elasticities?

Demand:

- Availability of substitutes
- How “essential” is a good

Supply:

What determines these elasticities?

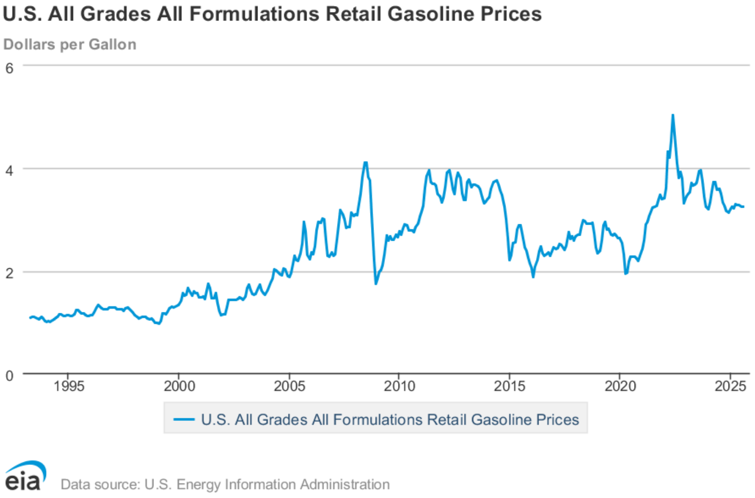
Demand:

- Availability of substitutes
- How "essential" is a good

Supply:

- Availability of inputs
- Capacity constraints

In the short run, both supply and demand are inelastic. This is why prices are so volatile.



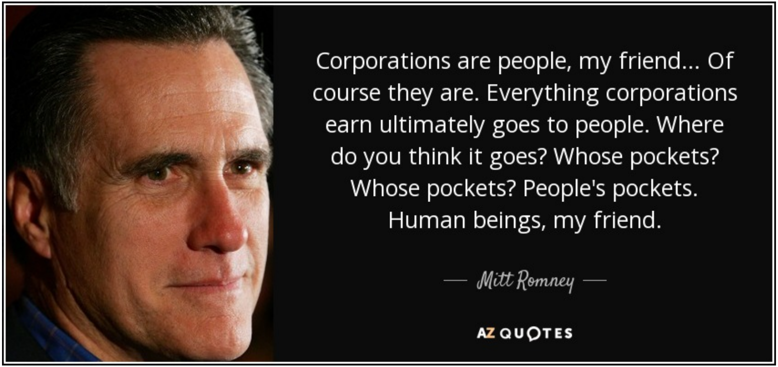
What about the long run?

Are things more or less elastic?

What about the long run?

Are things more or less elastic?

- In general, more elastic
- Demand: Drivers buy different cars
- Supply: Can open up new oil fields


Corporations are people, my friend... Of course they are. Everything corporations earn ultimately goes to people. Where do you think it goes? Whose pockets? Whose pockets? People's pockets. Human beings, my friend.
— Mitt Romney —
AZ QUOTES

Ultimately, costs are borne by individuals

Either consumers, taxpayers, or shareholders

Tax and Stock Ownership Inputs

Decile	Marginal Tax Rate	Average Tax Rate	Stock Ownership
1	-15%	4%	0.80%
2	3%	4%	0.50%
3	11%	10%	0.90%
4	16%	10%	1.70%
5	17%	14%	2.40%
6	19%	14%	4.20%
7	22%	17%	5.70%
8	27%	17%	7.00%
9	30%	23%	12.10%
10	36%	27%	64.70%

Sources: Supporting analysis for Cogressional Budget Office (2005); Department of Treasury (2007)

Wrapup on incidence theory

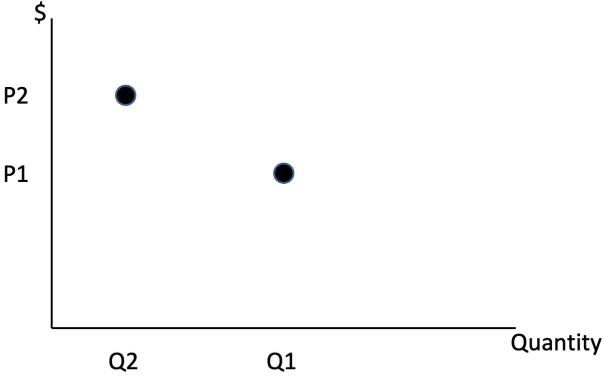
- Natural to think government can dictate who bears the burden of regulation.
- Result 1: Statutory incidence does not determine economic incidence.
    - In a market economy, costs or regulations on one side will eventually affect prices and quantity demanded. And these determine economic welfare.
- Result 2: Economic incidence depends on elasticities of supply and demand.
    - Relatively inelastic factors bear more of the tax burden.
- Note: This assumes perfect competition.

Estimating Elasticities

Elasticities are arguably the most important objects in economics

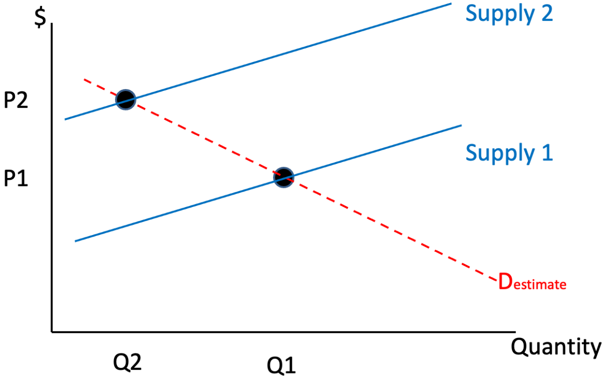
- How much much less gasoline will people use if we tax it at the social cost of carbon?
- What will the incidence of a carbon tax be on consumers versus producers?
- More generally, this is probably the most important object for many businesses: How much will demand fall if we increase prices?

To estimate a demand curve, we can look at how quantity has responded to price changes in the past



A typical dataset will look like this

It is tempting to draw a curve through those points and call it demand

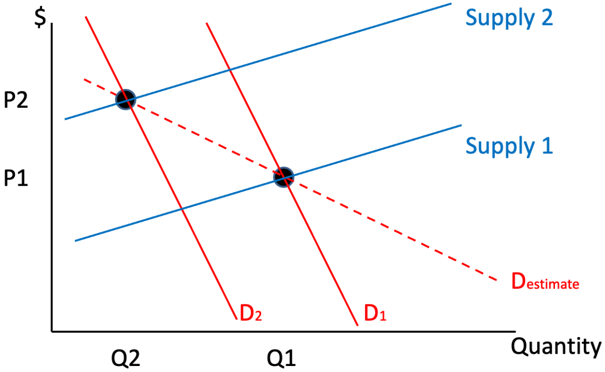


This assumes that <u>only supply changed</u> between periods 1 and 2

Shifts in versus along demand and supply curves

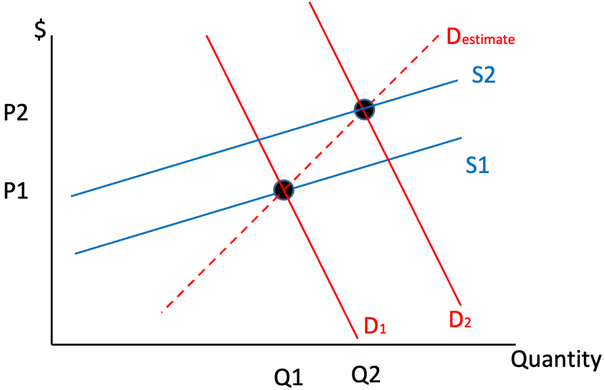
- Take the market for oil
- What are some things that cause the intercept of the **supply curve** to shift up / down?
  - These allow use to estimates the slope (~ elasticity) of demand.
- What are some things that cause the intercept of the **demand curve** to shift up / down?
  - These allow use to estimates the slope (~ elasticity) of demand.
- **Challenge:** Both curves can move over time

It is possible that supply *and demand* changed between periods 1 and 2



If we drew a line through these two dots and called it “demand” we would have significantly overstated elasticity (in this example)

If supply and demand shocks are positively correlated, you could even estimate *upward sloping* demand



Application: Incidence of the shale gas boom

Why this paper now?

You have just learned that **incidence depends on elasticities**.

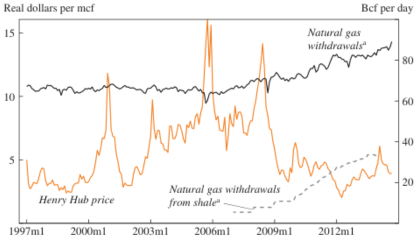
This paper asks the same basic question for a major energy-market shock:

> *When shale technology shifts natural-gas supply outward,* ***how much does price fall, who gains, who loses, and by how much?***

The key inputs are the **demand and supply elasticities**.

The shale gas shock was enormous

Figure 1. U.S. Natural Gas Production and Price, 1997–2015



Source: EIA.
a. Gross withdrawals include not only marketed production, but also natural gas used to repressure wells, vented and flared gas, and nonhydrocarbon gases removed.

- U.S. natural gas production rose by about **25% from 2007 to 2013**.
- Shale withdrawals rose from about **5 to 33 bcf/day**.
- Henry Hub prices fell from about **\$8.00 to \$3.82 per mcf**.
- But that raw price decline is **not yet a causal estimate** of the shale effect.

Source: Hausman & Kellogg (2015), Figure 1 and Section II.

Incidence lens: what determines the price response?

An outward supply shift produces two conceptually different effects:

1. **Price / transfer effect:** buyers pay less; owners of existing production receive less.
2. **Quantity / efficiency effect:** more gas is consumed and lower-cost gas replaces higher-cost gas.

> The slopes of demand and supply - equivalently, their elasticities - determine how much of the shock shows up as a price change versus a quantity change.

This is the same intuition as tax incidence, but here the shock is a **technology-driven supply expansion**.

Why not just use the observed price drop?

From 2007 to 2013:

- Observed Henry Hub price: **\$8.00 → \$3.82**
- Raw decline: **\$4.18/mcf**

But demand also changed over this period - recession/recovery, manufacturing changes, electricity-sector changes, renewables, etc.

So the relevant counterfactual is:

> ***What would the 2013 price have been with 2013 demand, but without the supply expansion?***

That requires estimated supply and demand curves.

Their preferred long-run elasticities

Sector	Demand elasticity
Residential	**-0.20**
Commercial	**-0.23**
Industrial	**-0.57**
Electric power	**-0.47**
Total demand, roughly	**-0.4**

Supply elasticity: 0.81

A 10% lower gas price implies, approximately:

- Residential demand rises **2%**
- Industrial demand rises **5.7%**

A 10% higher gas price is associated with about **8.1% more long-run supply**.

Source: Hausman & Kellogg (2015), Table 1.

The simultaneity problem

Suppose we regress quantity on price to estimate demand:

$$\log Q_t = \eta_D \log P_t + \text{controls} + \varepsilon_t.$$

But market prices are equilibrium outcomes.

Positive demand shock

$\rightarrow$

Higher quantity

$+$

Higher price

So observed high-price months can also be high-quantity months.

OLS therefore makes demand look too inelastic - the estimated slope is biased toward zero.

Their IV idea - in one example

They need something that moves **price** without directly moving **current local demand**.

Cold weather in other regions, months ago

$\rightarrow$

Gas taken out of storage

$\rightarrow$

Higher gas price today

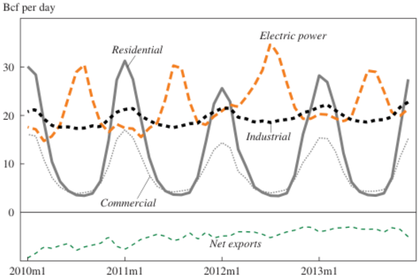
After controlling for current local weather and seasonality, **lagged weather elsewhere** should not directly change a state's current gas consumption.

So this variation isolates movements **along the demand curve** rather than shifts of the demand curve.

Implementation: cumulative heating-degree days in other census divisions, lagged 2-12 months. The supply equation uses

Why weather is useful: gas demand is highly seasonal

Figure 3. U.S. Natural Gas Consumption by Sector of End Use, 2010–14[a]



Source: EIA.
a. Natural gas used in vehicles, in drilling operations, and as fuel in natural gas processing plants is not shown, but all these amounts are small.

- Residential and commercial gas use spikes in cold months.
- Weather shocks therefore move gas demand and inventories.
- Storage carries those shocks forward into later prices.
- The clever step is to use **past weather elsewhere**, not current weather where demand is measured.

Source: Hausman & Kellogg (2015), Figure 3.

From elasticities to supply and demand curves

For each demand sector, they assume a constant-elasticity curve:

$$Q_i^D = A_i \, (P_i)^{\eta_i}, \qquad P_i = P_{HH} + \text{sector markup.}$$

Supply is also constant elasticity over the relevant range:

$$Q^S = A_S \, P_{HH}^{0.81}.$$

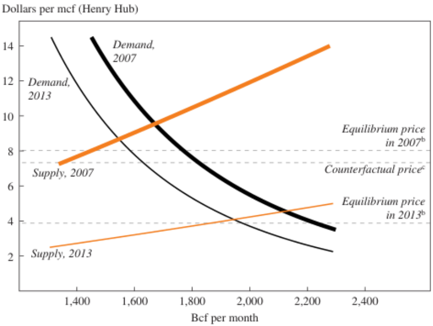
Step 1: use observed prices and quantities to calibrate the scale parameters A.

Step 2: keep **2013 demand** but replace 2013 supply with the **counterfactual 2007 supply curve**.

Step 3: solve for the price that clears the market, accounting for net imports.

The preferred counterfactual price

Figure 4. Supply and Demand in the U.S. Natural Gas Market, 2007 and 2013[a]



Source: Authors' calculations.
a. The thick lines show 2007, and thin lines 2013. For 2007 and 2013 net imports, we use the quantities observed in our data.
b. The equilibrium prices are not at the intersection of domestic supply and demand, since there are non-zero net imports.
c. For the counterfactual scenario, we assume a linear net import function, as described in the text.

2013 equilibrium
$3.88
per mcf
2013 without supply expansion
$7.33
per mcf
Shale supply effect
-$3.45
per mcf

The preferred estimate implies shale lowered the 2013 wholesale price by about **47% relative to the counterfactual price**.

Source: Hausman & Kellogg (2015), Figure 4 and Section II.

How much do the elasticities matter for the price estimate?

They redo the exercise with elasticities doubled or halved.

Assumptions	Estimated shale price decrease (\$/mcf)
Preferred estimates	**3.45**
Alternative 1	2.19
Alternative 2	3.06
Alternative 3	4.12
Alternative 4	4.16

So elasticity uncertainty matters - but every case says the shale expansion caused a **large price decline**.

Source: Hausman & Kellogg (2015), Table 2.

Turning the price change into consumer surplus

For sector i, with one-for-one pass-through of the wholesale price change:

$$\Delta CS_i = \int_{P_1}^{P_0} Q_i^D(P)\, dP.$$

With constant-elasticity demand $Q_i = A_i P^{\eta_i}$:

$$\Delta CS_i = \frac{A_i}{\eta_i + 1}\left(P_0^{\eta_i+1} - P_1^{\eta_i+1}\right).$$

They do this for all four sectors and add them up.

> Preferred estimate: consumer surplus rises by $74 billion per year.

This is larger than simple bill savings because consumers also

Who gets the $74 billion in consumer gains?

Sector	Change in consumer surplus ($bn/year)
Residential	**17**
Commercial	**11**
Industrial	**22**
Electric power	**25**
Total	**74**

The biggest gains go to **electric power and industrial users**, not residential heating customers.

Why? They use a lot of gas, and their estimated demand is relatively more elastic.

Source: Hausman & Kellogg (2015), Table 2.

Incidence needs pass-through too

Who actually receives the consumer-side benefit - end users or gas distributors?

Their estimated **long-run pass-through from Henry Hub to sector retail/citygate gas prices** is essentially one-for-one:

Residential	Commercial	Industrial	Electric power
0.99	1.03	0.99	1.02

So the wholesale gas price decline is not mainly retained by local distribution companies.

Incidence lesson: knowing the market-level price effect is not enough; you also need to know how input-price changes pass through downstream.

Source: Hausman & Kellogg (2015), Table 4, 2SLS estimates.

What happens to gas producers?

A crucial feature of natural gas production:

- Once a well is drilled, its marginal operating cost is very low.
- Existing wells are rarely shut in when price falls.
- The shale technology mainly changes the cost of **new production**, not the operating cost of old wells.

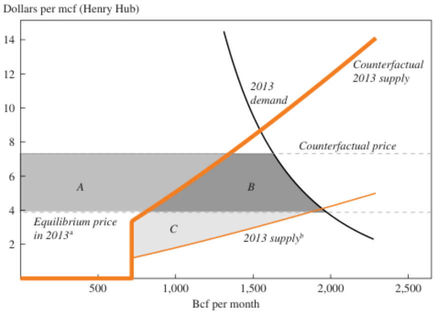
Preferred producer-surplus decomposition for 2013:

Component	Counterfactual	Actual 2013	Cha
Legacy / inframarginal wells	$63bn	$33bn	**-$3**
Elastic / new-well portion	$15bn	$19bn	**+$4**
Total producer surplus	**$78bn**	**$52bn**	-$2

Source: Hausman & Kellogg (2015), Section III.C.

Transfers versus true welfare gains

Figure 6. Change in Surplus[a]



Source: Authors' calculations.
a. As described in the text, the equilibrium prices are not at the intersection of domestic supply and demand, since they also account for imports and exports.
b. The vertical part of the supply curve denotes the quantity of 2013 natural gas production that we estimate to be coming from wells drilled during or prior to 2007. See text for details.

- **A:** mostly a transfer from legacy producers to gas purchasers.
- **B + C:** new surplus created by the supply expansion.

Consumer surplus +\$74bn
Producer surplus -\$26bn
Total market surplus +\$48bn/yr

Source: Hausman & Kellogg (2015), Figure 6.

Elasticities change incidence more than total surplus

Across their alternative elasticity assumptions:

- Consumer surplus gain: **$45-$93bn/year**
- Producer surplus change: **-$8 to -$40bn/year**
- Total surplus gain: **$37-$56bn/year**

> Elasticity assumptions strongly affect the price change and the transfer between consumers and producers, but the estimated total market-surplus gain is more stable.

This is a useful incidence lesson: **distribution can be more sensitive to elasticities than aggregate efficiency.**

Source: Hausman & Kellogg (2015), Table 2 and discussion of Figure 6.

Important caveat: this is not full social welfare

The **+$48bn/year** number includes consumer and producer surplus, but excludes environmental externalities.

The paper highlights:

- Methane leakage and climate effects
- Coal-to-gas substitution versus increased energy use
- Water contamination and water use
- Local air pollution, trucking, roads, seismic activity, and other local impacts

Their climate-change bounding exercise alone gives **$3-$28bn/year in environmental costs** for 2013, and many local damages could not be comprehensively monetized.

So do **not** interpret +$48bn as the final social-welfare effect of fracking.

Source: Hausman & Kellogg (2015), Section VI.

Main takeaways

1. A large supply shock is an **incidence problem**: elasticities determine the price and quantity response.
2. Estimating those elasticities is hard because price and quantity are **simultaneously determined**.
3. Their solution is to use **lagged weather elsewhere**, working through gas storage, to generate plausibly exogenous price variation.
4. Preferred estimates imply shale gas lowered the 2013 price by **\$3.45/mcf**.
5. Market surplus effects: **+\$74bn consumers, -\$26bn producers, +\$48bn total per year**.
6. Environmental externalities are outside that \$48bn calculation.

Discussion question

If natural-gas demand were much **more inelastic**, which would change more: the **price effect**, the **quantity effect**, or the **efficiency gain**?