Lecture 11

Hedonics

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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?

Revealed preference approaches

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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

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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

Hedonics: Property value models

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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 Waste in the Ne…
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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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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

It is also characterized by an environmental good q

The hedonic model

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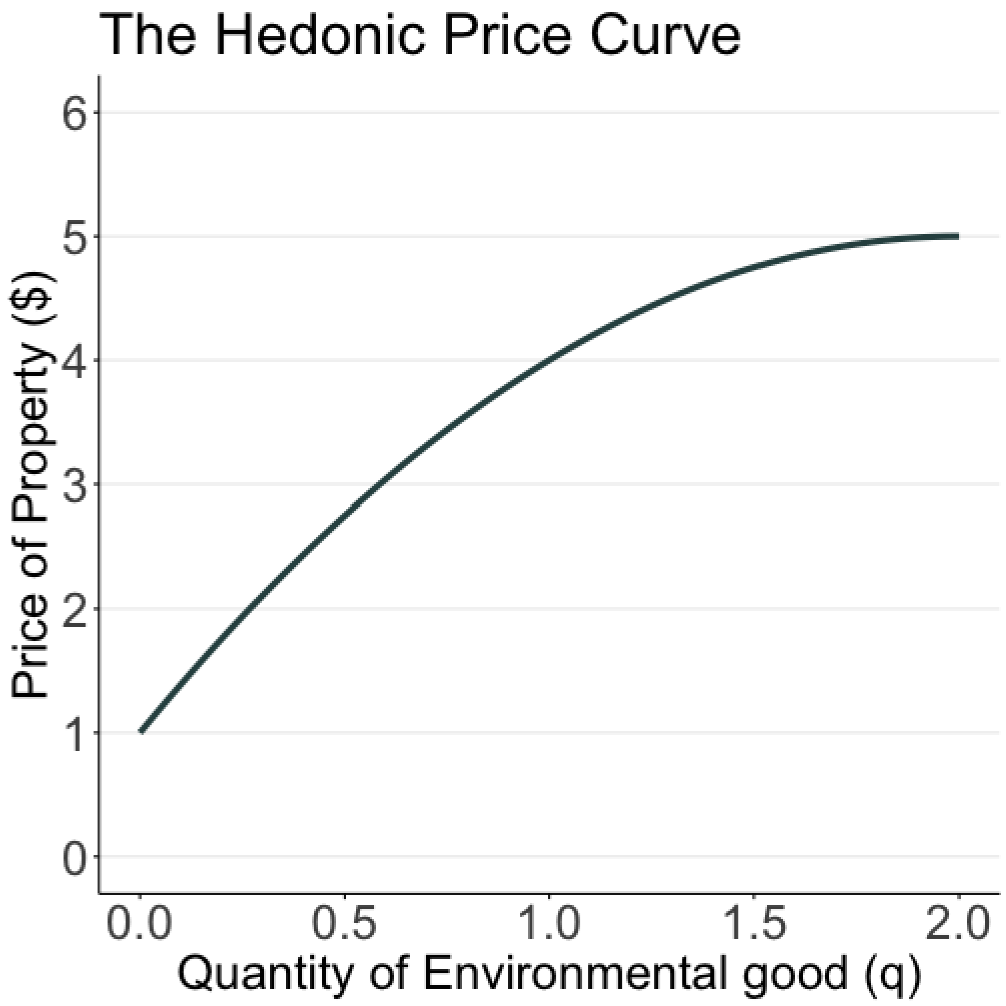
Here we will assume the supply of houses is fixed in the short run so the price curve arises solely from buyer behavior

The hedonic model: the price curve



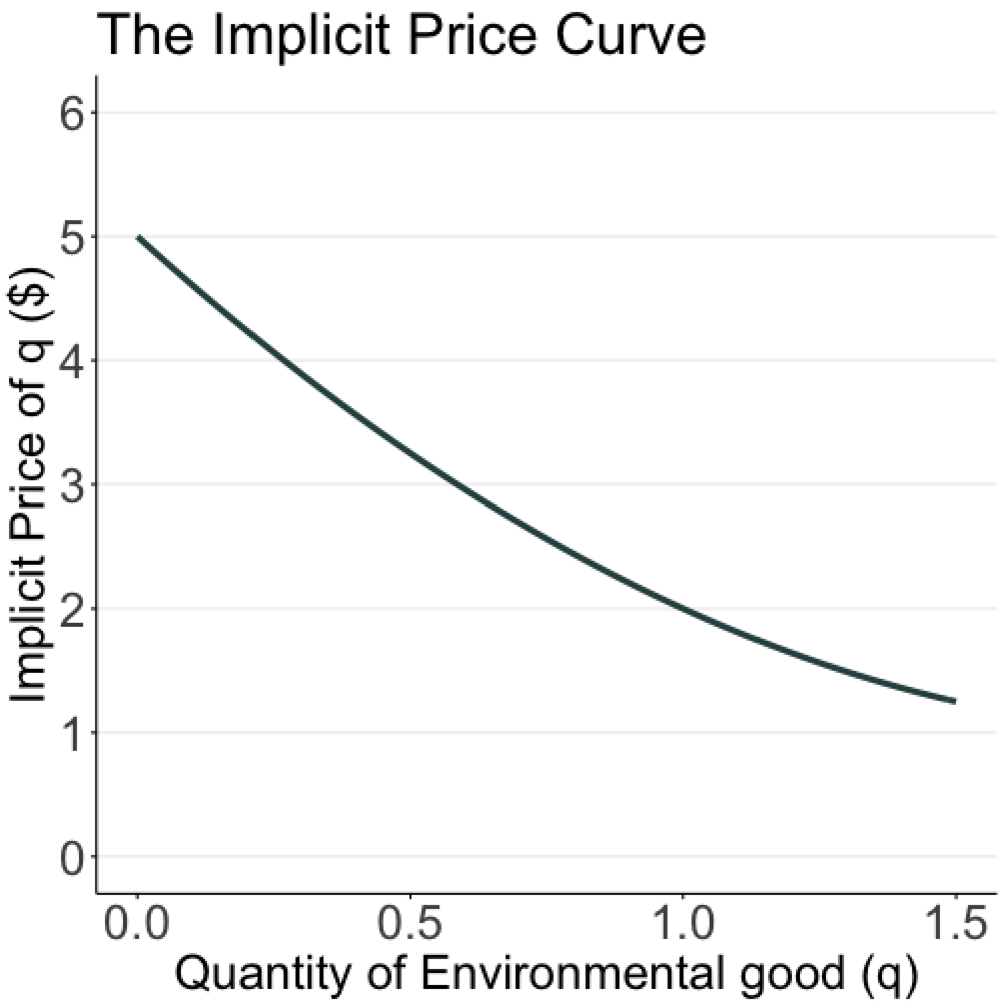
The hedonic price curve is $P(x, q)$

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

This is holding x fixed

Analogous to regular demand curves holding income fixed

The hedonic model: the price curve



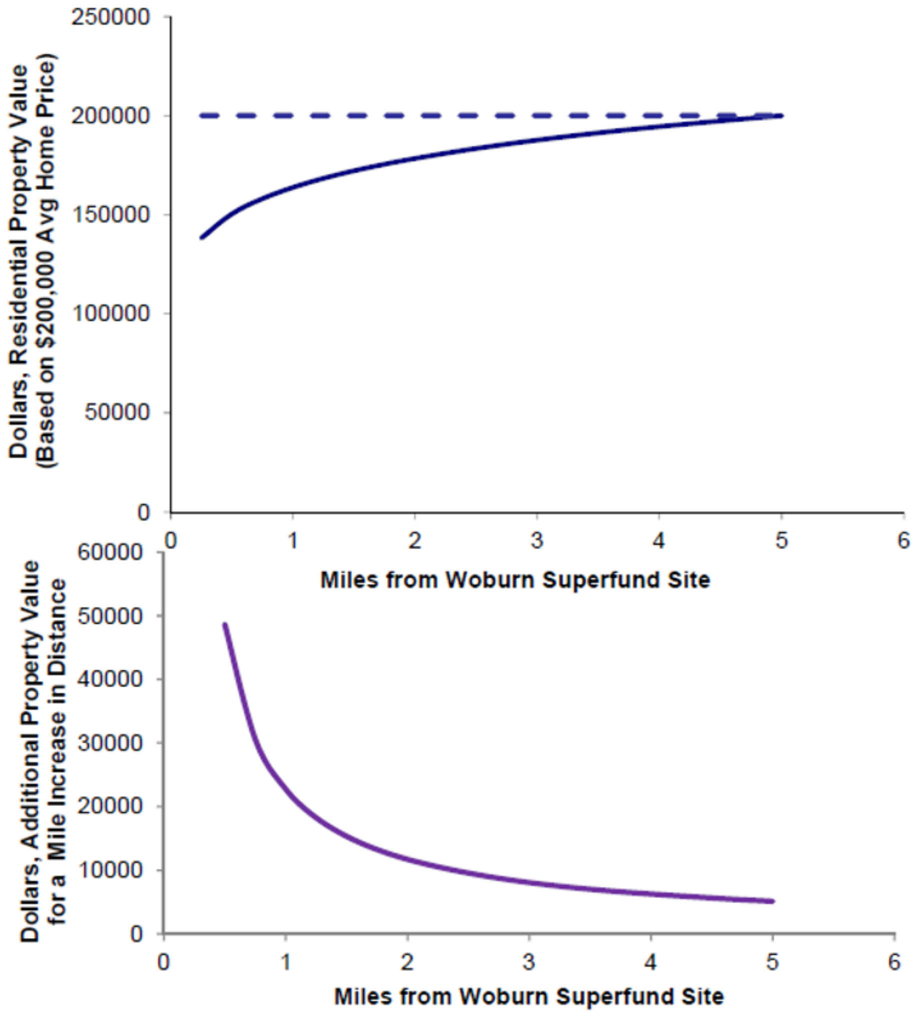
The implicit price curve for q is $\frac{\partial P(x,q)}{\partial q}$

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 for housing characteristics

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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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- 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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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

What is $P(x, q)$

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

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

Plug in the constraint for z to get:

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The FOCs for this problem are:

$$\frac{\partial U}{\partial x_j} = \frac{\partial U}{\partial z}\frac{\partial P}{\partial x_j} \quad j = 1,\ldots,J$$
$$\frac{\partial U}{\partial q} = \frac{\partial U}{\partial z}\frac{\partial P}{\partial q}$$

The hedonic model: consumer's choice problem

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What does this mean?

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At a utility-maximizing choice, a household equates their MRS between q and z and the marginal implicit cost of q

Recall from intro/intermediate micro: the MRS tells us how the household trades off q and z while keeping utility constant

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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 level of utility $\bar{u}$:

$$U(x, q, z; s) = \bar{u} \qquad \text{(indifference curve)}$$

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This equation just defines some indifference curve

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

The hedonic model: bid functions

The bid function $b(x, q, y, s, \bar{u})$ is the **maximum WTP** of the household for:

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

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Given this definition, and since $P = WTP$ in markets, we can plug b in for the hedonic price function:

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

The hedonic model: deriving MWTP

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We just proved that the maximum WTP for q is given by how housing prices change in q

The hedonic model: deriving MWTP

$$\underbrace{\pi^q(x, q, s, \bar{u})}_{\text{marginal WTP for q}} \equiv \frac{\partial b}{\partial q} = \frac{\partial P}{\partial q} = \frac{\partial U}{\partial q} \bigg/ \frac{\partial U}{\partial z}$$

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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**

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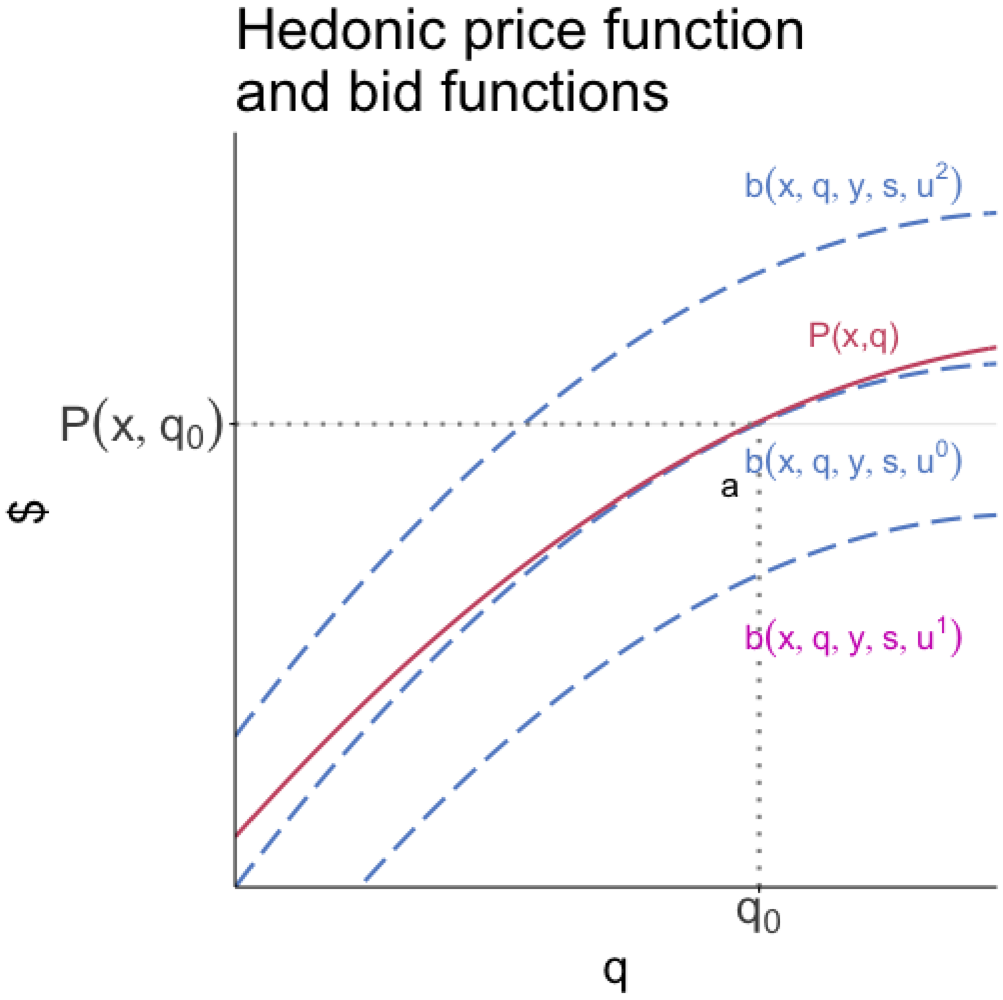
The difference is that with **Marshallian** demand curves, we are holding **income** constant on the curve, income changes are demand shifters, utility changes as you move along the curve

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

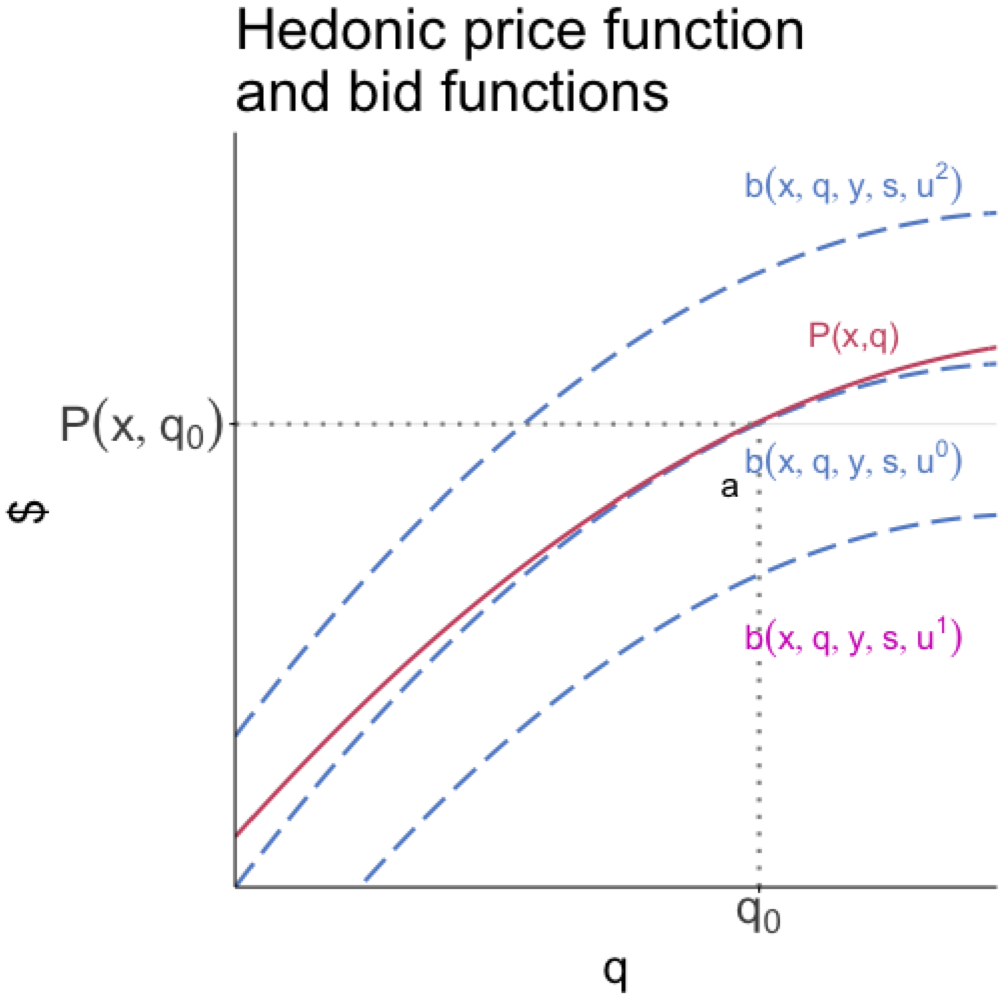


Bid functions and housing prices

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 $P(x, q)$



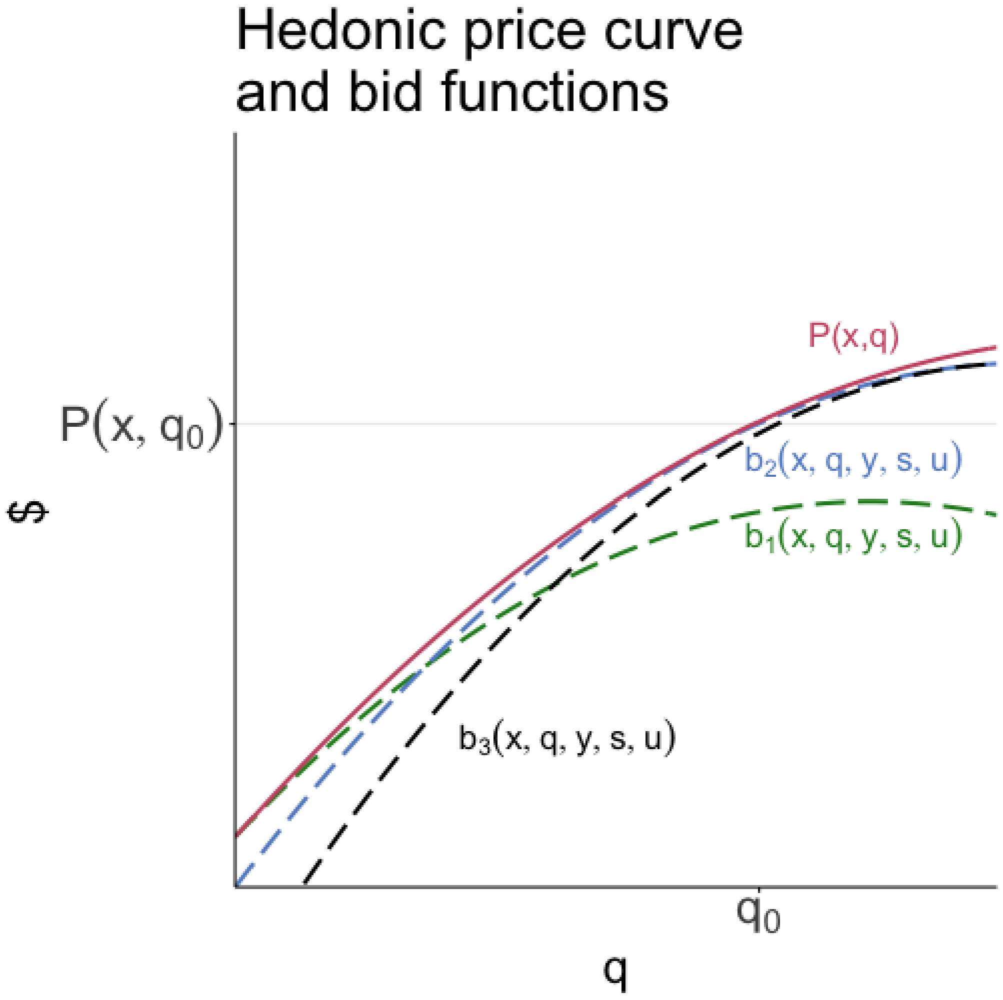
Bid functions and housing prices

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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The slope gives the marginal price of the attributes

At a given point on the curve, the slope also gives the marginal WTP of the consumer who purchase that level of attributes

Hedonic price curve and willingness to pay

The hedonic price curve shows how a house varies with attributes (such as air quality)

The slope gives the marginal price of the attributes

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But we don’t know the whole marginal WTP schedule for **that person**, why?

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 × 7
##    house_num ozone num_bedrooms num_bathrooms sq_feet log_price   price
##        <int> <dbl>        <int>         <dbl>   <dbl>     <dbl>   <dbl>
##  1         1  9.60            4             3    577.      12.7 341991.
##  2         2  4.49            4             3   1111.      12.7 334851.
##  3         3 15.6             4             1    820.      12.0 159567.
##  4         6 10.2             3             2    886.      12.7 325459.
##  5         8 30.8             4             3   4909.      12.9 399579.
##  6         9 14.7             2           1.5    798.      11.9 152339.
##  7        10  3.80            4           1.5    946.      12.5 278165.
##  8        11  5.62            4             1   1912.      12.2 206147.
##  9        12  8.62            3           1.5    720.      12.3 226051.
```

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?

Estimating the effect of ozone

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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.   :  0.8242   Min.   :1.00   Min.   :1.000   Min.   :  501.4   Min.   :10.47
##  1st Qu.: 245.0   1st Qu.:  7.9529   1st Qu.:1.00   1st Qu.:1.500   1st Qu.:  892.3   1st Qu.:12.10
##  Median : 491.0   Median : 15.3680   Median :2.00   Median :2.000   Median : 1395.0   Median :12.49
##  Mean   : 494.4   Mean   : 23.1940   Mean   :2.49   Mean   :1.977   Mean   : 2055.0   Mean   :12.51
##  3rd Qu.: 745.0   3rd Qu.: 28.6273   3rd Qu.:4.00   3rd Qu.:2.500   3rd Qu.: 2415.5   3rd Qu.:12.92
##  Max.   :1000.0   Max.   :192.8742   Max.   :4.00   Max.   :3.000   Max.   :21001.0   Max.   :14.49
```

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, color = "darkslategray") +                       # 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

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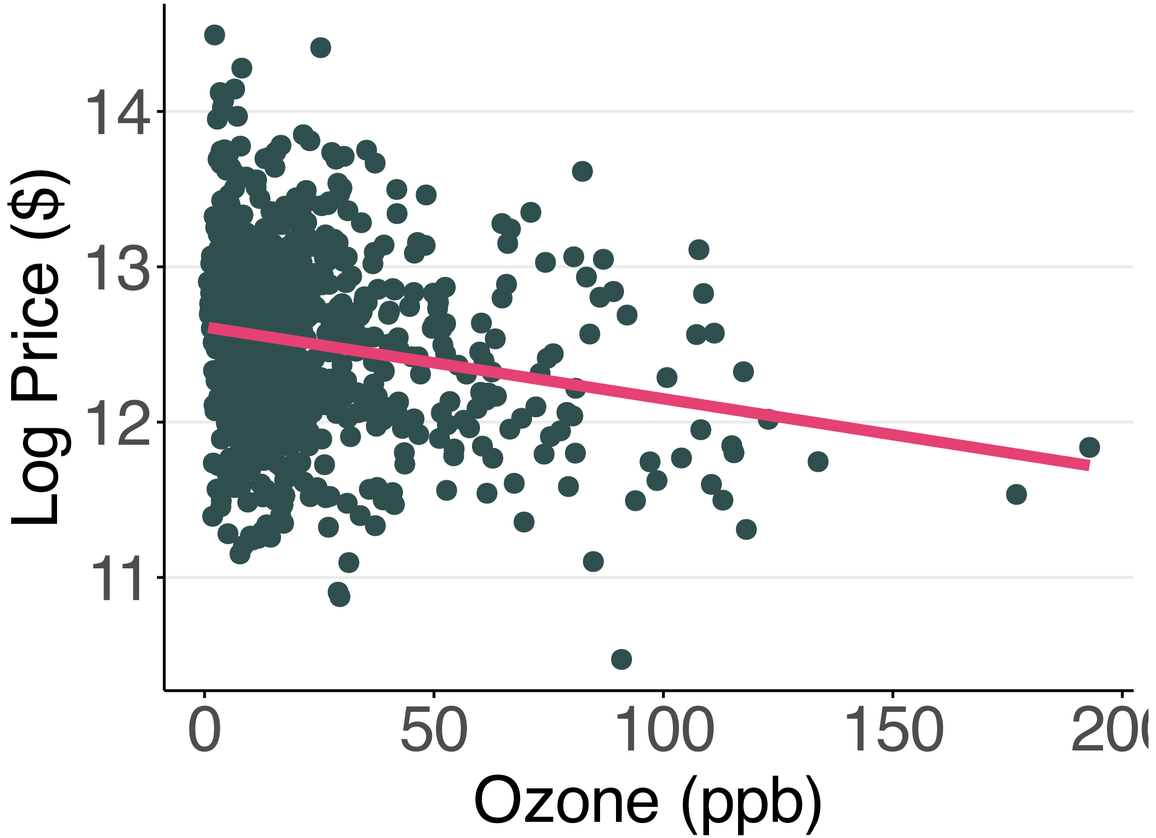

Estimating the effect of ozone

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 × 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         -0.00432   0.000767       -5.63 2.52e- 8
```

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

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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Unobserved differences between treated and untreated sites are likely to be small

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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Suggests the mean benefits of Superfund cleanup are small

Some recent and more granular studies (Timmins and Gamper) dispute these findings: http://www.nber.org/papers/w16655.pdf

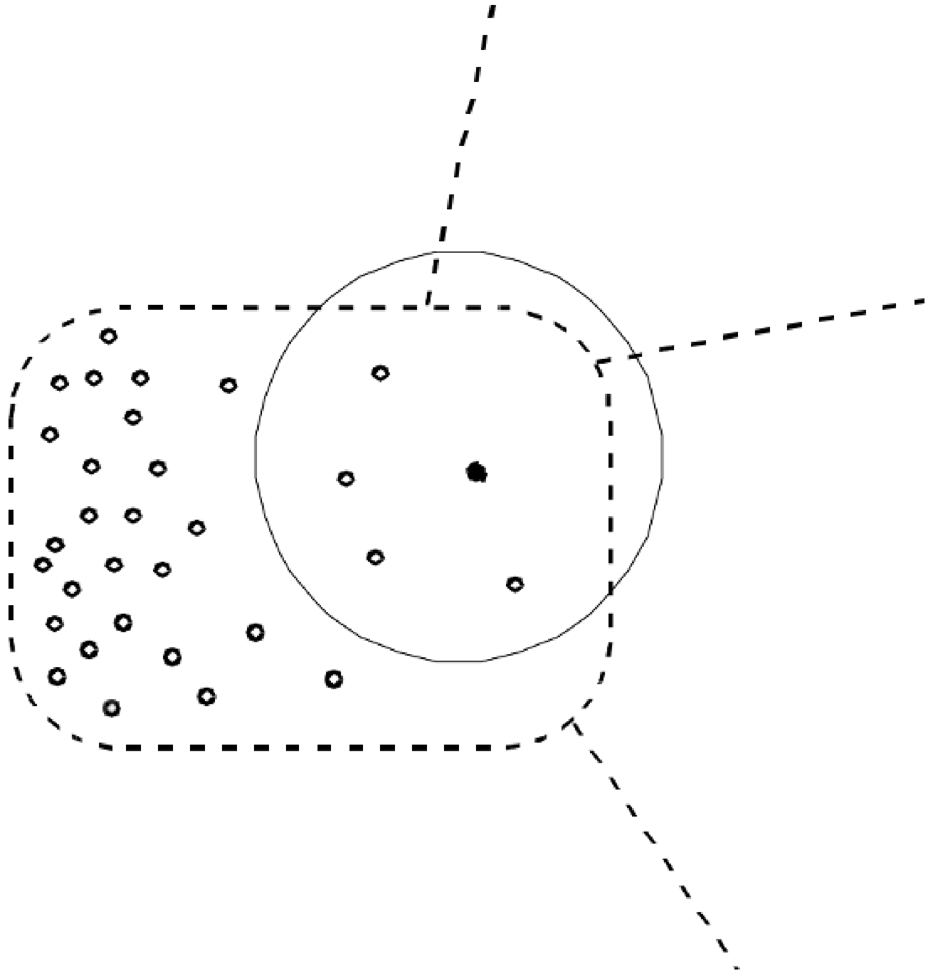
Why does granularity matter?

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

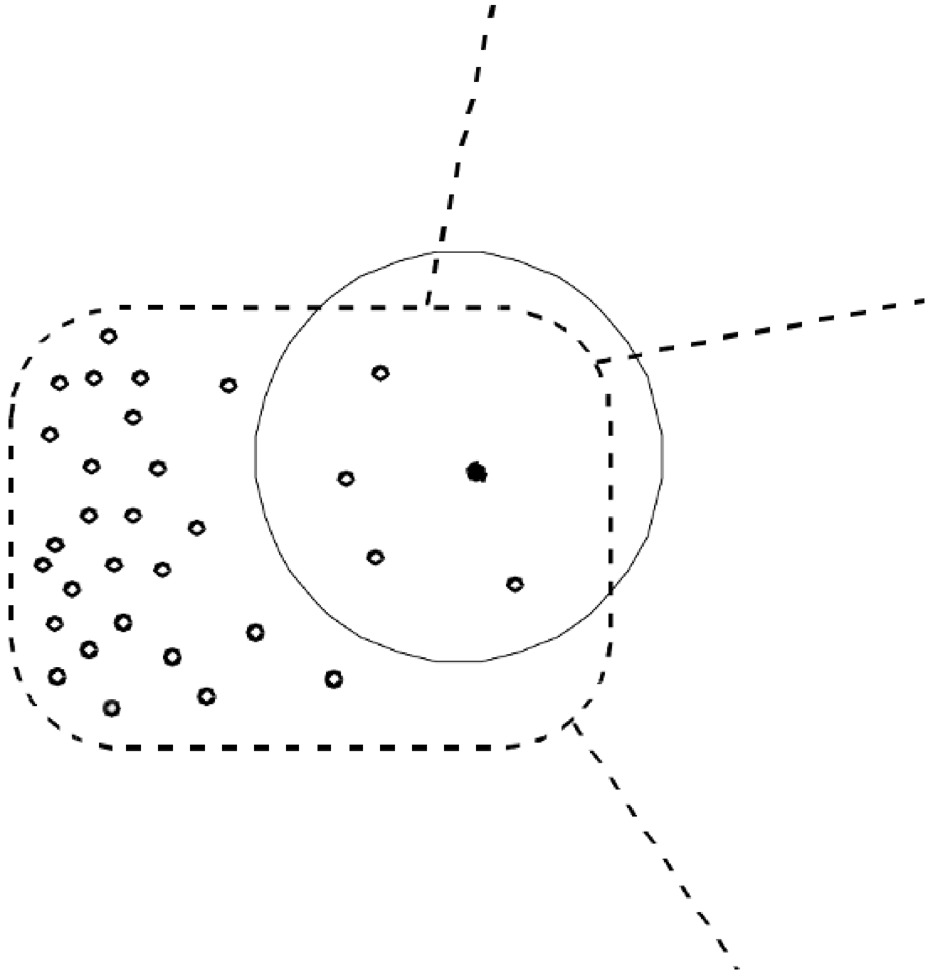
Need to look **within** census tracts



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

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

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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

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

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

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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?

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

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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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This procedure would result in one fewer person dying on average

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

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

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

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This means that:

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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).		