PARTIAL LOCAL MORAN

HANDLING LOCAL CONFOUNDING

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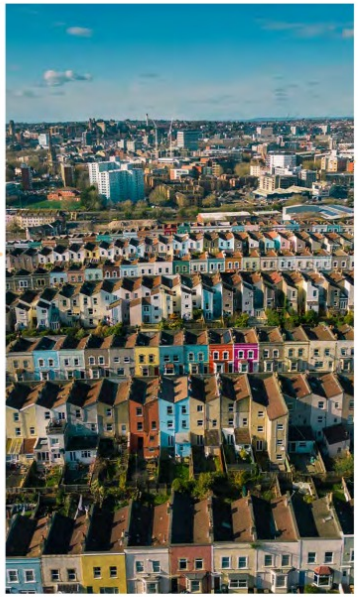
LOCAL CONFOUNDING

PRIOR ART IN ESDA

PARTIAL CONDITIONING

AFFORDABILITY OUTLIERS

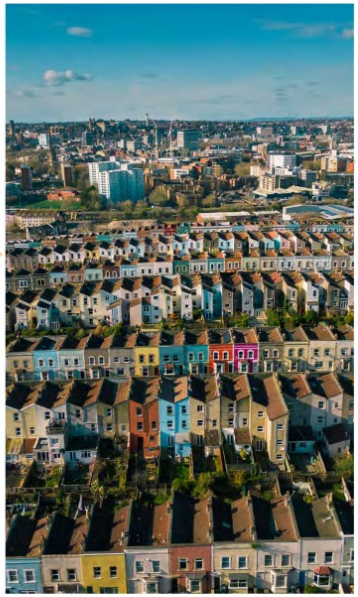


Bristol's big housing conversation

Bristol Living Rent Commission

BRISTOL ONE CITY

HOW CAN WE FIND RENT AFFORDABILITY OUTLIERS?



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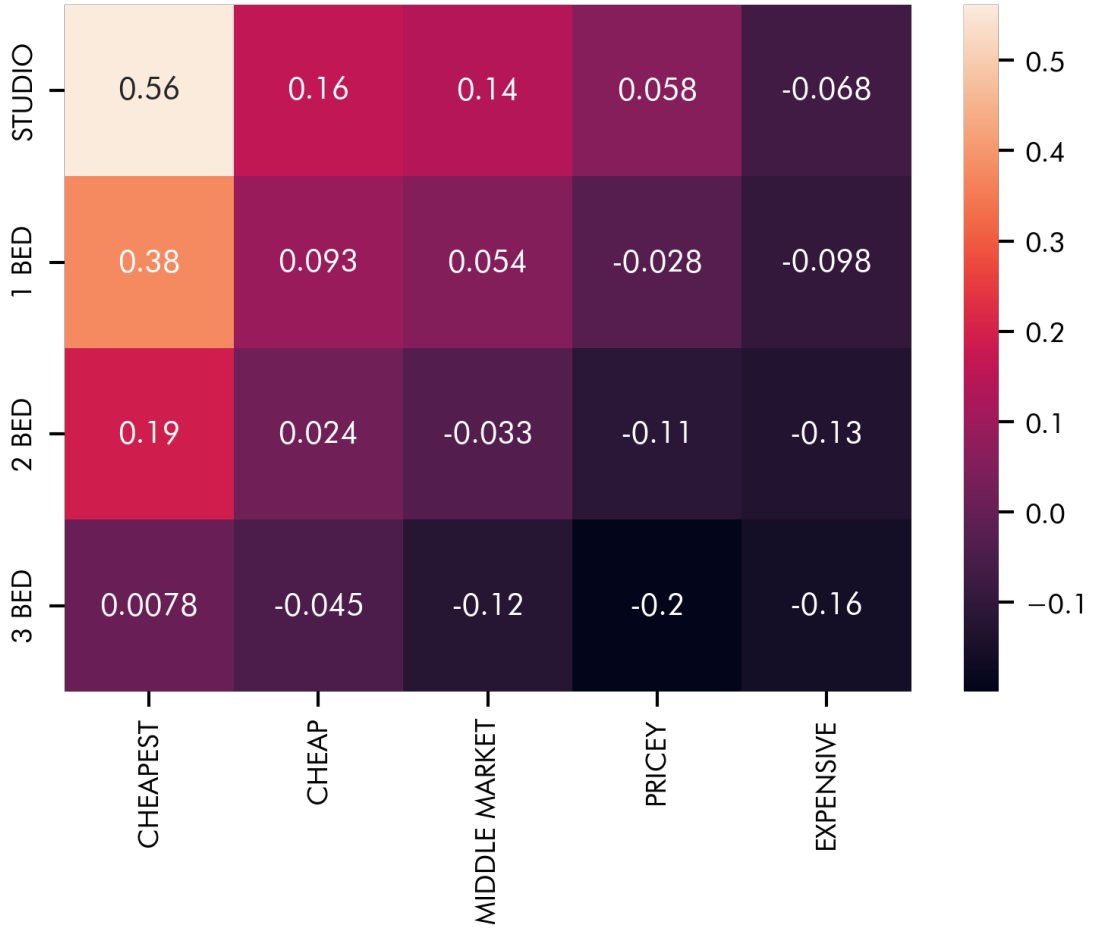

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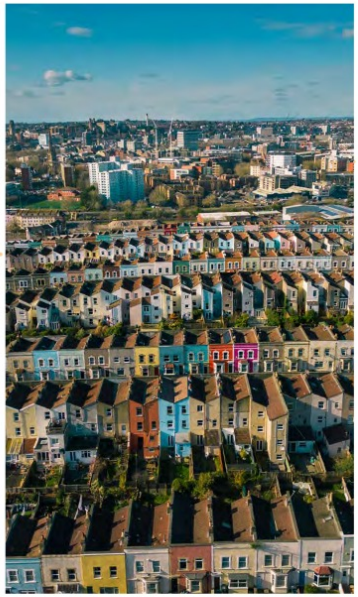

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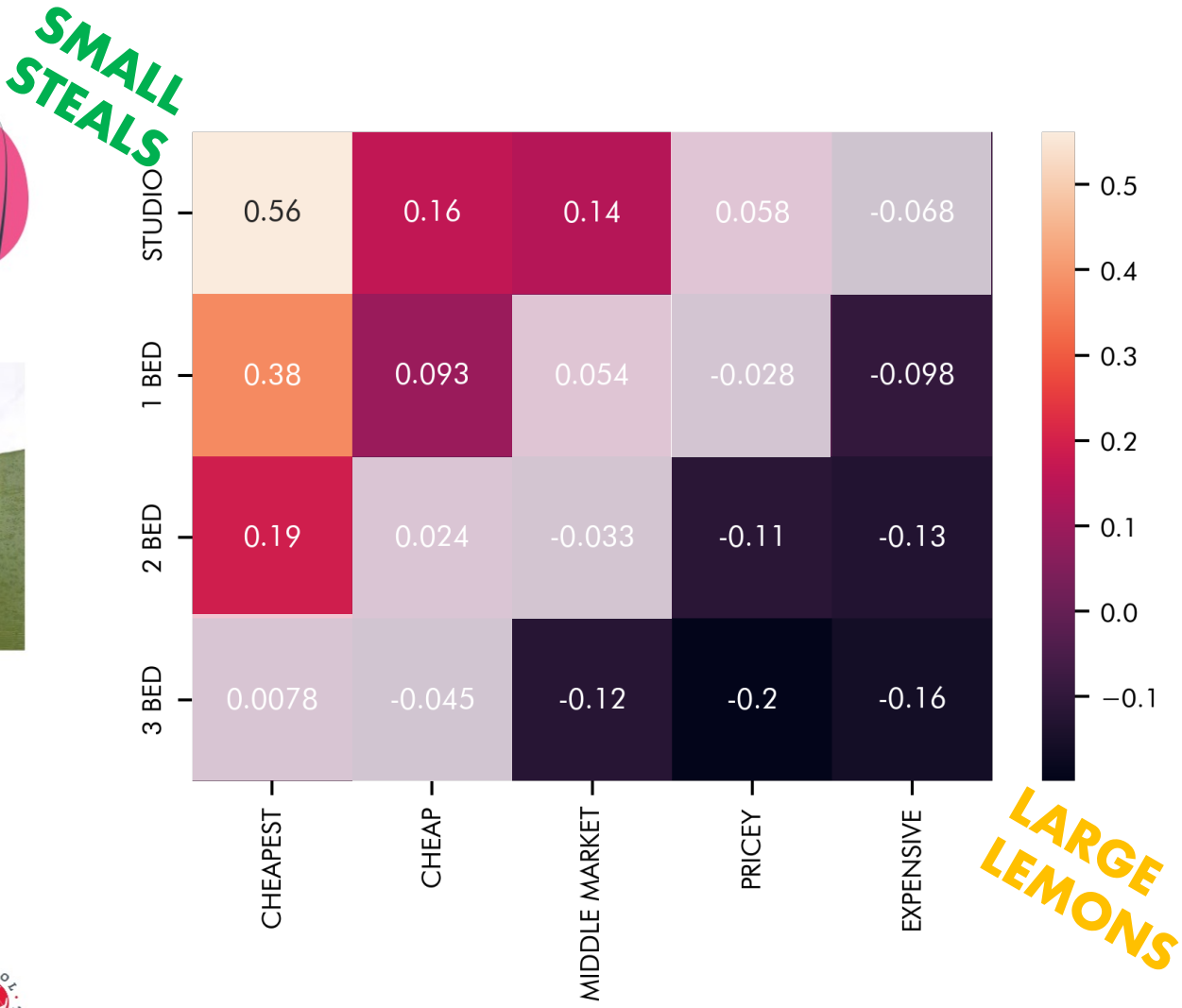

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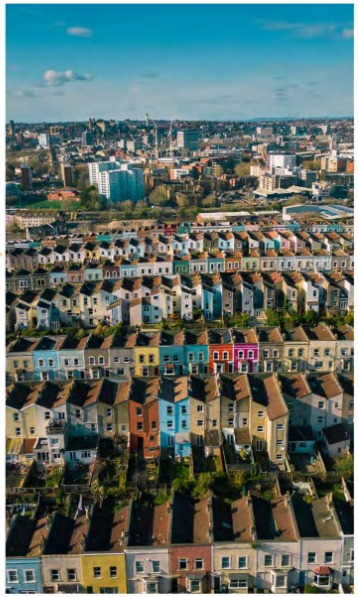

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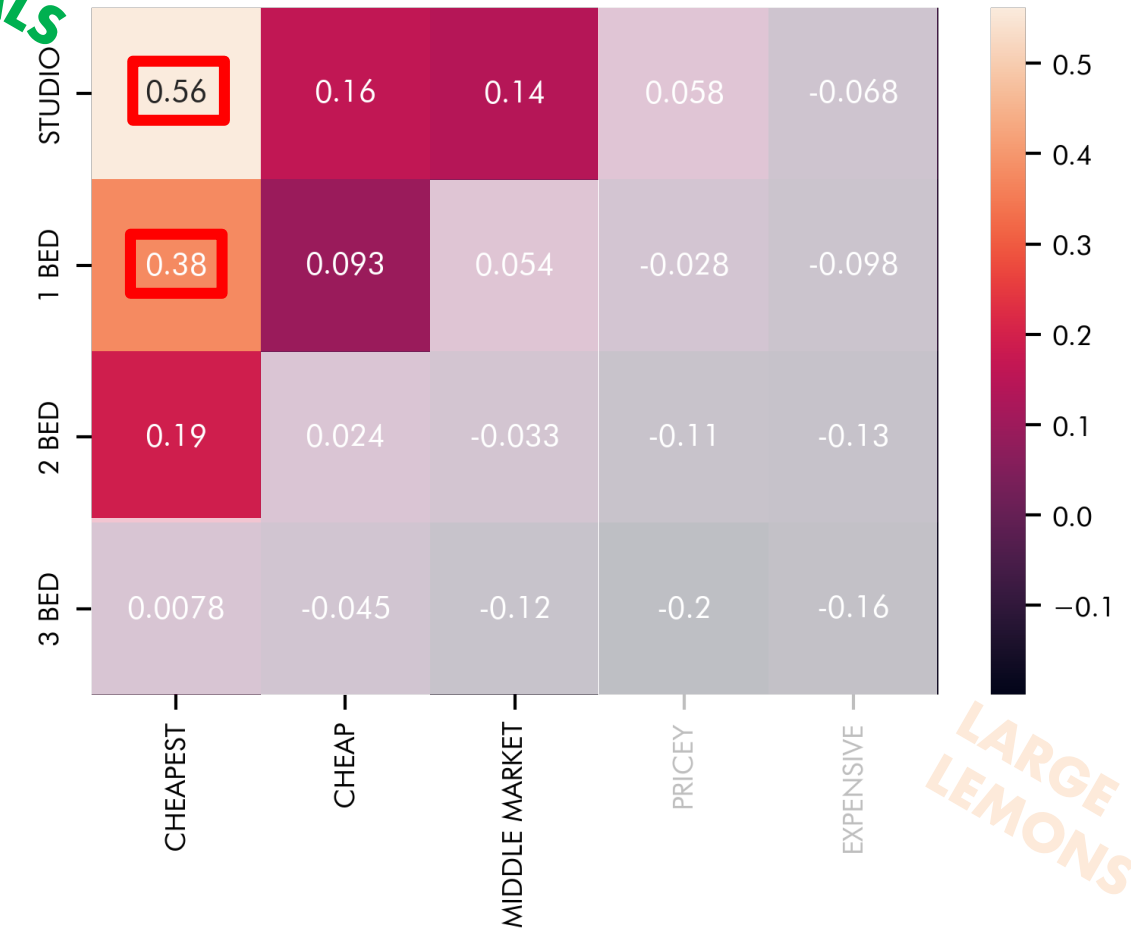
SMALL STEALS

DOUBLED RENT W/IN 2 YEARS



LARGE LEMONS

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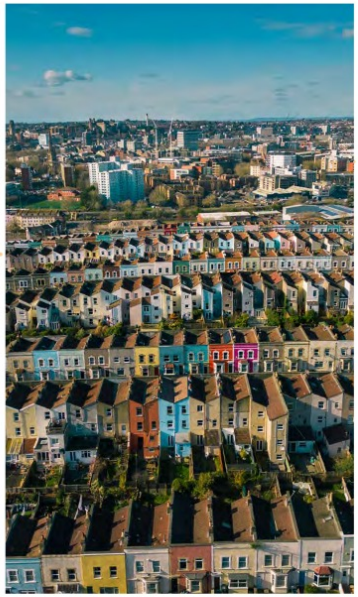

Bristol's big housing conversation

How the rent will be decided depends on the type of rent case…

The tribunal will look at the market or rents of similar properties in the local area.

Bristol Living Rent Commission

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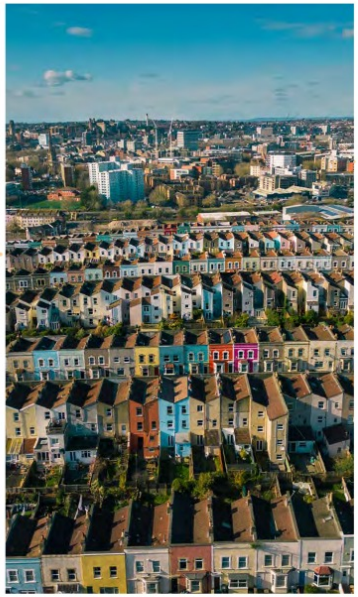

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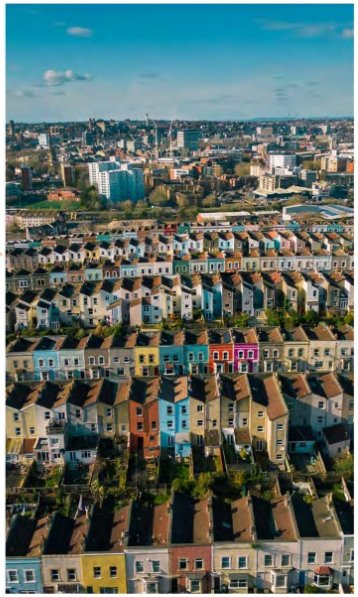

Bristol's big housing conversation

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BRISTOL ONE CITY

How the rent will be decided depends on the type of rent case…

The tribunal will look at the market or rents of similar properties in the local area.

What is the "rent?"

No central database of what rents are *charged,* only rents that are advertised.

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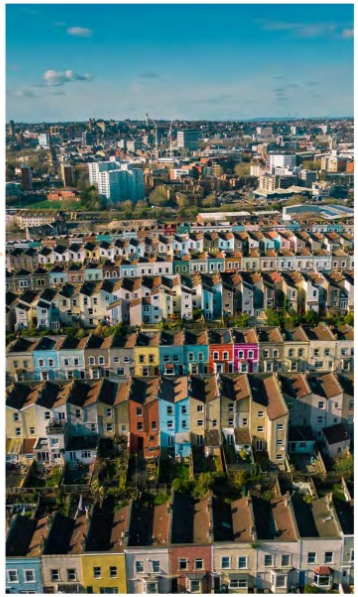

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How the rent will be decided depends on the type of rent case…

The tribunal will look at the market or rents of similar properties in the local area.

What is "similar?"

Depends on judgement of the assessor during inspection, structural factors, and local intangibles.

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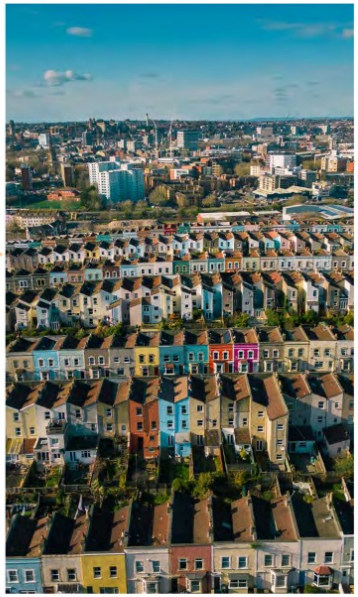

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How the rent will be decided depends on the type of rent case…

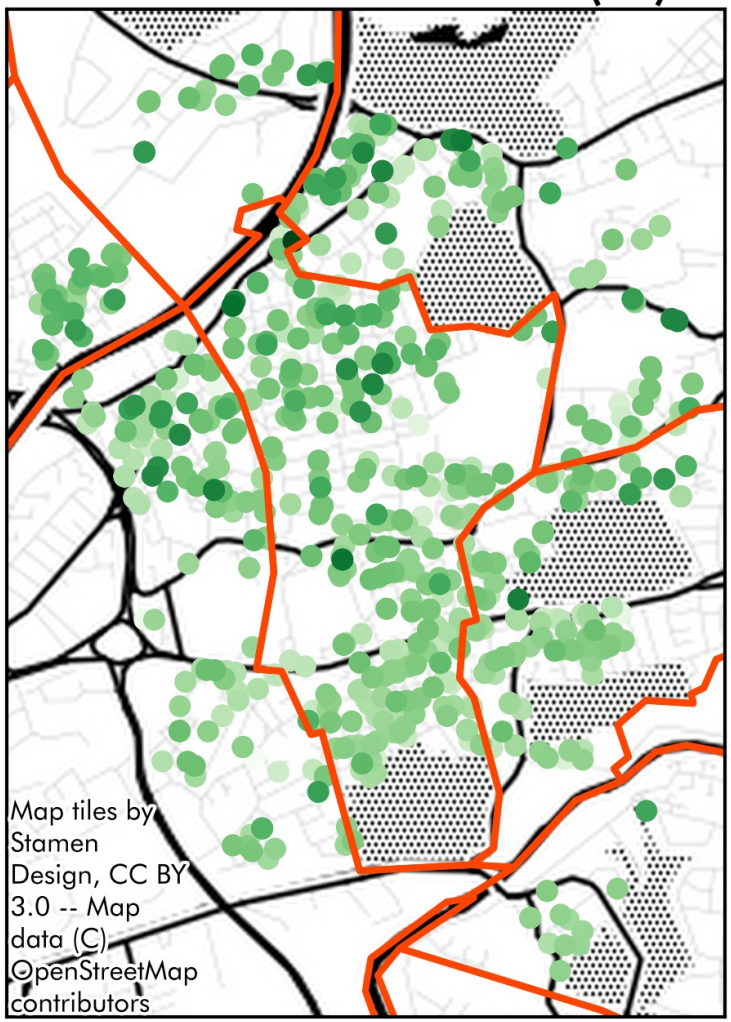
The tribunal will look at the market or rents of similar properties in the local area.

What is "local area?"

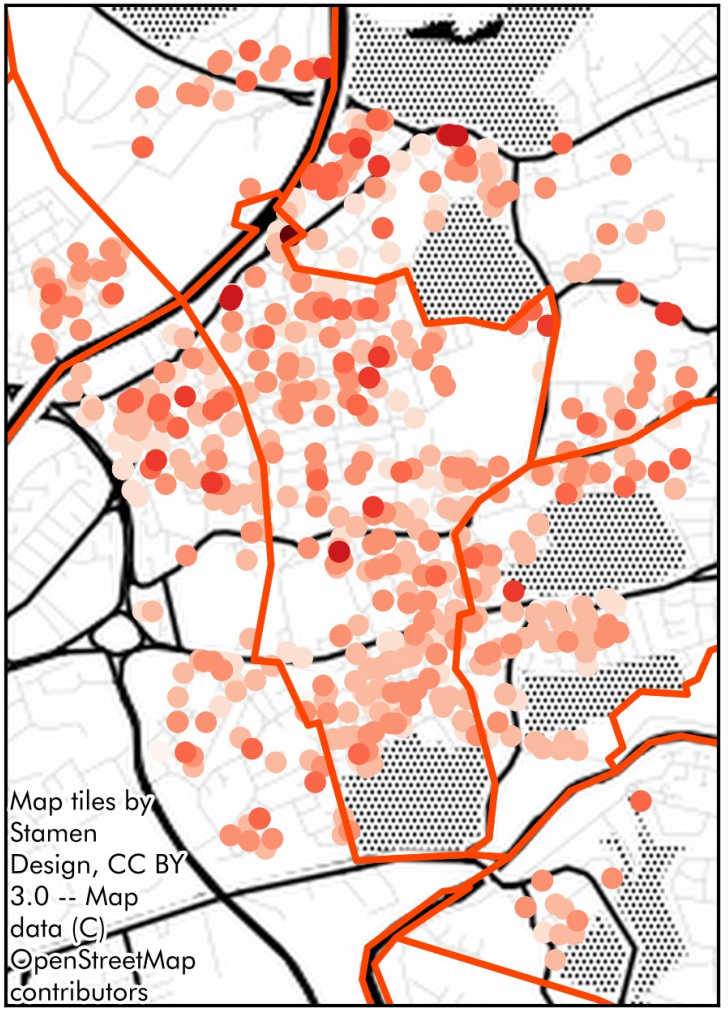
No specific guidance to decide upon street < n'hood < town < labor market

HOW CAN WE FIND RENT AFFORDABILITY OUTLIERS?

WEEKLY RENT (£)



BEDROOMS



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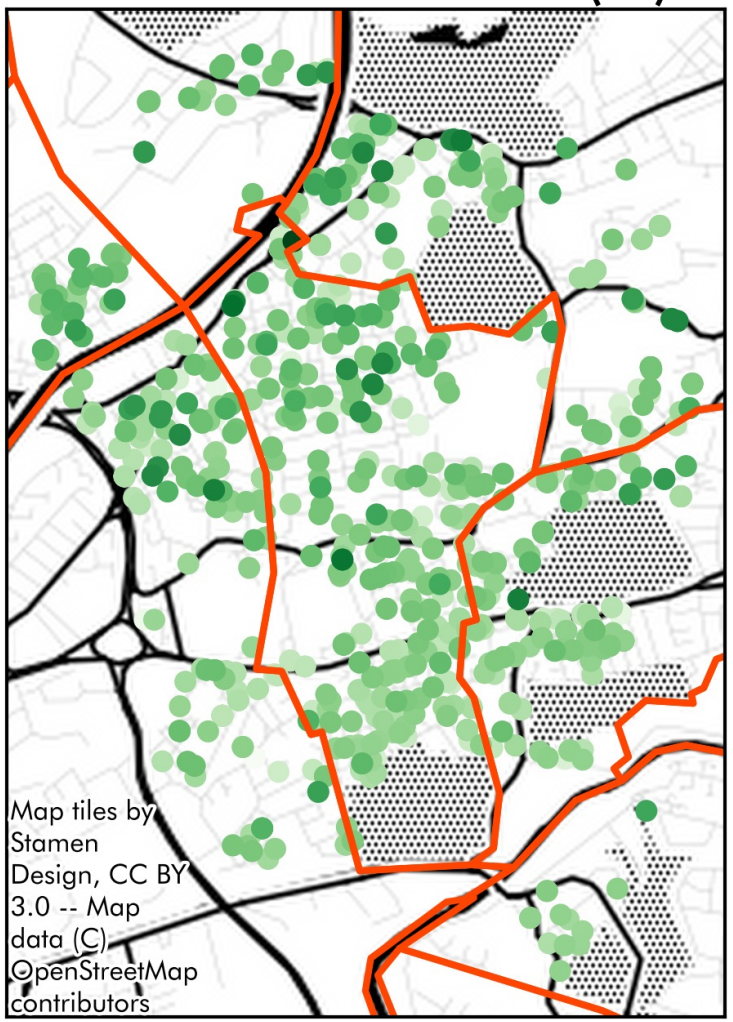
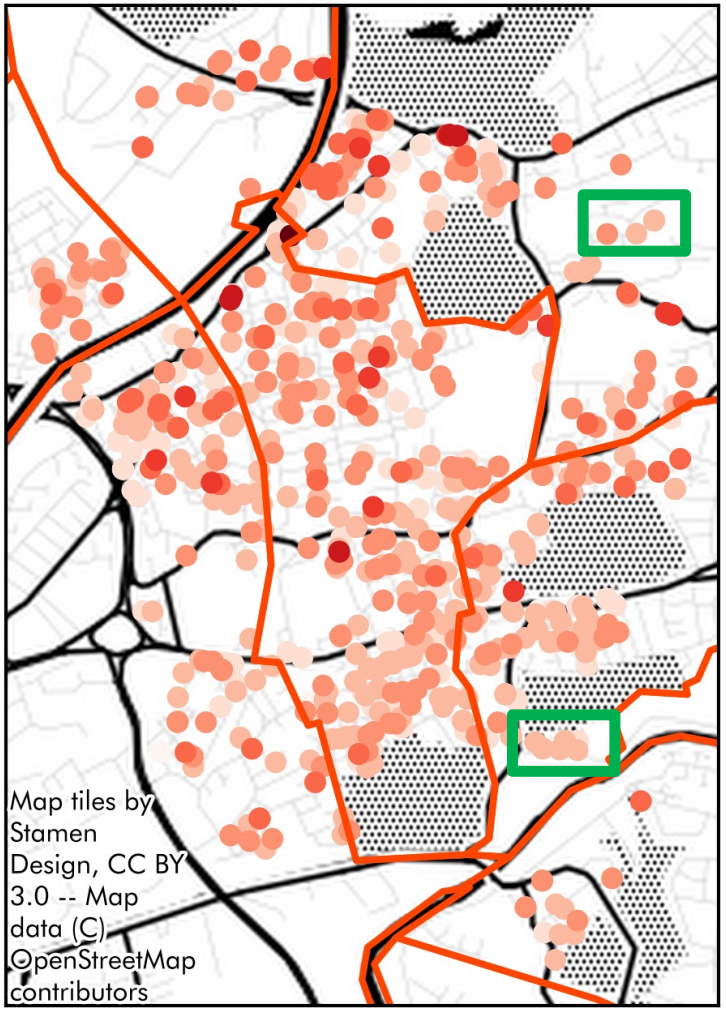


similar properties

Lettings that are substitutes for a reasonable tenant looking to house themselves or their family.

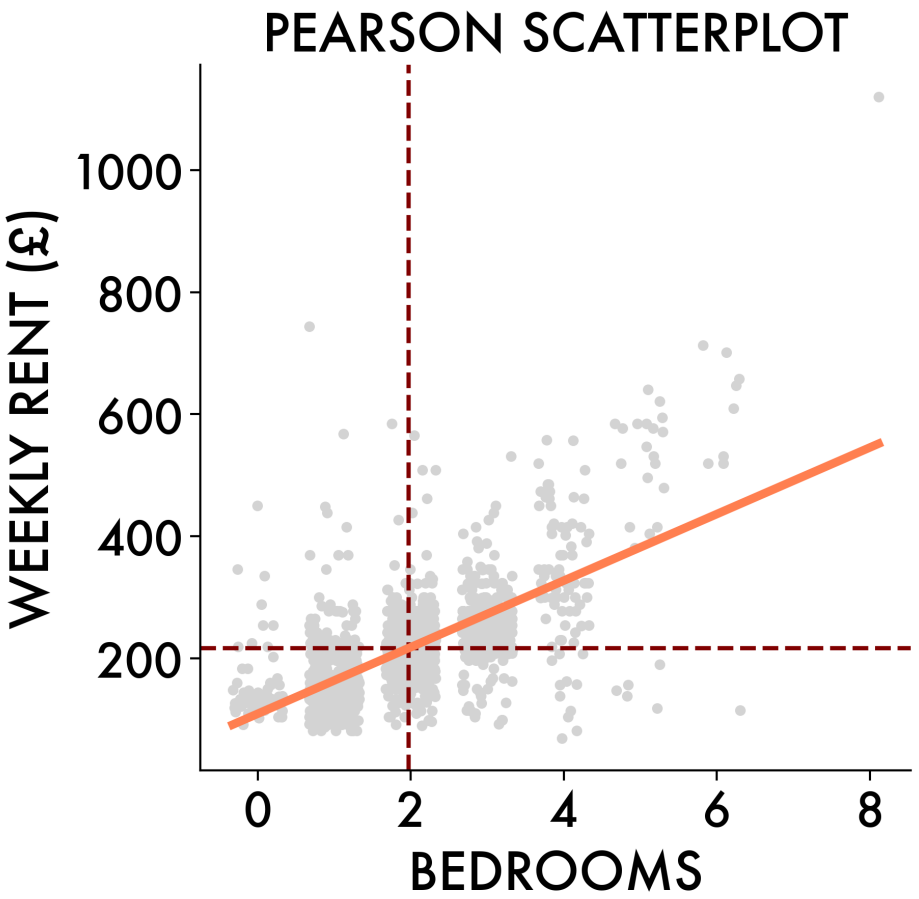
Same bedrooms, ca. baths, receptions within some distance

BEDROOMS



HOW CAN WE FIND RENT AFFORDABILITY OUTLIERS?

Properties with fewer bedrooms are generally lower rent.



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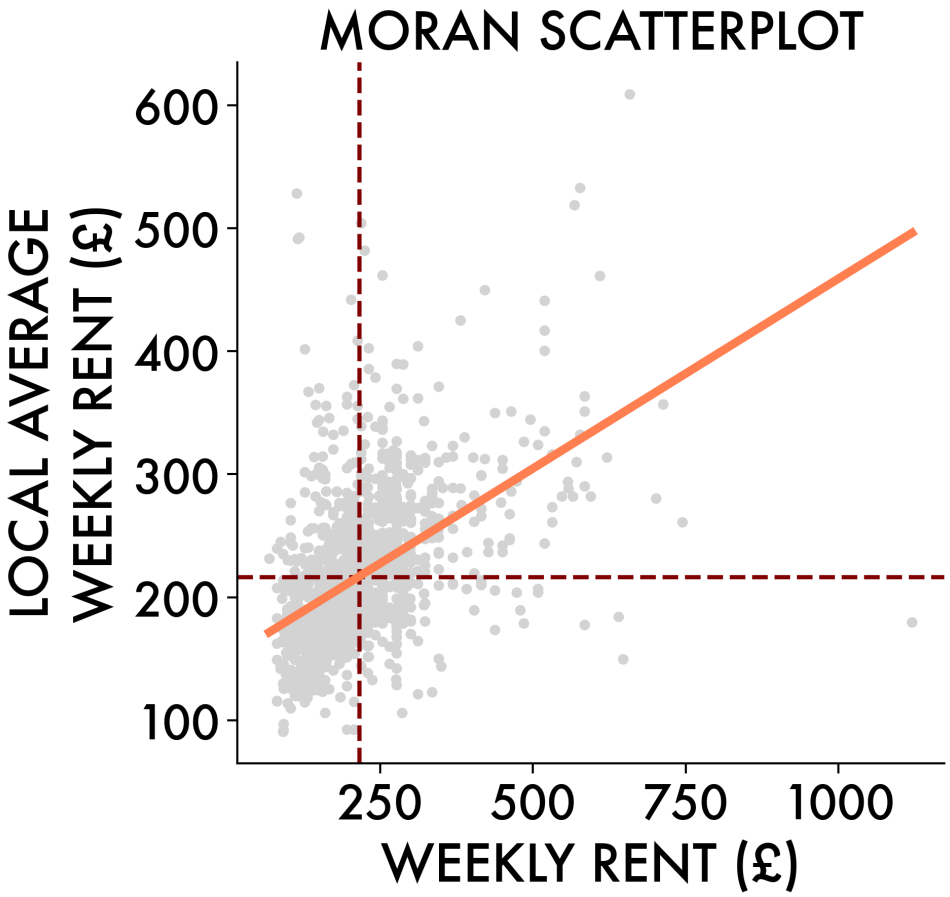
Nearby properties tend to have similar rent levels



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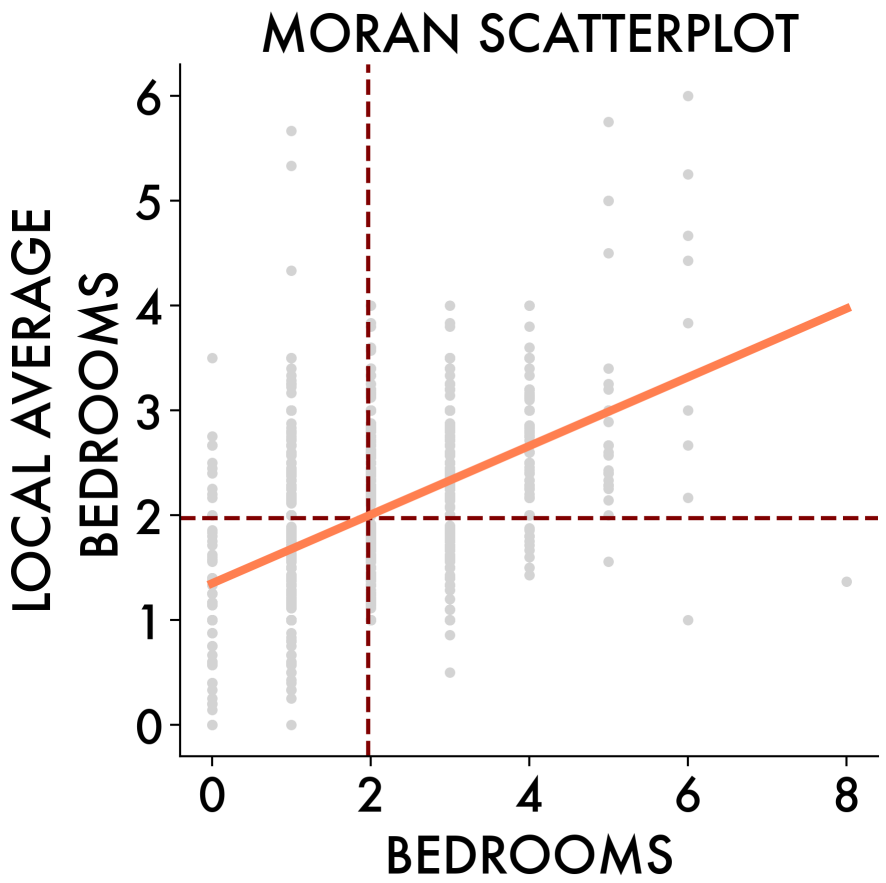
Properties with fewer bedrooms are generally lower rent.

Nearby properties tend to have similar rent levels

Nearby properties also tend to be of similar size as well



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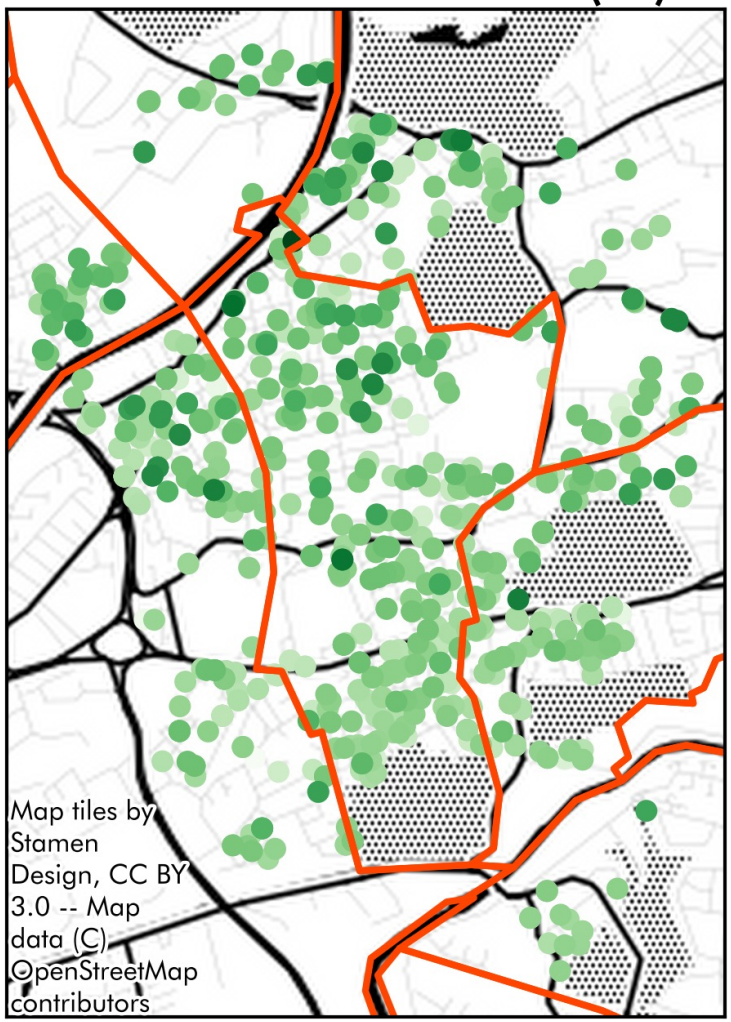

How can we find locally-unusual rents given the characteristics of properties?

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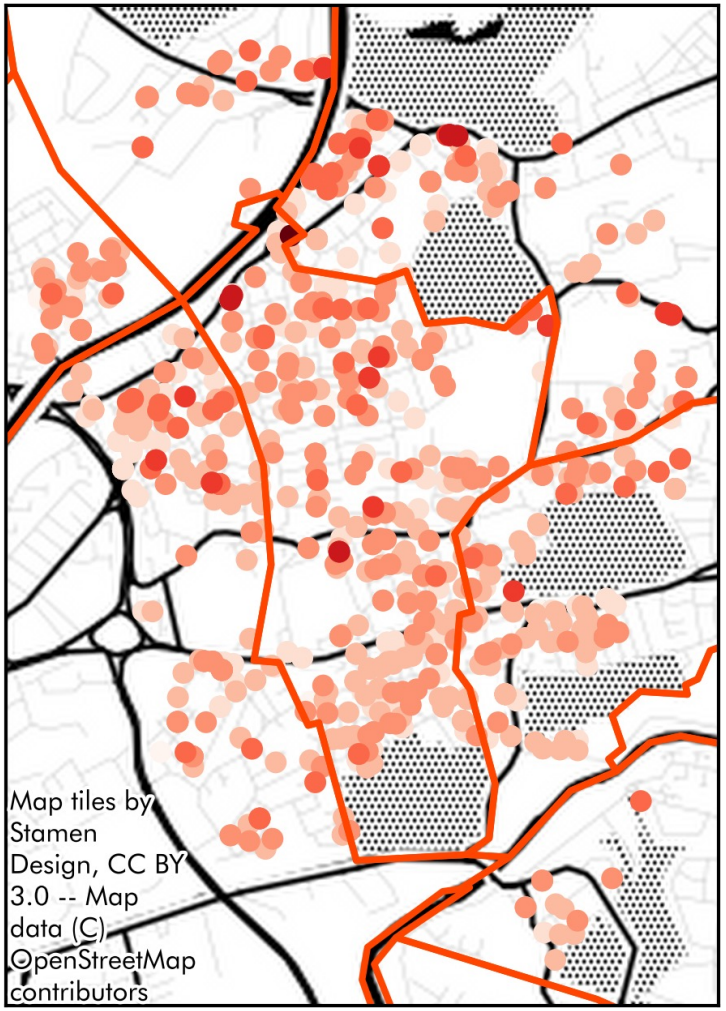

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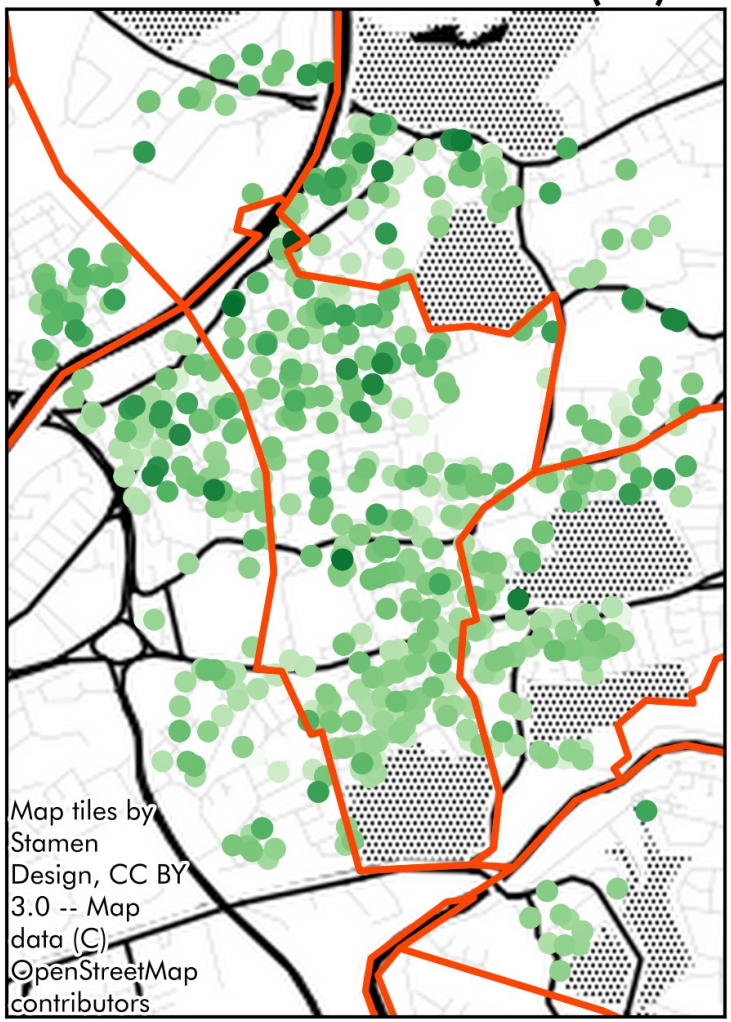
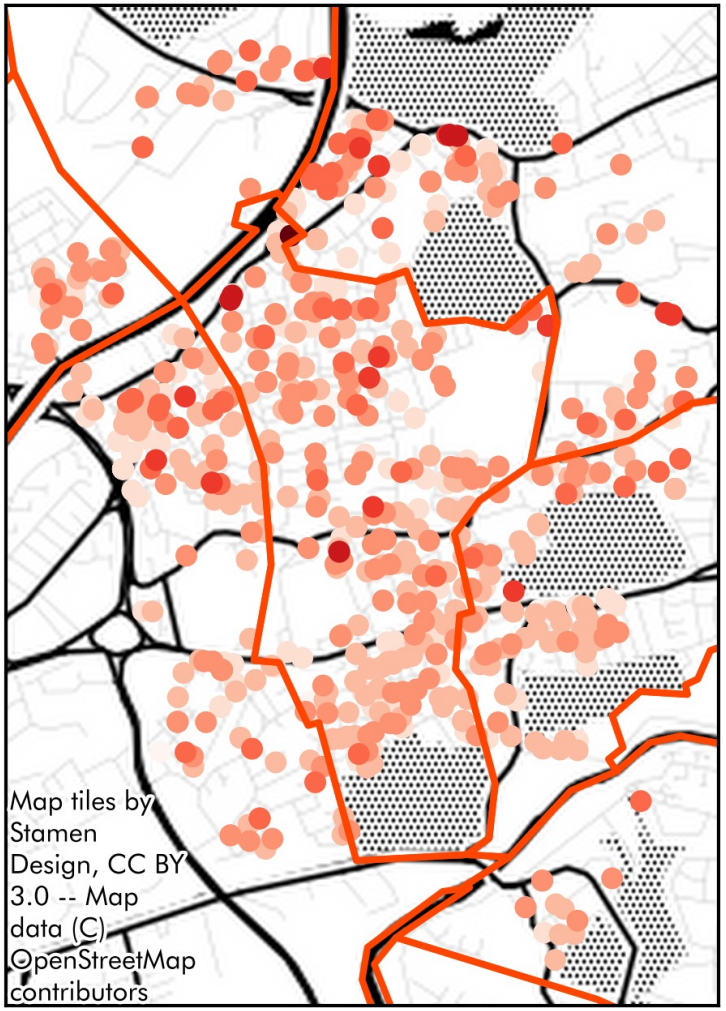


How can we find locally-unusual rents given the characteristics of properties?

How can we find local affordability outliers?

BEDROOMS



HOW CAN WE FIND RENT AFFORDABILITY OUTLIERS?

LOCAL CONFOUNDING

size effects on rent vary

PRIOR ART IN ESDA

PARTIAL CONDITIONING

AFFORDABILITY OUTLIERS

$$\rho = \sum_{i}^{N} \frac{(x'_i - \bar{x'})(y'_i - \bar{y'})}{\sigma(x')\sigma(y')}$$

CLASSICAL CORRELATION & LOCAL PEARSON

$$x = \frac{x' - \bar{x'}}{\sigma(x')} \qquad y = \frac{y' - \bar{y'}}{\sigma(y')}$$

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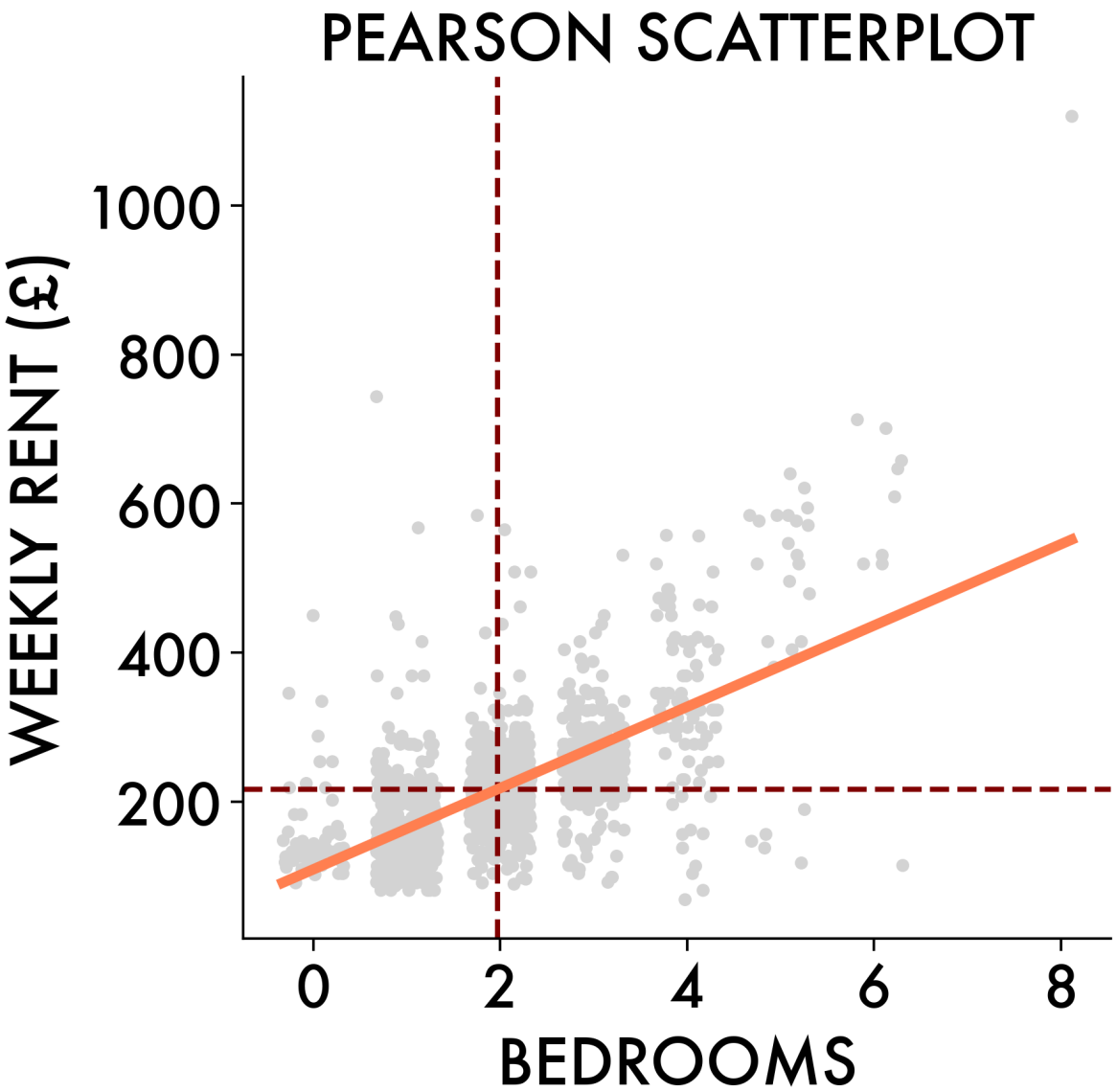
$$x = \frac{x' - \bar{x'}}{\sigma(x')} \qquad y = \frac{y' - \bar{y'}}{\sigma(y')}$$

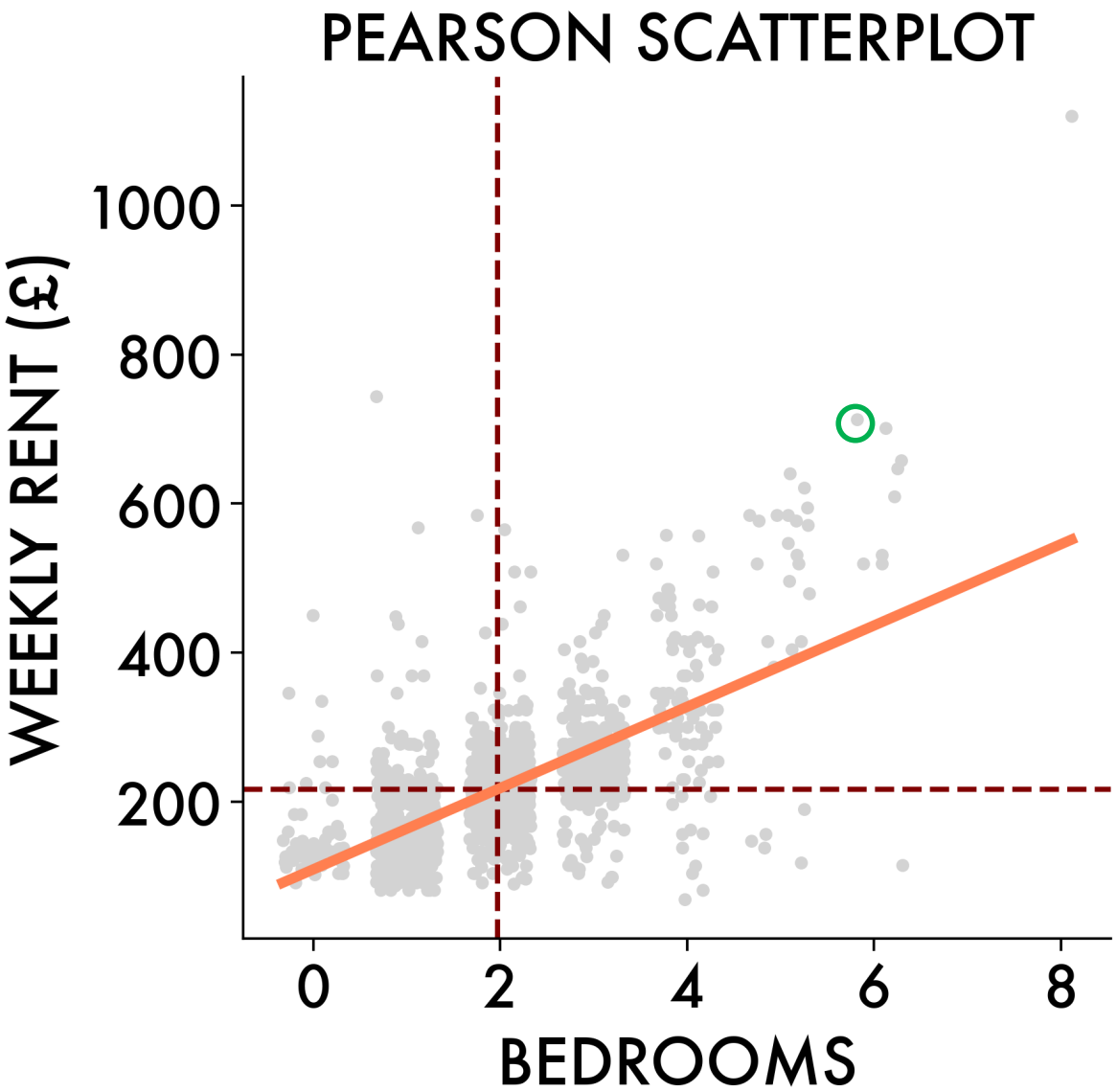
$$\rho_i = \frac{(x'_i - \bar{x'})(y'_i - \bar{y'})}{\sigma(x')\sigma(y')} = x_i y_i$$

CLASSICAL CORRELATION & LOCAL PEARSON



$x_i y_i$

CLASSICAL CORRELATION & LOCAL PEARSON



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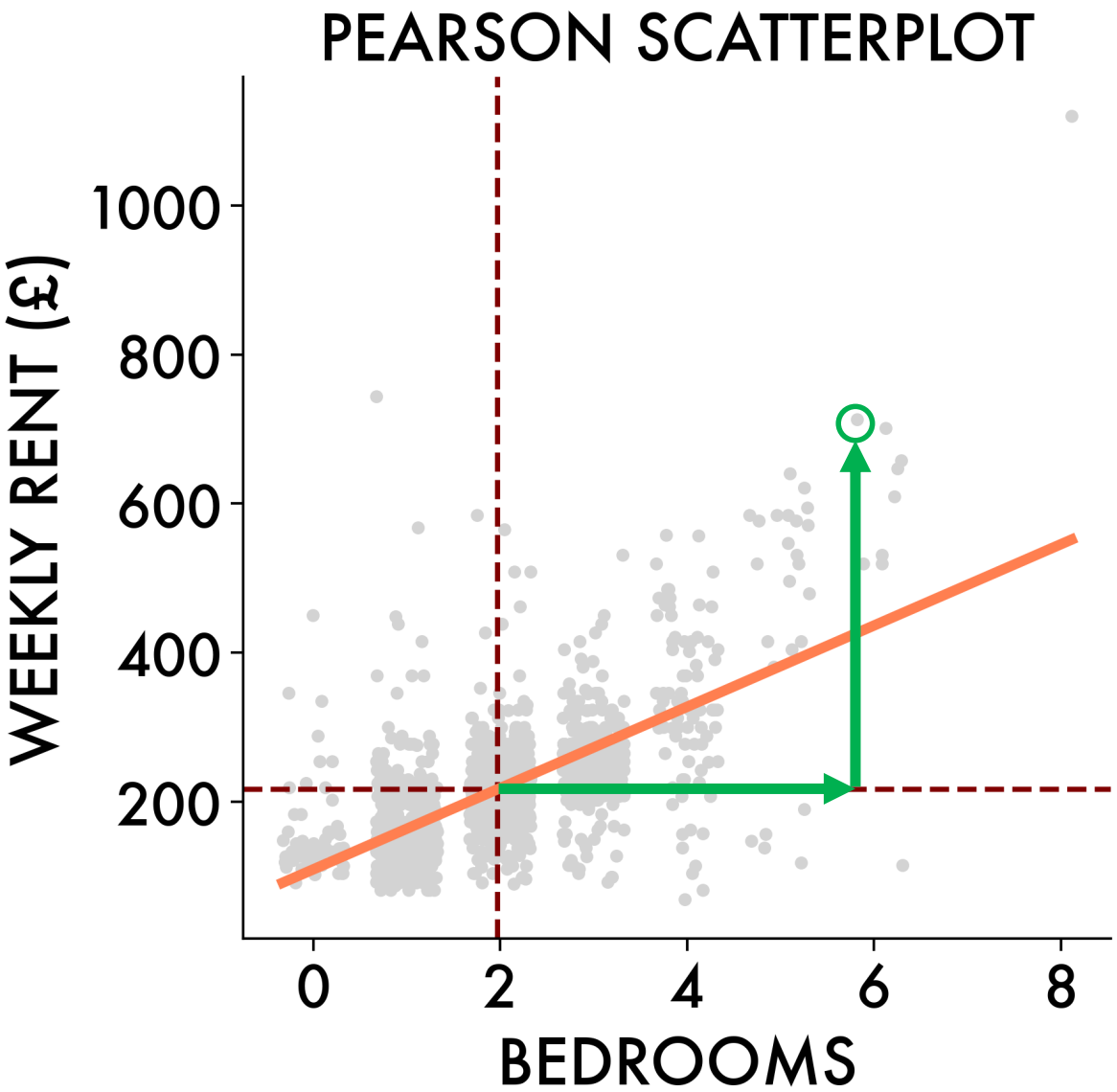

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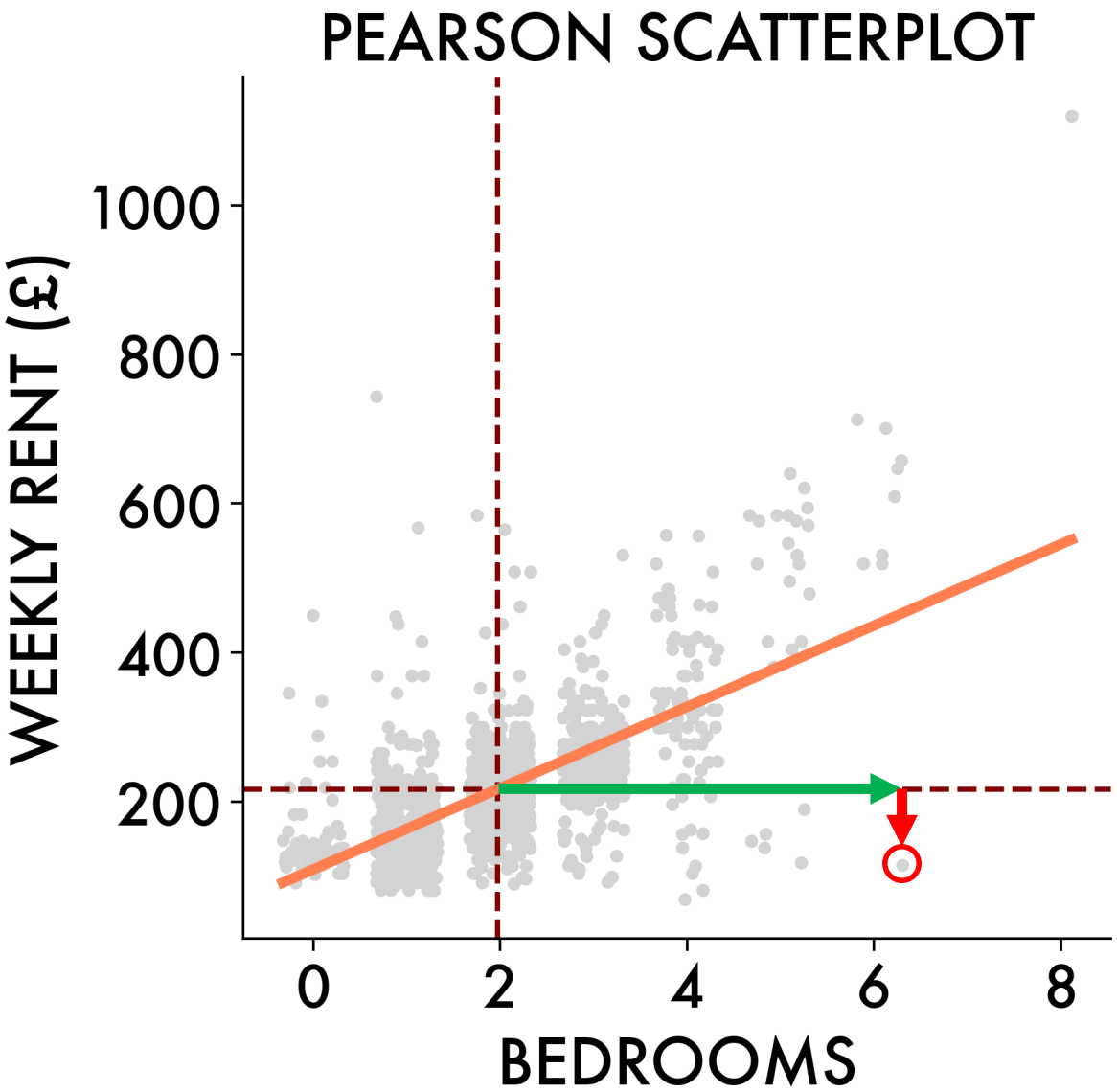

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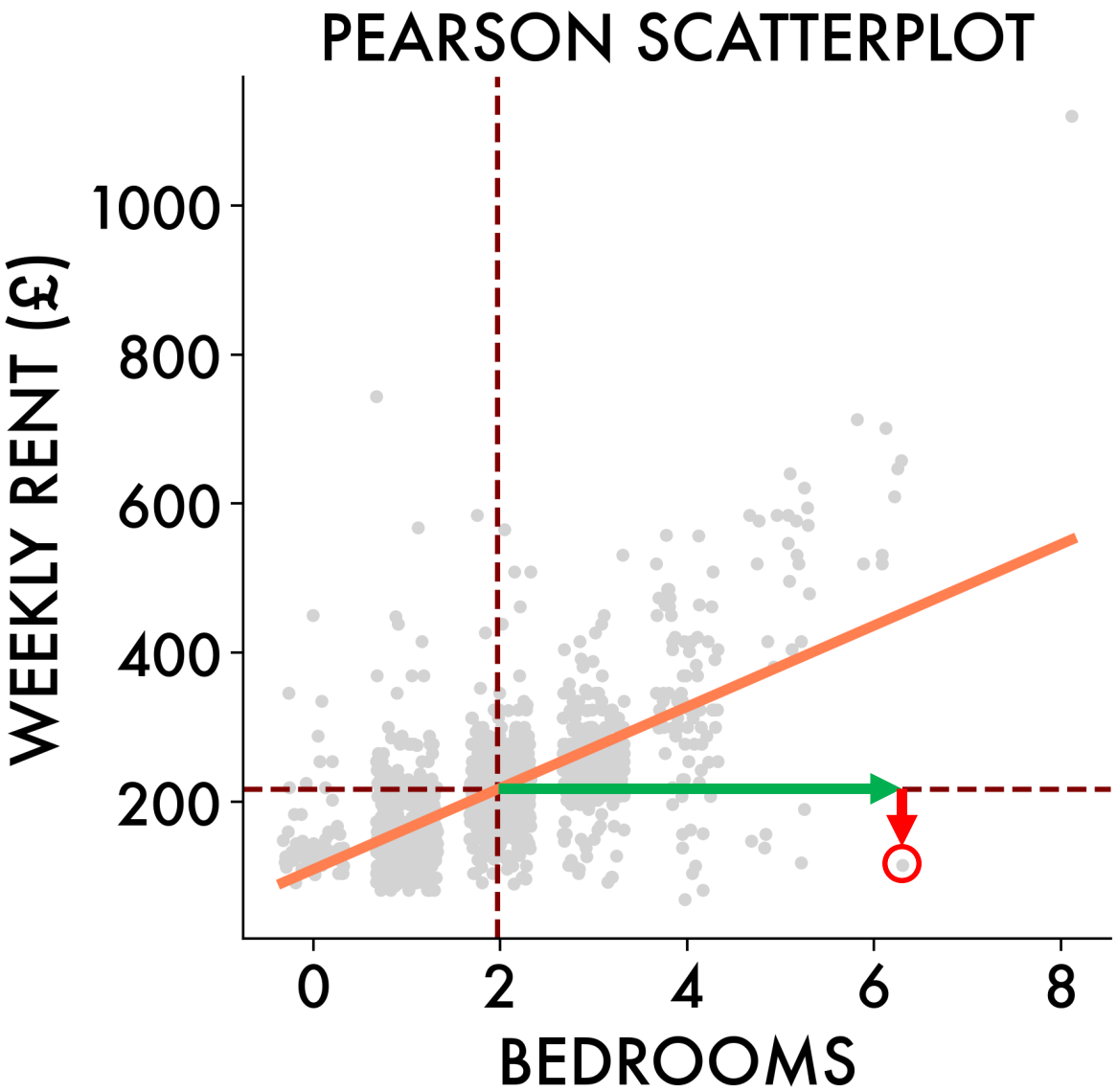
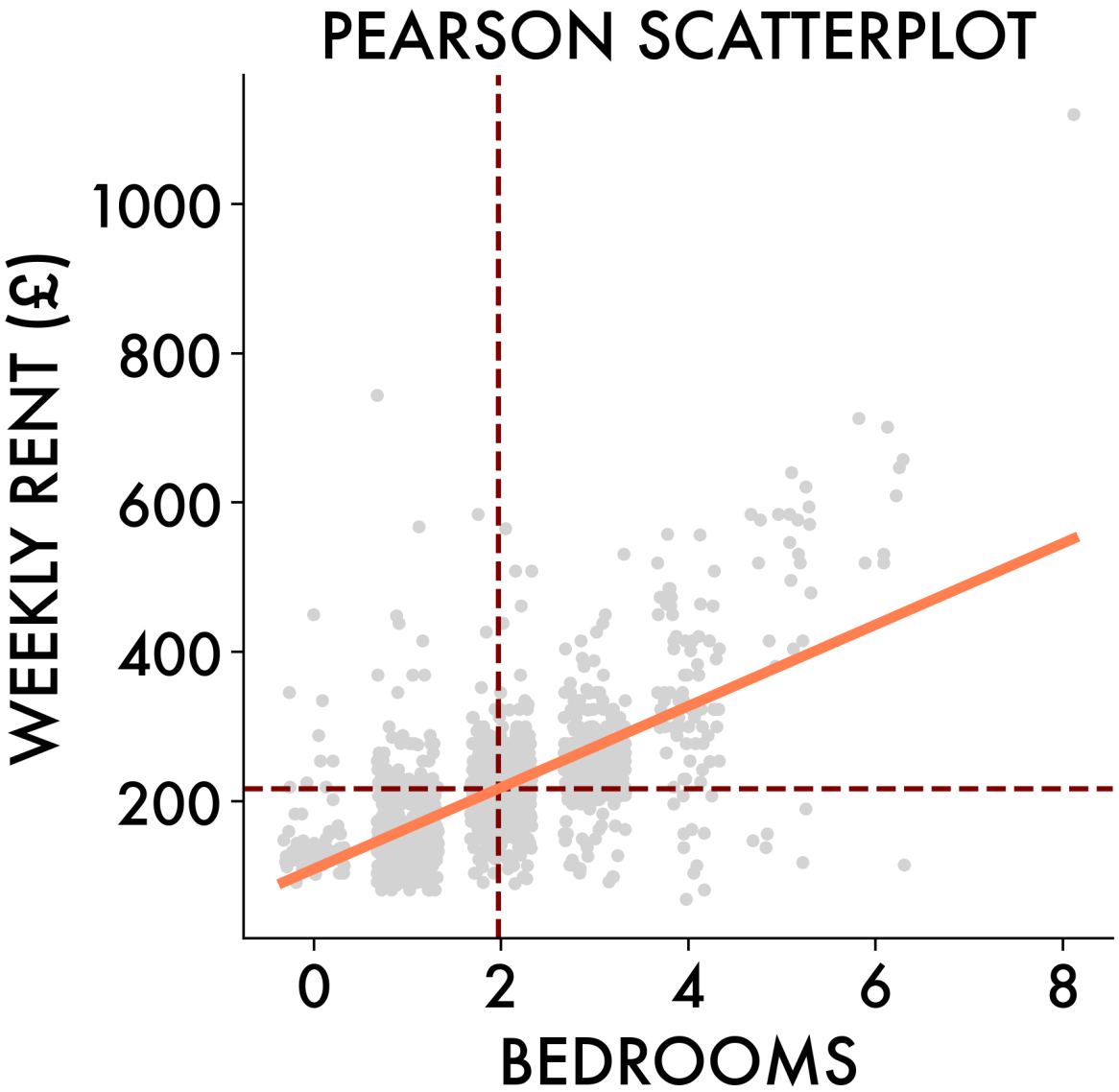


$$\rho_i = x_i y_i$$

CLASSICAL CORRELATION & LOCAL PEARSON



$$\rho = \begin{bmatrix} x_1 y_1 \\ x_2 y_2 \\ \vdots \\ x_N y_N \end{bmatrix} = x \circ y$$

$$\sum_i^N \rho_i = \rho$$

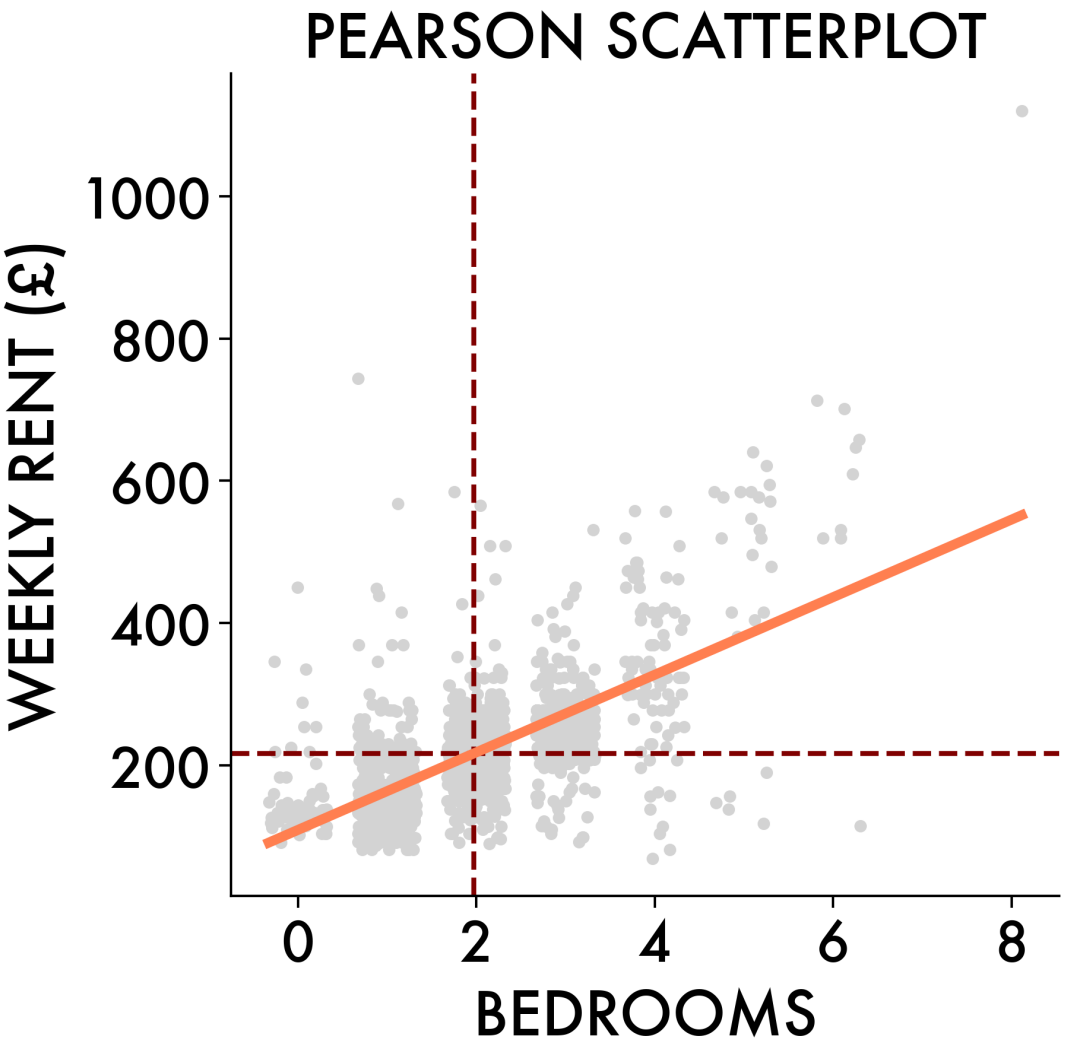
CLASSICAL CORRELATION & LOCAL PEARSON

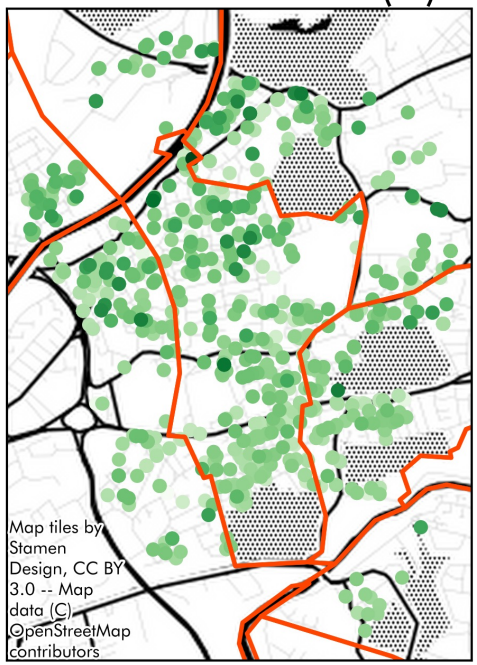
A sufficient condition to turn a global summary statistic into an Anselin (1995) LISA statistic is to swap in an elementwise product where an inner product is used.

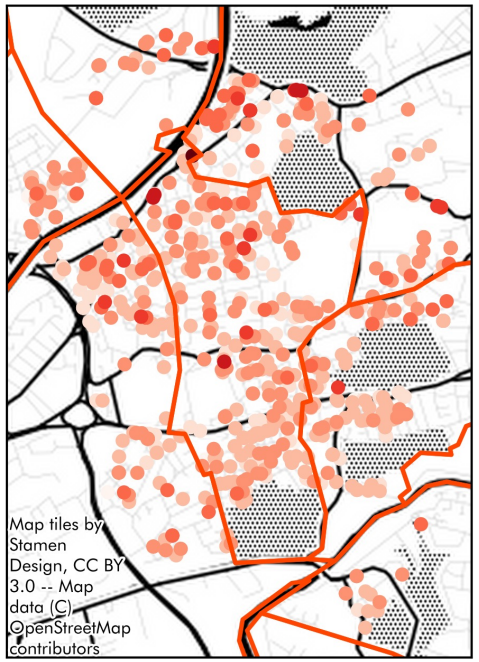
$$\boldsymbol{\rho} = \begin{bmatrix} x_1 y_1 \\ x_2 y_2 \\ \vdots \\ x_N y_N \end{bmatrix} = x \circ y$$

$$\rho = x \cdot y$$

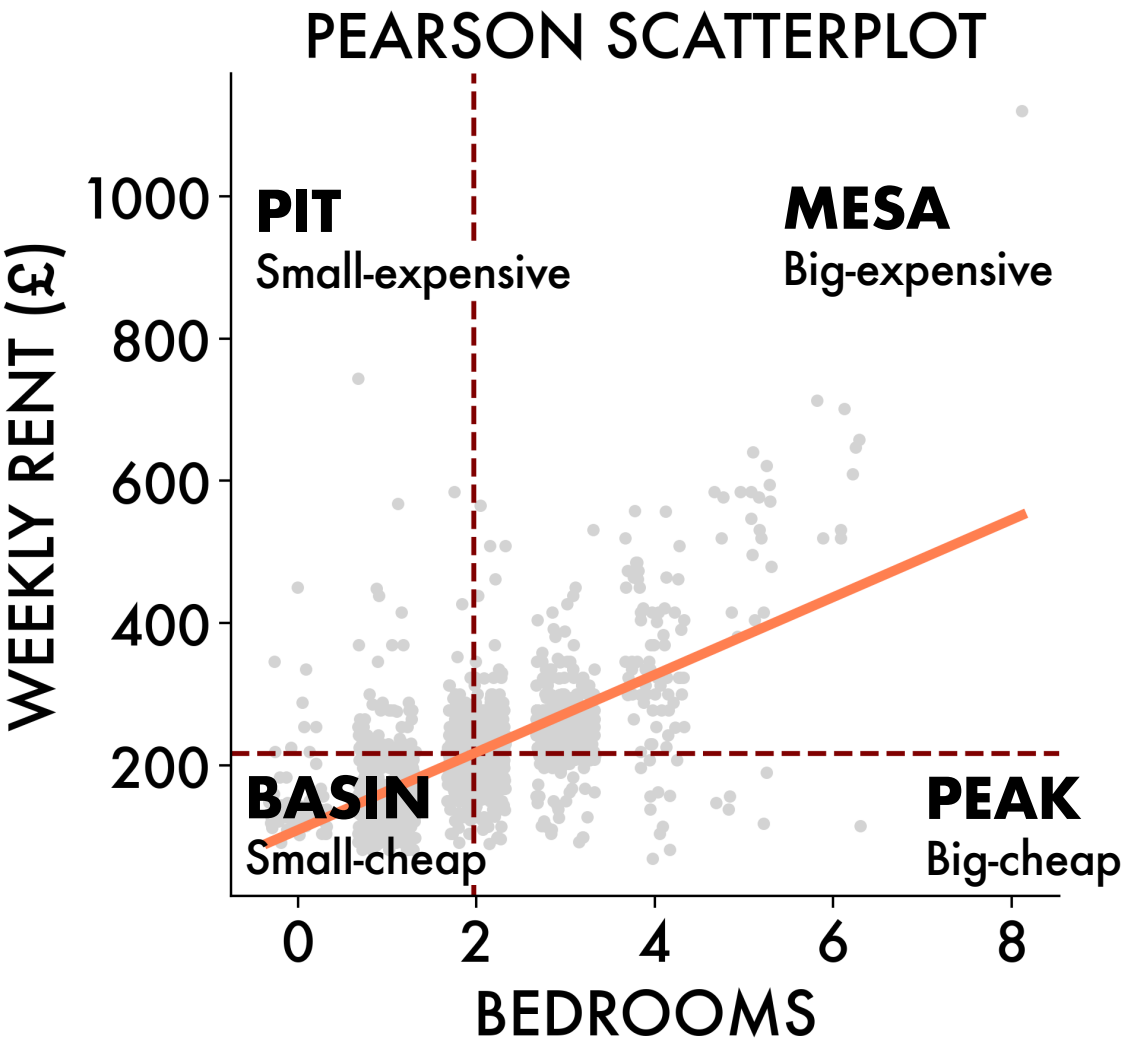
CLASSICAL CORRELATION & LOCAL PEARSON

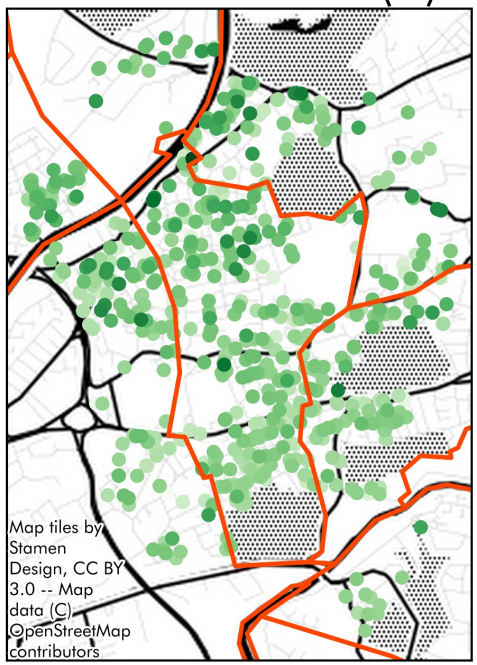


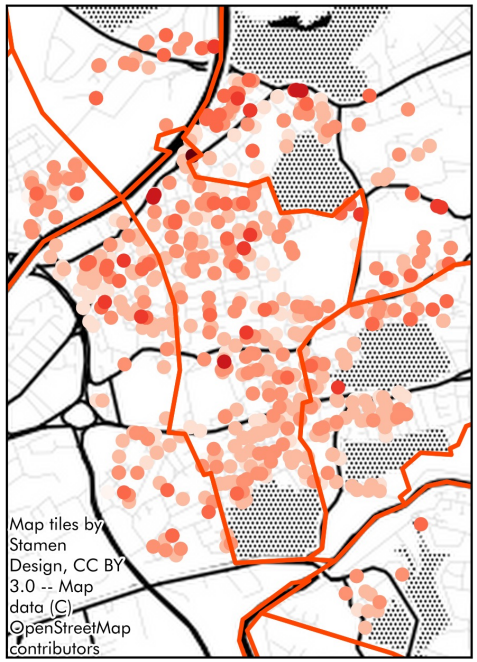




LOCAL PEARSON SCATTERPLOT







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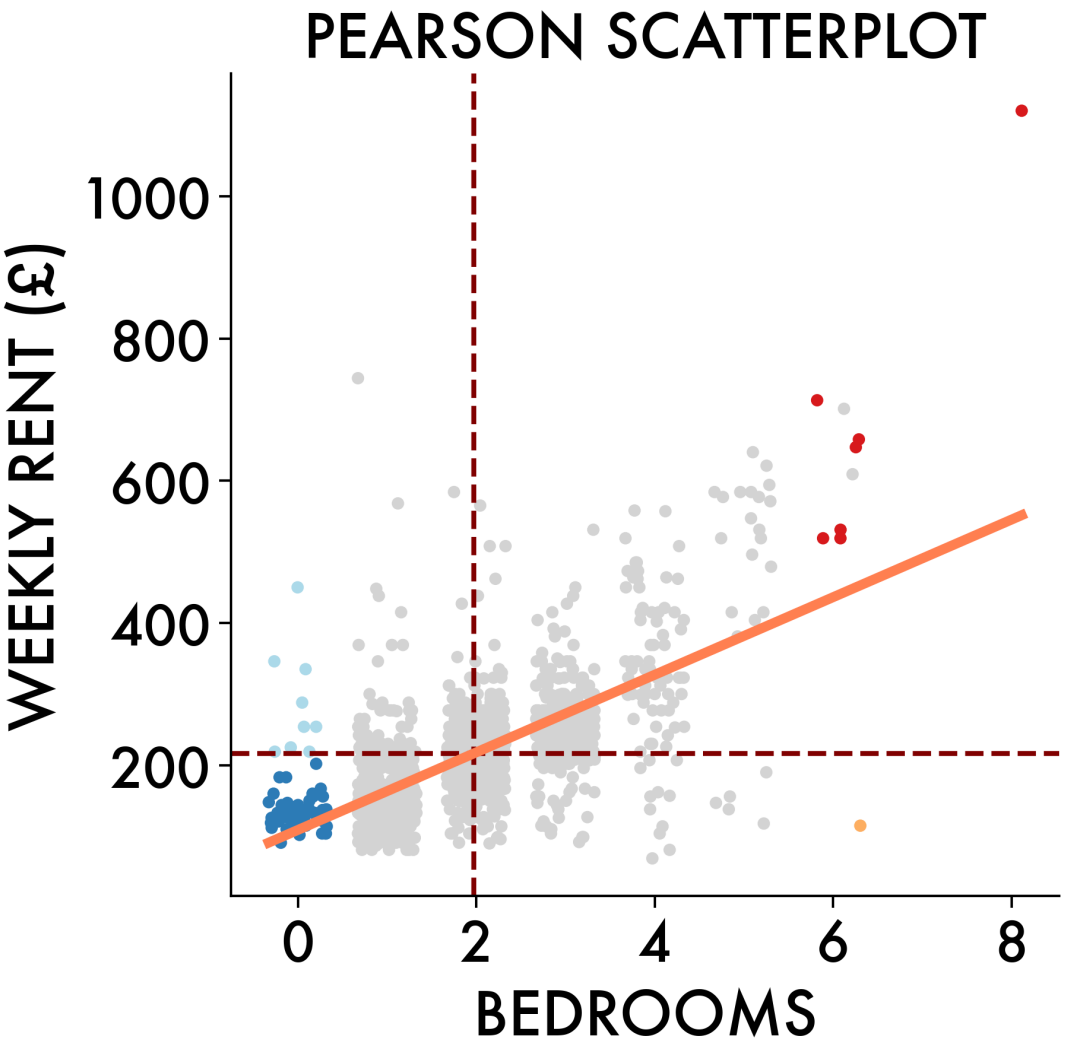

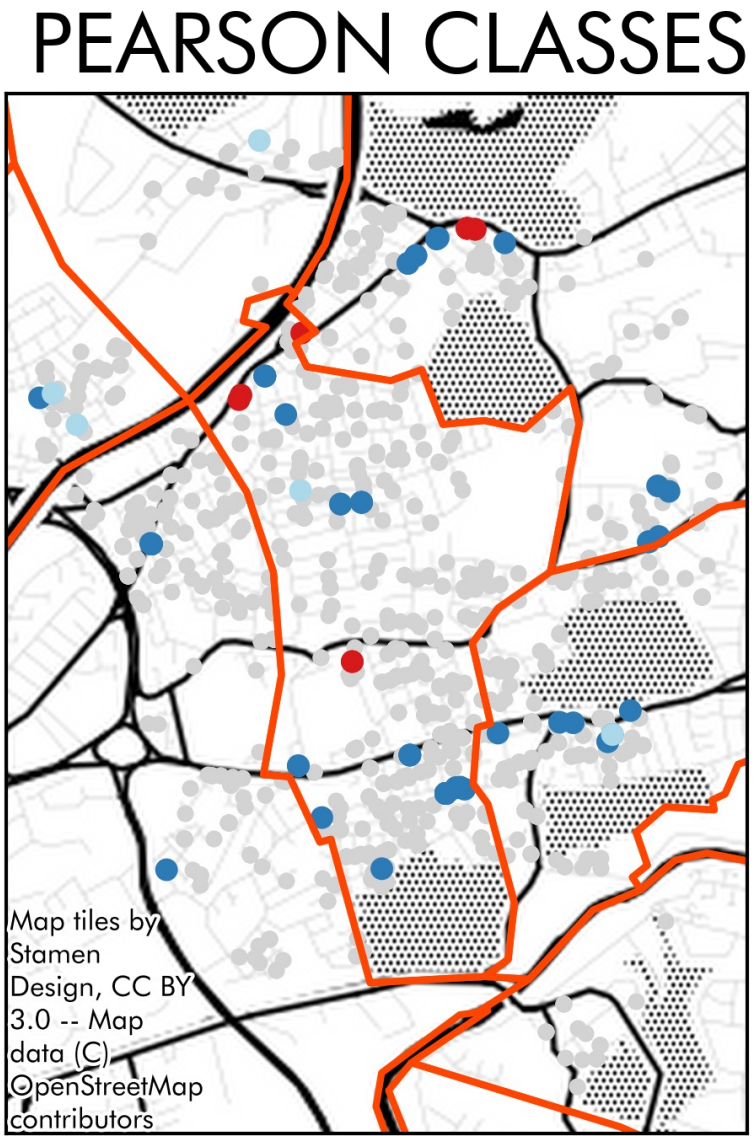

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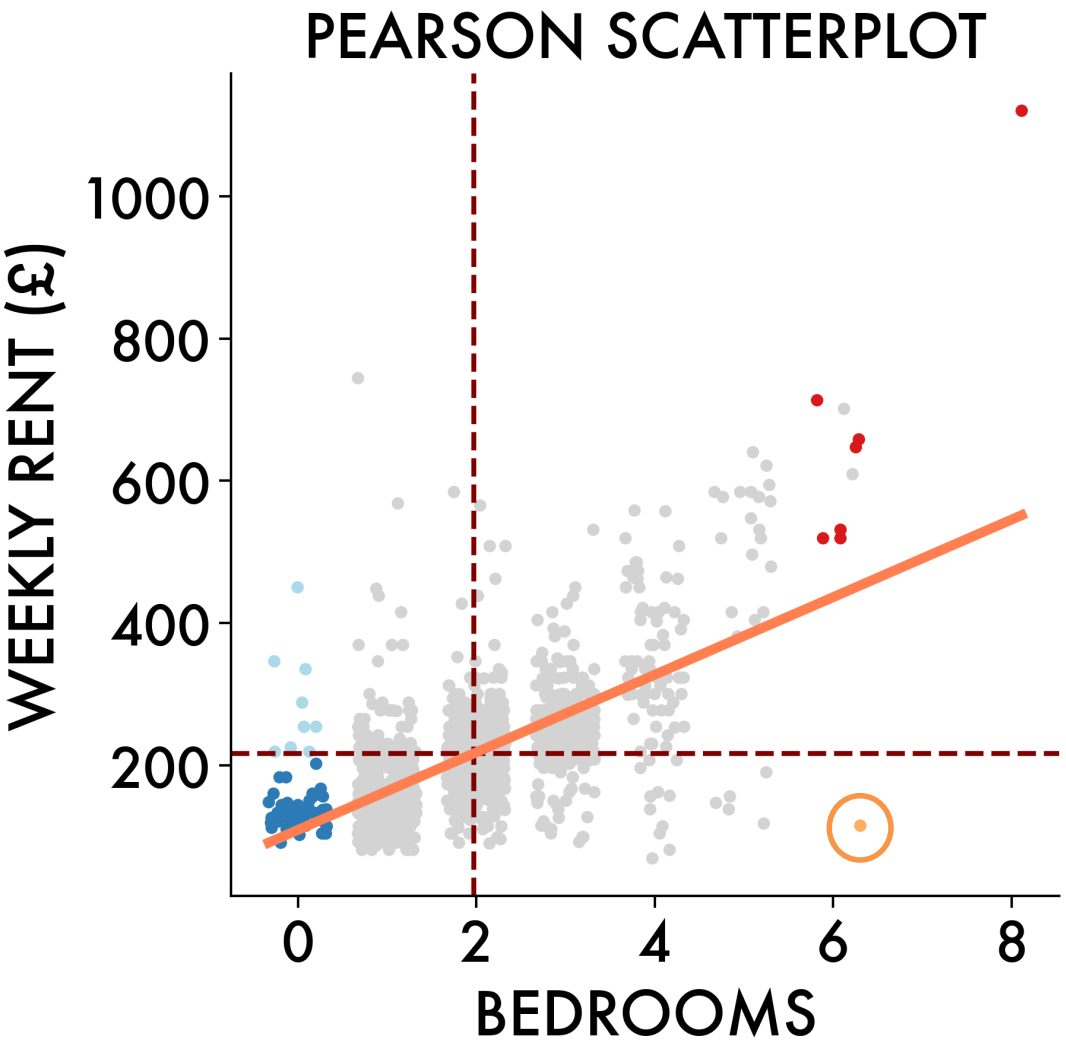

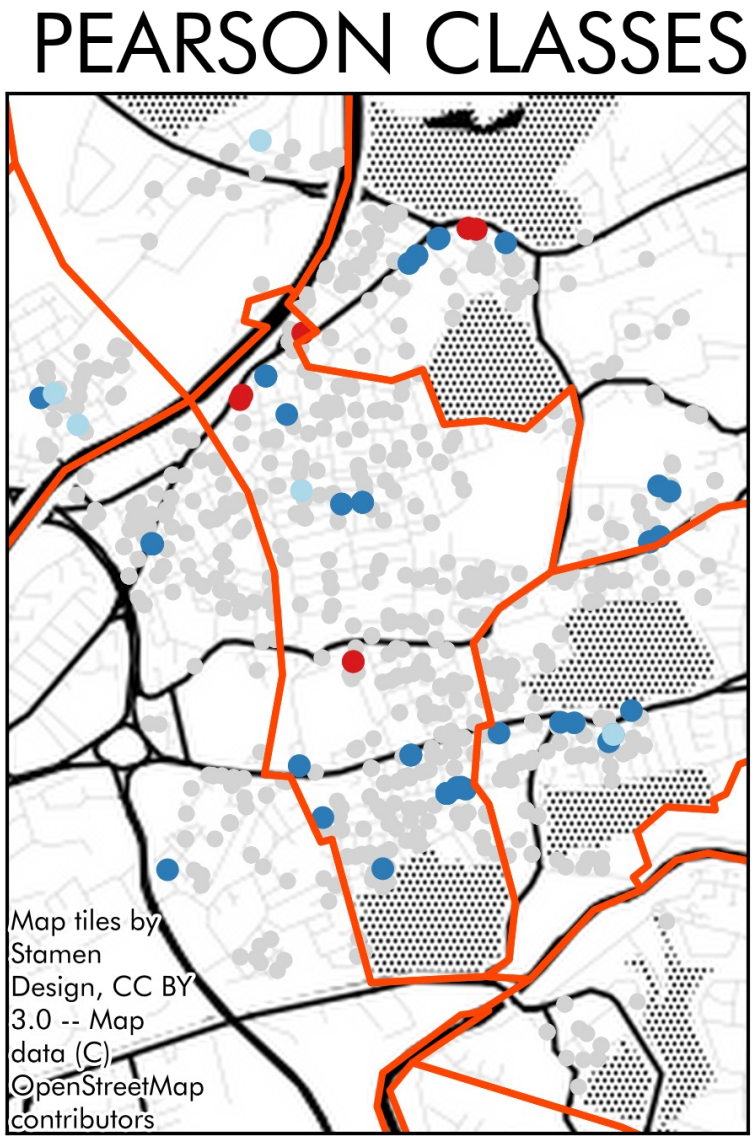

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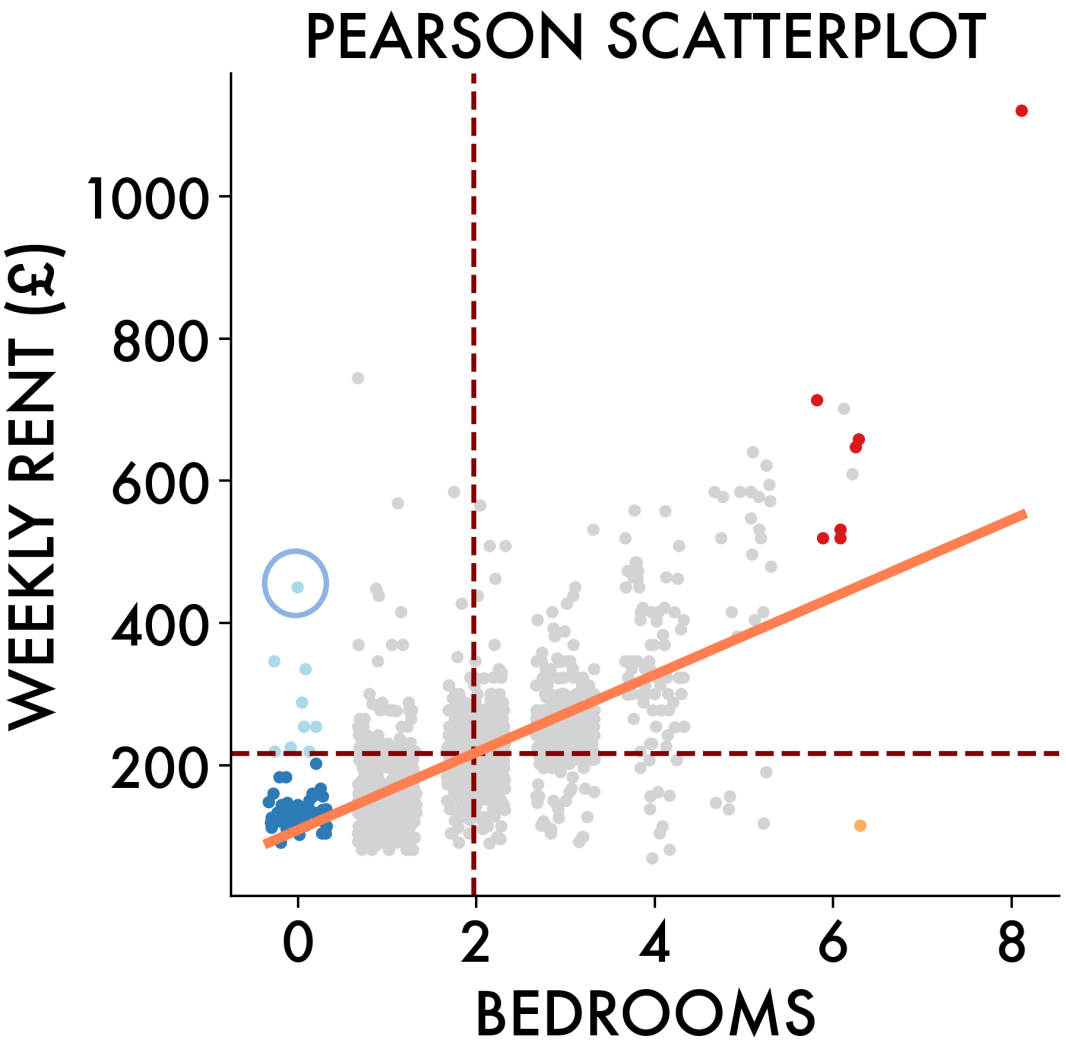

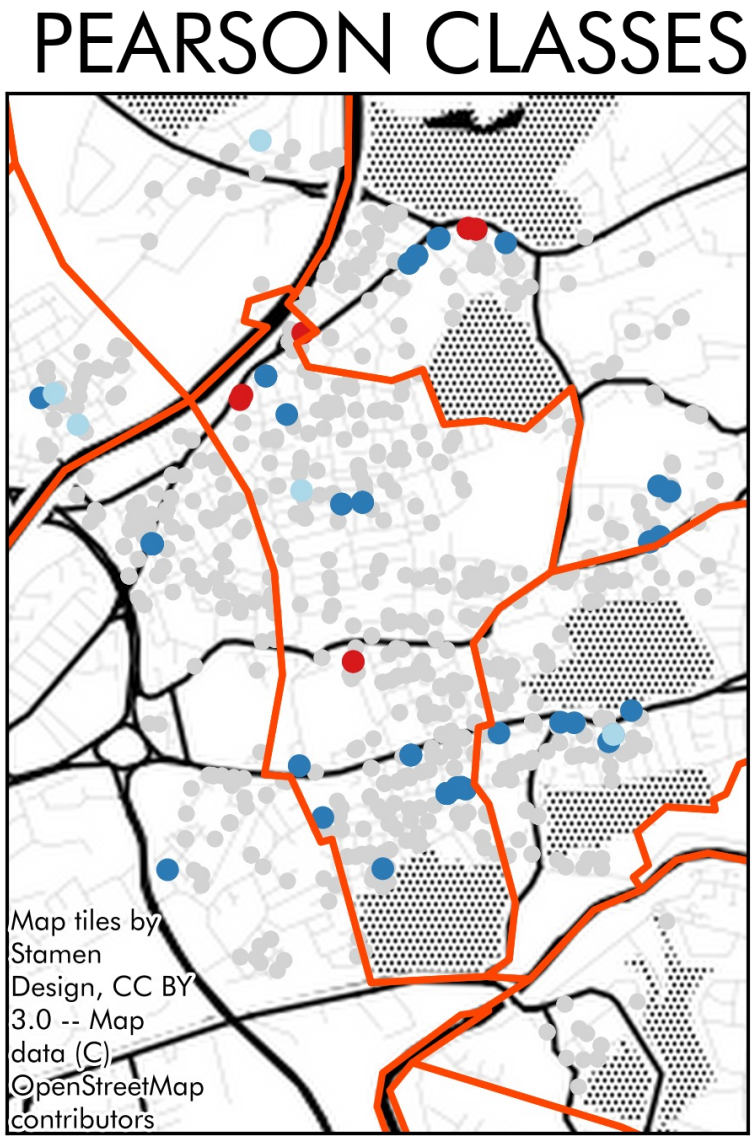

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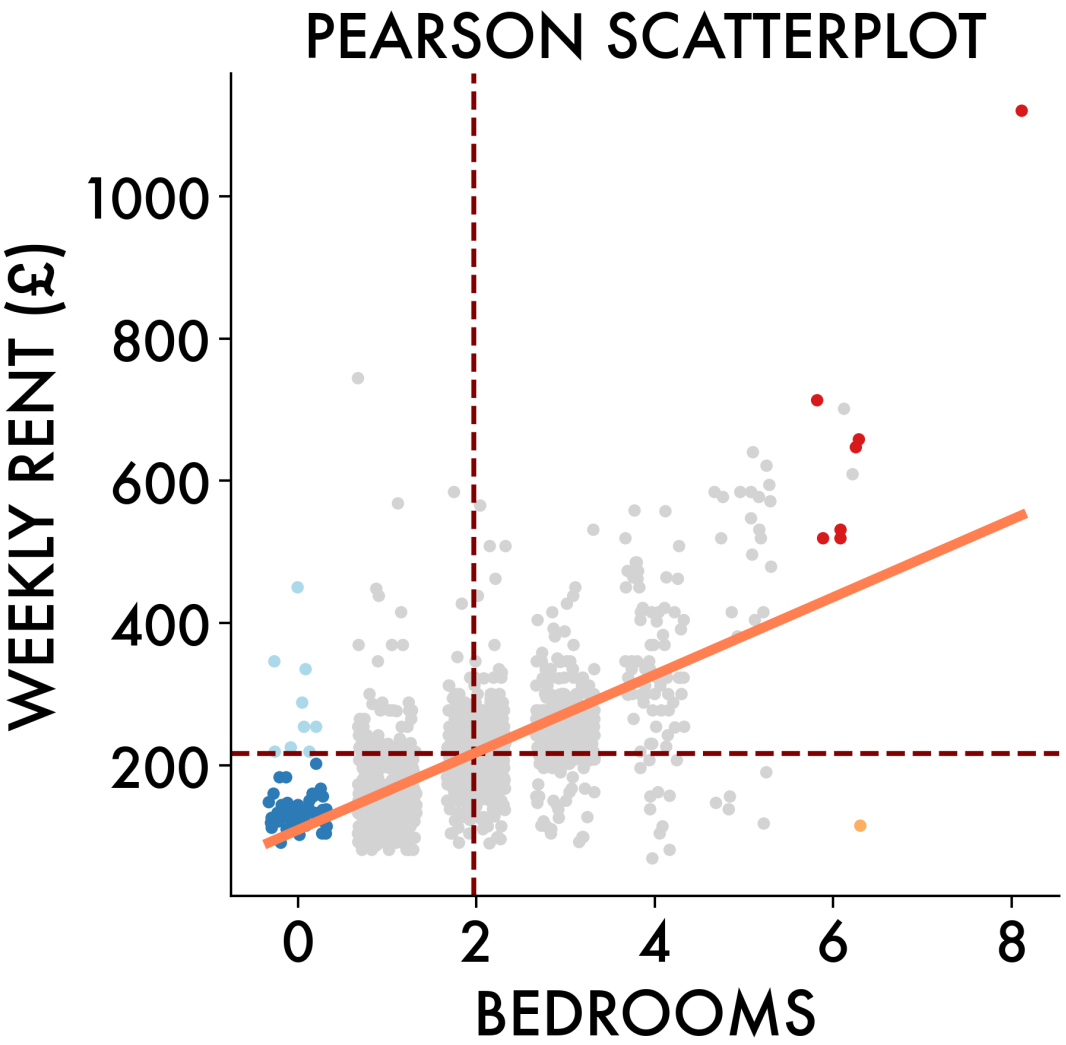


How can we find locally-unusual rents given the characteristics of properties nearby?

Local correlation only summarizes site by site

LOCAL PEARSON SCATTERPLOT

LOCAL CONFOUNDING

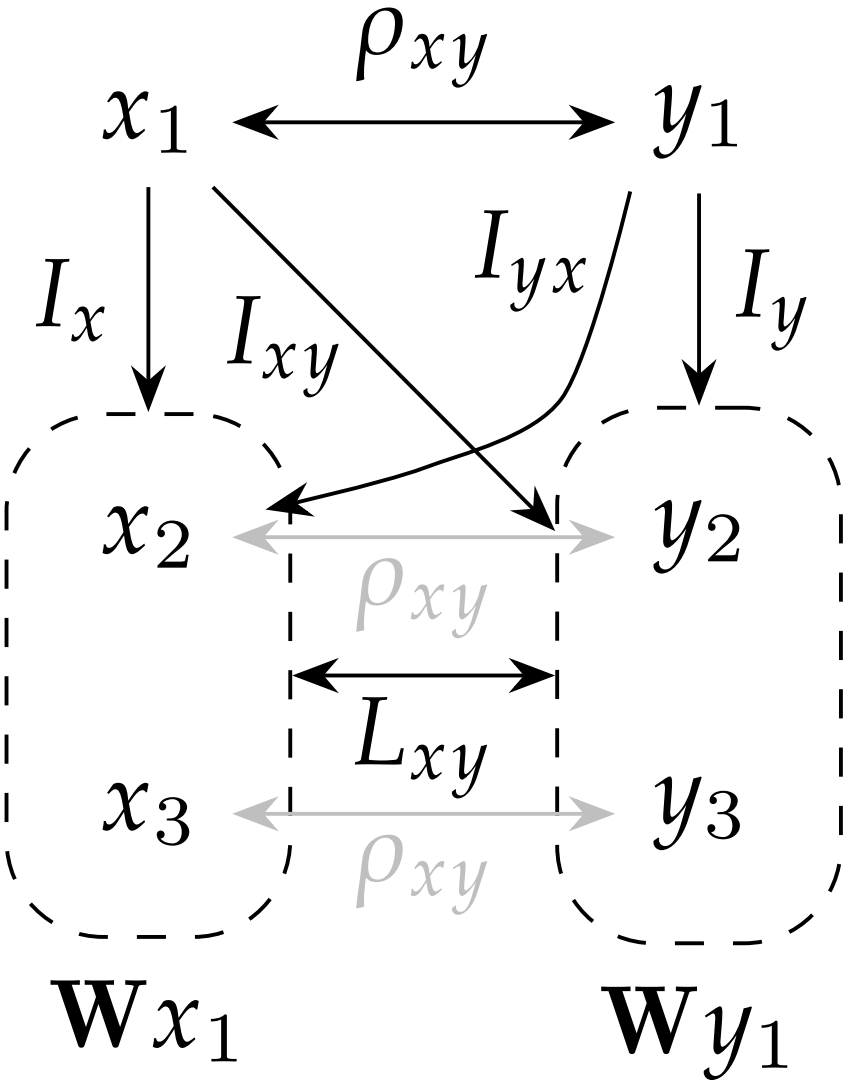
size effects on rent vary

PRIOR ART IN ESDA

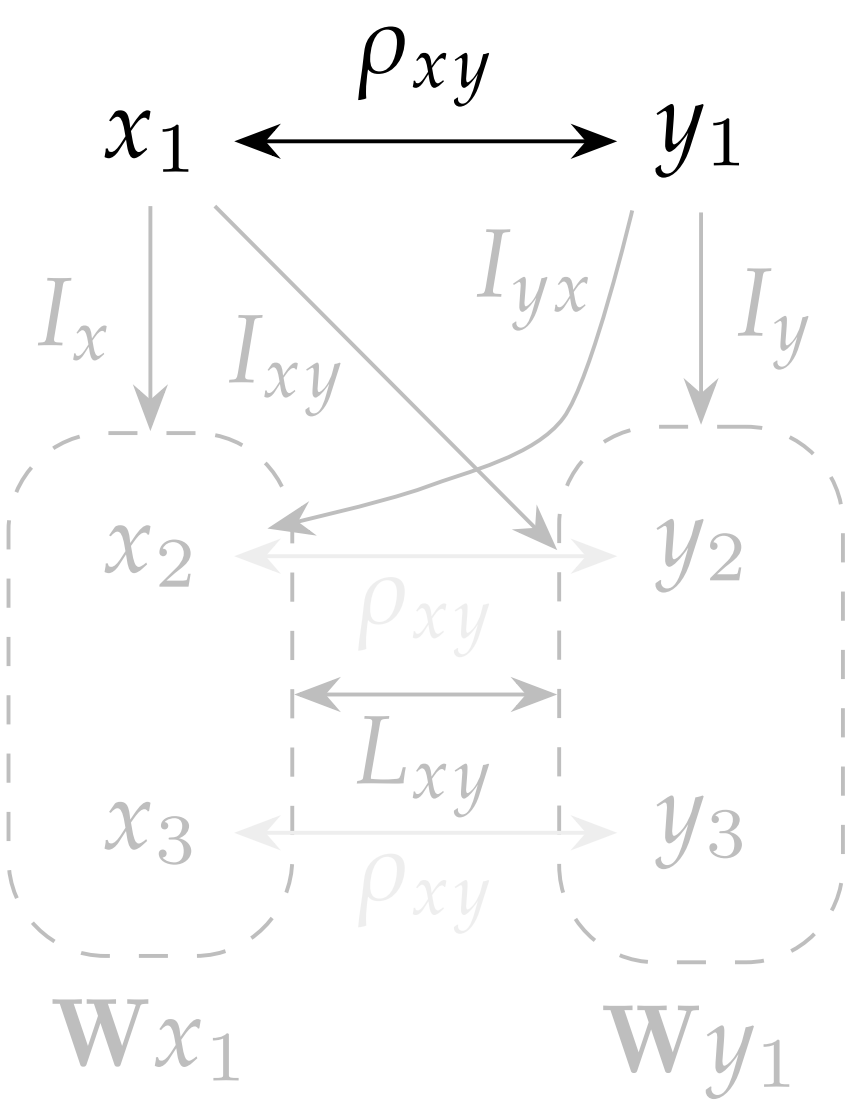
The Moran-Form Regression

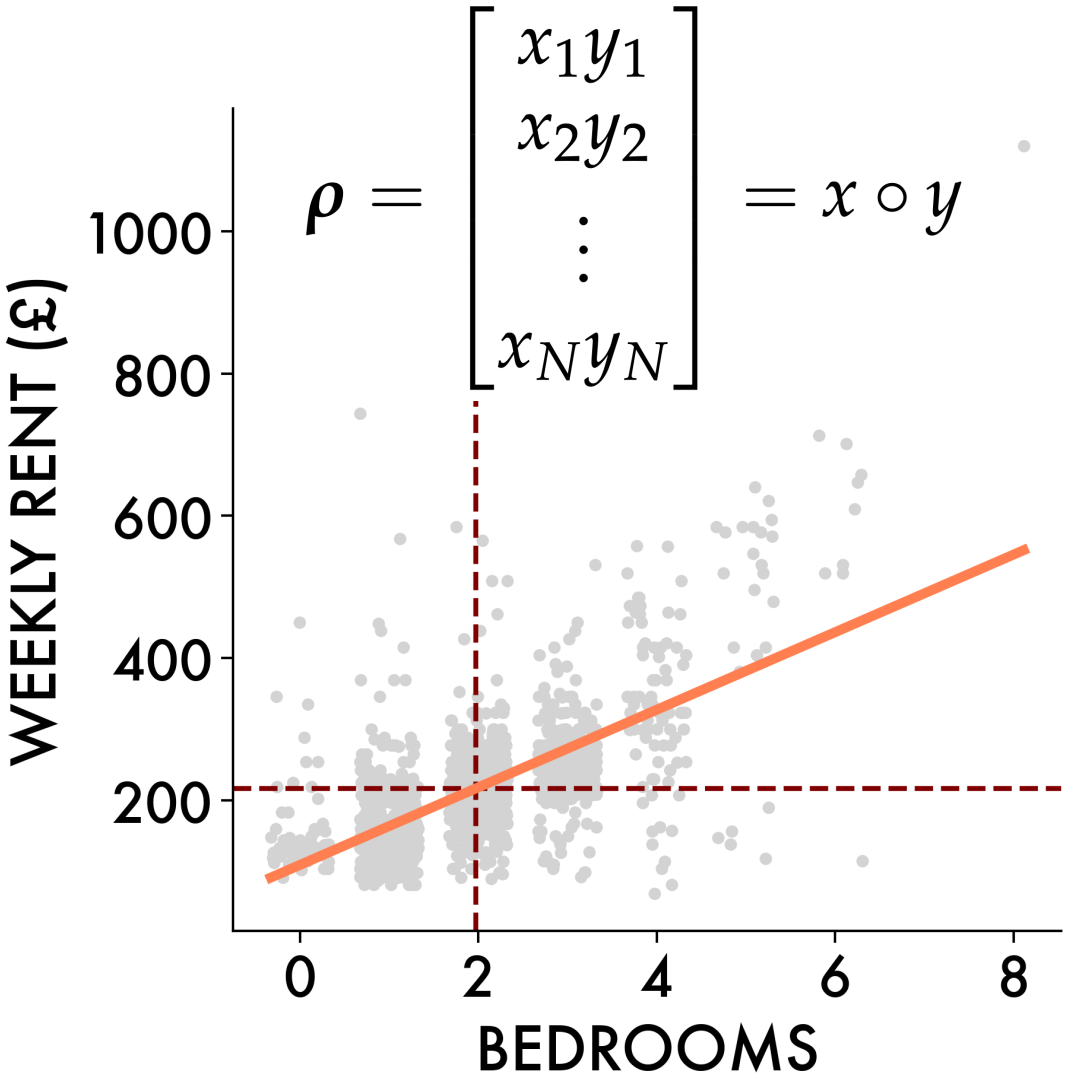
PARTIAL CONDITIONING

AFFORDABILITY OUTLIERS

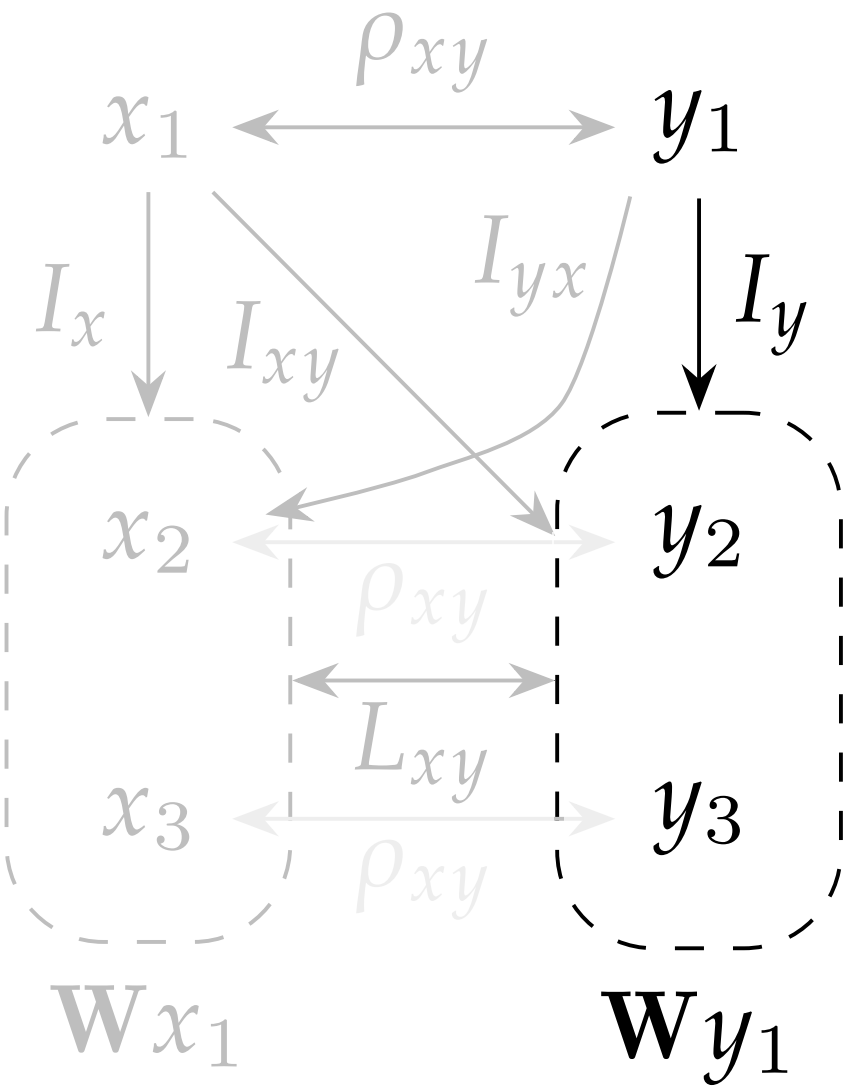


LOCAL COVARIANCE DAGS

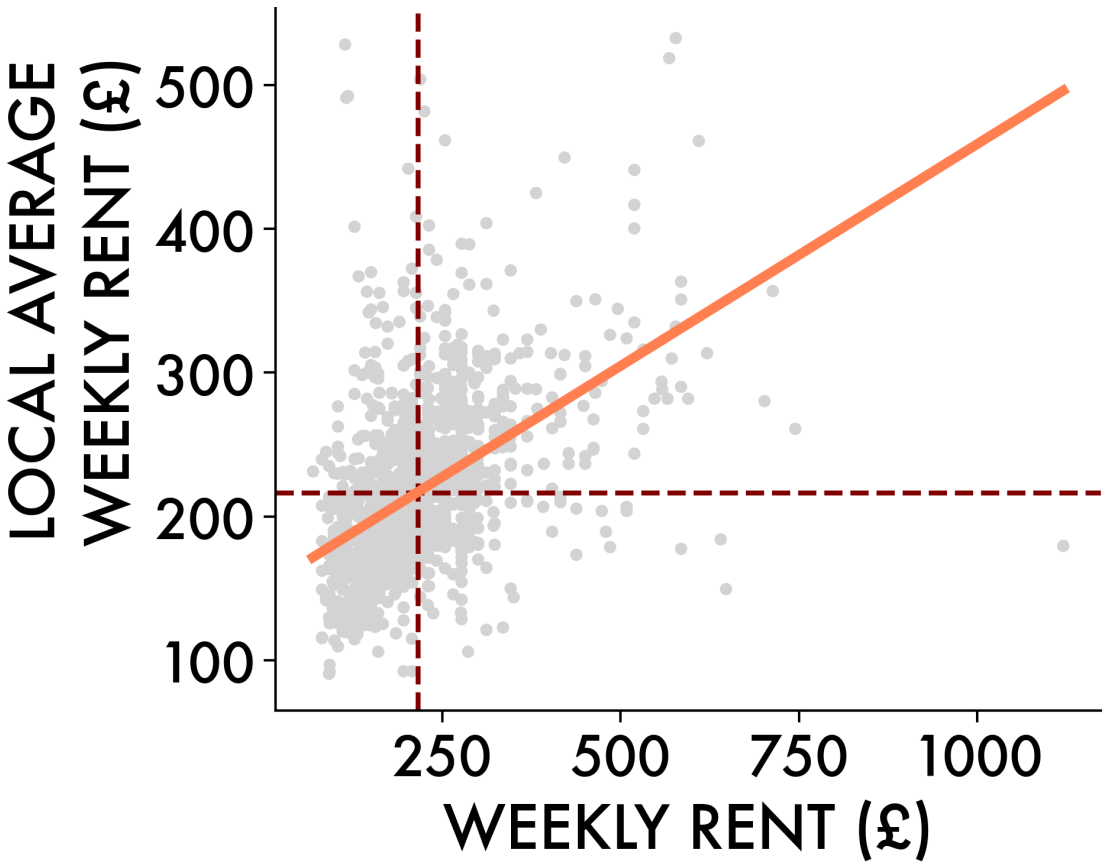




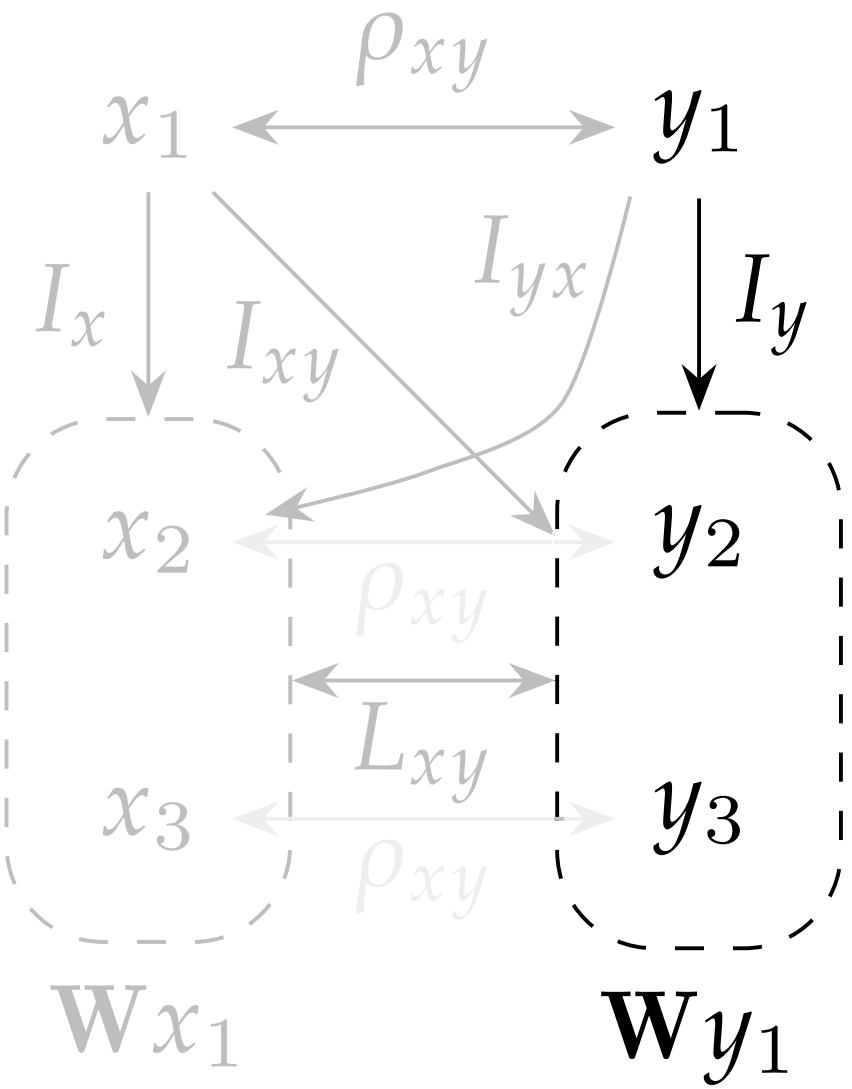
PEARSON CORRELATION



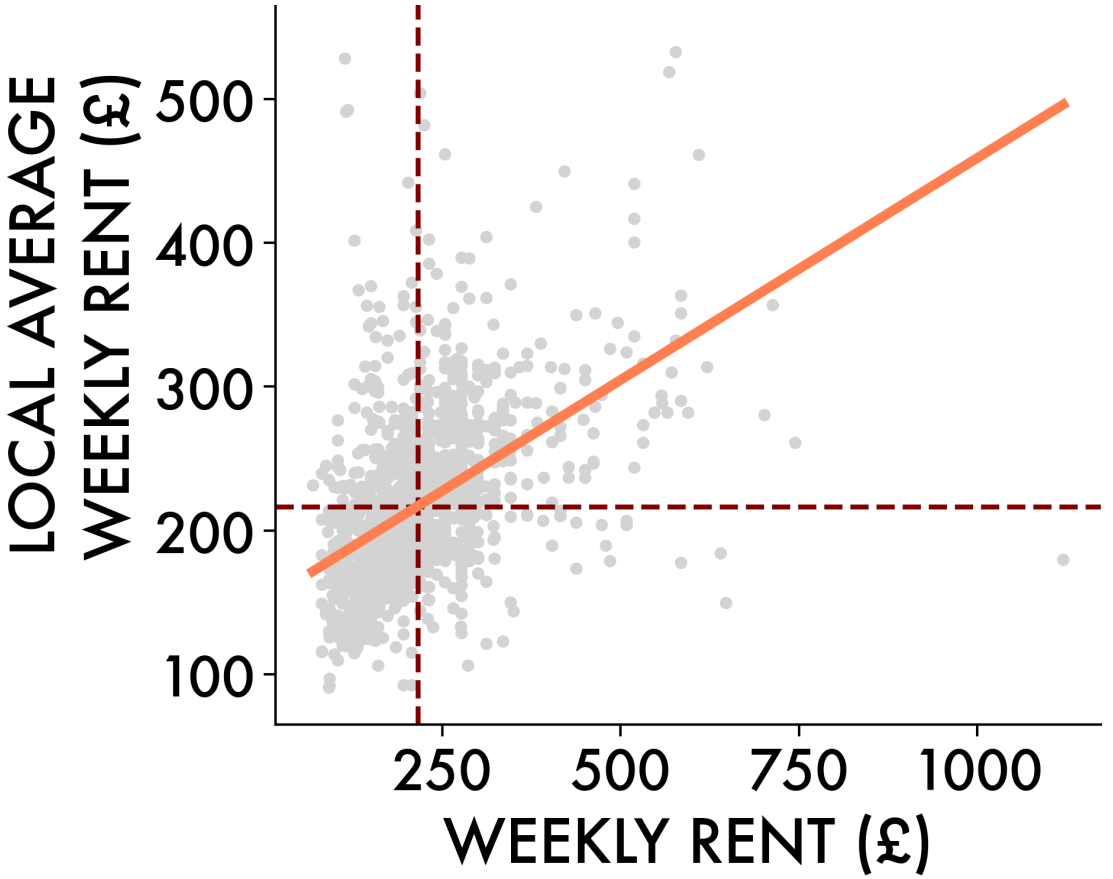
$$I = \sum_i^N \sum_j^N w_{ij} y_i y_j = y \cdot \mathbf{W} \cdot y$$



MORAN ASSOCIATION



$$\mathbf{I} = y \circ \mathbf{W} \cdot y$$



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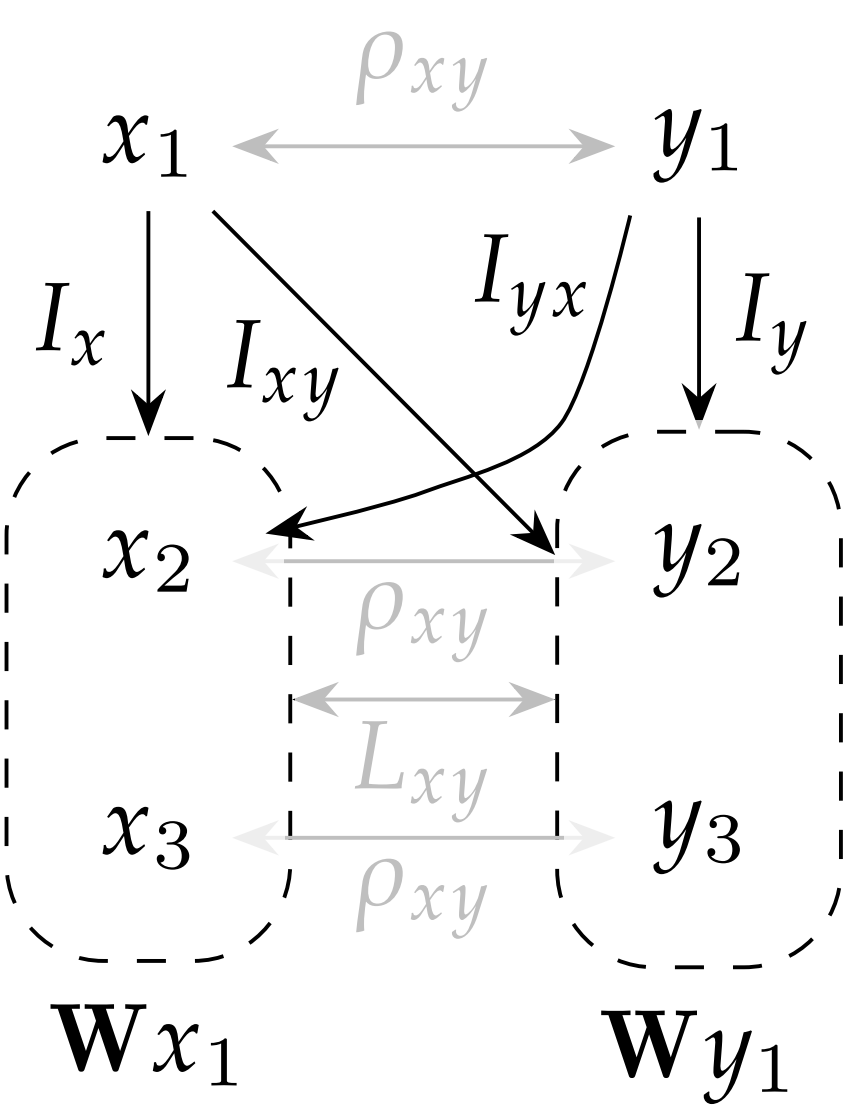
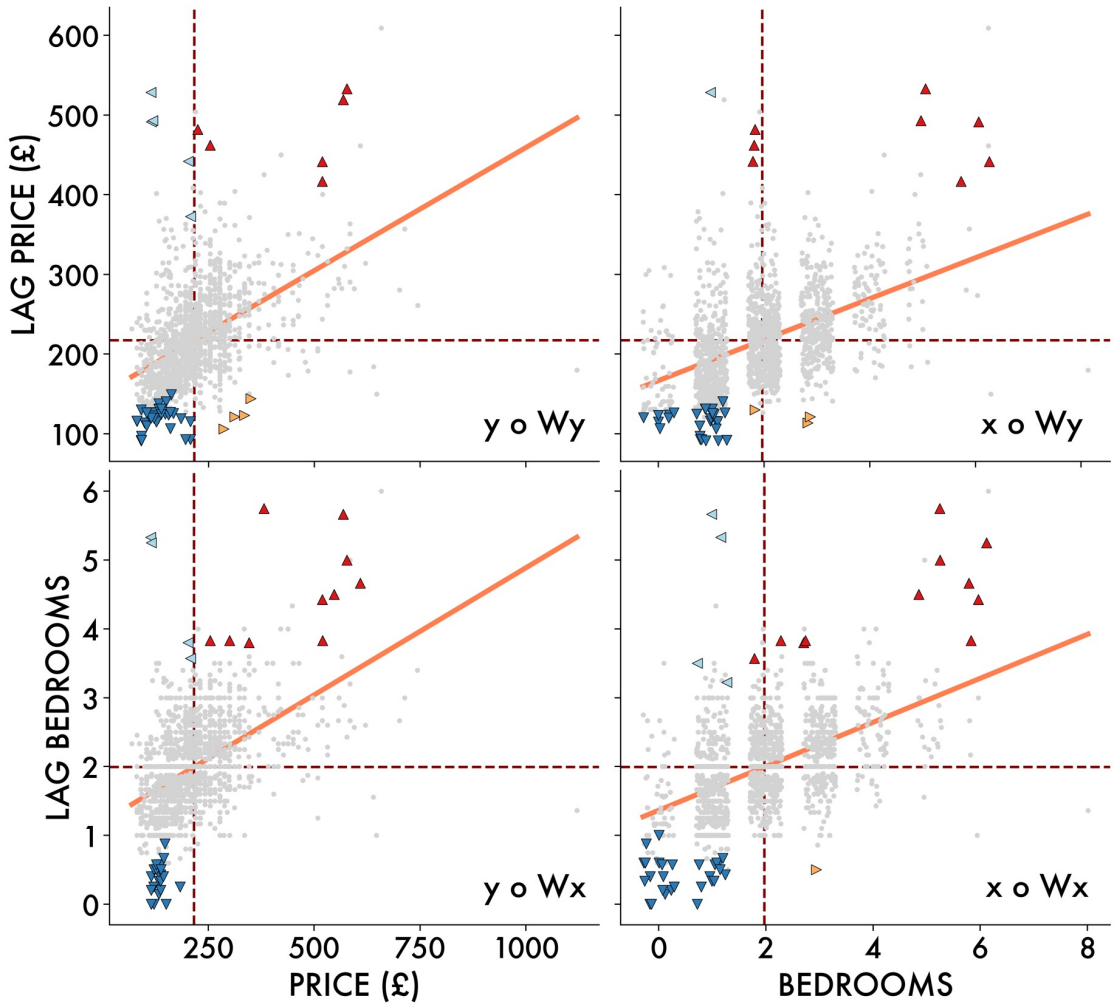
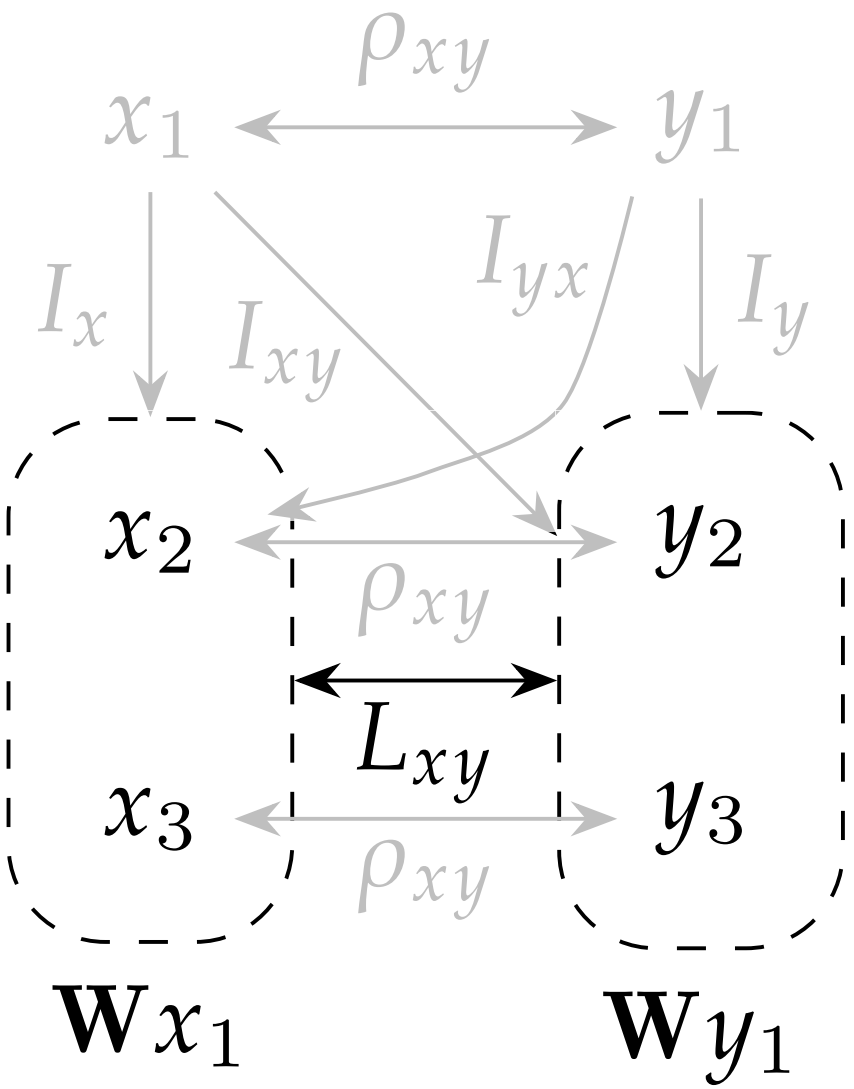


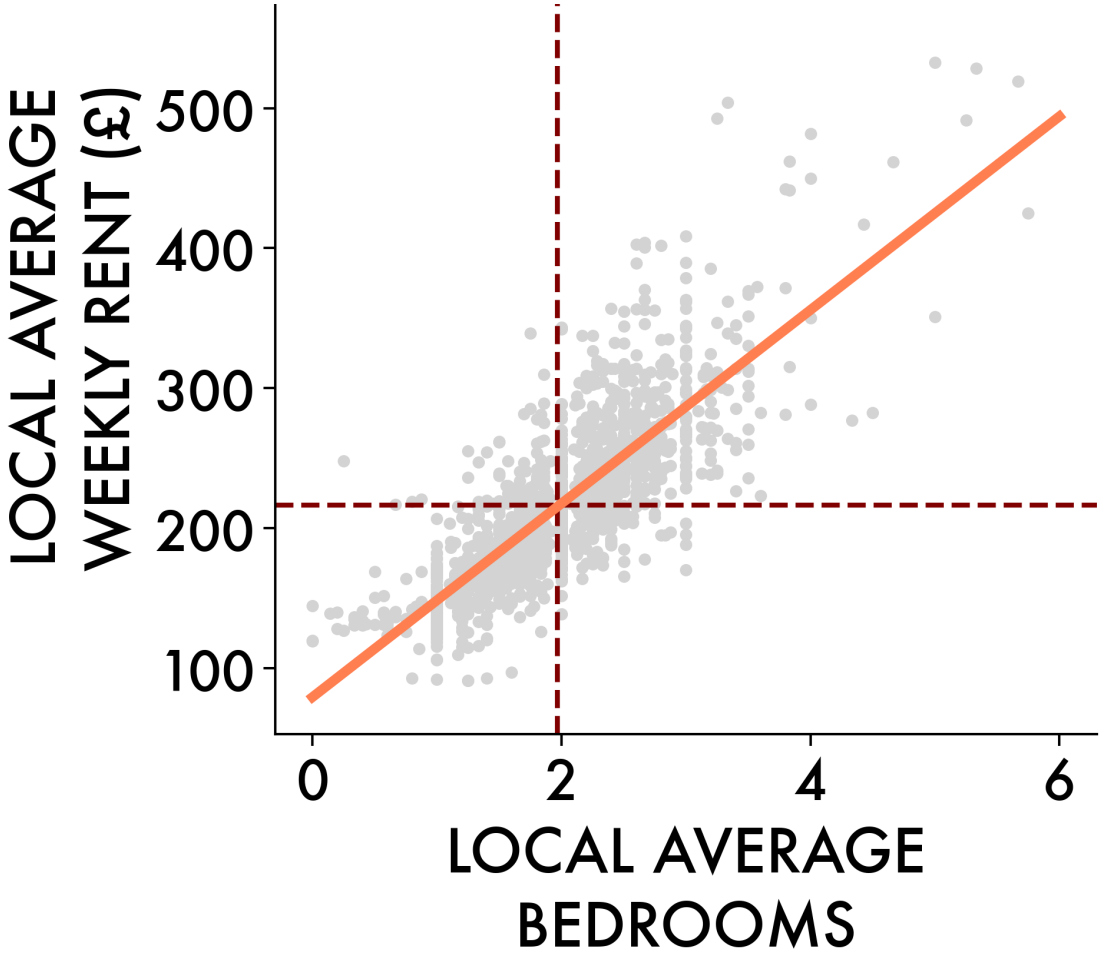
$$\mathbf{I}_{xy} = x \circ \mathbf{W} \cdot y$$



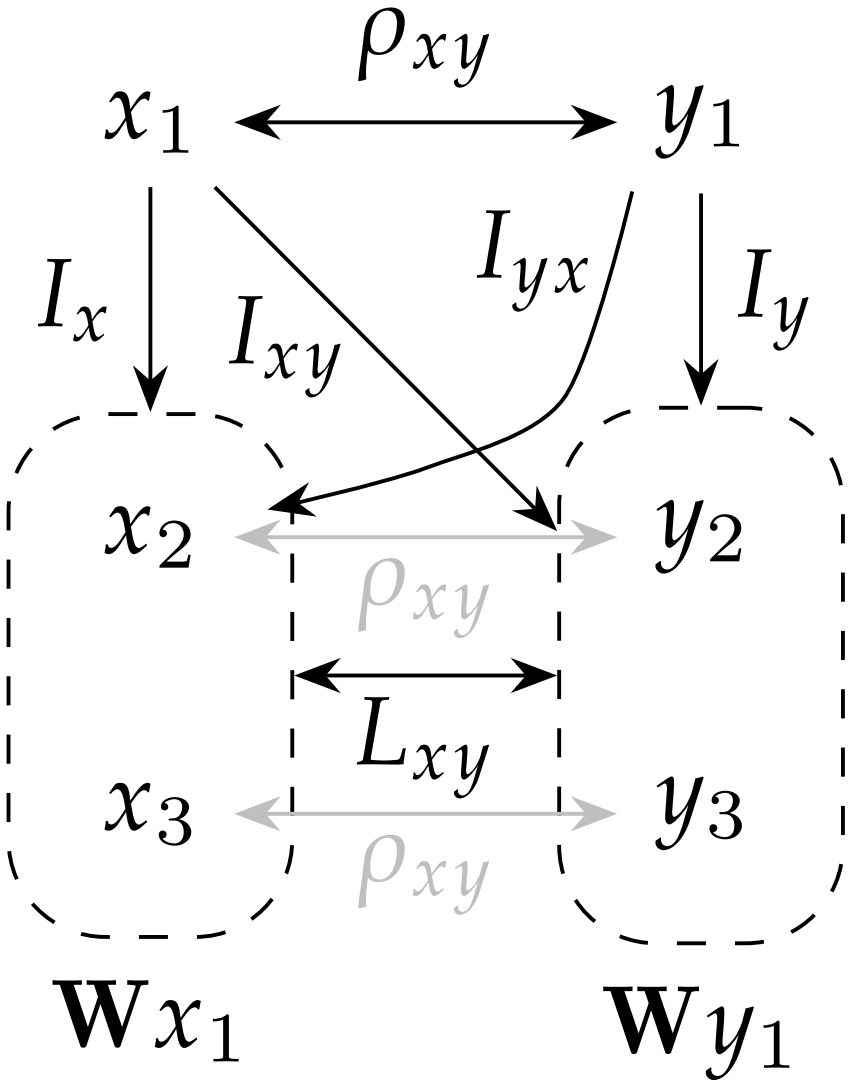
WARTENBERG MORAN MATRIX



$$\mathbf{L}_{xy} = \mathbf{W} \cdot x \circ \mathbf{W} \cdot y$$

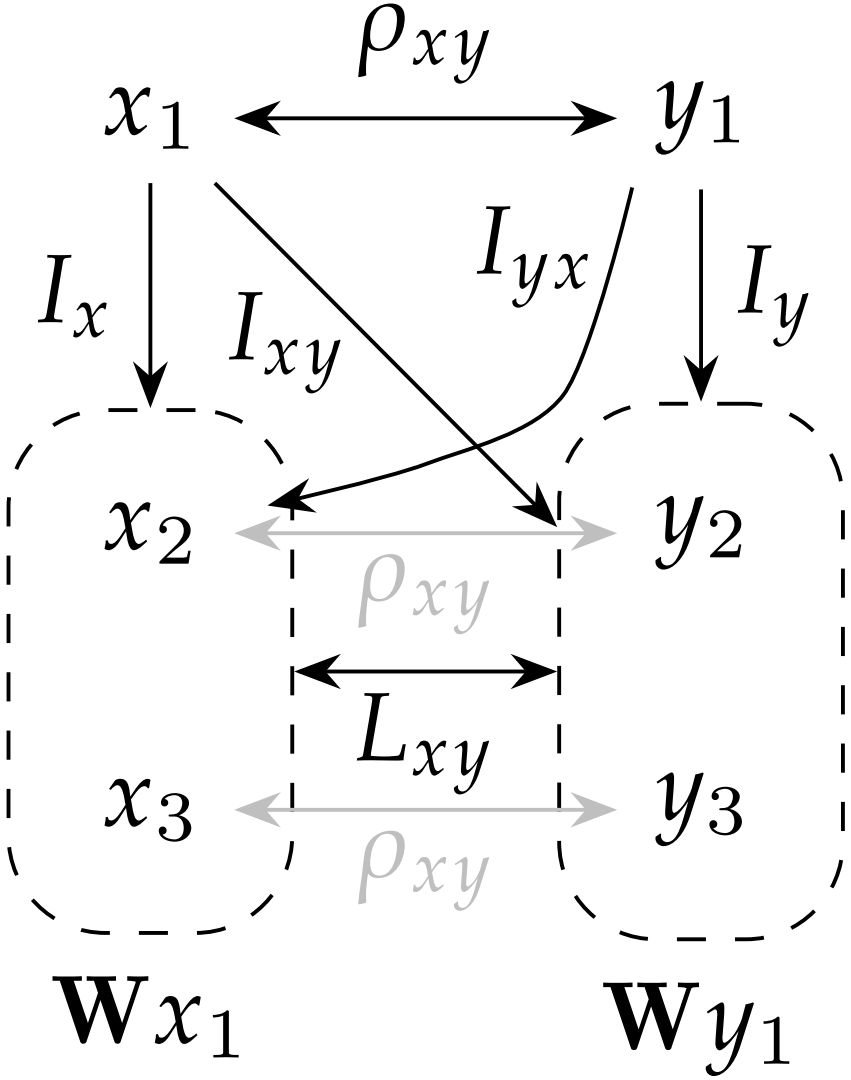


LEE'S SPATIAL PEARSON



Is this house's rent unusual for its area, given its size?

DO ANY OF THESE WORK?



Is this house's rent unusual for its area, given its size?

$$\mathbf{I} = y \circ \mathbf{W} \cdot y$$

Is this house's rent unusual for its area?

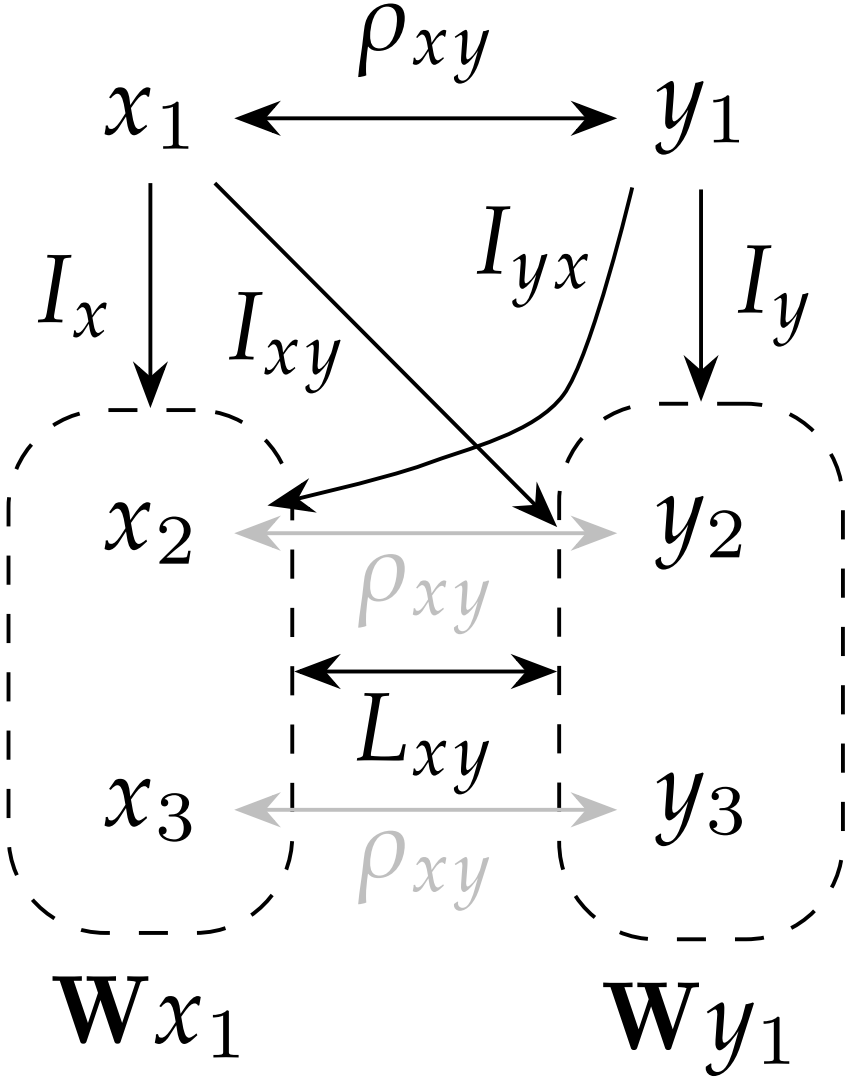
$$\mathbf{I}_{xy} = x \circ \mathbf{W} \cdot y$$

Is this lot size unusual for house rent in this area?

$$\mathbf{L}_{xy} = \mathbf{W} \cdot x \circ \mathbf{W} \cdot y$$

Are this area's rents unusual for this area's lot sizes?

DO ANY OF THESE WORK?



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$$\mathbf{L}_{xy} = \mathbf{W} \cdot x \circ \mathbf{W} \cdot y$$

Are this area's rents unusual for this area's lot sizes?

DO ANY OF THESE WORK? NOPE!

LOCAL CONFOUNDING

size effects on rent vary

PRIOR ART IN ESDA

The Moran-Form Regression

PARTIAL CONDITIONING

Three approaches to "control"

AFFORDABILITY OUTLIERS

$$y = (\mathbf{I} - \lambda \mathbf{W})^{-1}(x\beta + \epsilon)$$

THE SPATIAL LAG MODEL

$$y = (\mathbf{I} - \lambda \mathbf{W})^{-1}(x\beta + \epsilon)$$

Rents

At Site

Nearby

Bedrooms

THE SPATIAL LAG MODEL

$$y = (\mathbf{I} - \lambda \mathbf{W})^{-1}(x\beta + \epsilon)$$

Rents

At Site

Nearby

Bedrooms

Premium?

THE SPATIAL LAG MODEL

$$y = (\mathbf{I} - \lambda \mathbf{W})^{-1}(x\beta + \epsilon)$$

Rents — At Site — Nearby — Bedrooms — **Premium?**

$$e = y - (\mathbf{I} - \hat{\lambda} \mathbf{W})^{-1} x\hat{\beta}$$

$$e = y - x\hat{\beta} - \hat{\lambda}\mathbf{W}x\hat{\beta} - \hat{\lambda}^2\mathbf{W}^2x\hat{\beta} + \ldots$$

THE SPATIAL LAG MODEL

$$y = (\mathbf{I} - \lambda \mathbf{W})^{-1}(x\beta + \epsilon)$$

Rents — At Site — Nearby — Bedrooms — **Premium?**

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Premium? — Rents — Site Size — Nearby Sizes

THE SPATIAL LAG MODEL

$$y = (\mathbf{I} - \lambda \mathbf{W})^{-1}(x\beta + \epsilon)$$

Rents — At Site — Nearby — Bedrooms — **Premium?**

$$e = y - (\mathbf{I} - \hat{\lambda} \mathbf{W})^{-1} x\hat{\beta}$$

Still “filtered” by $(\mathbf{I} - \lambda \mathbf{W})^{-1}$

Can ID unusual prices

Not a *covariance*

THE SPATIAL LAG MODEL

$$y = x\beta + \epsilon$$

Rents

Bedrooms

Premium at site

AUXILIARY REGRESSION

$$y = x\beta + \epsilon$$

$$e = y - x\hat{\beta}$$

AUXILIARY REGRESSION

$$y = x\beta + \epsilon$$

$$e = y - x\hat{\beta}$$

$$\mathbf{I}_{x \to y} = e \circ \mathbf{W}e$$

Is this premium unusual given the premium people are paying for space in the area?

AUXILIARY REGRESSION

$$y = x\beta + \epsilon$$

$$e = y - x\hat{\beta}$$

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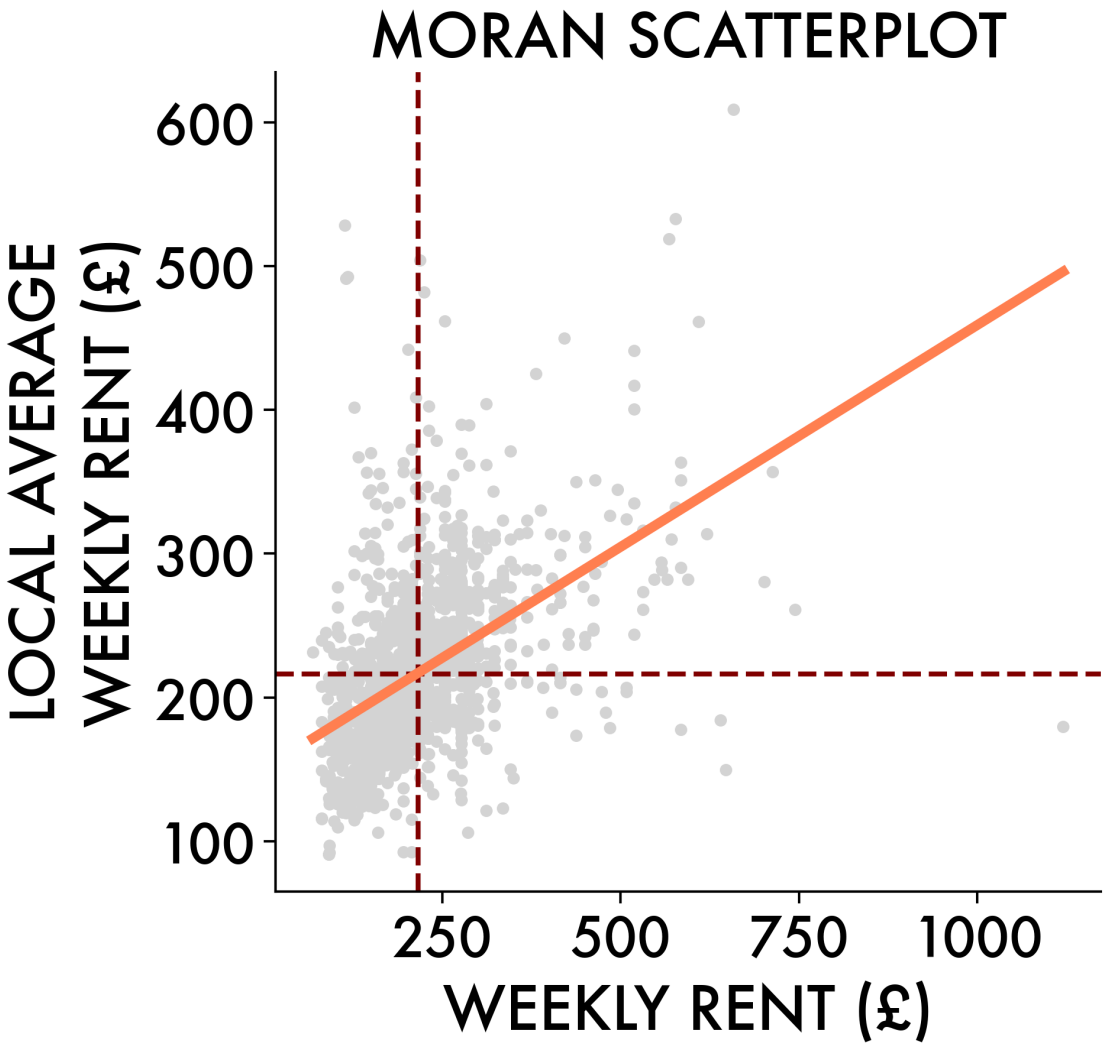
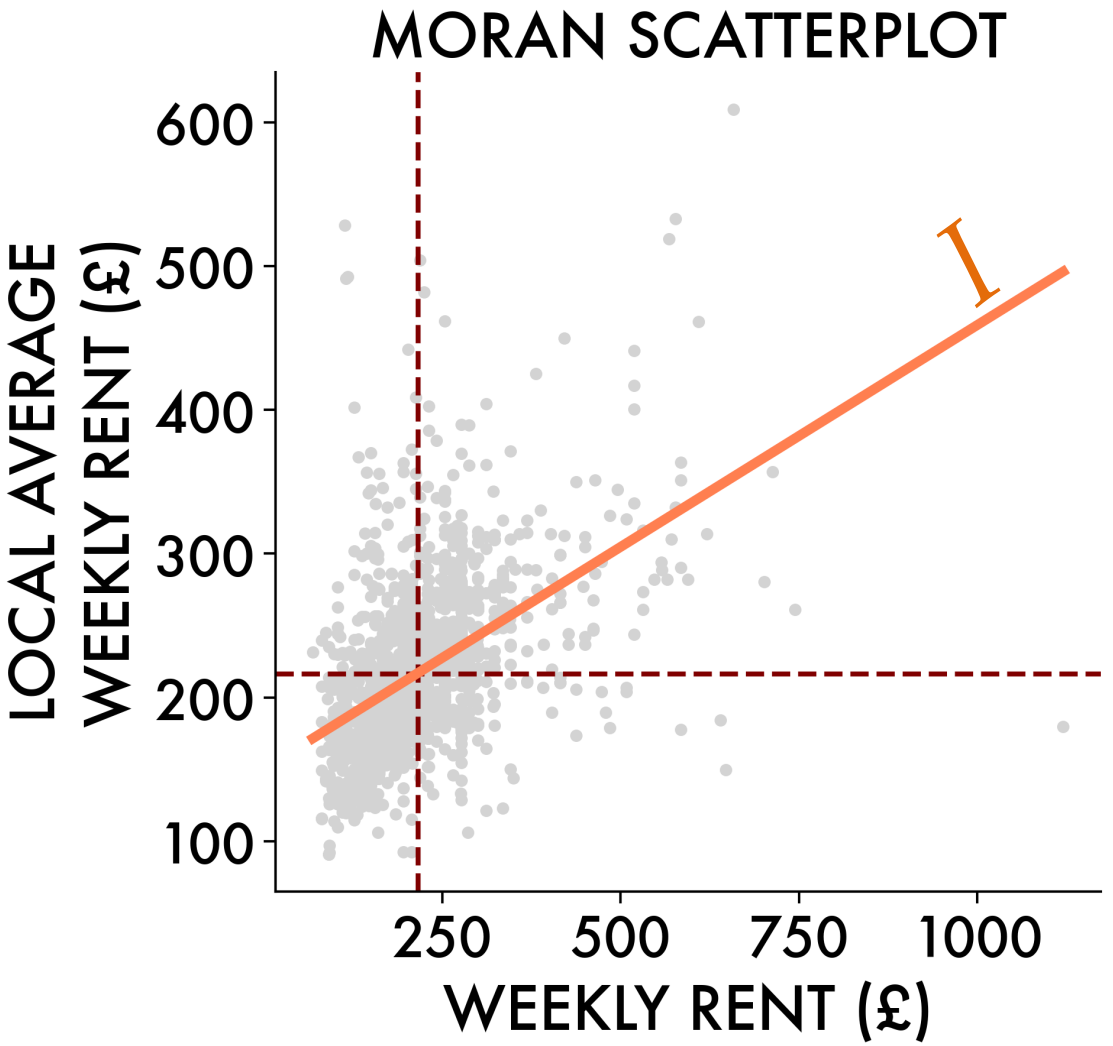
~~*Is this premium unusual given the premium people are paying for space in the area?*~~

AUXILIARY REGRESSION



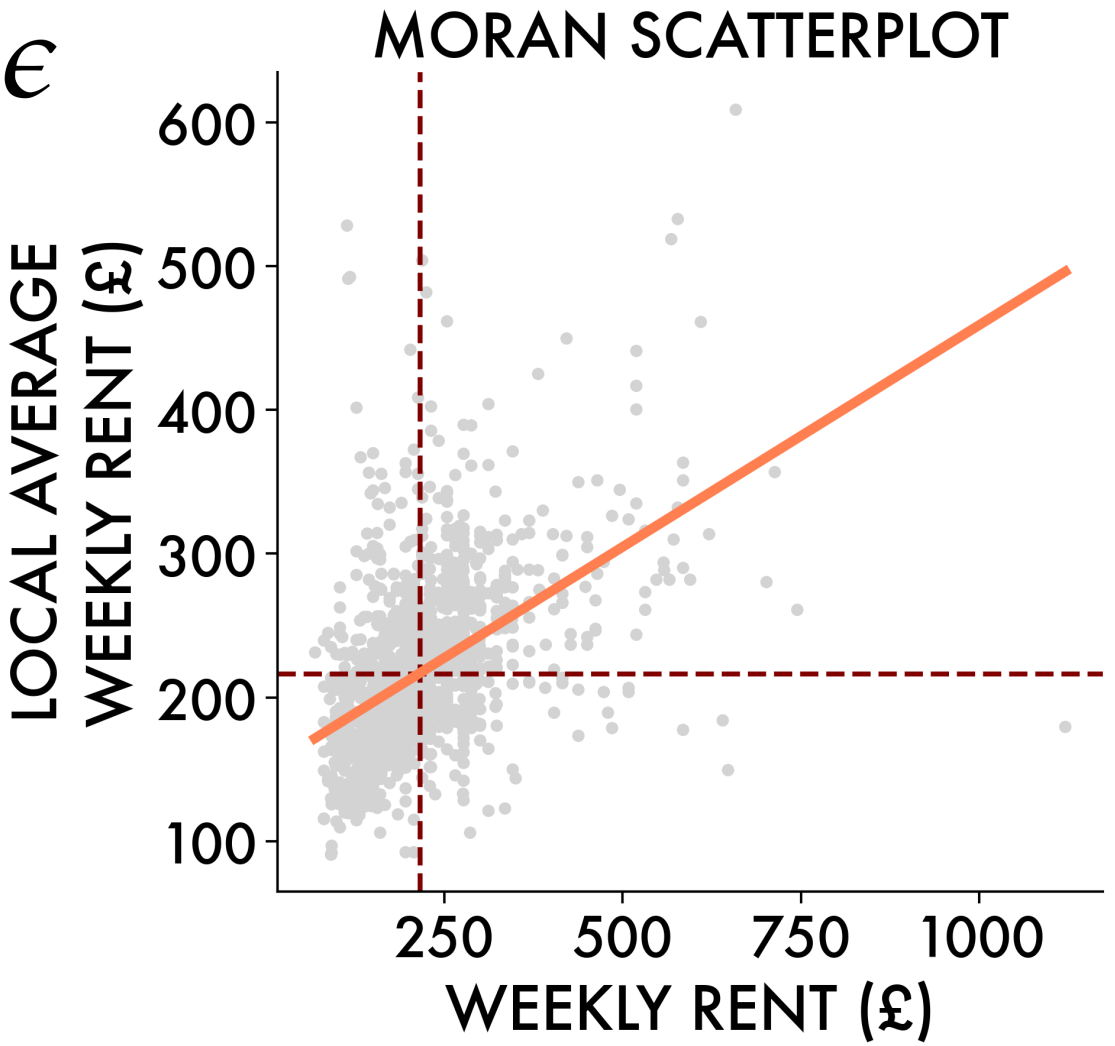
MORAN-FORM REGRESSIONS

$$\mathbf{W}y = Iy + \epsilon$$



MORAN-FORM REGRESSIONS

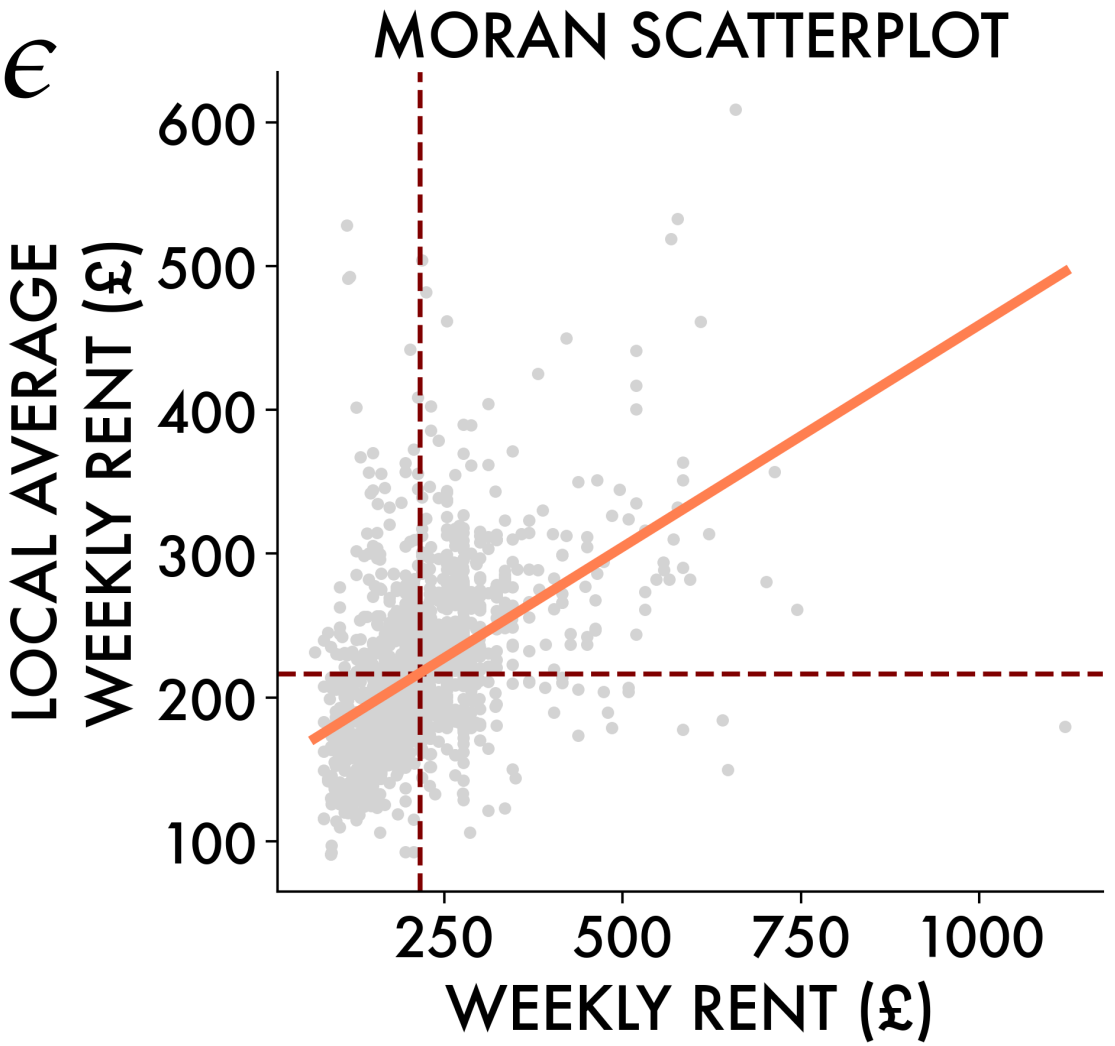
$$\mathbf{W}y = Iy + x\beta + \epsilon$$



MORAN-FORM REGRESSIONS

$$\mathbf{W}y = Iy + x\beta + \epsilon$$

What is the relationship between a house's rent and nearby rents, holding the house's size constant?



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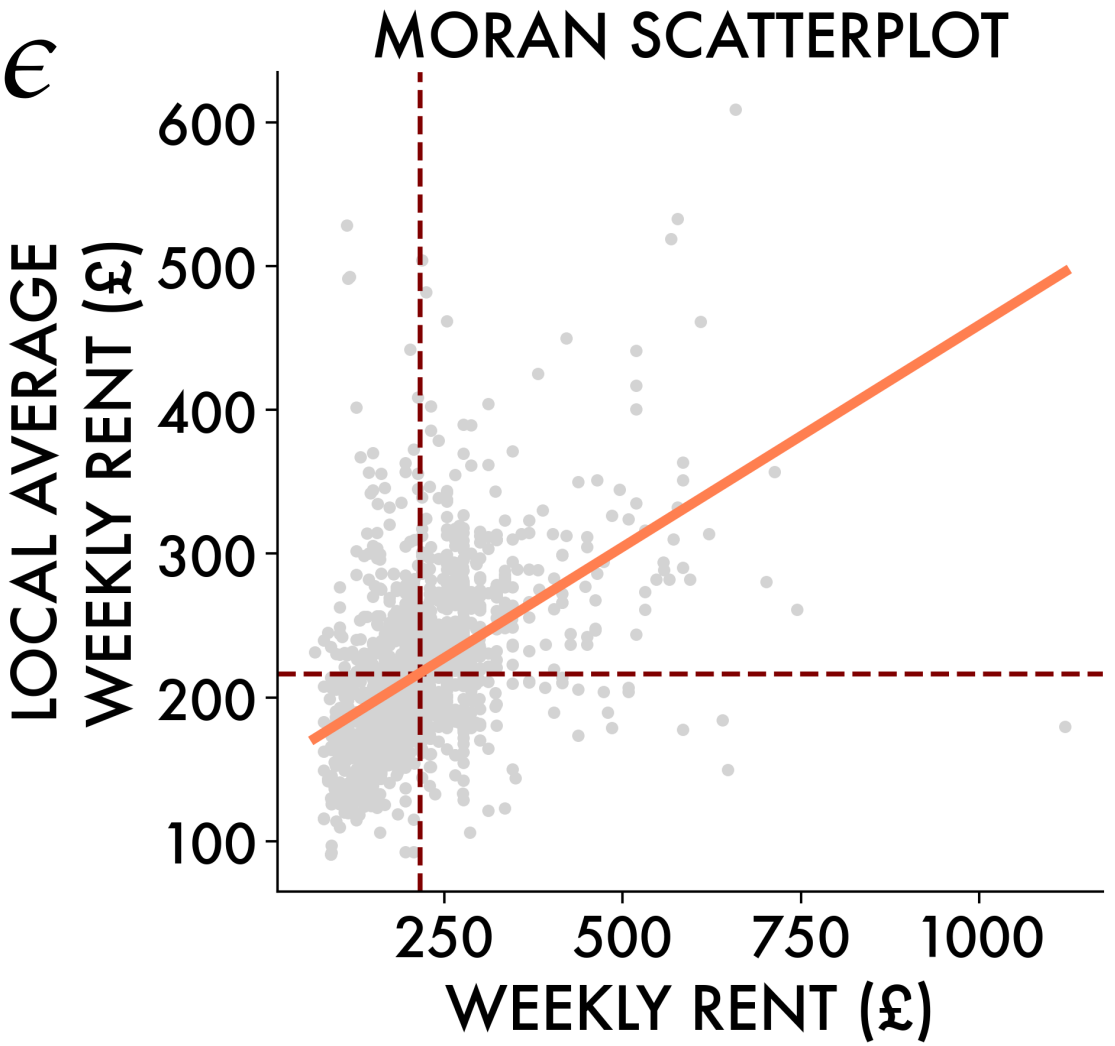

MORAN-FORM REGRESSIONS

$$\mathbf{W}y = Iy + x\beta + \epsilon \quad \mathbf{W}\vec{y} = \mathbf{W}\begin{bmatrix} y & y & \dots \end{bmatrix}$$

$$\mathbf{D} = \begin{bmatrix} y & x \end{bmatrix}$$

$$\mathbf{I}_{y|x} = (\mathbf{D}'\mathbf{D})^{-1}\mathbf{D} \circ \mathbf{W}\vec{y}$$

A LOCAL “CETERIS PARIBUS” STATISTIC

$$\mathbf{W}y = Iy + x\beta + \epsilon \quad \mathbf{W}\vec{y} = \mathbf{W}\begin{bmatrix} y & y & \dots \end{bmatrix}$$

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$$\mathbf{I}_{y|x} \propto \mathbf{I}_y - \rho\mathbf{I}_{xy}$$

A LOCAL “CETERIS PARIBUS” STATISTIC

$$\mathbf{I}_{y|x} \propto \mathbf{I}_y - \rho \mathbf{I}_{xy}$$

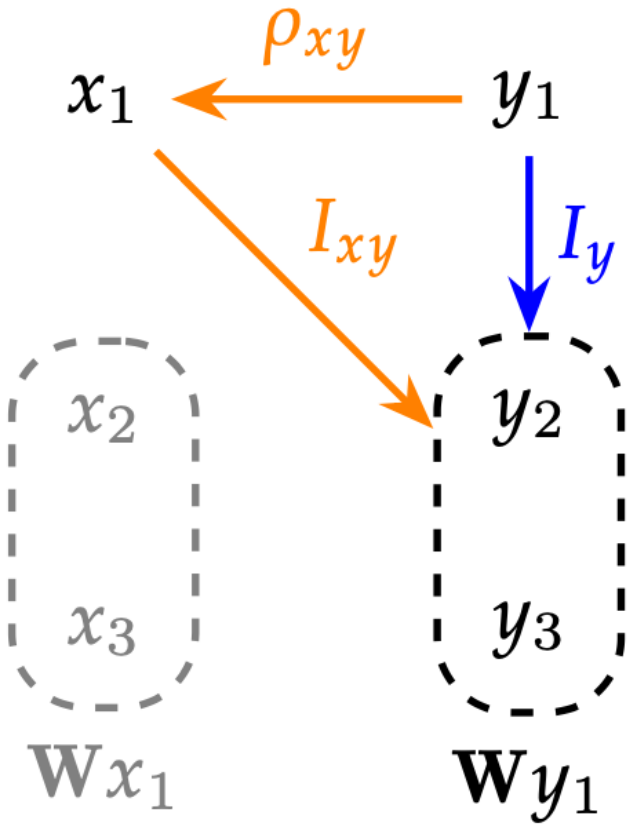
THE PARTIAL LOCAL MORAN

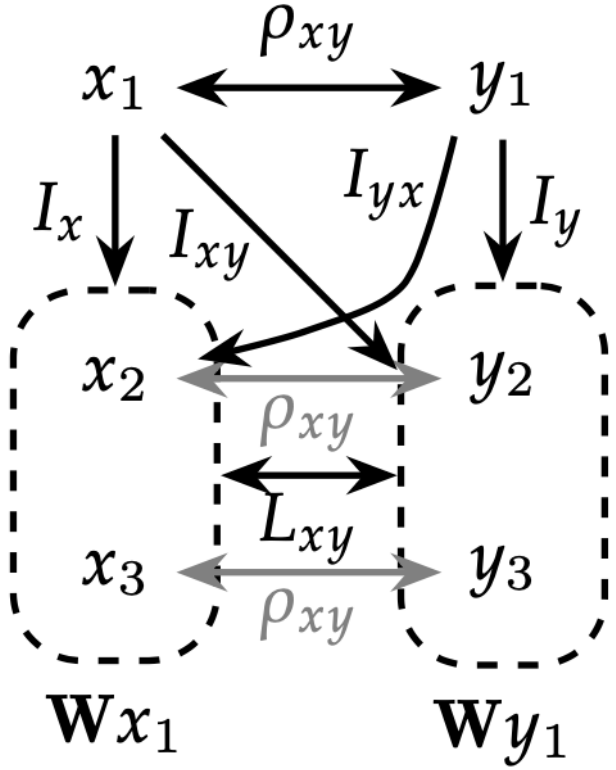
Spatial association within y

Adjusted by x's association with nearby y and y itself

$$\mathbf{I}_{y|x} \propto \mathbf{I}_y - \rho \mathbf{I}_{xy}$$

PARTIAL LOCAL MORAN

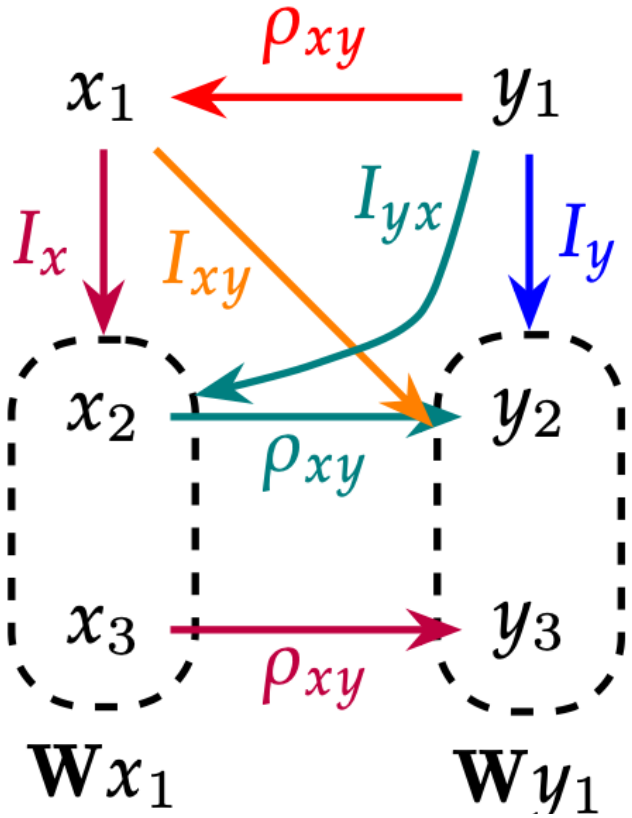


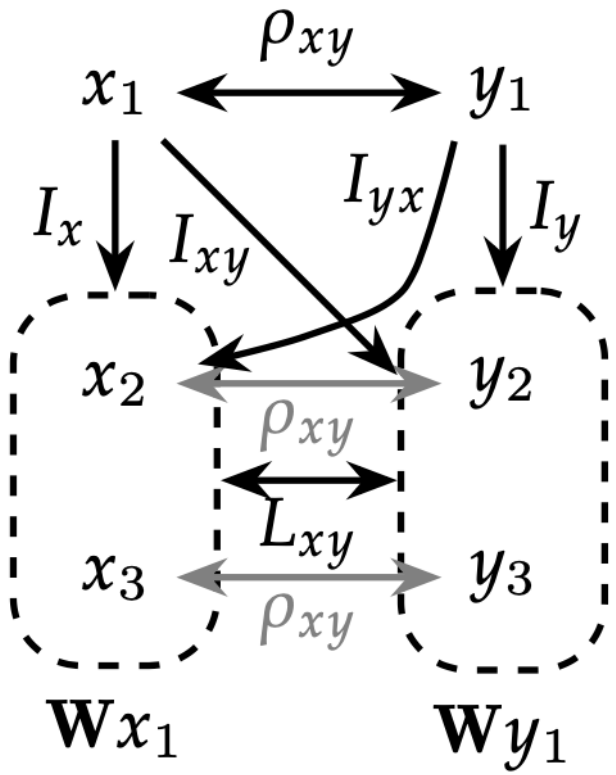


Classic Statistics

$$\mathbf{I}_{y|x} \propto \underline{\mathbf{I}_y} - \underline{\rho \mathbf{I}_{xy}}$$

PARTIAL LOCAL MORAN





$$\mathbf{I}_{x \to y} \propto \underline{\mathbf{I}_y} - \underline{\rho \mathbf{I}_{xy}} - \underline{\rho \mathbf{I}_{yx}} + \underline{\rho^2 I_x}$$

AUXILIARY REGRESSION MORAN IS FULL CONDITIONING

$$\mathbf{W}y = \mathbf{X}\beta + Iy + e$$

HIGHER DIMENSIONAL PARTIAL CONDITIONING BY FWL

$$\mathbf{W}y = \mathbf{X}\beta + Iy + e$$

Now have p features needing adjustment

HIGHER DIMENSIONAL PARTIAL CONDITIONING BY FWL

$$\mathbf{W}y = \mathbf{X}\beta + Iy + e$$

$$\mathbf{M} = \mathbf{I} - \mathbf{X}'(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'$$

Residual Maker Matrix, so-called because $\mathbf{M}y = e$

HIGHER DIMENSIONAL PARTIAL CONDITIONING BY FWL

$$\mathbf{W}y = \mathbf{X}\beta + Iy + e$$

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Residual Maker Matrix, so-called because $\mathbf{M}y = e$

$$\mathbf{M}\mathbf{W}y = I_{y \mid x}\mathbf{M}y + \epsilon$$

HIGHER DIMENSIONAL PARTIAL CONDITIONING BY FWL

$$\mathbf{MW}y = I_{y\,|\,x}\mathbf{M}y + \epsilon$$

$$I_{y|x} \propto (\mathbf{M}y)'\mathbf{MW}y$$

HIGHER DIMENSIONAL PARTIAL CONDITIONING BY FWL

$$\mathbf{MW}y = I_{y\,|\,x}\mathbf{M}y + \epsilon$$

$$I_{y|x} \propto (\mathbf{M}y)'\mathbf{MW}y$$

$$\propto\ y'\mathbf{W}y - (\mathbf{X}'(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'y)'\mathbf{W}y$$

$$I_y$$

HIGHER DIMENSIONAL PARTIAL CONDITIONING BY FWL

$$\mathbf{MW}y = I_{y\,|\,x}\mathbf{M}y + \epsilon$$

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$$\propto\ y'\mathbf{W}y - (\mathbf{X}'(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'y)'\mathbf{W}y$$

$$I_y \qquad\qquad (\mathbf{X}'\beta)'\mathbf{W}y$$

HIGHER DIMENSIONAL PARTIAL CONDITIONING BY FWL

$$\mathbf{MW}y = I_{y\,|\,x}\mathbf{M}y + \epsilon$$

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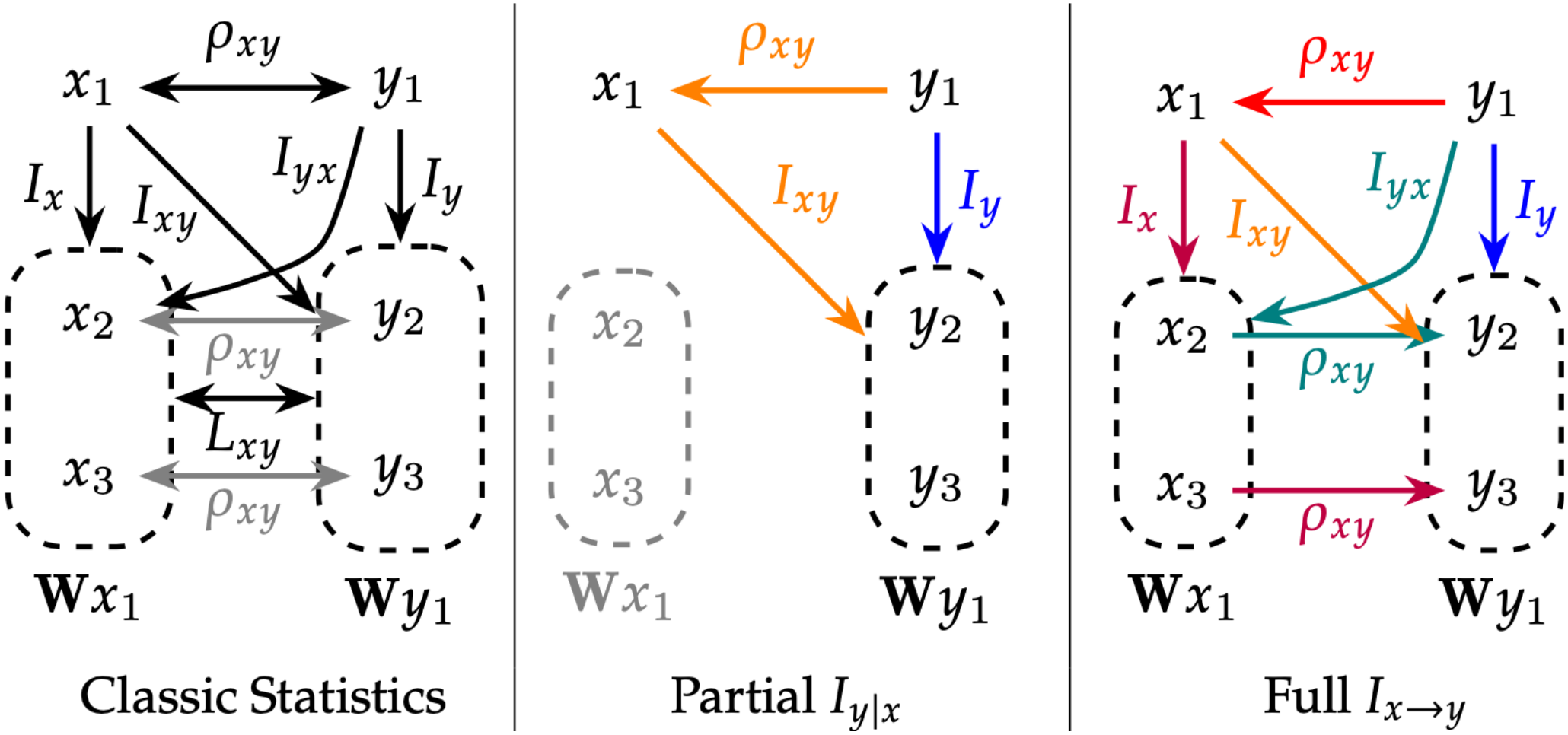
$$\propto\ y'\mathbf{W}y - (\mathbf{X}'(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'y)'\mathbf{W}y$$

$$I_y \qquad\qquad (\mathbf{P}y)'\mathbf{W}y$$

HIGHER DIMENSIONAL PARTIAL CONDITIONING BY FWL



THE POINT REMAINS: CORRECT Y FOR X (& MAYBE WX)

LOCAL CONFOUNDING

confounding is not stationary

PRIOR ART IN ESDA

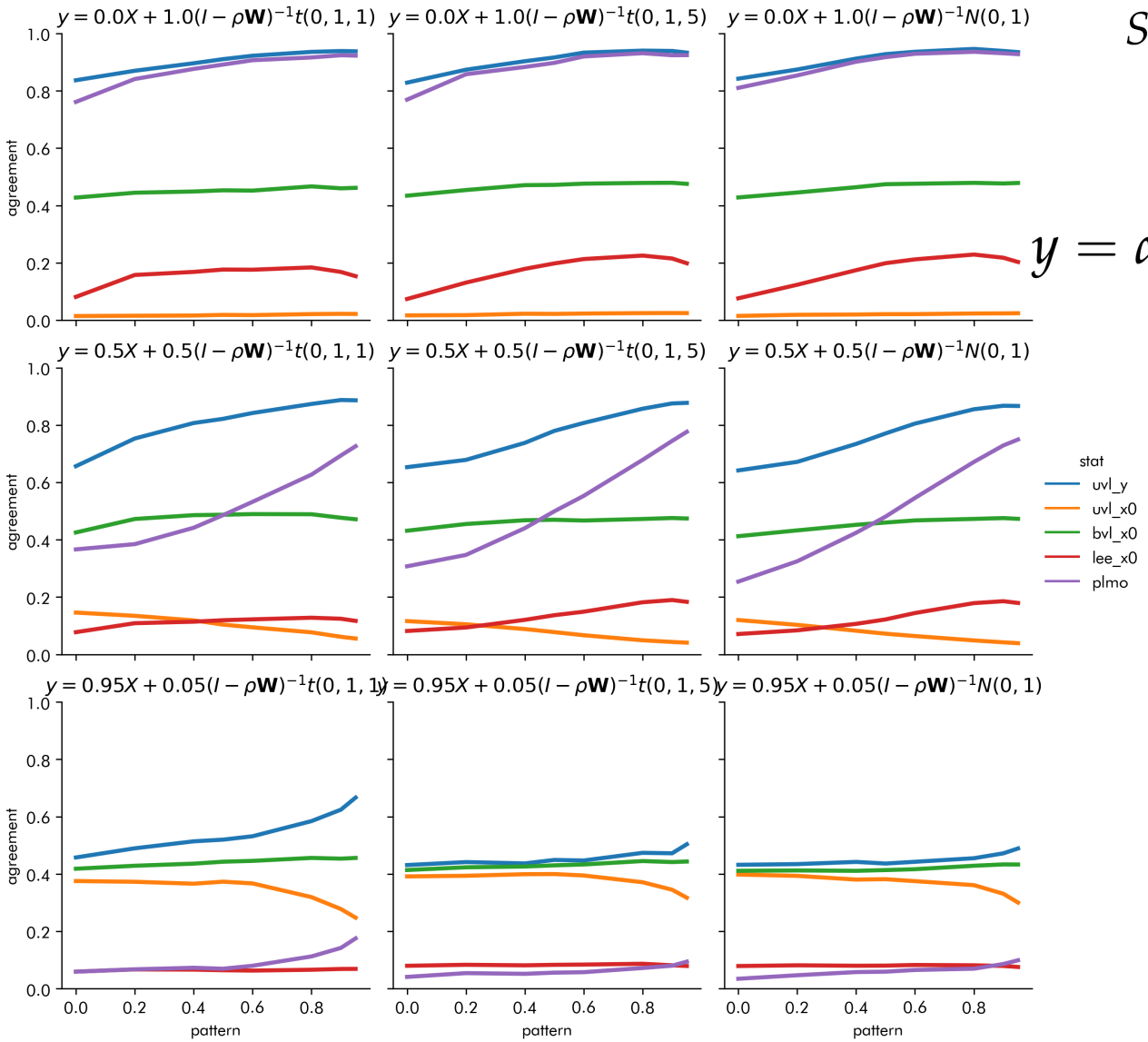
The Moran-Form Regression

PARTIAL CONDITIONING

Two approaches to "control"

AFFORDABILITY OUTLIERS

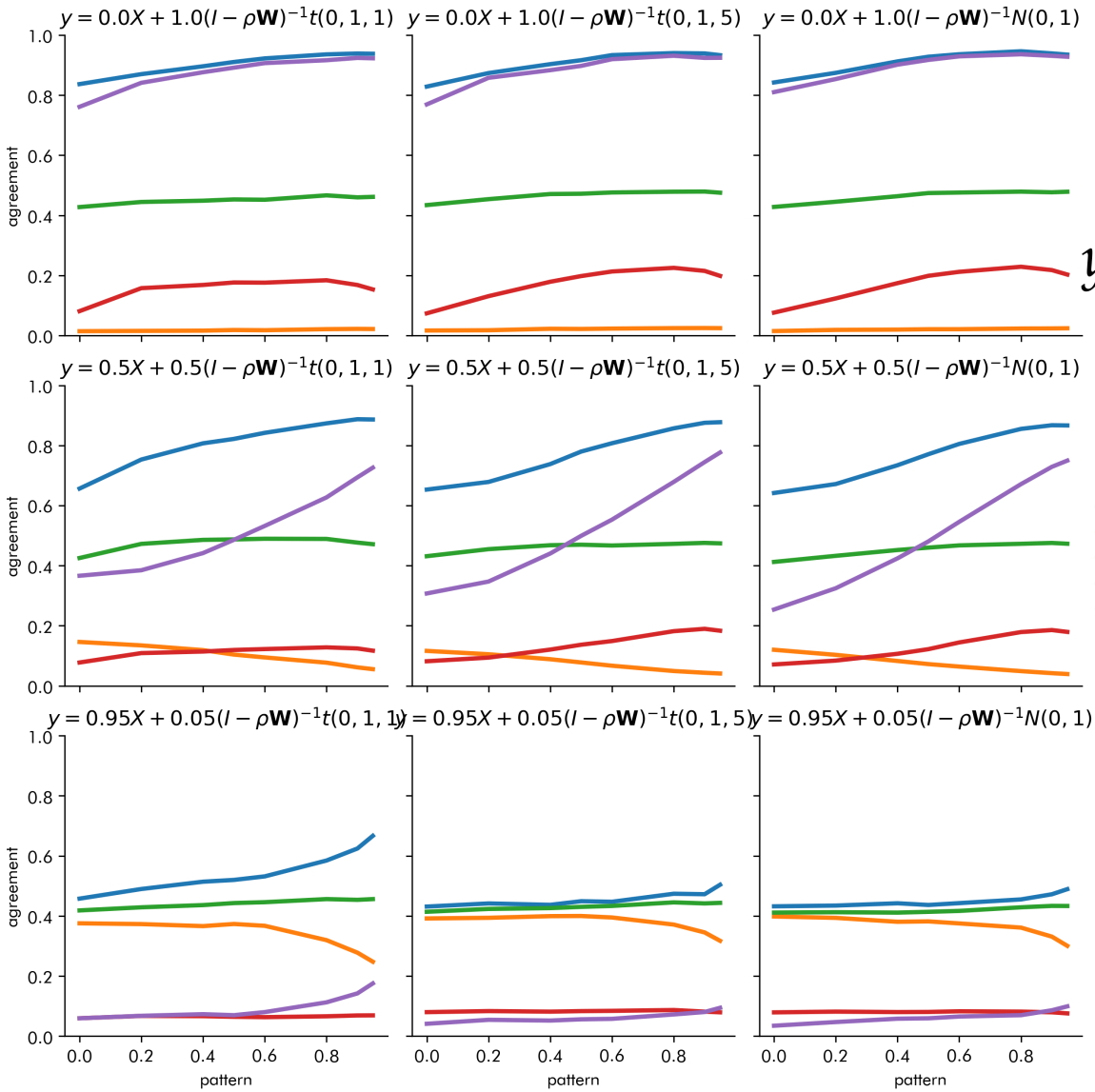
Where are the good deals?



SAR t-distributed random effects process (SARTRE)

$$y = \alpha x + (1 - \alpha)(I - \lambda\mathbf{W})^{-1}t(\mu, \tau^2, \nu)$$

SURPRISE! SIMULATION RESULTS FIRST!



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confounder $\alpha \in [0, 1]$ SAR patterning random effect

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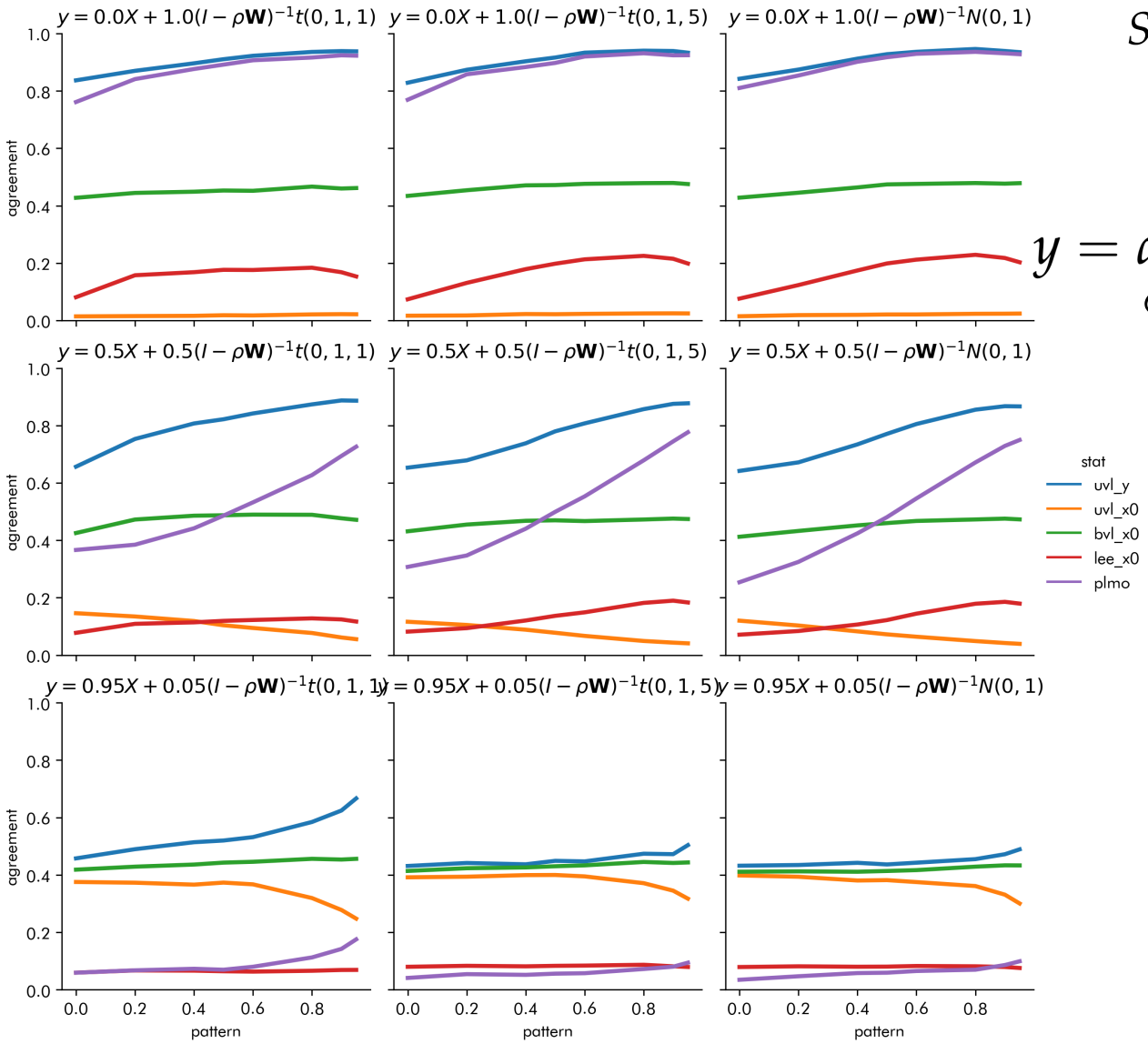

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Blend a spatially-unpatterned "confounding effect" with a spatially-structured part with controlled tail thickness.

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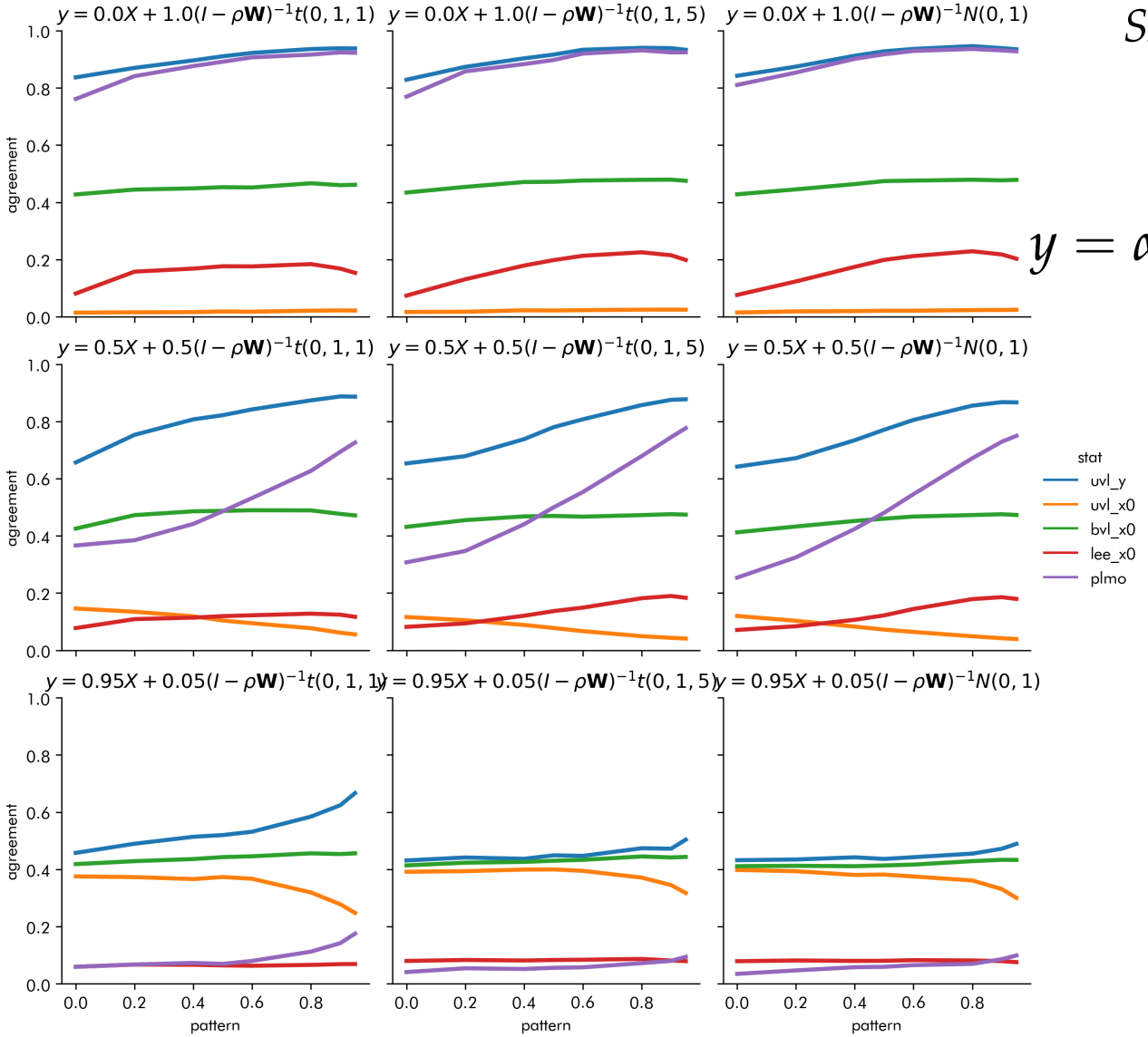

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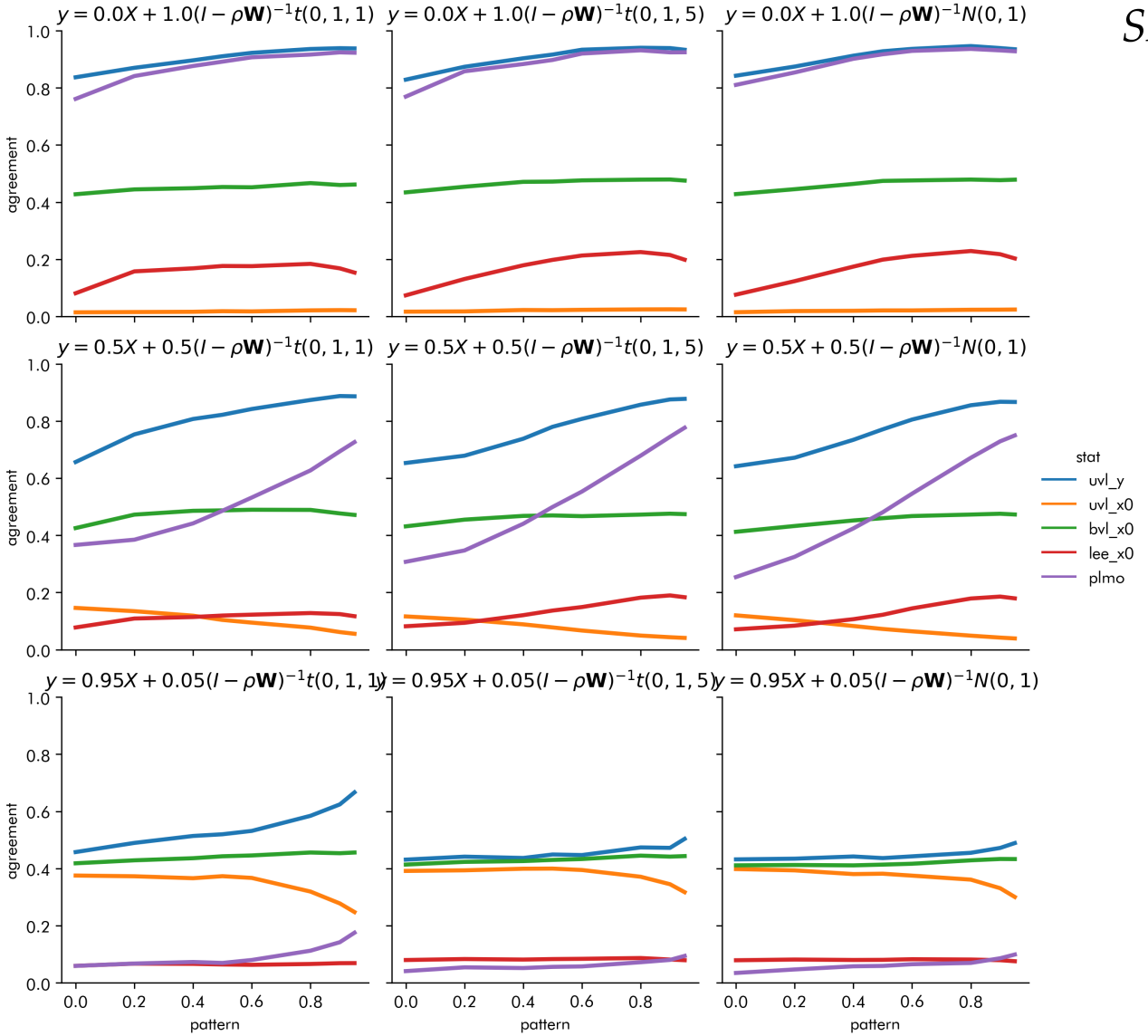

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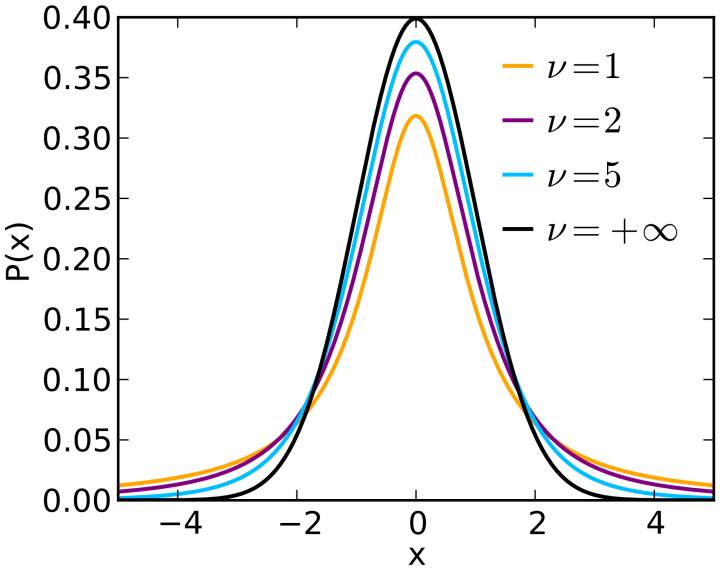

Blend a spatially-unpatterned "confounding effect" with a spatially-structured part with controlled tail thickness.

$$\nu \to \infty$$

$$t(\mu, \tau^2, \nu) \to \mathcal{N}(\mu, \tau^2)$$

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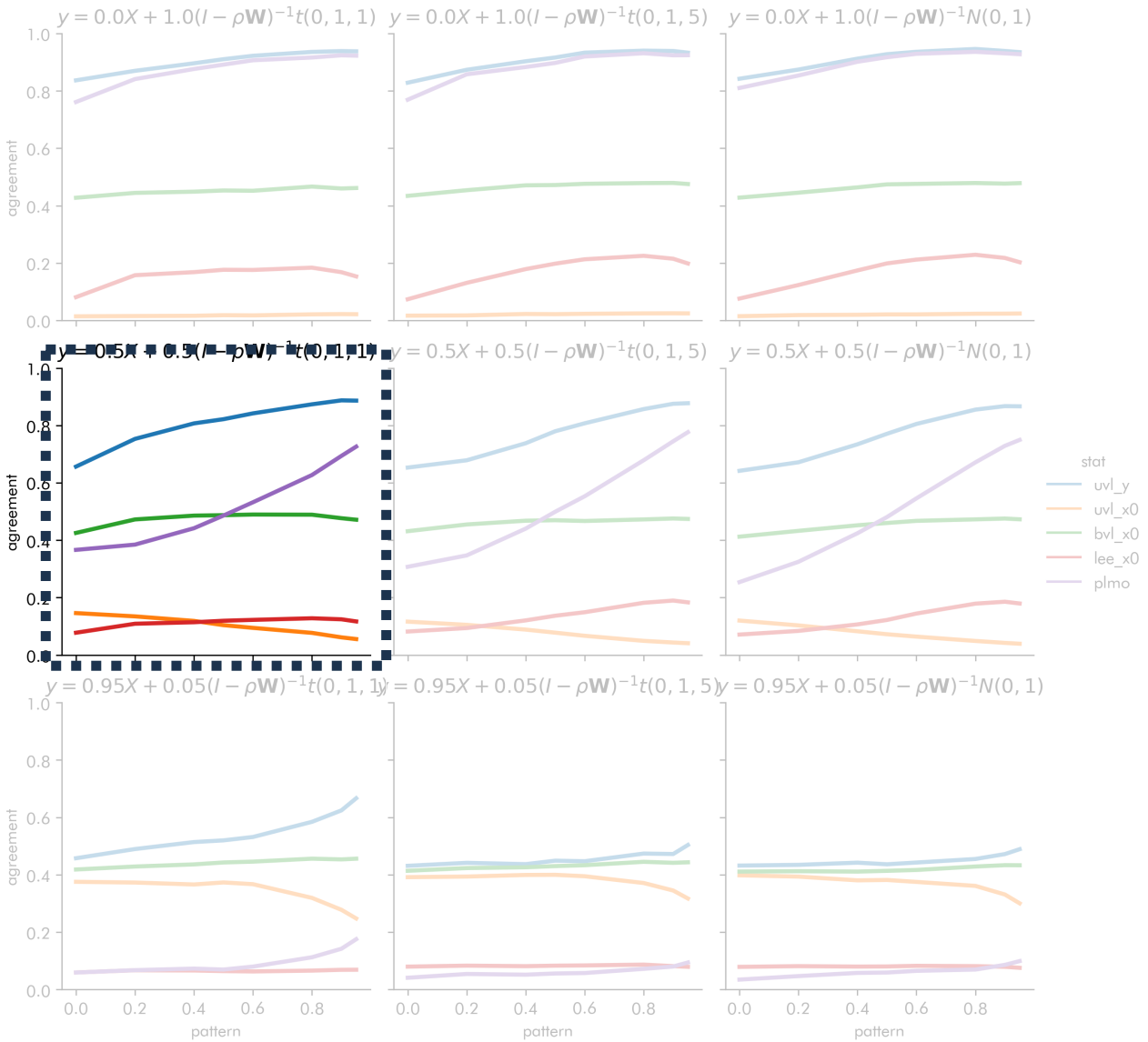

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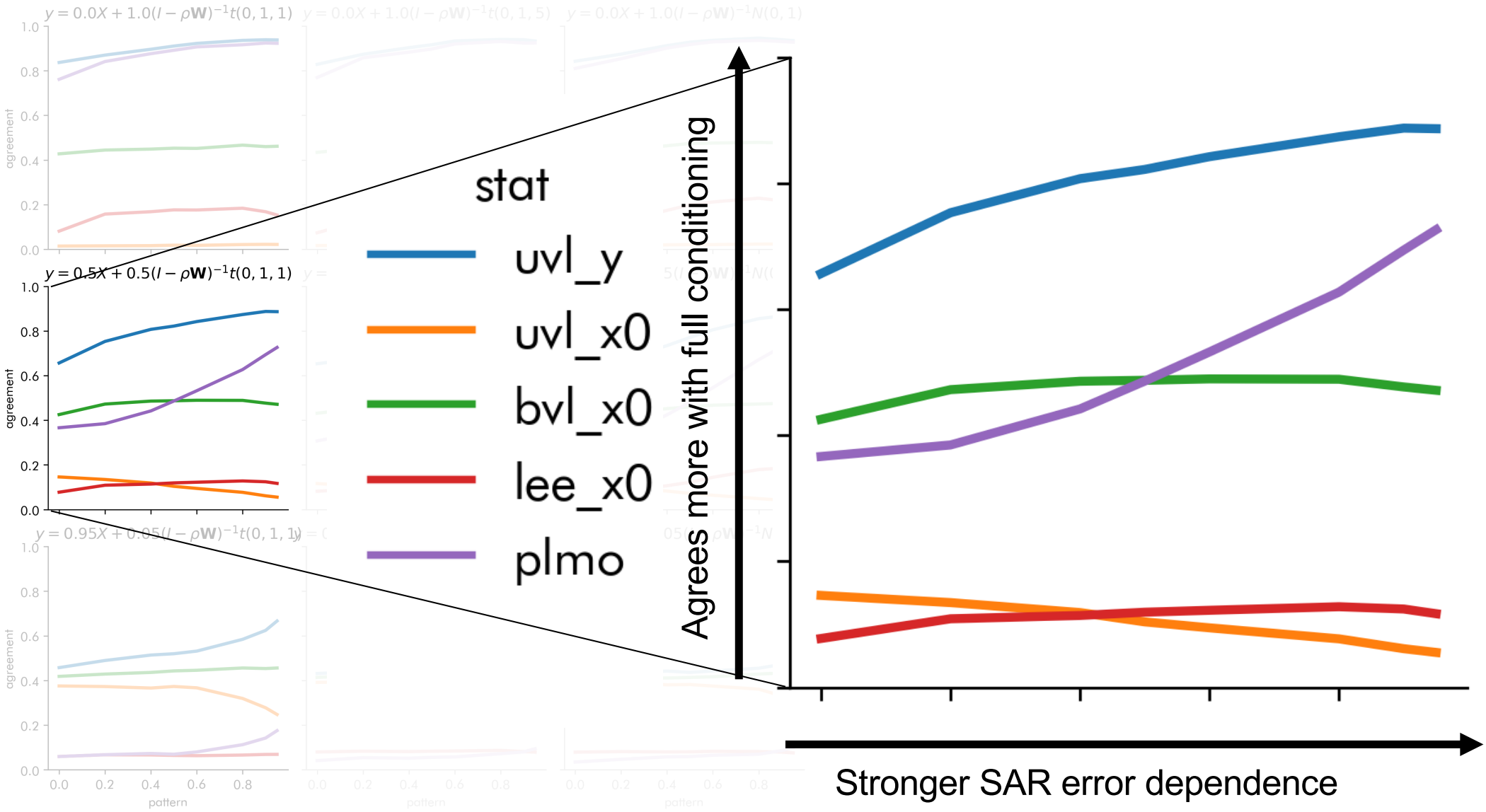

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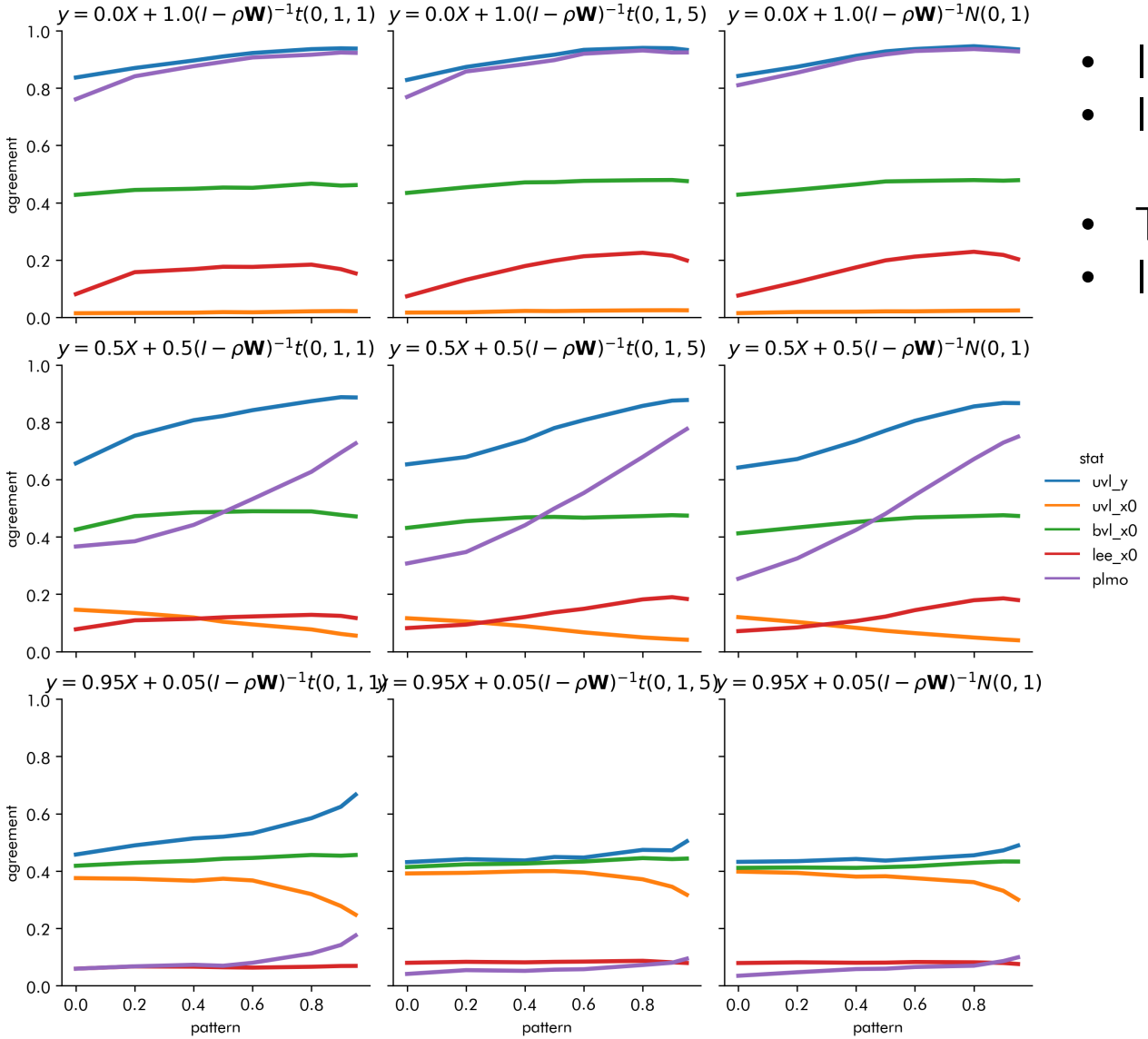

- Increasing SD right within facets
- Increasing "agreement" w/ aux. reg. moving up within facets
- Thinner tails moving right over facets
- Increasing confounding moving down over facets

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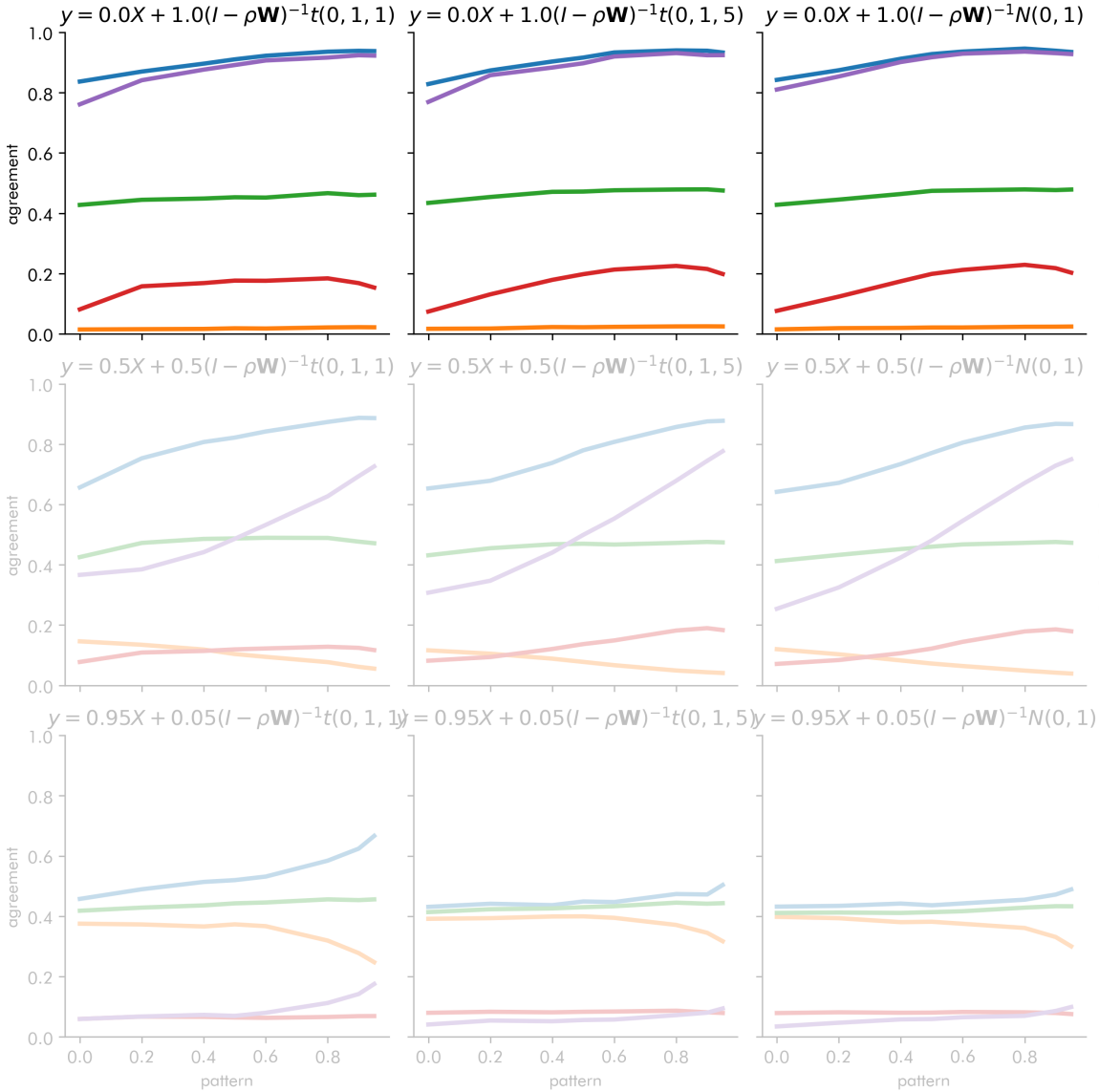

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WHEN x IS IRRELEVANT,

(P)LMo both correctly ignore x

Pairwise stats incorrectly sensitive to x

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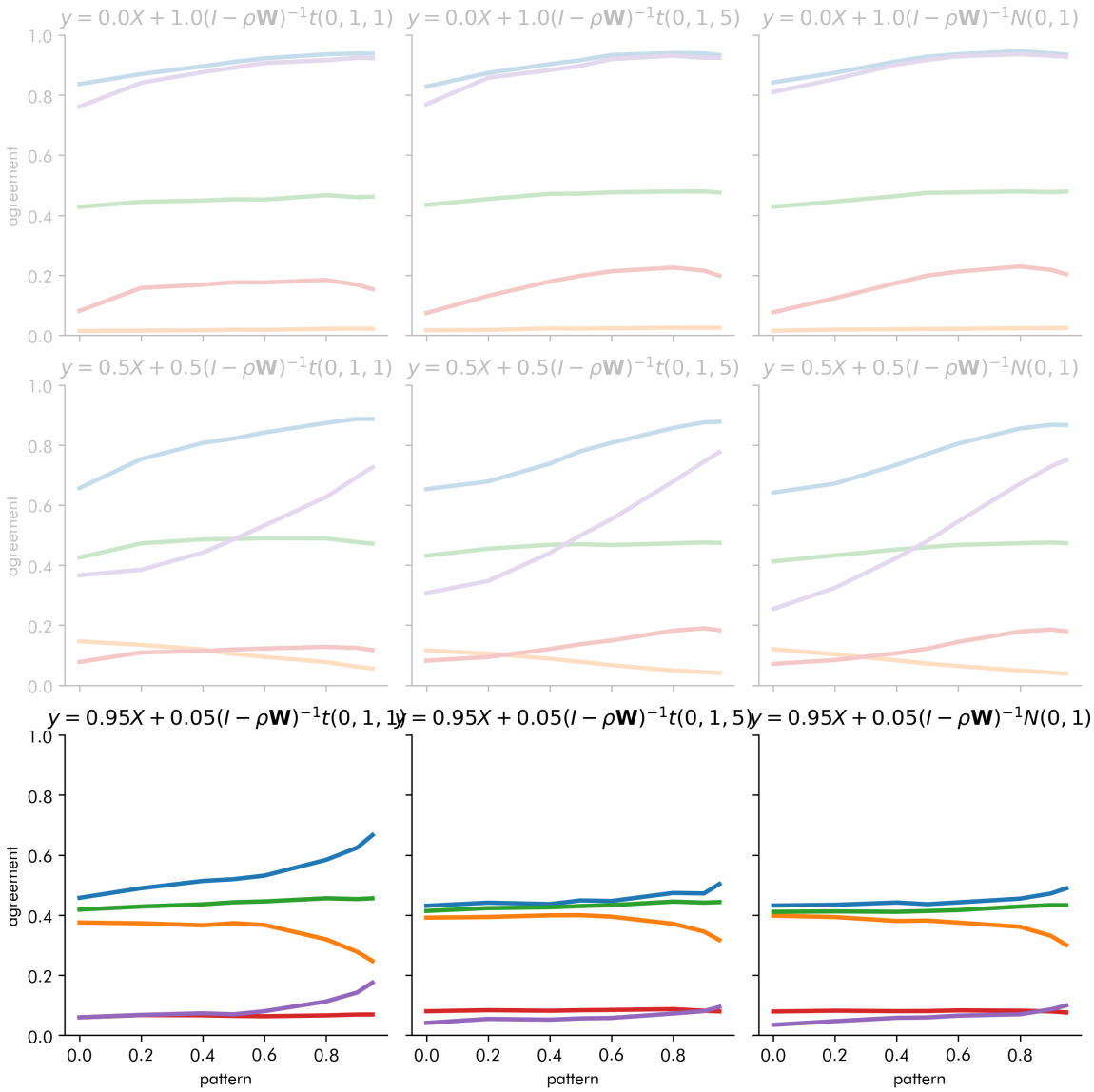

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Lee & PLMo disagree with full conditioning

Univariate approaches broadly agree

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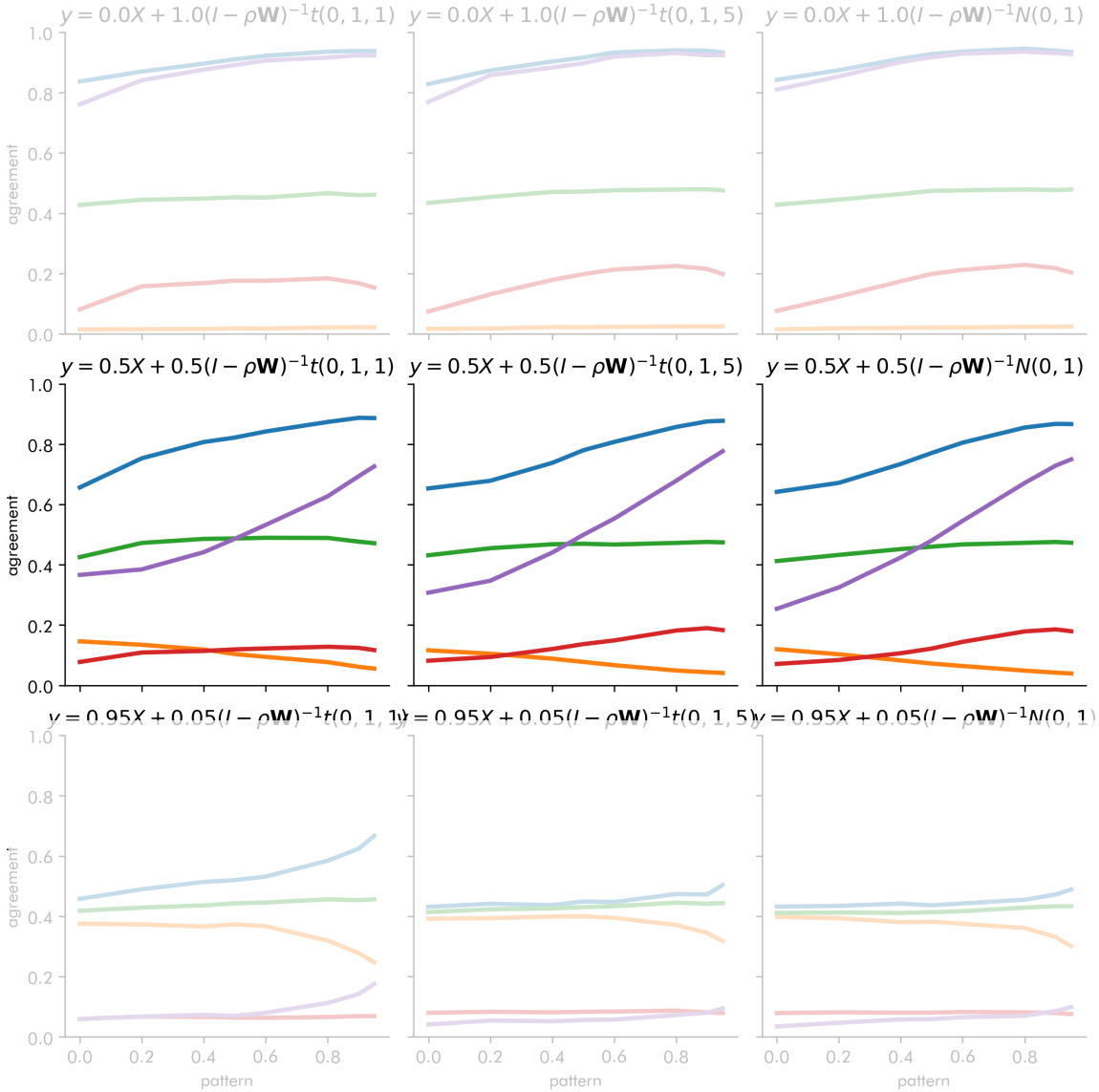

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WHEN BOTH MATTER

LMo_x and Lee both problematic

BVLMo fails to recognize SD+

(P)LMo become more similar as SD+

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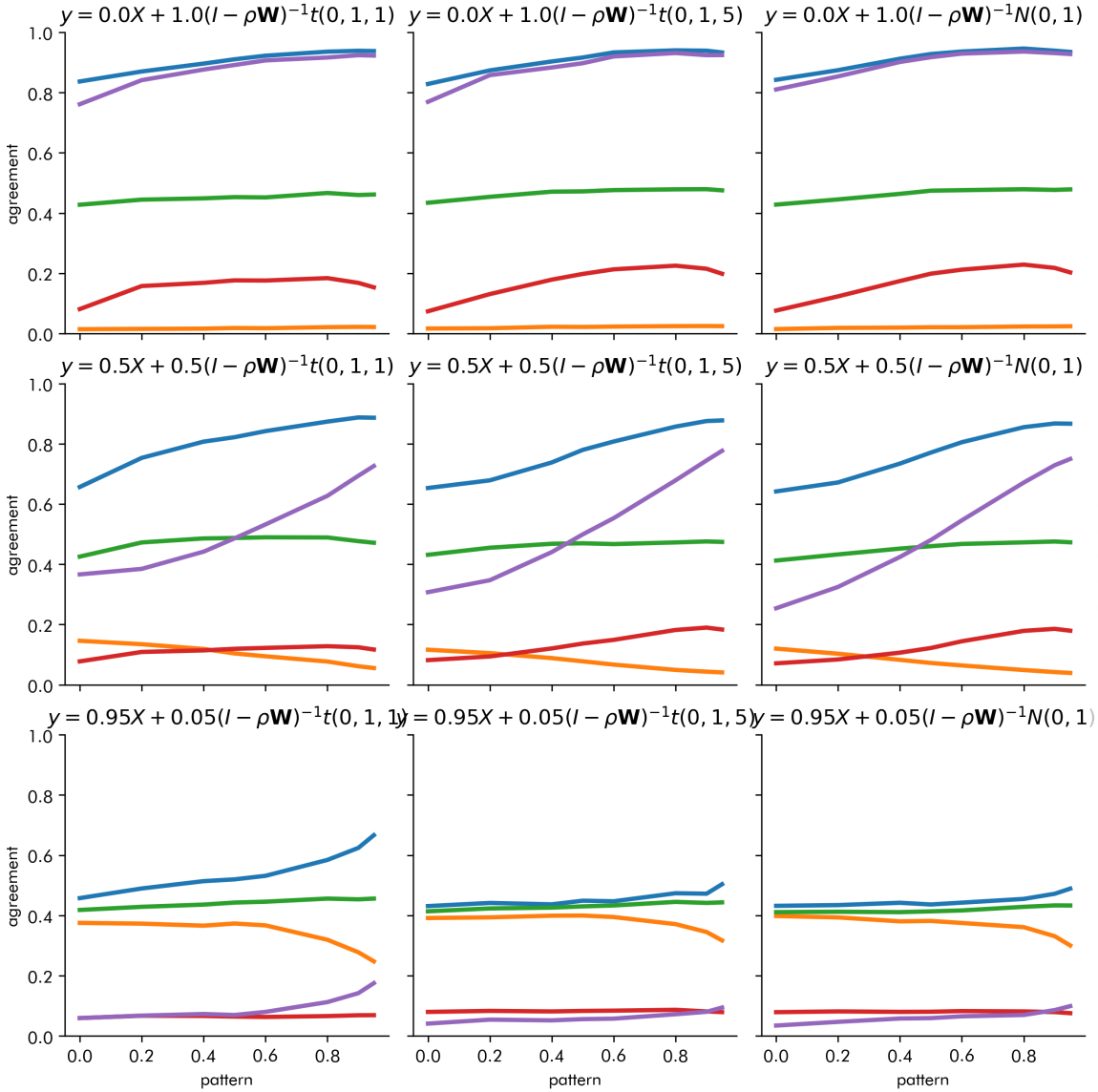

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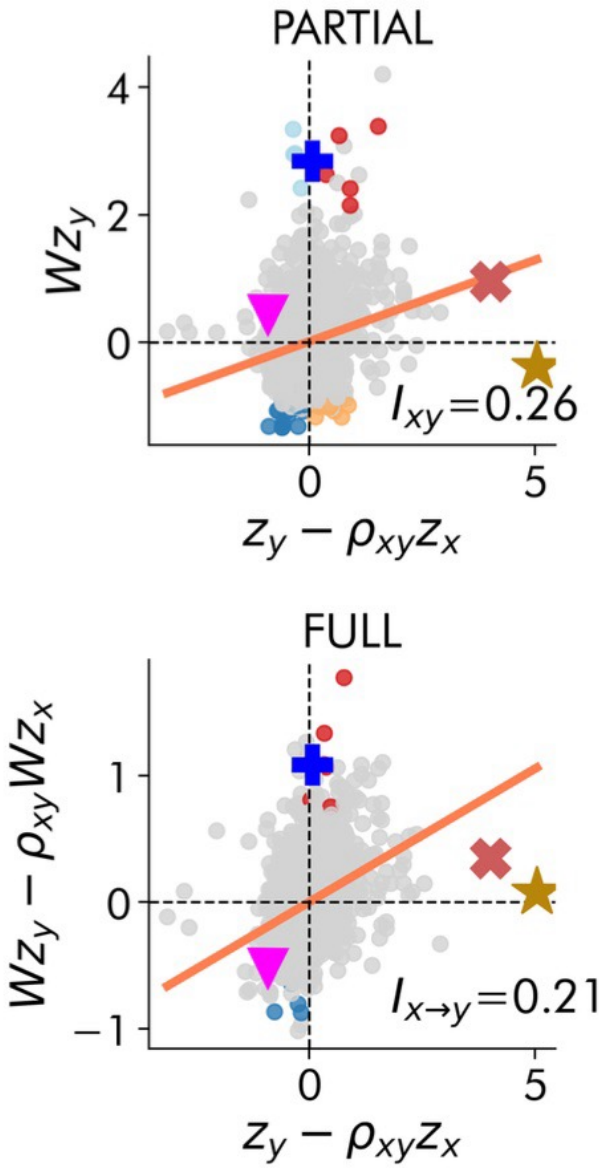
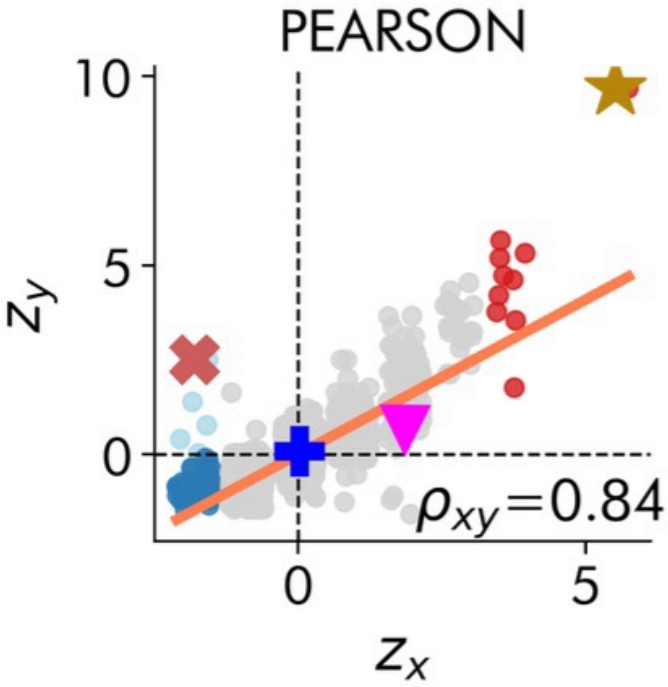
(P)LMo become more similar as SD+

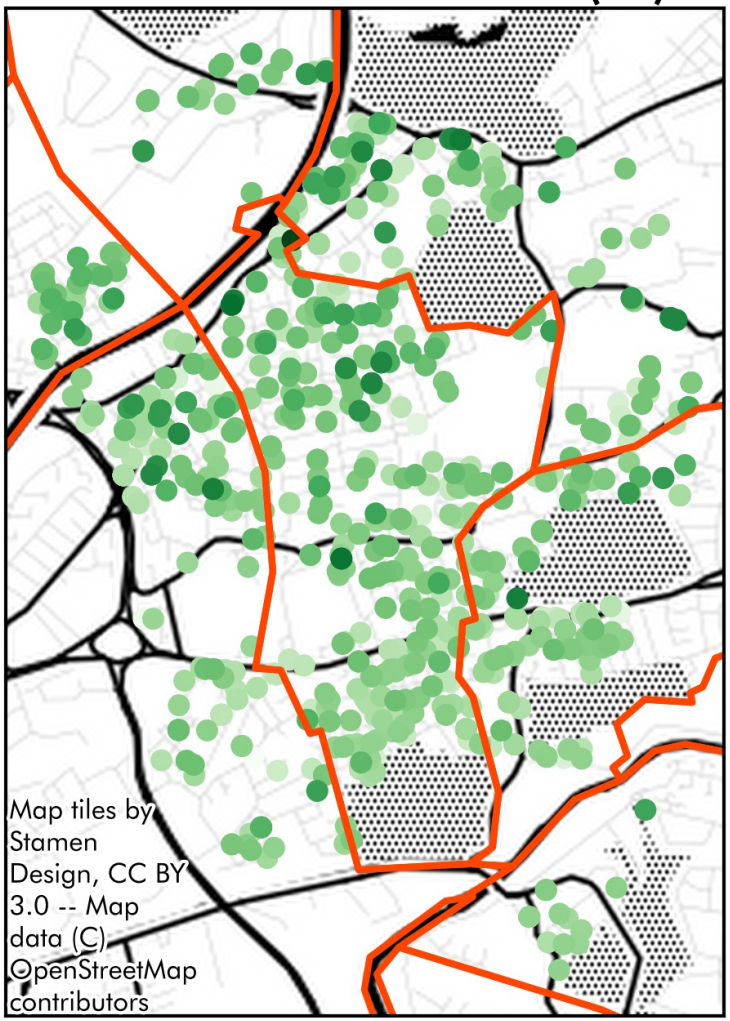
SURPRISE! SIMULATION RESULTS FIRST!



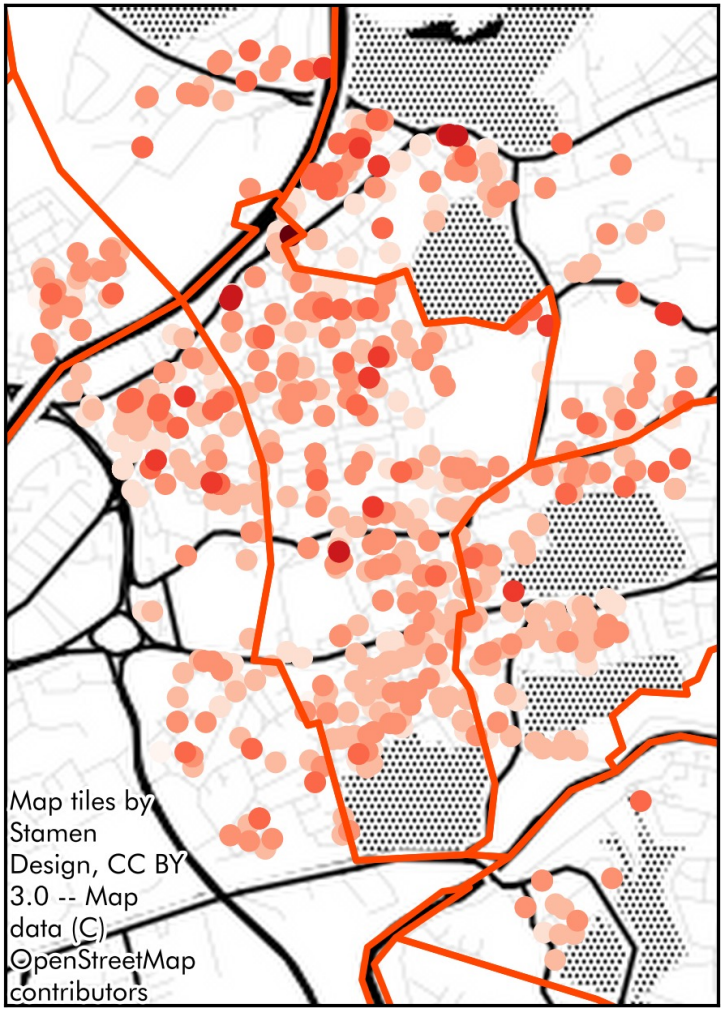
GOOD DEALS MAY NOT HAVE STRONG RELATIVE PREMIA



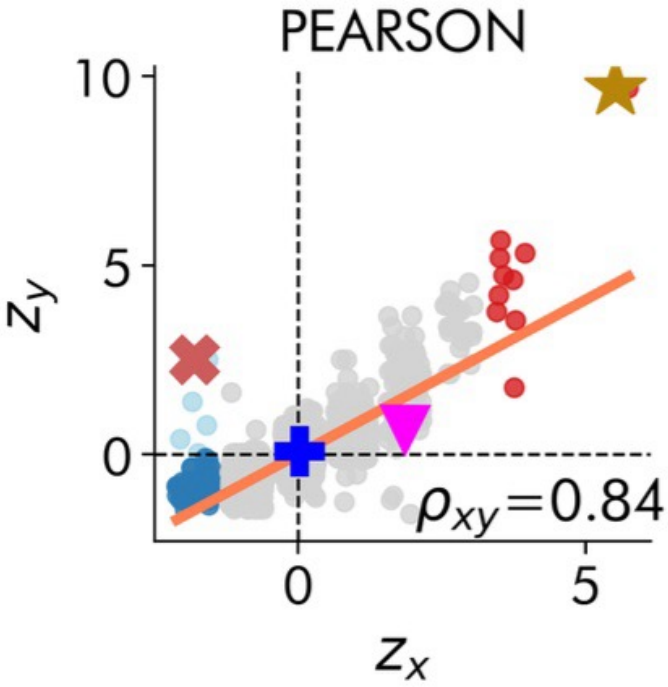
WEEKLY RENT (£)



BEDROOMS

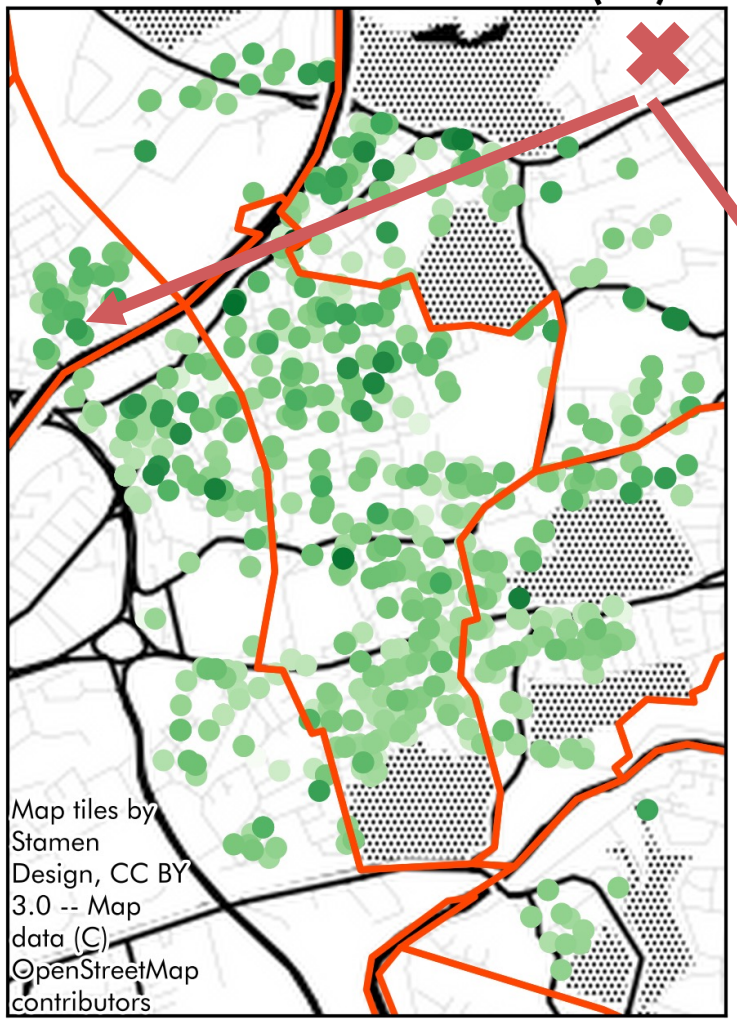


GOOD DEALS MAY NOT HAVE STRONG RELATIVE PREMIA

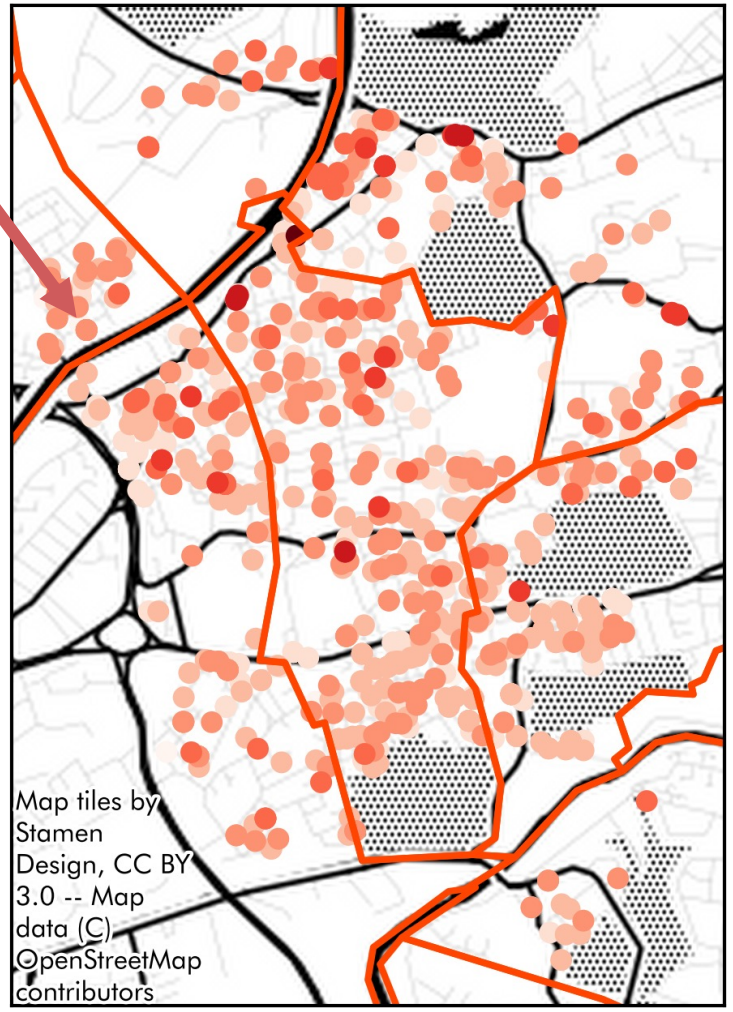


✖ is a very expensive studio

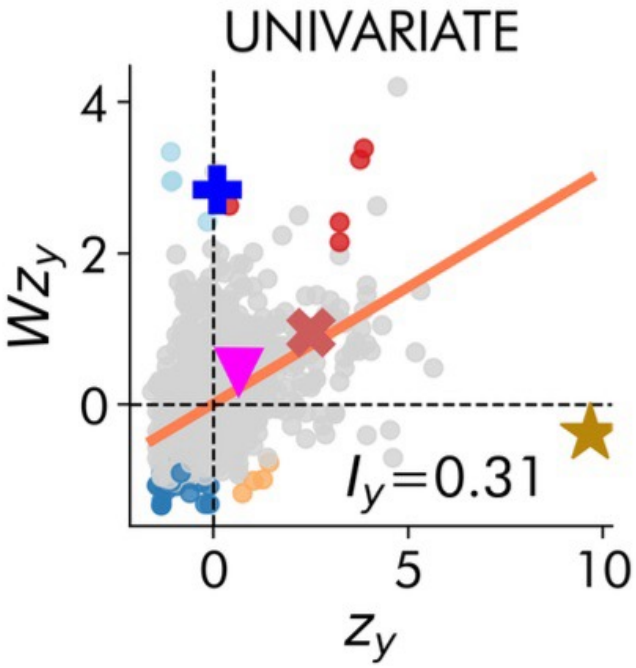
WEEKLY RENT (£)



BEDROOMS

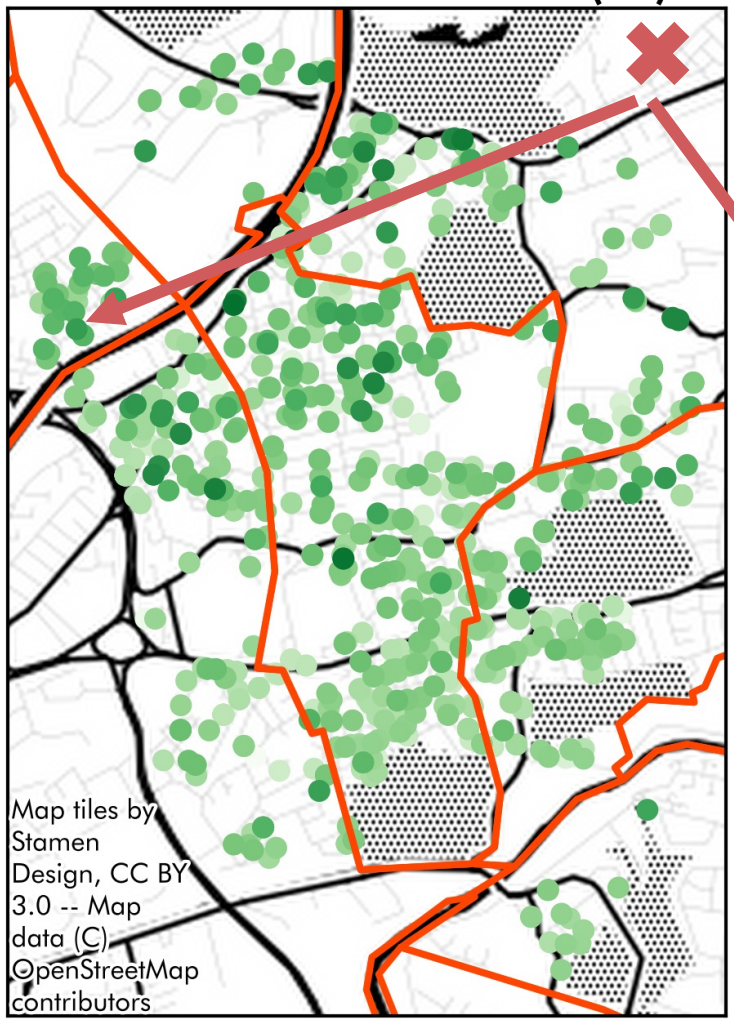


GOOD DEALS MAY NOT HAVE STRONG RELATIVE PREMIA

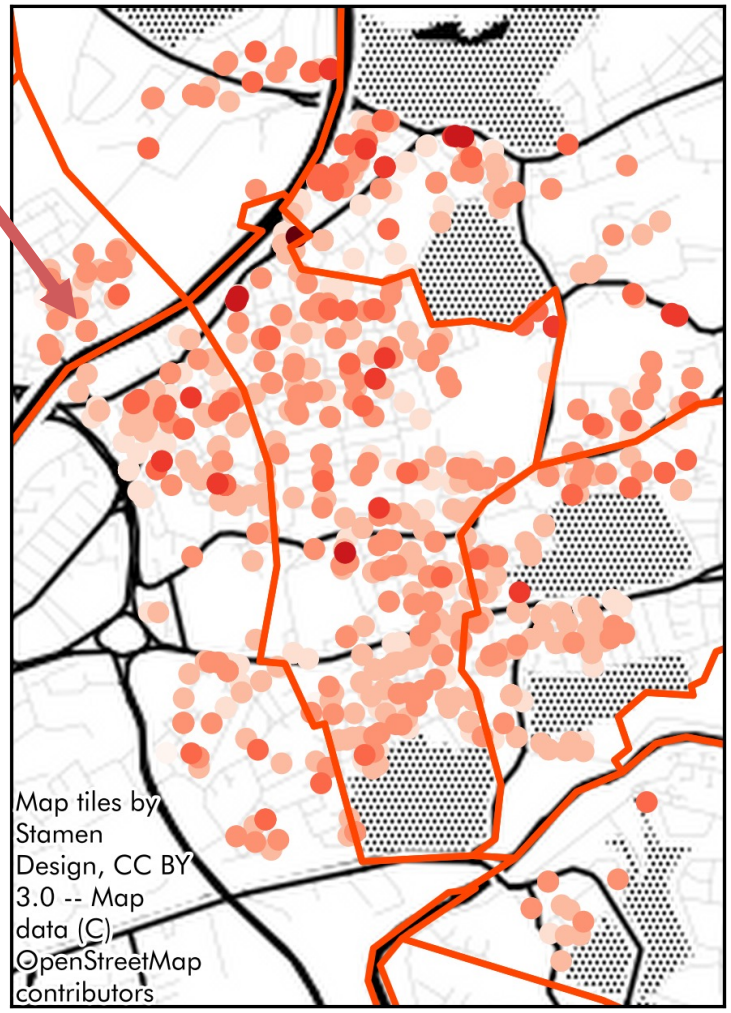


✖ is a very expensive studio, but it's not a rent outlier.

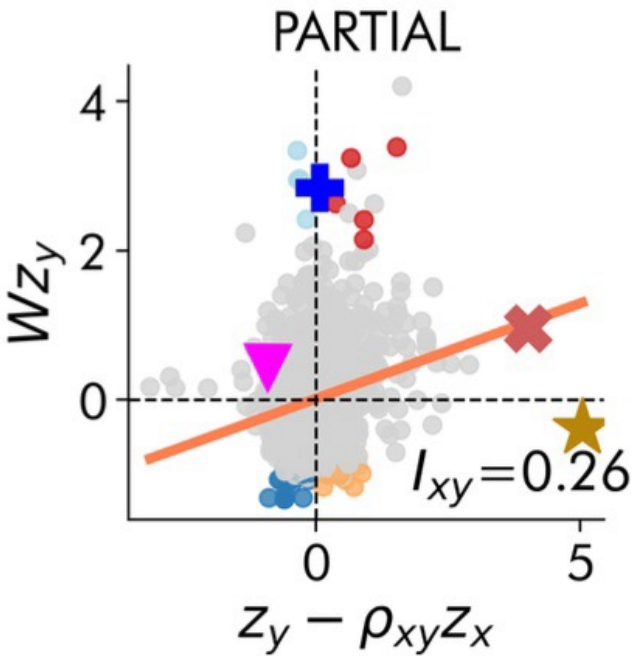
WEEKLY RENT (£)



BEDROOMS

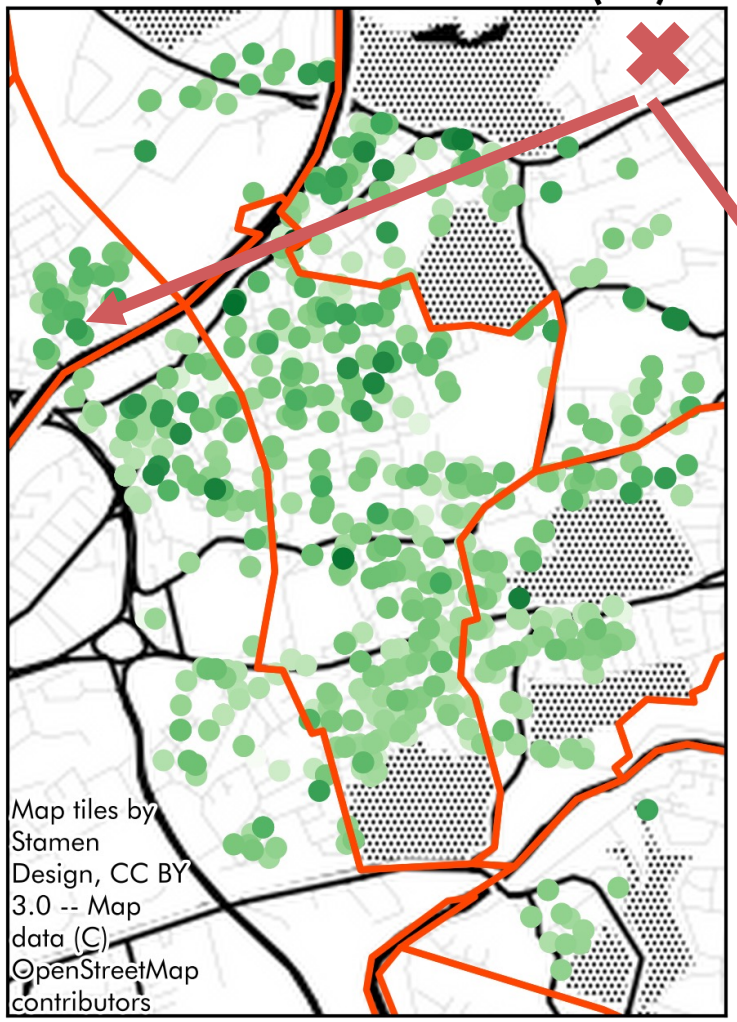


GOOD DEALS MAY NOT HAVE STRONG RELATIVE PREMIA

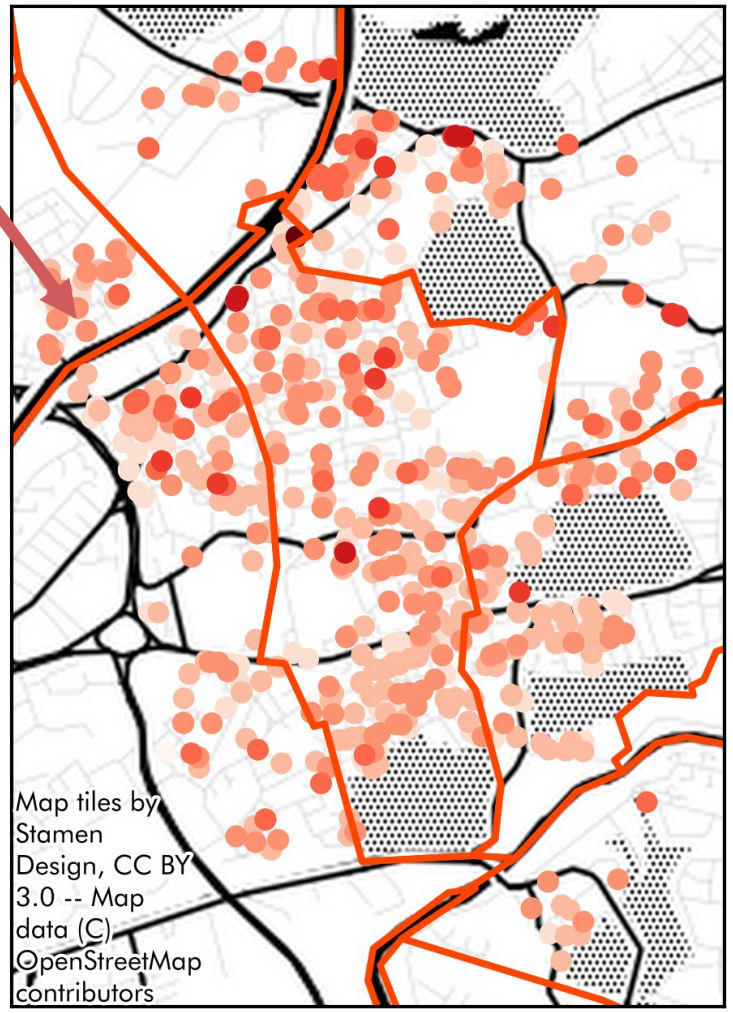


✖ is expensive for a studio, surrounded by expensive properties.

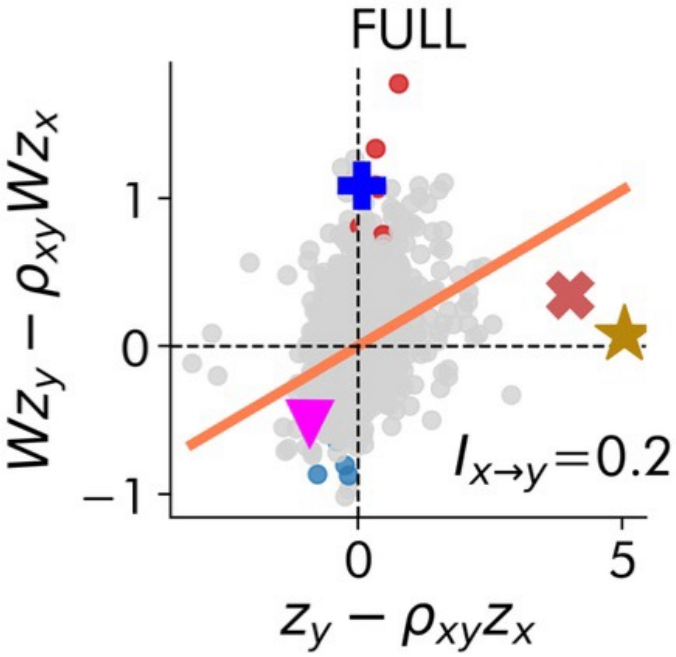
WEEKLY RENT (£)



BEDROOMS

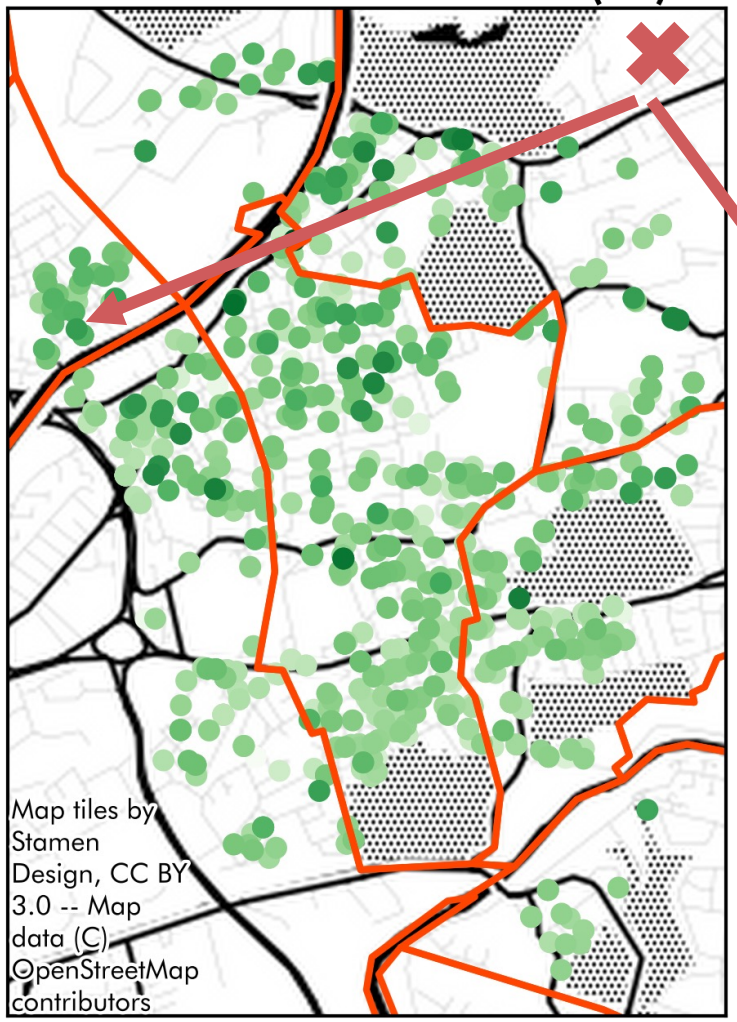


GOOD DEALS MAY NOT HAVE STRONG RELATIVE PREMIA

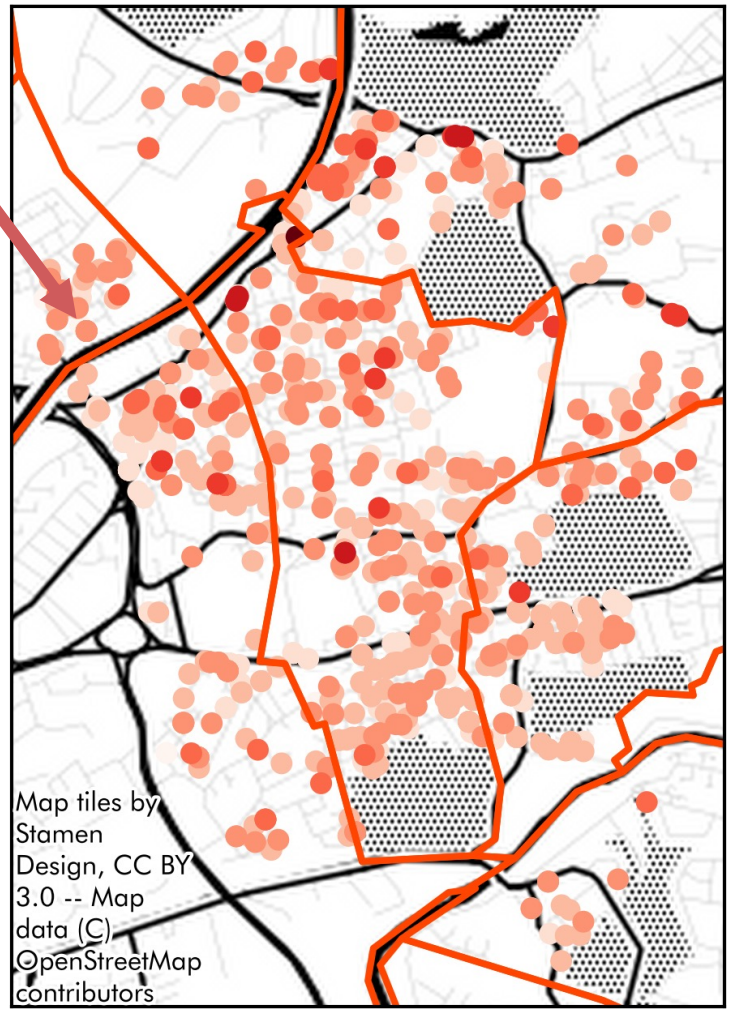


✖ is expensive for a studio, surrounded by other properties that are expensive for their size

WEEKLY RENT (£)



BEDROOMS



GOOD DEALS MAY NOT HAVE STRONG RELATIVE PREMIA

LOCAL CONFOUNDING

confounding is not stationary

PRIOR ART IN ESDA

The Moran-Form Regression

PARTIAL CONDITIONING

Two approaches to "control"

AFFORDABILITY OUTLIERS

Where are the good deals?

PARTIAL LOCAL MORAN

HANDLING LOCAL CONFOUNDING

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