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Estimating Housing Rent Depreciation for Inflation Adjustments

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Motivation

Depreciation is important in many ways

- Rent depreciation affects inflation statistics (this paper)
- Rent depreciation affects price depreciation, which in turn
  - determines a building life span (sustainability)
  - affects resource allocation in an economy
  - affects housing user costs
  - affects investment returns

Rent-Price-Relation

Effect of rent depreciation on inflation

- Aging affects rent changes
- For CPI, estimated rent depreciation rates are added to rent changes to estimate constant-quality inflation
- Age adjustments range from 0.11% for Houston to 0.36% for New York and Boston (Lane et al., 1988; Randolph, 1988; Campbell, 2006)
- Housing accounts for 33 percent of CPI and 41 percent for core CPI;

  A 1% bias in depreciation will cause $0.33 - 0.41\%$ underestimation in inflation.

Findings

1. The annual depreciation rate is large and non-linear in age.
   - New properties: 0.90% for SFR and 1.50% for condos
   - 46–50 years old: 0.46% for SFR and 1.49% for condos
2. Depreciation is larger for larger properties (one-s.d. larger structure $\rightarrow$ 0.13 and 0.43 percentage points larger depreciation for SFR and condos).
3. The estimated depreciation rate changes when controlling for census-tract fixed effects.
4. Functional obsolescence cauases large depreciation for condos. The sum of physical and functional depreciation for new properties is 1.2% for SFR and 1.8% for condos

Literature

Inflation measurement

- (Dougherty and Van Order, 1982; Hausman, 2003; Lebow and Rudd, 2003; Reinsdorf and Triplett, 2009; Hill et al., 2020; International Monetary Fund et al., 2020; Diewert, 2009; Diewert et al., 2009, 2020; Hill et al., 2020; Himmelberg et al., 2005; Blackley and Follain, 1996; Garner and Verbrugge, 2009; Verbrugge and Poole, 2010; Hill and Syed, 2016; Hill et al., 2020; International Monetary Fund et al., 2020; Diewert, 2009; Johnson, 2015; Bentley, 2018; Crone et al., 2010; Ambrose et al., 2015, 2018)

Rent depreciation

- (Bureau of Labor Statistics, 2018; Lane et al., 1988; Randolph, 1988; Campbell, 2006; Malpezzi et al., 1987; Gordon and van Goethem, 2007; Diewert et al., 2009; Verbrugge et al., 2017; Hill and Syed, 2016; Verbrugge et al., 2017; Walters, 2009; Dixon et al., 1999)

Price depreciation

- (Hulten and Wykoff, 1981; Xu et al., 2018; Goodman and Thibodeau, 1995, 1997, 1998; Clapp and Giaccotto, 1998; Coulson and McMillen, 2008; Yoshida and Sugiura, 2015; Bokhari and Geltner, 2018; Francke and van de Minne, 2017; Hayashi, 1991; Davis and Heathcote, 2005; Economic and Social Research Institute, 2011; Yoshida, 2020; Leigh, 1980; Knight and Sirmans, 1996; Harding et al., 2007; Davis and Heathcote, 2005)

Cohort Effects

- (Wilhelmsson, 2008; Browning et al., 2012; Coulson and McMillen, 2008; McKenzie, 2006; Francke and van de Minne, 2017; Rolheiser et al., 2020; Yang et al., 2004, 2008)

Data

Source: GLVAR MLS from 2009Q1 and 2019Q1

Listings: 283,818 leased and 45,976 withdrawn/expired (compared to 32K rental units in the CPI Housing Survey).

> **Criteria:** contract rent less than $10K per month, living area between 400 and 6K sqft, lot area between 0 and 50K sqft, bedrooms are between 0 and 5, bathrooms are between 0 and 6, no more than three fireplaces, and structure not older than 60 years, commission amount is less than $2,400.

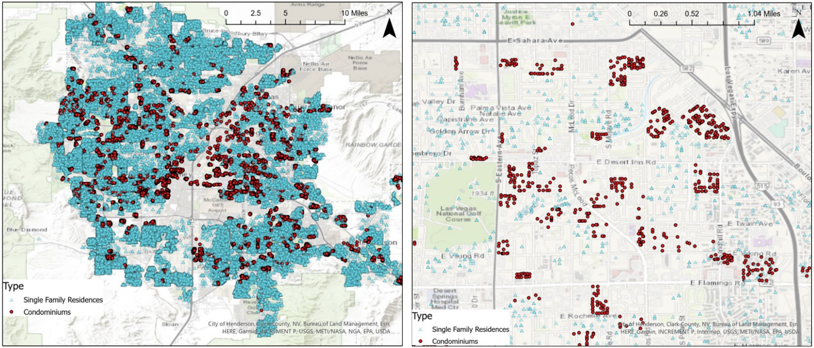
Variables:

- Contract Terms
- Property Characteristics
- Neighborhood Amenities

Merged with Clark County Tax Assessor Records

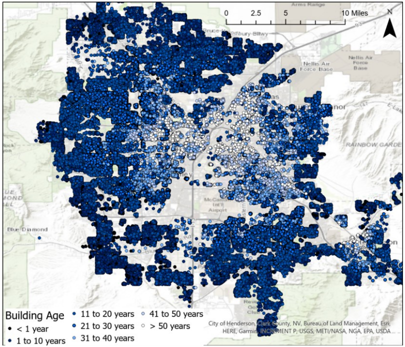
Validated that sample is representative of the housing market

Data – Location of SFR and condos

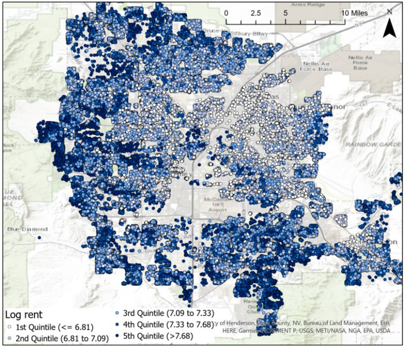


Light blue: Single family residences
Red: Condominiums

Data – Age and rents



Building age



Log rents

Estimation

We use cross-sectional variation in log rents by age:
$\ln Y_{it} = A_i C_i \delta + X_i \beta + \alpha_j + \tau_t + \epsilon_{it}$,

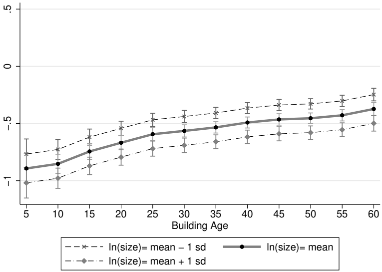
- Y_{it}: contract rent of property i at time t
- A_i: building age A_i
- C_i: interaction terms C_i
  - $C_i^1 = [1\ A_i\ Size_i]$, ($Size_i$: demeaned log square-footage)
  - $C_i^2 = [G_g\ Size_i]$, (G_g: indicators for 5-year age groups)
  - $C_i^{3,1} = \left[C_i^1\ CensusTract_j\right]$,
  - $C_i^{3,2} = \left[C_i^2\ CensusTract_j\right]$
- δ: vector of age coefficients
- X_i: observable characteristics
- α_j: location (census tract) fixed effects
- τ_t: time (listing year-quarter) fixed effects.

Average depreciation rate

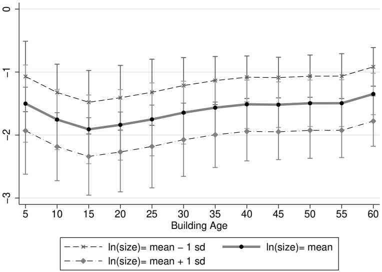
Dep. var. ln(Rent)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Sample:	SFR	SFR	COND	COND	SFR	SFR	COND	COND
Age/100	-0.78***		-2.14***		-0.52***		-2.22***	
	(0.04)		(0.44)		(0.09)		(0.36)	
$Age^2/1,000$	0.07***		0.14**		0.02		0.16**	
	(0.01)		(0.06)		(0.01)		(0.07)	
$(Age/100) \times \ln(Size)^{dm}$	-0.41***	-0.42***	-1.32***	-1.30***	-0.37***	-0.37***	-2.03***	-2.01***
	(0.04)	(0.04)	(0.21)	(0.21)	(0.07)	(0.07)	(0.28)	(0.28)
$(Age/100) \times$ TH			0.81***	0.81***			1.04***	1.06***
			(0.16)	(0.15)			(0.19)	(0.19)
Observations	188,216	188,216	89,318	89,318	188,219	188,219	89,323	89,323
Adjusted R^2	0.88	0.89	0.86	0.86	0.80	0.80	0.56	0.56
Age Groups		✓		✓		✓		✓
Structure controls	✓	✓	✓	✓	✓	✓	✓	✓
Neighborhood controls	✓	✓	✓	✓				
Service controls	✓	✓	✓	✓	✓	✓	✓	✓
Year-Quarter FE	✓	✓	✓	✓	✓	✓	✓	✓
Census Tract FE	✓	✓	✓	✓				

Depreciation estimates are large and significantly affected by neighborhood controls and structure size

Age coefficients by age group and size



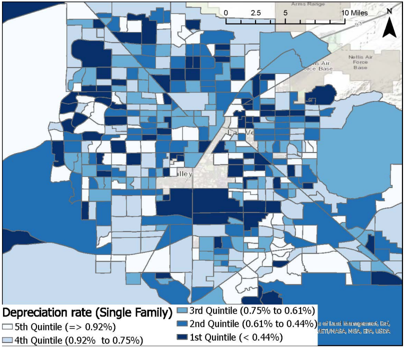
Single Family



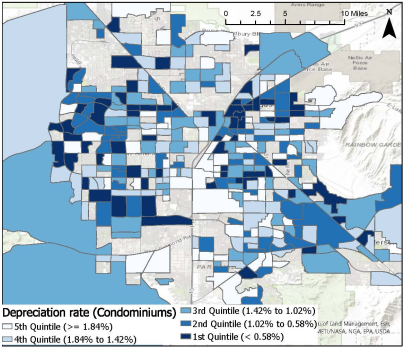
Condominiums

Depreciation rates are larger for newer and larger structures

Variation in depreciation rates by census tracts



Single Family

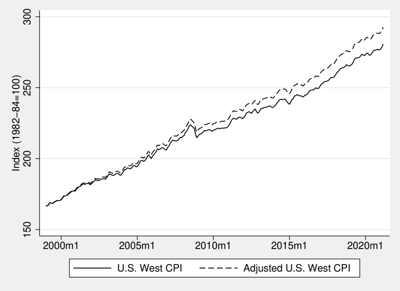


Condominiums

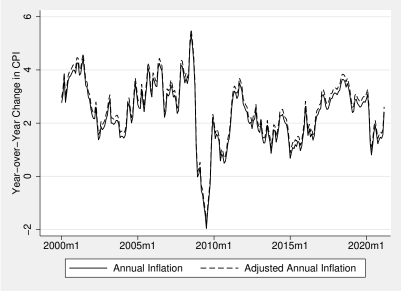
Variation is significant but cannot be easily explained by simple demographic characteristics

Effect on the West Region CPI

West Region depreciation rate = 0.23%
Las Vegas depreciation rate (11-15 years old) = 0.75%



Level



Year-over-year rate

Cumulative effects on inflation can be large.

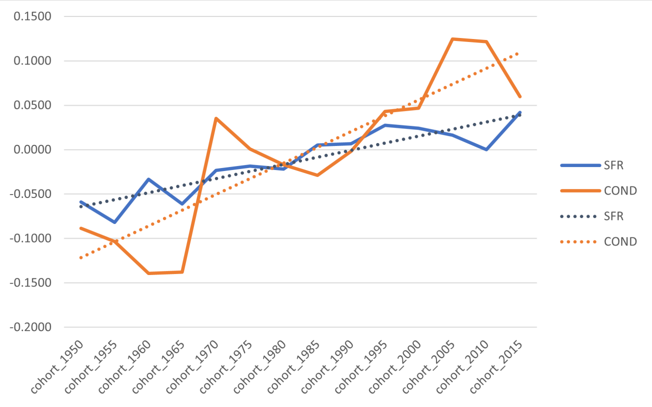
Cohort effects

- In CPI, cohort effects are assumed away (Randolph, 1988; Lane et al., 1988)
- But cohort effects exist (Coulson and McMillen, 2008) because technology, material, and styles change over time.
- Also, Francke and van de Minne (2017) argue that cohort effects include both functional obsolescence and vintage effects.
- But the following model is unidentified (collinearity) $\mathcal{Y} = [\textit{age period cohort}]\theta + \epsilon$,
    - $\mathcal{Y}$ is characteristics-controlled log rents,
    - [*age period cohort*] are age, period, cohort group dummies
    - $\theta = (\gamma_0, \gamma_5, \dots, \gamma_{55}, \tau_{2005}, \tau_{2010}, \kappa_{1945}, \kappa_{1950}, \dots, \kappa_{2010})'$

Intrinsic estimator to decompose age, period, and cohort

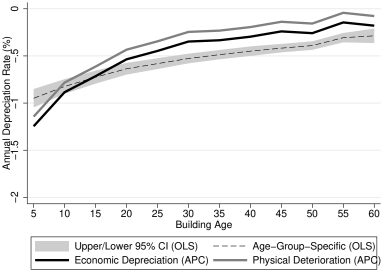
- We use the Intrinsic Estimator (IE) method to address the collinearity issue (Yang et al., 2004, 2008).
- $Z \equiv [\textit{age period cohort}]$ is one less than full column rank
- Parameter vector θ is the sum of two perpendicular linear subspaces: $\theta = T + sT_0$
  - $s \in \mathbb{R}$ and T_0 is the unit eigenvector corresponding to the unique zero eigenvalue of $Z'Z$, i.e., $(ZT_0 = 0)$
- Parameter vector T is IE, which is perpendicular to T_0.
- Computationally, we apply a principal components regression.
- IE is used in epidemiological research, economics (Diamond et al., 2020), and finance (Fagereng et al., 2017).

Cohort effects

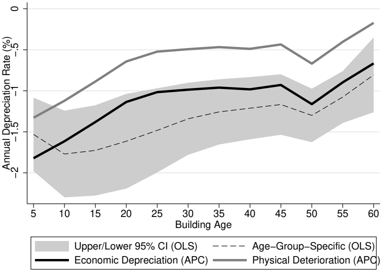


Cohort effects include both a trend (average functional obsolescence) and cycles (vintage effects).

Decomposition of depreciation rates



Single Family



Condominiums

Similar physical deterioration for SFR and condos but larger functional obsolescence for condos

Extensions

1. To identify factors determining physical and functional depreciation (in progress)
   - US rents for commercial real estate
   - US prices for housing and commercial real estate
   - Japanese rents for housing and commercial real estate

2. To estimate the proportion of land and depreciated structure in a housing service production function (in progress)

Conclusion

- We reexamine housing rent depreciation for a growing Western city to assess potential biases in inflation measurement.
- We estimate functional and physical depreciation by decomposing age, period, and cohort effects.
- We find that depreciation is
  - larger than the previous estimates, which can cause underestimation in inflation
  - lager for newer and larger structures
  - affected by location
  - significantly caused by functional obsolescence especially for condos

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Relationship between rent and price depreciation

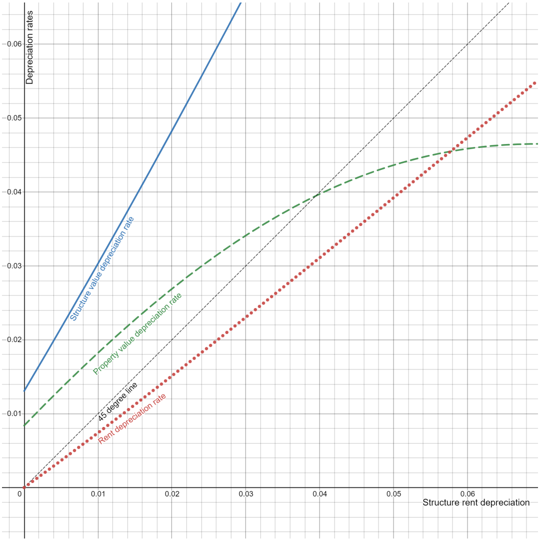
- Setting: Deterministic rents in a non-stochastic stationary urban economy without growth
- Housing rents are the sum of land rents C_L and structure rents $C_S(t) = C_{S1}(1-d)^{t-1}$ (DiPasquale and Wheaton, 1995)
- Rent depreciation rate is $d_C = -d \ln C(t)/dt$
- Land value is $L(t) = C_L/r$, and structure value is

$$S(t) = \frac{C_{S1}(1-d)^t}{r+d}\left[1 - \left(\frac{1-d}{1+r}\right)^{T-t}\right]$$

- Structure value depreciation rate is $d_S = -d \ln S(t)/dt$
- Property value depreciation rate is $d_V = -d \ln V(t)/dt$

Motivation

Relationship between rent and price depreciation



Motivation