Associations between Sea Level Rise Risks and Real Estate Prices: Evidence from a Singaporean Government Announcement

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Introduction

- Sea level rise (SLR) risks
  - A global threat attracting increasing attention and studies.
  - The global mean sea level could rise between 0.43 m and 0.84 m (up to 1.1 m) by the end of this century, relative to 1986-2005. (IPCC)
  - There is a 680 million population living in the low-lying coastal areas, which will exceed 1 billion by 2050.

Introduction

- Residential real estate
  - Essential asset for most households (approximately 42% of households' total assets in Singapore).
  - Large transaction volume and sensitive to information.
  - Long-lasting properties are vulnerable to the long-term risks of climate change and sea level rise (SLR).

Introduction

- Climate change/SLR and property market
  - Asaf Bernstein et al. (2019): sea level rise (*NOAA projection*) is associated to an approximately 7% discount in property prices, driven by buyers' sophistication and beliefs.
  - Markus Baldauf et al. (2020): homes projected to be submerged (*NOAA projection*) in a neighborhood with firmer belief in climate change are sold at an approximately 7% discount.
  - Gibson et al. (2017): climate-related shocks (Flood Insurance Reform Act, Hurricane Sandy, and new FEMA floodplain maps) led to depreciation in property sale prices.

Introduction

- Climate change/SLR and property market
  - Giglio et al. (2021): a doubling "climate attention index" is associated with a 2.4% drop in property prices in the flood zone (*NOAA projection*).
  - Murfin and Spiegel (2020): no significant effect of relative sea level rise (*FEMA floodplain maps, USGS, and NOAA*) exposure on property prices.

Introduction

- Very long-run discount rates
  - Evaluations of long-term projects, e.g., climate change and GHG control, heavily rely on choosing of discount rates. (Cline, 1992; Nordhaus, 1994; Weitzman, 2007)
  - Estimations of very long-run discount rates based on tenure structure of properties in UK and Singapore. (Giglio et al., 2015; Bracke et al., 2017; Fesselmeyer et al., 2020)
  - Lower long-run discount rates after incorporating SLR risks in this study.

Background

- Singapore
  - A city-state country in Southeast Asia.
  - Most of the land in Singapore has an elevation of no more than 15 meters, and approximately 30% of the total land is within 5 meters. (National Climate Change Secretariat, NCCS)
  - Singapore will experience unprecedented climate shifts by 2050.
  - Two separated and standardized housing markets.

Background

- A novel information shock
  - The 2019 Singapore National Day Rally (Aug 18, 2019).
  - Singapore Prime Minister Lee Hsien Loong announced that climate change would threaten Singapore.
  - A Singapore topography map where areas with higher SLR risks (i.e., sea level rise areas) were marked.

"Not only will property values be affected, but safety and liveability also. (Lee Hsien Loong, 2019)"

Background

- Government commitments
  - The PM discussed the measures to tackle climate change and sea level rise.
  - In the City area, the government tends to build another pump house at the Marina Barrage.
  - Construct polders or other alternative measures like reclaiming more islands offshore in the East Coast area.
  - Invest 100 billion S$ (74 billion USD) over 100 years.

Background

Figure 1: The 2019 Singapore National Day Rally
(Source: Prime Minister's Office Singapore)

Background

- Singapore housing system

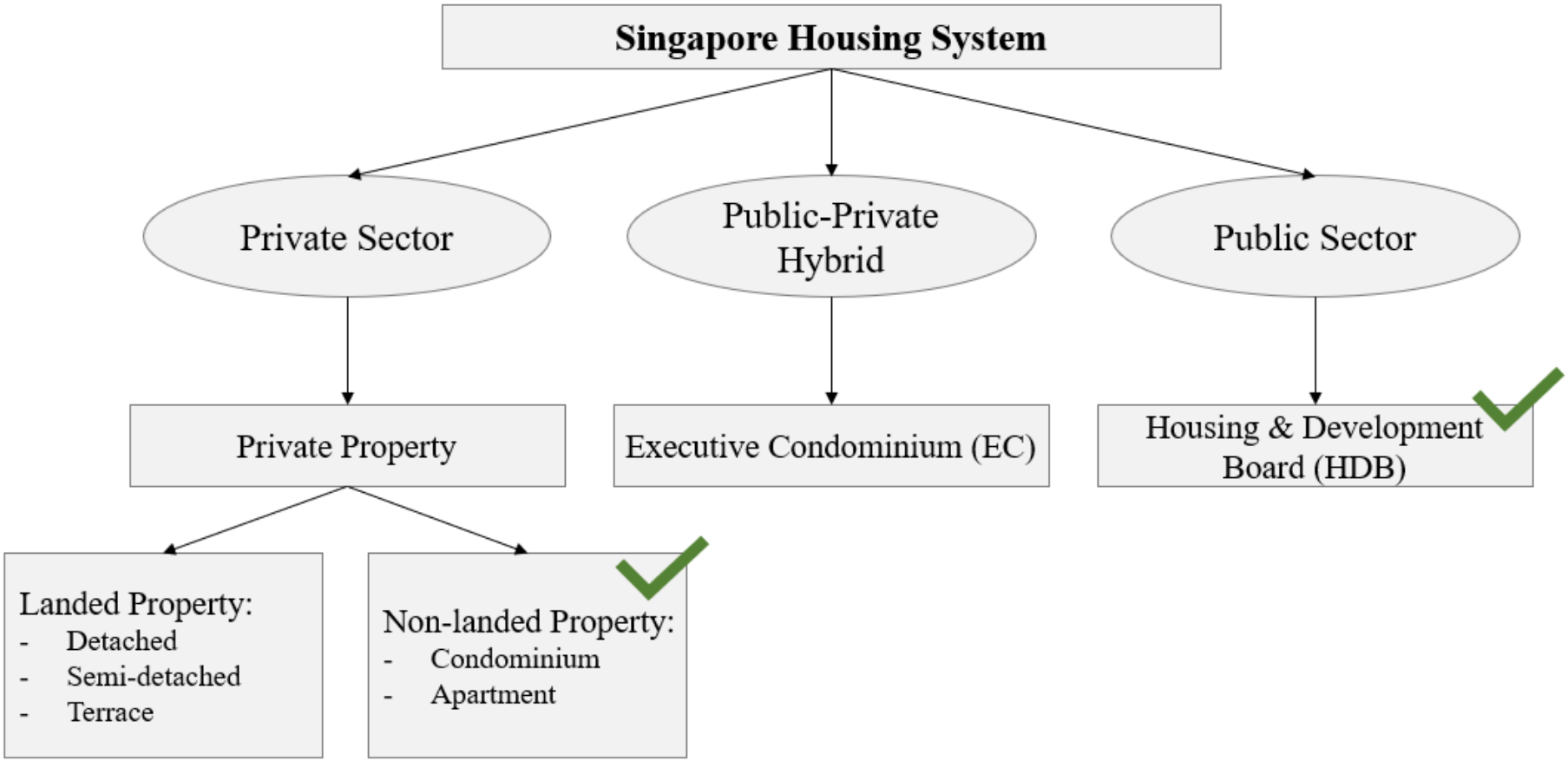

Figure 2: Singapore housing system

Data and Empirical Strategy

- Maps
  - The topography map shown by the Prime Minister on National Day Rally.
  - Digitizing:
    - ★ Georeferencing (SVY21/Singapore TM);
    - ★ Identify SLR by pixel color;
    - ★ Convert to vector map;
    - ★ Topology check.
    - ★ Fill holes in SLR area.
  - Amenities: MRT (urban transit) stations, bus stops, top 30 primary schools, CBD.

Data and Empirical Strategy

- Housing transactions
  - Private property:
    - ★ Source: Urban Redevelopment Authority (URA)
    - ★ 2018 - 2021
    - ★ New sale, resale, sub-sale
    - ★ Tenure: 99 years, 999 years, freehold (perpetual)
  - HDB:
    - ★ Source: HDB
    - ★ 2018 - 2021
    - ★ Resale
    - ★ Tenure: 99 years

⏩ Summary statistics

Data and Empirical Strategy

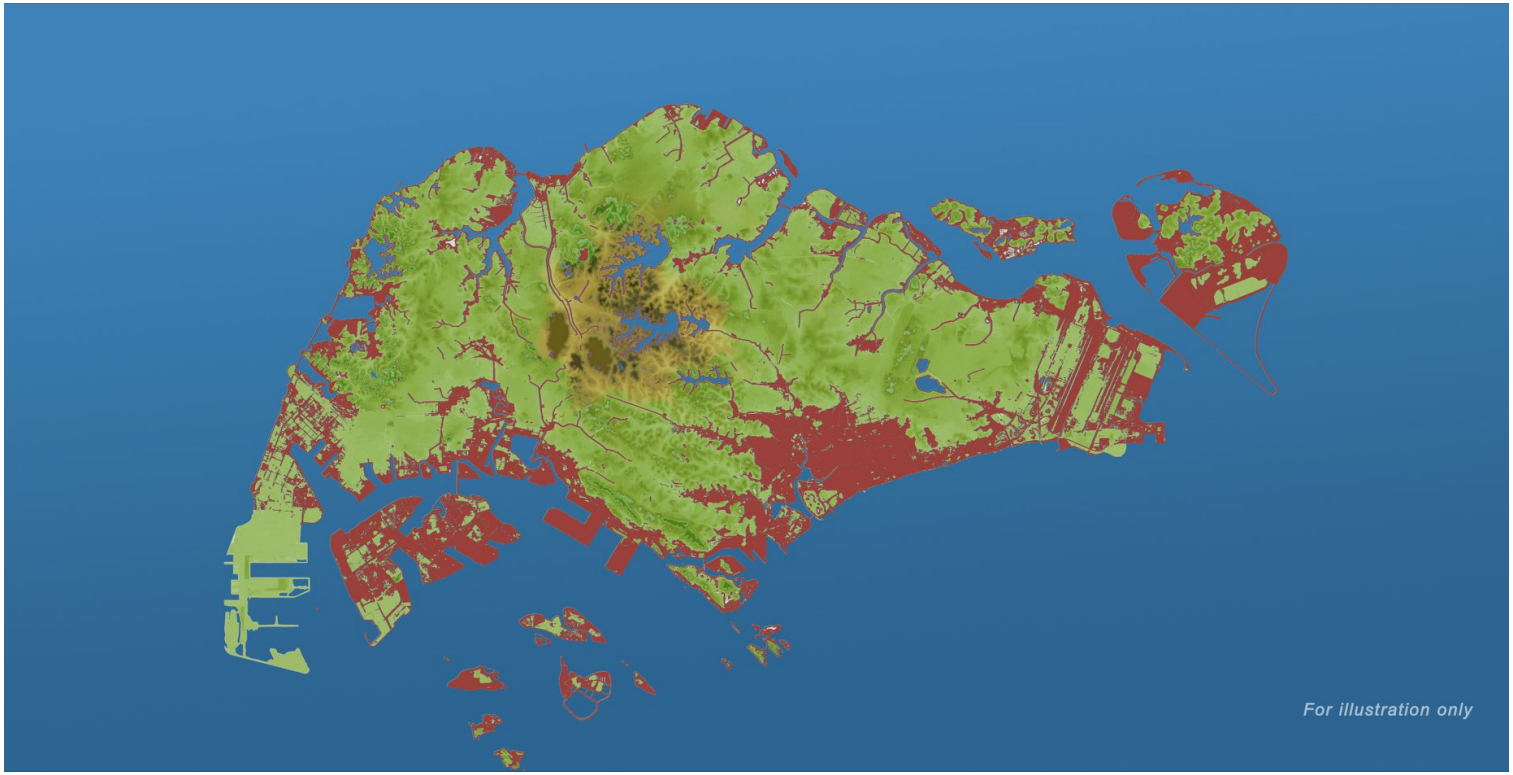

Figure 3: Original map displayed by Singapore Prime Minister

Data and Empirical Strategy

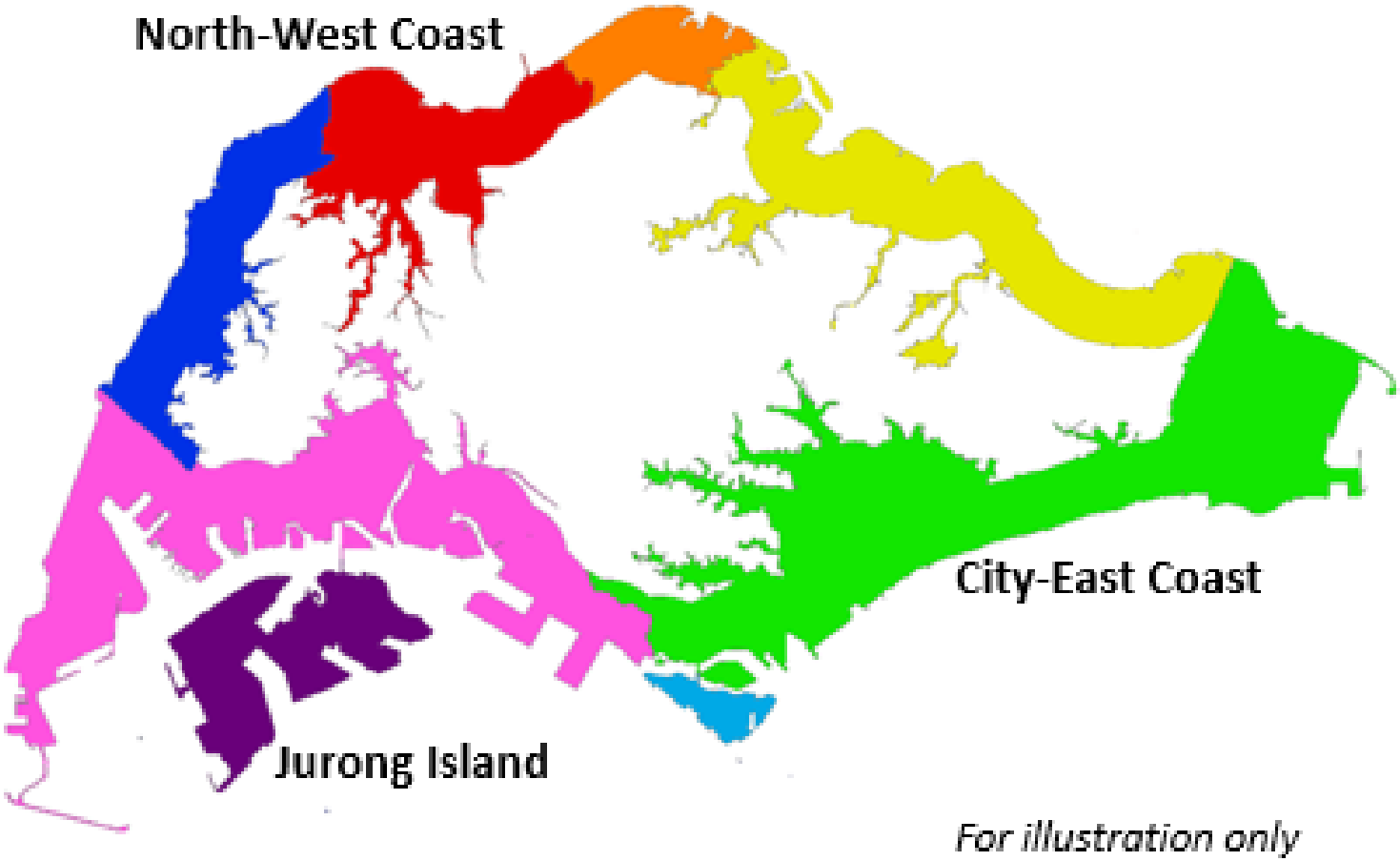

Figure 4: Coastal segments in Singapore

Data and Empirical Strategy

- Models

$$\ln(\text{unitprice})_{ijt} = \alpha + \beta \text{treat}_j * after_t + \text{X'}\Gamma + \lambda_{it} + \mu_j + \theta_{jt} + \epsilon_{ijt} \quad (1)$$

$$\ln(\text{unitprice})_{ijt} = \alpha + \sum_{k=2}^{16} \delta_k \, treat_j * yq_k + \text{X'}\Gamma + \lambda_{it} + \mu_j + \theta_{jt} + \epsilon_{ijt} \quad (2)$$

  - Dependent variable: unit price in log-form of transaction i at location j at date t.
  - X: property attributes and location attributes.
  - Fixed effects: postal code FE, year-month-flat type FE, project-aftercool FE (only for the private sample).
  - Robust standard errors clustered at postal code level.

Data and Empirical Strategy

- Models
  - SLR risks:
    - ★ $treat_j$: denotes 1 if in SLR areas, otherwise, 0; control group within 2 km.
    - ★ $after_t$ denotes 1 if after the announcement, otherwise, 0.
  - Mitigated SLR risks:
    - ★ $treat_j$: denotes 1 if in SLR areas & mitigation areas (City-East Coast), otherwise, 0; control group within 2 km.
    - ★ $after_t$ denotes 1 if after the announcement, otherwise, 0.

Data and Empirical Strategy

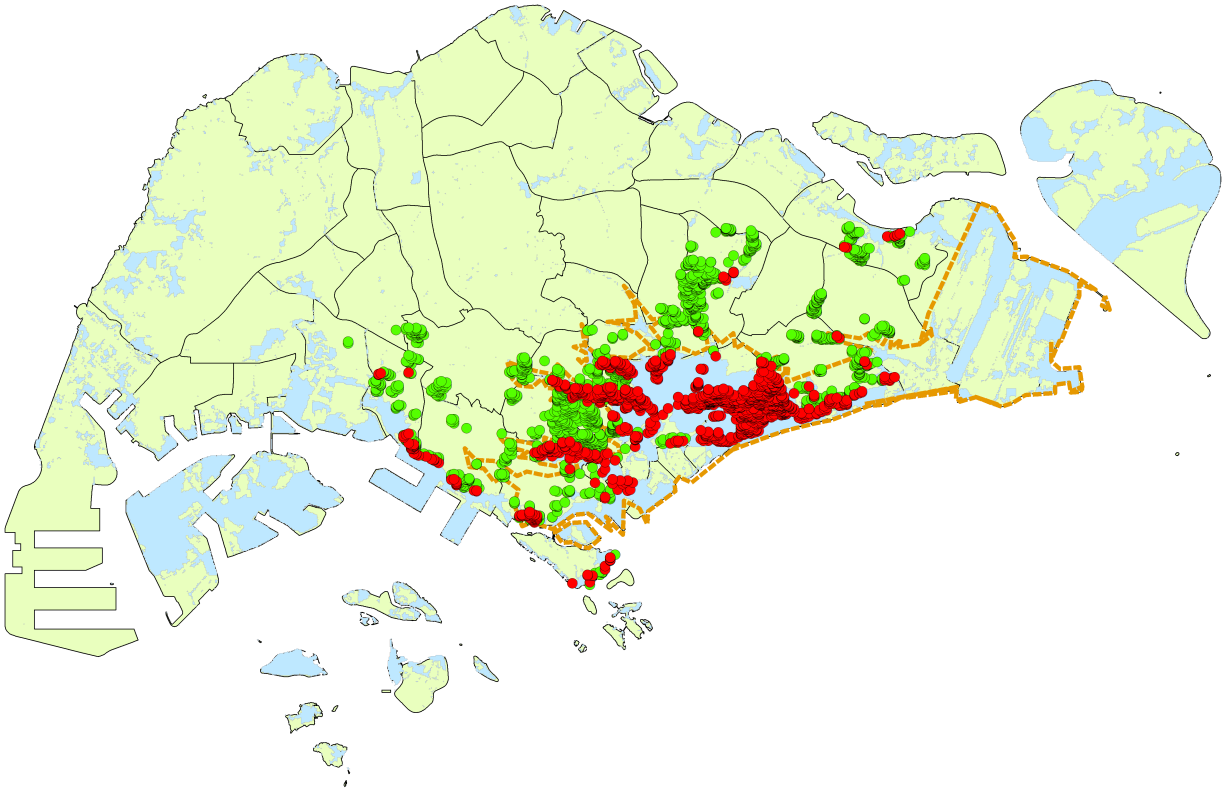

Figure 5A: Digitized map and private property transactions

Data and Empirical Strategy

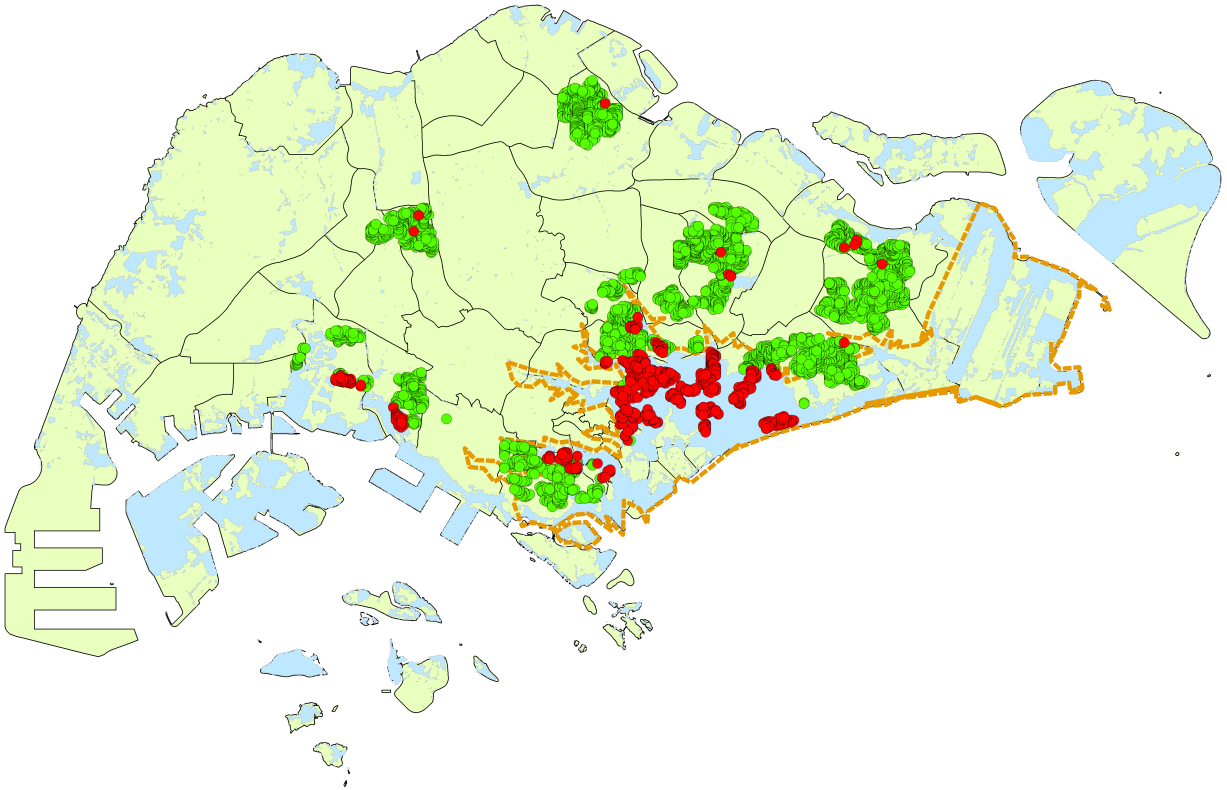

Figure 5B: Digitized map and HDB transactions

Results

- Baseline results

Table 1: Baseline results

	(1)	(2)	(3)	(4)
	Dependent variable: ln (unit price)			
	Private		HDB	
	SLR	Mitigated SLR	SLR	Mitigated SLR
$treat_j \times after_t$	-0.011***	-0.008*	-0.029***	-0.011***
	-0.004	-0.004	-0.003	-0.003
Property attributes	√	√	√	√
Year-month-flat type FE	√	√	√	√
Project-aftercool FE	√	√		
Postal code FE	√	√	√	√
Observations	41,515	31,127	42,283	20,418
R-squared	0.964	0.963	0.935	0.936

Results

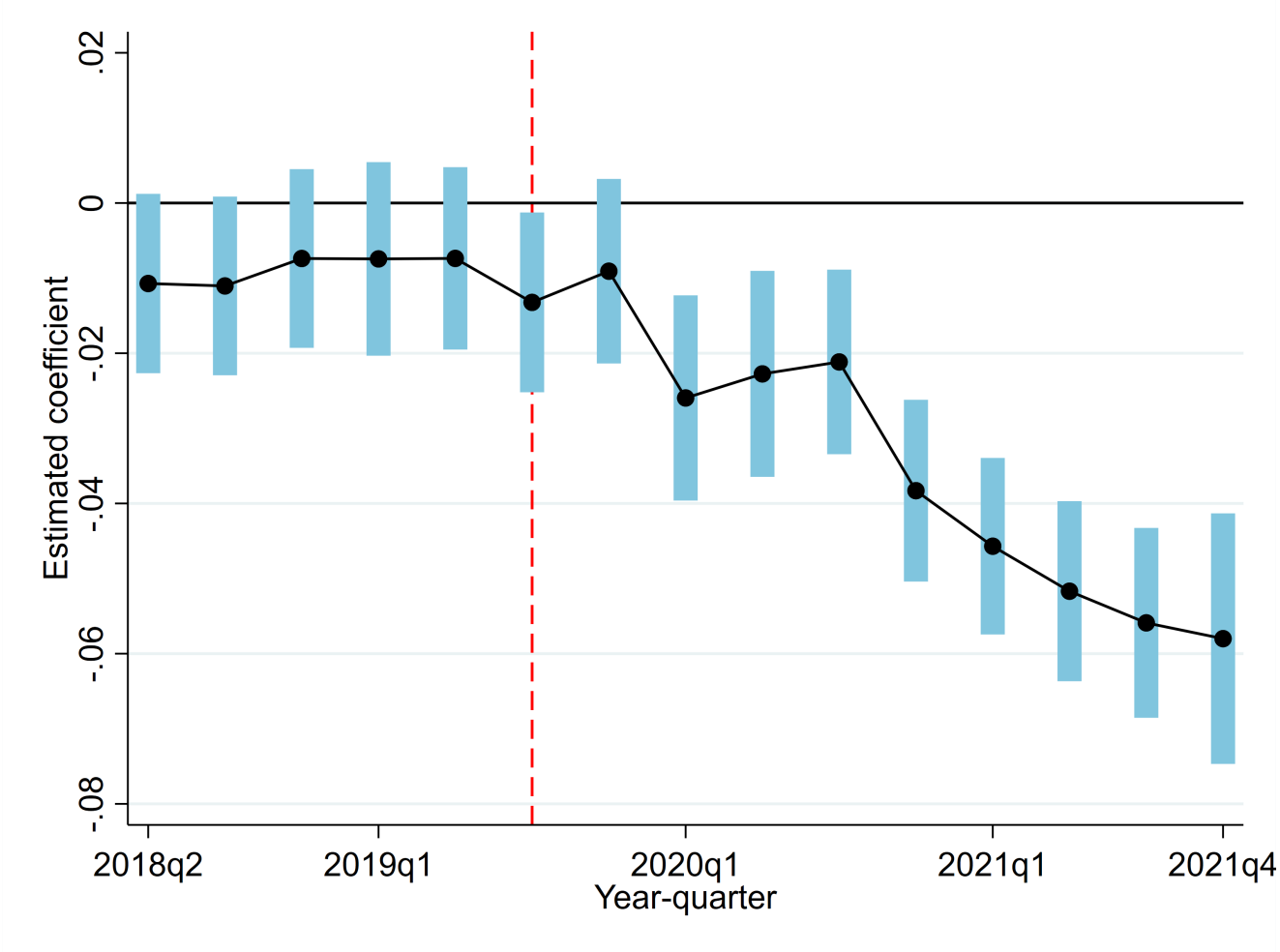

Figure 6A: Event studies (HDB, SLR risks effect)

Results

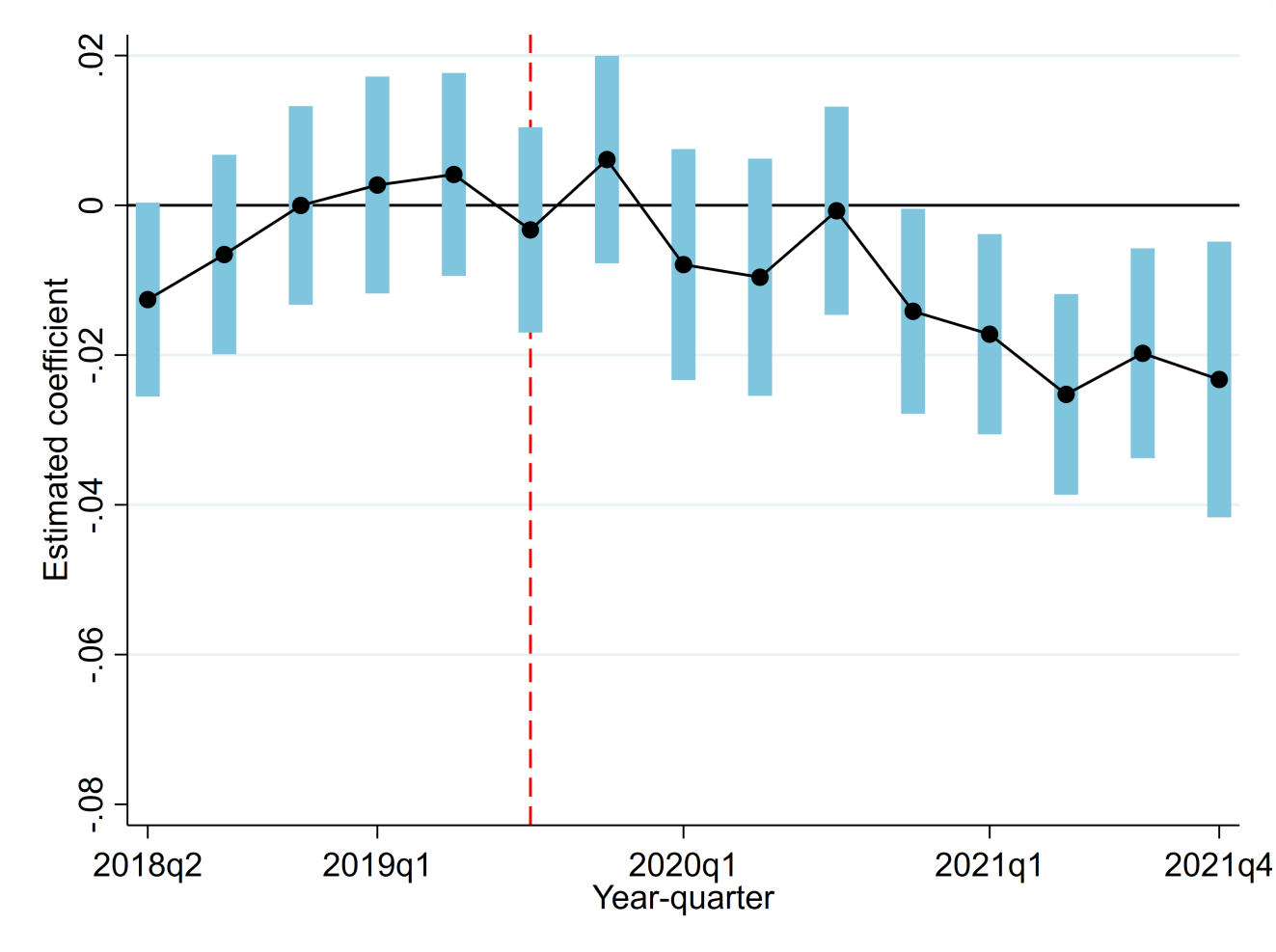

Figure 6B: Event studies (HDB, mitigated SLR risks effect)

Results

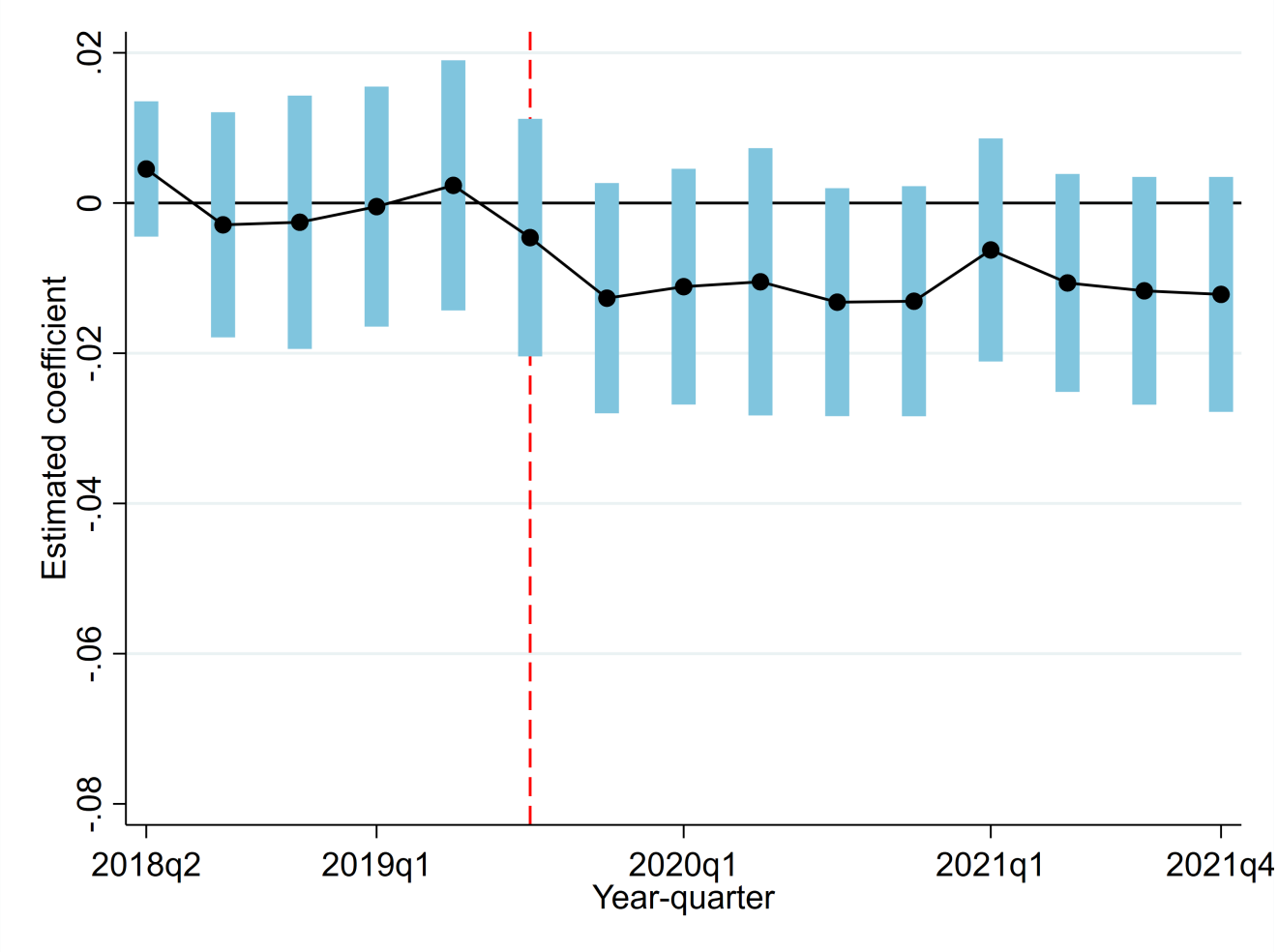

Figure 6C: Event studies (private property, SLR risks effect)

Results

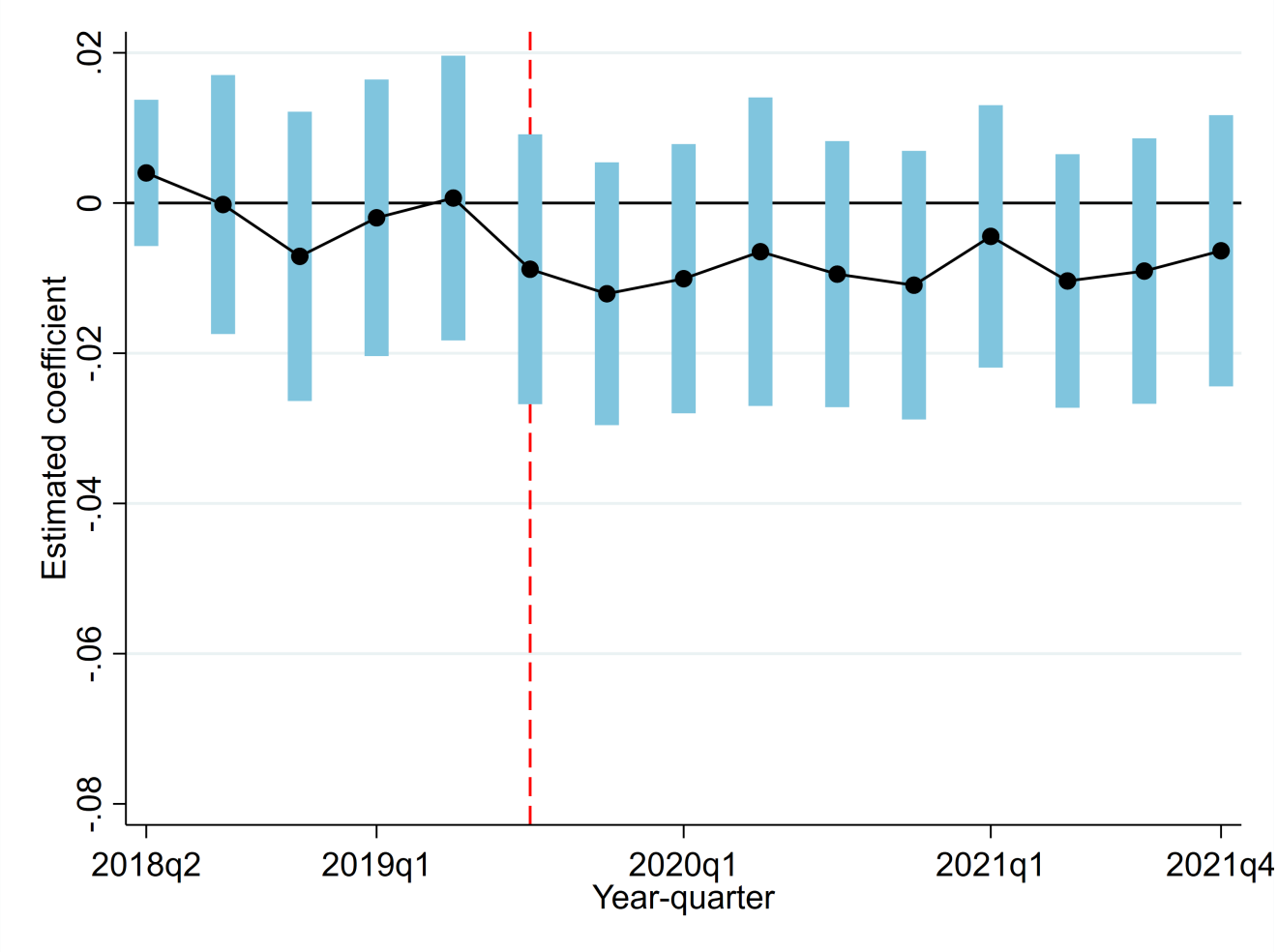

Figure 6D: Event studies (private property, mitigated SLR risks effect)

Results

- Leasehold vs freehold

Table 2: Heterogeneity by tenure type

	(1)	(2)	(3)	(4)
	Dependent variable: ln (unit price)			
	Private leasehold		Private freehold	
	SLR risks	Mitigation	SLR risks	Mitigation
$treat_j \times after_t$	-0.019***	-0.018***	0.008	0.010
	-0.005	-0.005	-0.006	-0.006
Property attributes	√	√	√	√
Year-month-flat type FE	√	√	√	√
Project-aftercool FE	√	√	√	√
Postal code FE	√	√	√	√
Observations	24,568	17,894	14,987	12,790
R-squared	0.968	0.967	0.959	0.960

Very long-run discount rates

- The freehold-leasehold structure is applicable to estimate very long-run discount rates.
- Leasehold properties are less valuable related to freehold properties after the announcement.
  - Leaseholder (and HDB residents) realized that the climate risk would come true in 100 years.
  - Demands on leasehold properties dropped after the shock.
- We follow the model of Giglio et al. (2015).

Very long-run discount rates

- Step 1: discounts between leasehold and freehold (treat or control, before or after)

$$\ln(\text{unitprice})_{ijt} = \alpha + \sum_T \delta_T \, D_T + \text{X'}\Gamma + \lambda_{it} + \mu_j + \theta_{jt} + \epsilon_{ijt} \quad (3)$$

  - T: remaining tenure year groups (69-74, 75-79, 80-84, 85-89, 90-94, 95-99 years) at purchase.
  - D_T: $=1$ if T years remained at purchase, otherwise, 0.
  - Benchmark: freehold properties with perpetual tenure.
  - Year-month-flat type FE, 4-digit FE.

Very long-run discount rates

- Step 2: calibration

$$\text{Disc}_t^T = \text{-}e^{-(r-g)T} \tag{4}$$

  - $Disc_t^T$: discount between freehold and leasehold with T reamining years at timt t.
  - r: long-run discount rate.
  - g: rent growth rate, set as 0.17% as Giglio et al. (2015).

Very long-run discount rates

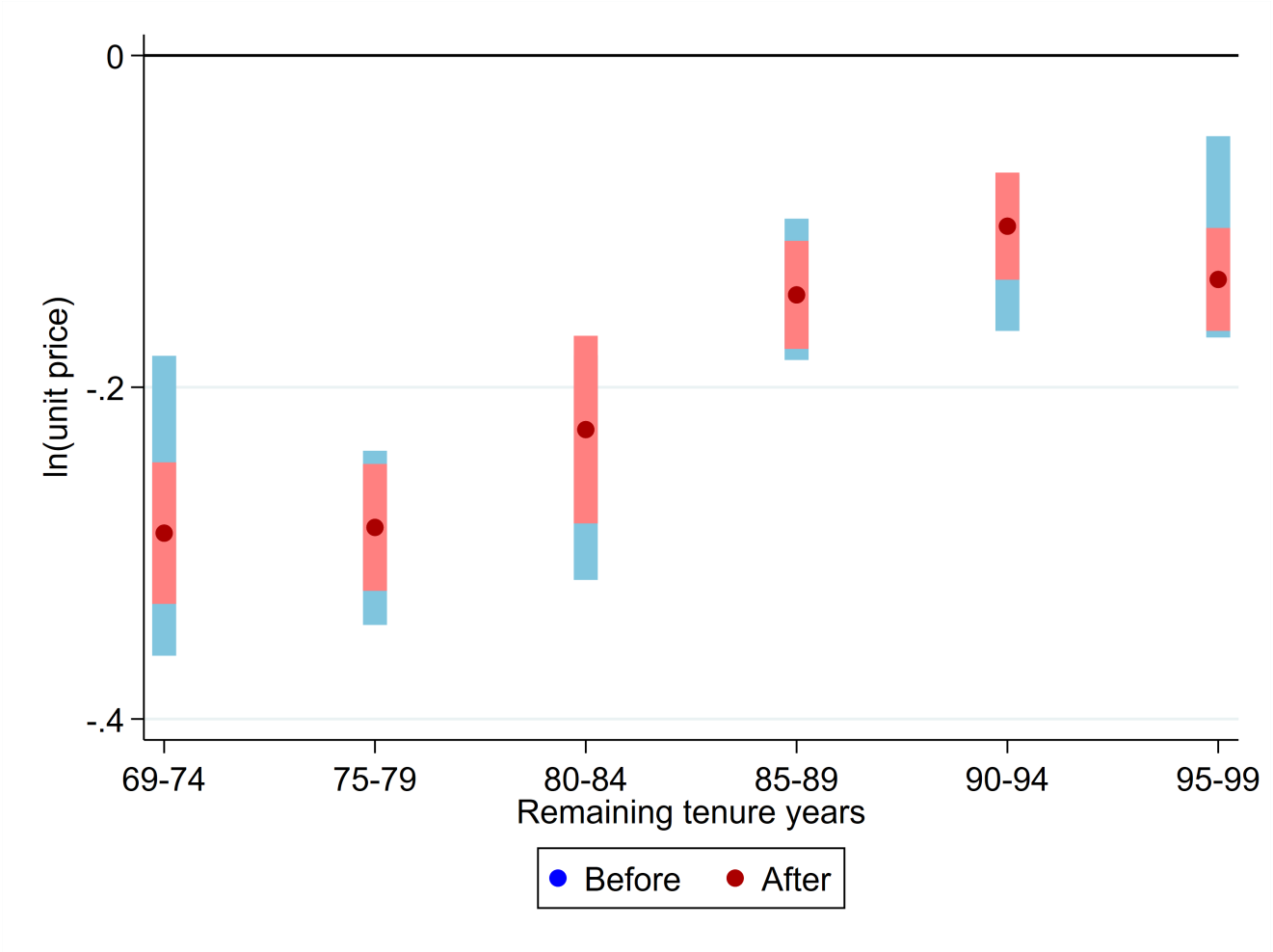

Figure 7: Discounts between leasehold and freehold properties (control group)

Very long-run discount rates

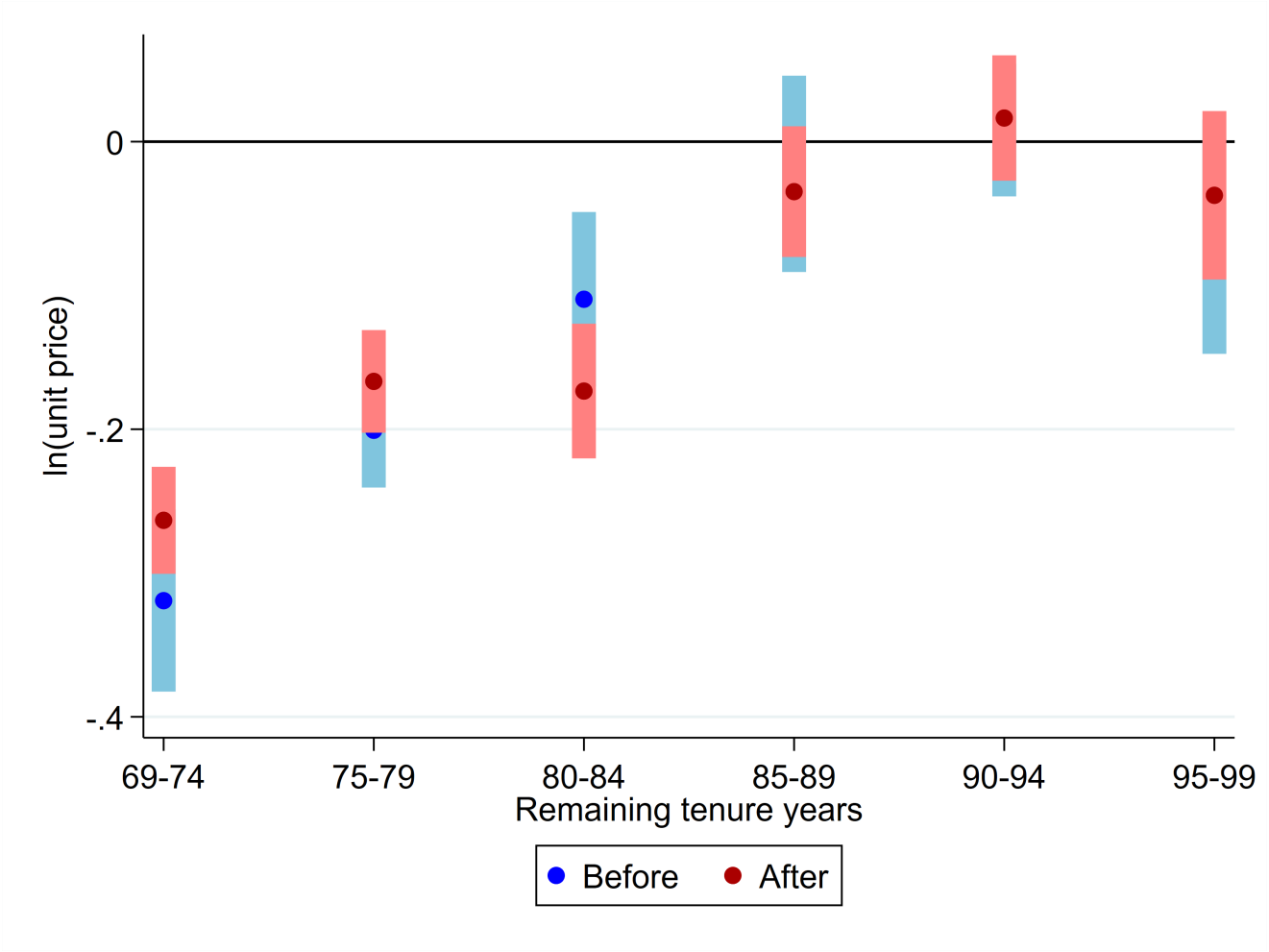

Figure 7: Discounts between leasehold and freehold properties (treatment group)

Very long-run discount rates

- Long-run discount rates based on the control group: 2.11% (before) -> 2.26% (after).
- Long-run discount rates based on the treatment group: 2.33% (before) -> 2.36% (after).
- Indicating higher NPV when evaluating climate-related projects.
- Estimations are robust and consistent when we set g as 0.2%, 0.4%, and 0.6%.

Additional tests

- Adaptation effect and flash floods.

Table 3: Tests on adaptation and flash floods

	(1)	(2)	(3)	(4)
	Dependent variable: ln (unit price)			
	Adaptation		Flash floods	
	Private	HDB	Private	HDB
$treat_j \times after_t$	-0.015	-0.006		
	-0.010	-0.008		
$treat_j \times after_t \times newconstruction_i$	-0.010	-0.003		
	-0.013	-0.010		
$nearflood_j \times afterflood_t$			-0.007	-0.013
			-0.010	-0.008
Property attributes	√	√	√	√
Year-month-flat type FE	√	√	√	√
Project-aftercool FE	√		√	
Postal code FE	√	√	√	√
Observations	9,382	4,377	1,973	1,629
R-squared	0.957	0.960	0.980	0.970

Additional tests

- Robustness test: control group within 1 km buffer.

Table 4: Robustness test by adjusting the control group

	(1)	(2)	(3)	(4)
	Dependent variable: ln (unit price)			
	Private		HDB	
	SLR risks	Mitigation	SLR risks	Mitigation
$treat_j \times after_t$	-0.011**	-0.003	-0.030***	-0.011***
	-0.004	-0.005	-0.003	-0.003
Property attributes	√	√	√	√
Year-month-flat type FE	√	√	√	√
Project-aftercool FE	√	√		
Postal code FE	√	√	√	√
Observations	32,145	26,099	23,596	12,608
R-squared	0.964	0.961	0.945	0.942

Additional tests

- Purchaser type

Table 5: Heterogeneity by purchaser type

	(1)	(2)	(3)	(4)
	Dependent variable: ln (unit price)			
Purchaser type of private property	in private property		in HDB	
	SLR risks	Mitigation	SLR risks	Mitigation
$treat_j \times after_t$	-0.010**	-0.010*	-0.011**	-0.006
	(0.005)	(0.005)	(0.004)	(0.005)
Property attributes	√	√	√	√
Year-month-flat type FE	√	√	√	√
Project-aftercool FE	√	√	√	√
Postal code FE	√	√	√	√
Observations	15,056	10,083	25,333	20,117
R-squared	0.969	0.968	0.965	0.963

Additional tests

- Landed property

Table 6: Test on landed property sample

	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent variable: ln (unit price)					
	All		Landed leasehold		Landed freehold	
	SLR risks	Mitigation	SLR risks	Mitigation	SLR risks	Mitigation
$treat_j \times after_t$	-0.025	-0.027	-0.019	-0.036	-0.030	-0.032
	-0.017	-0.020	-0.024	-0.049	-0.020	-0.024
Property attributes	√	√	√	√	√	√
Location attributes	√	√	√	√	√	√
Year-month-flat type FE	√	√	√	√	√	√
Four-digit postal code FE	√	√	√	√	√	√
Observations	4,254	2,393	802	225	2,895	1,998
R-squared	0.820	0.794	0.917	0.928	0.783	0.751

Landed properties have low transaction frequencies at postal code level, therefore, we control for four-digit postal code FE and include location attributes in regressions.

Concluding Remarks

- Conclusions
  - Government announcement of climate change in Singapore caused public property prices to drop by 2.9% (which strengthened to 6% two years after), and private property prices, 1.1%.
  - Government commitments take effect by mitigating price depreciation in mitigated SLR areas.
  - Freehold properties are relatively more valuable, indicating lower long-run discount rates estimations.

Concluding Remarks

- Limitations
  - Lack of information to test mechanisms of different responses between private property and HDB (we rule out potential channels like citizenship).
  - Samples in non-mitigated areas have small sizes and therefore, low statistical power.
  - We could not directly measure individuals' belief (and its change) on climate change and SLR.

THANK YOU!

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Appendix

Table A1: Summary statistics

	Treatment (SLR areas)			Control (non-SLR areas)		
	N	Mean	SD	N	Mean	SD
Panel A: private leasehold						
Unit price (S$/m2)	15,485	18139.240	5635.638	26,955	17055.980	5433.861
Flat age	15,485	8.574	9.268	26,955	6.564	8.500
Floor level	15,485	10.478	8.477	26,955	10.388	8.875
Area (m2)	15,485	96.478	43.247	26,955	96.303	44.665
Freehold	15,485	0.499	0.500	26,955	0.301	0.459
Private purchaser	15,485	0.679	0.467	26,955	0.588	0.492
Condominium	15,485	0.365	0.481	26,955	0.582	0.493
Apartment	15,485	0.635	0.481	26,955	0.418	0.493
New sale	15,485	0.292	0.455	26,955	0.404	0.491
Resale	15,485	0.698	0.459	26,955	0.575	0.494
Sub-sale	15,485	0.009	0.097	26,955	0.021	0.144
Distance to MRT station (km)	15,485	0.702	0.553	26,955	0.717	0.434
Distance to bus stop (km)	15,485	0.149	0.198	26,955	0.151	0.152
Distance to top 30 primary school (km)	15,485	1.632	0.753	26,955	1.356	0.628
Distance to CBD (km)	15,485	4.535	2.326	26,955	7.447	3.785
Panel B: HDB						
Unit price (S$/m2)	6,350	5394.242	1316.152	36,106	4691.697	1142.747
Flat age	6,350	35.896	12.500	36,106	29.269	10.710
Floor level	6,350	8.954	5.871	36,106	7.990	5.362
Area (m2)	6,350	85.875	24.157	36,106	99.344	24.946
Distance to MRT station (km)	6,350	0.674	0.505	36,106	0.660	0.383
Distance to bus stop (km)	6,350	0.128	0.065	36,106	0.115	0.057
Distance to top 30 primary school (km)	6,350	1.242	0.727	36,106	1.515	1.277
Distance to CBD (km)	6,350	4.924	2.749	36,106	10.416	3.648

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