SUSTAINABLE USE OF FOREST ECOSYSTEM SERVICES

THE HEDONIC PRICING METHOD

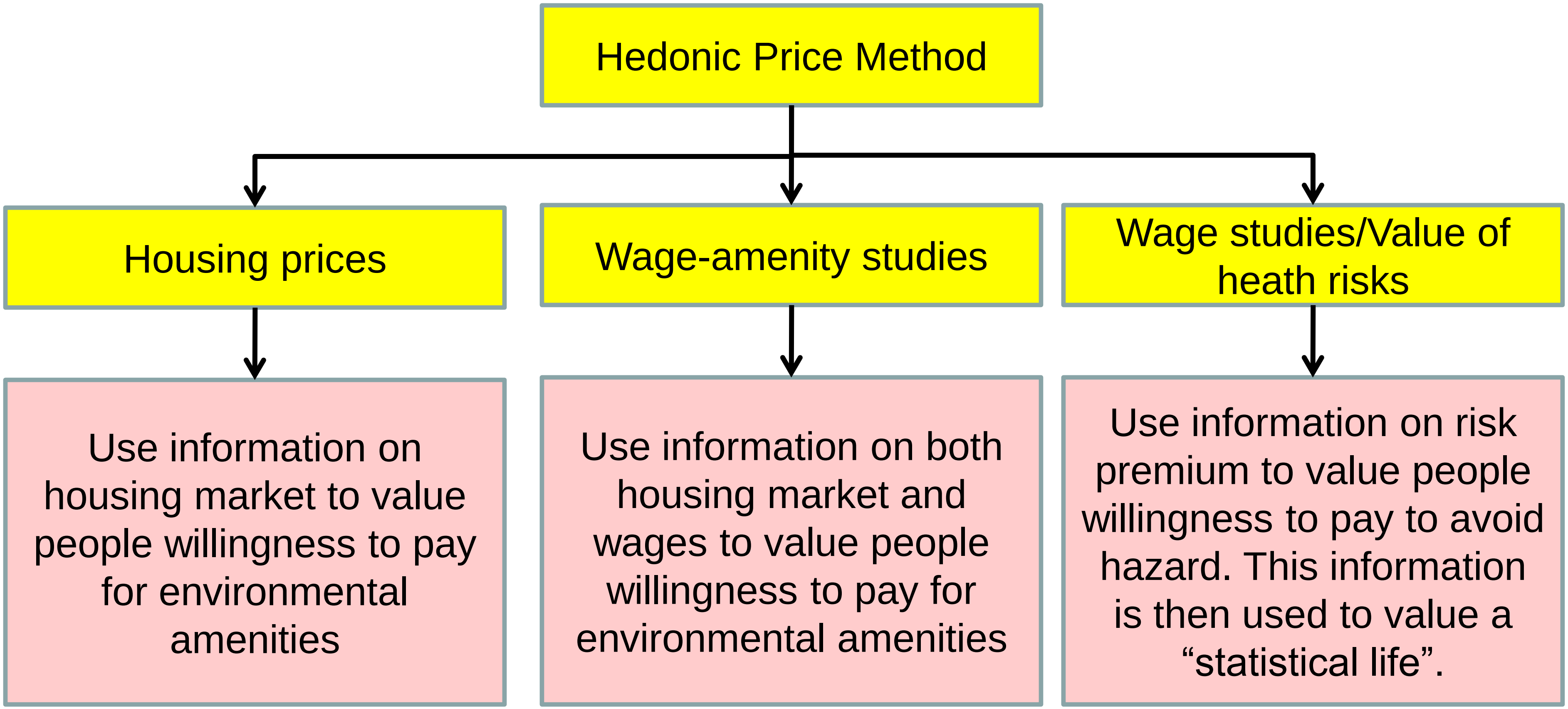
General Background

- In the “real world” we are often confronted with goods and services with a single price for the whole bundle the good or service (e.g. house)
- We are interested in the price of a characteristics of the good. For example, the price of a house depends on many factors including environmental characteristics of the location
- This is the focus of the hedonic price theory. Other hedonic price is concerned with labour markets, timber markets, child care services, agricultural products, fishery products, health services and other commodities
- In the case of housing market, by observing the prices of many houses with different characteristics, we can infer the implicit value that is being placed on one characteristic, for example, air quality or tree cover or landscape beauty or neighbourhood, etc
- In the case of labour market, by observing wages associated with many different occupations we can infer the value of small changes in risk or any other factor
- Applied to prices of farmland as early as 1922
- The formal model was developed by Rosen (1974)

Historical Background

- 1926 Waugh studies the variation of prices of vegetables
- 1938 Court looks at the car market in Detroit
- 1967 first application to the housing market: Ridker and Henning
  - Study the effects of air pollution on prices of housing
- 1974 Rosen describes the first formal model of the hedonic pricing method
- Other applications:
  - Agricultural goods
  - Job market
  - Child care service
  - Cars
  - Forestry
  - Health
  - Statistical life
  - Amenities and landscapes

Applications of Hedonic Price Methods



Introduction

- Hedonic price method derive from consumer theory in which utility is related to the attributes of a good.
- It is one of the revealed preference techniques used in valuing nonmarket goods and services
- No questionnaire required to conduct the study or survey in HPM
- Data are gathered from the market, i.e. transaction of house sales. Thus, there is no need to a hypothetical market. For example, some of the questions related to decision of buying a house:
  - The type of the house
  - The location of our house
  - Why we choose this location
  - Which factors that push to choose one location rather than another
  - The characteristics of the area, etc

The choice of localization

- It can be seen that, the choice of housing is a composite good.
- For example, we decide the location based on distance from work, availability of public services, distance to central business district, distance from schools, availability of green areas, availability of sport facilities, characteristics of housing (# of bedrooms, # of bathrooms, flat, detached, etc.) , neighbourhood characteristics, etc.
- We assume that buyers choose houses that maximize their utility
- However, the constraints in the maximization problem is that the consumers have limited by income, the price of the houses and also the level of taxes that to be paid to the government
  – Therefore, the housing market give us some information on buyers preferences for housing and for their localization

Basic Idea of Hedonic Pricing Method

- The hedonic pricing method that applies to a house purchase is composed by a set of characteristics.
- Consider the characteristics of a house:
  - Number of floors, presence of a garden, GCH, number of bedrooms, number of bathrooms, square footage of the house, type of house, age, materials, etc.
  - And also:
    - Distance from public transport, distance from the city centre, distance from main roads, distance from shops, distance from sport facilities, crime rate, average income of inhabitants, presence of a university, etc.
    - The composite good has a price, but there is no explicit price for each characteristic that compose the good.

- The hedonic pricing method applies this concept to the environmental characteristics of residential properties
- The price difference between houses that have different levels of environmental quality, keeping constant all other characteristics, reflects the WTP for the different level of environmental quality
- Thus, we can assess the value of an environmental quality, according to market prices of residential properties
- The variation in environmental quality affects the price of housing

Factors affecting house purchase

- In hedonic pricing method, it is hypothesized that each house represents a unique combination of characteristics
- The price a potential buyer is willing to pay (WTP) depends upon:

1. **Physical characteristics**: number of rooms, bathrooms, central heating, age and condition of structure, etc.
2. **Accessibility characteristics**: access to major centres of employment, shops, etc.
3. **Public sector characteristics**: accessibility to schools, post office, etc., local tax rates, etc.
4. **Neighbourhood and environmental characteristics**: aspect, view, tree cover, road traffic, water frontage, etc.
5. **Alternative use characteristics**: land with planning permission for a higher value use, etc.

Theoretical Framework

- Consider an homogenous area that can be considered a single market from the point of view of, say, houses
- For simplification, each house is characterised by a single characteristic, z, say, air pollution
- We are interested in the relation between price and air quality, $p = p(z)$
- The price function is an equilibrium concept (partial equilibrium) resulting from interaction of supply and demand
- We assume that the market is perfect
  - Producers and consumers cannot control the market price
  - Both producers and consumers take $p(z)$ as given

The consumer

- The consumer buys one house as well as other goods *x*
- The consumer's problem is maximize utility : $\max_{x,z} U(x,z) \text{ s.t. } x + p(z) = y$
- U is utility, y is income

- What is the amount of x for particular values of z to achieve a certain level of utility: $\hat{U} = U(x,z)$

- The budget for buying the house, guaranteeing a certain level of utility is $\theta = y - x$

- Alternatively, we can define the consumer's problem as

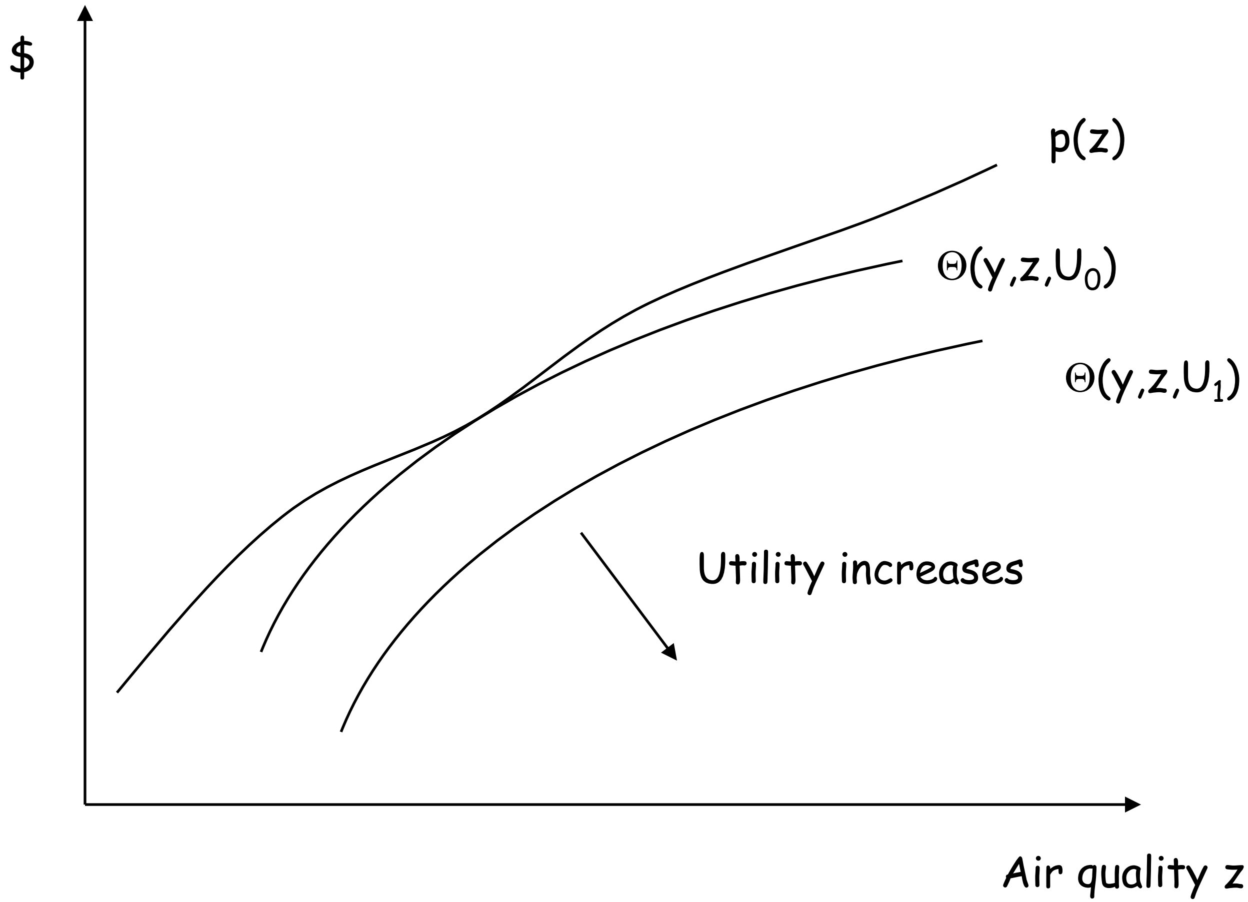
$$U(y-\theta, z) = \hat{U}$$

$$\Leftrightarrow \theta(y, z, \hat{U})$$

- This is known as the bid function – it tells you the maximum amount a consumer is willing to pay as a function of income and air pollution

Consumer choice

Hedonic price function and two bid functions for two different levels of utility



The producer

- The costs *c* of producing one house depend on input prices *r* and the characteristics *z: c(r,z)*
- The producer maximises profits

$$\Pi = \phi - c(r,z)$$

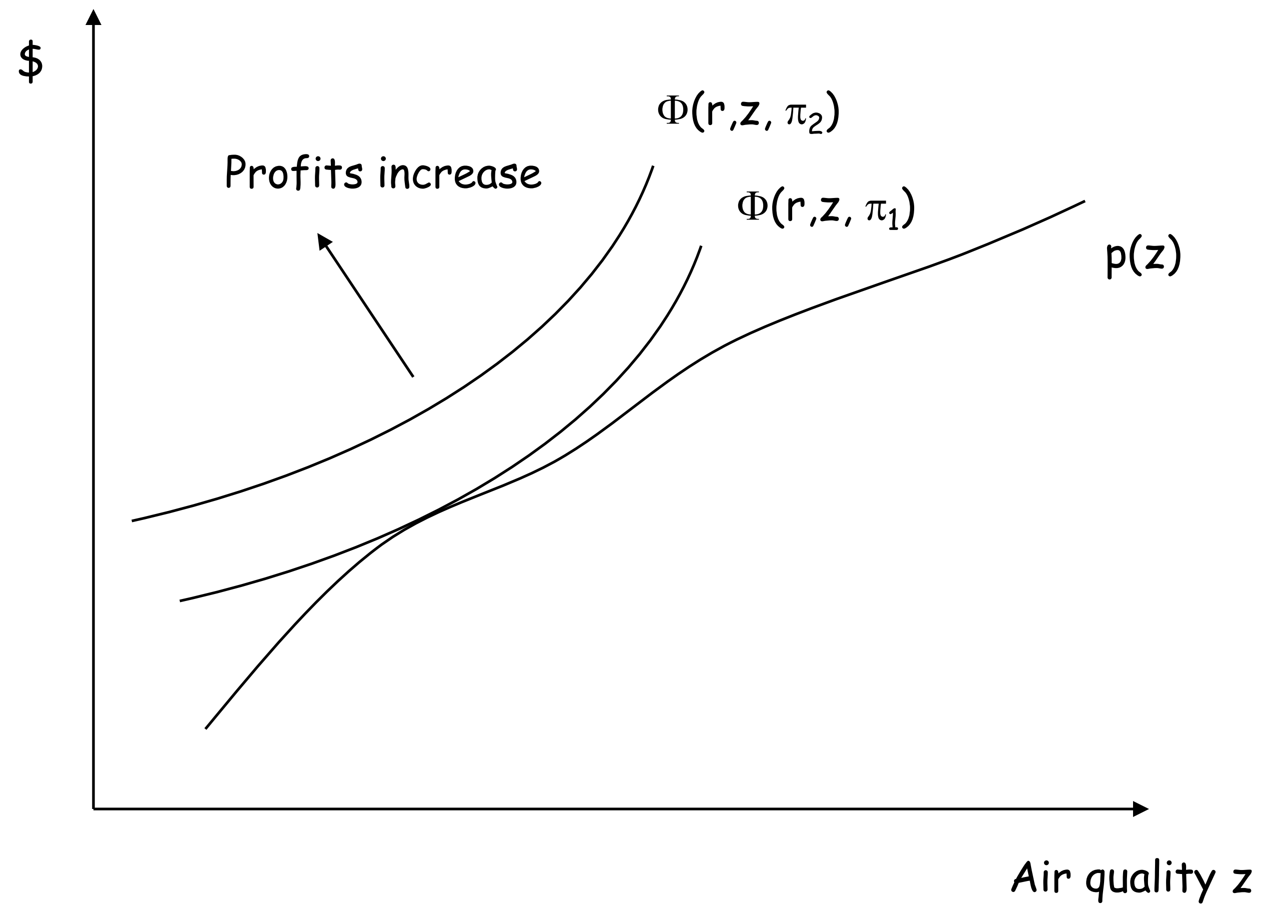
- Alternatively the price to obtain a certain level of profit given a level of z is

$$\Pi = \phi - c(r,z) \Leftrightarrow \phi(r,z,\hat{\Pi})$$

- This is known as the offer function – it tells you the minimum amount a producer is willing to accept as a function of costs and air pollution

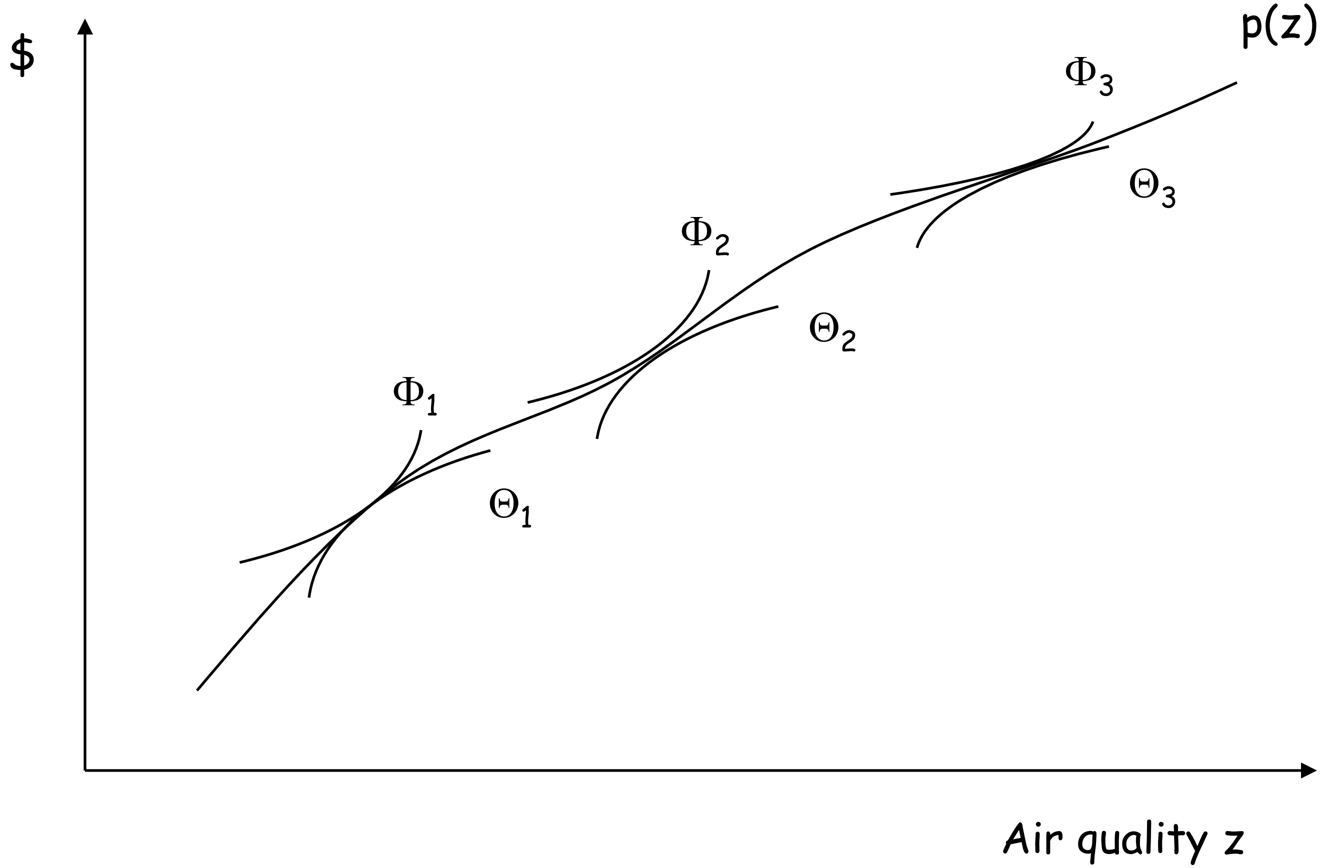
Producer choice

Hedonic price function and two offer functions for two different levels of profit

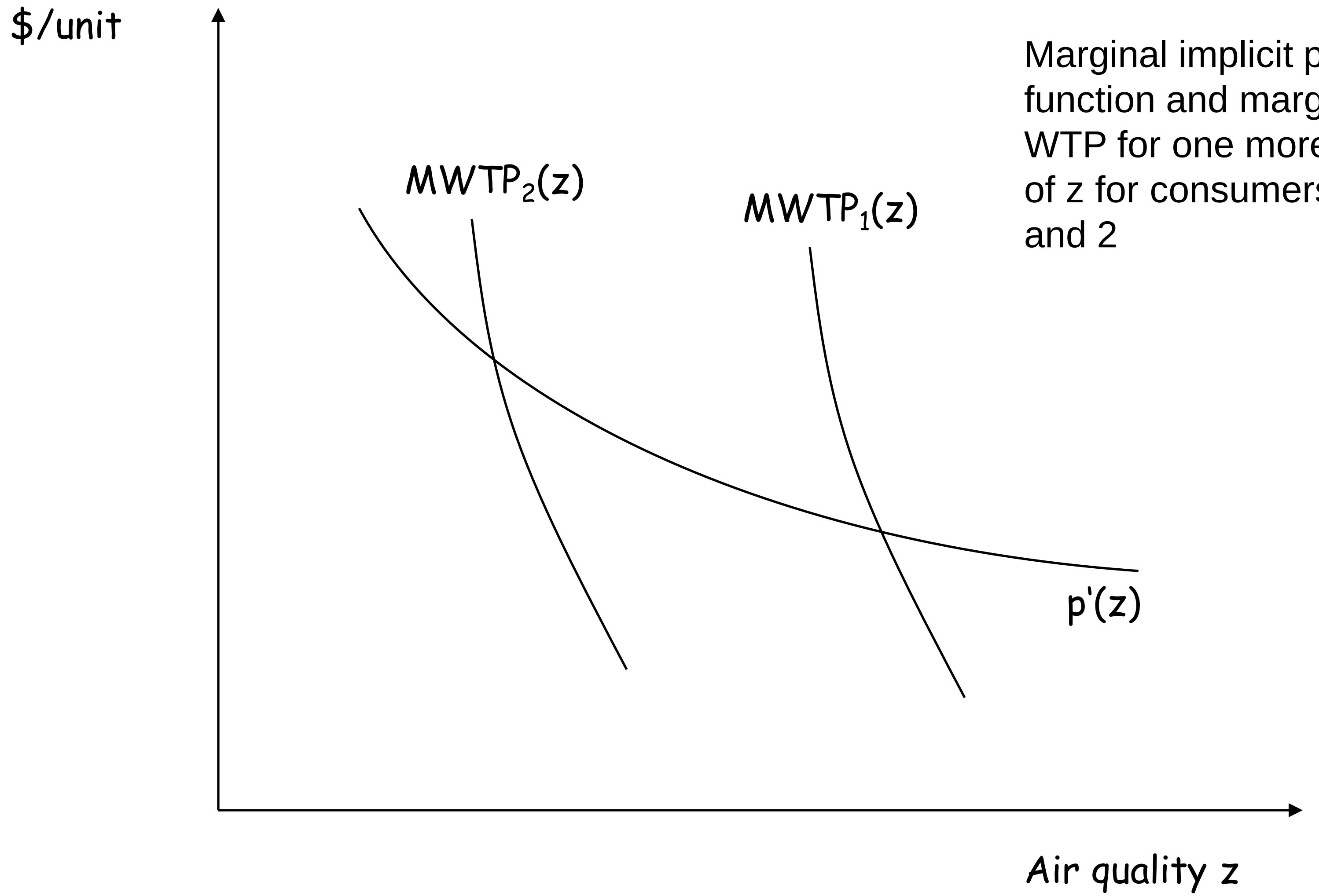


Market equilibrium

In the equilibrium, the marginal bid, the marginal offer, and the house price are identical – all parties in the market value the house the same, at the margin



Willingness to pay



Marginal implicit price function and marginal WTP for one more unit of z for consumers 1 and 2

Step-by-step procedures for calculating of the consumer surplus with hedonic pricing method

1. Define value to be estimated
   – Marginal willingness to pay as revealed by marginal implicit prices

2. Collection of data on prices and houses features
   – Various methods exist to collect these data. For complex studies this data must be complemented with information on the socio-economic characteristics of the households investigated
   – Sales price: preferred measure of value, may need to consider selection bias
   – Tax assessment or homeowner survey of value: measurement error may be a significant concern
   – Rental or lease prices: appropriate for some applications , timing issues can be of concern, care should be taken when interpreting the implicit prices

3. Choose functional form for the hedonic price function
   – Linear usually not appropriate. Non-linear functions imply non-constant marginal prices
   – Semi-log functional form often used, care must be taken when interpreting the coefficient estimates for the dummy variables
   – Researcher judgment must be applied, and expectations about relationships between certain characteristics and sales price will guide choice of functional form

4. Estimation of the house price function
   – This relates the price of houses to the characteristics explaining the house

Step-by-step procedures for calculating of the consumer surplus with hedonic pricing method

5. Calculation of the implicit marginal price of the environmental good for each observation
   - This is the first derivative of the house price function with respect to environmental attribute

6. Estimation of the implicit inverse demand function of the environmental attribute
   - The price paid is explained by the quantity/quality of the environmental attribute but also by the socio-economic characteristics of the households

7. Calculation of the consumer surplus
   - Integration of the implicit demand curve between the former level of environmental quality/quantity and the new one
   - For localized changes in amenities, the change in sales price resulting from the change in the amenity is the measure of net-benefits if there are no transactions costs associated with moving between properties. If there are transactions costs, the change in the price net of transaction costs measures net benefits (or is an upper bound on net benefits)
   - For non-localized changes in amenities, a second-stage demand analysis is most appropriate for computing a bound on net-benefits

Rosen's model

- Consumers (buyers) have a utility function:

  U(s,n,c)

  s = house characteristics
  n = characteristics of the area where the house is located
  c = other consumption goods

- Budget constraint:

  m = c + p(s,n)

  – *m* = income
  – *p(s,n)* expenditure for a house
  – *p(s,n)* is assumed to change in a non linear relationship with the characteristics of houses. That is, the cost of houses change in an unknown relationship with number of rooms, etc.
  – *c* is the expenditure for all other goods

- The maximization of the utility function subject to the budget constraint, gives the usual first order conditions.

  That is, the marginal rate of substitution between each characteristic *n* and the consumption of other goods is equal to the 'price' (coefficient) of *n* and the price of *c*.

- The price of *c* is our numeraire and we put it equal to 1.
- The price of *n* describes the price of a **marginal change** in n.
- The first order conditions are:

$$\frac{U_n(s,n,c)}{U_c(s,n,c)} = p_n(s,n)$$

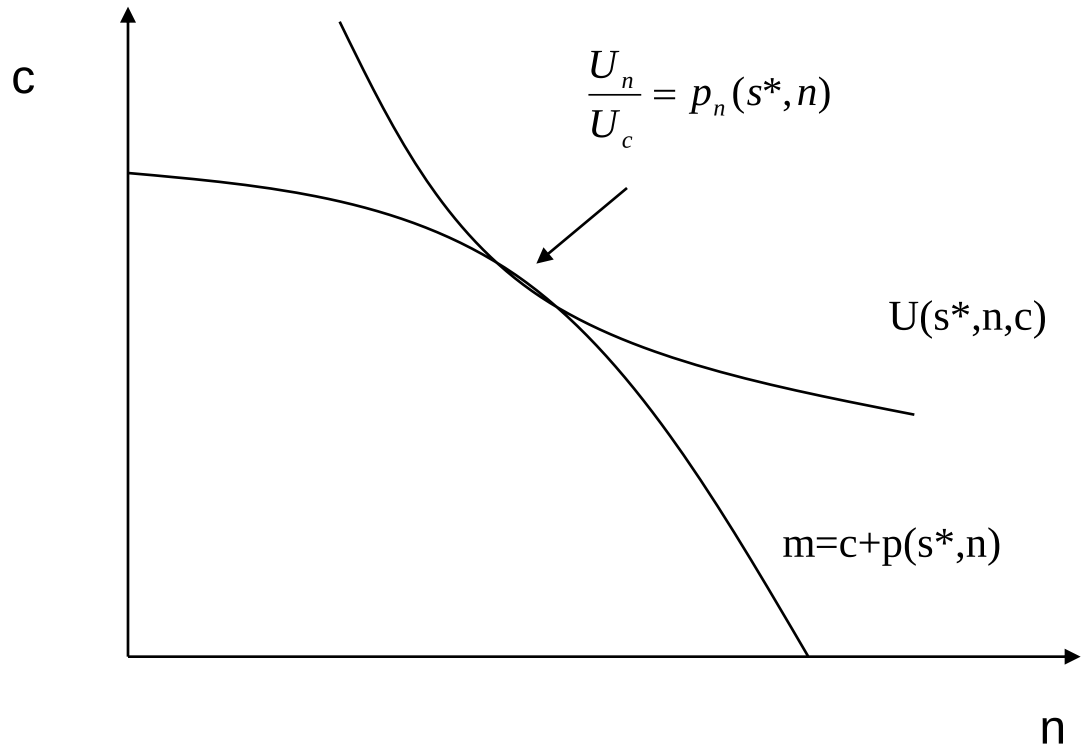
- (U_n is the partial derivative of *U* with respect to *n*)

$$p_n = \frac{\partial p(s,n)}{\partial n}$$

- First order conditions simply say that the consumer (buyer) is willing to pay p_n for a marginal change of *n*

Utility maximization and budget constraint

- This looks like a normal example from your microeconomic class. We only add a non linear constraint for a given value of s, s*:



The hedonic price function

- The function that describes how housing price changes when housing characteristics change:

  p(s,n)

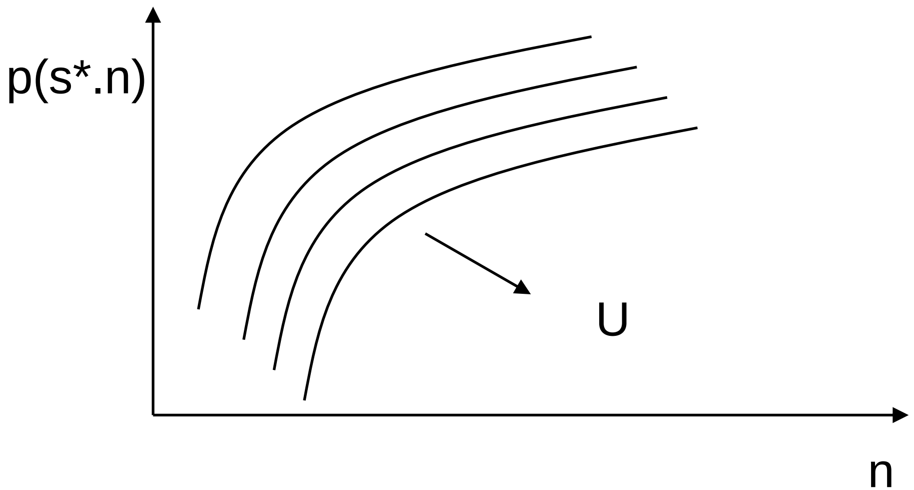
  is the hedonic price function

- The derivative of the function with respect to one of the characteristics *n* is the 'implicit price' of *n*.
- If we knew the hedonic price function and the implicit price of *n*, we could estimate buyers' WTP for n, given that this is equal to the marginal rate of substitution between *n* and the other goods (numeraire)

Indifference curves

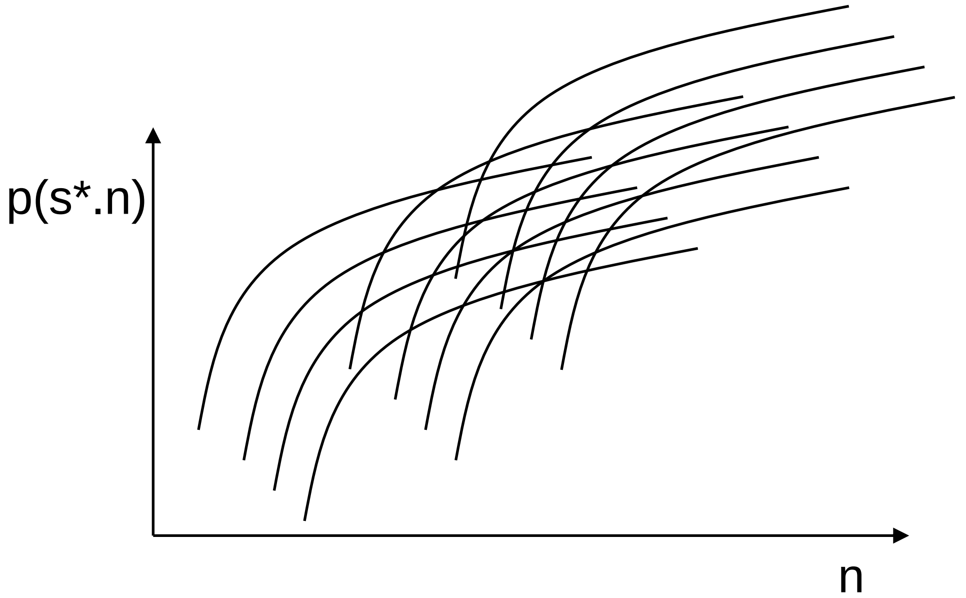
- The budget constraint says that what we don't spend for other goods is spent for housing:

  p(s,n): c = m – p(s,n)
- The utility function can be written in this way:
- U(s,n,c)=U(s,n,m – p(s,n))
- Therefore we can describe the utility function of consumers (buyers) with indifference curves (for given values of *m* and *s*):
- Each indifference curve gives for a constant level of utility the expenditure on housing and *n* for a given level of income and *s*.



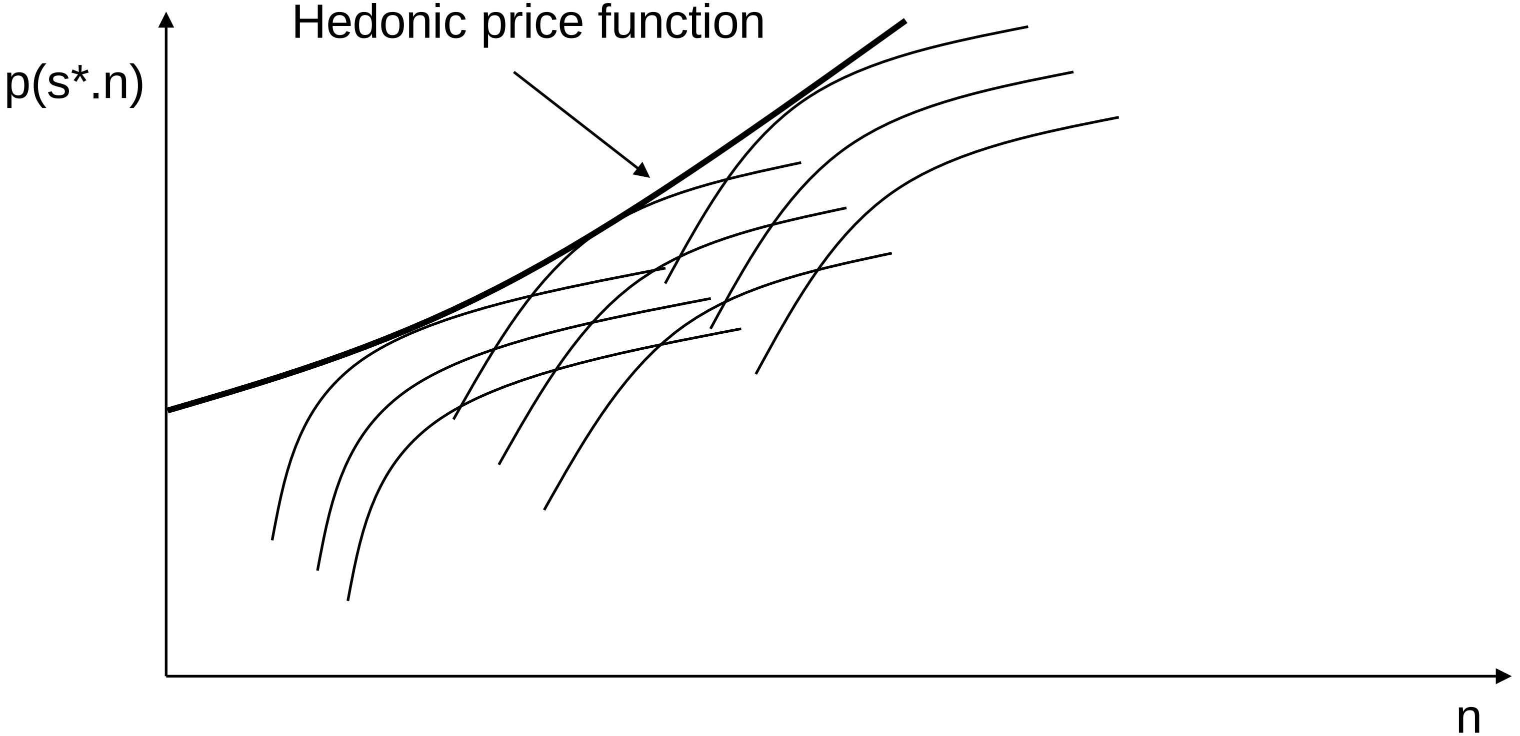
Heterogeneous consumers

- People with different incomes have different indifference curves, even if they have the same preferences (U has the same functional form for all respondents)
- People with different preferences have different indifference curves
- In a world of heterogeneous consumers (buyers) that have different levels of income, we have a continuum of indifference curves:



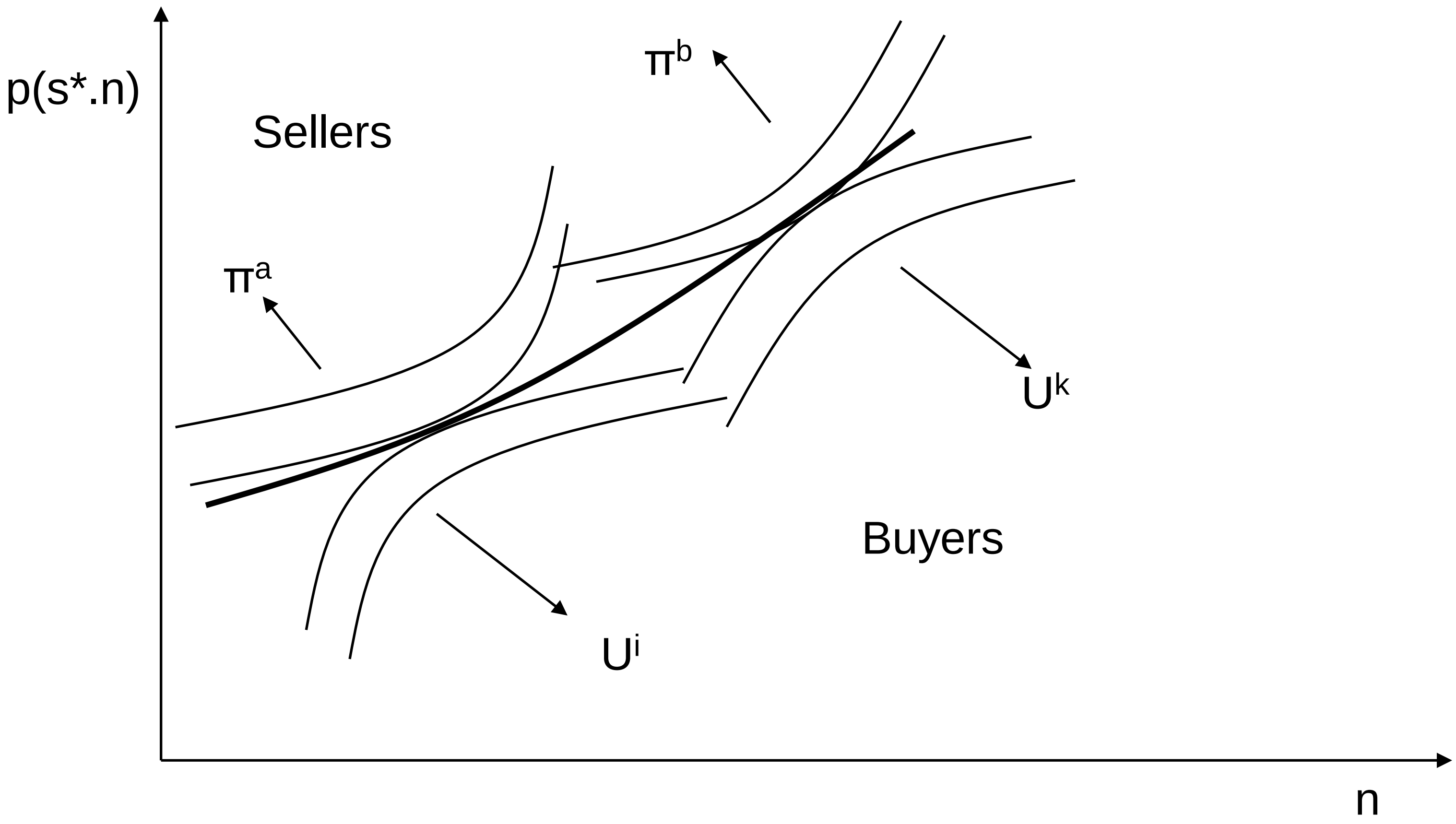
Hedonic equilibrium

- Suppose that consumers (buyers) consider exogenous the hedonic price function
- Consumers (buyers) maximize utility subject to the budget constraint and to the hedonic price function:



Hedonic equilibrium considering the supply

- The hedonic price function comes from the equilibrium of demand and supply of housing. Both are considered exogenous.
- Sellers have isoprofit curves (π)



Marginal Willingness To Pay

- The main characteristic of the model is that buyers and sellers are efficiently matched along the hedonic price function

- At any point along the hedonic price function, buyers marginal willingness to pay (and sellers willingness to accept) for a change in *n* is given by the derivative of the hedonic price function with respect to *n*.
- This implicit price changes with n if the hedonic price function is non linear.

- The model can be generalized to the case where we consider several characteristics of residential properties and of the area where houses are located:

  $p(x_1,x_2,\ldots x_k)$

The Basic Hedonic Pricing Method

- A differentiated or heterogeneous commodity is one in which the characteristic of the good are fundamental to its value
- All goods are heterogeneous top a certain extent but heterogeneity is particularly apparent in the housing market
- The hedonic function is a mathematical form that links the characteristics, defined as X t the price of the house, P.
- Thus we can present the hedonic function: P=H(X)

Linear function

- The easiest way of hedonic function is a linear function:

$$p_i = \alpha + \beta_1 x_{1i} + \beta_2 x_{2i} + \ldots + \beta_k x_{ki} + \varepsilon_i$$

- Where x_1 through x_k are the attribute levels for k selected attributes, α, β_k through β_k are coefficients.
- Suppose that x_1 is land area. The equation tells us that if x_1 goes up by one square metre, the price of the house rises by β_1 dollars. It means that: $$\frac{\partial P}{\partial x_{1i}} = \beta_1$$
- i.e. the change in P is due to a change in x is constant and equal to β_1 , holding all other independent variables constant.
- The question is how to determine the hedonic prices for a particular housing market
- In empirical work, multiple regression analysis is used
- If we were to value the environmental asset or resource, one of the independent variables should include environmental characteristic, such air quality, percentage of tree cover, percentage of view, etc

Model estimate

- Now we need to specify a functional form for p.
- Some possible functional forms are given in the next slide
- A common functional form is the semi-log:

$$\ln p_i = \alpha + \beta_1 x_{1i} + \beta_2 x_{2i} + \ldots + \beta_k x_{ki} + \varepsilon_i$$

- The coefficients of the regression function give the implicit price, in natural logarithm terms, of the characteristics of the house
- The implicit price can be estimated for specific value of the characteristics of houses (for example, the average value)
- For the semi-log function, the implicit price of x_1 is given by:

$$\frac{\partial p}{\partial x_1} = p\beta_1$$

- β_1 gives the percentage change in the price of housing given a percentage change in x_1
- We usually estimate the implicit price at the average value of housing

Functional Forms for the Hedonic Price Function

Name	Equation	Implicit Price
Linear	$P = \alpha + \sum \beta_i z_i$	$\frac{\partial P}{\partial z_i} = \beta_i$
Semi-log	$\ln P = \alpha + \sum \beta_i z_i$	$\frac{\partial P}{\partial z_i} = \beta_i . P$
Double-log	$\ln P = \alpha + \sum \beta_i \ln z_i$	$\frac{\partial P}{\partial z_i} = \beta_i . \frac{P}{z_i}$
Quadratic	$P = \alpha + \sum_{i=1}^{N} \beta_i z_i + \frac{1}{2} \sum_{i=1}^{N} \sum_{j=1}^{N} \delta_{ij} z_i z_j$	$\frac{\partial P}{\partial z_i} = \beta_i + \frac{1}{2} \sum_{j \neq i} \delta_{ij} z_j + \delta_{ii} z_i$
Quadratic Box-Cox[a]	$P^{(\theta)} = \alpha + \sum_{i=1}^{N} \beta_i z_i^{(\lambda)} + \frac{1}{2} \sum_{i,j=1}^{N} \delta_{ij} z_i^{(\lambda)} z_j^{(\lambda)}$	$\frac{\partial P}{\partial z_i} = (\beta_i z_i^{\lambda-1} + \frac{1}{2} \sum_{j=1} \delta_{ij} z_j^{\lambda-1} z_j) P^{1-\theta}$

[a] The transformation function is $P(\theta)=(P^{\theta}-1)/\theta$ for $\theta \neq 0$, and $P(\theta)=\ln(P)$ for $\theta=0$. The same transformation applies to lambda. The marginal effect is computed for $\theta \neq 0$. The marginal effect when $\theta=0$ and $\lambda=0$ is the same for the double log. The quadratic Box-Cox is equivalent to the linear Box-Cox, another common functional form when $\delta_{ij}=0$ for all i and j. The marginal price of the linear Box-Cox is simply $\beta_i z_i^{\lambda-1} P^{1-\theta}$

Some limitations and assumptions

- Perfect information:
  - Buyers observe the characteristics of houses and are able to perfectly describe the hedonic price function
- Buyers can purchase whatever combination of characteristics they desire.
  - They can always find the combination of bedrooms, bathrooms, location of the house that they want
- Implicit prices allow us only to assess **marginal** variations in the characteristics of houses (but if we consider that all buyers are identical then we can consider non marginal changes as well – too strong assumption!)
  - Example: if the average house has 3 bedrooms and costs X, I cannot say that buyers are willing to pay Y for a house that has 7 bedrooms. We can't say that an increase of 4 bedrooms is a marginal change
- The estimate of non-marginal variations requires the estimate of individual demand parameters, which is very difficult

Econometric problems

- Multicollinearity
  - if a house has several bedrooms, it will likely have several bathrooms, etc.
  - distances: don't use too many distances in your function
- Heteroskedasticity
- Spatial autocorrelation
  - The value of one house will be influenced by the value of surrounding houses
- Market extension: homogeneous markets => bias
- If I only use the data of sold properties and do not consider the characteristics of unsold properties, my coefficient can be biased (sample selection bias)
  - Solution: 2 steps estimate 1) Probit model for the probability of a sale with both sold and unsold properties 2) regression model with only sold properties + Inverse Mills Ratio calculated in 1. Check if the coefficient of the inverse mills ratio is significantly different from zero. If it is not, then delete it from the regression

Welfare Measurement with Hedonic Price Function

- Econometric model shows the implicit price of amenity I is equal to the consumer's marginal WTP for the amenity
- Implicit prices are most commonly reported result from hedonic studies
- If we were the value of consumers might place on a change in an environmental amenity, need to find the relationship between implicit prices and WTP for the change. This depends on the situation.
- Two changes:
  - Change in localized amenity (e.g. highway noise, hazardous waste, incinerator, local parks). Affects a small number of properties → equilibrium hedonic price function for the entire market is unaffected
  - Change in non-localized amenity (e.g. air quality). Amenity change affects a large number of houses → shift in supply will occur, thus we would expect a change in market equilibrium hedonic price function

Welfare Measurement with Hedonic Price Function

Change in localized amenity

- First: Effect of renters, no transaction costs
  - Decrease in amenity→ renter is no longer at the optimal solution, face the same hedonic price schedule as before the change at their home
  - If no transaction cost → no change in welfare for the renter
- Owners:
  - Realize a capital loss on the property because the decrease in amenity associated with the property
  - WTP – an amount of money up to the value loss of the property top avoid amenity change → **the implicit price**
  - Total WTP: sum of the implicit prices across property owners that receive a change in the amenity

Example: A hedonic Price Model with Housing Attributes (Haab and McConnel, 2002, p. 264)

- The environmental disamenity is nitrogen reading in well water
- The houses are part of the suburban housing market of Baltimore, Maryland
- When a house with well water is sold, the water must be tested -> test of nitrate levels in the water
- Nitrates stem from excess agricultural nutrients and undesirable for medical reasons
- Standard for nitrates – 10 ppm
- Levels higher than that must be treated
- Illustration is to emphasize the importance of housing attributes
- Dependent variable: Sales price is actual selling price – 1985-1991
- Independent variables: house attributes, neighborhood attributes, scores of third grade students

Hedonic Price Function Variables

Variable	Description	Mean (n=1853)
PRICE	Sales price	202719.00
TIMETREND	Monthly time trend, running from 1 to 84 over months of sales	69.23
NUMBED	Number of bedrooms	3.59
FULLBATH	Number of full baths	1.98
LIVAREA	Square feet of living area	1070.80
LOTSIZE	Lot size in acres	24.10
DIST	Distance to Baltimore	4.04
SCORE	Neighborhood elementary school test score	0.18
NITRATES	Nitrates in well in ppm	4.05
HALFBATH	House on public sewer	0.25
POOLIN	Number of half baths	0.66
HEATPUMP	Inground pool	0.06
PUBSEW	Heatpump	0.49
CARROL	House in Carrol County	0.35
HOWARD	House in Howard Country	0.13
BALTO	House in Baltimore Country	0.28

Welfare measurement: Example (Haab and McConnel, 2002, p. 264)

	Linear Model		Semi-log Model	
Characteristic	**Estimate**	**S.E**	**Estimate**	**S.E.**
TIMETREND	-254.0b	137.9	-0.00014	0.0006
NUMBED	15206a	1856	0.082a	0.008
FULLBATH	22772a	2140	0.127a	0.009
LIVAREA	129.4a	5.45	0.00055a	0.00002
LOTSIZE	4085.2a	291	0.018a	0.0012
DIST	-2042.1a	244	-0.0077a	0.001
SCORE	9123.3a	3672	0.037a	0.016
NITRATES	-1151.5a	384	-0.0036	0.0017
HALFBATH	16805a	1969	0.105a	0.009
POOLIN	8762.4a	4296	0.062a	0.018
HEATPUMP	35270a	2325	0.173a	0.01
PUBSEW	138.0	2436	-0.0002	0.01
CARROL	11752a	2979	0.053a	0.013
HOWARD	59708a	4010	0.254a	0.17
BALTO	22798a	3728	0.103a	0.016
Constant	-57425a	20188	10.78a	0.87
Log-likelihood	-22467.00		421.50	
$-2\ln(L_R/L_U)$	2506.00		2706.00	
Adjusted R^2	0.74		0.76	

a – significant at the 5% level; b – significant at the 10% level

Interpretation from the regression results

Linear Model:

- Marginal value of an extra bedroom is about $15,000 (coefficient of NUMBED). The value of additional full bath is about $22,000 (coefficient of FULLBATH)

Semi-log function

- Provides approximate percent changes in housing prices from a change in the attribute level
- An extra bedroom would imply an increment in price of about $16,500 for a house worth $200,000 (0.082*200,000=16,400)

Valuing Changes in Environmental Disamenity

- Consider environmental disamenity – nitrates in the well water. Increase in nitrates from 10 p to 15 ppm.

Linear model: $WTP = \Delta zc \frac{\partial h(z)}{\partial z_c} = 5 * 1151 = \$5755$

- 95% confidence interval: 5755$\pm$5*19.6*384 = $1992 to $9518

Semi-log model (when price is valued at $200,000)

$$\frac{\partial h(z)}{\partial z_c} * p = -0.0036 * 20{,}000 = -\$720$$

$$WTP = 5 * 720 = \$3600$$

$$CI = 20000 * (0.0036 \pm 1.96 * 0.0017) * 5$$

$$= \$268 \text{ to } \$6932$$

Further readings:

- Haab, T. C., & McConnell, K. E. (2002). *Valuing environmental and natural resources: the econometrics of non-market valuation*. Cheltenham: Edward Elgar Publishing. ISBN: 1 84064 7043 5

- Taylor, L.O. (2003). The hedonic price. In P.A. Champ, K.J. Boyle & T.C. Brown, (Eds.), *A primer on nonmarket valuation* (Vol. 3) (pp.331-394). Dordrecht, The Netherlands: Kluwer Academic Publishers. ISBN 0-7923-6498-8