Hedonics and Sorting

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Definitions

- **Hedonics:** Anything involving a function relating amenities to prices
- **Sorting:** Heterogeneous households demanding different levels of amenities

Motivation

- Why study hedonics and sorting?
- Applications in urban economics, housing policy, environmental economics
- Benefits:
  - Economically rich
  - Econometrically tractable
  - Policy relevant
- Extremely popular:
  - Rosen (1974) has $\approx$ 17,000 citations
  - Tiebout (1956) has $\approx$ 26,000 citations

General Research Framework

1. Define the question (e.g., model)
2. Determine identification
3. Estimate

Outline

1. Preliminaries
2. Question(s) of Interest
3. Hedonic Model of Sorting
4. Best Practices and Pitfalls
5. Non-marginal Analysis
6. Extensions

Outline

Predictive Relationship Between Amenities and Price

- $P = g(Z; \gamma) + \epsilon$
  - Linear form: $P = \gamma_0 + \gamma_1 Z + \epsilon$
- Regression parameters (γ) describe prediction, not causation
- Identification is free, but question is limited
- Useful for property assessment
  - In fact, may want predictive, and not causal, effect of Z on P

Price Indices

- Early work focused on constructing indices
  - Griliches (1961)
- Unclear whether want predictive or causal effects
- Used to create house price indices
  - Laspeyres, Paasche, Fisher

Causal Relationship Between Amenities and Price

- $P = f(Z; \beta) + u$
  - Linear form: $P = \beta_0 + \beta_1 Z + u$
- Interesting:
  - Practitioner
  - Policy maker
  - Provide information
    - Chetty et al. (2025): Opportunity Atlas
    - Bishop, Kuminoff, Mathes, Murphy (2024): price of mortality

Causal Relationship Between Amenities and Price

- $P = f(Z; \beta) + u$
  - Linear form: $P = \beta_0 + \beta_1 Z + u$
- Interesting:
  - Practitioner
  - Policy maker
  - Provide information
    - Chetty et al. (2025): Opportunity Atlas
    - Bishop, Kuminoff, Mathes, Murphy (2024): price of mortality
  - **Infer demand / welfare analysis**

Inferring Demand

Two reasons to be optimistic that we can learn something about demand:

1. Prices determined by demand and supply
2. Atomistic agents take price as fixed and optimize given their preferences

Outline

Question(s) of Interest

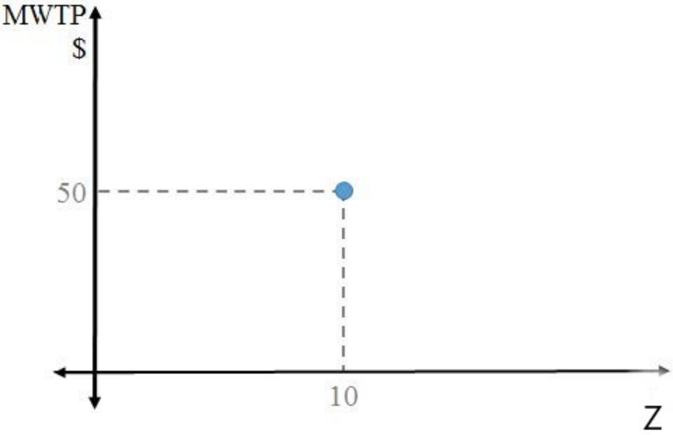
What is the key question of interest?

- Willingness to pay for marginal changes?
  - i.e., demand/marginal willingness to pay at point of consumption
- Willingness to pay for non-marginal changes?
  - i.e., demand/marginal willingness to pay function

Welfare Analysis and Marginal Willingness to Pay Function

- For example:
  - Household i consumes 10 units of amenity Z
  - MWTP for household i at Z=10 is \$50, i.e. $MWTP(10) = \$50$
- Household i would be willing to pay \$50 to increase Z from 10 to 11
  - where 1 unit is a marginal change

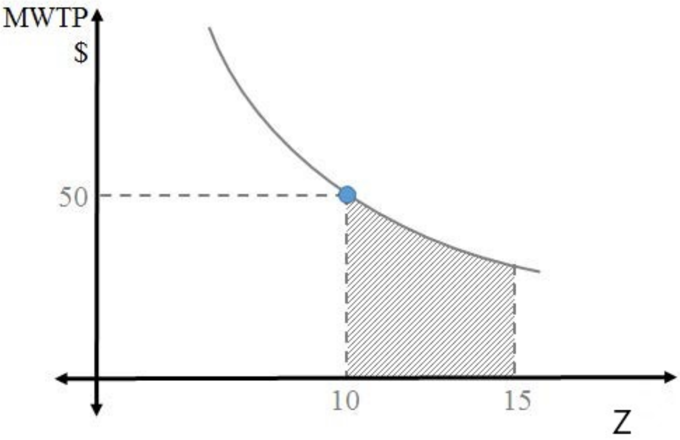
Welfare Analysis and Marginal Willingness to Pay Function



Welfare Analysis and Marginal Willingness to Pay Function

- What would be the willingness to pay to increase Z from 10 to 15?
  - Corresponds to area under MWTP function
  - Need to know the MWTP **function**

Welfare Analysis and Marginal Willingness to Pay Function



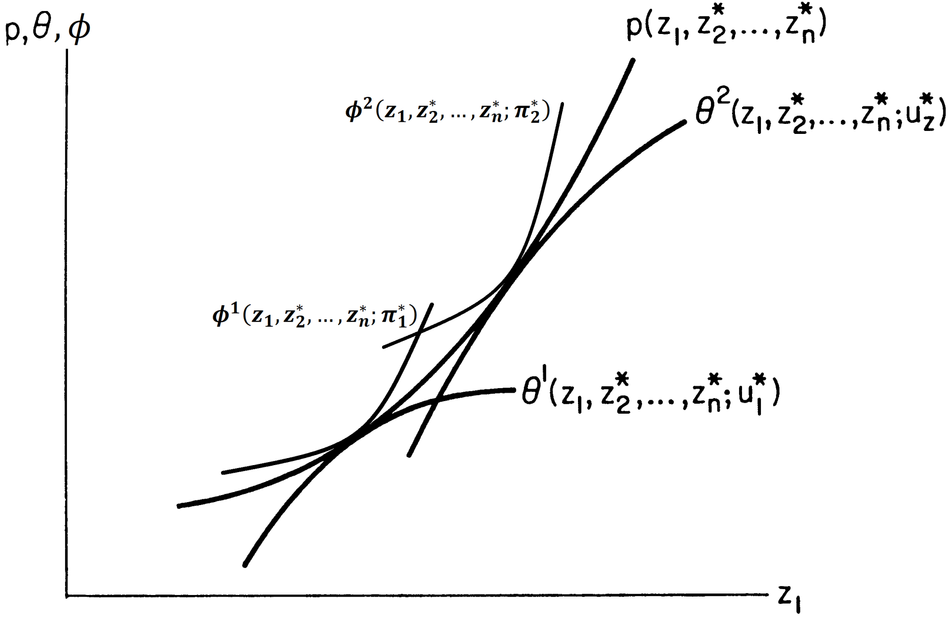
Welfare Analysis and Marginal Willingness to Pay Function

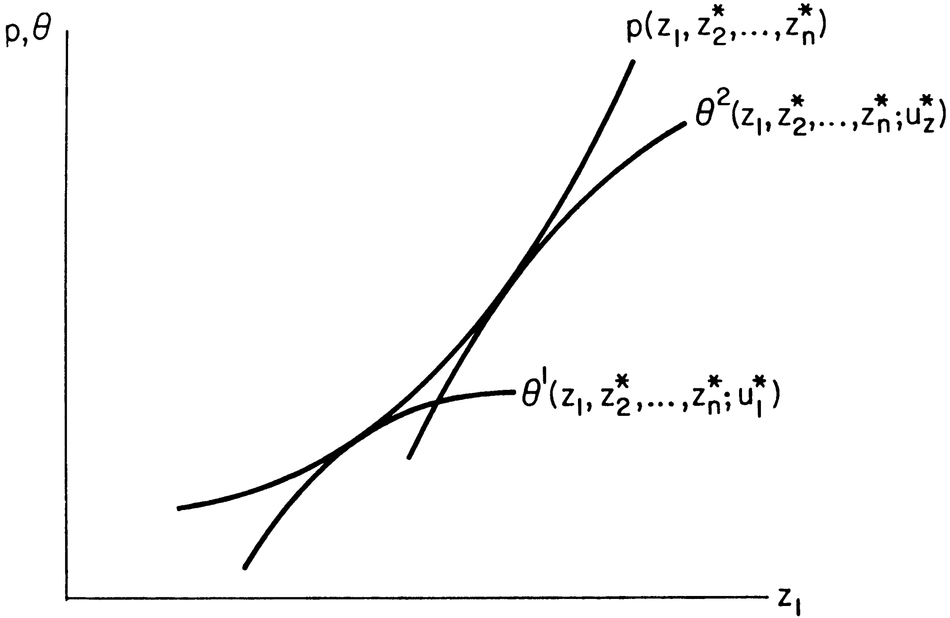
- Obvious questions for us:
- What are benefits and costs of identifying/estimating
  - $MWTP(Z_i^*)$
  - $MWTP(Z)$
- It is first worth thinking about where the price function comes from
  - Rosen (1974)
  - Diagrams
  - Algebra

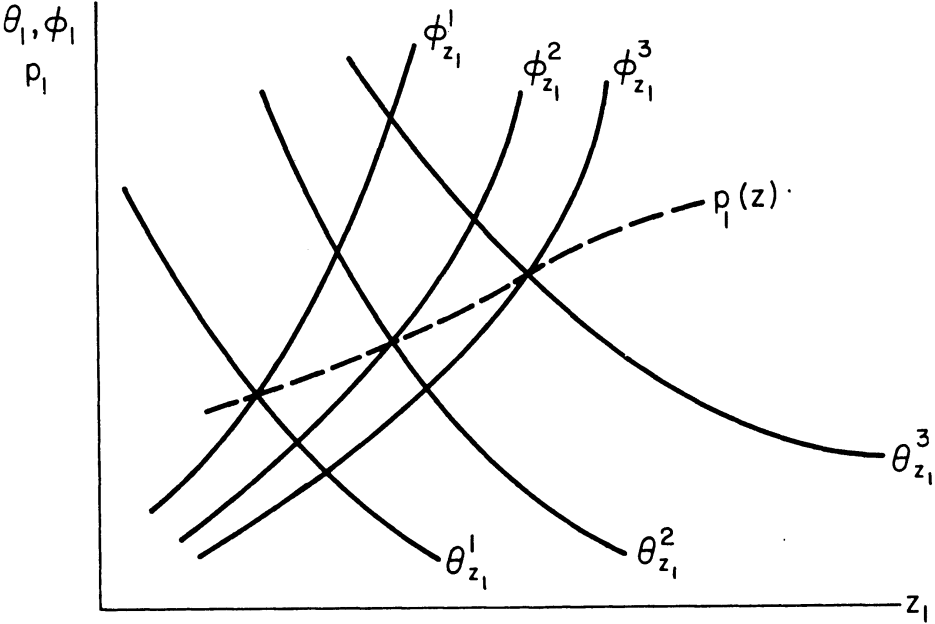
Outline

But first some background on what is a Hedonic Model?

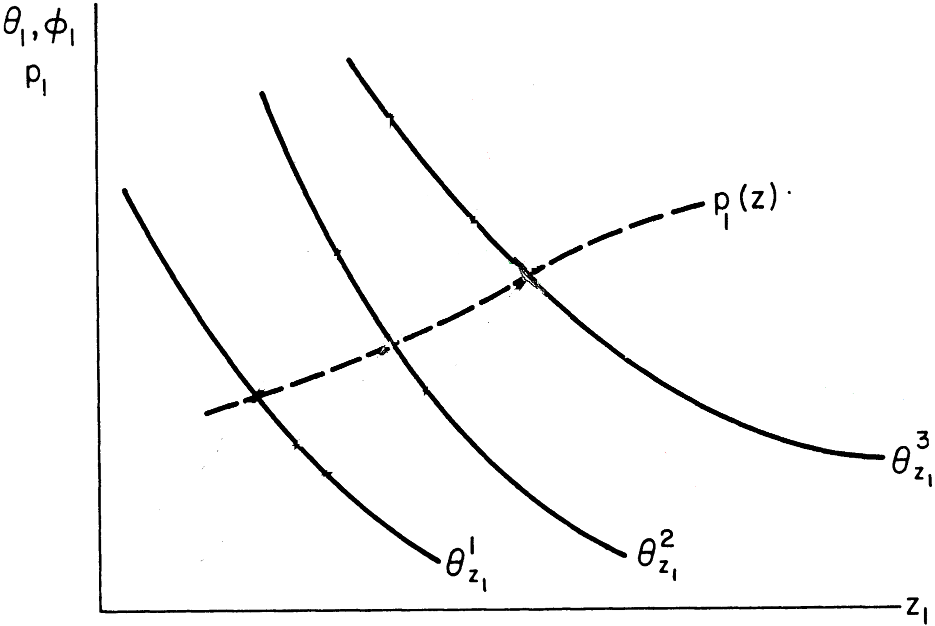
- Model of differentiated products
- Price reflects bundle of characteristics
- Historical origins:
  - Waugh (1929), Court (1939), Griliches (1961)
  - Lancaster (1966): utility over characteristics
  - Rosen (1974): equilibrium of bid and offer functions

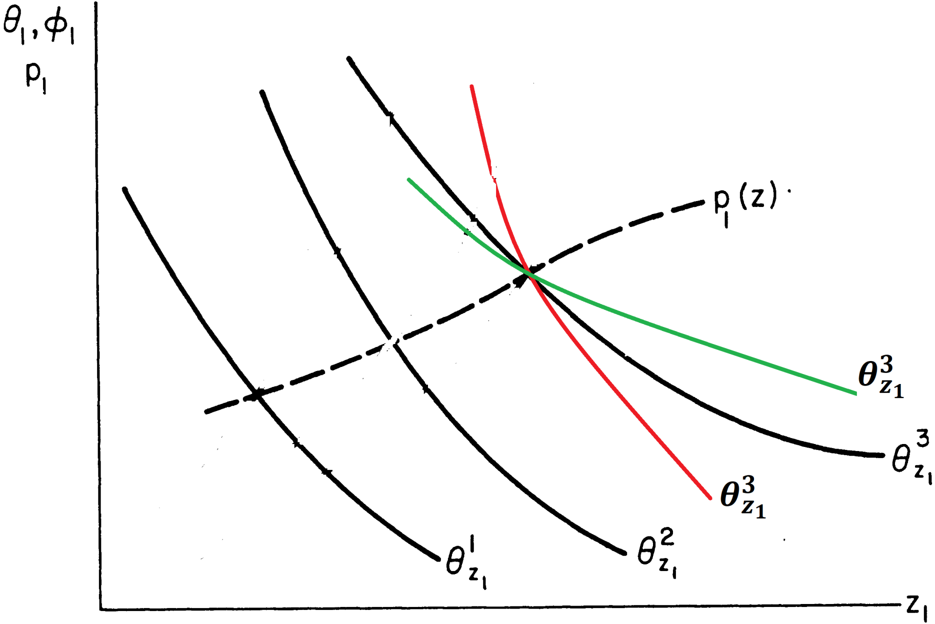

p, θ, φ
p(z1, z2*, ..., zn*)
φ2(z1, z2*, ..., zn*; π2*)
θ2(z1, z2*, ..., zn*; uz*)
φ1(z1, z2*, ..., zn*; π1*)
θ1(z1, z2*, ..., zn*; u1*)
z1


p, θ
$p(z_1, z_2^*, \ldots, z_n^*)$
$\theta^2(z_1, z_2^*, \ldots, z_n^*; u_z^*)$
$\theta^1(z_1, z_2^*, \ldots, z_n^*; u_1^*)$
z_1

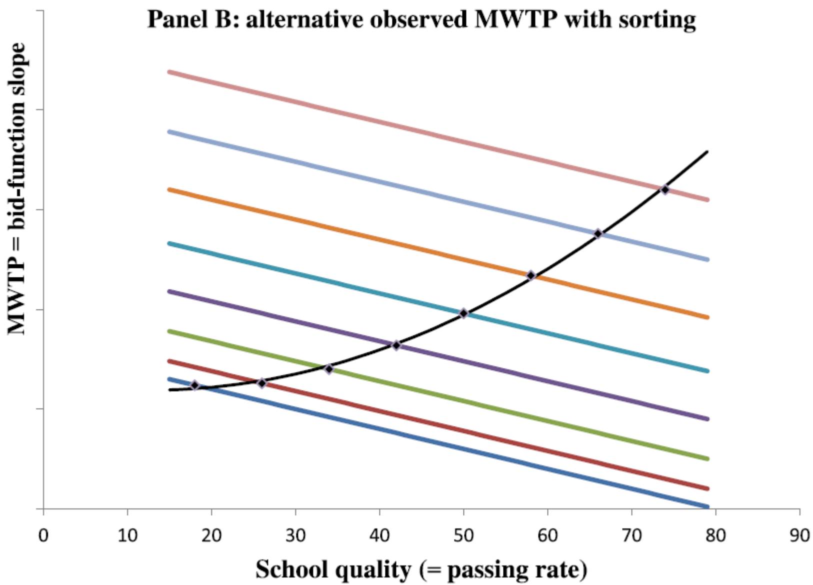


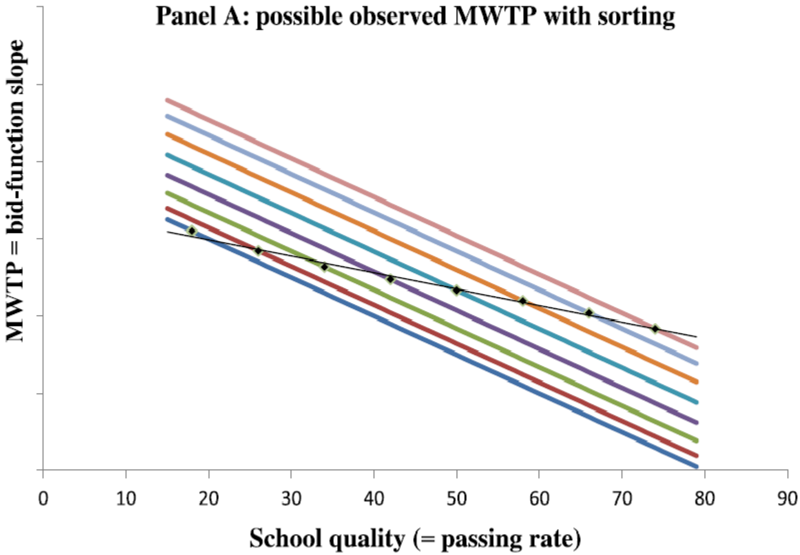
θ_1, ϕ_1
p_1
$\phi^1_{z_1}$
$\phi^2_{z_1}$
$\phi^3_{z_1}$
$p_1(z)$
$\theta^3_{z_1}$
$\theta^1_{z_1}$
$\theta^2_{z_1}$
z_1


θ_1, ϕ_1
p_1
$p_1(z)$
$\theta^1_{z_1}$
$\theta^2_{z_1}$
$\theta^3_{z_1}$
z_1



θ_1, ϕ_1
p_1
$p_1(z)$
$\theta_{z_1}^3$
$\theta_{z_1}^3$
$\theta_{z_1}^3$
$\theta_{z_1}^1$
$\theta_{z_1}^2$
z_1


Panel B: alternative observed MWTP with sorting
MWTP = bid-function slope
0
10
20
30
40
50
60
70
80
90
School quality (= passing rate)


Panel A: possible observed MWTP with sorting
MWTP = bid-function slope
0
10
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School quality (= passing rate)

Hedonics – Model

- $i = 1, \ldots, N$ indexes households
- House characteristics P, Z, and ϵ.
  - P: price
  - Z: amenity of interest
  - ϵ: unobservable housing and neighborhood amenities.
- Individual characteristics
  - I: Income
  - X: observable individual characteristics,
  - ν: unobservable preference for Z

Hedonics – Model

- Households take the hedonic price function as given.
- Households choose Z to maximize utility
- Household preferences are determined by a vector of observed household characteristics, X, and unobserved taste shifters, ν.
- X and ν are typically assumed to be orthogonal in the hedonic model

Hedonics – Model

- The price function is known up to the parameter vector β

$$P = P(Z_i, \epsilon_i; \beta)$$

- The utility function is known up to the parameter vector α

$$U = U(Z_i, \epsilon_i, C_i, X_i, \nu_i; \alpha)$$

- Budget constraint with price of numeraire consumption normalized to one.

$$I_i \geq P(Z_i, \epsilon_i; \beta) + C_i$$

Hedonics – Model

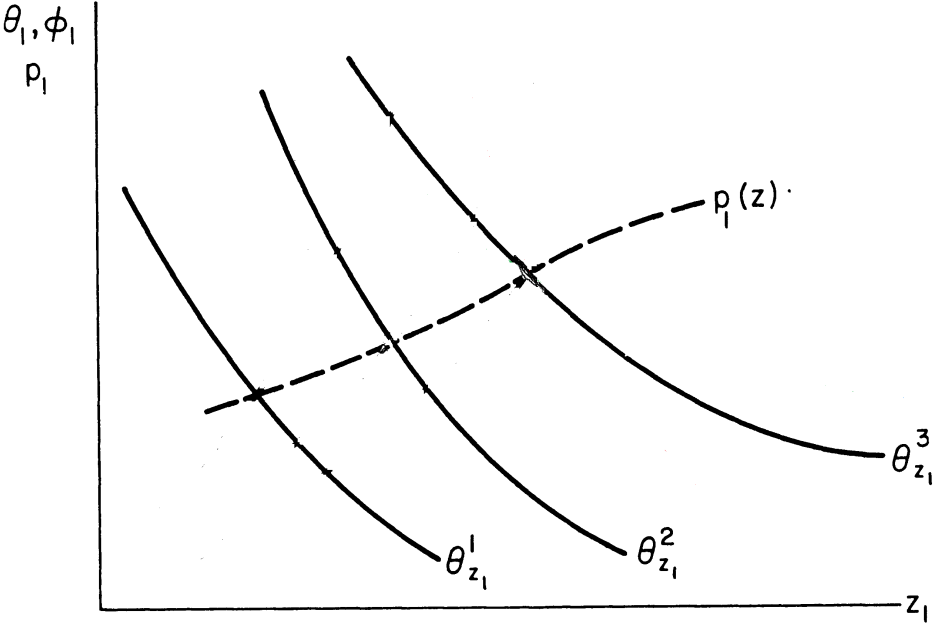
- By definition, the MWTP function is slope of indifference curve (at optimum):

$$\frac{\partial U_i/\partial Z}{\partial U_i/\partial C} \equiv MWTP(Z_i; X_i, \alpha, \nu_i)$$

- Maximizing utility yields first order condition:

$$\partial P_i/\partial Z^* = \frac{\partial U_i/\partial Z^*}{\partial U_i/\partial C^*}$$

- Price gradient at point of consumption equals MWTP at point of consumption.


θ₁, φ₁
p₁
p₁ (z)
θ^3_{z₁}
θ^2_{z₁}
θ^1_{z₁}
z₁

Outline

Estimating Causal Effect of Amenity on Price

- Recap: If $P(Z)$ is known, then $MWTP(Z_i^*) = P'(Z_i^*)$
  - Rosen First Stage
- Ignore issues of estimating full MWTP function for now
  - Rosen Second Stage
- $P(Z)$ is a causal function
- Focus on econometric and economic issues in estimating $P(Z)$

Best Practices and Pitfalls – Market Definition

- Market definition
- Data Collection
- Functional Form
- Controls
- Omitted Variable Bias
- Diff-in-Diff
- Average MWTP
- Bishop et al. (2020), Yinger and Nguyen-Hoang (2015)

Best Practices and Pitfalls – Market Definition

- Should be defined so that "law of one price function" holds
  - Identical houses should sell for same price
- Single metro at single point
- Beware other margins of adjustment
  - Moving costs, wages, taxes
  - Single metro should ameliorate this
- Longer time periods problematic if function time-varying
- Careful use of econometric flexibility across space/time may also be used
  - Still somewhat difficult to justify

Best Practices and Pitfalls – Data Collection

- Gold standard is transactions data
  - Coverage not fully national
  - Merge in buyer characteristics (HMDA merge, BMMT (2016))
- Method of assigning amenity to house is key
  - Frequently difficult
- Predicted values may introduce non-random measurement error
  - e.g. Census self-reports, appraisals
- Spatially aggregated data have unknown mapping to a hedonic price function
  - e.g. Means or medians

Best Practices and Pitfalls – Functional Form

- Shape of price function depends on market primitives
- EHN (2004) show price gradients are generically nonlinear
- Ideally, price function would be nonparametric
  - As usual, non-parametric approaches comes with costs
  - Bajari and Kahn (2005) estimate a “flexible” local-linear function
- Linear price functions should be avoided
  - Imply limited forms of sorting or strong supply conditions
  - Supply may be considered fixed in many urban settings
  - Sometimes justified as estimating average gradient/MWTP

Best Practices and Pitfalls – Controls

- Ideally like to control for many other amenities
  - Standard selection-on-observables reasons
- Tension with desire for flexibility
  - Clapp (2004) and BT(2019) use Robinson-style semi-parametric approaches
- Buyer attributes should not be included
  - Want to estimate price function, not bid function
  - Tests of discrimination are a separate question
- What about neighborhood demographics, e.g., average neighborhood income?

Best Practices and Pitfalls – OMV

- Kuminoff, Parmeter, Pope (2010) recommend using fine spatial fixed effects
  - Yinger and Nguyen-Hoang (2015) recommend caution
- Matching (e.g. Walls et al. 2017)
- Boundary discontinuity (e.g. Black 1999)
- Instrumental variables (e.g. Chay and Greenstone 2005)
- Repeat sales (e.g. Davis 2004)

Best Practices and Pitfalls – Diff-in-Diff

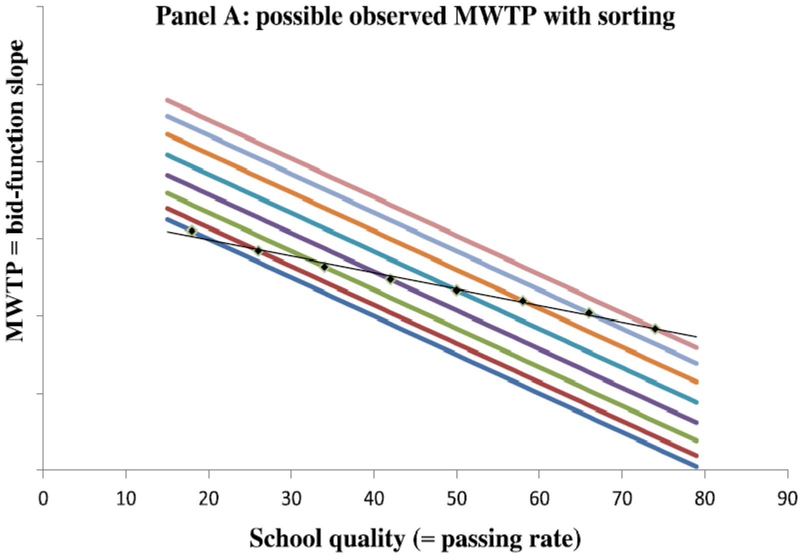
- Diff-in-Diff (or first difference) requires stability of price function

$$\begin{aligned} \text{Period 1 price function:} \quad & P_1 = \beta_1 Z_1 + u_1 \\ \text{Period 2 price function:} \quad & P_2 = \beta_2 Z_2 + u_2 \\ \text{First-difference:} \quad & \Delta P = \beta_2 Z_2 - \beta_1 Z_1 + u_2 - u_1 \\ \text{Capitalization model:} \quad & \Delta P = \phi \Delta Z + \Delta u \end{aligned}$$

- What does ϕ represent when $\beta_1 \neq \beta_2$?
- Kuminoff & Pope (2014) show amenity shocks generate temporal instability

Best Practices and Pitfalls – Average MWTP

- Interpretation of linear price function as average MWTP
- Why do it?
- Econometrcially wrong
  - OLS yields BLP of price function, not BCP of derivative
  - Quadratic e.g. $\beta_1 + 2\beta_2 \bar{Z} \neq Cov(P, Z)/Var(Z)$
- Average MWTP may not be an interesting object
  - May not be policy relevant
  - Cannot be compared across scenarios


Panel A: possible observed MWTP with sorting
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Outline

Why MWTP Function Matters

- Needed to evaluate non-marginal policy changes
- Use in welfare analysis and cost-benefit analysis

Hedonics – Parameterized Model

- For simplicity, parameterize quasi-linear utility as:

$$U = \alpha_{0,j} + \alpha_{1,j} Z_{i,j} + \frac{1}{2}\alpha_{2,j} Z_{i,j}^2 + \alpha_{3,j} X_{i,j} Z_{i,j} + \nu_{i,j} Z_{i,j} + \left(I_{i,j} - P(Z_{i,j}, \epsilon_{i,j}; \beta_j)\right)$$

  where j indexes market (e.g., city or year)

$$\alpha_{1,j} + \alpha_{2,j} Z_{i,j} + \alpha_{3,j} X_{i,j} + \nu_{i,j} \equiv MWTP(Z_{i,j}; X_{i,j}, \alpha_j, \nu_{i,j})$$

- The FOC for a household's optimal choice of Z is then given by:

$$P'(Z_{i,j}; \beta_j) = \alpha_{1,j} + \alpha_{2,j} Z_{i,j} + \alpha_{3,j} X_{i,j} + \nu_{i,j}$$

Hedonics – Early Estimation

- Traditional Rosen (1974) estimation strategy
  - First isolate $P'(Z;\beta)$ as the dependent variable
  - Replace $P'(Z;\beta)$ with an estimate from a first-stage price-function regression
  - Estimate the resulting equation in a 2^{nd} stage, treating ν as the regression error:

$$P'(Z_{i,j};\hat{\beta}_j) = \alpha_{1,j} + \alpha_{2,j}Z_{i,j} + \alpha_{3,j}X_{i,j} + \nu_{i,j}$$

Hedonics – Early Estimation

$$P'(Z_{i,j};\hat{\beta}_j) = \alpha_{1,j} + \alpha_{2,j}Z_{i,j} + \alpha_{3,j}X_{i,j} + \nu_{i,j}$$

- This equation effectively puts Z on the LHS and the RHS
- What is $\nu_{i,j}$?
- Epple(1987) Bartik(1987)
- $\nu_{i,j}$ is a preference shock that shifts $Z_{i,j}$, therefore it also shifts $P'(Z_{i,j};\beta_j)$
- Therefore, $\hat{\alpha}_{2,j}$ is inconsistent

Hedonics – Early Estimation

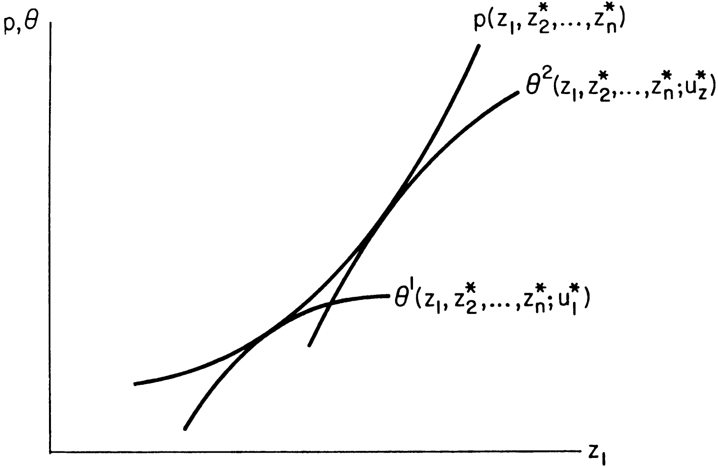


Fig. 1

Simple Approaches to Estimating MWTP

- Assume slope $= 0$
  - Flat MWTP curve hard to justify
  - However, MWTP can't slope upwards, so bounds welfare
- Assume constant elasticity of 1
  - Bajari-Benkard-Kahn
  - Seems arbitrary, but Cobb Douglas hardly a radical assumption

Estimating MWTP function

- Stable preferences across markets
  - Bartik (1987), Zabel and Kiel (2000)
- Stable preferences across time
  - Bishop and Timmins (2018), Banzhaf (2020)
- Assume constant elasticity
  - Yinger (2015a,b)
- Separability in MWTP function
  - Ekelend, Heckman, Neshim (2004), Bishop & Timmins (2019)

Estimating MWTP function

- IV: Find a variable that shifts $Z_{i,j}$ but is uncorrelated with $\nu_{i,j}$
- Market dummies may work if the supply-side differs by market
  - Bartik (1987), Zabel and Kiel (2000)
- Also need an exclusion restriction
  - Cross market homogeneity restriction

$$MWTP(Z_{i,j}; X_{i,j}, \alpha_j, \nu_{i,j}) = \alpha_{1,j} + \alpha_{2,j} Z_{i,j} + \alpha_{3,j} X_{i,j} + \nu_{i,j}$$

$$MWTP(Z_{i,j}; X_{i,j}, \alpha_j, \nu_{i,j}) = \alpha_1 + \alpha_2 Z_{i,j} + \alpha_3 X_{i,j} + \nu_{i,j}$$

Hedonics – Early Estimation

- Need to justify IV
- What about sorting?
- Markets could be geographic- or time-based
    - Kuminoff and Pope (2012) discuss using time as market

Hedonics – Identification

- Many assumed that inconsistent $\hat{\alpha}_{2,j}$ implies $\alpha_{2,j}$ is unidentified in a single market.
- However, this is not how identification works
- Ekeland, Heckman, and Nesheim (2004)
- "Issues of identification are confused with issues of estimation."

Hedonics – Identification

- Bishop and Timmins (2019)
  - "In the ... hedonic model, there is no fundamental endogeneity problem"
  - "households take the hedonic price function as given and choose Z to maximize utility based on their individual preferences."
  - "As ν and X are typically assumed to be orthogonal in the hedonic model, we are left with a familiar econometric modeling environment"
  - "An endogenous outcome variable, Z, which is a function of a vector of exogenous variables, X, and an econometric error, ν."

Hedonics – Identification

- So, need to return to issue of identification.
- Begin with **over**-simplified model where $P'(Z_{i,j};\beta) = \beta_{1,j} + \beta_{2,j} Z_{i,j}$
- FOC:

$$\alpha_{1,j} + \alpha_{2,j} Z_{i,j} + \alpha_{3,j} X_{i,j} + \nu_{i,j} - \beta_{1,j} - \beta_{2,j} Z_{i,j} = 0$$

- Solve for Z:

$$Z_{i,j} = (\frac{\alpha_{1,j} - \beta_{1,j}}{\beta_{2,j} - \alpha_{2,j}}) + (\frac{\alpha_{3,j}}{\beta_{2,j} - \alpha_{2,j}}) X_{i,j} + (\frac{1}{\beta_{2,j} - \alpha_{2,j}}) \nu_{i,j}$$

Hedonics – Identification

$$Z_{i,j} = \underbrace{(\frac{\alpha_{1,j} - \widehat{\beta_{1,j}}}{\widehat{\beta_{2,j}} - \alpha_{2,j}})}_{\theta_{0,j}} + \underbrace{(\frac{\alpha_{3,j}}{\widehat{\beta_{2,j}} - \alpha_{2,j}})}_{\theta_{1,j}} X_{i,j} + \underbrace{(\frac{1}{\widehat{\beta_{2,j}} - \alpha_{2,j}})\nu_{i,j}}_{u_{i,j}}$$

- Structural parameters: $\{\alpha_{1,j}, \alpha_{2,j}, \alpha_{3,j}, \sigma_j\}$
- Reduced-form parameters $\{\theta_{0,j}, \theta_{1,j}, \sigma_{u,j}\}$
- Model is unidentified

Hedonics – Multi-Market Identification

$$Z_{i,j} = \underbrace{\left(\frac{\alpha_{1,j} - \widehat{\beta_{1,j}}}{\widehat{\beta_{2,j}} - \alpha_{2,j}}\right)}_{\theta_{0,j}} + \underbrace{\left(\frac{\alpha_{3,j}}{\widehat{\beta_{2,j}} - \alpha_{2,j}}\right)}_{\theta_{1,j}} X_{i,j} + \underbrace{\left(\frac{1}{\widehat{\beta_{2,j}} - \alpha_{2,j}}\right)\nu_{i,j}}_{u_{i,j}}$$

- Make cross market restrictions
- E.g. $\{\alpha_{1,j},\, \alpha_{2,j},\, \alpha_{3,j},\, \sigma_j\} = \{\alpha_1,\, \alpha_2,\, \alpha_3,\, \sigma\}$ (over-identification)
- Reduced form parameters will still vary by market (if $\hat{\beta}$ varies by market)
- Overall $\bar{Z}$, $Cov(Z, X)$ and $Var(Z)$ will identify α_1, α_3, σ
- Cross-market variation in $\bar{Z}_j$, $Cov(Z_j, X_j)$, and $Var(Z_j)$ will identify α_2

Hedonics – Single-Market Identification

- $\alpha_{1,j}$, $\alpha_{2,j}$, $\alpha_{3,j}$, σ_j not identified if $P'(Z_{i,j};\beta) = \beta_{1,j} + \beta_{2,j} Z_{i,j}$
- Ekeland, Heckman, and Nesheim (2004): gradient unlikely to be linear
- EHN prove identification when $P'(Z_{i,j};\beta)$ is non-linear.
  - given assumptions about MWTP
- Additive separability of MWTP in $X_{i,j}$ and $\nu_{i,j}$ is sufficient

Hedonics – Single-Market Identification

- For example: $MWTP(Z_{i,j}; X_{i,j}, \alpha, \nu_{i,j}) = \alpha_{1,j} + \alpha_{2,j} Z_{i,j} + \alpha_{3,j} X_{i,j} + \nu_{i,j}$
- $P'(Z_{i,j}; \beta)$ is non-linear
- If MWTP is a linear function of X (by assumption), Z will still be a non-linear function of X. Nature of non-linearity identifies α_2.
- If $\nu_{i,j}$ is symmetric, $Z_{i,j}$ is not.
- Extent of asymmetry of z identifies slope of MWTP, α_2

Hedonics – Estimating MWTP Function

- EHN show how to estimate MWTP given additive separability assumptions
  - General and elegant, but complicated
- BT show ML is straightforward given parameterization of MWTP
  - $\alpha_{1,j} + \alpha_2 Z_{i,j} + \alpha_{3,j} X_{i,j} + \nu_{i,j} \equiv MWTP(Z_{i,j}; X_{i,j}, \alpha, \nu_{i,j})$
- Don't use $P'(Z_{i,j}; \hat{\beta}_j) = \alpha_{1,j} + \alpha_2 Z_{i,j} + \alpha_{3,j} X_{i,j} + \nu_{i,j}$ as estimating equation
- Use MLE using $f(Z|X, \alpha, \sigma)$

Hedonics – Estimating MWTP Function

- Generally, no closed-form for Z
- Solve for $\nu_{i,j}$: $\nu_{i,j} = P'(Z_{i,j}; \hat{\beta}_j) - \alpha_{1,j} - \alpha_2 Z_{i,j} - \alpha_{3,j} X_{i,j}$
- Assume $\nu \sim N(0, \sigma^2)$
- Density of Z is given by: $\frac{1}{\sigma\sqrt{2\pi}} \exp\{-\frac{1}{2\sigma^2}(\nu_{i,j}(\alpha))^2\} \left|\frac{\partial \nu_{i,j}(\alpha)}{\partial Z_{i,j}}\right|$
- where the Jacobian determinant for the change of variables is given by: $\left|\frac{\partial \nu_{i,j}(\alpha)}{\partial Z_{i,j}}\right| = |P''(Z_{i,j}; \widehat{\beta}_j) - \alpha_2|$
- Choose, $\alpha_{1,j}, \alpha_2, \alpha_{3,j}, \sigma$ to max likelihood
  - Treating $\hat{\beta}$ as known data from a first stage

Hedonics – Estimating MWTP Function

- Potentially complicated non-linear optimization
- Dimensionality of $\alpha_{1,j}, \alpha_{3,j}$ potentially quite large
- BT insight is that one can work with a concentrated likelihood.
- For a given $\hat{\alpha}_2$ there is a closed-form solution to finding the likelihood minimizing values of $\hat{\alpha}_{1,j}, \hat{\alpha}_{3,j}, \hat{\sigma}$
- Very fast!

Application

- Bishop and Timmins (2019) estimate WTP for non-marginal changes in crime
- Areas experienced both non-marginal increases or deceases in crime
- The first stage involves estimating $P(Z_{i,j}, \epsilon_{i,j}; \beta_j)$ with a non-parametric estimator (with census tract fixed effects)

Figure: Results - Housing Price Functions by Year, $P_t(Z_{i,t})$

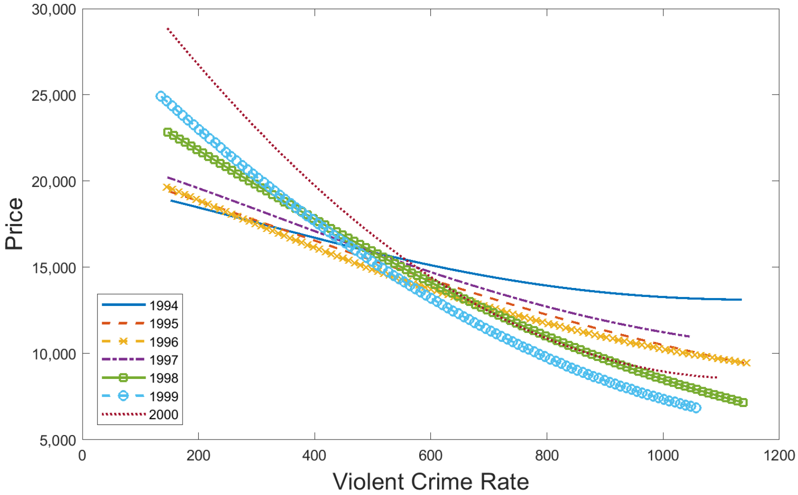


Figure: Results - Hedonic Gradients by Year, $P'_t(Z_{i,t})$

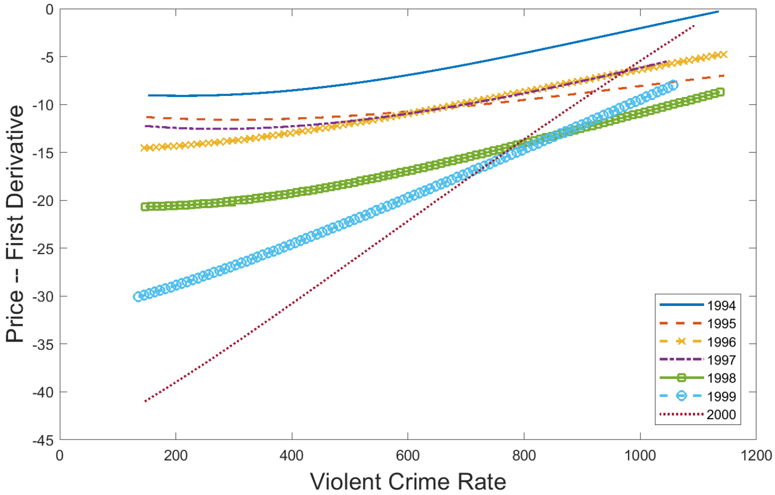


Figure: Results - Second Derivatives of Price by Year, $P_t''(Z_{i,t})$

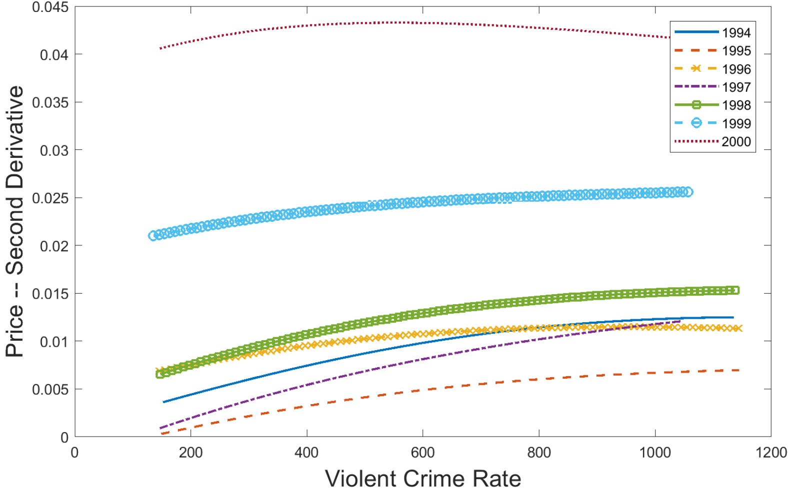
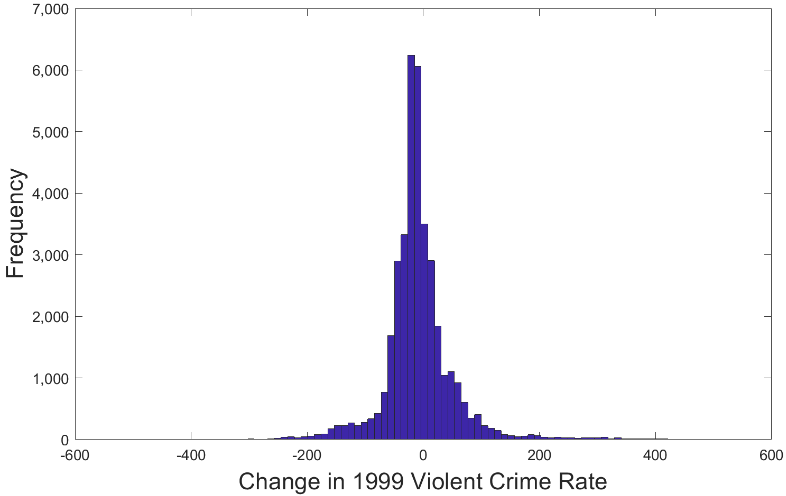
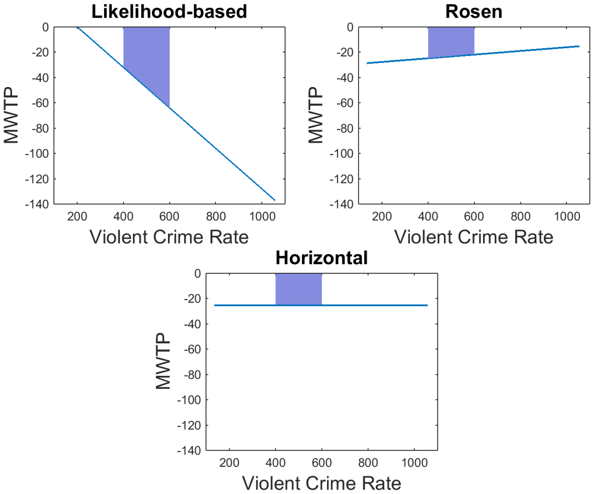


Figure: Distribution of One-Year Crime Rate Changes for 1999 Buyers



WTP for Non-Marginal Increases in Violent Crime



BT Application – WTP for Non-Marginal Changes

	Buyers with Reductions ($n = 24,791$)			Buyers with Increases ($n = 12,900$)		
	Average WTP	25th % WTP	75th % WTP	Average WTP	25th % WTP	75th % WTP
Likelihood Based	652	294	917	-1710	-1828	-290
Rosen	878	309	1113	-1147	-1501	-281
Horizontal	858	308	1099	-1194	-1537	-282

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Outline

Extensions: Salience

- Do agents perceive amenities correctly?
- Bishop, Kuminoff, Mathes, & Murphy (2024)
  - Get policy relevant price of mortality
- Bishop, Kuminoff, Murphy, & Price (2025)
  - Model/measure perceived amenity mapping
  - Combine with $P(Z)$ to get MWTP

Extensions: Existence of Price Function

- Under what conditions does a price function exist?
  - Versus a correspondence
  - Bajari & Benkard (2005) give technical conditions for function
  - Asymetric information can cause a correspondence
    - Pope (2008), Kumbhakar & Parmeter (2010)

Extensions: Existence of Price Function

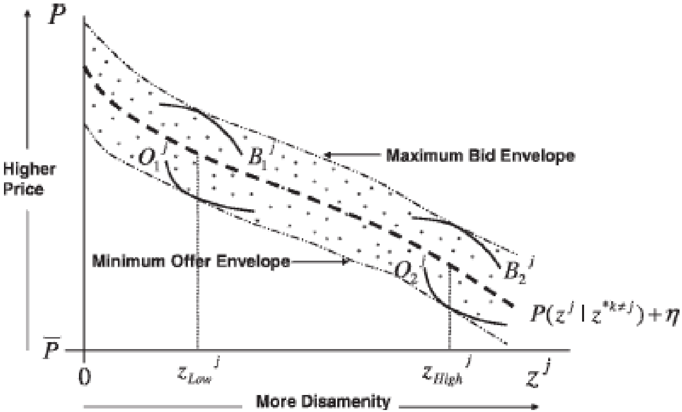


FIGURE 3
Incomplete Information and the Hedonic

Extensions: Moving Costs

- Frictions in mobility may bias inference
- Households may be at corner solution
  - Bajari & Kahn (2005): use recent movers

Extensions: Dynamics

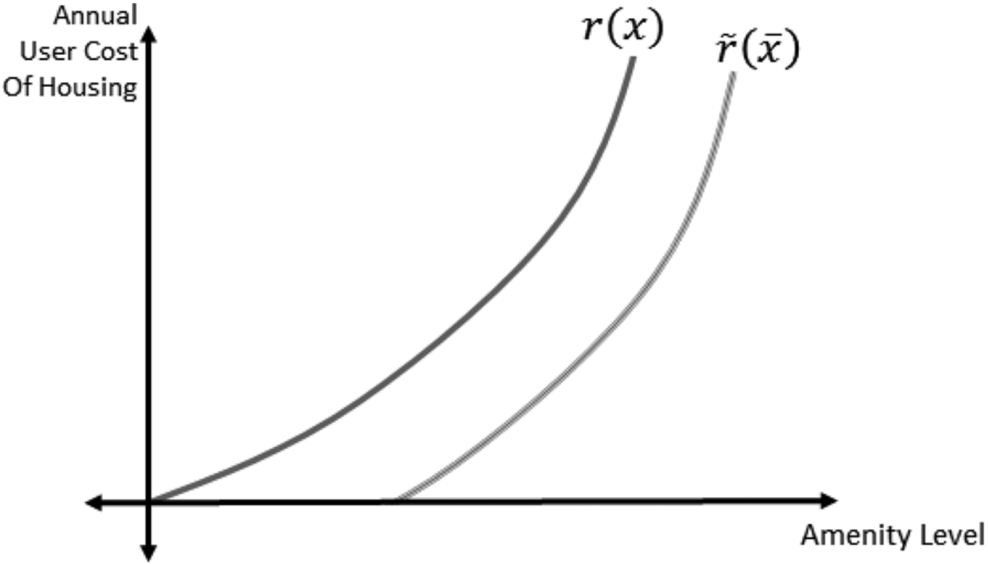
- What if households forward-looking with respect to corner solutions?
- Dynamic behavior complicates static models
- The FOC for a household's optimal choice of Z is then given by:

$$P'(Z_{i,j};\beta_j) = MWTP(Z_{i,j};X_{i,j},\alpha_j,\nu_{i,j}) + \partial E[V(Z_{t+1}|Z)]/\partial Z$$

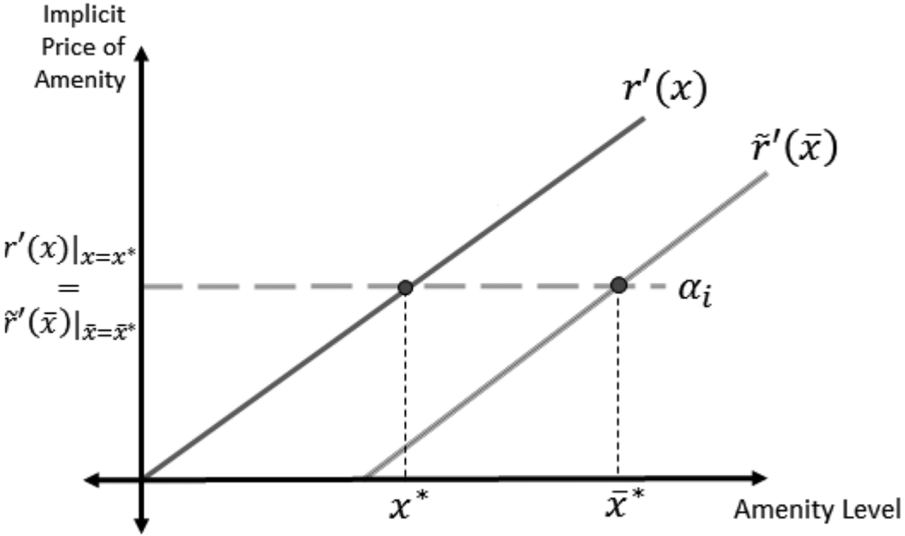
- Bishop and Murphy (2011) show how to estimate full structural model

Extensions: Dynamics

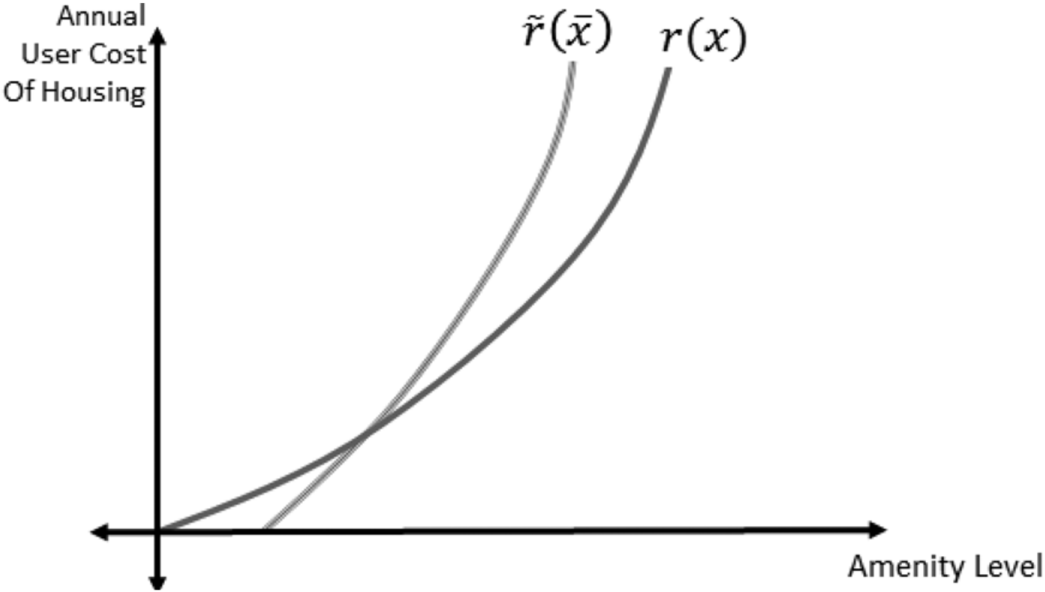
- Bishop and Murphy (2019) show how forward-looking behavior affects inference
- Focus on the two ingredients in identifying MWTP at point of consumption
  - (Implicit) price of amenity
  - Quantity of amenity consumed
- Switch notation: x now denotes amenity
- With forward-looking behavior, relevant amenity is future average, $\bar{x}$
- Consider two cases:
  - $\bar{x} = x + c$
  - $\bar{x} = \rho x$

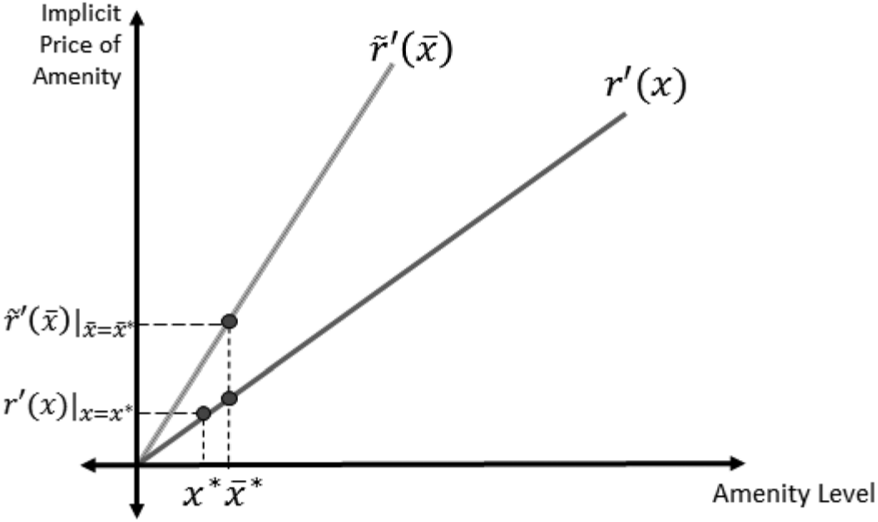


(a) The Housing Price Functions

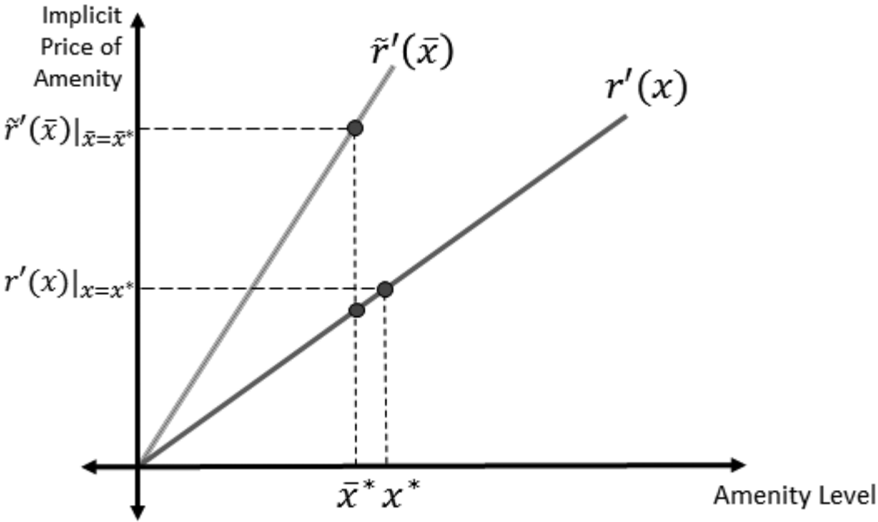


(b) The Implicit Price Functions and Household i's MWTP


Annual
User Cost
Of Housing
$\tilde{r}(\bar{x})$
$r(x)$
Amenity Level



(b) The Implicit Price Functions and Household i's MWTP Below-Mean Choice of x^*



(c) The Implicit Price Functions and Household i's MWTP Above-Mean Choice of x^*

Connection to Discrete Choice

- Many view Hedonics and Discrete Choice models very distinctly
  - Hedonics reduced form; discrete choice is structural
  - Hedonics have price on the left; discrete choice has quantity on the left

Connection to Discrete Choice

- I disagree:
  - Both frameworks are revealed preference
  - In both frameworks, households demand amenities based on given prices
  - In hedonics, choice is continuous; in discrete choice it is discrete
    - A big deal?
  - In hedonics, price function must be estimated to reveal counterfactual price
  - In discrete choice, counterfactual prices are directly observed
    - In both cases, endogeneity is an issue to be dealt with

Hedonics and Sorting

- Thank you
- Questions?

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