Lecture 3:
Value of Environmental Amenities with Migration
ECO 567A

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Syllabus

- Part I: Demand for Local Environmental Quality
  - Intro (Jan 10)
  - Demand I - Estimation (Jan 17)
  - Demand II - Sorting and Environmental Justice (Jan 24)
  - Amenities and Quant. Spatial Economic Models (Jan 31)
- Part II: Supply of Local Environmental Quality - Energy
  - Energy Production (Feb 7)
  - Energy Demand (Feb 14)
  - Energy Efficiency Innovation (Feb 21)
  - Trade and Pollution (March 7)
- Part III: Global Externalities
  - Climate Change (March 14)

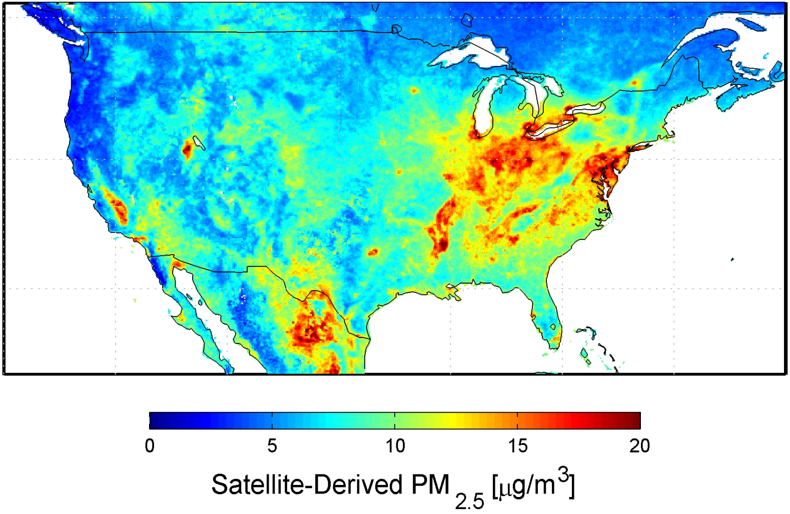
Research Project

- Pick a question that interests you in Sustainable Development/Environment/Energy/Geography
- Brief literature review on what has been done, what are outstanding questions
- Develop empirical strategy to address the question (real world)
- Identify dataset
- Obtain dataset and describe

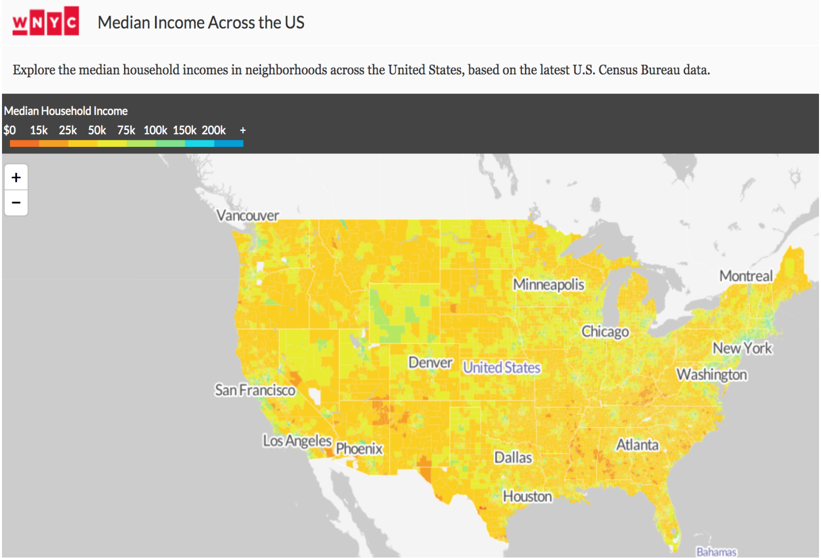
Today

- How to estimate MWTP with endogenous sorting?
- Do people sort based on income/ethnicity?

Air Quality in the US (average 2001 - 2006)



Median Income in the US by Census District



Questions

- Can we explain with an economic model variation in wages , housing prices, and air pollution across space?
- What is the relationship between housing prices, wages, and pollution in spatial equilibrium?
- Can we still derive MWTP for amenities from housing prices?

Spatial Equilibrium

- Key idea:
  - Workers/consumers equalize utility across space
  - Firms equalize costs across space

Roback (JPE, 82)

- Worker-consumers (N)
  - Choose x traded good with price normalized to 1
  - Choose L_c Land with price r
  - earn wage w from a firm
  - affected by pollution z
- Firms
  - Choose N_p number of workers with wage w
  - Choose L_p Land with price r
  - Produce traded goods $x = F(N_p, L_p; z)$
- Land Constraint $N * L_c + L_p(1) * x_p = L$

Solving Consumer and Firm Problems

- The consumer's problem is

$$\begin{aligned} &\underset{x, L_c}{\text{Max}} && U(x, L_c; z) \\ &\text{subject to} && x + rL_c \leq w \end{aligned}$$

$\Longrightarrow$ Indirect utility function $V(w, r; z)$, $\frac{\partial V(w,r;z)}{\partial z} \equiv V_z < 0$

- A firm's problem is

$$\begin{aligned} &\underset{N_p, L_p}{\text{Min}} && w * N_p + r * L_p \\ &\text{subject to} && x = F(N_p, L_p; z) \end{aligned}$$

$\Longrightarrow$ Yields unit cost function

$w * N(1)^*_p + r * L(1)^*_p = c^1(w, r; z)$, $\frac{\partial c^1(w,r;z)}{\partial z} \equiv c^1_z \gtrless 0$

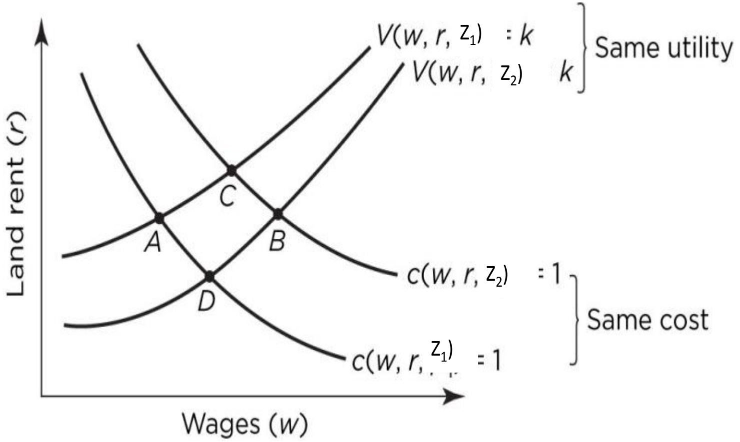
Assumptions

- Spatial equilibrium equates indirect utility in all regions
  $V(w, r; z) \equiv k$

- Spatial equilibrium equates unit cost functions everywhere
  $c^1(w, r; z) \equiv 1$

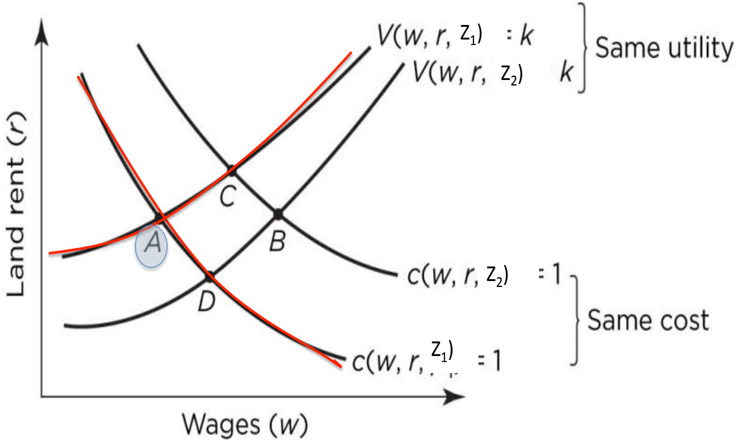
Equilibrium, $z_1 < z_2$

If pollution is "productive" (lax pollution regulation)



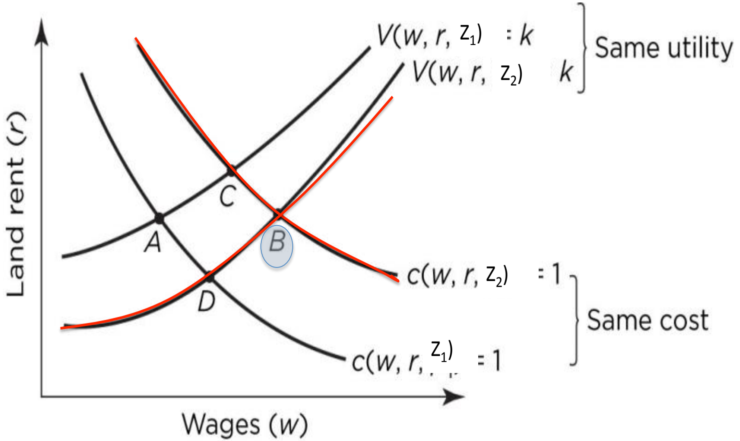
Equilibrium

If pollution is "productive" (lax pollution regulation)



Equilibrium

If pollution is "productive" (lax pollution regulation)



Comparative Statics

- What are $\frac{dw}{dz}$ and $\frac{dr}{dz}$?
- Totally differentiate equilibrium conditions $V(w, r; z) \equiv k$, $c^1(w, r; z) \equiv 1$:

$$V_w \frac{dw}{dz} + V_r \frac{dr}{dz} = -V_z \tag{1}$$

$$C_w^1 \frac{dw}{dz} + C_r^1 \frac{dr}{dz} = -C_z^1 \tag{2}$$

- In matrix notation

$$\begin{bmatrix} V_w & V_r \\ C_w^1 & C_r^1 \end{bmatrix} \begin{bmatrix} \frac{dw}{dz} \\ \frac{dr}{dz} \end{bmatrix} = \begin{bmatrix} -V_z \\ -C_z^1 \end{bmatrix}$$

- Inverting the matrix and multiplying

$$\begin{bmatrix} \frac{dw}{dz} \\ \frac{dr}{dz} \end{bmatrix} = \frac{1}{\Delta} \begin{bmatrix} -V_z C_r^1 + C_z^1 V_r \\ -V_w C_Z^1 + V_z C_w^1 \end{bmatrix}$$

with

$\Delta = V_w C_r^1 - V_r C_w^1 = V_w \left(L_p^*(1) + L_c^* N_p^*(1) \right) = LV_w / x > 0$

(By Shephard's lemma and Roy's Identity)

Comparative Statics

- Suppose pollution is "productive", so $C_z^1 < 0$

$$\frac{dw}{dz} = \underbrace{\frac{1}{\Delta}}_{+} \left[\underbrace{-V_z C_r^1}_{+} + \underbrace{C_z^1 V_r}_{+} \right] > 0 \tag{3}$$

$$\frac{dr}{dz} = \underbrace{\frac{1}{\Delta}}_{+} \left[\underbrace{-V_w C_z^1}_{+} + \underbrace{V_z C_w^1}_{-} \right] \lesseqgtr 0 \tag{4}$$

Comparative Statics

- Suppose pollution is "neutral", so $C_z^1 = 0$

$$\frac{dw}{dz} = \underbrace{\frac{1}{\Delta}}_{+} \left[\underbrace{-V_z C_r^1}_{+} + \underbrace{C_z^1 V_r}_{=0} \right] > 0 \tag{5}$$

$$\frac{dr}{dz} = \underbrace{\frac{1}{\Delta}}_{+} \left[\underbrace{-V_w C_z^1}_{=0} + \underbrace{V_z C_w^1}_{-} \right] < 0 \tag{6}$$

What is z worth in dollars to worker/consumers?

- Totally differentiate equilibrium conditions $V(w, r; z) \equiv k$:

$$\underbrace{V_w \frac{dw}{dz} + V_r \frac{dr}{dz}}_{\text{indirect/observable}} = \underbrace{-V_z}_{\text{direct/unobservable}}$$

- Divide by V_w and apply Roy's Identity:

$$\frac{dw}{dz} - L_c^* \frac{dr}{dz} = -V_z / V_w \equiv MWTP$$

- this is the dollar equivalent of utility change from a small change in z.
- i.e. the amount of money someone would pay to avoid a small increase in pollution.

What is z worth in dollars to Firms?

- Totally differentiate equilibrium conditions $c^1(w, r; z) \equiv 1$

$$\underbrace{C^1_w \frac{dw}{dz} + C^1_r \frac{dr}{dz}}_{\text{indirect/observable}} = \underbrace{-C^1_z}_{\text{direct/unobservable}}$$

- Apply Shephard's Lemma:

$$-\left[\frac{N^*_p}{x}\frac{dw}{dz} + \frac{L^*_p}{x}\frac{dr}{dz}\right] = C^1_z$$

- this is the change in the unit cost function of a firm from a small change in z.
- i.e. the amount of money a firm would pay to avoid a small increase in pollution.

What is z worth in dollars to workers+Firms?

- Add dollar valuations to firms and workers yields "Total Value of Amenity" (Ω)

$$\Omega \equiv \underbrace{\left[\frac{dw}{dz} - L_c^* \frac{dr}{dz}\right] * N^*}_{workers} - \underbrace{\left[\frac{N^*}{x}\frac{dw}{dz} + \frac{L_p^*}{x}\frac{dr}{dz}\right] * x}_{\text{Firms}} = -L^* \frac{dr}{dz}$$

- I.e., the value to a region (workers + firms) of a small increase in z is just the change in the value of land

Estimating MWTP

- Re-write MWTP

$$
\begin{aligned}
L_c^* \frac{dr}{dz} - \frac{dw}{dz} &= w\left[\frac{L_c * r}{w}\frac{dr}{dz}\frac{1}{r} - \frac{dw}{dz}\frac{1}{w}\right] \\
&= w\left[s_L \frac{d\ log\ r}{dz} - \frac{d\ log\ w}{dz}\right] \\
&= w\left[s_L \gamma_r - \gamma_w\right]
\end{aligned}
$$

- estimate γ's from regressions

$$
\begin{aligned}
log\ w_{ic} &= x_i \beta + \gamma_w * z_c + \epsilon_{ic} \\
log\ r_c &= \gamma_r * z_c + \epsilon_c
\end{aligned}
$$

Quality of Life Index

- What if people care about more than 1 amenity

$$QOL_c = \sum_k MWTP_k * Z_{k,c}$$

Endogeneity

- So evaluating $\frac{dr}{dz}$ and $\frac{dw}{dz}$ are very important and tell us a lot.
- But can we just regress r or w on z?

Other problems

- Agglomeration effects
- Trade costs
- Migration costs
- Individual preferences/heterogeneity

Albouy (Restat 2016)

- Model non-tradable goods
  - Differentiates between housing values and land rents
- Model productivity differences across cities
  - Back these out from observables
- Explicitly model taxation

Introduce Q and A (productivity)

- Roback (1982)

$$V_w \frac{dw}{dz} + V_r \frac{dr}{dz} = -V_z \quad (7)$$

$$C_w \frac{dw}{dz} + C_r \frac{dr}{dz} = -C_z \quad (8)$$

- Albouy (2016)

$$\theta_{vw}\hat{w} + \theta_{vr}\hat{r} = \hat{Q} \quad (9)$$

$$\theta_{cw}\hat{w} + \theta_{cr}\hat{r} = \hat{A}_x \quad (10)$$

Extend to non-traded goods

- Full model with non-traded goods

$$\begin{aligned} \hat{Q} &= \theta_{vw}\hat{w} + \theta_{vp}\hat{p} && (11) \\ \hat{A}_x &= \theta_{cw}\hat{w} + \theta_{cr}\hat{r} && (12) \\ \hat{A}_y + \hat{p} &= \theta_{gw}\hat{w} + \theta_{gr}\hat{r} && (13) \end{aligned}$$

- modified model accounting for missing r

$$\begin{aligned} \hat{Q} &= \theta_{vw}\hat{w} + \theta_{vp}\hat{p} && (14) \\ \hat{A}_x &= \theta_{cw}\hat{w} + \frac{\theta_{cr}}{\theta_{gr}}\left[\hat{A}_y + \hat{p} - \theta_{gw}\hat{w}\right] && (15) \end{aligned}$$

- Assuming $\hat{A}_y = 0$

$$\begin{aligned} \hat{Q} &= \theta_{vw}\hat{w} + \theta_{vp}\hat{p} && (16) \\ \hat{A}_x &= \theta_{cw}\hat{w} + \frac{\theta_{cr}}{\theta_{gr}}[\hat{p} - \theta_{gw}\hat{w}] && (17) \end{aligned}$$

Total Value of Amenities

- Roback (1982)

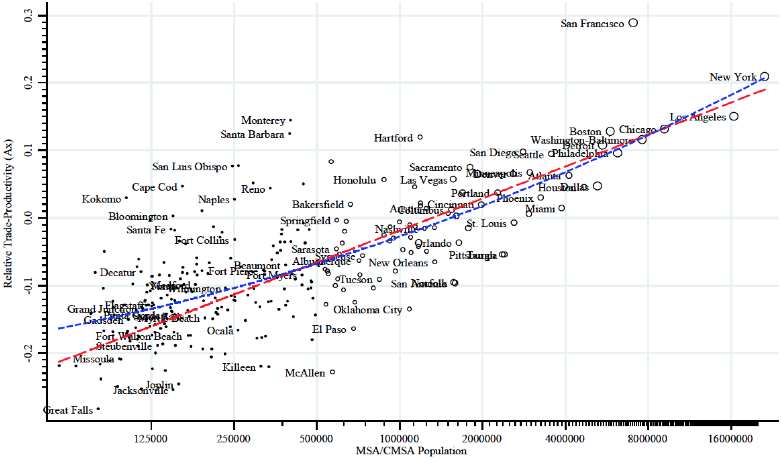
$$\Omega \equiv \underbrace{\left[\frac{dw}{dz} - L_c^* \frac{dr}{dz}\right] * N^*}_{workers} - \underbrace{\left[\frac{N^*}{x}\frac{dw}{dz} + \frac{L_p^*}{x}\frac{dr}{dz}\right] * x}_{\text{Firms}} = -L^* \frac{dr}{dz}$$

- Albouy (2016)

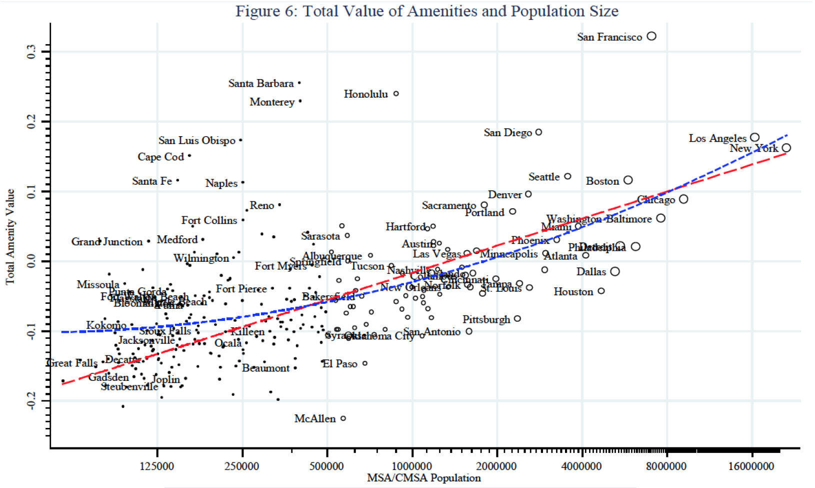
$$\widehat{\Omega^j} \equiv \widehat{Q^j} + s_x \widehat{A_x^j} + \underbrace{s_y \widehat{A_y^j}}_{=0}$$

Productivity Estimates

Figure 5: Trade-Productivity and Population Size



Total Value of Amenities



Individual Amenities

	Mean	Standard Deviation	Observables: Housing Cost (1)	Observables: Wage (2)	Amenity Type: Quality of Life (3)	Amenity Type: Trade Productivity (4)
Logarithm of Metro Population	14.63	1.32	0.056***	0.038***	-0.001	0.036***
			(0.007)	(0.004)	(0.002)	(0.004)
Percent of Population College Graduates	0.26	0.07	1.718***	0.714***	0.213***	0.748***
			(0.169)	(0.069)	(0.042)	(0.067)
Whartron Residential Land-Use Regulatory Index (WRLURI)	0.05	0.93	0.008	0.004	0.001	0.004
			(0.012)	(0.007)	(0.004)	(0.006)
Minus Heating-Degree Days (1000s)	-4.38	2.15	0.039***	0.014**	0.006	0.015***
			(0.010)	(0.006)	(0.004)	(0.005)
Minus Cooling-Degree Days (1000s)	-1.28	0.89	0.105***	0.017	0.025***	0.025**
			(0.018)	(0.012)	(0.007)	(0.010)
Sunshine (percent possible)	0.60	0.08	1.248***	0.290***	0.260***	0.363***
			(0.129)	(0.089)	(0.044)	(0.078)
Inverse Distance to Coast (Ocean or Great Lake)	0.04	0.04	0.078***	0.024***	0.013***	0.027***
			(0.008)	(0.005)	(0.002)	(0.004)
Average Slope of Land (percent)	1.68	1.59	0.023***	-0.006*	0.010***	-0.002
			(0.005)	(0.003)	(0.002)	(0.003)

Variance Decomposition

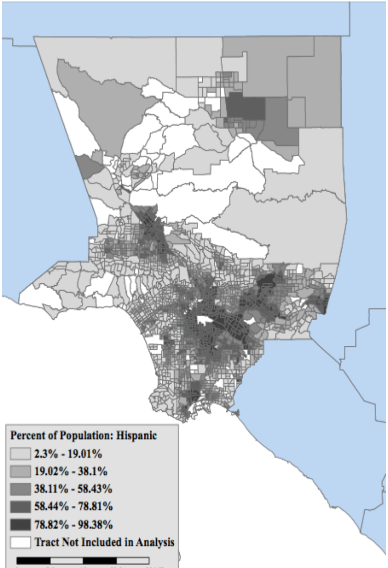
$$var\left(\widehat{V^j}\right) \equiv wt_{vQ} * var\left(\widehat{Q^j}\right) + wt_{vA_x} * var\left(\widehat{A_x^j}\right) + wt_{vQA_x} * cov\left(\widehat{Q^j}, \widehat{A_x^j}\right)$$

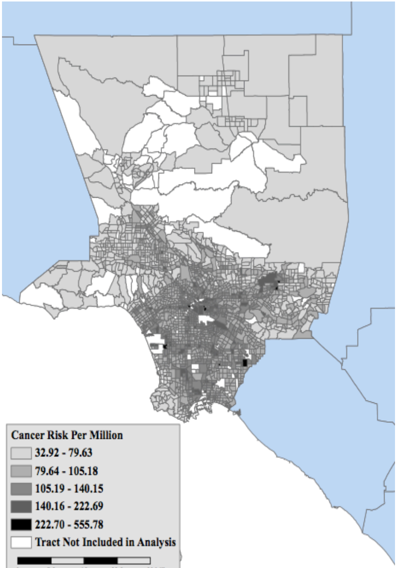
	Variance	*Variance Decomposition* Fraction of variance explained by: Quality of Life	Productivity	Covariance
	(1)	(2)	(3)	(4)
Panel A: With Federal Taxes				
Land Rents	1.002	0.370	0.287	0.342
Wages	0.019	0.018	1.132	-0.150
Housing Costs	0.093	0.184	0.498	0.318
Tax Differential	0.001	0.113	1.276	-0.398
Total Value	0.015	0.181	0.503	0.317

But what about endogenous sorting by preferences?

- What is the relationship between income, race, and pollution?
  $\Longrightarrow$ Environmental Justice

Correlation of Hispanic Share and Cancer Risk





What explains the correlation?

- Toxic sites are placed near poor/minority populations?
- Poor/minority migrate towards toxic sites because of cheap housing?

OLS Estimates:

Table 4. Traditional Model: NATA Cancer

	$\Delta\%Asian$		$\Delta\%Black$		$\Delta\%Hispanic$		$\Delta\%White$	
	Estimate	t-stat	Estimate	t-stat	Estimate	t-stat	Estimate	t-stat
NATA (Cancer)	-4.41E-05	-1.27	-8.45E-06	-0.28	-4.64E-05	-0.88	9.38E-05	2.00

Table 5. Traditional Model: NATA Respiratory

	$\Delta\%Asian$		$\Delta\%Black$		$\Delta\%Hispanic$		$\Delta\%White$	
	Estimate	t-stat	Estimate	t-stat	Estimate	t-stat	Estimate	t-stat
NATA (Respiratory)	-2.43E-04	-1.70	1.53E-05	0.12	-7.88E-04	-3.67	9.57E-04	4.98

Table 6. Traditional Model: NATA Neurological

	$\Delta\%Asian$		$\Delta\%Black$		$\Delta\%Hispanic$		$\Delta\%White$	
	Estimate	t-stat	Estimate	t-stat	Estimate	t-stat	Estimate	t-stat
NATA (Neurological)	-8.38E-03	-0.76	-5.80E-03	-0.61	-3.67E-02	-2.20	4.88E-02	3.26

Depro et al (2015)

- Model individual neighborhood choice $\Longrightarrow$ predictions for neighborhood population size
- Back out common utility levels from aggregate population dynamics
- Regress common utility levels on neighborhood characteristics

Structural Model

- transition dynamics

$$pop_j^B = \sum_k s_{j,k} * pop_k^A$$

- individual utility

$$u_{ij} = \delta_j + \eta_{ij}$$

- mean utility

$$\delta_j = f(x_j, \xi_j; \beta)$$

- individual mobility decision

$$u_{ij} - u_{ik} = (\delta_j - \delta_k) - \mu MC_{jk} + (\eta_{ij} - \eta_{ik})$$

- Analytic expression for transition shares

$$prob_{j,k} = s_{j,k} = \frac{e^{\delta_j - \delta_k - \mu MC_{jk}}}{\sum_l e^{\delta_l - \delta_k - \mu MC_{lk}}}$$

Structural Model

- predicted movements

$$\sigma_j^{2007} = \sum_k \frac{e^{\delta_j - \delta_k - \mu MC_{jk}}}{\sum_l e^{\delta_l - \delta_k - \mu MC_{lk}}} \sigma_k^{2000}$$

- Estimation algorithm
  - guess μ
  - guess δ_j^0
  - compute $\widetilde{\sigma_j^{2007,0}}$
  - compute $\delta_j^1 = \delta_j^0 + (\ln \sigma_j^{2007} - \ln \widetilde{\sigma_j^{2007,0}})$
  - iterate until convergence ($\delta_j^{n+1} - \delta_j^n < \epsilon$)
  - find μ to fit "stayer" population.
  - regress δ_j on cancer risk and covariates

Structural Estimates:

Table 9. Sorting Model: NATA Cancer

	δ_{Asian}		δ_{Black}		$\delta_{Hispanic}$		δ_{White}	
	Estimate	t-stat	Estimate	t-stat	Estimate	t-stat	Estimate	t-stat
NATA (Cancer)	-0.2302	-2.53	-0.0702	-0.97	-0.0300	-1.20	-0.3210	-5.09

Table 10. Sorting Model: NATA Respiratory

	δ_{Asian}		δ_{Black}		$\delta_{Hispanic}$		δ_{White}	
	Estimate	t-stat	Estimate	t-stat	Estimate	t-stat	Estimate	t-stat
NATA (Respiratory)	-1.7258	-4.43	-0.4322	-1.42	-0.2046	-1.64	-1.8496	-6.26

Table 11. Sorting Model: NATA Neurological

	δ_{Asian}		δ_{Black}		$\delta_{Hispanic}$		δ_{White}	
	Estimate	t-stat	Estimate	t-stat	Estimate	t-stat	Estimate	t-stat
NATA (Neurological)	-26.4143	-0.90	-6.0258	-0.26	-16.5163	-1.83	-119.2423	-6.08

Depro et al (2015) conclusions

- Race correlates with cancer risk
- Structural model yields MWTP to avoid extra risk of 1 case per million
  - 32 cents for whites $\Longrightarrow$ need to pay \$320,000 to a group for them to accept an increase risk of 1 per 1 million people
  - 3 cents for Hispanics
- Consistent with residential sorting model
  - Nobody likes cancer risk
  - But Whites dislike it more than Hispanics, so they sort away in equilibrium

Summary

- In general equilibrium, both wages and housing prices may be related to amenities
- Firm costs/productivity may also be related to amenities
- In the standard economic geography framework (Roback 82), MWTP of worker/consumers is a linear combination of $\frac{dr}{dz}$ and $\frac{dw}{dz}$.
- But to the aggregate of workers+ firms, MWTP is just $\frac{dr}{dz}$
- Extended model with productivity differences concludes that productivity is more important than QOL for explaining wage/rent differentials
- Data suggest that minorities sort towards nuisance in equilibrium

References

- Roback, Jennifer. "Wages, rents, and the quality of life." Journal of political Economy 90.6 (1982): 1257-1278.
- Albouy, David. "What are cities worth? Land rents, local productivity, and the total value of amenities." Review of Economics and Statistics 98.3 (2016): 477-487.
- Depro, Brooks, Christopher Timmins, and Maggie O'Neil. "White flight and coming to the nuisance: can residential mobility explain environmental injustice?." Journal of the Association of Environmental and resource Economists 2.3 (2015): 439-468.
- Tiebout, Charles M. "A pure theory of local expenditures." Journal of political economy 64.5 (1956): 416-424.
- Kolstad (Chapter 8)