Lecture 11

Hedonics

Ivan Rudik
AEM 4510

Roadmap

- What can we use to infer the demand for environmental goods?
- What do housing prices tell us?
- When do changes in house prices give us welfare measures

Hedonic valuation

Revealed preference approaches

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Is there a way we can reveal the value of these goods?

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If there are changes in the environmental good, holding everything else fixed, that should be reflected in *some way* in changes in the price of the related private good

This change in price can tell us something about how people value the change in the environmental good

Revealed preference approaches: example

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What does this price change mean?

Hedonics: Property value models

Common market goods to use for revealed preference valuation are **properties**

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- Rooms
- Bathrooms
- School quality
- Environmental quality

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Homes located in pristine areas are likely to be more valuable than identical homes located near toxic facilities

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Real estate is virtually ideal for measuring environmental changes

Real estate markets are often competitive and thick

Property purchases are large and consequential: buyers and sellers are likely to be well-informed

It is uncontroversial that property values should reflect local attributes

e.g. homes in better school districts are typically more expensive

BCA of Superfund

Superfund

The Love Canal Disaster: Toxic Was...
Watch later
Share
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By 2005: $35 billion in federal funding has been spent at roughly 800 sites

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How do we do it?

Superfund

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Take two otherwise very similar houses: one in a neighborhood surrounding a site that has been cleaned up and one in a neighborhood surrounding a site that has not

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How do their prices differ?

The hedonic method

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Ridker and Henning (1967) first applied method to environmental valuation in a study of the effect of air pollution on property values in St. Louis

It motivated the conceptual model of Rosen (1974) of how we might use hedonic prices to estimate peoples' values for site-specific amenities

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Environmental quality (air quality, noise, etc)

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This good is characterized by a set of J property characteristics x

- parcel size, school quality, bedrooms, etc

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This good is characterized by a set of J property characteristics x

- parcel size, school quality, bedrooms, etc

It is also characterized by an environmental good q

The hedonic model

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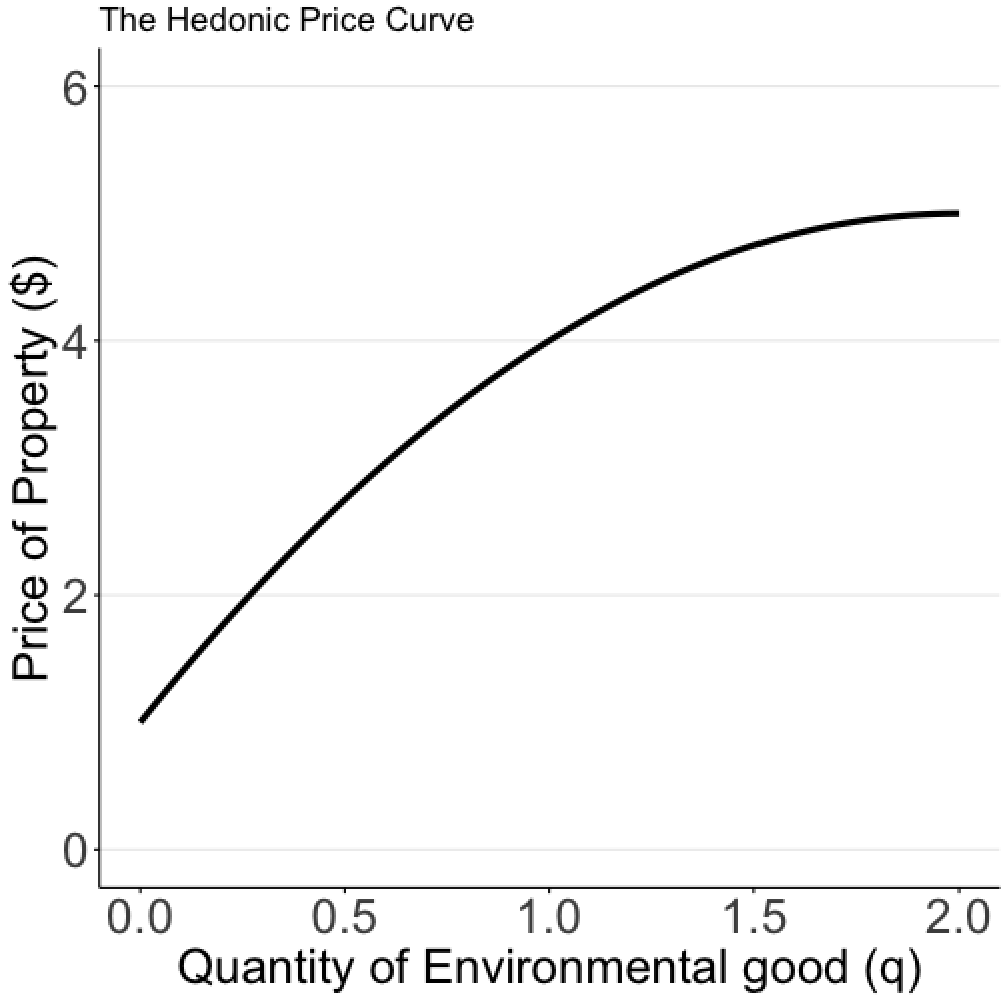
P arises in equilibrium from the interaction of all buyers in sellers in the market

Here we will assume the supply of houses is fixed in the short run so the price curve arises from buyer behavior

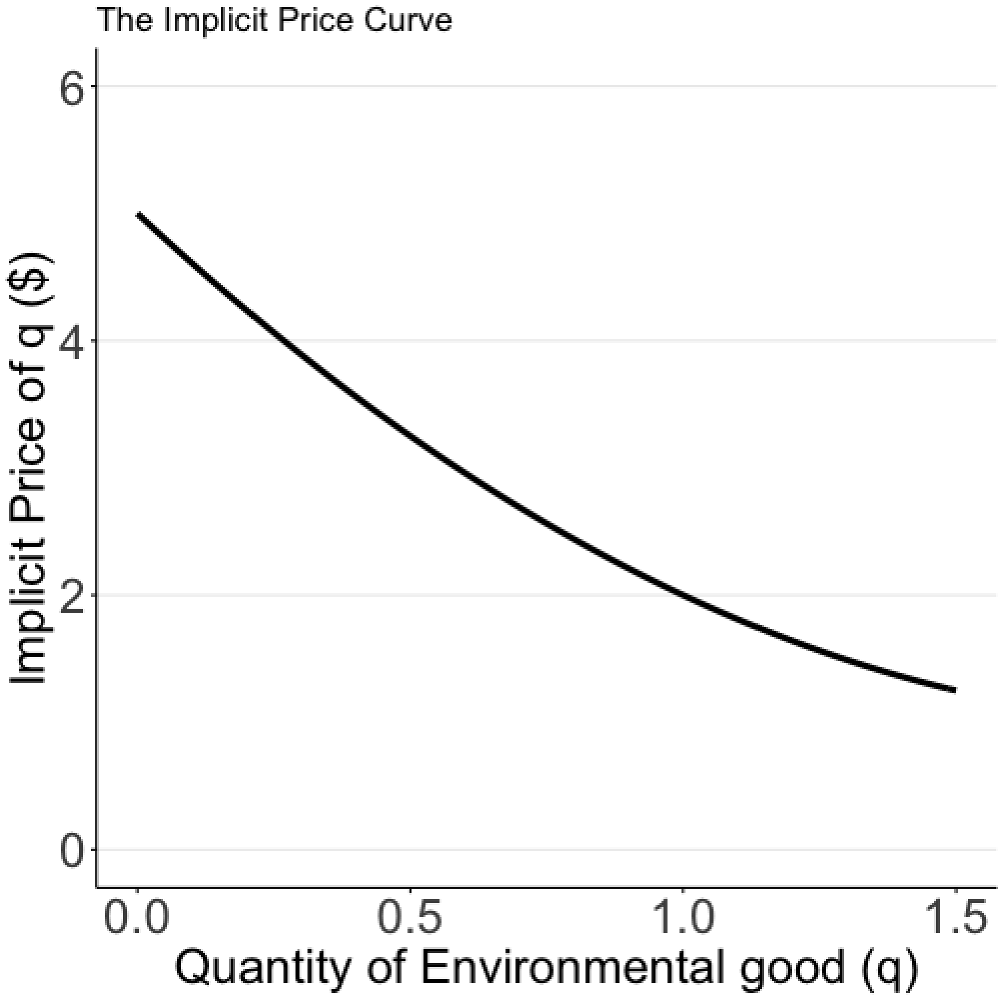
The hedonic model: the price curve



The hedonic price curve is $P(x, q)$

It's increasing in q (q is good) but at a decreasing rate (decreasing marginal utility)

The hedonic model: the price curve



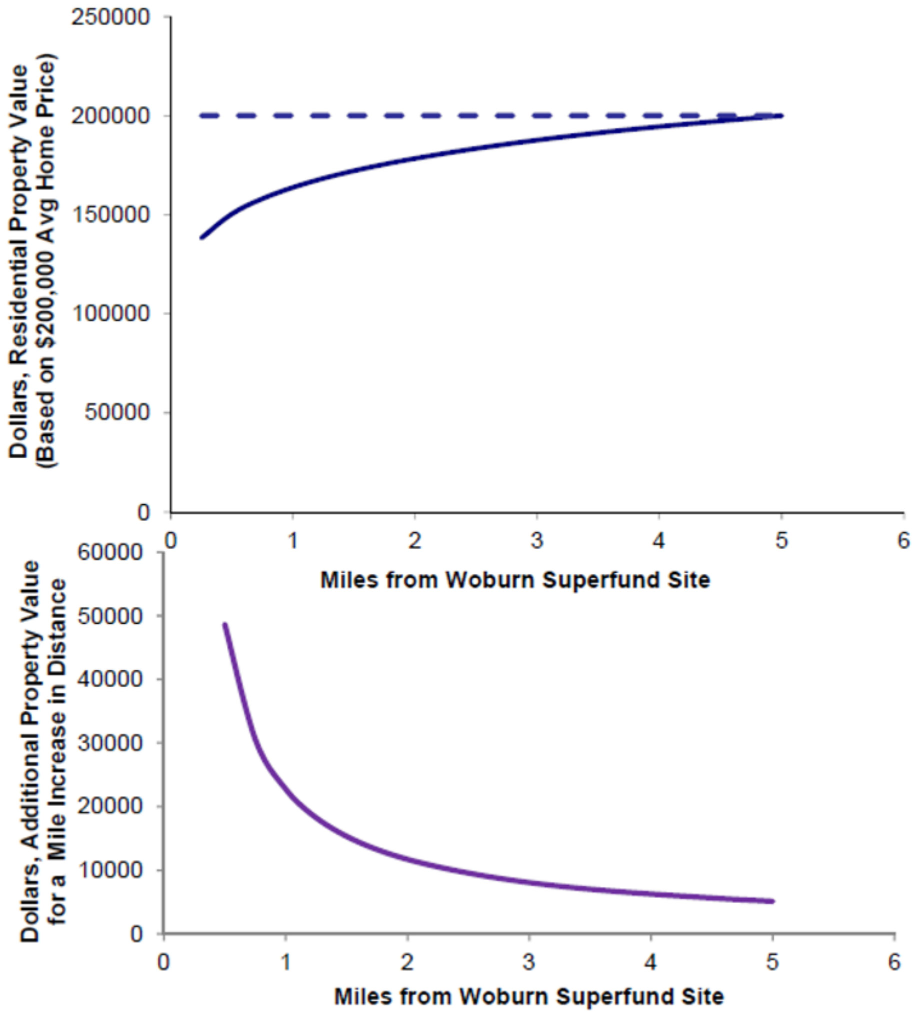
The implicit price curve for q is $\frac{\partial P(x,q)}{\partial q}$

It tells us how the price changes in q

It's positive, but downward sloping

Effectively the q demand curve

Price curve example



Total Value

“Marginal” Value
(one mile increment)

Source: Messer et al. *Env. and Res. Econ.* 2006

The hedonic model: consumer's choice problem

Households buy a single property given their budget constraint and their preferences

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Here we will assume that households are effectively just choosing (x, q) instead of a specific house with the following objective:

$$\max_{x,q,z} U(x, q, z; s) \quad s.t. \quad y = z + P(x, q)$$

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$$\max_{x,q,z} U(x, q, z; s) \quad s.t. \quad y = z + P(x, q)$$

- z is the numeraire good (spending on other private goods)
- y is income
- s is the set of the household's characteristics like family size

Unrealistic pieces of the model

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Many housing characteristics are discrete (bedrooms, bathrooms, etc)

Another is that you just can't purchase some sets of x (i.e. a huge lot in downtown manhattan with a farm)

We won't touch on this in class because it's a bit more complicated, but economists know how to deal with these problems

Choosing q

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We are thus also implicitly assuming q varies across space so that households can sort into areas they prefer

- q is really picking up local environmental goods

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For homeowners we are basically assuming they rent from themselves every year

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The FOCs for this problem are:

$$\begin{aligned}
\frac{\partial U}{\partial x_j} &= \lambda \frac{\partial P}{\partial x_j} \quad j = 1, \ldots, J \\
\frac{\partial U}{\partial q} &= \lambda \frac{\partial P}{\partial q} \\
\frac{\partial U}{\partial z} &= \lambda
\end{aligned}$$

Where λ is the Lagrange multiplier

Next, combine the last two FOCs

The hedonic model: consumer's choice problem

$$\begin{aligned}\frac{\partial U}{\partial q} &= \lambda \frac{\partial P}{\partial q} \\ \frac{\partial U}{\partial z} &= \lambda\end{aligned}$$

gives us that

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

The hedonic model: consumer's choice problem

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What does this mean?

The hedonic model: consumer's choice problem

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®emember the MRS tells us how the household trades off q and z while keeping utility constant

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

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This means that $\frac{\partial U}{\partial q} / \frac{\partial U}{\partial z}$ is the WTP for q, the reduction in income needed to compensate for an additional unit of q, while maintaining the same level of utility

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Knowledge of the hedonic price curve P is enough to tell us about household WTP for q!

The hedonic model: bid functions

Now let's dive deeper by looking at some reference utility level $\bar{u}$:

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Next we will define something called a **bid function** $b(x, q, y, s, \bar{u})$ where:

$$U(x, q, y - b(x, q, y, s, \bar{u}); s) = \bar{u}$$

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$$U(x, q, y - b(x, q, y, s, \bar{u}); s) = \bar{u}$$

The bid function b is the maximum amount the household is willing to pay for:

- A house with characteristics x, q
- Given income y and household characteristics s
- And achieving utility $\bar{u}$

The hedonic model: deriving MWTP

$$U(x, q, y - b(x, q, y, s, \bar{u}); s) = \bar{u}$$

Differentiate with respect to q to get:

$$\frac{\partial U}{\partial q} + \frac{\partial U}{\partial z}\frac{\partial b}{\partial q} = 0$$

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We can then rearrange to get:

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The maximum WTP is given by the implicit price curve

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We can then use the bid function (which maps into prices) to understand the marginal WTP for q

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It's called a **Hicksian** demand curve, whereas our regular demand curves are **Marshallian**

The hedonic model: deriving MWTP

The difference is that with **Marshallian** demand curves, we are holding **income** constant on the curve, income changes are demand shifters, utility changes as you move along the curve

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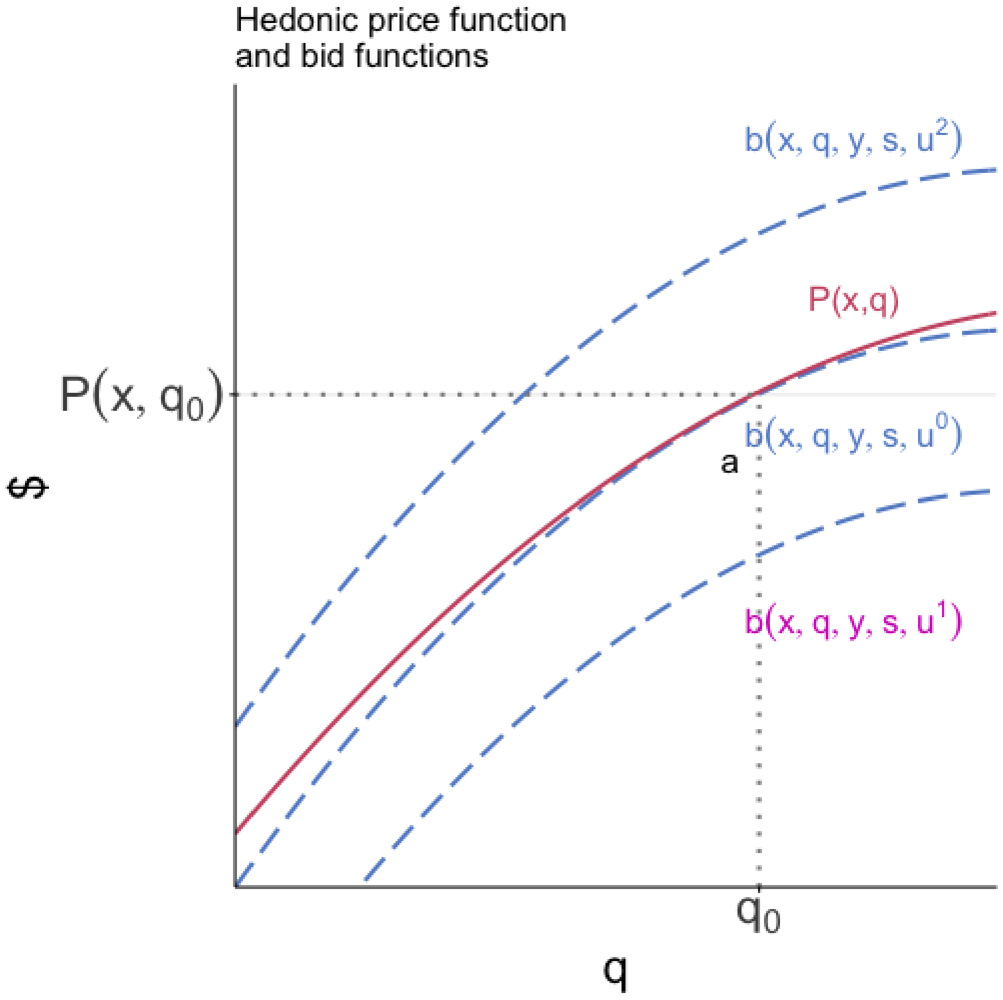
The difference is that with **Marshallian** demand curves, we are holding **income** constant on the curve, income changes are demand shifters, utility changes as you move along the curve

With **Hicksian** demand curves, we are holding **utility** constant, income can change along the curve, utility changes are demand shifters

Bid functions and housing prices

The red line is the hedonic price function

The blue lines are a single household's bid functions at different reference utility levels

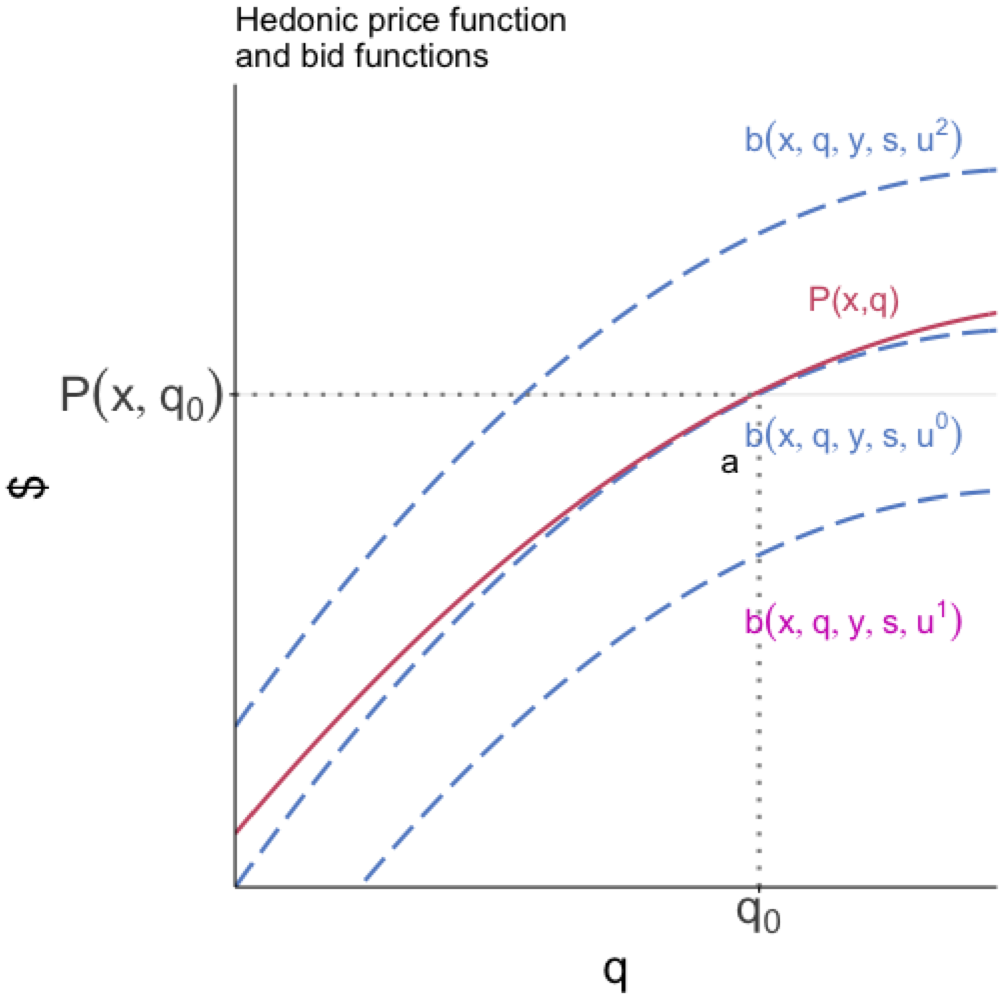


Bid functions and housing prices

Optimal choice is where the household's bid function is tangent to the hedonic price schedule: a

This gives us an observed consumption level q_0, observed price $P(x, q_0)$, and realized utility u^0

Different households will have different tangency points, different q and $P(x, q)$



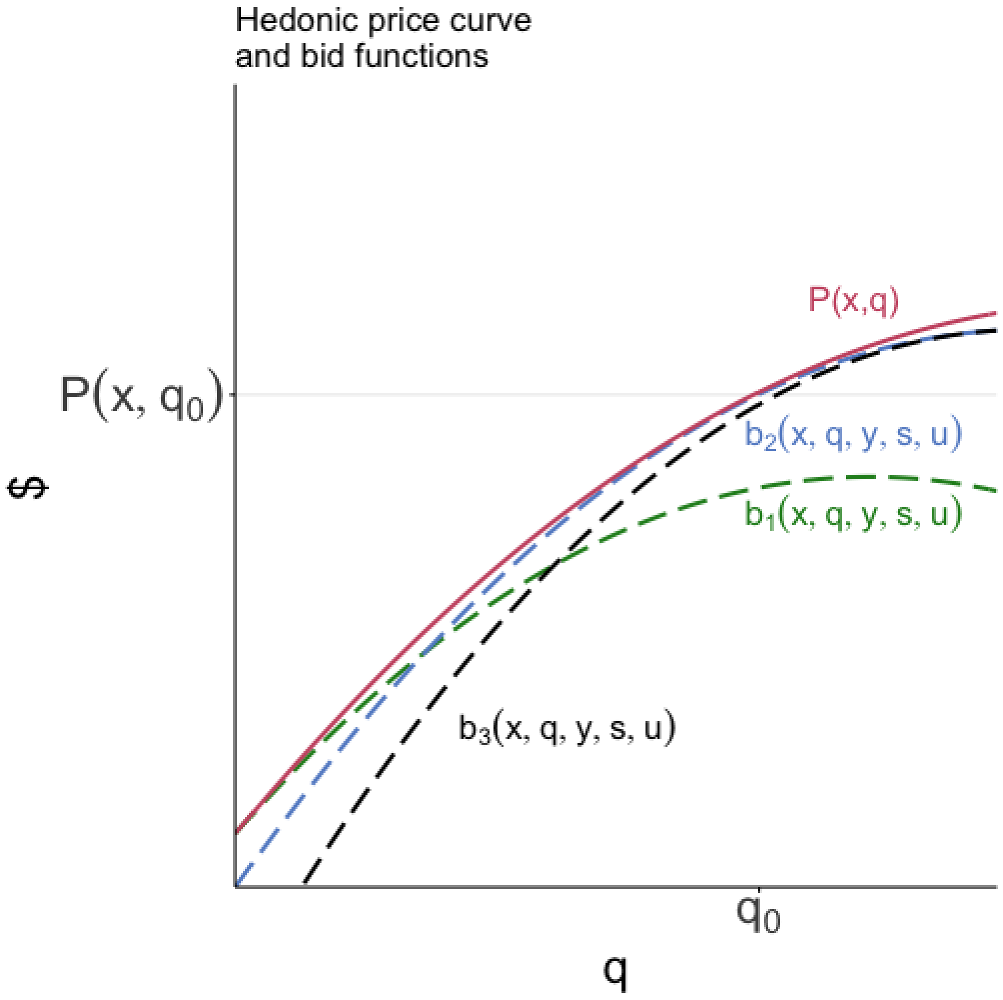
Bid functions and housing prices

The hedonic price function is the upper envelope of all the bid functions

i.e. all the bid functions are tangent to it

The other piece of the story is we need the landlord problem

It's almost identical to the buyer, but replace utility with profit



Hedonic price curve and willingness to pay

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Their bid curve is only tangent at that one point, we don't see their whole bid curve, people don't buy 1,000 houses to trace out the whole curve

Estimating the effect of ozone

Let's work through an example where we estimate the effect of ozone

You have a dataframe `house_data` available on RStudio Cloud:

```
house_data
```

```
## # A tibble: 757 x 7
##    house_num ozone num_bedrooms num_bathrooms sq_feet log_price   price
##        <int> <dbl>        <int>         <dbl>   <dbl>     <dbl>   <dbl>
##  1         1 19.2             4           3      577.      12.7 325955.
##  2         2  8.98            4           3     1111.      12.7 327415.
##  3         3 31.3             4           1      820.      11.9 147572.
##  4         6 20.4             3           2      886.      12.6 309274.
##  5         8 61.6             4           3     4909.      12.7 342533.
##  6         9 29.4             2           1.5    798.      11.9 141526.
##  7        10  7.60            4           1.5    946.      12.5 272931.
##  8        11 11.2             4           1     1912.      12.2 200438.
##  9        12 17.2             3           1.5    720.      12.3 216520.
```

Estimating the effect of ozone

We want to understand the effect of ozone on housing prices: how much does a unit increase in ozone cost?

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Let's take a look at the summary statistics of our dataset first:

```
summary(house_data)
```

```
##    house_num          ozone           num_bedrooms  num_bathrooms     sq_feet           log_price
##   Min.   :   1.0   Min.   :  1.648   Min.   :1.00   Min.   :1.000   Min.   :  501.4   Min.   :10.02
##   1st Qu.: 245.0   1st Qu.: 15.906   1st Qu.:1.00   1st Qu.:1.500   1st Qu.:  892.3   1st Qu.:11.98
##   Median : 491.0   Median : 30.736   Median :2.00   Median :2.000   Median : 1395.0   Median :12.39
##   Mean   : 494.4   Mean   : 46.388   Mean   :2.49   Mean   :1.977   Mean   : 2055.0   Mean   :12.39
##   3rd Qu.: 745.0   3rd Qu.: 57.255   3rd Qu.:4.00   3rd Qu.:2.500   3rd Qu.: 2415.5   3rd Qu.:12.82
##   Max.   :1000.0   Max.   :385.748   Max.   :4.00   Max.   :3.000   Max.   :21001.0   Max.   :14.48
```

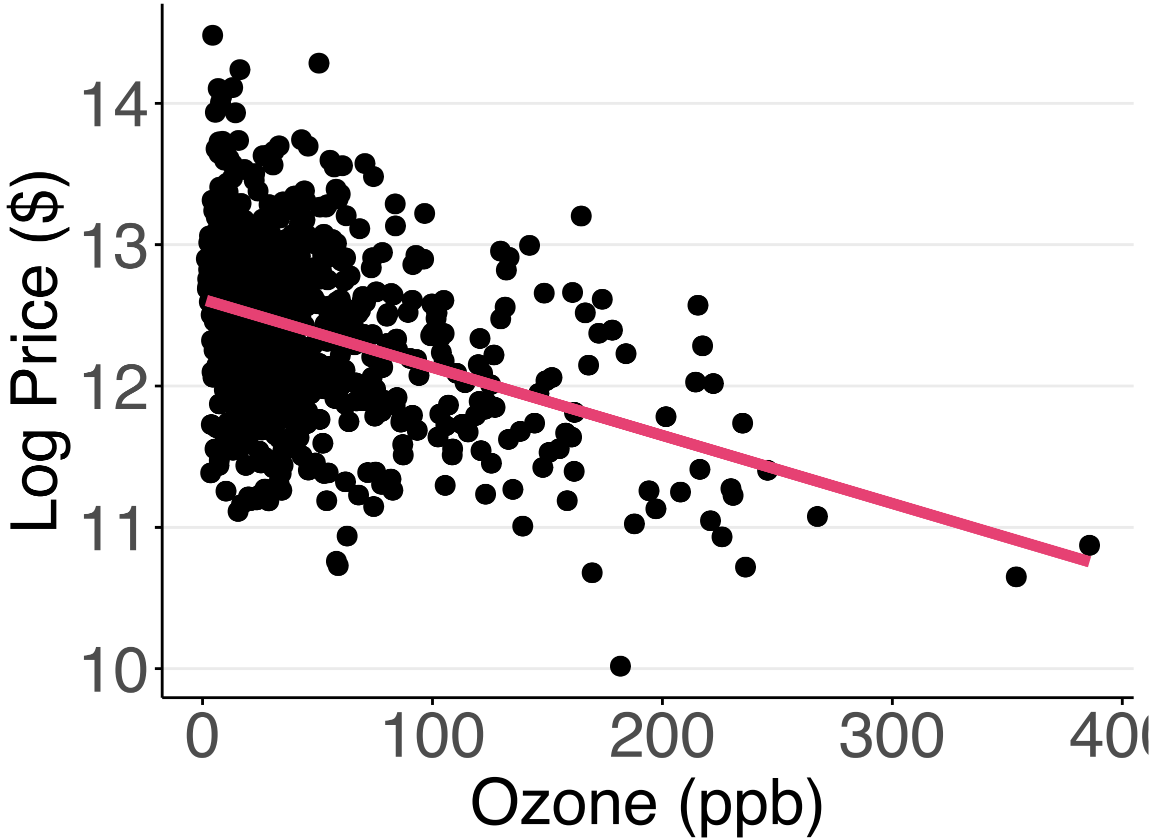
Estimating the effect of ozone

Now let's plot the relationship between log house prices and ozone to see what the data actually look like:

```
ggplot(house_data, aes(x = ozone, y = log_price)) +   # start plot
  geom_point(size = 3) +                              # plot points
  geom_smooth(formula = y ~ x, se = F, method = "lm", size = 2, color = red_pink) +
  theme_regular +                                     # apply theme
  labs(x = "Ozone (ppb)", y = "Log Price ($)")        # assign labels
```

Estimating the effect of ozone

Now let's plot the relationship between log house prices and ozone to see what the data actually look like:



Estimating the effect of ozone

Now it's time to do the regression:

```
lm(log_price ~ num_bedrooms + num_bathrooms + sq_feet + ozone, house_data) %>%
  broom::tidy()
```

```
## # A tibble: 5 x 5
##   term            estimate  std.error statistic  p.value
##   <chr>              <dbl>      <dbl>     <dbl>    <dbl>
## 1 (Intercept)   11.7        0.0722        163.   0.
## 2 num_bedrooms   0.136      0.0163          8.39 2.45e-16
## 3 num_bathrooms  0.161      0.0256          6.29 5.54e-10
## 4 sq_feet        0.0000971 0.00000900     10.8  2.46e-25
## 5 ozone         -0.00466   0.000383      -12.2  3.77e-31
```

A 1 unit increase in ozone decreases housing values by 0.466%!

Housing prices and superfund clean up

Greenstone, Michael, and Justin Gallagher (2008). "Does Hazardous Waste Matter? Evidence from the Housing Market and the Superfund Program." Quarterly Journal of Economics

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Main question: How does superfund site clean up affects the housing price in the adjacent areas?

How they do it: Compare housing market outcomes in the areas surrounding the first 400 hazardous sites chosen for Superfund clean-ups to the areas surrounding the 290 sites that narrowly missed qualifying for these clean-ups

Housing prices and superfund clean up

Each site is given a Hazardous Ranking System (HRS) Score (0-100)

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Minimizes any bias with things that might be correlated with clean up

Superfund location

Figure IIa
GEOGRAPHIC DISTRIBUTION OF HAZARDOUS WASTE SITES IN THE 1982 HRS SAMPLE
SITES WITH 1982 HRS SCORES EXCEEDING 28.5

Figure IIb
GEOGRAPHIC DISTRIBUTION OF HAZARDOUS WASTE SITES IN THE 1982 HRS SAMPLE
SITES WITH 1982 HRS SCORES BELOW 28.5

Regression

What do GG 2008 do?

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They regress:

$$\log(2000 \text{ median home price})_c = \theta \underbrace{1(\text{cleaned up in } 2000)_c}_{= 1 \text{ if true}, = 0 \text{ otherwise}} + \beta X_c + \varepsilon_c$$

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$-\theta$ is telling us the **cost** of a superfund site to households

Superfund results: "quasi-experimental"

QUASI-EXPERIMENTAL ESTIMATES OF THE EFFECT OF NPL STATUS ON HOUSE PRICES, SAMPLES BASED ON THE 1982 HRS SAMPLE SITES

					RD-Style Estimators		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
A. Own Census Tract							
1(NPL Status by 2000)	0.035	0.037	0.043	0.047	0.007	0.022	0.027
	(0.031)	(0.035)	(0.031)	(0.027)	(0.063)	(0.042)	(0.038)
B. Adjacent Census Tracts							
1(NPL Status by 2000)	0.071	0.066	0.012	0.015	-0.006	-0.002	0.001
	(0.031)	(0.035)	(0.029)	(0.022)	(0.056)	(0.035)	(0.035)
C. 2-Mile Radius from Hazardous Waste Sites							
1(NPL Status by 2000)	0.021	0.019	0.011	0.001	0.023	-0.018	-0.007
	(0.028)	(0.032)	(0.029)	(0.023)	(0.054)	(0.035)	(0.034)
Ho: > 0.138, P-Value	0.000	0.000	0.000	0.000	0.018	0.000	0.000

Superfund results

Superfund cleanups had economically and statistically insignificant effects on property values, rental rates, housing supply, population, who lives near the site

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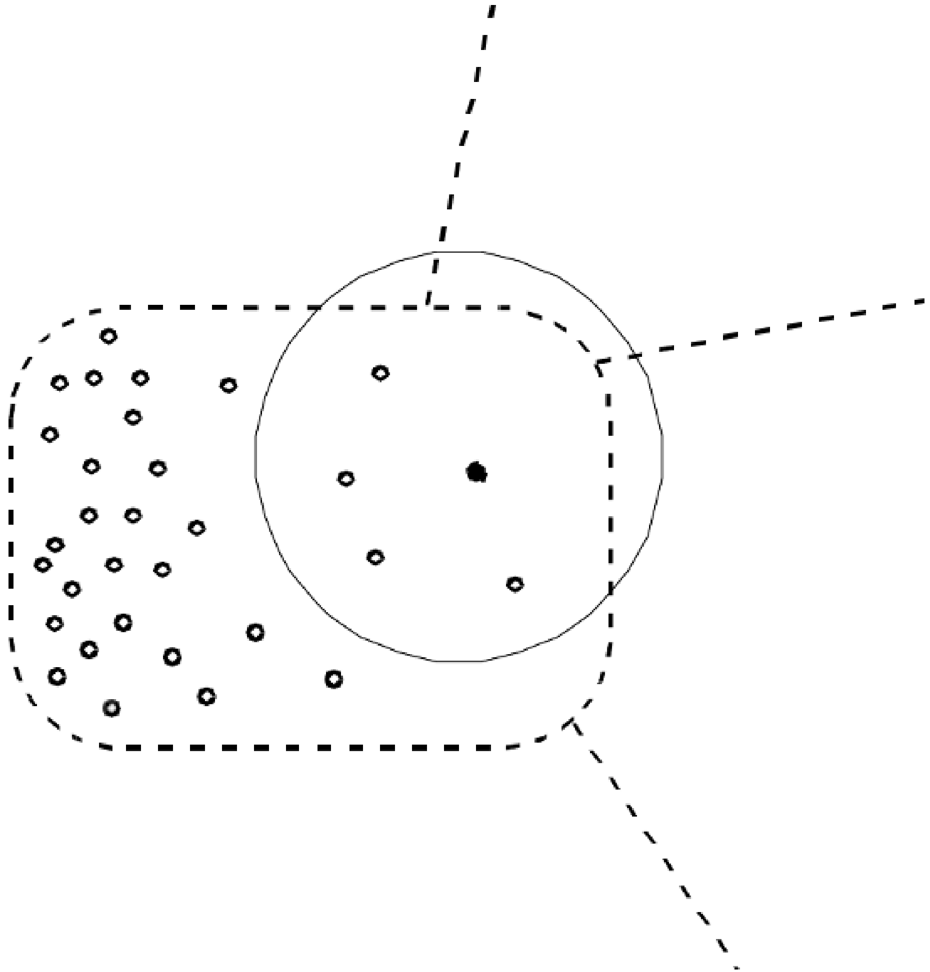
Why does granularity matter?

Superfund: zoom in

Superfund sites are a localized disamenity

Previous attempts to value cleanup looked at changes in census tract median housing values and found no impacts

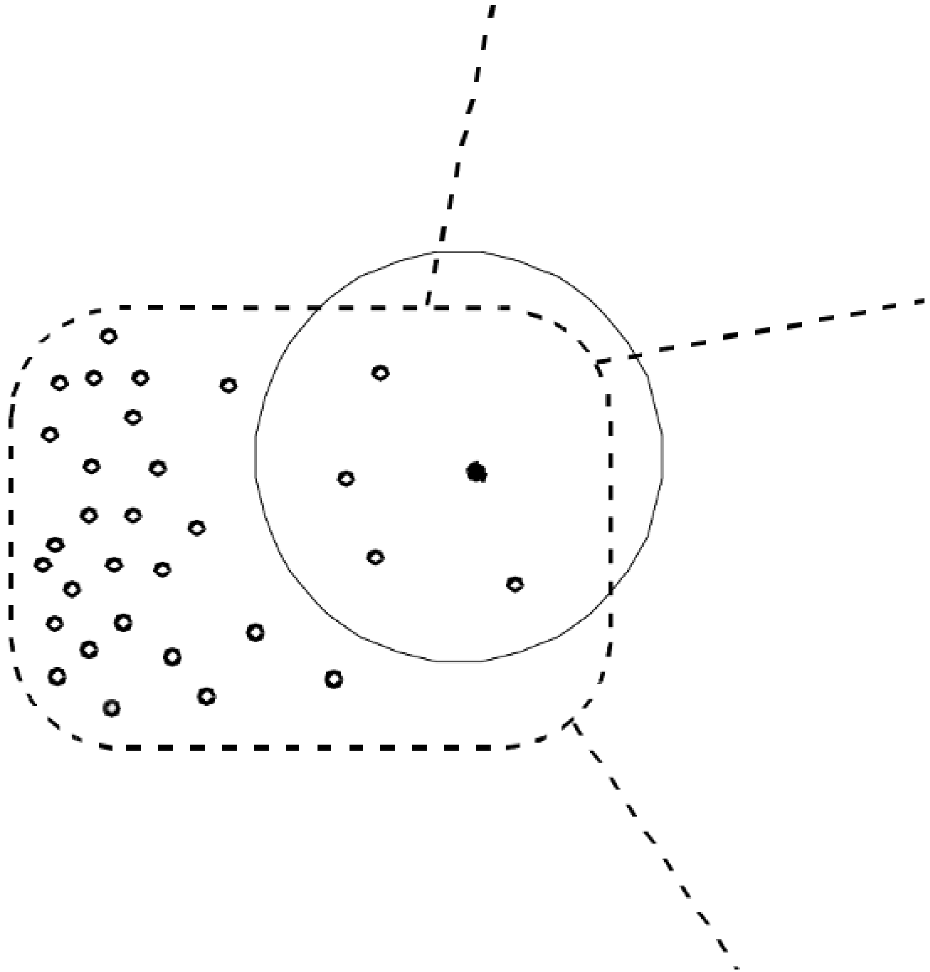
Need to look within census tracts



Superfund: zoom in

Consider changes in other percentiles of within-tract house value distribution:

deletion of a site raises tract-level housing values by 18.2% at the 10th percentile, 15.4% at the median, and 11.4% at the 60th percentile



Hedonics closing intuition: L.O. Taylor, 2003

Imagine the following hypothetical scenario in which there are two identical lakes each with 100 identical homes surrounding them

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

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Imagine the following hypothetical scenario in which there are two identical lakes each with 100 identical homes surrounding them

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

At the current equilibrium price of $200,000 per house, all 200 hundred homes on either lake are equally preferred

Hedonics closing intuition: L.O. Taylor, 2003

Now let's imagine the clarity on one lake, Lake A, for example, is improved

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Now let's imagine the clarity on one lake, Lake A, for example, is improved

Now if any home on Lake A were offered at the original equilibrium price of $200,000, consumers would uniformly prefer this house to any house on Lake B

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Now let's imagine the clarity on one lake, Lake A, for example, is improved

Now if any home on Lake A were offered at the original equilibrium price of $200,000, consumers would uniformly prefer this house to any house on Lake B

In other words, at current prices, there would be excess demand on Lake A, and as such the price of these houses must rise to bring the market into equilibrium

Hedonics closing intuition: L.O. Taylor, 2003

The price differential that results from a change in water quality at Lake A is the implicit price that consumers are willing to pay for that incremental increase in water clarity

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This willingness to pay for water clarity is directly revealed to us through the market prices of the homes

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The price differential that results from a change in water quality at Lake A is the implicit price that consumers are willing to pay for that incremental increase in water clarity

This willingness to pay for water clarity is directly revealed to us through the market prices of the homes

If in the new equilibrium houses on Lake A sell for 210,000, while house on Lake B sell for 200,000, the "implicit price" associated with the increased water clarity is 10,000 dollars

Value of a statistical life (VSL)

This is a topic that makes non-economists uncomfortable

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But for policy analysis, there is no way around it

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A statistical life is a probabilistic concept

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How much should society spend, at the margin, to save a 'statistical life'?

A statistical life is a probabilistic concept

VSL reflects willingness to pay for a reduction in the risk of death

VSL is more appropriately called the value of mortality risk

Value of a statistical life (VSL)

How do you get a credible estimate of the VSL?

Value of a statistical life (VSL)

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People can't just tell you it

Value of a statistical life (VSL)

How do you get a credible estimate of the VSL?

People can't just **tell** you it

But we can observe it from behavior

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How?

See tradeoffs people make between cost and safety

Value of a statistical life (VSL)

Some examples:

Value of a statistical life (VSL)

Some examples:

Driving speed

Value of a statistical life (VSL)

Some examples:

Driving speed

Vehicle choice

Value of a statistical life (VSL)

Some examples:

Driving speed

Vehicle choice

Wage-risk relationship

Value of a statistical life (VSL)

Some examples:

Driving speed

Vehicle choice

Wage-risk relationship

There's lots of studies, and lots of different answers

VSL

> EPA recommends that the central estimate of $7.4 million ($2006), updated to the year of the analysis, be used in all benefits analyses that seek to quantify mortality risk reduction benefits regardless of the age, income, or other population characteristics of the affected population until revised guidance becomes available

VSL thought experiment

Suppose that individuals are willing to adopt a safety procedure, for which they have to give up 25 cents per hour, to reduce risk of on-the-job fatality by 1 in 10,000 (annual risk)

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Consider 10,000 independent workers

This procedure would result in one fewer person dying on average

VSL = $500*10,000 = 5 million dollars

Estimating a hedonic wage function

We can estimate a **hedonic wage function:**

$$w_i = \alpha + \beta_1 H_i + \beta_2 X_i + \beta_3 p_i H_i + \gamma_1 p_i + \gamma_2 q_i + \gamma_3 q_i WC_i + \varepsilon_i$$

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w: wage

H: worker personal characteristics

X: job characteristics

p: risk of death at the job

q: non-fatal risk at the job

WC: workers' compensation benefits for injury

$\frac{\partial w}{\partial p}$ is the wage-risk trade off for marginal changes in risk

VSL from the hedonic wage function

Suppose the coefficient on mortality risk was 0.4 where wages were in thousands of dollars and risk is deaths per 10,000 (WTP 400 dollars to reduce risk by 1/10,000)

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This means that:

$$VSL = (0.4/10,000) * 1000) = 4 \text{ million dollars}$$

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Suppose a policy reduces mortality risk by 1/10,000 for 60,000 people

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Suppose a policy reduces mortality risk by 1/10,000 for 60,000 people

This policy has a value of:

$$400 * 60,000 = 24 \text{ million dollars}$$

VSL estimates

Exhibit 7-3 Value of Statistcal Life Estimates (mean values in 1997 dollars)

Study	Method	Value of Statistical Life
Kneisner and Leeth (1991 - U.S.)	Labor Market	$0.7 million
Smith and Gilbert (1984)	Labor Market	$0.8 million
Dillingham (1985)	Labor Market	$1.1 million
Butler (1983)	Labor Market	$1.3 million
Miller and Guria (1991)	Contingent Valuation	$1.5 million
Moore and Viscusi (1988)	Labor Market	$3.0 million
Viscusi, Magat and Huber (1991)	Contingent Valuation	$3.3 million
Marin and Psacharopoulos (1982)	Labor Market	$3.4 million
Gegax et al. (1985)	Contingent Valuation	$4.0 million
Kneisner and Leeth (1991 - Australia)	Labor Market	$4.0 million
Gerking, de Haan and Schulze (1988)	Contingent Valuation	$4.1 million
Cousineau, Lecroix and Girard (1988)	Labor Market	$4.4 million
Jones-Lee (1989)	Contingent Valuation	$4.6 million
Dillingham (1985)	Labor Market	$4.7 million
Viscusi (1978, 1979)	Labor Market	$5.0 million
R.S. Smith (1976)	Labor Market	$5.6 million
V.K. Smith (1976)	Labor Market	$5.7 million
Olson (1981)	Labor Market	$6.3 million
Viscusi (1981)	Labor Market	$7.9 million
R.S. Smith (1974)	Labor Market	$8.7 million
Moore and Viscusi (1988)	Labor Market	$8.8 million
Kneisner and Leeth (1991 - Japan)	Labor Market	$9.2 million
Herzog and Schlottman (1987)	Labor Market	$11.0 million
Leigh and Folsom (1984)	Labor Market	$11.7 million
Leigh (1987)	Labor Market	$12.6 million
Garen (1988)	Labor Market	$16.3 million
Derived from EPA (1997) and Viscusi (1992).		