Estimation of Perceived Flood Damage in Tokyo Metropolitan Area

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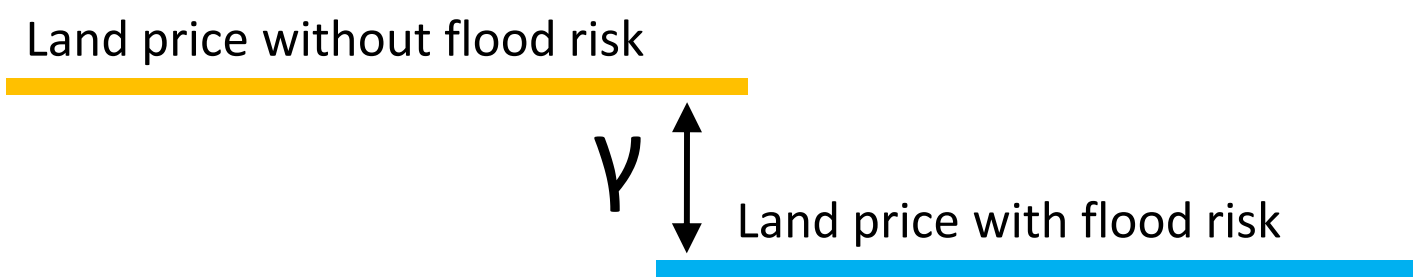
Overview

Comparing prices of lands with/without flood risk



$$LP_i = \alpha + \sum_n \beta_n \cdot Atribute_{n,i} + \gamma \cdot FloodRisk_i + u_i$$

Unobservable variables

Perceived flood risk might correlate with unobservable determinant of land prices.

=> Two-stage estimation with instrumental variables

Background

Climate change will bring an increase in frequency and severity of flood.

Current flood control policy has been implemented based on the plan in absence of perspective on adaptation to climate change.

The measure of cost and benefit should be examined with the perspective on adaptation.

The heavy rainfall having 100 year recurrence interval

- Tokai heavy rain disaster, September 2000
- 37% of city area was flooded in Nagoya
  - Nagoya is a central city of Tokai area with population of 2 million.
- The flood caused by overflow banks.
  - Most of recent floods in urban area are inland flooding.
  - Some water overflowed Nagoya's 10 dikes.

Tokyo metropolitan govt prepared flood hazard map.

Cars under water*

Overflow water*
(Nishi-Biwajima)

Waste due to flood*

* Cabinet office
<http://www.bousai.go.jp/oshirase/h13/130126chubo/shiryo3_3.html >

Previous studies

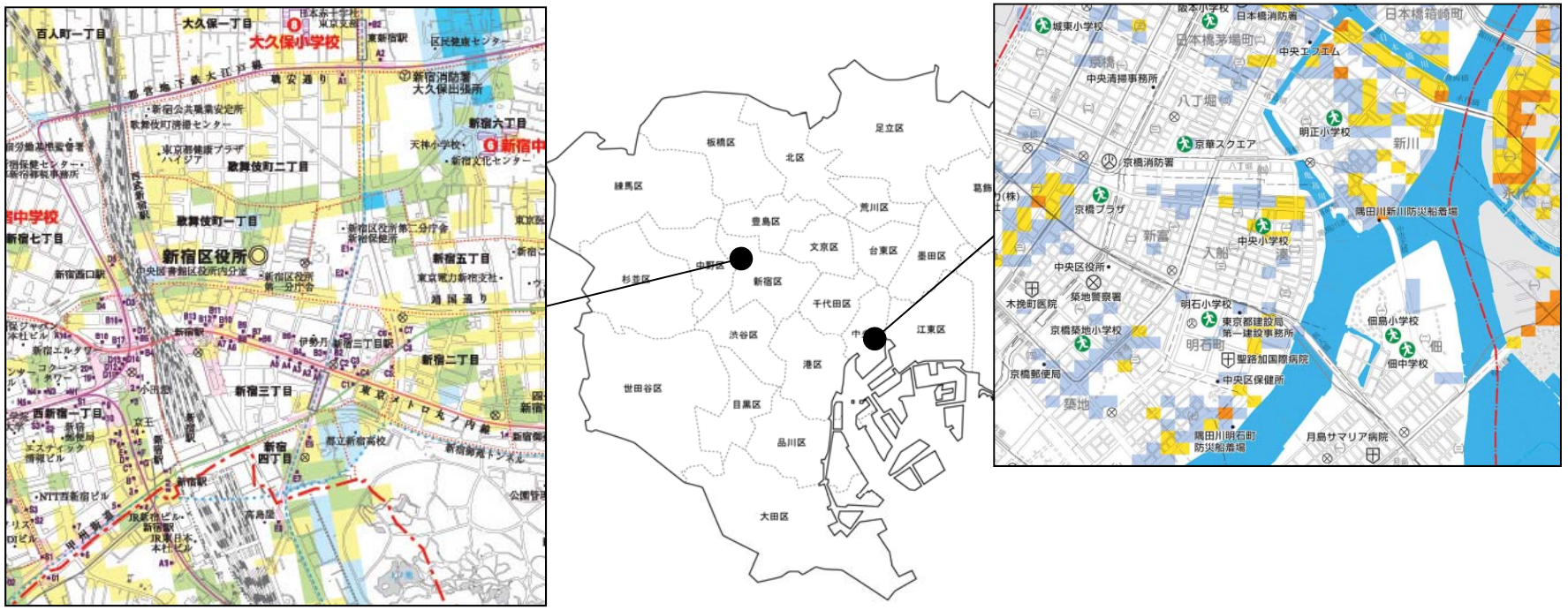
- Flood risk -> Reduction of land price
  - Hallstrom and Smith (2005)
  - Bin and Polasky (2004)

- There exist many studies on flood damage by hedonic approach in Japan

- Problem of previous studies
  - Estimation bias caused by omitted variables

Flood risk variable

Flood hazard map Issued by the Tokyo Metropolitan Govt



この地図の作成に当たっては、国土地理院長の承認を得て、同院発行の数値地図200000（地図画像）を使用したものである。（承認番号　平19総使、第82号）

This hazard map is based on the result of flood simulation on the assumption of the equivalent heavy rain to the Tokai Flood Disaster which is expected to occur once every 100 year.

Flood risk variable:

If the site *i* is included in hazard area, $DRisk_i = 1$ otherwise $DRisk_i = 0$

Problem of previous studies

Hedonic Land Price model

Land Price　　Attributes　　Flood risk dummy

$$\ln LP_i = \alpha + \boldsymbol{X}_i\boldsymbol{\beta} + \gamma DRisk_i + u_i$$

Unobservable variables

Attribute variables:
Bulk ratio, elevation, Time distance to terminal stations,
23 special wards dummy, Railway line dummy, etc.

Omitted variables bring estimation bias on gamma and flood risk impact on land price cannot be identified.

$$p\lim \hat{\gamma} = \gamma + \frac{Cov(FloodRisk, OmittedVariables)}{Var(FloodRisk)} \neq \gamma$$

Two-stage procedure

Two-stage estimation

Flood Hazard model

$$Risk_i = \delta + \boldsymbol{Y}_i\boldsymbol{\theta} + e_i$$

Flood factors:

$DisRiver_i$, $Hollow_i$, 23 special wards dummy, etc.

$$PRisk_i = 1 - \varphi(-\hat{\delta} - \boldsymbol{Y}_i\hat{\boldsymbol{\theta}})$$

Predicted probability

Hedonic Land Price model

replaced $DRisk_i$

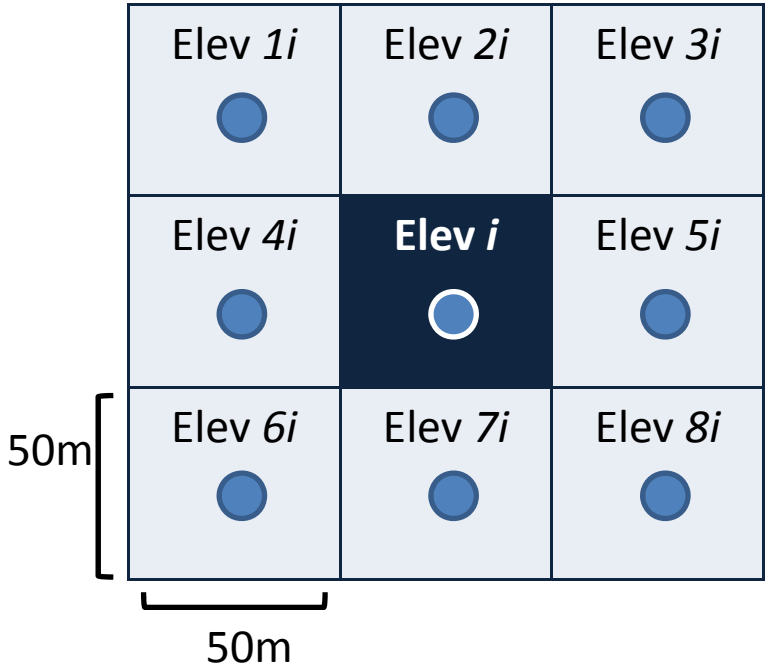
$$\ln LP_i = \alpha + \boldsymbol{X}_i\boldsymbol{\beta} + \gamma PRisk_i + u_i$$

Instrumental variables

$$Hollow_i = \min(Elevation_{n,i}) - Elevation_i$$

If the site *i* is lowest, the water cannot run off.

➡ Flood risk could be higher.



$Hollow_i \leq 0$ if the site *i* is lowest

$Hollow_i > 0$ otherwise

$DisRiver_i$: Distance to the nearest river

If the site *i* is close to rivers, flood risk could be higher.

Coverage area and data

- Coverage area
  - Tokyo 19 special wards
  - Excluding Katsushika, Shibuya, Aarakawa, Sumida
- The flood hazard map
  - Published by the Tokyo Metropolitan Government
  - Flood Risk Dummy
  - If the site *i* is located in the area explored by flood, $DRisk_i = 1$

- Official Land Price
  - Reported by Ministry of Land, Infrastructure, Transport and Tourism in 2009
  - Land price, land shape, land-use zoning, accessibility to the gas, water and sewerage utilities, the name of the nearest station, the distance from it, lot percentage regulation, bulk ratio regulation, etc.

- Yahoo! route search
  - Accessibility to terminal stations of JR Yamanote line.
  - http://transit.map.yahoo.co.jp/

Main estimation result – Flood Hazard model

	Coef		Std. error
Intercept	-0.475		0.323
DisRiver	-0.000	***	0.000
Hollow	0.063	**	0.029

Predected flood risk $PRisk_i$

Main estimation result 1—Hedonic land price model

Model 1

	OLS estimation		2-stage estimation	
	Coef	Std err	Coef	Std err
Constant	12.990***	0.135	12.891***	0.130
Flood risk	-0.034*	0.018	-0.157***	0.018
Bulk ratio X Flood risk				
Building coverage rate X Flood risk				
Height X Flood risk				
Elevation	0.008***	0.001	0.007***	0.000
Area (m^2)	0.000***	0.000	0.000***	0.000
Distance from Station	-0.000***	0.000	-0.000***	0.000
Time distance to terminal station	-0.010***	0.002	-0.010***	0.001
Inner Yamanote line	0.131***	0.047	0.114***	0.041
Bulk ratio	0.003***	0.000	0.003***	0.000
Residential area 1 dummy	-0.109***	0.027	-0.090***	0.027
Residential area 2 dummy	-0.196***	0.029	-0.174***	0.029
Industrial area dummy	-0.125***	0.029	-0.074***	0.030
Adj R squared	0.876		0.853	
Endogeniety test			採択	
Over identification test			採択	

Reduction of land price (%)　OLS: -3.4%　2-stage : -14.5%

Main estimation result 2—Hedonic land price model

Model 2

	OLS estimation		2-stage estimation	
	Coef	Std err	Coef	Std err
Constant	12.960***	0.136	12.878***	0.136
Flood risk	0.029	0.033	−0.081**	0.036
Bulk ratio X Flood risk	−0.000**	0.000	−0.000***	0.000
Building coverage rate X Flood risk				
Height X Flood risk				
Elevation	0.008***	0.001	0.007***	0.001
Area (m^2)	0.000***	0.000	0.000***	0.000
Distance from Station	−0.000***	0.000	−0.000***	0.000
Time distance to terminal station	−0.010***	0.002	−0.009***	0.001
Inner Yamanote line	0.130***	0.047	0.102***	0.043
Bulk ratio	0.003***	0.000	0.003***	0.000
Residential area 1 dummy	−0.112***	0.027	−0.102***	0.028
Residential area 2 dummy	−0.200***	0.029	−0.183***	0.030
Industrial area dummy	−0.129***	0.029	−0.077***	0.031
Adj R squared	0.877		0.843	
Endogeniety test			採択	
Over identification test			採択	

Reduction of land price (%)　OLS: -3.5%　2-stage：-16.0%

Main estimation result 3—Hedonic land price model

Model 3

	OLS estimation		2-stage estimation	
	Coef	Std err	Coef	Std err
Constant	12.930***	0.135	12.892***	0.134
Flood risk	0.489***	0.092	−0.247***	0.102
Bulk ratio X Flood risk				
Building coverage rate X Flood risk	−0.009***	0.002	0.004***	0.000
Height X Flood risk	0.011	0.008	−0.041***	0.009
Elevation	0.008***	0.001	0.007***	0.001
Area (m^2)	0.000***	0.000	0.000***	0.000
Distance from Station	−0.000***	0.000	−0.000***	0.000
Time distance to terminal station	−0.010***	0.002	−0.009***	0.001
Inner Yamanote line	0.132***	0.046	0.098**	0.042
Bulk ratio	0.003***	0.000	0.003***	0.000
Residential area 1 dummy	−0.135***	0.027	−0.100***	0.028
Residential area 2 dummy	−0.238***	0.030	−0.172***	0.031
Industrial area dummy	−0.159***	0.029	−0.072***	0.031
Adj R squared	0.879		0.847	
Endogeniety test			採択	
Over identification test			採択	

Reduction of land price (%)　OLS: -3.7%　2-stage：-18.2%

Discussion

$$Reduction\ rate\ of\ LP = \left(\frac{LP\ w/o\ Risk}{LP\ w/\ Risk} - 1 \right) \times 100 = (e^{0.157} - 1) \times 100 = 14.5\,(\%)$$

➡ Reduction in Land Price: 169,438 yen/m² (1,631 EUR)

$$Reduction\ in\ LP = \sum_{t=0}^{100} \frac{d(1-d)^{99} D}{(1+\rho)^t} = 169{,}483\ yen/m^2$$

$d \cong 0.01$: occurrence probability $\rho = 0.03$: discount rate

13,552 EUR/m²

Average flood damage D = 1,408,049 yen/m²

Not only physical damage, but also indirect damage such as loss of life, loss of profit, mental damage, etc.

The Govt estimation D = 33,199 yen/m²

Only physical damage

Conclusion

- We estimated Hedonic Land Price model by two-stage estimation to correct the bias caused by omitted variables.

- The reduction rate of land price in hazardous area is 14.5% and the perceived flood damage is 1,408,049 yen/m^2 (13,552 EUR/m^2).

- Our estimate is much higher than that of the Tokyo Metropolitan Government since our estimate include not only physical damage, but also indirect damage such as opportunity profit and mental damage.

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