THE UNIVERSITY OF TEXAS AT AUSTIN

CITY LAND USE & RENT DYNAMICS WITH LOCATION EXTERNALITIES & ZONING REGULATIONS

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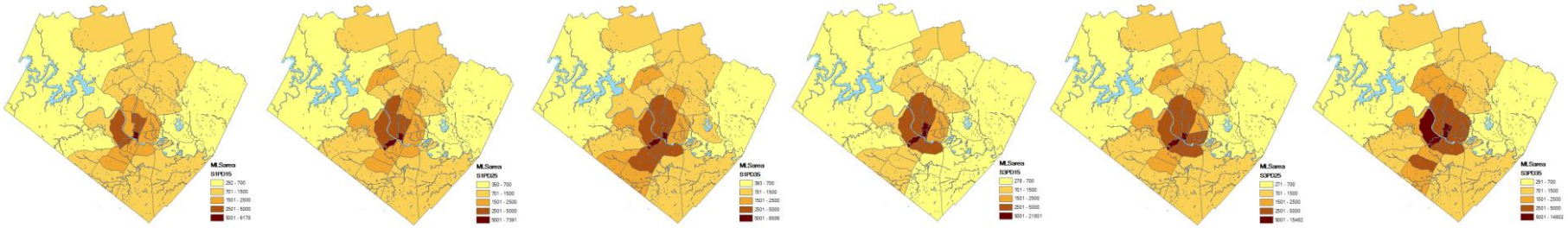


LAND USE MODELS (LUMs)

Theoretical Urban Economic Models

- **Monocentric** & **non-monocentric** models

Agent-based LUMs

- **Fine resolution** of space & actors, with **transitional dynamics**
- **Lack many market mechanisms**
- **Recent Development:** adding **competitive bidding** & **market-clearing** process (Parker & Filatova 2008, Magliocca et al. 2009, Zhou & Kockelman 2011)

Applied Spatial Equilibrium Model (SEMs)

- Explicit representation of **land markets**
- **Lack** sufficient **spatial resolution, heterogeneity, & dynamics**
- **Recent Developments: multiple market interactions** & **real estate development** (Anas &Liu 2007), **demographic dynamics** (Anas 2014a&b), **static location externalities** (Martínez&Donoso 2001)

RESEARCH OBJECTIVES

To develop a **zone-based SEM** enabling **more dynamics** (by extending **Anas** & Liu's (2007) **RELU model** :

- **Demographic changes over time:** location & land use preferences vary across household groups
- **Spatial dynamics** (& **dynamic location externalities**): "a change over time at one location is dependent on the state or changes in the state at other locations" (Irwin 2010)
  - For **households**: their neighborhood's **land use diversity** (e.g., the degree of mixture & job-housing balance)
  - For **firms**: **production externalities** emerging from **innovation diffusion**
- **Transitional costs & constraints**
  - **Residential relocation costs** plus costs & constraints (due to **zoning regulations**) on **building stock conversions**

OBJECTIVES (2)

Analyze effects of **demographic** shifts, different **land-use preferences, & low-density zoning regulations** on evolution of **land use, housing demand, rents**.

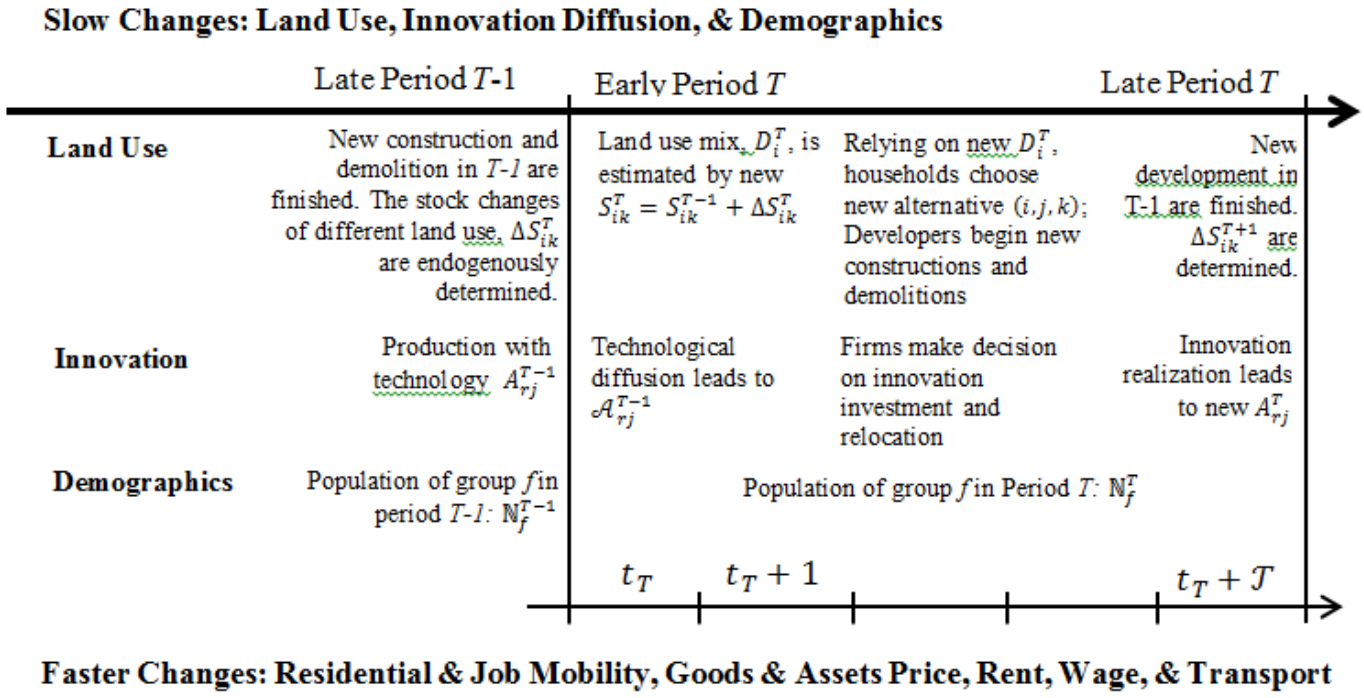


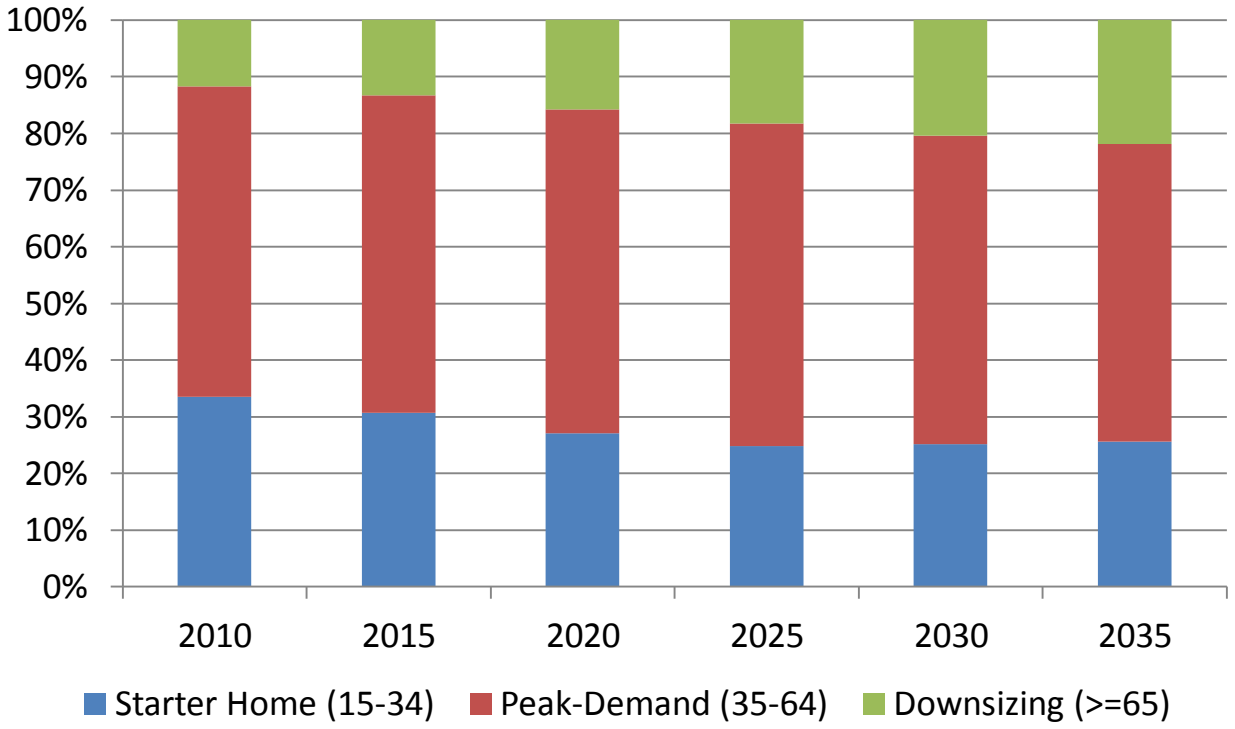
Figure 1 Model Dynamics

MODEL SPECIFICATION

Households: 9 types, with 3 **skill levels** (income) & **3 lifecycle stages –** each having different housing preference

Assumed shares of 3 lifecylce types in Austin (TxSDC 2014)

- **Starter Home (15-34):** falling until 2025
- **Peak-Demand (35-64):** Peak in year 2025
- **Downsizing (>65):** Rising over time



Household Shares for 3 lifecycle stages in Austin (2010-2035)

Households

Utility Function: Households' **location-choice utility** is not only associated with goods consumption, housing size, & exogenous variations in inter- (or intra-) zonal attractiveness, but also with **zonal diversity features**, including land use mixture & job-housing ratio.

Building Types: **Low- & high-density single- & multi- family** housing, **industrial, & commercial** buildings

Moving Costs: Households enjoy perfect foresight within each period *T* & moving costs are only associated with housing rents.

Firms

Maximize each period's **profits** by deciding **inputs of capital, labor, & floor space, intermediate inputs** (from other firms), & **innovation investment**, subject to output demand X_{rj}^T in period T:

$$X_{rj}^T = \left(A_{rj}^T\right)^{\gamma} F\left(K_{rj}^T, L_{hs|rj}^T, B_{k|rj}^T, Y_{rj}^T\right)$$

A_{rj}^T = **technology level** of type-*r* firm in zone *j*

= a **function of access** to new technologies in other locations (diffusion since the previous period), probability of innovation, & inputs of innovation investment.

Developers

For construction decisions, we assume perfectly competitive markets, so **expected profits** of investors (after collecting rents on vacant land at start of year & paying property taxes) equal zero, as follows:

$$(15)\quad E\{max[\pi_{i00}(Y_{i0}^T), \pi_{i0k}(Y_{ik}^T, p_{\mathcal{R}+1}^T, \mathbb{C}_{i0k}^T); k = 1, \dots, n_k \;\&k \in \mathbb{z}_i]\} + R_{i0}^T - \frac{1}{1+\rho}\tau_{i0}Y_{i0}^T = 0$$

$$(16)\quad E\{max[\pi_{ikk}(Y_{ik}^T, \mathbb{C}_{ikk}^T), \pi_{ik0}(Y_{i0}^T, p_{\mathcal{R}+2}^T, \mathbb{C}_{ik0}^T)]\} + E\{max[r_v(\mathbb{V}_{ik}^T), r_o(R_{ik}^T, \mathbb{O}_{ik}^T)]\} - \frac{1}{1+\rho}\tau_{i0}Y_{ik}^T = 0$$

Note: $\mathbb{Z}_i$ = set of possible building types that are allowed in the modeled zone *i* under **zoning regulations**

Market Clearing within Each Period

Product Markets: Supply = Demand

$$\sum_{r'=1,\dots,\mathcal{R}+2} \sum_{i'=1,\dots,N_z} Y^T_{ri\to r'i'} + \mathbb{E}^T_{ri} = X^T_{ri}, \forall\, r = 1,\dots,\mathcal{R}-1$$

$$\sum_{\forall hs} \mathbb{N}_{hs} \sum_{\forall i',j,k} P^T_{i'jk|hs} C^T_{i|i'jk} + \mathbb{E}^T_{\mathcal{R}i} = X^T_{\mathcal{R}i}$$

Real Estate (Land Use) Markets

$$(23)\quad \sum_{\forall hs} \mathbb{N}^T_{hs} \sum_{\forall j} P^T_{ijk|hs} b^T_{ijk|hs} = S^T_{ik} \frac{r_o(R^T_{ik}, \mathbb{O}^T_{ik})}{r_v(\mathbb{V}^T_{ik}) + r_o(R^T_{ik}, \mathbb{O}^T_{ik})}, k = 1,\dots,n_r$$

$$(24)\quad \sum_{\forall hs} B^T_{k|ri} = S^T_{ik} \frac{r_o(R^T_{ik}, \mathbb{O}^T_{ik})}{r_v(\mathbb{V}^T_{ik}) + r_o(R^T_{ik}, \mathbb{O}^T_{ik})}, k = n_r + 1,\dots,n_k$$

Labor Markets

$$(25)\quad \sum_{r=1}^{\mathcal{R}+2} L^T_{hs|rj} = \mathbb{N}^T_{hs} \sum_{\forall i,k} H^T_{ijf} P^T_{ijk|f}$$

DYNAMICS

Building stocks change **evolve toward equilibrium** & do not reach equilibrium levels within each period.

$$S_{ik}^{T+1} = \begin{cases} S_{i0}^{T} Q_{i00} + X_{\mathcal{R}+2}^{T}, & if\ k = 0 \\ S_{ik}^{T} - S_{ik}^{T} Q_{ik0}, & if\ k \notin \mathbb{Z}_i \\ S_{ik}^{T} - S_{ik}^{T} Q_{ik0} + m_{ik} S_{i0}^{T} Q_{i0k}, & if\ k \in \mathbb{Z}_i \end{cases}$$

Spatial dynamics mean **evolving location externalities**:

- **Zonal diversity** in period T+1 differs from that in period T, due to the **redistribution of firms & households, plus** the **construction & demolition** of buildings.
- **Locational technology** levels (A_{rj}^{T+1}) , also evolve due to **technology diffusion** (across periods) **& innovation investment**.

SIMULATIONS OF AUSTIN, TX

- **38 MLS areas**
- Base period: 2010
- **2015-2035** projections

Parameter Calibration

- Using Austin's land use, travel diary, real estate, & Census data
- Some parameters rely on existing literature (Anas & Rhee 2006, Zhou & Kockelman 2011, Desmet & Rossi-Hansberg 2014).

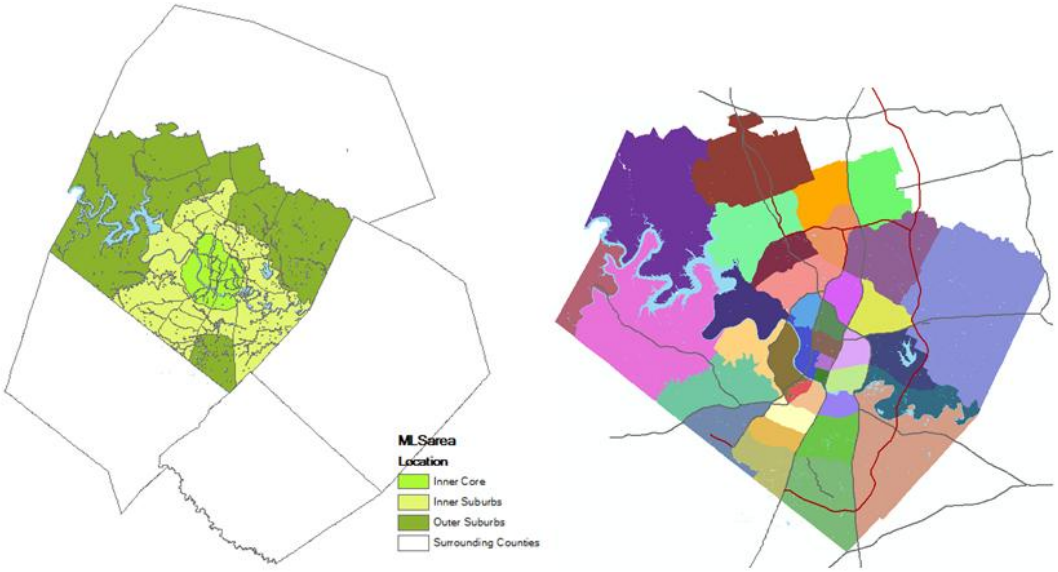


Figure 2 38 MLS areas in Austin, Texas

FOUR POLICY SCENARIOS

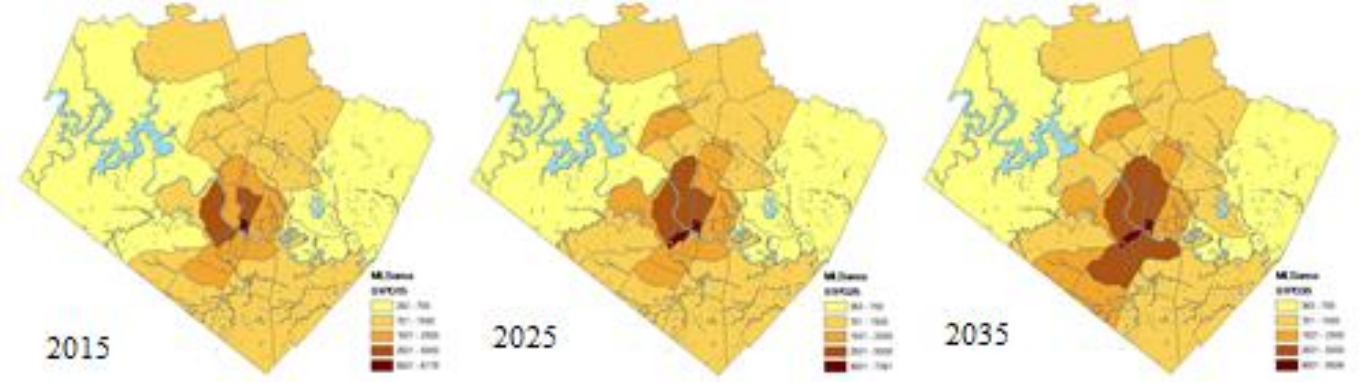
Scenario 1 (S1): **Demographic changes** only

Scenario 2 (S2): **S1 +** evolving **Location externalities** on the household side (i.e., neighborhood diversity changes affect household relocation choices)

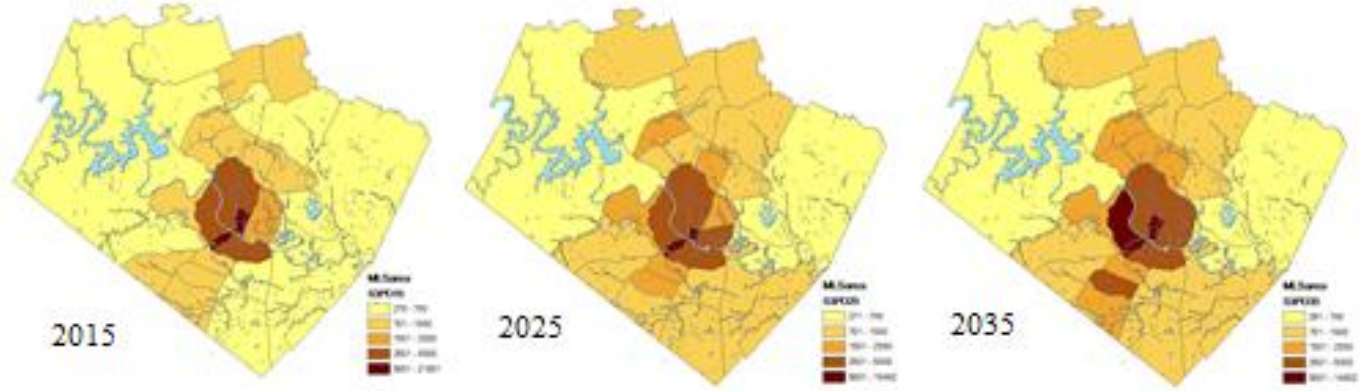
Scenario 3 (S3): **S1 + Low-density zoning** regulation (excluding high-density residential development) in **outer suburbs** (10 zones).

Scenario 4 (S4): **S2 + Low-density zoning** regulations in outer suburbs.

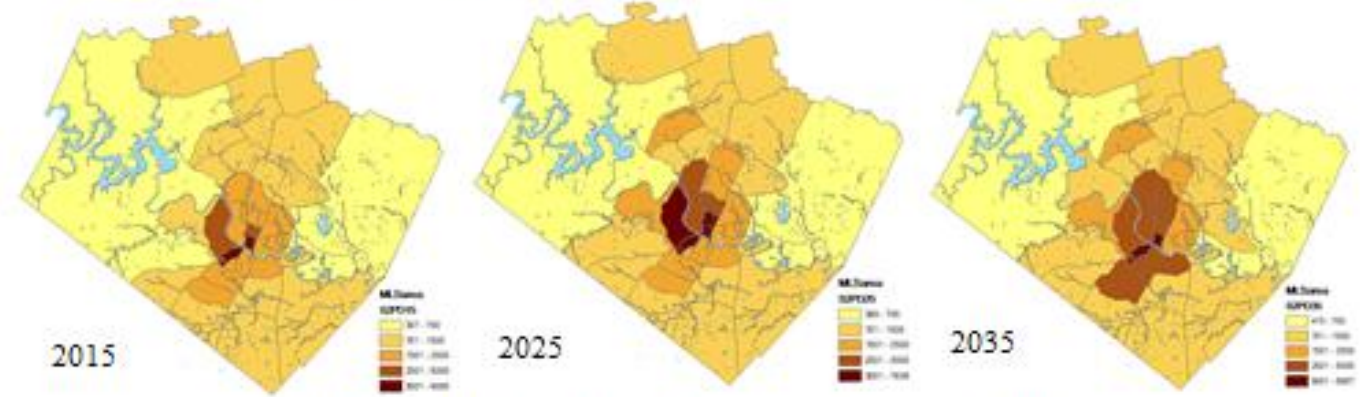
Population Density Dynamics



(a) Household density in S1 (with exogenous population growth only)



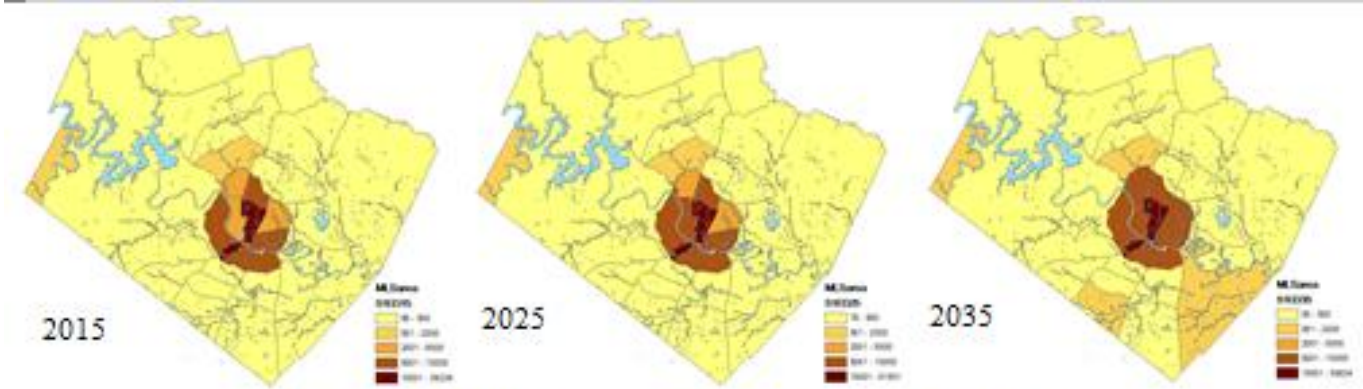
(b) Household density in S2 (S1 + preference for mixed-use environments)



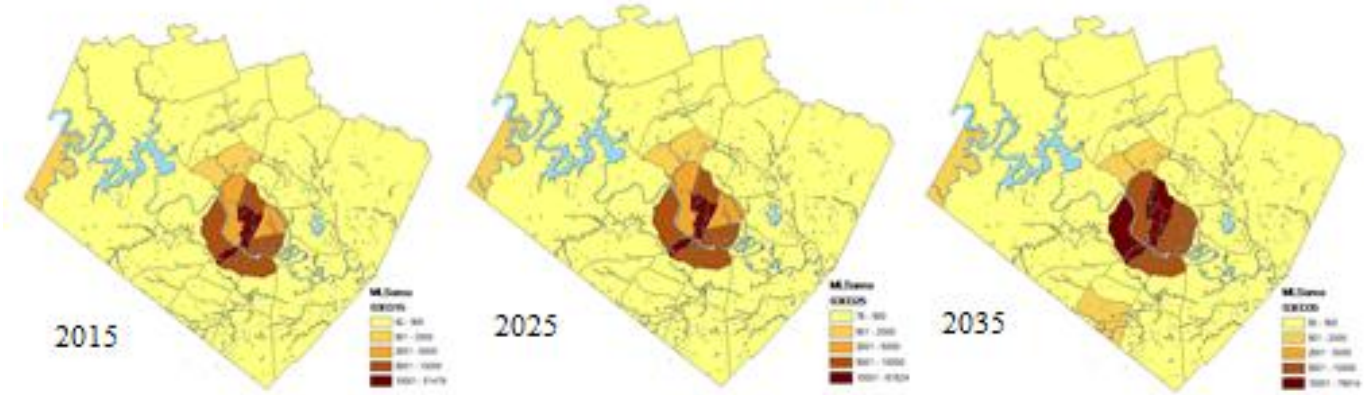
(c) Household density in S3 (S1 + low-density zoning regulation)

Figure 4 Trends of household density 2015-2035 under three scenarios (S1 vs. S2, S1 vs. S3)

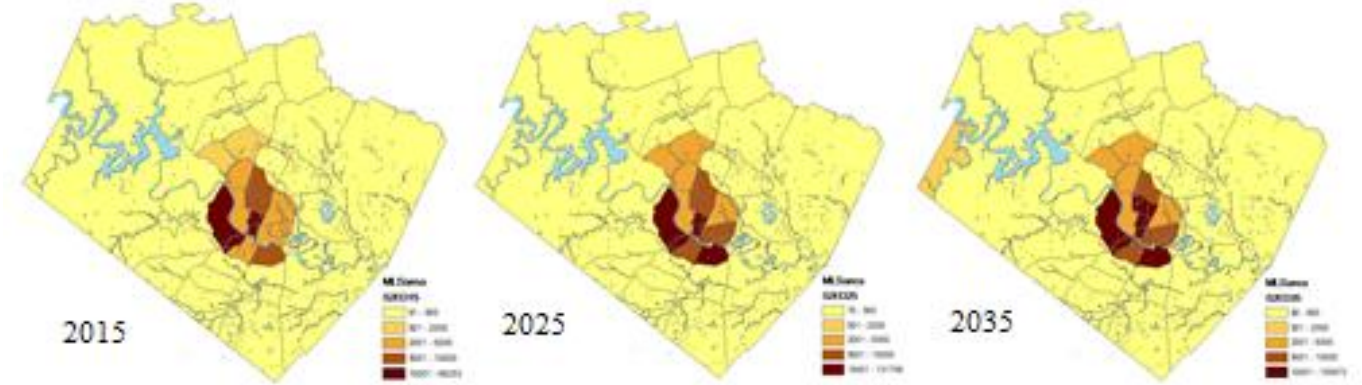
Job Density Dynamics



(a) Employment density in S1 (with exogenous population growth only)



(b) Employment density in S2 (S1 + preference for mixed-use environments)



(c) Employment density in S3 (S1 + low-density zoning regulation)

Figure 5 Trends of employment density 2015-2035 under three scenarios (S1 vs. S2, S1 vs. S3)

Land Use Differences between S1 & S2

Rising demand for mixed-use environments may increase both population & employment in the **urban core** & lower them in the suburbs, while **improving land use diversity** in suburban areas at the same time.

S2 vs. S1	Land Use	2015	2020	2025	2030	2035
Urban Core	#Households	45.69%	22.66%	26.73%	23.25%	24.11%
	#Jobs	1.88%	1.32%	1.38%	1.33%	1.43%
	LU Mix	-0.88%	-0.04%	-0.54%	0.26%	-0.31%
	Jobs/Housing	-36.38%	-19.69%	-28.60%	-23.02%	-25.87%
Inner Suburbs	#Households	-14.87%	-6.61%	-7.70%	-6.56%	-6.80%
	#Jobs	-4.32%	-2.19%	-3.30%	-2.99%	-3.32%
	LU Mix	0.15%	0.12%	-0.15%	0.16%	0.06%
	Jobs/Housing	5.98%	0.11%	0.84%	0.24%	0.40%
Outer Suburbs	#Households	-12.77%	-7.34%	-8.81%	-7.99%	-8.40%
	#Jobs	-4.72%	-4.55%	-4.11%	-4.18%	-4.37%
	LU Mix	4.77%	5.84%	5.97%	6.28%	6.36%
	Jobs/Housing	5.08%	2.37%	5.05%	4.87%	5.28%

Note: %'s are calculated as (land use varriable value in S2 – value in S1) / (value in S1)

Demographic Changes Before vs. After Low-density Zoning

"Zoned-Out" Effects: The low-density zoning regulation appears to encourage population decentralization alongside job centralization, causing **citywide job-housing mismatches** & **urban sprawl**.

		2015	2020	2025	2030	2035
S3 vs. S1						
Urban Core	#Household	0.37%	0.16%	-0.02%	-0.12%	-0.20%
	#Jobs	7.75%	7.61%	7.48%	7.57%	7.69%
Inner Suburbs	#Household	0.28%	0.28%	0.27%	0.22%	0.18%
	#Jobs	-1.53%	-2.58%	-3.18%	-3.36%	-3.49%
Outer Suburbs	#Household	-0.64%	-0.49%	-0.34%	-0.20%	-0.09%
	#Jobs	-34.44%	-35.96%	-37.11%	-37.57%	-37.91%

Note: %'s are calculated as (land use varriable value in S2 – value in S1) / (value in S1)

Demographic Changes Before vs. After Low-density Zoning

When real estate market realizes residents' preferences for mixed-use neighborhoods, the **negative sprawling effects** of land use regulation may be **mitigated**.

		2015	2020	2025	2030	2035
S4 vs. S2						
Urban Core	#Household	2.79%	2.18%	2.24%	2.31%	2.27%
	#Jobs	1.19%	1.53%	1.69%	1.65%	1.56%
Inner Suburbs	#Household	-0.42%	0.20%	0.38%	0.52%	0.59%
	#Jobs	-5.91%	-7.36%	-7.51%	-7.54%	-7.34%
Outer Suburbs	#Household	-2.78%	-2.34%	-2.73%	-2.94%	-3.03%
	#Jobs	-0.45%	-0.94%	-2.01%	-1.79%	-1.46%

Note: %'s are calculated as (land use varriable value in S2 – value in S1) / (value in S1)

Changes in Housing Demands

- **S2 vs. S1:** Demand for LDSF housing falls when mixed-use preference is realized in the market, while demand for HDMF homes rises the most.
- **S3 vs. S1:** Effects of low-density zoning regulation seem small at first, but will increase LDSF demand in the long term.

Housing Demand Comparisons	2015	2020	2025	2030	2035
S2 vs. S1					
Low-Density Single-Family	-6.99%	-4.27%	-4.81%	-4.44%	-4.61%
High-Density SF	9.39%	5.22%	5.96%	5.23%	5.48%
Low-Density Multi-Family	3.57%	2.77%	3.38%	3.38%	3.53%
High-Density MF	25.25%	15.71%	16.66%	15.38%	15.61%
S3 vs. S1					
Low-Density Single-Family	-0.20%	-0.10%	-0.02%	0.03%	0.07%
High-Density SF	0.28%	0.20%	0.12%	0.06%	0.01%
Low-Density Multi-Family	0.19%	0.08%	-0.03%	-0.09%	-0.14%
High-Density MF	0.35%	0.06%	-0.15%	-0.27%	-0.36%

Note: %'s are calculated as (land use varriable value in S2 – value in S1) / (value in S1)

Changes in Housing Rents

- **S2 vs. S1:** Demand for mixed-use neighborhoods significantly raises LDMF & HDSF housing rents.
- **S3 vs. S1:** Supply constraint on high-density development will raise HD housing rents, especially in the long term.

Housing Types	2015	2020	2025	2030	2035
S2 vs. S1					
Low-Density Single-Family	-1.31%	5.51%	3.07%	4.89%	3.92%
High-Density SF	16.97%	27.30%	26.22%	28.76%	27.79%
Low-Density Multi-Family	76.04%	82.70%	74.64%	77.68%	75.61%
High-Density MF	-2.41%	8.91%	4.93%	5.87%	4.87%
S3 vs. S1					
Low-Density Single-Family	-3.01%	-0.24%	1.94%	2.58%	3.13%
High-Density SF	19.61%	22.87%	25.08%	25.42%	26.21%
Low-Density Multi-Family	-3.75%	0.34%	4.64%	6.72%	7.21%
High-Density MF	-4.26%	-1.79%	0.24%	-0.35%	0.02%

Note: %'s are calculated as (land use varriable value in S2 – value in S1) / (value in S1)

CONCLUSION

Developed a **dynamic spatial general equilibrium model** with exogenous (demographic) & endogenous (spatial) features.

Policy implications from 4 policy scenarios:

- **Rising demand for mixed-use neighborhoods** may improve land use diversity in suburban areas & lower demand for low-density single-family housing across the city/region.
- **Low-density zoning regulation in Austin's outer suburbs** may lead to citywide job-housing mismatches & population sprawl, while raising rents on high-density housing & LDSF demand, especially in long term.
- When **existing low-density zoning regulations cannot be changed** in the near term, the promotion of mixed-use development may increase households' mixed-use preferences & mitigate sprawl forces.

LIMITATIONS

- **Effects of transition costs** (e.g., residential moving costs) **& innovation diffusion** should be included in further simulation analyses.
- **More sensitivity analyses** will also support land use policy analysis & regional decision-making.
- Better **calibration of parameters** wanted.
- **Transportation system** is exogenous here.
- Need for **welfare analysis**, with more policies related to zoning changes, road tolls, & subsidies for alternative development.

Thank you for your kind attention.

Questions & Suggestions?

Papers available at

www.caee.utexas.edu/prof/kockelman