The implications of land-market representation for the interpretation of empirical land-use change models

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Why model land values?

- Understand existing determinants of land prices
- Anticipate future land price trajectories
- Test policies, scenarios, etc.

➢ Last two require projections of future patterns and trajectories

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Limits of available tools

- Geographical model effectively project change patterns, but haven’t accounted for market influences
- Hedonic regressions track drivers of value, but don’t project or account for market dynamics
- Agent-based market models hold promise, but are not yet fully empirical

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Open methodological questions

- What might be “best practice” for using hedonic regression to project land-value change?
- What important issues might research face as they more fully develop empirical agent-based land market models?
- ➢ How might agent-based modeling be used as a computational laboratory to shed light on these questions?

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What is an Agent-Based Model (Agent-based computational economics)?

- A simulation model that includes:
  - A collection of autonomous decision-making agents
  - A specification of an environment through which agents interact
  - A specification of interdependencies among agents, their environment, or both
  - A set of rules governing sequencing of actions and information flows
- Often implemented through computer code
- NOT a set of equilibrium conditions

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How is this different?

- Standard approach: story about “invisible hand” motivates a set of equilibrium conditions
- ABM approach simulates the interactions behind the story
- Equilibrium may be reached when gains from trade are exhausted
- Equilibrium is not imposed
- There may not be an equilibrium!

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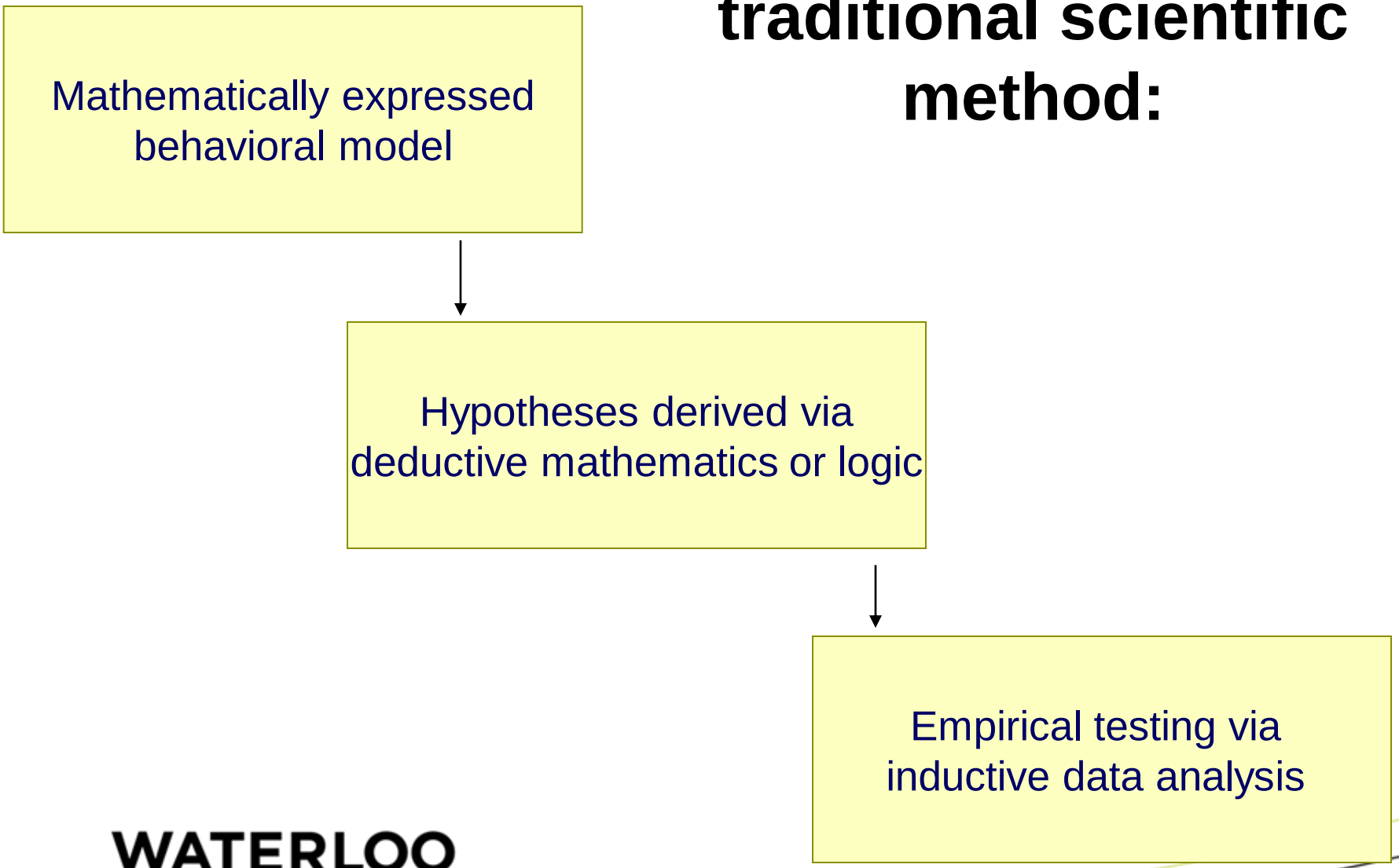
Modeling in the traditional scientific method:



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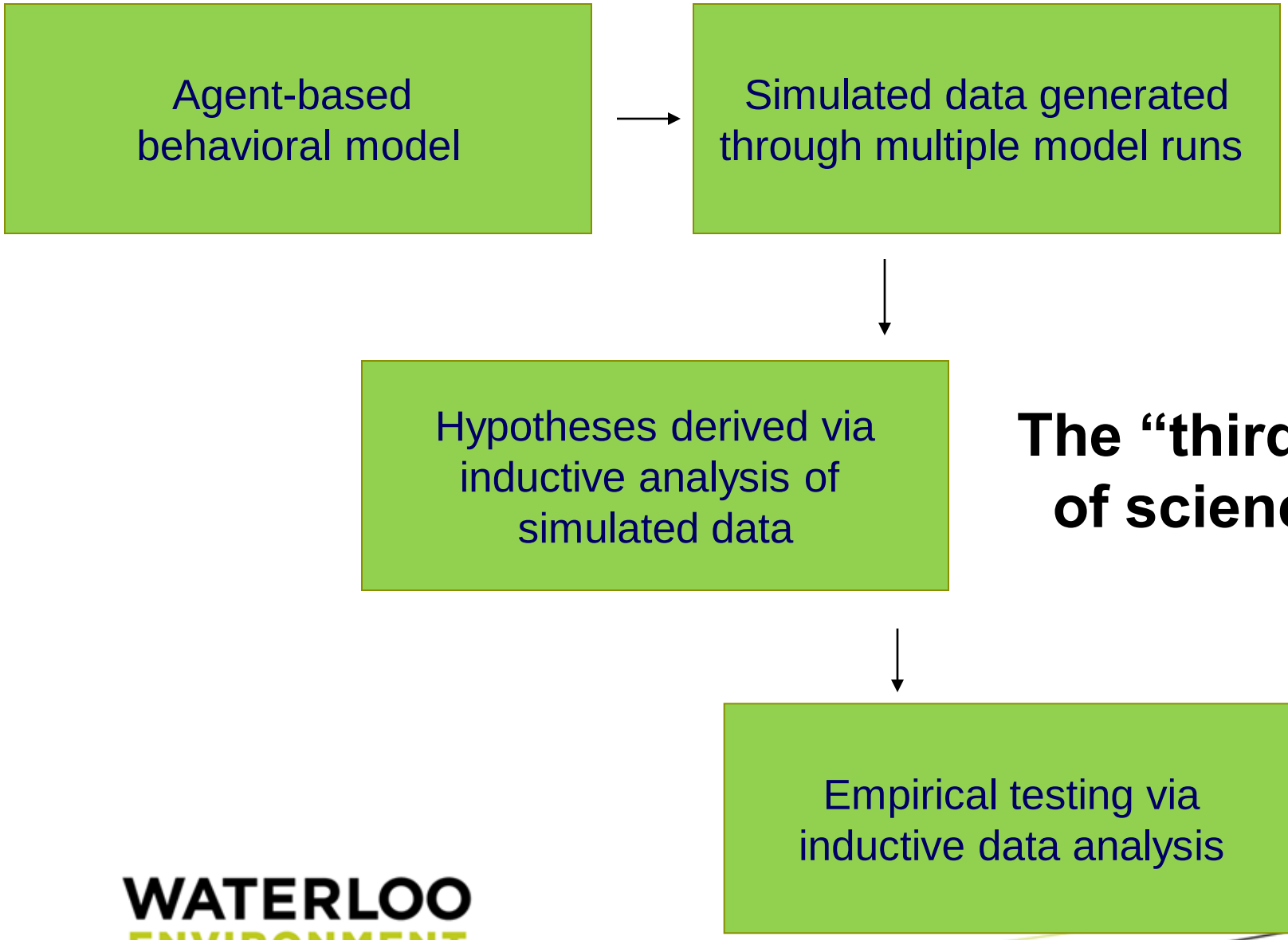

The "third way of science":

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Land use modeling in the traditional econscientific method

- Analytical, theoretical, deductive models

↓

- Theoretical land values
- Simple urban land-use development patterns

Regression models (Hedonic, lim-dep, duration) → Probabalistic transition rules → Simulated future trajectories, location and pattern

↓

- Planners
- Economists
- Policy makers

…

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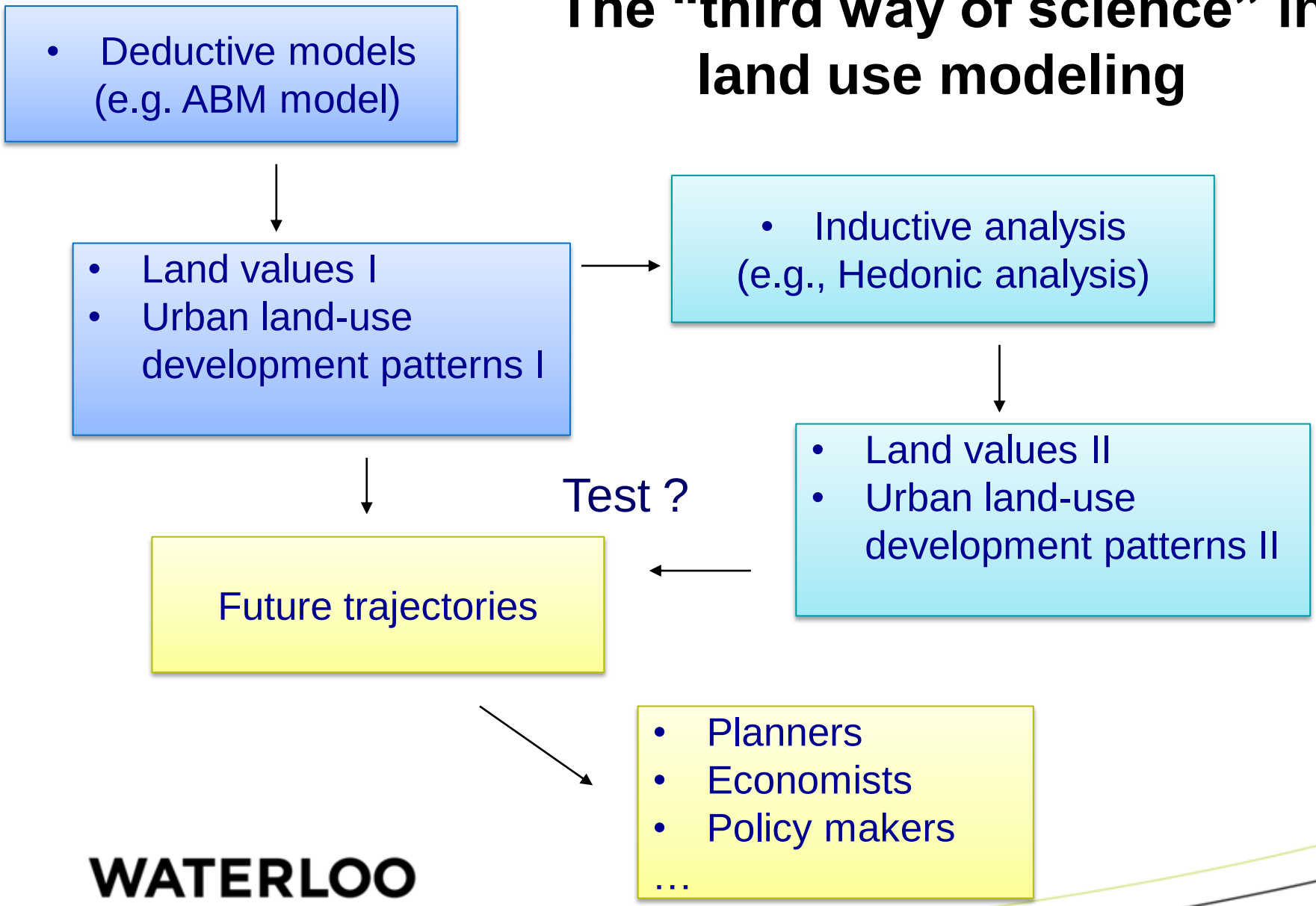
The “third way of science” in land use modeling



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Hedonic analysis

- **Merit**--wide use in the analysis of land market interactions and endogenous price formation
- **Biases--**Omission of agent data and important market mechanisms

	Common case	**Best case**
Research data	Spatial data only	Spatial and agent data (buyers/sellers)
Market representation	Sequential or sophisticated location and allocation	Including budget constraints and competitive bidding

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Research questions

Hedonic-regression-based projection algorithms

How successfully can hedonic models project/recreate market landscapes?

How is the projection accuracy affected by available data and representation of market mechanisms ?

Land-use and land-value change

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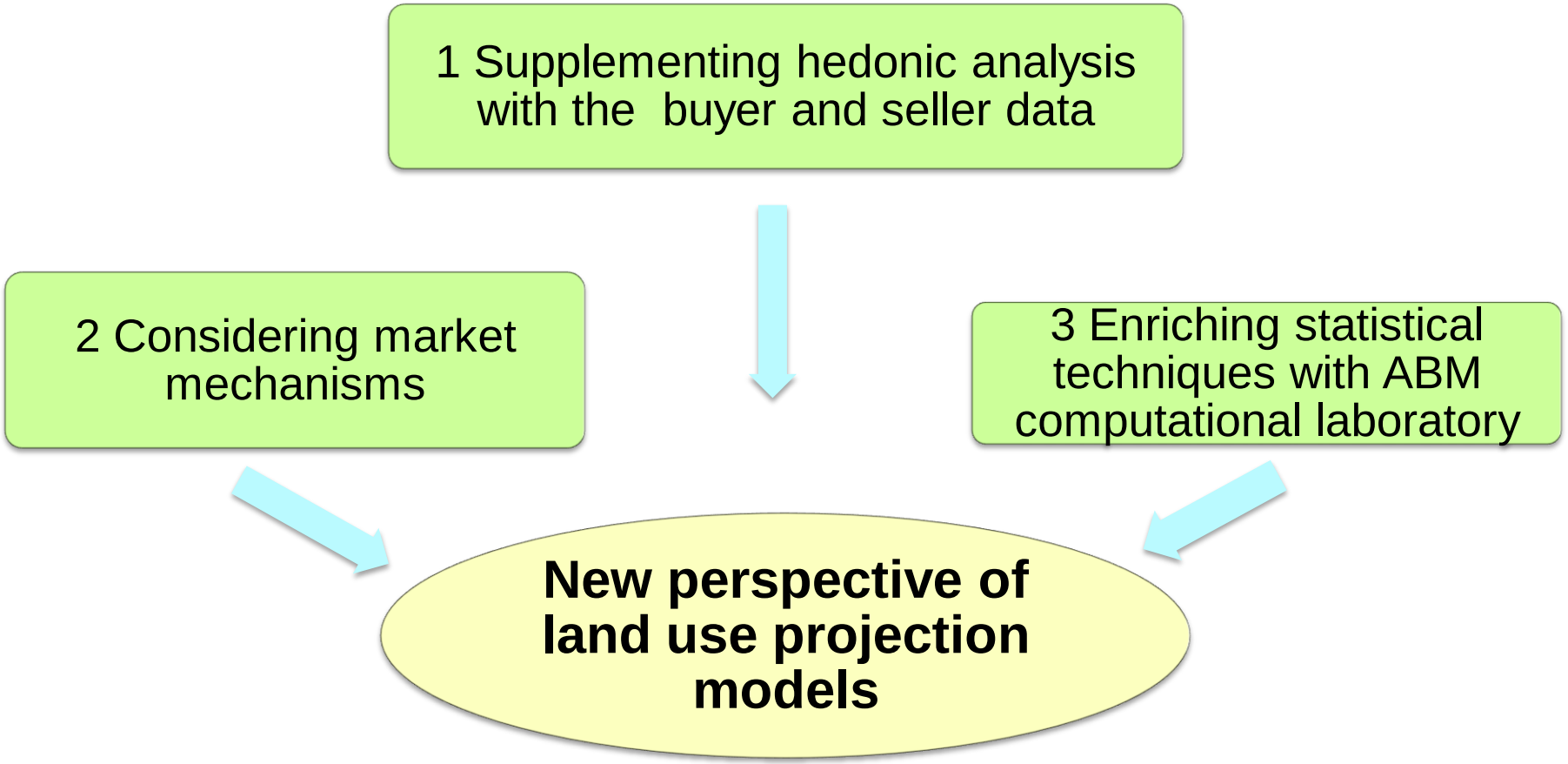
Research goals: Explore value added of:



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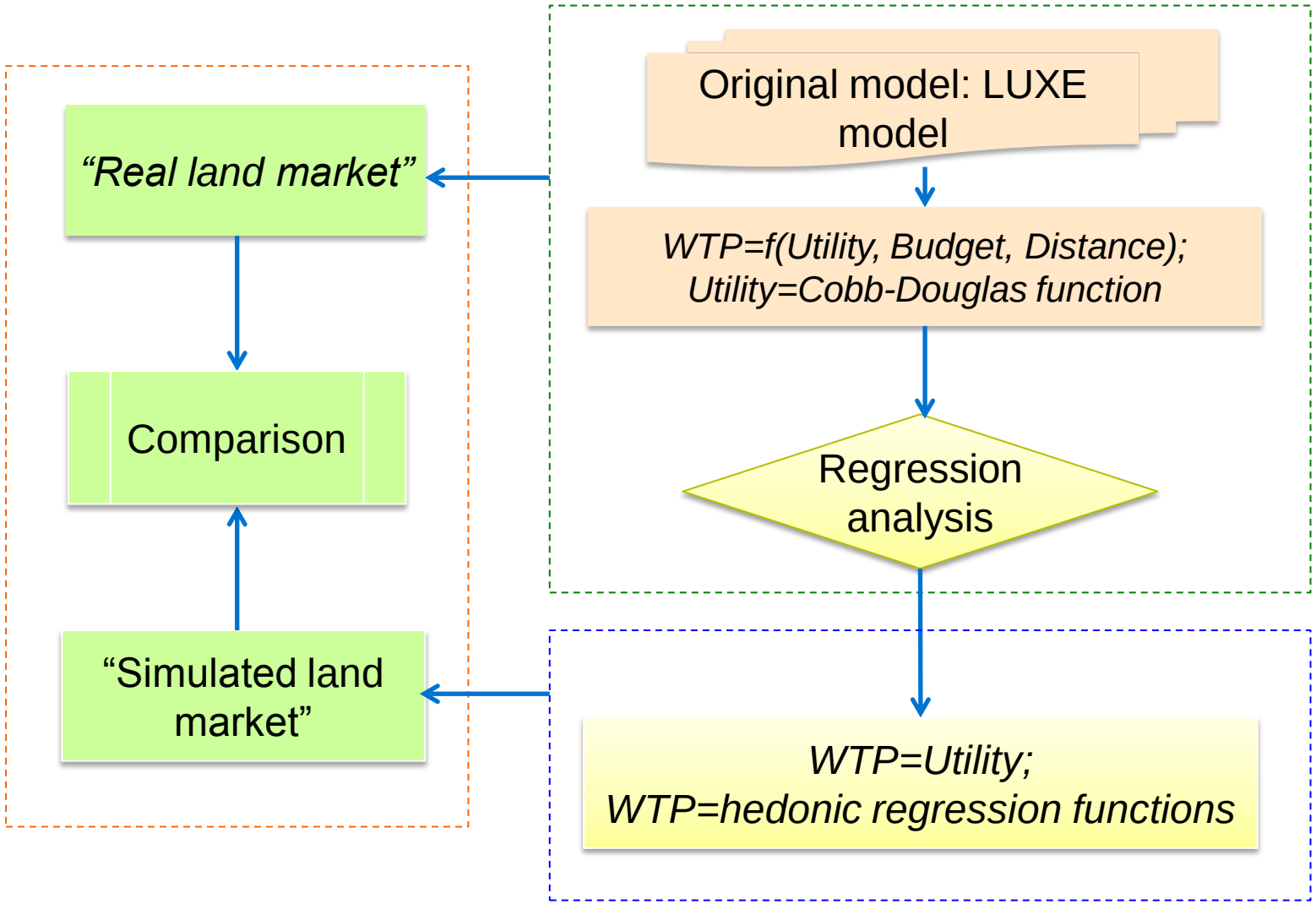
Flow chart



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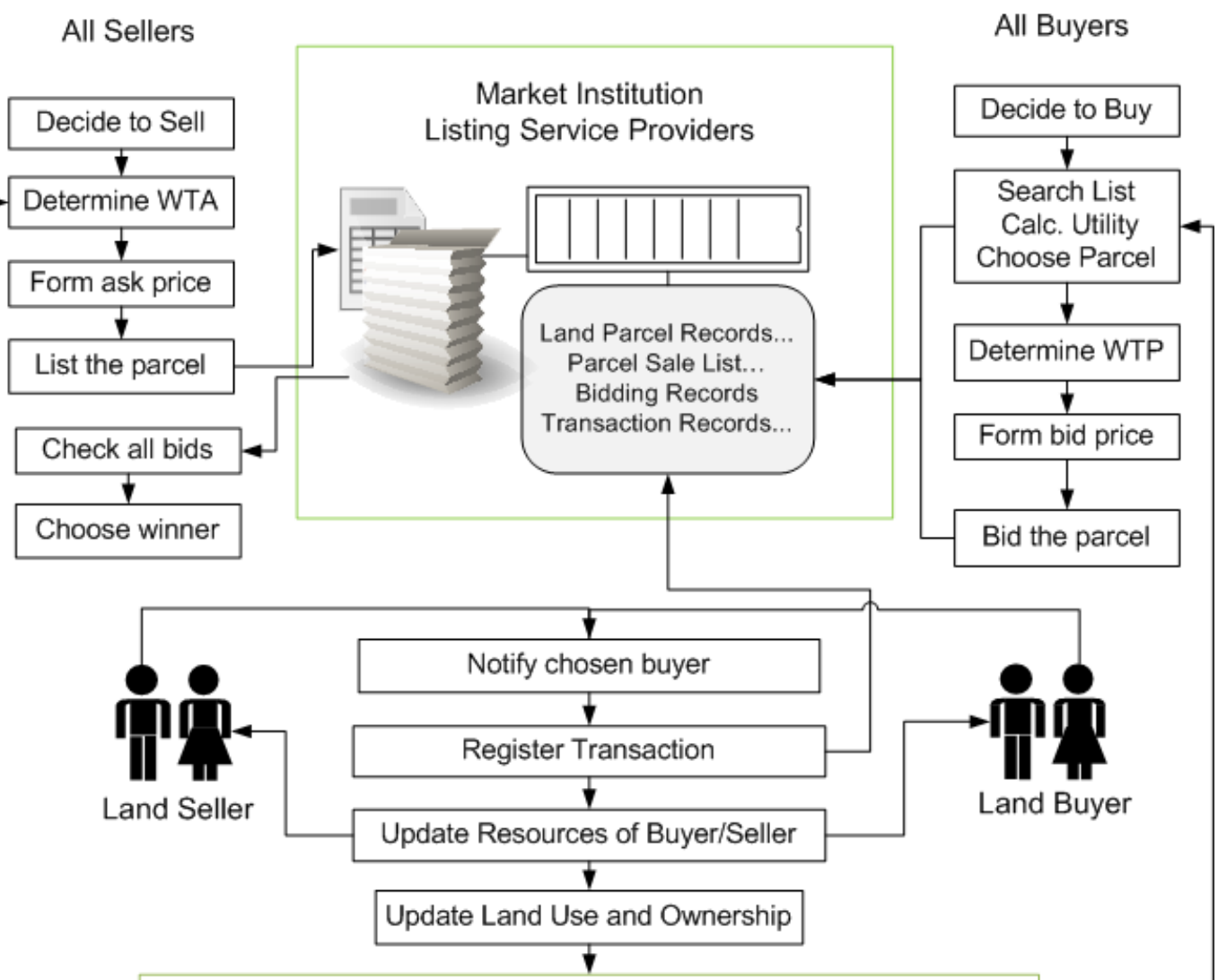
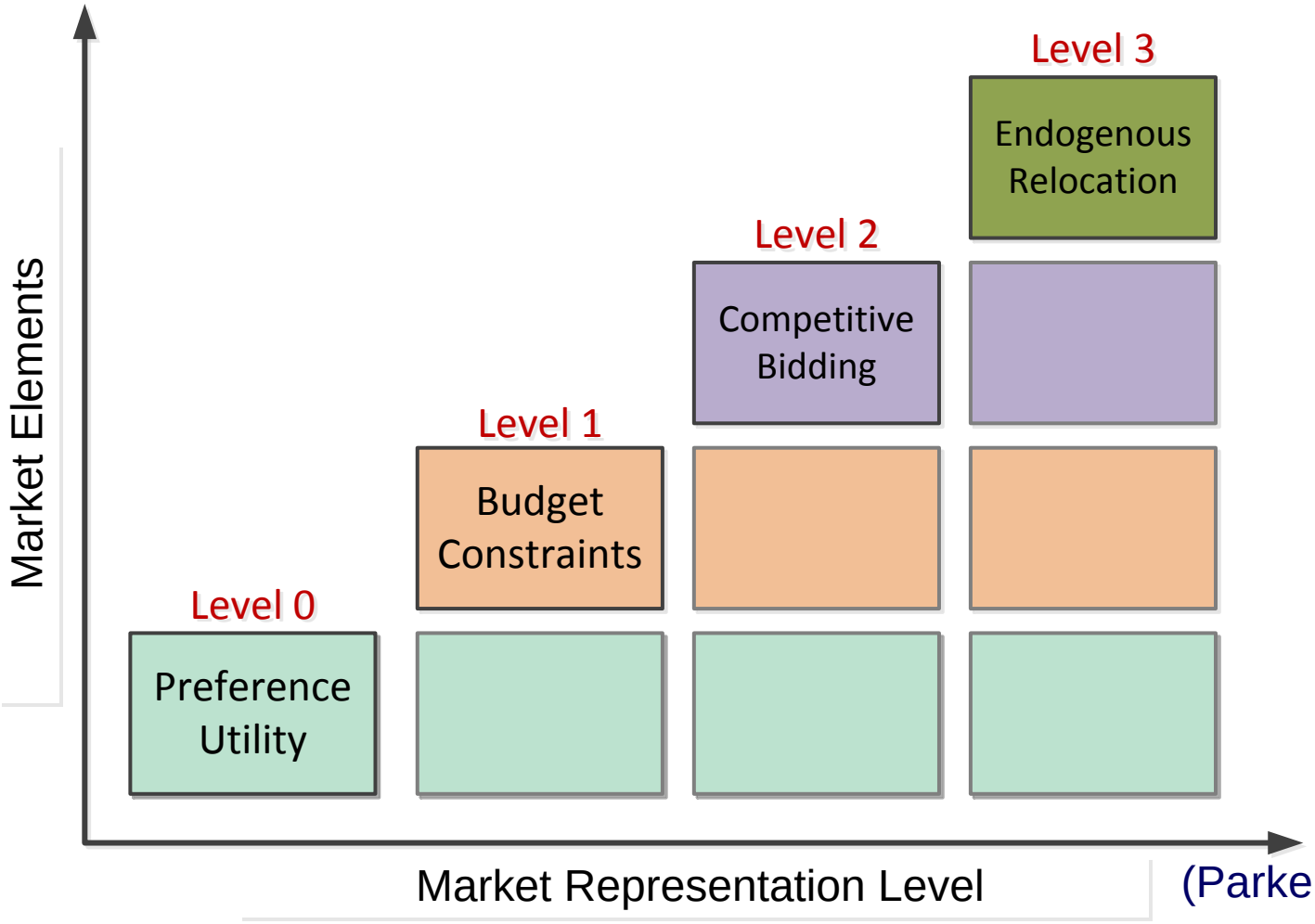


Land Market of LUXE model (Sun et al. 2014)

Land market elements



(Parker, 2012)

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Experimental design

	Analytical WTP	WTP_S	WTP_AS
Level 0		L0_WTP_S	L0_WTP_AS
Level 2	Original Model	L2_WTP_S	L2_WTP_AS

- Level 0: First come first served
- Level 2: Budget-constrained competitive bidding
- WTP_S: Only spatial data (distance to CBD; open space amenities)
- WTP_AS: Spatial and agents' data (budget; preferences)

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Key functions in experiments

	WTP function	Utility function
Original Model	*WTP = f(BUD, DIS, Utility)*	*Cobb-Douglas*
WTP_S	*WTP_S = f(DIS, OSA)*	*Utility = WTP_S*
WTP_AS	*WTP_AS = f(DIS, OSA, BUD, PRE)*	*Utility = WTP_AS*

$$WTP = (BUD - TransCost) \times \frac{Utility^2}{Utility^2 + b^2}$$

$$Utility = A^a \times P^b$$

$$WTP\_S = a_1 + b_1' \, DIS + c_1' \, OSA$$

$$WTP\_AS = a_2 + b_2' \, DIS + c_2' \, OSA + d_2' \, BUD + e_2' \, PRE$$

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A: measure of open space amenity, equals *OSA*;
P: standardized measure of distance to CBD(*DIS*);
PRE: preference for distance to CBD, equals b; $a + b = 1$

Hedonic regression analysis

Land-use change and transaction prices patterns

Spatio-temporal patterns of land rents

Finding and comparisons

Quantity of change

Economic metrics

Measures of fragmentation

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Hedonic analysis (baseline model)

WTP_S	
r^2	80.76%
a_1 (cons)	25.53***
b_1 (DIS)	-3.57***
c_1 (OSA)	125.99***

WTP_AS	
r^2	99.62%
a_2 (cons)	-21.09***
b_2 (DIS)	-1.79***
c_2 (OSA)	41.14***
d_2 (BUD)	0.66***
e_2 (PRE)	-7.48***

- As expected, travel cost and open-space amenities are overvalued when budget and preferences are omitted

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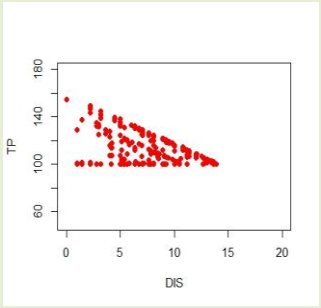
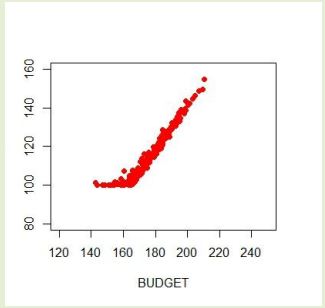
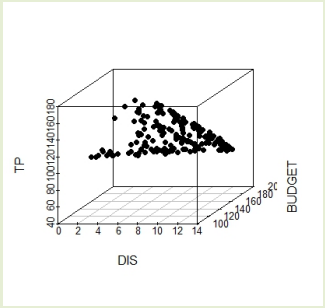
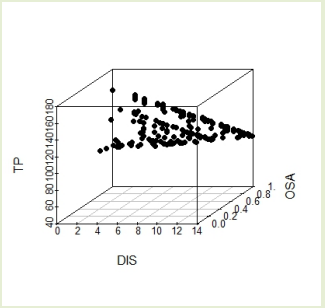
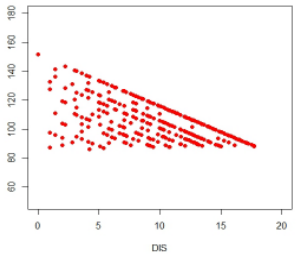
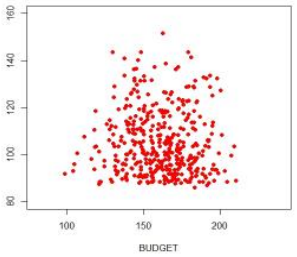
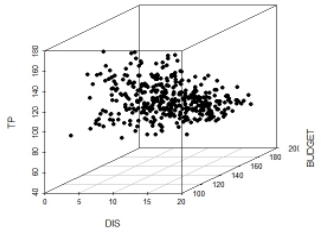
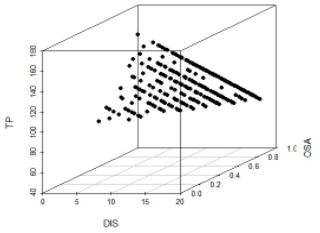
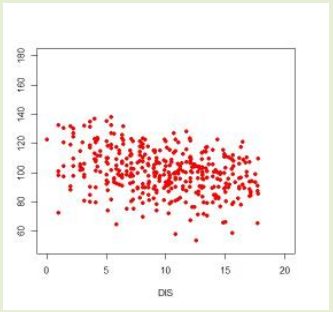
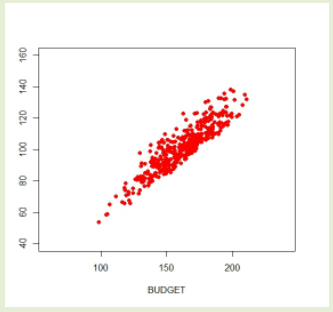
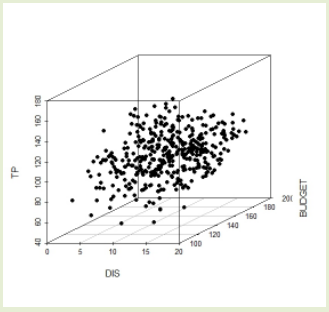
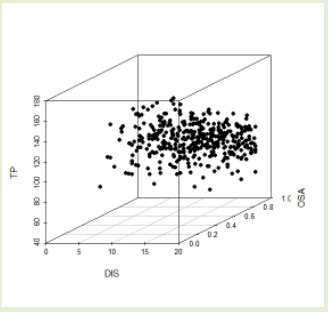
Land-use change and transaction prices patterns

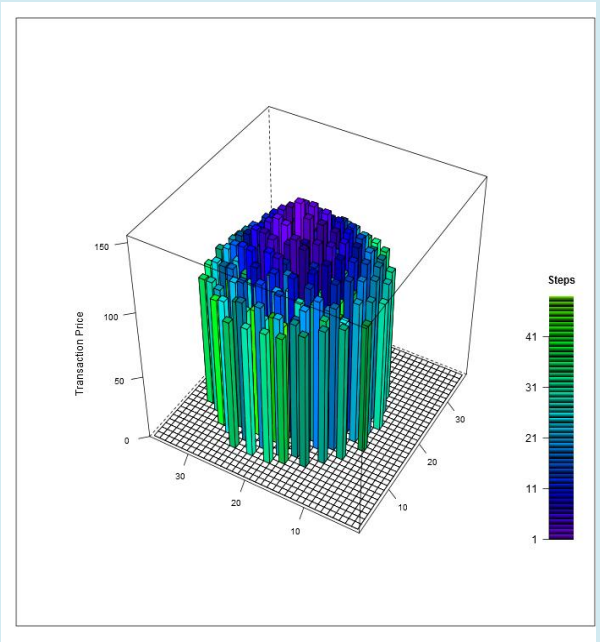
- **Level 0**

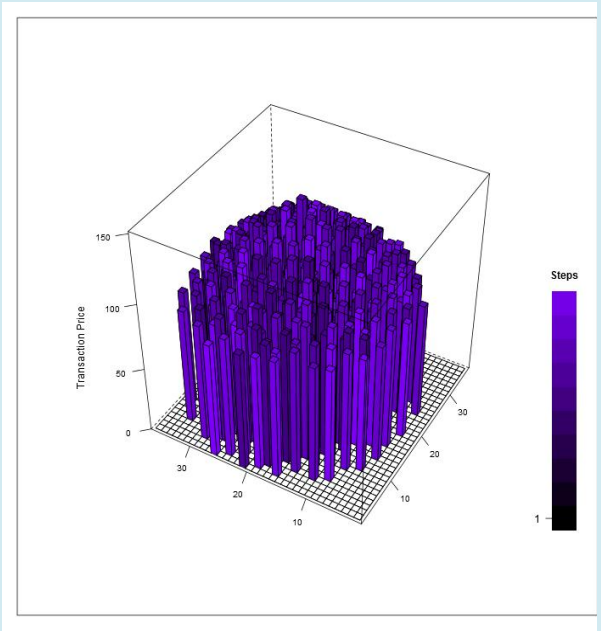
	TP VS DIS	TP VS BUDGET	TP VS DIS & BUDGET	TP VS DIS & OSA
Original Model				
L0_WTP_S				
L0_WTP_AS				

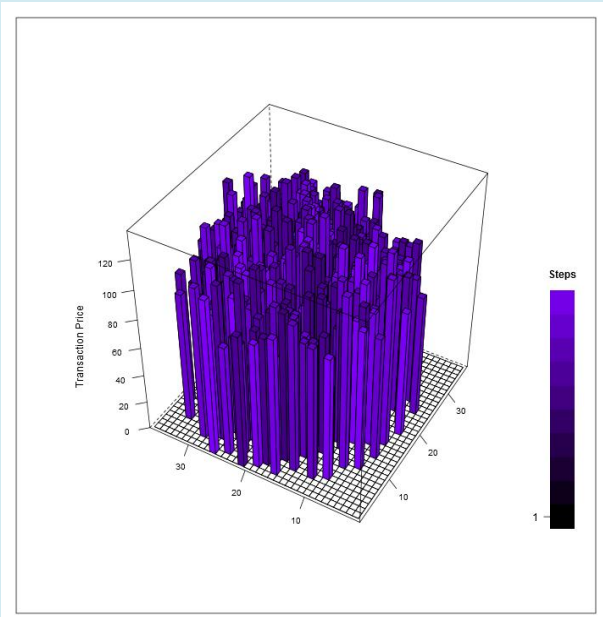
Spatio-temporal patterns of land rents

- **Level 0**

Original Model	L0_WTP_S	L0_WTP_AS







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Points to note:

- Original model reveals clear land-rent gradient, positive relationship between budget and sales price, and value of OSA
- Spatial-only regression plus L0 (standard practice in econometric projections) reveals land-rent gradient but not income effect
- Spatial-plus-agent regression reveals income effects but not rent gradient

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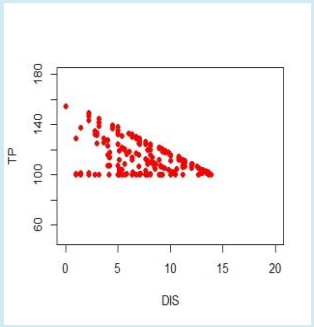
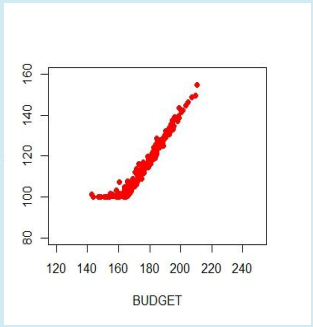
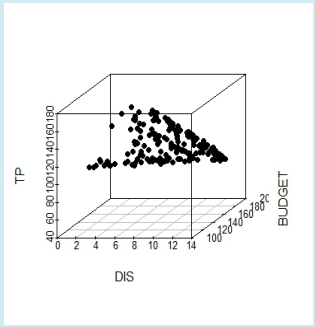
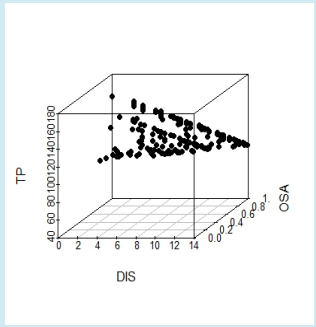
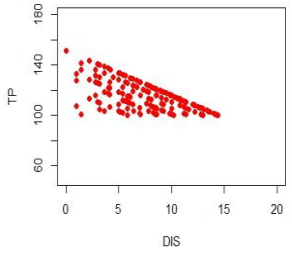
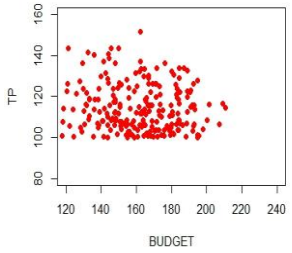
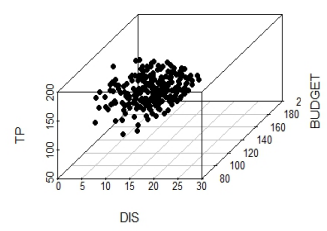
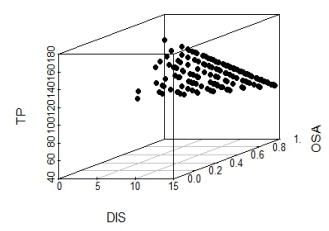
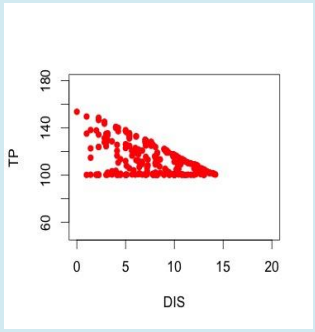
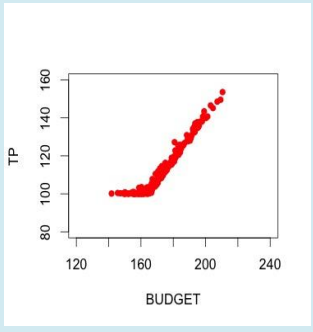
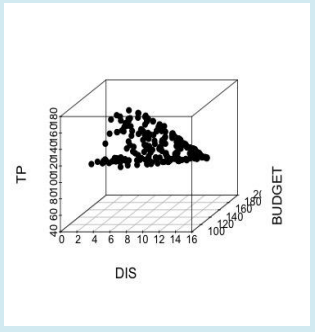
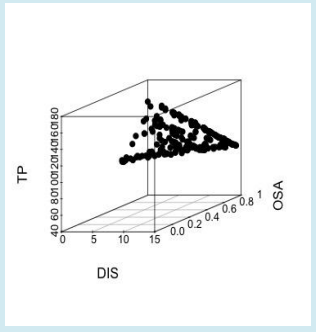
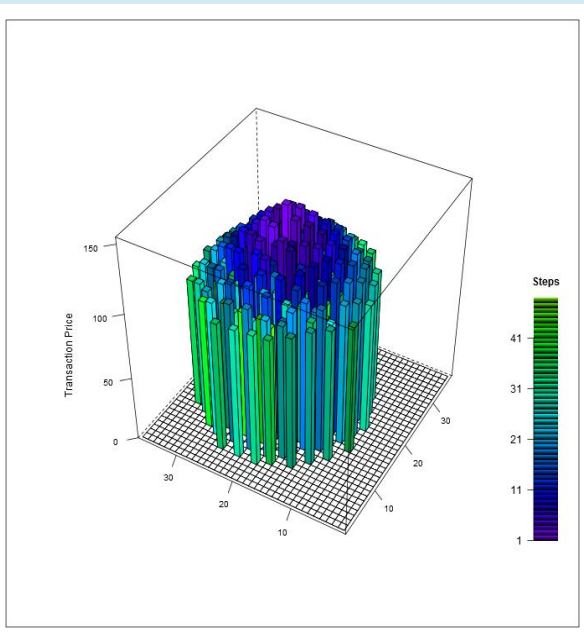
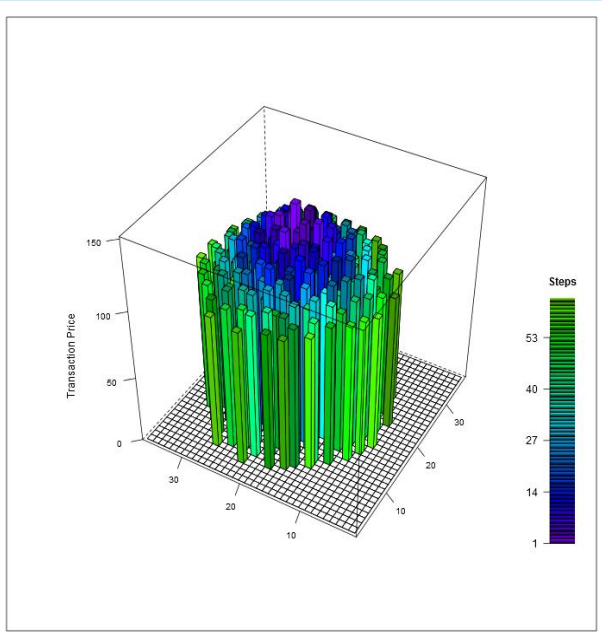
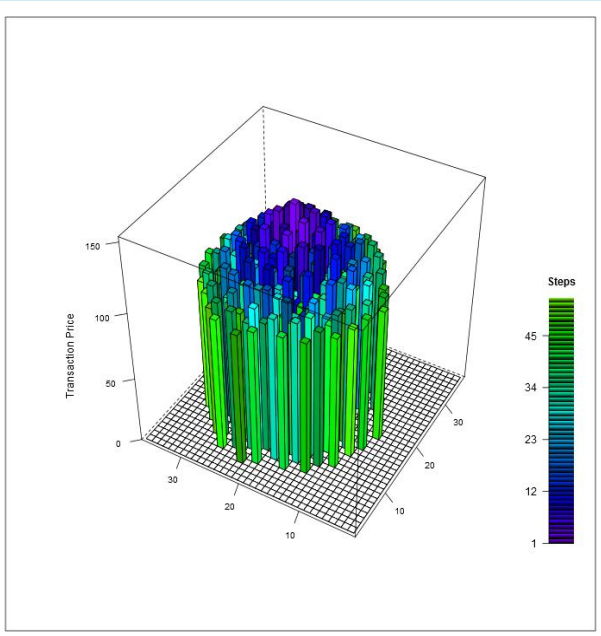
Land-use change and transaction prices patterns

- **Level 2**

	TP VS DIS	TP VS BUDGET	TP VS DIS & BUDGET	TP VS DIS & OSA
Original Model				
L2_WTP_S				
L2_WTP_AS				

Spatio-temporal patterns of land rents

- **Level 2**

Original Model	L2_WTP_S	L2_WTP_AS
		

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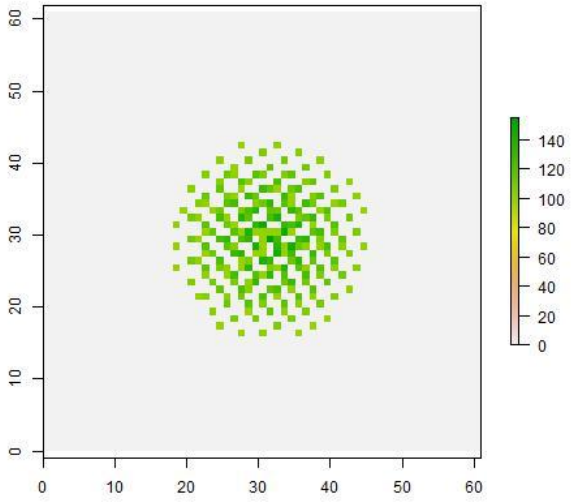
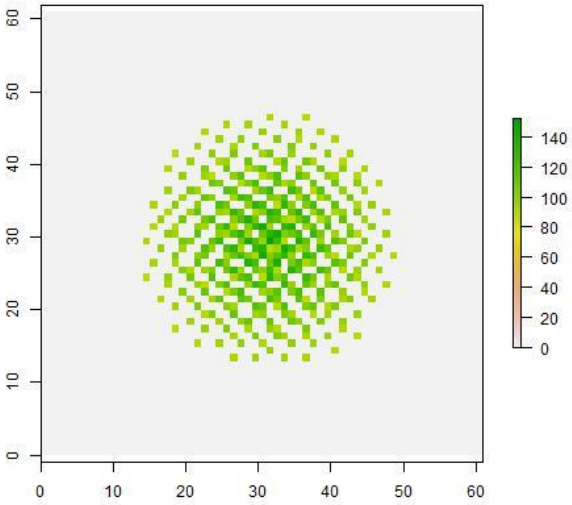
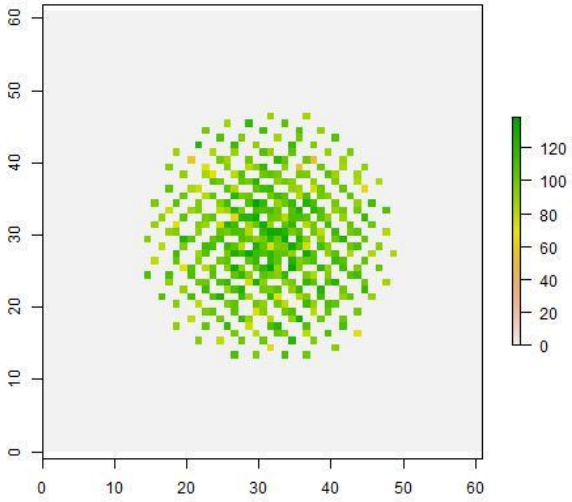
Points to note

- As expected, both L2 models reveal the land-rent gradient
- Only the spatial-plus-agent model reveals budget effects

Quantity of land-use change: Over-projected if no quantity constraint

- **Level 0**

Level 0 of Land Use Change (LUC)

Original Model	L0_WTP_S	L0_WTP_AS
		

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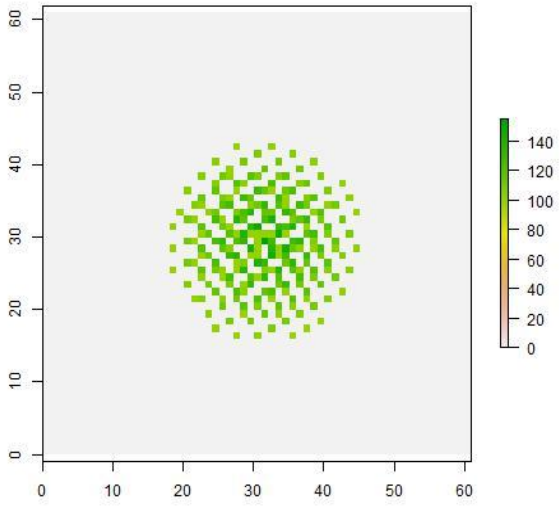
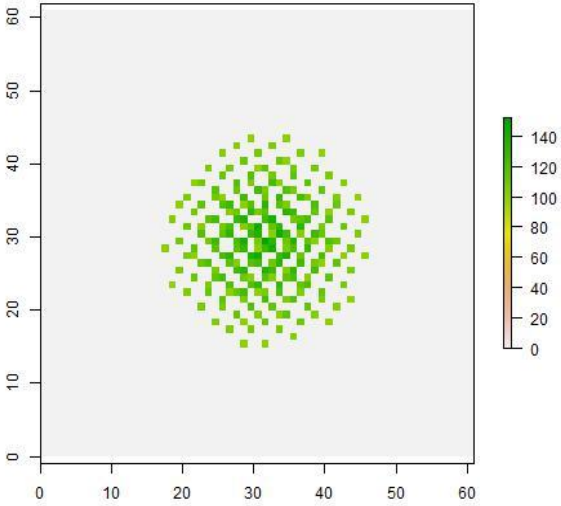
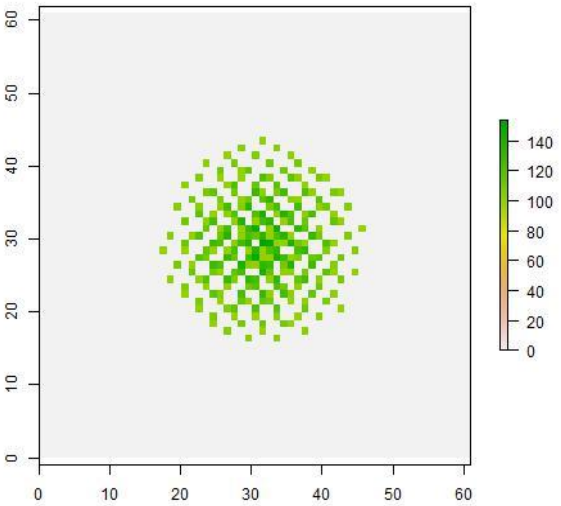
Quantity of land-use change: Fairly closely replicated!

- **Level 2**

Original Model	L2_WTP_S	L2_WTP_AS







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Economic metrics and measures of fragmentation

Key model output metrics from market levels, mean value and standard deviation

	$\bar{C}_{tran}$	Q	$\bar{T}p$	$Tp\max$	$Tp\min$	r_e^q	AI^q	LSI^q	CI^q
L0_WTP_S	9.90***	400***	103.24***	149.82***	76.53***	3.69***	0.11***	9.05***	0.10***
	0.09	0.00	1.02	2.27	5.04	0.15	0.02	0.15	0.01
L0_WTP_AS	9.90***	400***	100.23***	143.50***	55.93***	3.69***	0.11***	9.05***	0.10***
	0.09	0.00	0.65	5.12	5.92	0.15	0.02	0.15	0.01
L2_WTP_S	8.39***	211***	114.03***	149.82***	100.11***	1.87***	0.30***	7.29***	0.29***
	0.35	12.71	0.67	2.27	0.10	0.09	0.03	0.24	0.02
L2_WTP_AS	8.02***	257***	111.28***	159.44*	100.00*	1.80*	0.33*	7.00*	0.31*
	0.31	14.85	0.86	5.45	0.00	0.21	0.06	0.50	0.05
Original Model	8.18	225	112.94	159.98	100.01	1.76	0.34	6.97	0.31
	0.20	8.44	0.59	5.82	0.01	0.11	0.03	0.27	0.03

Mean transport cost ($\bar{C}_{tran}$); Quantity of converted land (Q); Mean transaction price ($\bar{T}p$); Maximum transaction price ($Tp\max$); Minimum transaction price ($Tp\min$); Quantity-controlled edge density (r_e^q); Quantity-controlled aggregation Index (AI^q); Quantity-controlled landscape shape index (LSI^q); Quantity-controlled contiguity index (CI^q)

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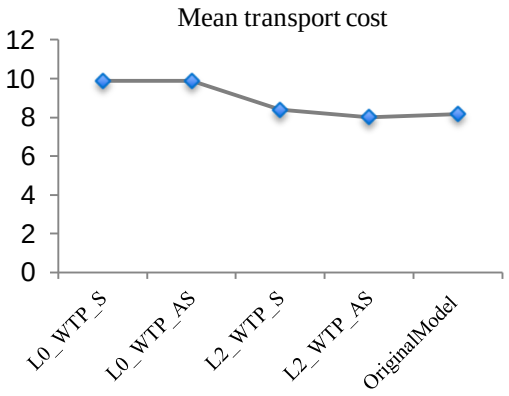
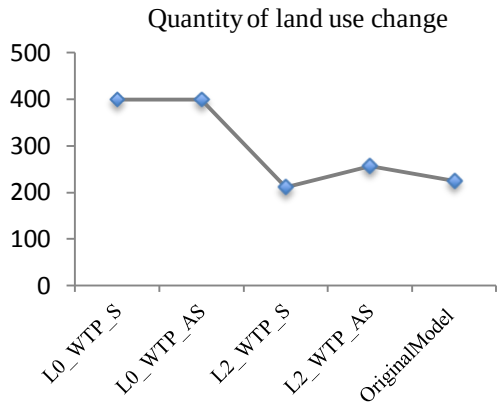
Points to note

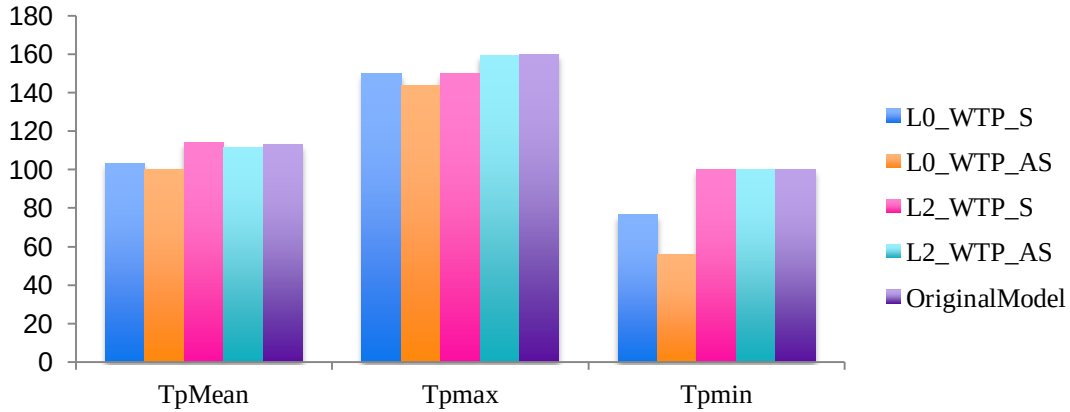
- All models statistically significantly different from original landscape
- L2_WTP_AS differs least
- Questions in simulation world about whether statistical significance is relevant (population comparisons)



Overall Spread



Quantity-Controlled Sprawl



Economic Metrics

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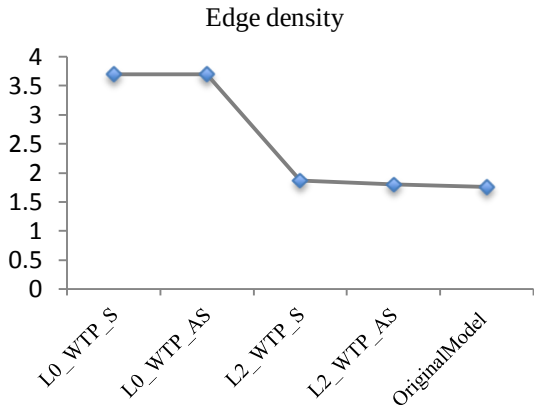

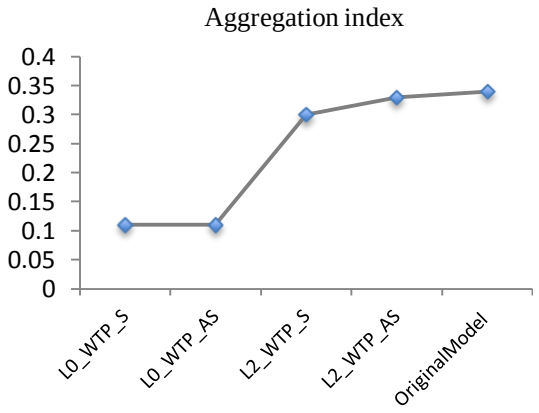

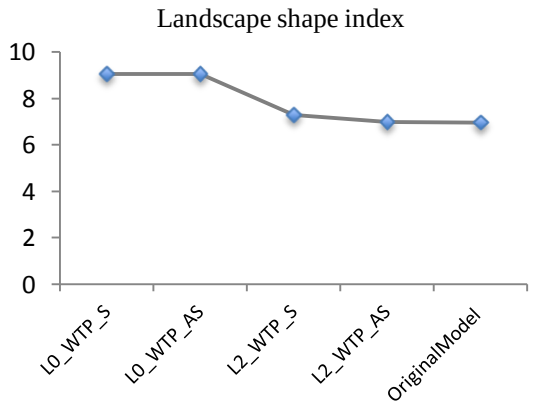

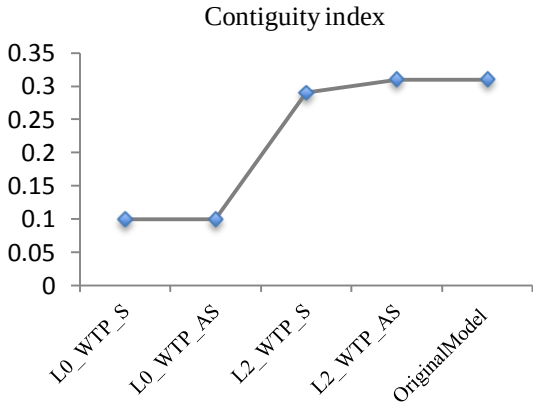

Fragmentation

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Conclusions

- Hedonic regression with agents' characteristics
  - Combined with key market mechanisms

Reasonable degree of confidence for land-use change projection

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Conclusions, cont.

- Hedonic regression without agents' characteristics
  - Standard suitability projection algorithms

Caveats/cautions for land-use change projection

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Future research directions

- Test two additional analysis methods for a comparison of the landscape (map comparison plus regression)
- Perform additional analysis of the macro metrics, controlling for independent variables
- Evaluate two additional land-use change projection algorithms: parcel based, and lim-dep
- Include endogenous relocation mechanism

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