Lecture 6: Hedonics, Voting with Your Feet, and Why it’s Not That Simple

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Econ 4075

The "Characteristics" Model

Lancaster (1966) – A New Approach to Consumer Theory

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2. In general, a good will possess more than one characteristic, and many characteristics will be shared by more than one good.
3. Goods in combination may possess characteristics different from those pertaining to the goods separately.

“A meal (treated as a single good) possesses nutritional characteristics, and different meals will possess these characteristics in different relative proportions. Furthermore, a dinner party, a combination of two goods, a meal and a social setting, may possess nutritional, aesthetic, and perhaps intellectual characteristics different from the combination obtainable from a meal and a social gathering consumed separately.”

Quality-differentiated market goods

A quality-differentiated good is one defined by its characteristics.

Examples?

Quality-differentiated market goods

A quality-differentiated good is one defined by its attributes.

Examples:

- An automobile is defined by vehicle class, engine size, gas mileage, safety equipment,…
- A US health insurance plan is defined by deductible, co-insurance, out-of-pocket-max, available doctors, quality of care metrics,…
- A house is defined by its structural attributes, lot attributes, neighborhood, local environmental conditions,…

The modern availability of data means we know a lot about the environment, and a lot about real estate markets

- Digitized property transaction databases
- Detailed GIS information on land use
- Spatial techniques for linking data from numerous sources

Quality-differentiated market goods

What if the level of environmental quality affects the market price of a private real estate transaction?

We generally accept in economics that all (known) things about a good will capitalize into its price.

And we (often but not always) know about local environmental quality.

Hedonic Price Theory

Conceptual Model: Rosen (1974) –
Hedonic Prices and Implicit Markets,
Product Differentiation in Pure Competition

1. Products are objectively measured in characteristics
2. Observed prices, combined with the set of characteristics, define a set of implicit or “hedonic” prices
3. This theory guides both producers *and* consumers in characteristics space

HEDONIC PRICES 39

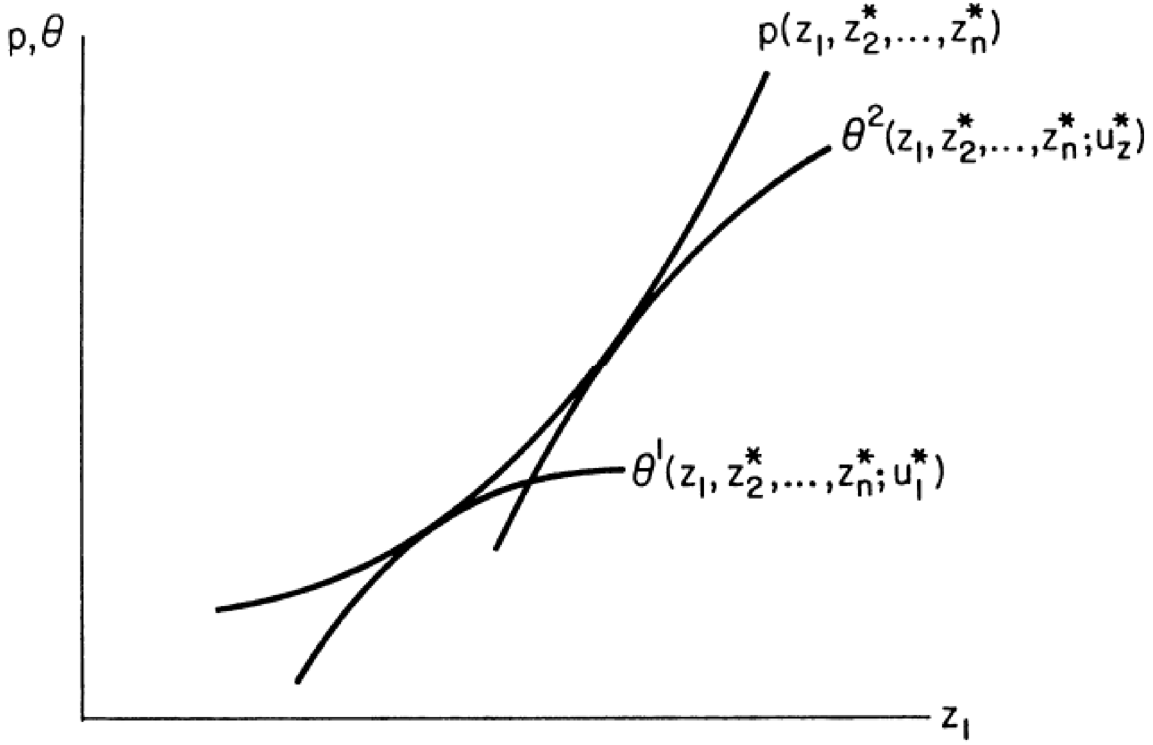
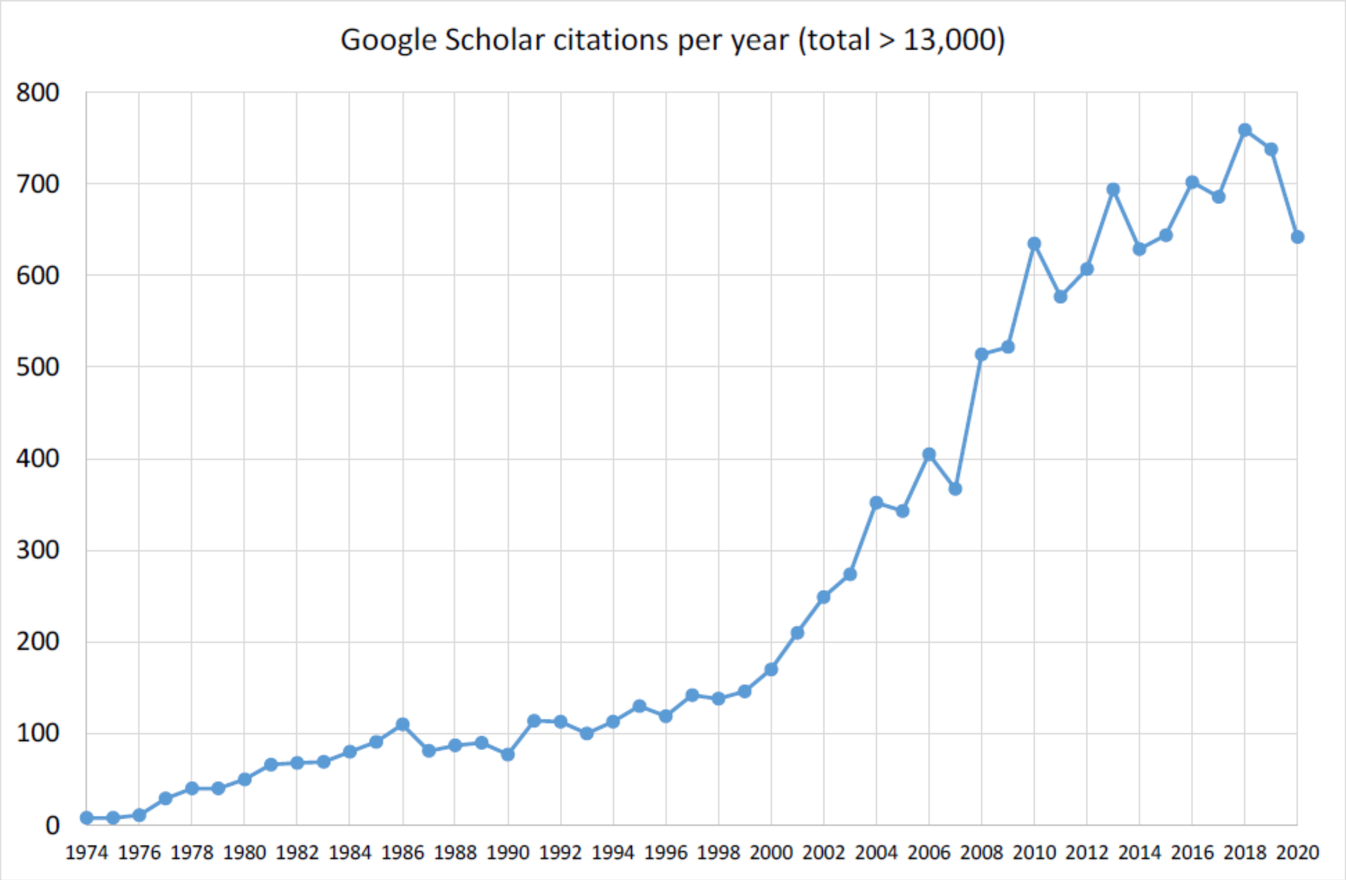


Fig. 1

Enduring Popularity of Hedonic Property Models



Rosen, Sherwin. 1974. "Hedonic prices and implicit markets: product differentiation in pure competition." *Journal of Political Economy*, 82(1): 34-55.

Figure from N. Kuminoff.

Some intuition first, then the theory…

Imagine there are two identical lakes in western VA, each with 100 homes surrounding them.

All homes are lakefront, all the characteristics of the homes themselves, the land, and the neighborhoods are identical across all properties.

At current equilibrium price of $500,000/house, all 200 homes on either lake are equally preferred.

Hedonics intuition

Suppose the water quality on Lake A is improved; the water is clearer, which is beneficial to the residents who live on the lake.

If prices have not changed, consumers would now all prefer to buy Lake A homes.

In econ-speak: at current prices, there would be ***excess demand*** for Lake A homes.

To bring the market back into equilibrium, we know that excess demand will be satisfied by Lake A prices ***increasing***.

Hedonics intuition

The new equilibrium price difference between Lake A and Lake B homes is the implicit price that consumers are willing to pay for the improvement in water quality.

If Lake A homes now sell for $525,000, while Lake B homes have an unchanged price, the implicit price of the water quality improvement is $25,000.

WTP for water clarity is revealed to us through the homes' market prices!

A question for you to check your understanding: could we have measured this implicit price before the improvement in Lake A's water quality?

Another: how much more WTP in this market for an additional 1 unit of improvement?

Hedonic Price Theory

Hedonic model build around housing prices in equilibrium. Equilibrium needs a buyer and a seller. Buyers and sellers choose *characteristics* for a single housing unit.

To simplify things for this course, assume supply of houses from sellers is fixed in the short run, so the price curve comes strictly from buyer's behavior.

Buyer solves the utility maximization problem:

$$\max_{x,q,z} U(x,z,q;s) \qquad s.t. \qquad \underbrace{y = P(x,q) + z}_{(budget\ constraint)}$$

- *x* denotes a home's characteristics
- *q* denotes a home's environmental quality attribute (variable of interest)
- *z* denotes numeraire consumption (this is just $)
- *s* denotes household characteristics (things that shift preferences)
- *y* denotes household income
- *P(·)* is equilibrium price function. A particular house, *k*, has price $P(x_k, q_k)$

Solving buyer's choice problem

$$\max_{x,q,z} U(x,z,q;s) \qquad s.t. \qquad \underbrace{y = P(x,q) + z}_{(budget\ constraint)}$$

Move the budget constraint into the objective function:

$$\max_{x,q} U(x, \underbrace{y - P(x,q)}_{z}, q; s)$$

Solve for the FOCs:

$$[x_j] \qquad \frac{\partial U}{\partial x_j} = \frac{\partial U}{\partial z}\frac{\partial P}{\partial x_j}, j = 1, \dots, J$$

$$[q] \qquad \frac{\partial U}{\partial q} = \frac{\partial U}{\partial z}\frac{\partial P}{\partial q}$$

Solving buyer's choice problem

Rearranging:

$$\frac{\partial P}{\partial q} = \frac{\frac{\partial U}{\partial q}}{\frac{\partial U}{\partial z}}$$

What does this tell us?

Solving buyer's choice problem

At the buyer's optimal choice of *q*...

$$\boxed{\underbrace{\frac{\partial P}{\partial q}}_{\text{implicit cost of } q} = \underbrace{\frac{\partial U}{\partial q} \Big/ \frac{\partial U}{\partial z}}_{\text{MRS between } q \text{ and } z}}$$

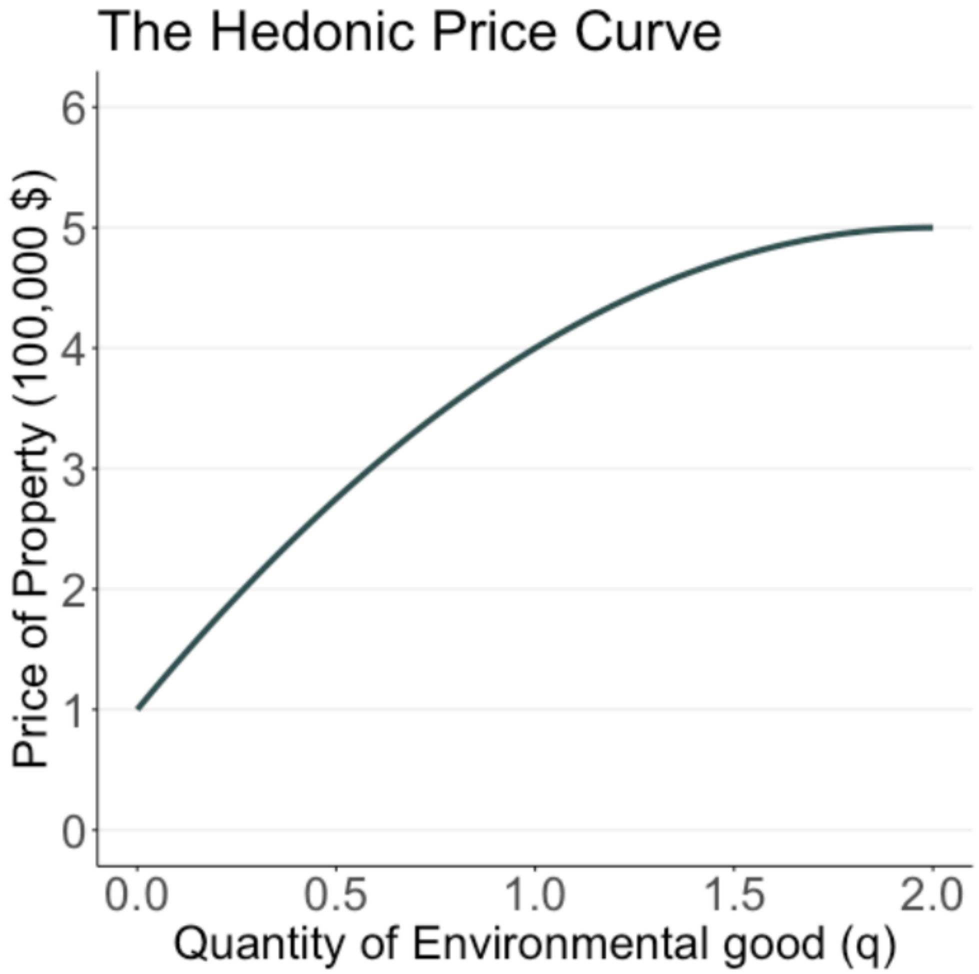
... the household equates their MRS between environmental quality and \$ to the implicit price of environmental quality.

From last lecture and micro theory, recall that a MRS with \$ in the denominator is equivalent to *marginal willingness to pay.*

- If MWTP > implicit price, buyers should buy more *q*
- If MWTP < implicit price, buyers should buy less *q*

KEY TAKEAWAY: holding all else constant, **a buyer's MWTP for environmental quality (i.e. a point on their demand curve) can be inferred from a regression of house prices on environmental quality**!

Using the price curve



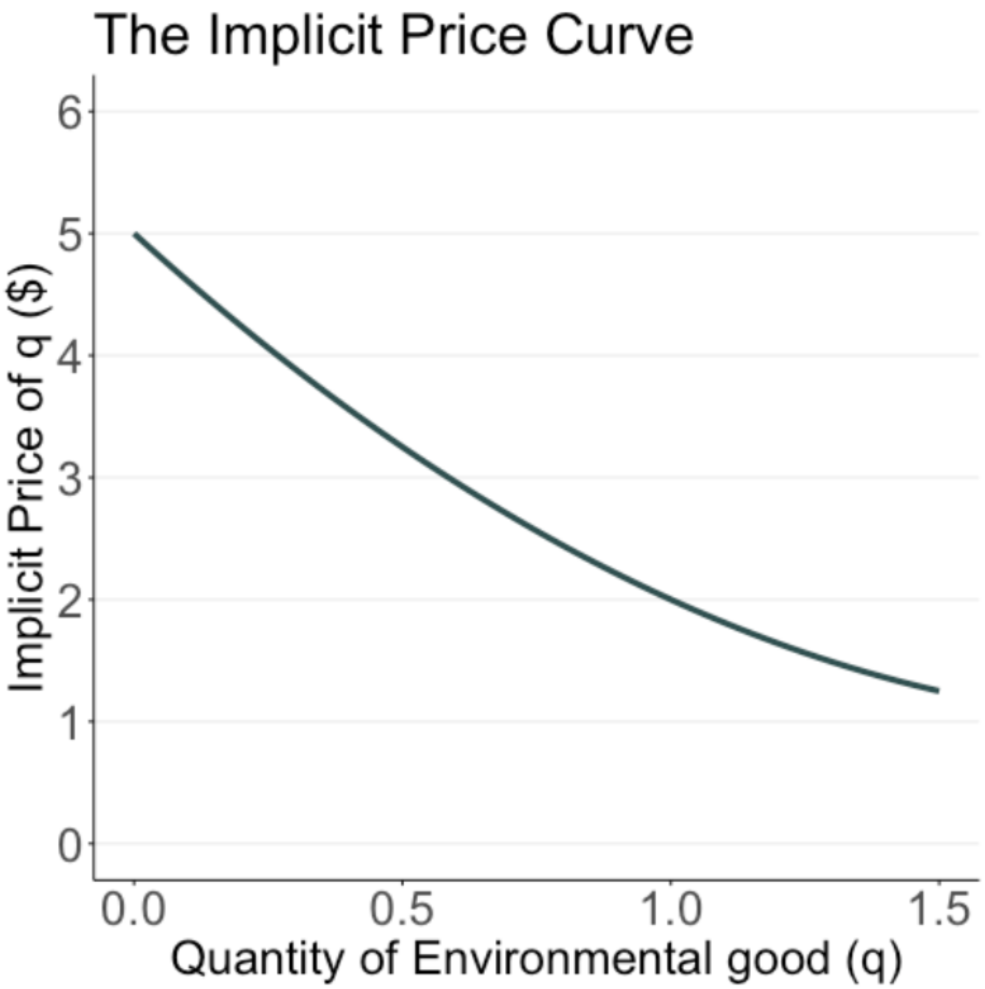
Hedonic price curve: *P(x, q).* Go on Zillow and you can trace out something like this.

As shown here in (*q*, $) space, *P(x, q)* is increasing in *q*. (Note we're holding *x* constant in this figure!)

We typically assume buyers get decreasing marginal utility from additional unit of environmental quality

For example: let *q* be distance from coal-powered electricity generation facility.

Implicit price curve



Recall, implicit price curve is $\frac{\partial P(x,q)}{\partial q}$.

So this graph corresponds to the slope of the previous graph.

We know from our buyers' first order condition on q that MWTP is equal to the implicit price. Thus, for the purposes of this class, **we can effectively think of this as an inverse demand curve.**

To test your understanding: in words, what does the implicit price curve at left tell us if q is measuring distance from coal-powered electricity generation?

Estimating the implicit price curve

Let's move this discussion into an econometric framework.

In general, we observe a set of market property transactions, with prices and property attributes.

To find the implicit price of some q, a general model would be: $p_i = f(x_i, q_i, \beta, \varepsilon_i)$

A commonly used functional form for the price function is:

$$\ln(p_i) = \beta_x x_i + \beta_q q_i + \varepsilon_i$$

Some algebraic maneuvering results in an implicit price function of the form:

$$\frac{\partial p_i}{\partial q_i} = \frac{\partial(\exp(\beta_x x_i + \beta_q q_i + \varepsilon_i))}{\partial q_i} = \beta_q \exp(\beta_x x_i + \beta_q q_i + \varepsilon_i)$$

$$\frac{\partial p_i}{\partial q_i} = \beta_q p_i$$

Estimating the implicit price curve

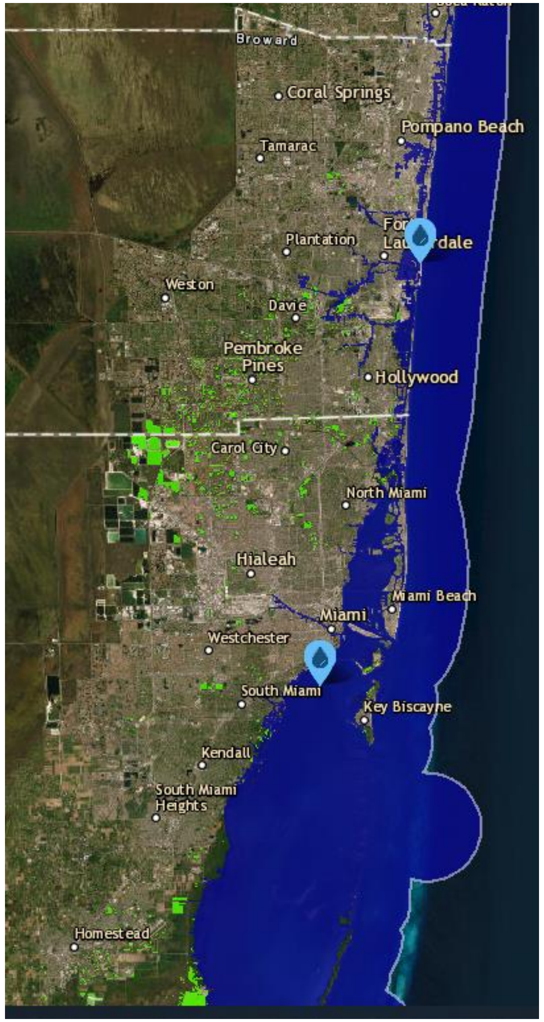
When estimating a hedonic model, analysts make necessary assumptions and decisions on several fronts.

Some examples:

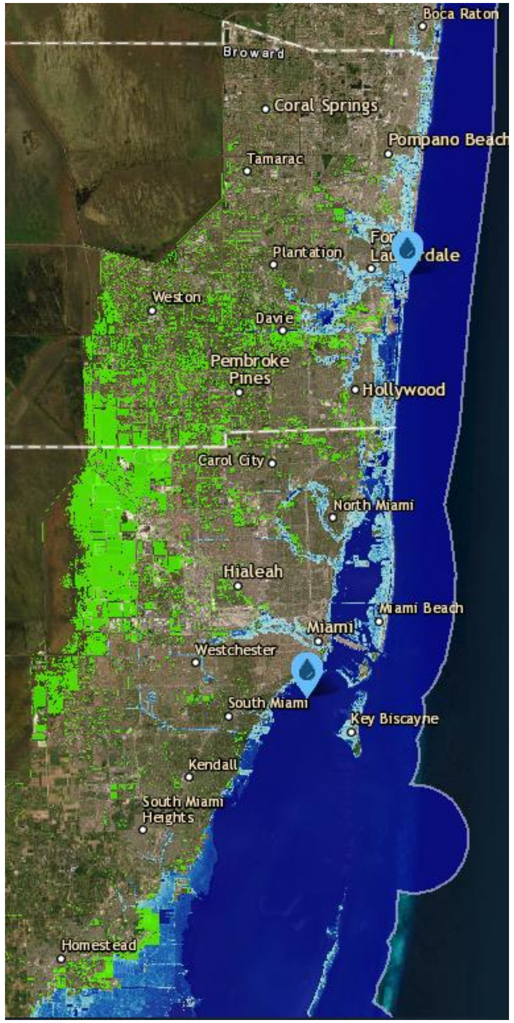
Table 18.1: Examples of First Stage Hedonic Estimation Issues

ISSUE	COMMENT	SELECTED REFERENCES
Extent of the market	▪ What is the spatial extent of the market: city, county, metropolitan area with multiple counties; a larger region? ▪ What is the length of time over which the equilibrium price function is stable?	Palmquist (1991, 2005), Taylor (2003)
Functional specification	▪ What is the functional relationship between p_i and (x_i,q_i)? Simple or flexible forms? Liberal or limited use of spatial fixed effects? Selection of structural explanatory variables.	Cropper et al. (1988), Kuminoff et al. (2010)
Unbiased estimation of $\partial P(\cdot)/\partial q$	▪ Omitted variable bias ▪ Endogenous household sorting and sample selection ▪ Use of quasi-experimental techniques	Chay and Greenstone (2005), Bockstael and McConnell (2007), Parmeter and Pope (2010)
Variable measurement	▪ Observed transactions, self-reported values, professionally assessed values for p_i? ▪ Asset (purchase) price or rental rate? ▪ Objective (e.g. monitored air quality) or subjective (e.g. residents' impression of air quality) measurements of environmental attributes?	Taylor (2003), Kiel and Zabel (1999), Palmquist (1991, 2005)
Spatial econometrics	▪ Are the disturbances spatially autocorrelated? ▪ Do prices exhibit spatial lag dependence?	Bell and Bockstael (2000) Kim et al. (2003), LaSage and Pace (2009)
Timing of impacts	▪ When can we expect changes in environmental conditions to capitalize into property values? What is the role of information dissemination?	Pope (2008a, 2008b), Gayer et al. (2000)

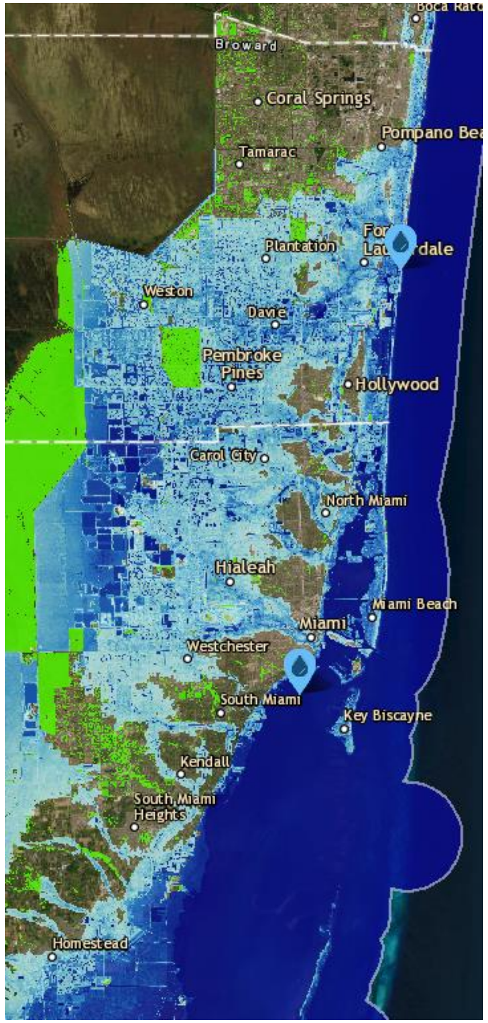
An Example: Sea Level Rise & Hedonics



Current levels



3 feet of SLR



6 feet of SLR

An Example: Sea Level Rise & Hedonics

Sea level rise is happening slowly today.

By end of century, however, optimistic projections are around 2 feet of rise along US coastlines.

Pessimistic projections: 7 feet of rise.

So while SLR should have little immediate physical impact on homebuyers today, can we detect positive homebuyer WTP for higher-lying properties along US coasts?

Do you think SLR has been capitalizing into housing prices over recent years?

An Example: Sea Level Rise & Hedonics

One can make an argument that SLR should feed into current prices:

- Future owners of the home will face costs due to flooding/evacuation/inhabitability.
- Therefore future buyers of the home may discount value of home.
- Therefore current buyers will not be able to resell home for “full” value in future
- Therefore current buyers are not willing to pay as much for home right now.

Nevertheless, the question we pose is an empirical question. Markets are not always efficient, and this is something that can be tested.

An Example: Sea Level Rise & Hedonics

Bernstein, Gustafson, and Lewis (2019, Journal of Financial Economics) estimate how expected SLR affected coastal real estate transaction prices from 2006-2017.

They link a national dataset of real estate transactions during that period with NOAA SLR modelling to assess whether a property would be underwater in global SLR scenarios ranging from 1 foot to 6 feet.

They estimate hedonic models to measure the capitalization of potential SLR:

$$\ln(p_{it}) = \beta_x x_{it} + \beta_e exposure_{it} + \lambda_{ztmeopb} + \varepsilon_{it}$$

What kind of omitted variables should the authors have been worried about?

An Example: Sea Level Rise & Hedonics

Identifying β_e, in the authors' words:

There are a number of empirical challenges to identifying the price effect of SLR exposure on coastal real estate, the *most prominent of which is that exposure probability decreases with distance to coast and properties closer to the coast differ from those that are farther away…*

The goal of our empirical design is to compare properties that transact in the same month and zip code and are observably equivalent (i.e., have the same number of bedrooms, distance to the coast line, owner occupancy status, and elevation above sea level), but vary in the amount of SLR that would cause them to be underwater.

An Example: Sea Level Rise & Hedonics

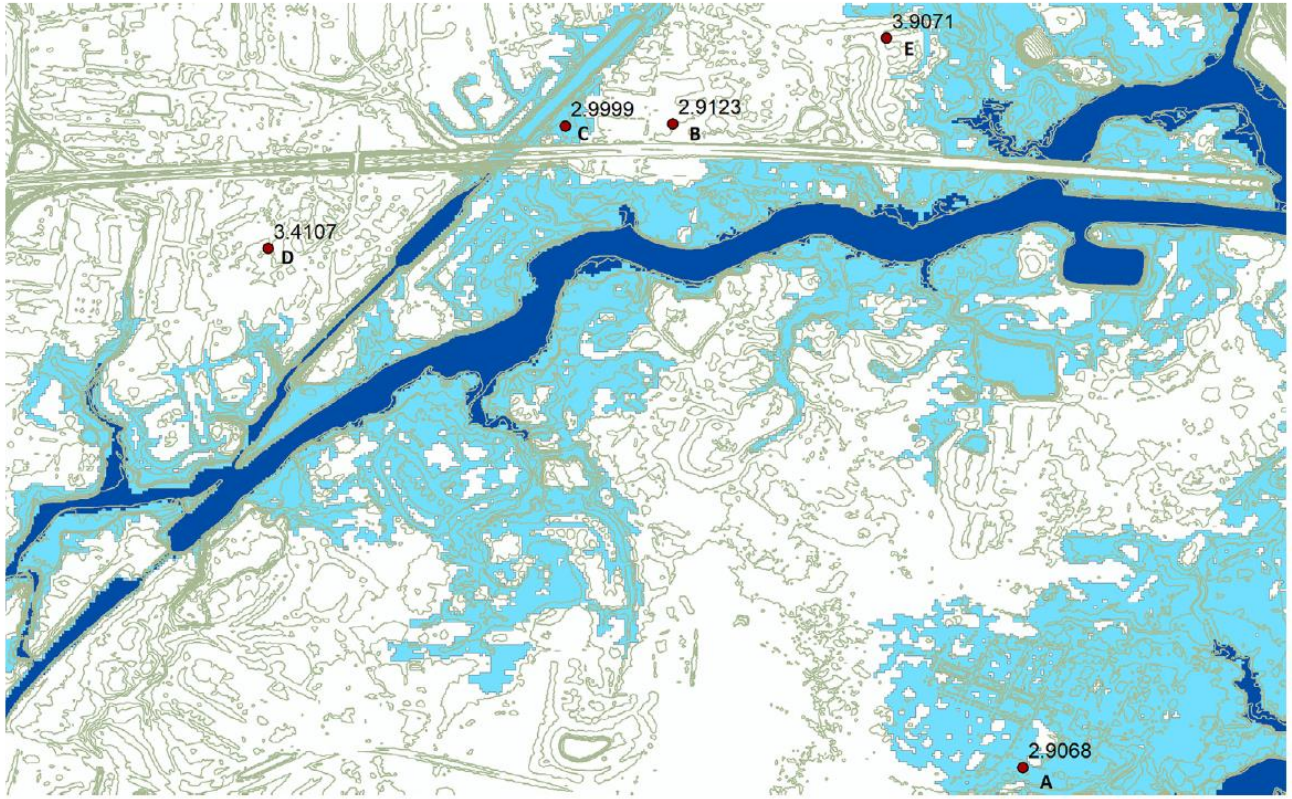


Fig. 2. Example of within-bin variation in SLR exposure. Fig. 2 displays five transactions in zip code 23323 (in Chesapeake, VA) during July of 2014, each of which involves a property that is (1) between 0.16 and 0.25 miles from the coast, (2) elevated between two and four meters above sea level, (3) four bedrooms, (4) a non-condominium, (5) owner occupied, (6) bought by a non-local buyer. Properties are labeled A–E, with elevation in meters above the property label. The olive contour lines represent 2-foot elevation contours. The dark blue area is the NOAA zero-foot SLR layer indicating the point of the highest high tide today while the light blue is the 6-foot layer indicating the highest high tide after six feet of global average sea level rise.

The fixed effects in the main regression ensure price comparisons are made only between properties

- In the same ZIP code
- In the same month/year
- In the same 2-meter elevation bin
- With the same owner occupancy/out-of-town buyer status
- In the same "distance to coast" bin (0.01,0.02,0.04,0.08,0.16,0.25 miles)
- With the same # of bedrooms
- With the same home type (SF/condo)

$$\ln(p_{it}) = \beta_x x_{it} + \beta_e exposure_{it} + \lambda_{ztmeopb} + \varepsilon_{it}$$

An Example: Sea Level Rise & Hedonics

Estimated effects:

Houses that would be under water with 1ft of SLR sell for 15% cheaper than the "comparison" house that is unexposed to SLR.

This effect tapers off for homes that are less exposed to SLR. Homes that would be underwater with 6ft of SLR sell for only 5% cheaper than an unexposed comparison.

In other results:

- Using similar empirical design, SLR has no effect on rental price.
- A dynamic estimation of SLR effect on sales price suggests the discount is growing over time as projections of SLR improve and buyers become informed.

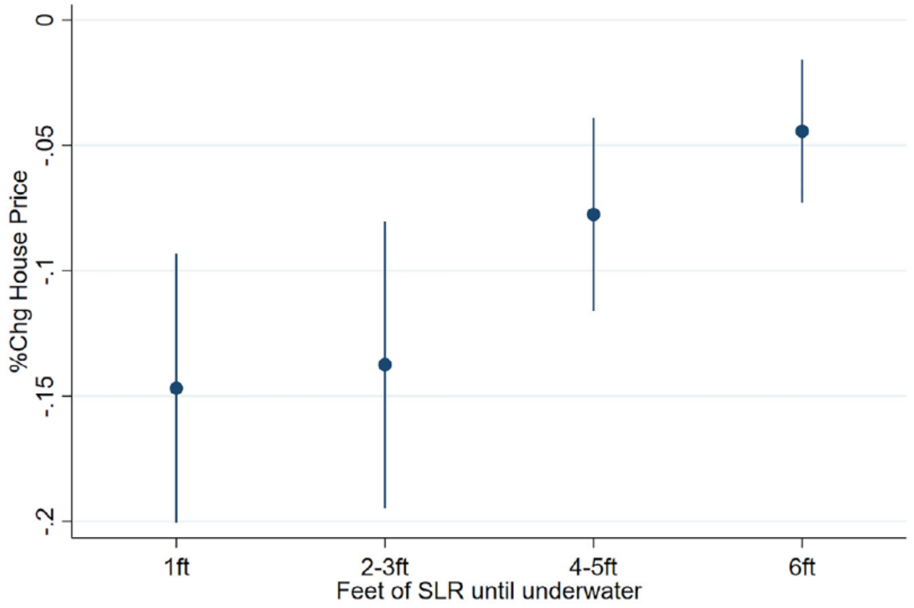


Fig. 3. SLR exposure and house price effects. Fig. 3 demonstrates the relationship between the % change in house price of exposed properties (relative to unexposed properties), partitioned by the amount of SLR required to make the property underwater. These coefficients are based on a regression of log house price per square foot on categorical dummies for feet of SLR until inundation after including zip code (Z) × time (T) × distance-to-coast bin (D) × elevation bin (E) × owner occupied property and non-local buyer (O) × condominium (P) × total bedrooms (B) fixed effects. Time is measured on a monthly basis, there are seven miles-to-coast bins, corresponding to the following miles-to-coast cutoffs: 0.01, 0.02, 0.04, 0.08, and 0.16, and elevation bins are defined in six-foot increments based on the elevation above sea level. The regression also includes fixed effects for property age and square footage percentiles. 95% confidence intervals based on standard errors that are clustered by zip code are included as bands in the figure.

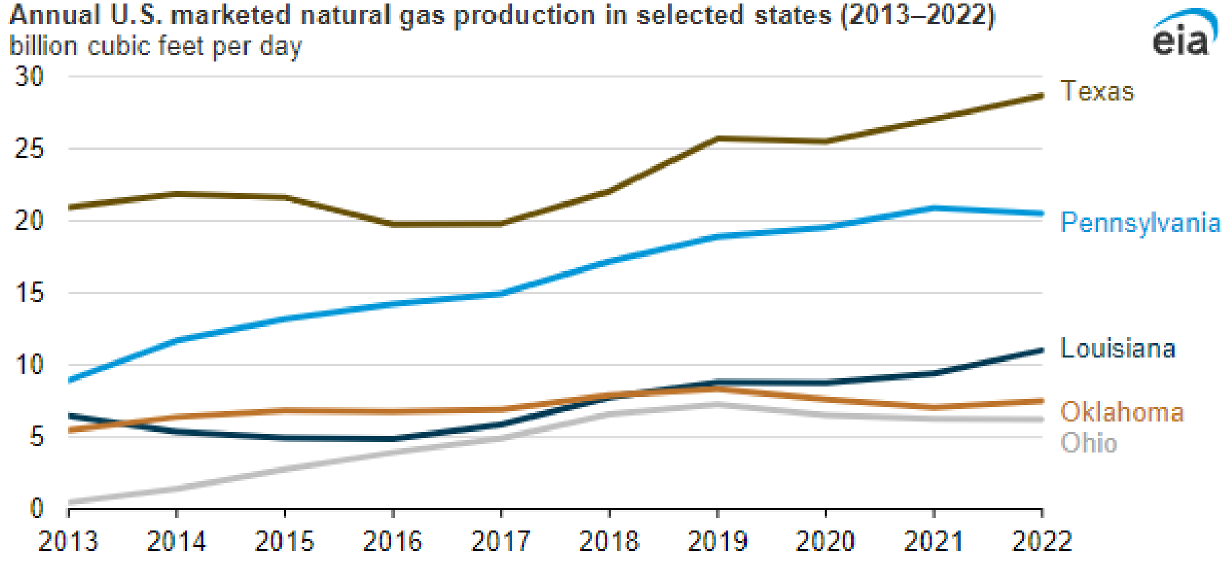
The Housing Market Impacts of Shale Gas Development
Muehlenbachs et al. (2015, AER)

Research Context:

Marcellus shale gas play in PA is the second largest natural gas producer in the US.

Boom in production began in early-mid 2000s, continues to date.

Shale gas extraction is a classic natural resource story with winners and losers:
- Locals with mining rights /employed in the energy sector benefit
- US (and world) benefit from increased production/use of natural gas – it's cleaner than coal/gasoline
- Locals (maybe?) left with external costs of production, pollution and cleanup…
    - Mixed evidence: Here. Here. Here.



Data source: U.S. Energy Information Administration, *Natural Gas Monthly*

In 2022, Pennsylvania accounted for 19% of U.S. marketed natural gas production, with more natural gas produced than in any other state except Texas. Marketed natural gas production in Pennsylvania fell slightly by 2% to average 20.5 billion cubic feet per day (Bcf/d) in 2022 after reaching an annual high of 20.9 Bcf/d in 2021, according to our *Natural Gas Monthly*. Natural gas production in Pennsylvania comes largely from the Marcellus shale gas play. In 2022, productivity declines and a plateauing of natural gas takeaway capacity resulted in the small decrease in production of 0.4 Bcf/d in Pennsylvania.

The Housing Market Impacts of Shale Gas Development
Muehlenbachs et al. (2015, AER)

Research Question: What are the property value impacts of shale gas development?

The Housing Market Impacts of Shale Gas Development
Muehlenbachs et al. (2015, AER)

Research Question: What are the **(heterogeneous)** property value impacts of shale gas development?

"Our results demonstrate that groundwater-dependent homes are, in fact, negatively affected by nearby shale gas development, indicating that the oft-debated risk to groundwater contamination has indeed materialized into a real impact. Similarly proximate homes that have access to publicly supplied piped water, on the other hand, appear to receive small benefits from that development. However, that benefit only comes from producing wells, suggesting that it reflects royalty payments to the homeowner from natural gas production. Recently drilled wells (i.e., drilled within the past year) do not contribute to this benefit, providing evidence that the drilling and hydraulic fracturing stages of shale gas development are the most disruptive. The burden of aesthetic disruptions is corroborated by the finding that the positive impacts are only driven by wells that are not in view of the property."

The Housing Market Impacts of Shale Gas Development
Muehlenbachs et al. (2015, AER)

Data:

1. Property transaction data for 36 Pennsylvania counties between 1995 and 2012.
2. Location and drill date for 6,260 wellbores
3. GIS boundaries of public water service areas

With 1 + 2: for each property transaction, calculate counts of the number wellpads drilled, within distance of {1,1.5,2km} by the date of the sale.

With 1 + 3: for each property transaction, create indicator variable for whether drinking water in home is from PWSA or a groundwater well.

The Housing Market Impacts of Shale Gas Development
Muehlenbachs et al. (2015, AER)

Research Design

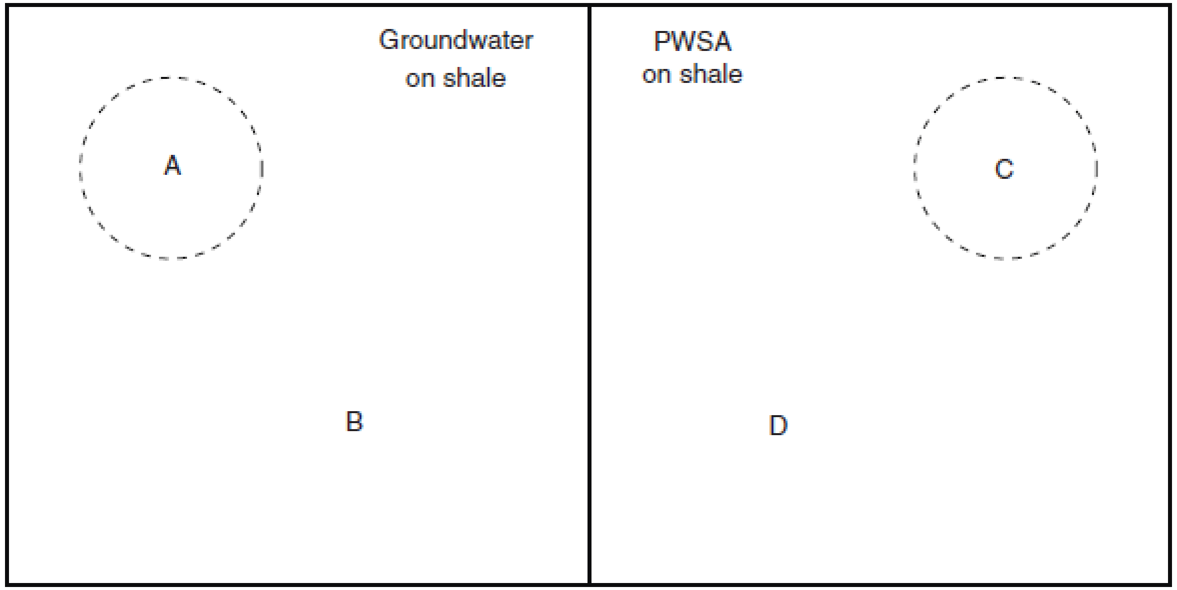


Figure 1. Types of Areas Examined

The Housing Market Impacts of Shale Gas Development
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Research Design

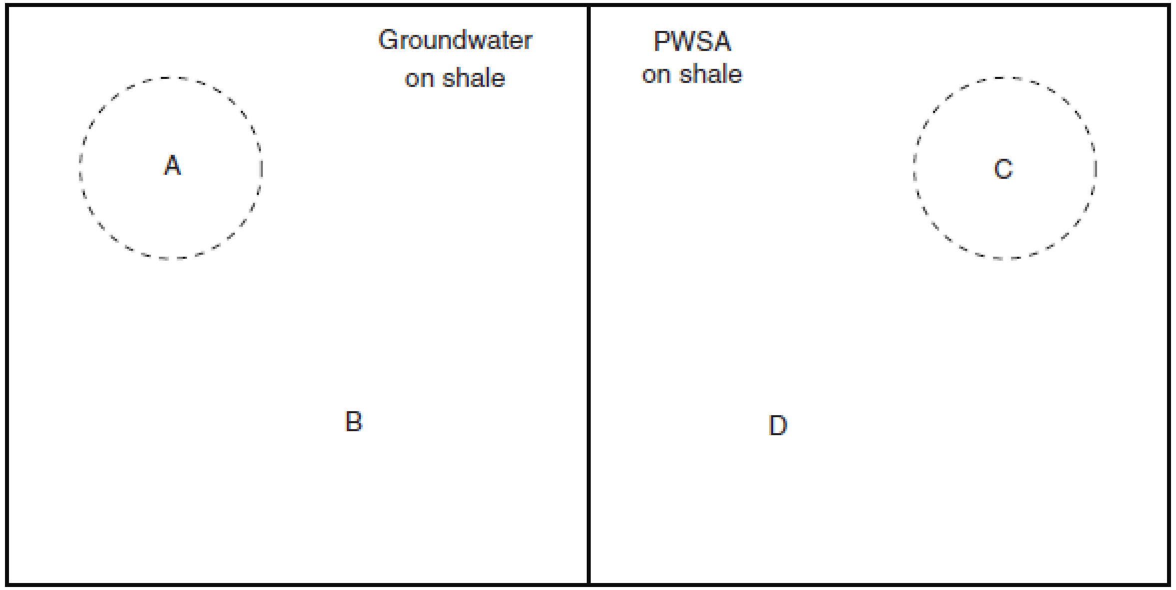

FIGURE 1. TYPES OF AREAS EXAMINED

Considering the impact categories described in Section IA and in Figure 1, we begin by defining the components of the change in a *particular* property's value over time (ΔP) in each area:

$$
\begin{aligned}
\Delta P_A &= \Delta Adjacency + \Delta GWCR + \Delta Vicinity_{GW} + \Delta Macro \\
\Delta P_B &= \Delta Vicinity_{GW} + \Delta Macro \\
\Delta P_C &= \Delta Adjacency + \Delta Vicinity_{PWSA} + \Delta Macro \\
\Delta P_D &= \Delta Vicinity_{PWSA} + \Delta Macro,
\end{aligned} \tag{1}
$$

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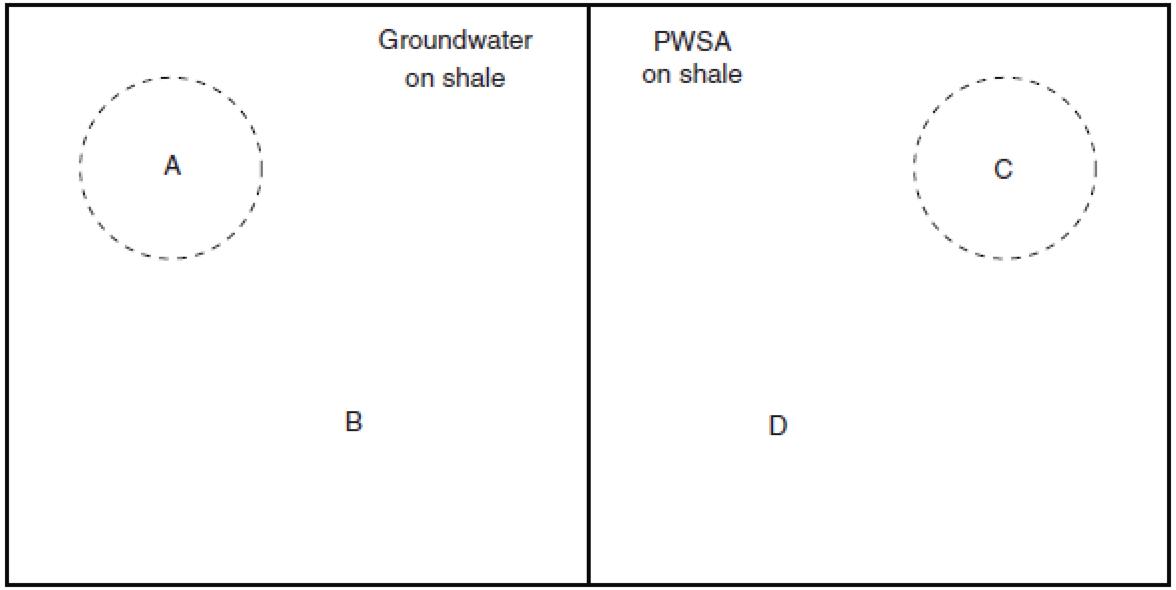

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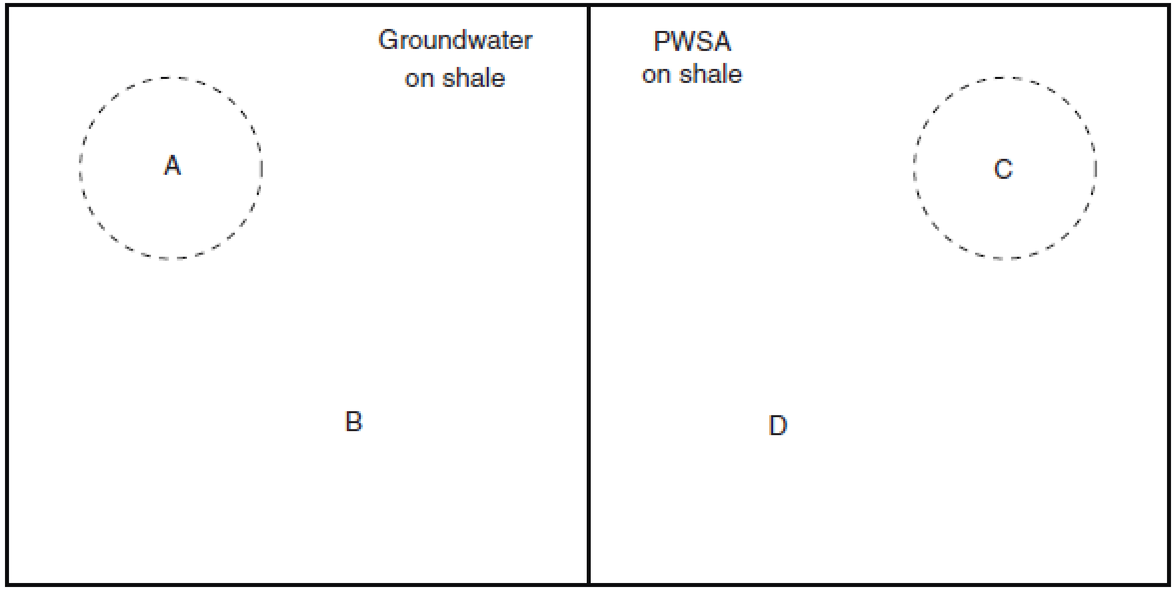
\Delta P_D &= \Delta Vicinity_{PWSA} + \Delta Macro,
\end{aligned} \tag{1}$$

$$\begin{aligned}
\ln P_{it} = {} & \alpha_0 + \alpha_1(\text{Pads in 20 km})_{it} + \alpha_2 GW_i(\text{Pads in 20 km})_{it} \\
& + \alpha_3(\text{Pads in 2 km})_{it} + \alpha_4 GW_i(\text{Pads in 2 km})_{it} + \mu_i + \nu_{it} + q_t + \epsilon_{it}.
\end{aligned} \tag{4}$$

The Housing Market Impacts of Shale Gas Development
Muehlenbachs et al. (2015, AER)

Research Design



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$$(4)\quad \ln P_{it} = \alpha_0 + \alpha_1(\text{Pads in 20 km})_{it} + \alpha_2 GW_i(\text{Pads in 20 km})_{it} + \alpha_3(\text{Pads in 2 km})_{it} + \alpha_4 GW_i(\text{Pads in 2 km})_{it} + \mu_i + \nu_{it} + q_t + \epsilon_{it}.$$

Referring back to Figure 1, the coefficients correspond to the areas A, B, C, and D in the following way:

$$\begin{aligned} \Delta P_A &= \alpha_1 + \alpha_2 + \alpha_3 + \alpha_4 \\ \Delta P_B &= \alpha_1 + \alpha_2 \\ \Delta P_C &= \alpha_1 + \alpha_3 \\ \Delta P_D &= \alpha_1. \end{aligned}$$

This implies the following:

$$\begin{aligned} \Delta P_A - \Delta P_C &= \alpha_2 + \alpha_4 \\ \Delta P_B - \Delta P_D &= \alpha_2 \\ (\Delta P_A - \Delta P_C) - (\Delta P_B - \Delta P_D) &= \alpha_4. \end{aligned}$$

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Research Design

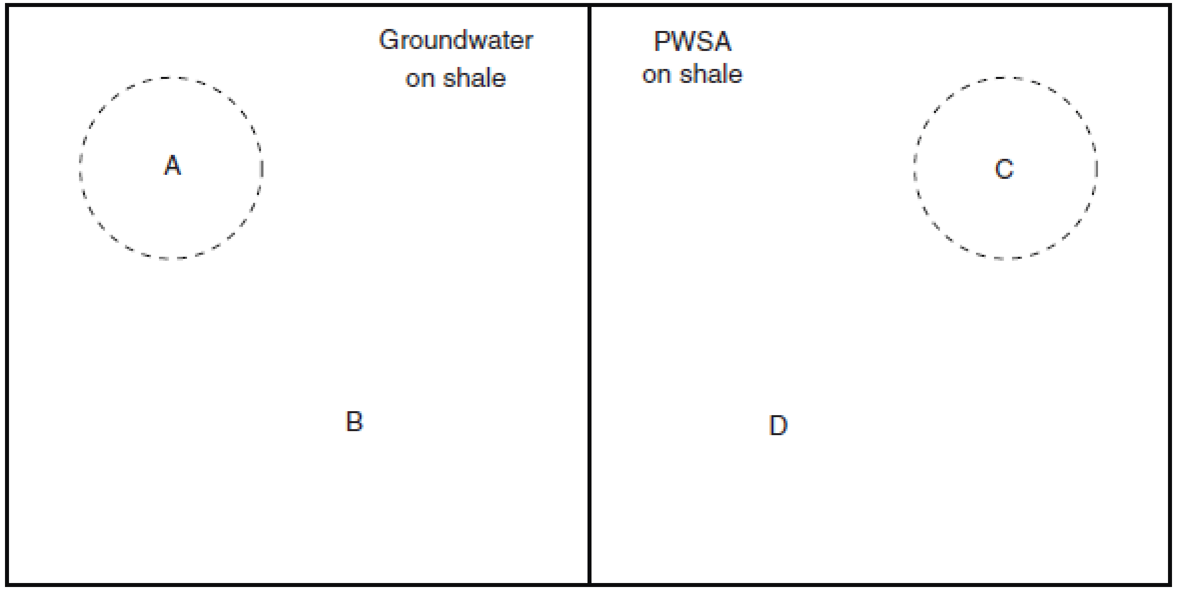

Figure 1. Types of Areas Examined

Omitted variable bias?

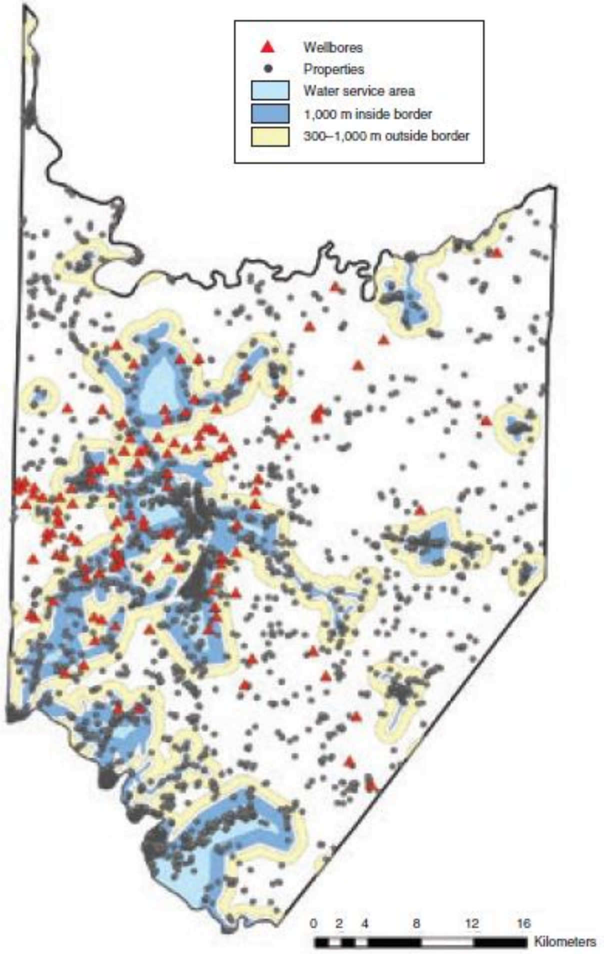

Figure 6. Example Indicating the 1,000 m Boundary Inside and 300–1,000 m Boundary Outside of Public Water Service Areas in Armstrong County, Pennsylvania

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Research Design

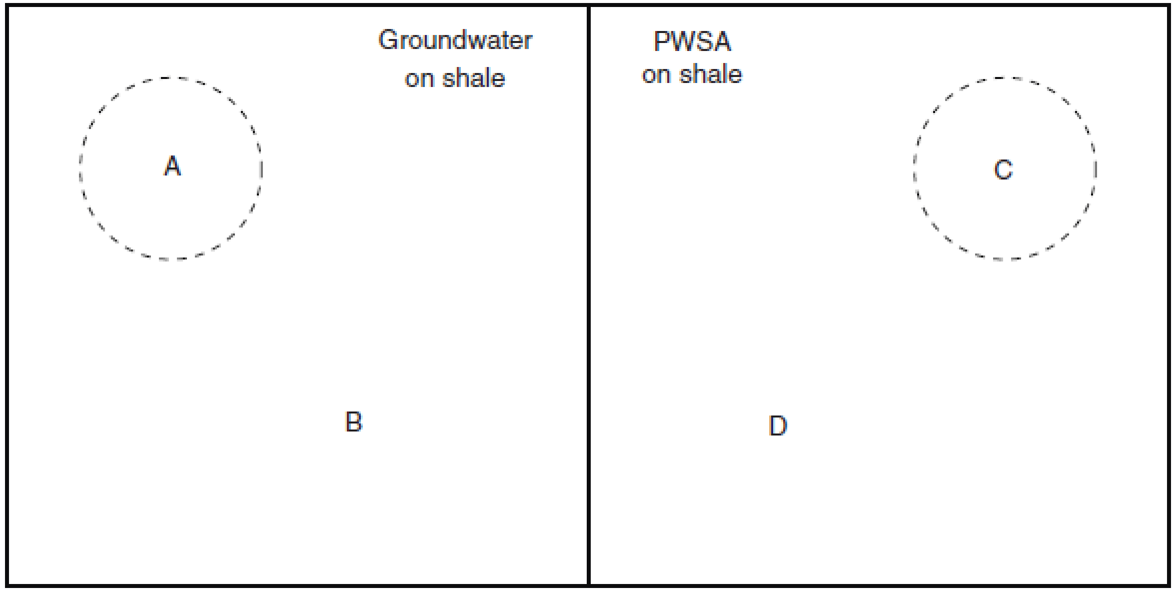

FIGURE 1. TYPES OF AREAS EXAMINED

“Rural groundwater-dependent neighborhoods may be different in unobservable but important ways when compared with more urban PWSA neighborhoods, and these differences might vary over time.”

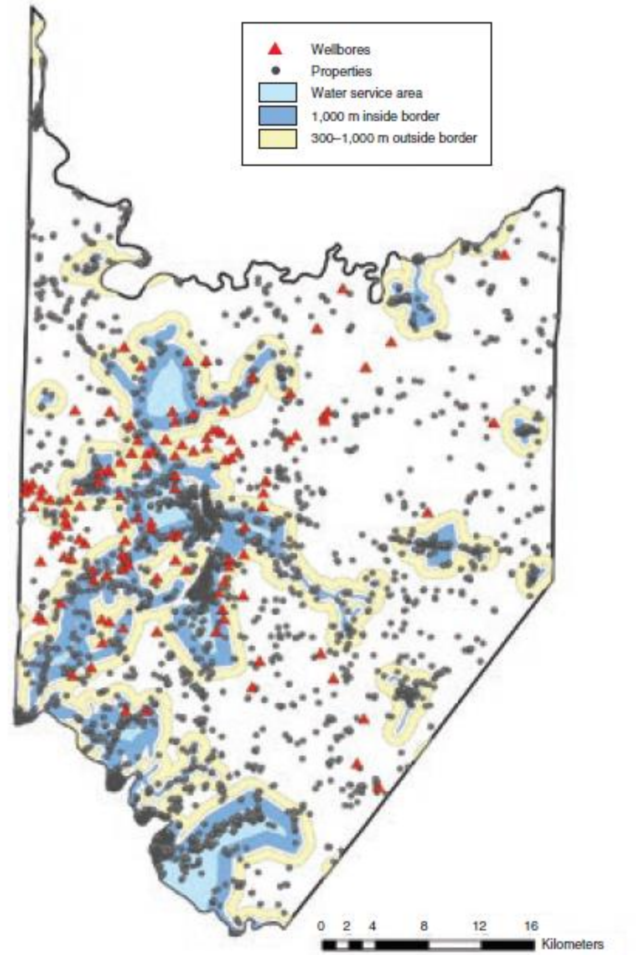

FIGURE 6. EXAMPLE INDICATING THE 1,000 M BOUNDARY INSIDE AND 300–1,000 M BOUNDARY OUTSIDE OF PUBLIC WATER SERVICE AREAS IN ARMSTRONG COUNTY, PENNSYLVANIA

The Housing Market Impacts of Shale Gas Development
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$$(4)\quad \ln P_{it} = \alpha_0 + \alpha_1(\text{Pads in 20 km})_{it} + \alpha_2 GW_i(\text{Pads in 20 km})_{it} + \alpha_3(\text{Pads in 2 km})_{it} + \alpha_4 GW_i(\text{Pads in 2 km})_{it} + \mu_i + \nu_{it} + q_t + \epsilon_{it}.$$

Table 2—Log Sale Price on Well Pads

	$K \leq 1$ km		$K \leq 1.5$ km		$K \leq 2$ km	
	Full (1)	Boundary (2)	Full (3)	Boundary (4)	Full (5)	Boundary (6)
Panel A. County-year fixed effects						
Pads in K km	0.028	0.026	0.029**	0.034*	0.016**	0.018*
	(0.025)	(0.035)	(0.014)	(0.02)	(6.9e-03)	(0.01)
(Pads in K km) × GW	–0.062	–0.165**	–0.042*	–0.099***	–0.023	–0.013
	(0.046)	(0.072)	(0.025)	(0.036)	(0.02)	(0.052)
Pads in 20 km	–7.8e-04***	–8.1e-04	–8.3e-04***	–9.3e-04*	–8.4e-04***	–9.4e-04*
	(3.0e-04)	(5.3e-04)	(3.0e-04)	(5.5e-04)	(3.0e-04)	(5.6e-04)
(Pads in 20 km) × GW	6.6e-04	2.0e-03***	7.0e-04	2.0e-03***	7.1e-04	1.7e-03**
	(4.7e-04)	(7.0e-04)	(4.9e-04)	(6.8e-04)	(5.2e-04)	(6.8e-04)
Property effects	Yes	Yes	Yes	Yes	Yes	Yes
County-year effects	Yes	Yes	Yes	Yes	Yes	Yes
Quarter effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	229,946	66,327	229,946	66,327	229,946	66,327
p-value ($\alpha_3 + \alpha_4 = 0$)	0.414	0.051	0.544	0.090	0.740	0.919
Avg. pads in K km	0.003	0.006	0.009	0.015	0.018	0.031
Avg. pads in 20 km	4.725	5.108	4.725	5.108	4.725	5.108

The Housing Market Impacts of Shale Gas Development
Muehlenbachs et al. (2015, AER)

In summary:

The costs of shale gas groundwater contamination risk, as proxied by the drilling and operation of an additional wellpad, range from -9.9% to -16.5% of a home's value.

Netting out adjacency impacts (from royalties, etc.), average loss to groundwater-dependent homes within 1.5km of a well was ~$30,000.

Average gain in value for homes with PWS and within 1.5km of a well was ~$5,000.

These estimates are a lower bound – do not account for **defensive behaviors*** like installation costs of water filters, or using bottled water.

Other points to discuss?

What are the limits and challenges associated with hedonic approaches to measuring nonmarket value?

1. **Hedonic model assumes consumers can select from *continuum* of (*x, q*) values. Realistic?**

   My description of ideal DC home, price be damned, to RE agent: “On Capitol Hill in a smaller rowhouse, quiet street, with a BIG and private yard.” (His response: “LOL. That doesn’t exist.”)

   Economists have tools to try and work around this. Take grad level metrics.

2. **Household’s implied prices, as measured econometrically, are based on real-world amenity levels.**

   In reality, buyer’s beliefs are heterogeneous and based on perception/available information. Beliefs may be correlated with reality, or not; based on current amenity levels, or past/future levels. Hedonic analysis **can** accommodate for distortion between belief/reality, with clever econometrics.

3. **Households are mobile and can choose the level of a public good (*q*) as they desire.**

   Increasing body of work suggesting frictions in mobility. These frictions are often correlated with local amenity levels…

The Damages and Distortions from Discrimination in the Rental Housing Market
Christensen and Timmins (forthcoming, QJE)

By constraining an individual's choice during a search, housing discrimination distorts sorting decisions away from true preferences and results in a ceteris paribus reduction in welfare. This study combines a large-scale field experiment with a residential sorting model to derive utility-theoretic measures of renter welfare loss associated with the constraints imposed by discrimination in the rental housing market. Results from experiments conducted in five cities show that key neighborhood amenities are associated with higher levels of discrimination. Counterfactual simulations based on the sorting model suggest that discrimination imposes damages equivalent to 4.4% and 3.5% of the annual incomes for African American and Hispanic/ LatinX renters, respectively. Damages are increasing in income for African American renters, such that impacts become stronger for economically mobile households. Renters of color must make substantial investments in additional search to mitigate the costs of these constraints. We find that a naive model ignoring discrimination constraints yields biased estimates of willingness to pay for key neighborhood amenities.

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Next class

- Using Expenditures and Wages to Estimate Environmental Benefits:
  - Defensive behaviors + the VSL.
  - Wrenn et al (2016) is assigned reading.
  - Optional: Shogren and Stamland (2005).

- Reminder, Case Study #1 due Sep 17 @ 11:59pm.

Appendix: Solving seller's choice problem

For completeness... the seller's profit max problem:

$$\max_{x,q} \Pi(x, q; t) = P(x, q) - C(x, q; t)$$

- *P(·)* is still equilibrium price function. A particular house, *k*, has price $P(x_k, q_k)$
- *C(·)* is a "housing production" cost function. Could be cost of new build, remodelling, etc.
  - *C(·)* typically increasing in *x*.
  - If *q* is "open space", *C(·)* is likely increasing in *q* also.
  - *t* is a firm "technology" parameter that allows for heterogeneity in firm costs.

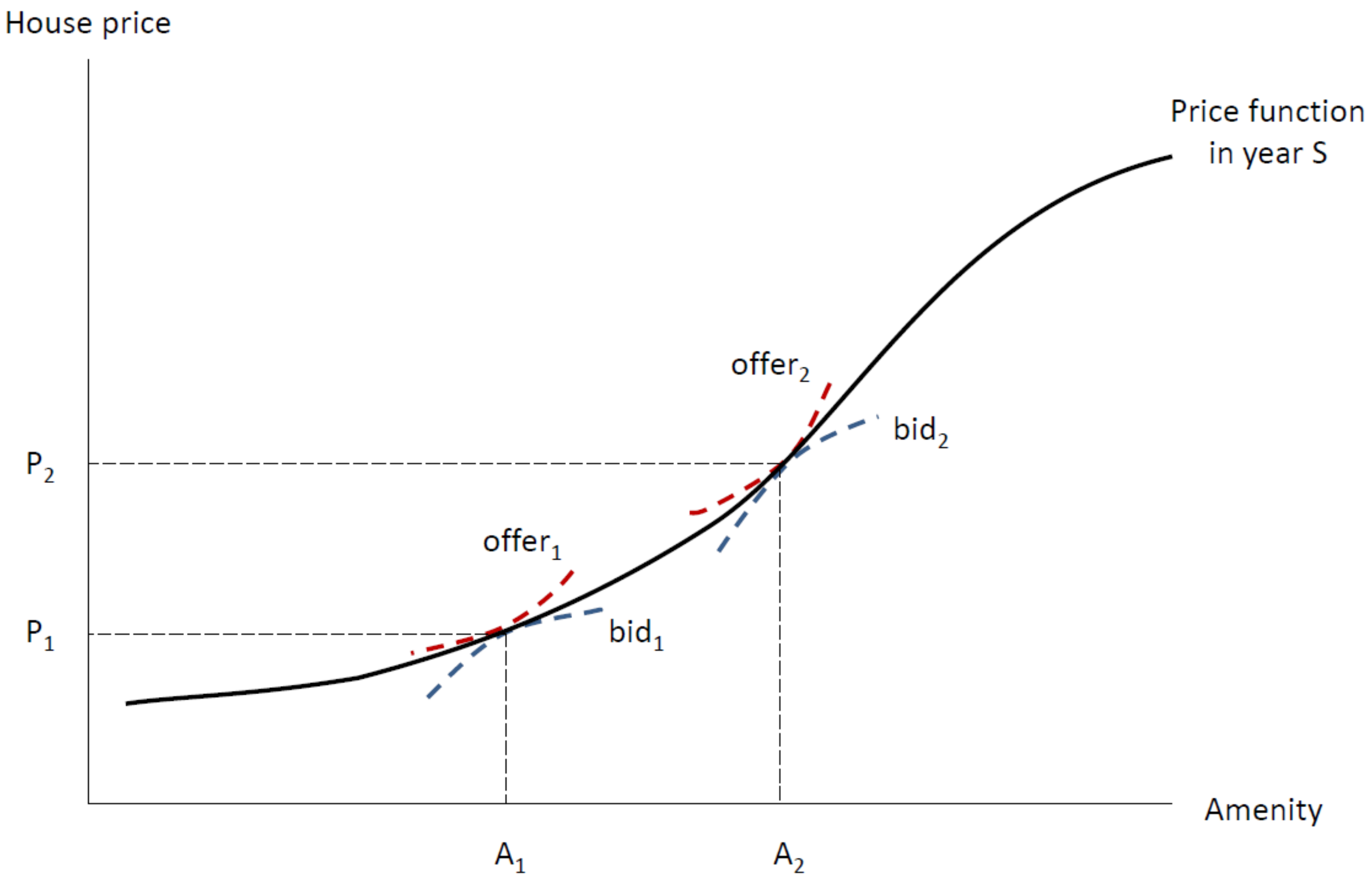
Firm FOCs imply:

$$[x_j] \qquad \frac{\partial P}{\partial x_j} = \frac{\partial C}{\partial x_j}, j = 1, \ldots, J$$

$$\boxed{[q] \qquad \boxed{\frac{\partial P}{\partial q}} = \frac{\partial C}{\partial q}}$$

So firms optimize by picking *q* such that **marginal costs are equal to the implicit price.**

Appendix: Tracing out the price curve



Sellers and buyers meet in the market. Buyers have bid curves; sellers have offer curves. These are essentially indifference curves (holding all but *q* and $ fixed).

Where bid curves and offer curves are tangent, an exchange happens. The curve tracing out all these exchanges/tangencies is the **price curve**.

We observe this curve using transaction prices!