Economic and Demographic Effects of Emergency Risk Communication: Evidence from the Fukushima Daiichi Nuclear Disaster

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Fukushima Daiichi Nuclear Disaster

- As a result of the Great East Japan Earthquake(2011/3/11), a large amount of radioactive material was accidentally released from the Fukushima Daiichi Nuclear Power Plant, which resulted in radioactive contamination of the plant and surrounding areas.
- Fukushima nuclear disaster was rated at highest level, same as Chernobyl in the International Nuclear and Radiological Event Scale(INES)
- Radiation is invisible and odorless, and any risk we cannot detect leaves us feeling powerless to protect ourselves, which makes it extremely scary.
- The Japanese citizens, especially those in Fukushima were very anxious about health problems as well as food and soil pollution.

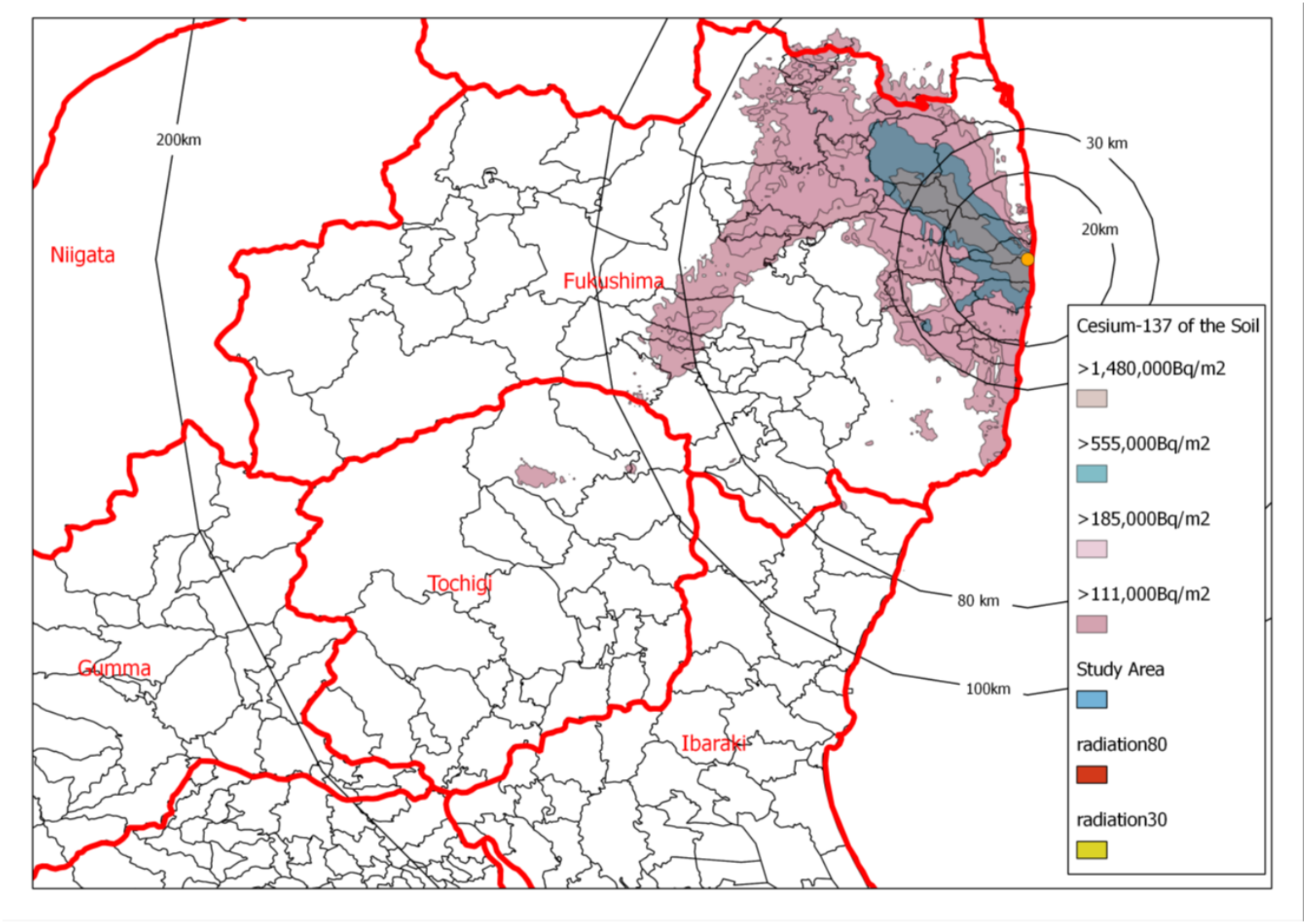
The Role of Risk Communication

- Radiation is invisible and odorless
- People are more likely to react to the perceived risk rather than the actual risk.
- Risk information shapes people's perceptions of risk, influences their actions with respect to disaster responses, and ultimately impacts local economy
- Accurate, trustable, and up-to-date risk information is crucial and makes people feel a sense of being safer by increasing the individual control of risk
- Accurate information was understandably difficult to obtain in the weeks immediately following the accident, but misinformation persisted even when scientific data on radiation levels and reactor stability had become more readily available.

How Japanese Government Communicated with the Public?

- Distance-based risk communication
- Administrative boundary-based risk communication
  - Prefecture-based risk communication
    - 47 prefectures in Japan
    - Fukushima is one of them
  - Municipality-based risk communication
    - 1742 municipalities
- Actual level of radiation

Cesium 137 Contamination of the Soil in Bq/m2



The Government's Communication with the Public in the Early Stage of the Disaster (Communication by Distance)

- Just after the nuclear emergency was declared by the government of Japan , the Fukushima prefecture ordered the evacuation within a distance of **2 km** from the plant. Two hours later, this was extended to **3 km**, together with instructions for residents within 10 km of the plant to stay indoors.
- This was again expanded to a **10 km** radius at 5:44 on 12 March, and then to **20** km at 18:25, and urged that those living between **20 km and 30 km** from the site to stay indoors. The latter groups were also urged to evacuate on 25 March.
- As of 23 February 2012, 62,674 Fukushima residents had evacuated from the prefecture.

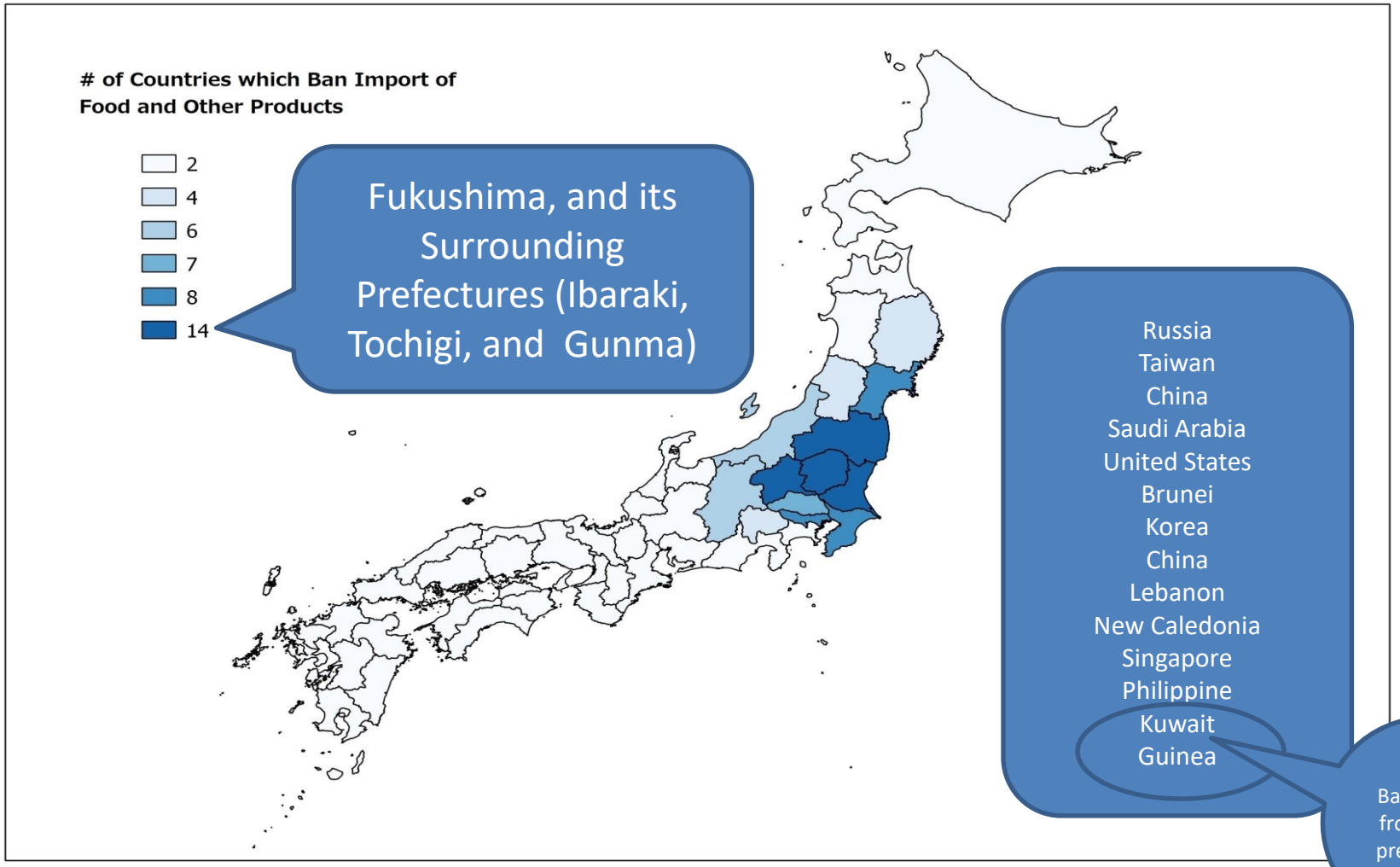
International Response (Communication by Distance)

- On the 16th of March, US Government recommends **80 Km (50 miles)** Fukushima evacuation zone
- Spanish government advised to leave an area within **120.7 km (75miles)** from the cite
- German government advised to leave even from the metropolitan area of Tokyo
- South Korean government advised to leave **farther than 80 km** and plans to evacuate by all possible means.

Restriction on Sale of Food and Other Products near Fukushima (Communication by Prefecture)

- On March 21, 2011 the Prime Minister ordered the Governors of the affected prefectures of Fukushima, Gunma, Ibaraki, and Tochigi to stop the distribution of spinach and kakina into the market, and ordered the Governor of Fukushima prefecture to stop the distribution of raw milk.
- All products with 50 becquerels per kilogram, one-tenth of the government's provisional limit were rejected and not offered in the stores.
- On April 1, 2012, the government introduced stringent food safety regulations, setting a radioactive cesium limit of 100 becquerels per kilogram. But Fukushima, Gunma, Ibaraki, and Tochigi vegetables have taken the brunt of radiation rumors, prices declining even further. (People feel that risk information does not necessarily guarantee their safety)

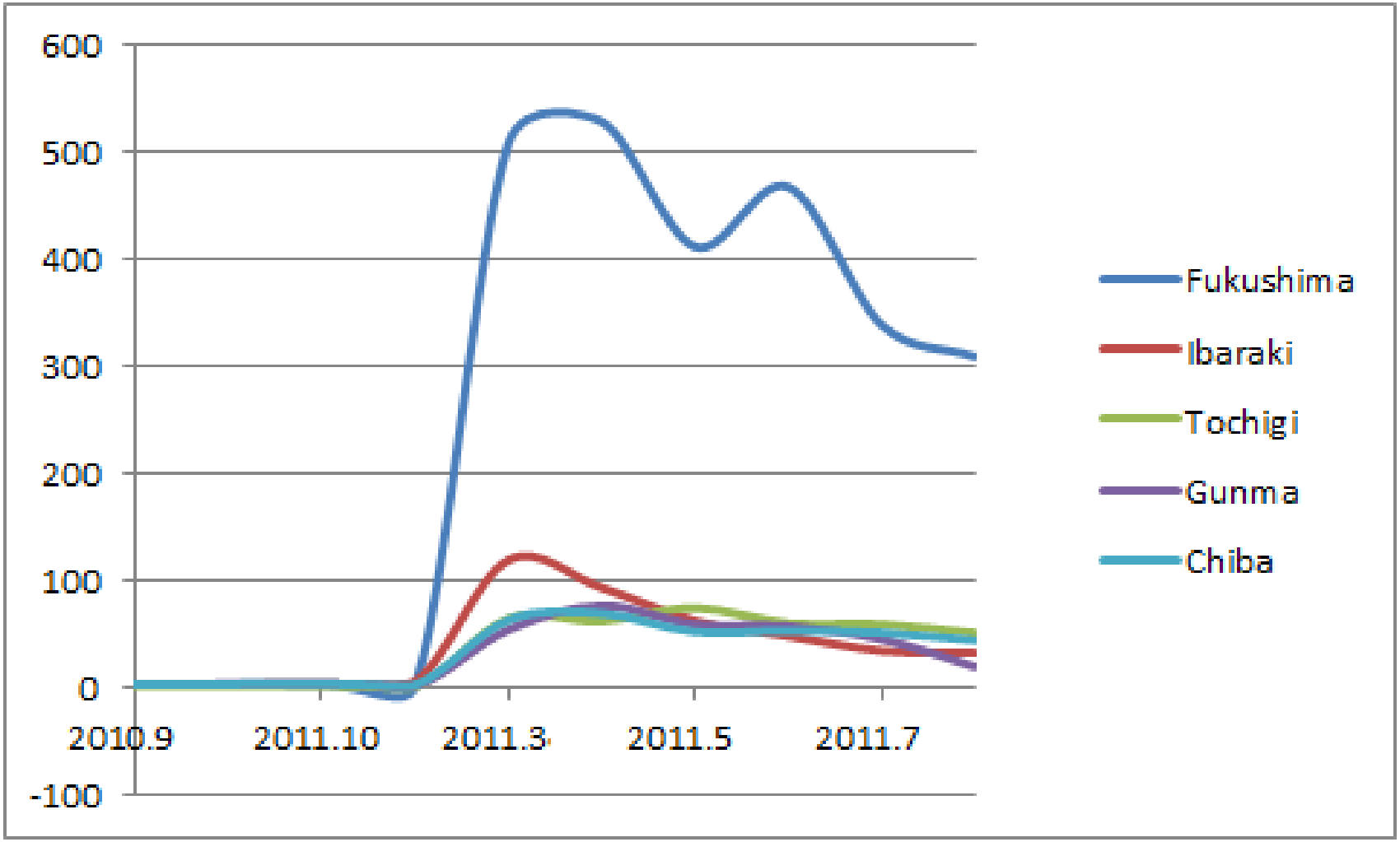
Restriction on Import of Food and Other Products near Fukushima by Other Countries (Communication by Prefecture)



Risk Communication by Mass Media in Japan

- In the early stage of the nuclear crisis, Japanese media reported whatever government said to them.
- Thus, **distance-based information** was predominantly used in the early stage of the disaster, and **prefecture-based information** is used for food and other products safety.
- Since mid-March, “Radioactivity Information Today (“今日の放射線情報”)” has been broadcasted in the part of weather forecast programs
- But still, prefecture’s name was predominantly used to describe high level of radiation in the region.
- A high level of concern, coupled with a low level of trust in mass media lead some people to report Geiger counter (personal radiation detector) readings and distributed the collected data to those who were concerned about the level of nuclear radiation by using social media such as Twitter.
- Such information is much noisier and leads to more stigmatization based on the region/distance (partly because Twitter limits Tweet length to 140 characters. It is necessary to distill the information, accordingly .

Bibliographic Analysis of Fukushima and Its Surrounding Prefectures



Yomiuri Shimbun Database (Keyword :“Radiation”+ Prefecture Name)

Bibliographic Analysis of Fukushima and Its Municipalities

	2011.3-2011.8	2010.9-2011.2
Municipality Name + "Radiation"		
Futaba-machi&Okuma-machi, Fukushima (where the Fukushima Daiichi Nuclear Power Plant is located)	327	1
Tomioka-machi, Fukushima(Within 20km)	55	0
Taruha-machi, Fukushima (Within 20km)	122	0
Tamura-shi, Fukushima (Some part within 20km)	77	0
Hirono-Machi, Fukushima (Within 30km)	99	0
Iwaki-shi, Fukushima (Some part within 30km)	281	2
Nasu-Shiobara, Tochigi	51	0
Nasu-machi, Tochigi	158	0
Kita-Ibarakishi, Ibaraki	40	0
Prefecture Name +"Radiation"		
Fukushima	2580	8
Ibaraki	389	12
Tochigi	370	5

Yomiuri Shimbun Database (Keyword :"Radiation"+ Municipalities' Name)

Region-based v. Distance-based Information

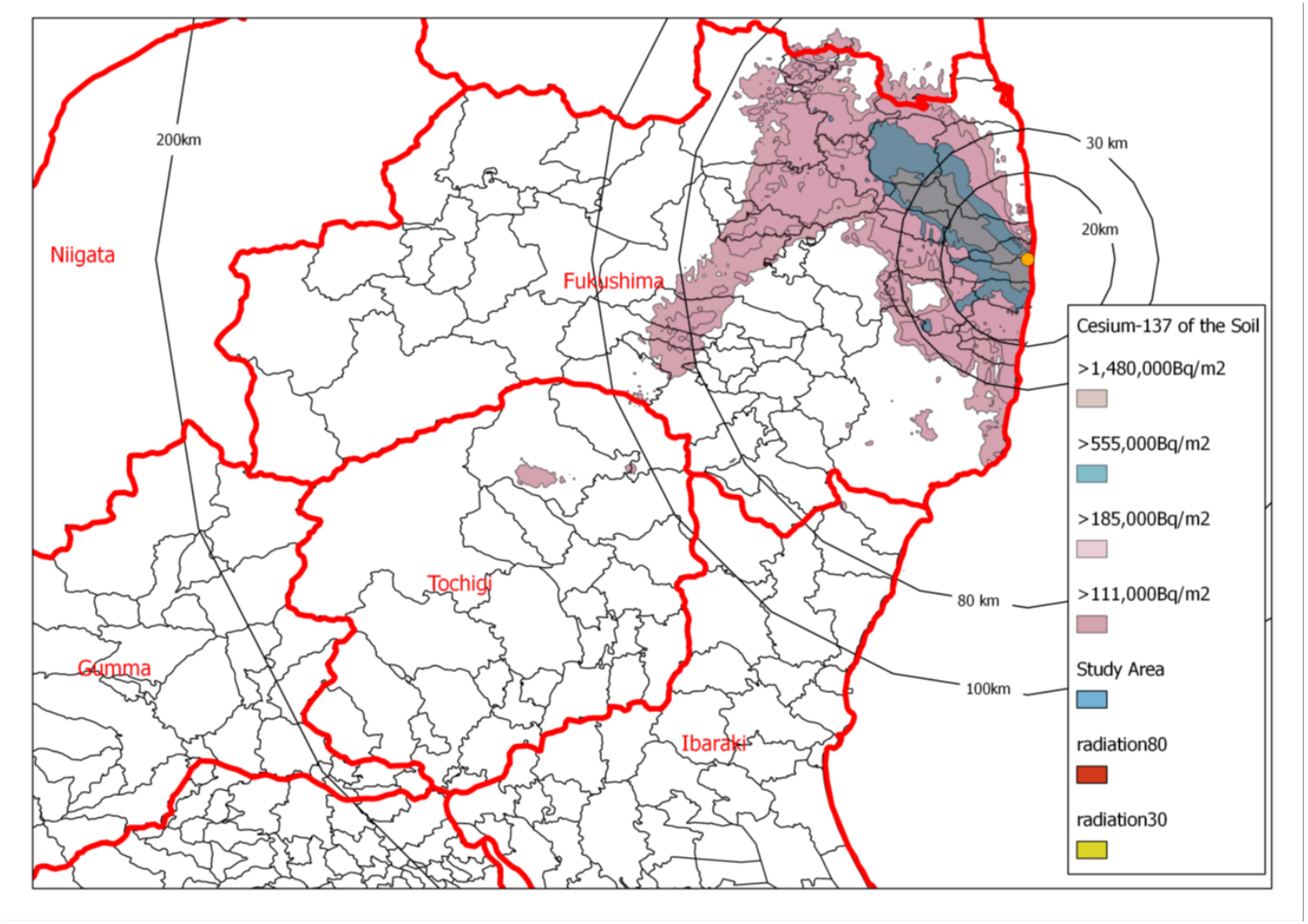
Radial distance from release site

- Useful when the exact cause of risk is unknown but possible
- cf) Risk Assessment of Unregulated Waste Disposal Sites
- Can be easily processed
- Larger the unsafe area, more safe area is misclassified into the unsafe area
- Misclassification is large when radioactive substance is not uniformly spread over its circumference

Political/administrative unit

- Unit of public policy response
  - You need rough idea f geographic distribution risk
- Can be more easily processed
- Town, City, Village/Municipalities/ Fukushima Prefecture/Fukushima and Surrounding Prefectures (Ibaraki, Tochigi, and Gunma)/Kanto and Tohoku Region/Japan/Asia?/Earth?
- The larger the unit used, more safe area is potentially misclassified into the unsafe area
- Misclassification is large when large unit is used and radioactive substance is spread across the political/administrative boarder

Cesium 137 Contamination of the Soil in Bq/m2



“Rumor-related Damage”

- Japanese government is very keen on rumor-related damage
- Estimated amount of the rumor-related damage (even without the actual radiation exposure) by the government panel is **1304 billion yen**
  - Agriculture/Forestry/Fisheries/Food (Domestic) : 834 billion yen
  - Agriculture/Forestry/Fisheries/Food (Export) : 65 billion yen
  - Tourism: 337 billion yen
  - Manufacturing services and export industry : 68 billion yen
- This estimated amount is much larger than money damages for lost value of property due to the radiation exposure **is 571 billion yen**
  - No compensation for the loss of land/housing value outside of the evacuation zone
- An additional budget is allocated to tackle future “rumor-related damage”.

What was the role of misleading information?

Motivation of the Study

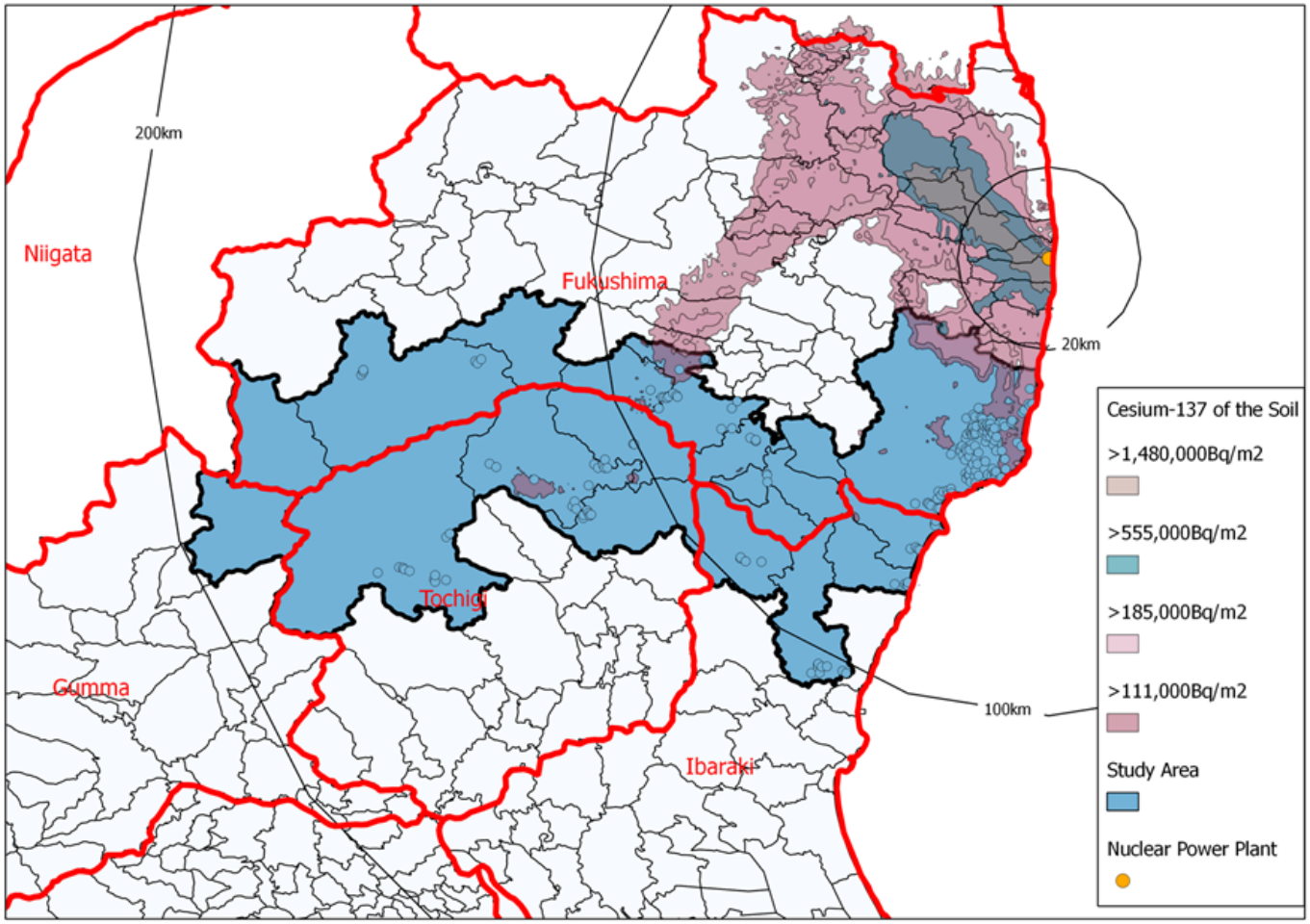
- Since radiation is invisible, people are more likely to react to the perceived risk that are affected by risk information.
- However, risk information are generally provided with a lot of undesirable noise.
- Thus, it is useful to examine what impact such risk information and rumors, separate from the actual health risk, have on the economy.
- Using border identification method, we aim to estimate whether a decline in land price or number of tourists in southern Fukushima (prefecture) is differ from the municipalities of the Ibaraki and Tochigi prefectures adjacent to the southern border of Fukushima, after controlling for (1) effect of the actual radiation level, (2) effect of radial distance from the Fukushima Daiichi nuclear power plant, and (3) effect of municipalities that observed relatively high radiation level at least one monitoring point.
- If land price or number of tourists in Fukushima declines more significantly in the specification, the amount of extra decline in number of visitor can be regarded as some kind of penalty to just be located in Fukushima.

Empirical Strategy

Pre-disaster

Post-disaster

Study Area I and Land Price Monitoring Locations(2012)



Summary Statistics

Study Area I	Obs	Mean	Std. Dev.	Min	Max
Land Price (yen/m2)	750	32658	15425	5000	158000
Log(Land Price)	750	10.28	0.51	8.52	11.97
Air dose rates 1m above the ground surface (μSv/h)	750	0.192	0.164	0.070	1.000
A Dummy Variable of Fukushima	750	0.693	0.461	0	1
Distance from the Power Plant (km)	750	71.7	31.0	31.3	151.1

Specification for Study Area I

- We estimate the following regression

$$\log(LANDPRICE_{h,t}) = \alpha_h * 1(LOCATION_h) + \gamma_t * 1(Year) + \beta_1 * POSTDIS_s * 80Within_h + \beta_2 * POSTDIS_s * 100Within_h$$
$$+ \beta_3 * POSTDIS_s * FUKUSHIMA_h + \beta_4 * POSTDIS_s * MUNICIP_h + \beta_5 * POSTDIS_s * RADIATION_{h,t}$$
$$+ \sum_{s=1}^{3} \kappa_s * (PREF_s * TIME_t) + \varepsilon_{s,h,t}$$

- s: prefecture, h:location, t: year
- Location and year fixed effects as well as prefecture-specific time trends
- **A dummy variable of post-disaster (After 2011.3)** is interacted with
  - Dummy variables of distances
    - 1 if within 80km from the Fukushima Daiichi Nuclear Power Plant, otherwise 0
    - 1 if within 100km from the Fukushima Daiichi Nuclear Power Plant, otherwise 0
  - A dummy variable of Fukushima
    - 1 if located in Fukushima, otherwise 0
  - A dummy variable of municipalities with relatively high levels of radiation
    - 1 if located in the municipalities which have observed relatively high radiation levels at least one monitoring point, otherwise 0
  - Dummy variables of actual radiation level
    - 1 if air dose rates 1m above the ground surface is more than 0.23μSv/h, otherwise 0
    - 1 if air dose rates 1m above the ground surface is more than 0.4μSv/h, otherwise 0
    - 1 if air dose rates 1m above the ground surface is more than 0.7μSv/h, otherwise 0

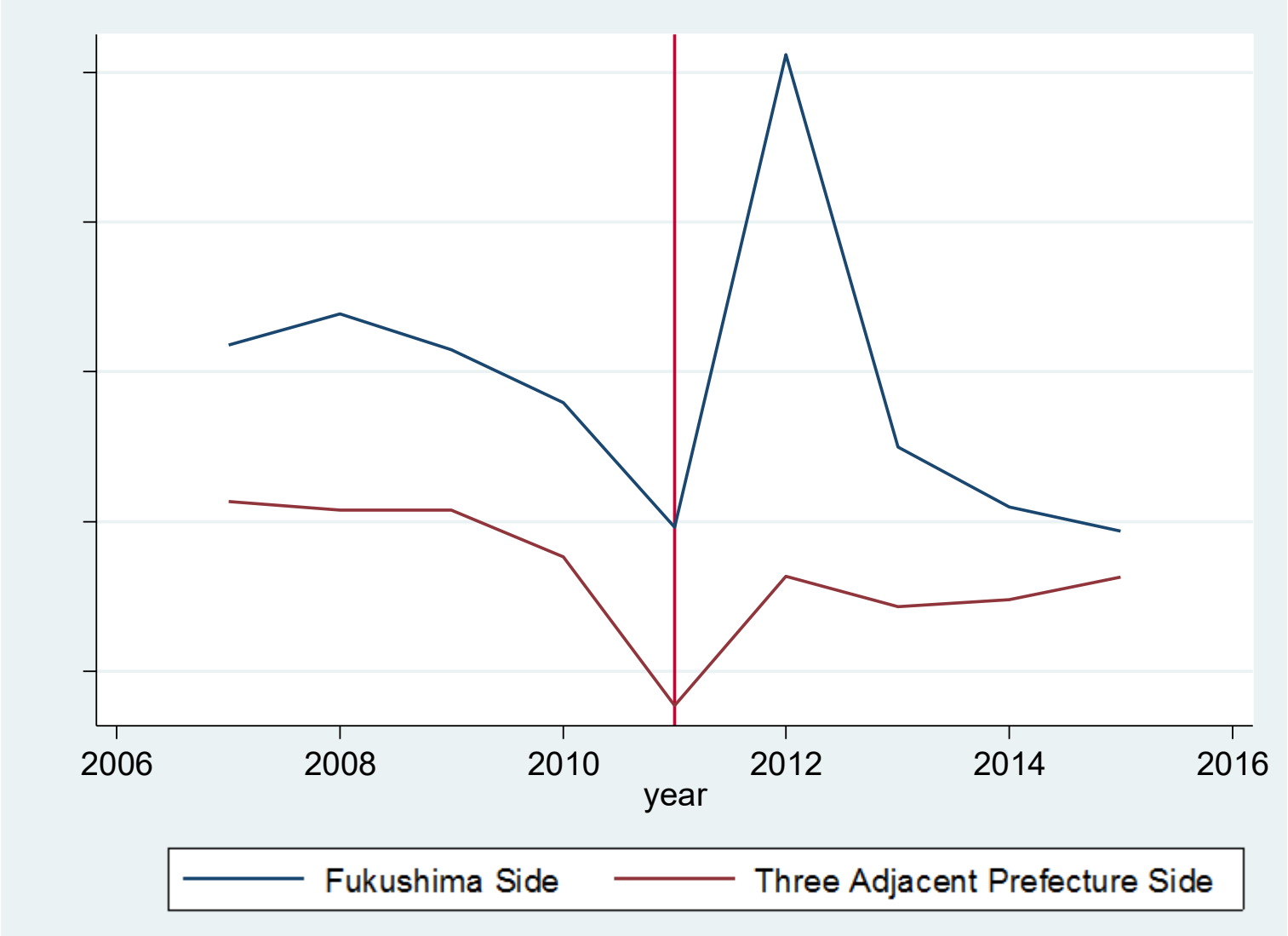
Result: Study Area I

VARIABLES	(1)	(2)	(3)	(4)	(5)
Effect within Fukushima Prefecture	-0.02				-0.00390**
	[0]				[0.000680]
Effect within Municipalities with high level of radiations		-0.00480**			0.00334
		[0.00102]			[0.00583]
Effect within 80km from the Nuclear Power Plant			-0.0112		-0.0094
			[0.0140]		[0.00956]
Effect within 100km from the Nuclear Power Plant			-0.0125		-0.0137
			[0.0173]		[0.0193]
Air dose rate>0.23(μSv/h)				0.00488	0.00455
				[0.00670]	[0.00410]
Air dose rate>0.45(μSv/h)				0.0114	0.0096
				[0.00430]	[0.00346]
Air dose rate>0.7(μSv/h)				0.00111	0.00285
				[0.00284]	[0.00166]
Location fixed effect	YES	YES	YES	YES	YES
Year fixed effect	YES	YES	YES	YES	YES
Prefencture-specific Trends	YES	YES	YES	YES	YES
Observations	750	750	750	750	750
R-squared	0.999	0.999	0.999	0.999	0.999

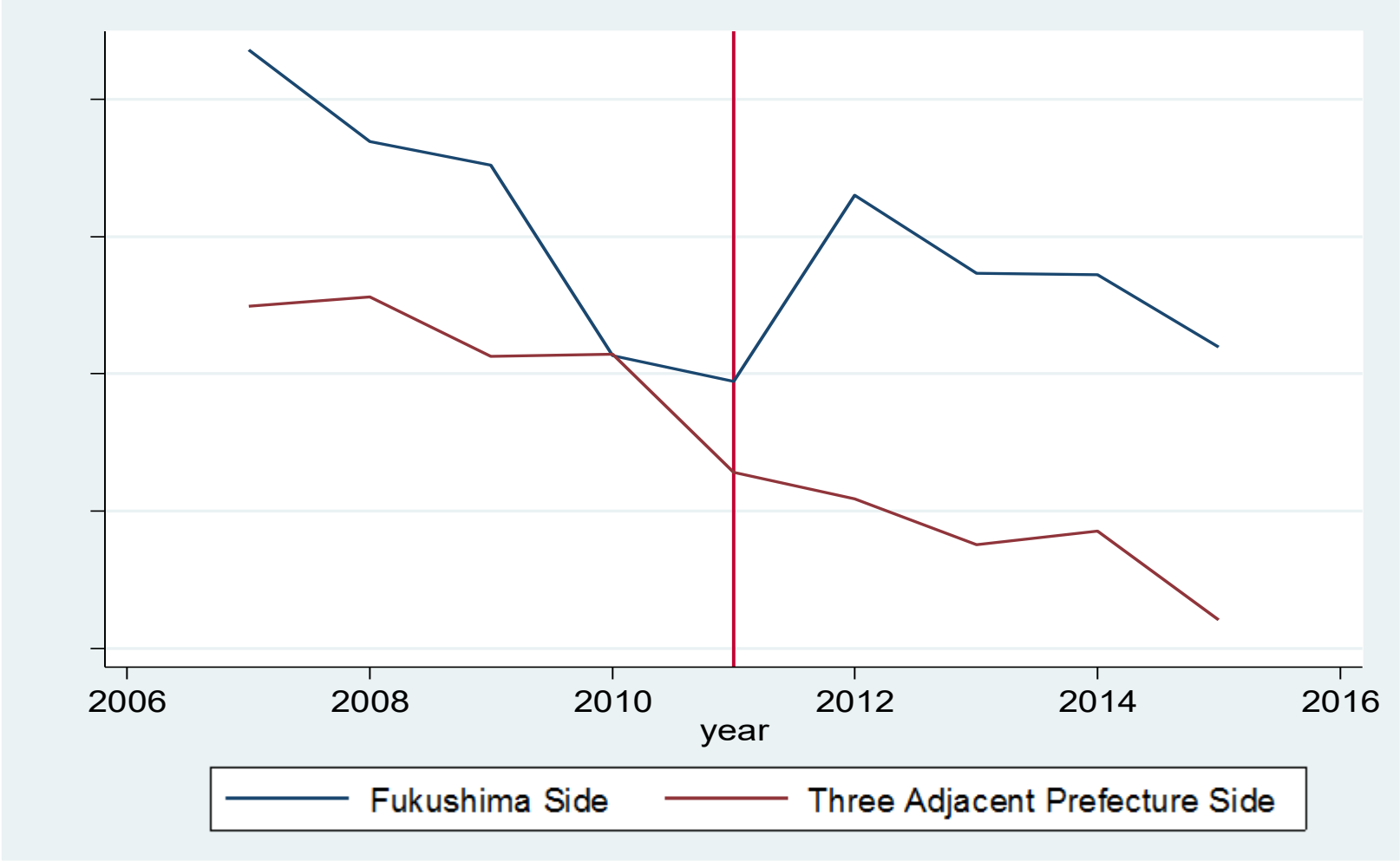
Standard errors are clustered at prefecture levels.

of Moving Out

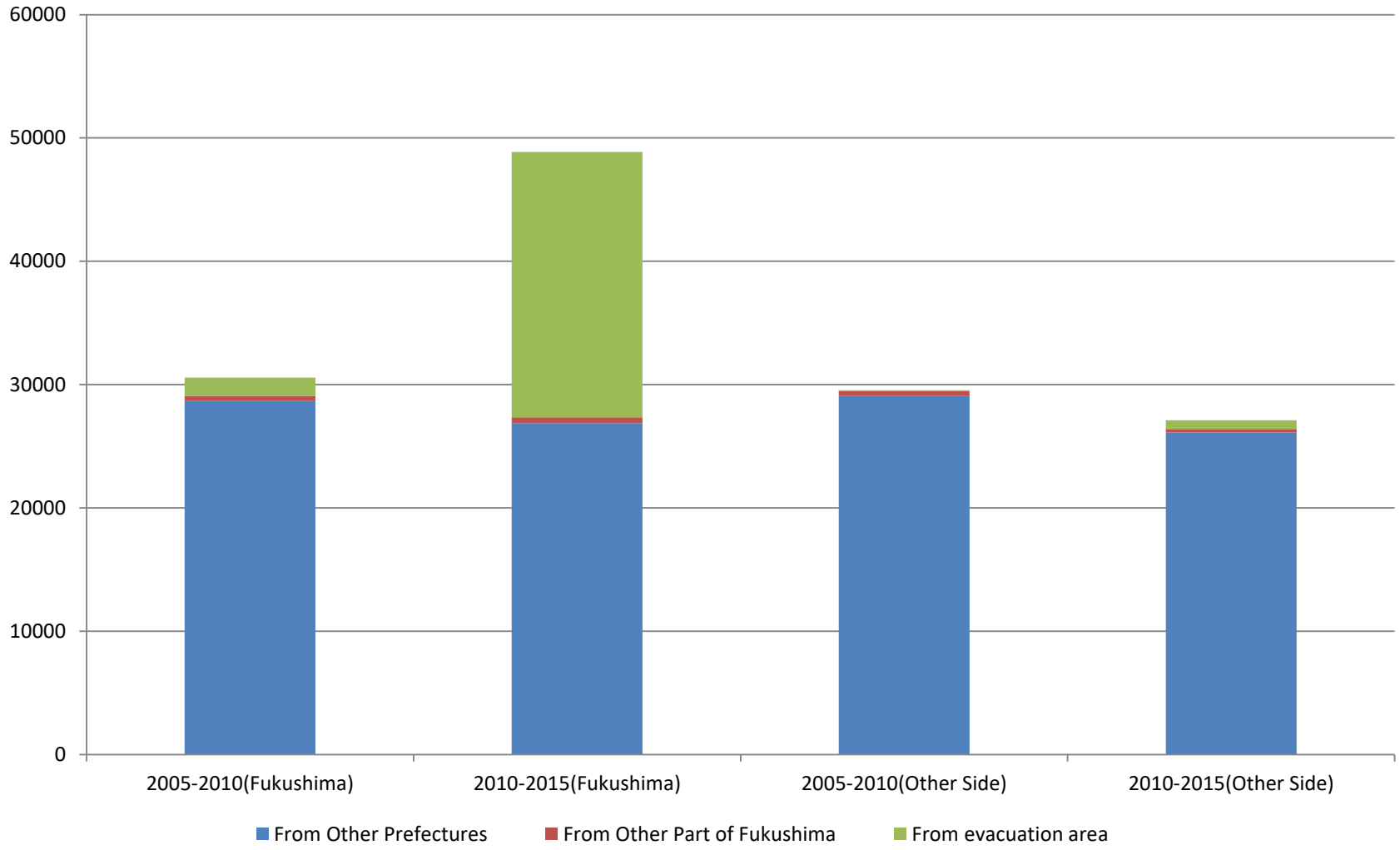
Based on Basic Resident Register



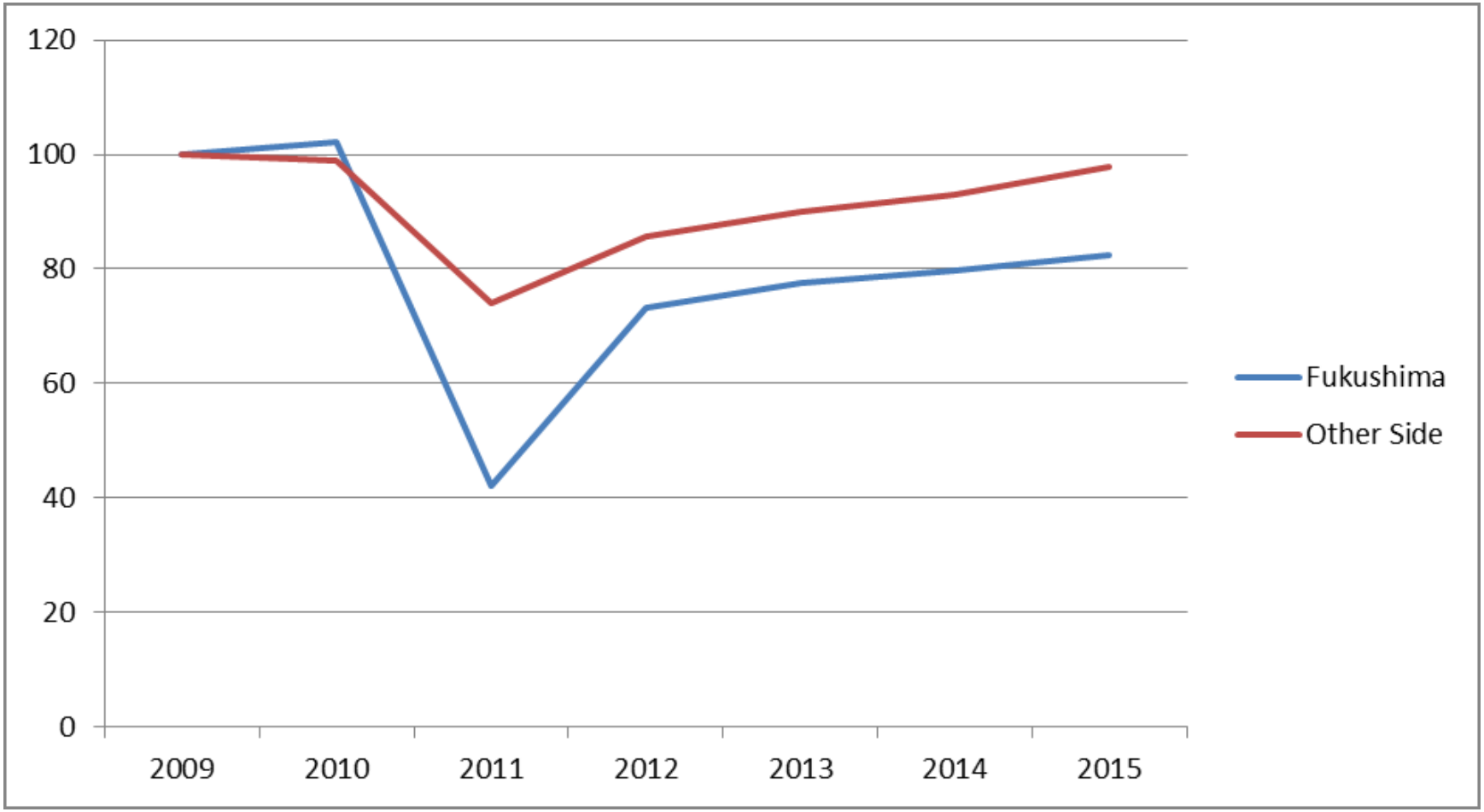
of Moving In
Based on Basic Resident Register



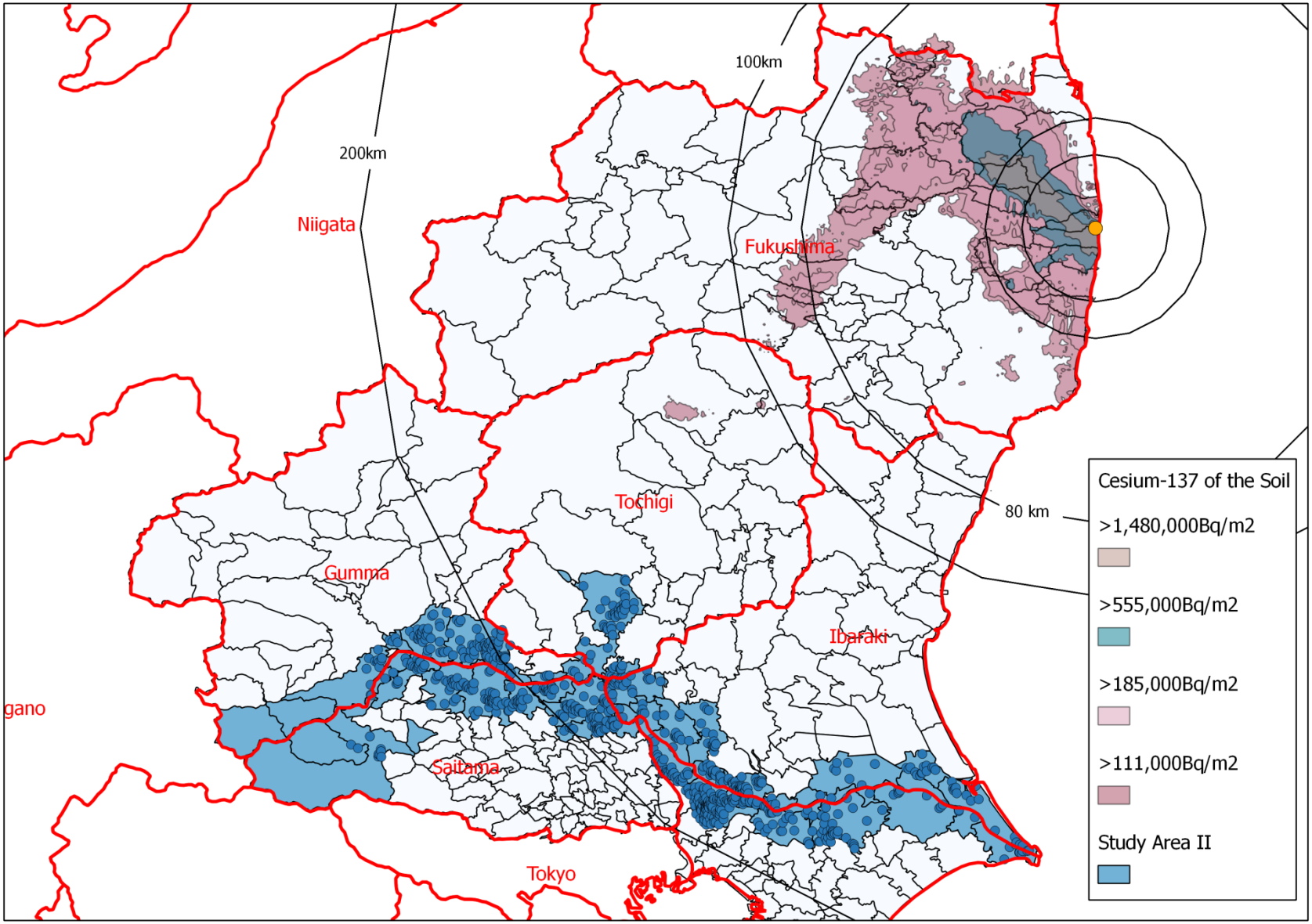
Where they came from?
Based on Census Data



of Tourists


120
100
80
60
40
20
0
2009
2010
2011
2012
2013
2014
2015
Fukushima
Other Side

Study Area II and Land Price Monitoring Locations(2012)



Specification for Study Area II

- We estimate the following regression

$$\log(LANDPRICE_{h,t}) = \alpha_h * 1(LOCATION_h) + \gamma_t * 1(Year_t) + \beta_1 * POSTDIS_t * 200Within_h$$
$$+ \beta_2 * POSTDIS_t * ITG_h + \beta_3 * POSTDIS_t * MUNICIP_h + \beta_5 RADIATION_{h,t} + \sum_{s=1}^{5} \kappa_s * (PREF_s * TIME_t) + \varepsilon_{s,h,t}$$

- s: prefecture, h:location, t: year
- Location and year fixed effects as well as prefecture-specific time trends
- **A dummy variable of post-disaster (2011.3)** is interacted with
  - Dummy variables of locations
    - 1 if within 200km from the Fukushima Daiichi Nuclear Power Plant, otherwise 0
  - A dummy variable of
    - 1 if located in Fukushima's Surrounding Prefectures(Ibaraki, Tochigi, and Gunma) , otherwise 0
  - Dummy variables of actual radiation level
    - 1 if air dose rates 1m above the ground surface is more than 0.23μSv/h, otherwise 0
    - 1 if air dose rates 1m above the ground surface is more than 0.4μSv/h, otherwise 0

Summary Statistics

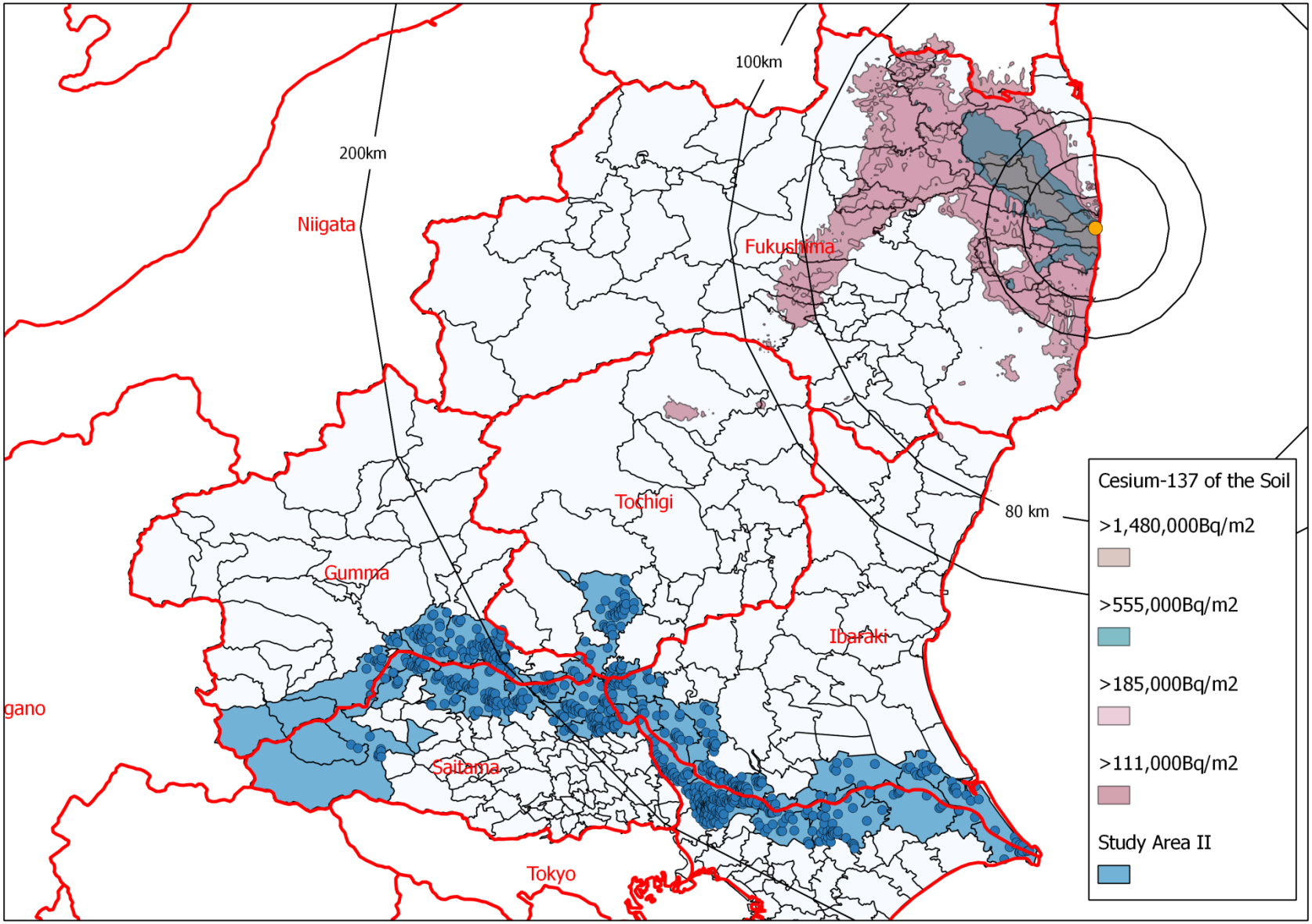
Study Area II	Obs	Mean	Std. Dev.	Min	Max
Land Price (yen/m2)	3096	60794	83812	535	1490000
Log(Land Price)	3096	10.71	0.74	6.28	14.21
Air dose rates 1m above the ground surface(μSv/h)	3096	0.134	0.078	0.054	0.700
A Dummy Variable of the Surrounding Prefectures of Fukushima	3096	0.478	0.500	0	1
Distance from the Power Plant (km)	3096	192.5	12.8	155.5	238.7

Result: Study Area II

VARIABLES	(1)	(2)	(3)	(4)
Effect within the Surrounding Prefectures of Fukushima	-0.0231			-0.0237**
	[0.0130]			[0.00678]
Effect within 200km from the Nuclear Power Plant		-0.0132		-0.0101
		[0.0127]		[0.0110]
Air dose rate>0.23(μSv/h)			-0.00664*	-0.0086
			[0.00299]	[0.00498]
Air dose rate>0.45(μSv/h))			0.00575***	0.0136*
			[0.000701]	[0.00324]
Location fixed effect	YES	YES	YES	YES
Year fixed effect	YES	YES	YES	YES
Prefencture-specific Trends	YES	YES	YES	YES
Observations	3,096	3,096	3,096	3,096
R-squared	0.999	0.999	0.999	0.999

Standard errors are clustered at prefecture levels. Highest value of air dose rate is 0.7. Thus, a dummy variable of air dose rate >0.7 is dropped from the regression

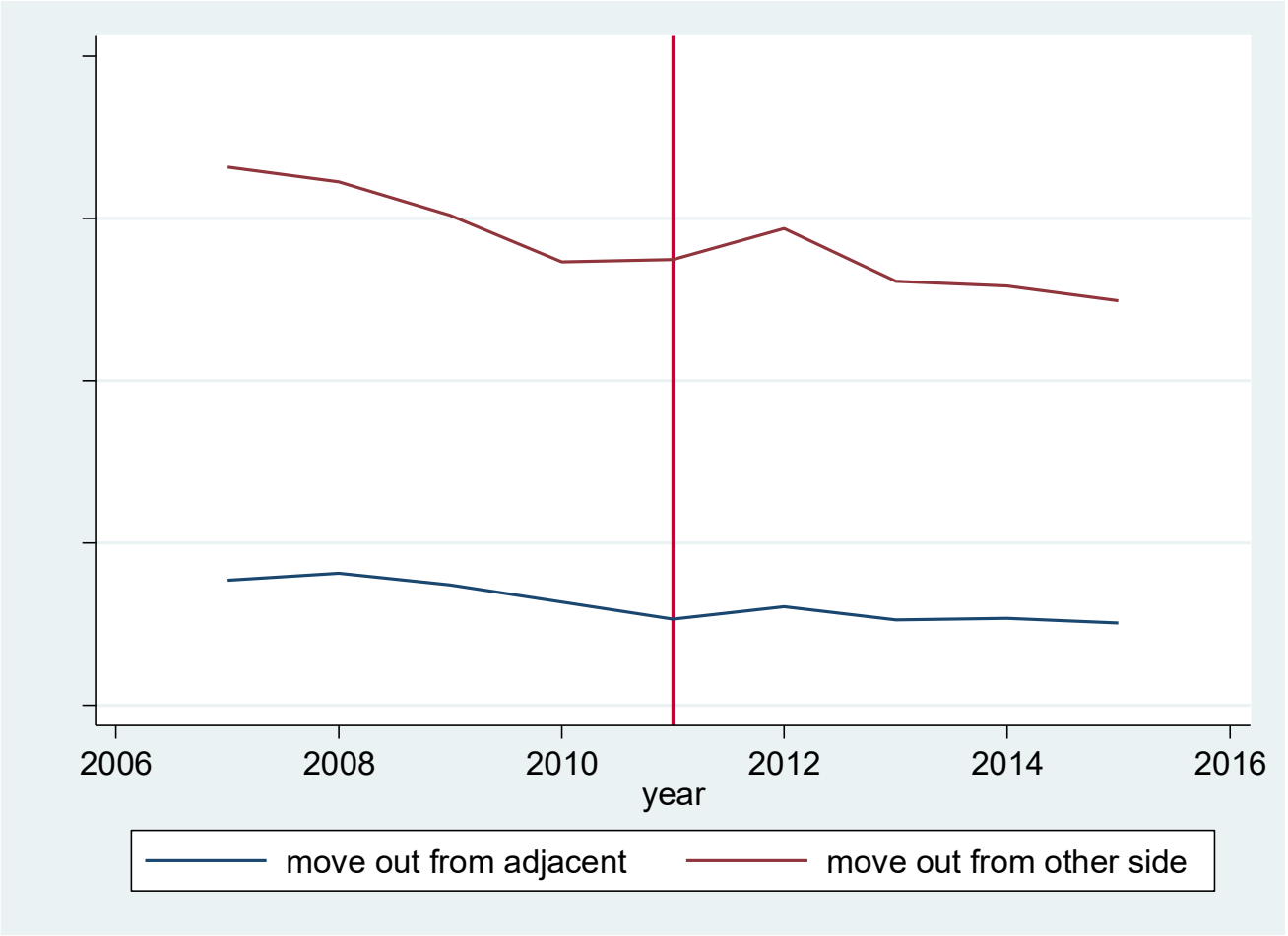
Study Area II and Land Price Monitoring Locations(2012)



Move in


2006
2008
2010
2012
2014
2016
year
move into adjacent
move into other sides

Move out


2006
2008
2010
2012
2014
2016
year
move out from adjacent
move out from other side

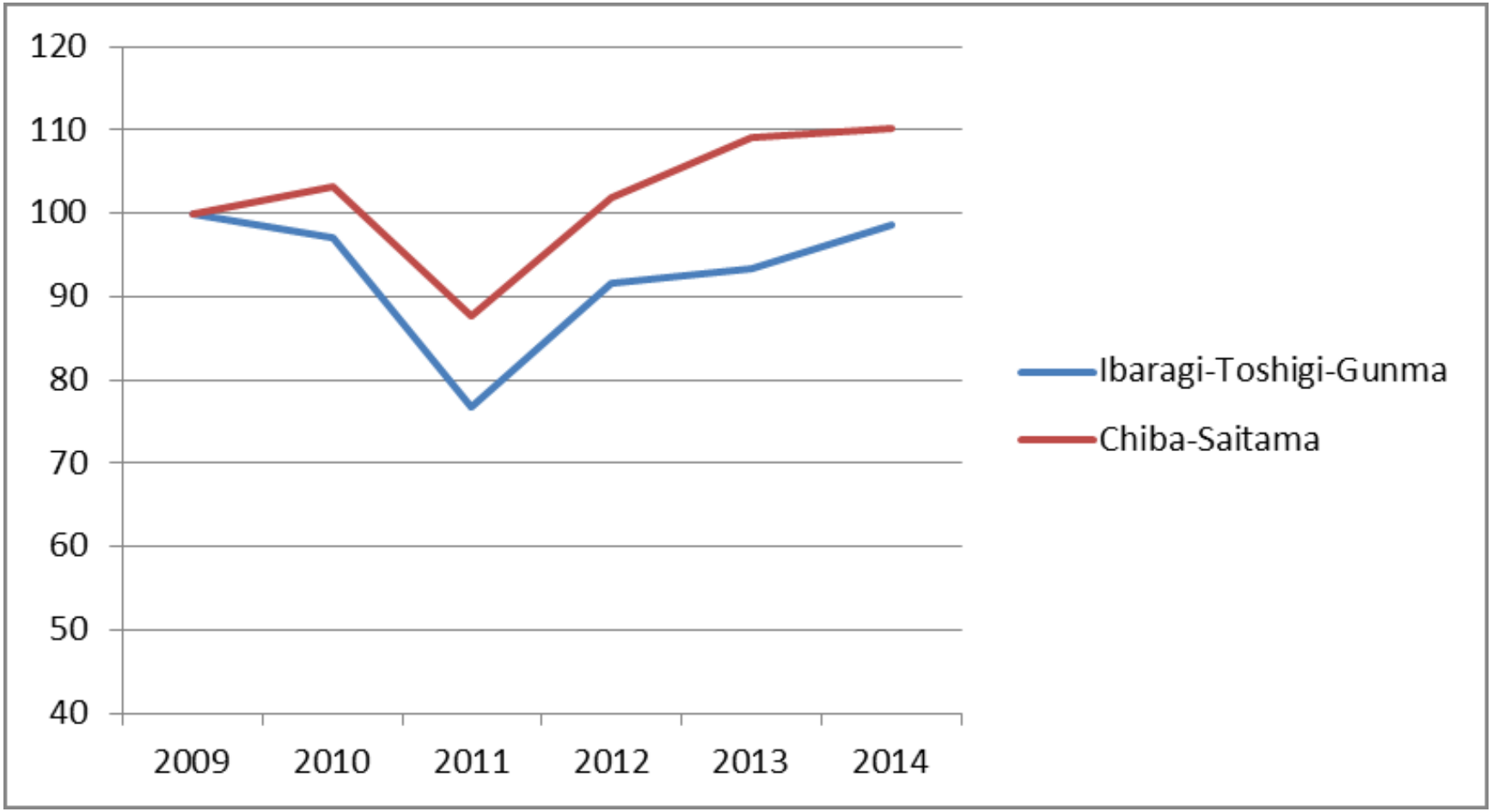
Population Movement Census

Move in	2005-2010	2010-2015	Reduction (%)
To Adjacent Prefectures	96050	82410	14.2%
To Other Sides	276420	242924	12.1%
Move Out			
From Adjacent Prefectures	142000	131432	7.4%
From Other Sides	200152	183899	8.1%

Population Movement Census

Move out from	Where?	2005	2010	Reductio(%)
Adjacent	inter-prefecture	79637	73538	7.66%
Adjacent	intra-prefecture	62363	57894	7.17%
Other side	inter-prefecture	102767	97003	5.61%
Other side	intra-prefecture	97385	86896	10.77%

Ibragi-Tochigi-Gunma v. Chiba-Saitama Number of Tourists



Main Results

- Controlling for the effects of the actual levels of radiation and radial distance from the Fukushima Daiichi Nuclear Power Plant, we find that the land price of the sites located in the Fukushima side of the border decreased significantly more than the ones located in the other side of the border, after the incidence of Fukushima Daiichi nuclear disaster
- We also find that the land price of the sites in the Ibaraki, Tochigi, and Gunma side of the border decreased more than the ones in the other side of the border, after the incidence of Fukushima Daiichi nuclear disaster
- We do not find any significant decline in the land price in the sites of relatively high levels of actual radiation as well as within 80km/100km/200km radial distance from the Fukushima Daiichi nuclear power plant.
- This shows that people responded to health risk information based on prefecture boundaries rather than the actual health risk or radial distance from the nuclear power plant.
- We also show that tourists responded to prefecture-based information.
- Stigmatization on Fukushima and its surrounding three prefectures.

Residential Movement

- More people move out from the Fukushima side of the border within one year from the disaster. After one year, it goes back to the previous trend
- More people move into to the Fukushima side of the border. Many are displaced from the area near the Fukushima nuclear plant. This did not lead to the increase in land price in the Fukushima side.
- In the border between three adjacent prefectures of Fukushima and their outer prefectures, no significant change in # of move in and out was observed
- However, land price was declined even in three adjacent prefectures of Fukushima prefecture.

How much is the total loss?

- Assuming that (1) this prefecture-border effect is purely a product of misinformation of risks or/and noisy rumors about radiation risks , (2) the estimate is applicable to the entire Fukushima, Gunma, Tochigi, Ibaraki prefecture, and (3) northern municipalities of Chiba and Saitama were NOT affected by misinformation or/and noisy rumors about radiation risks.
- Given that average land price in Fukushima prefecture was 31579 yen/m2
- Total residential area of Fukushima : 431.21km^2
- Our estimate suggests that 376 billion yen ($3.8 billion) losses attributed to the misinformation of risks or/and rumors.
- Accordingly,
  - **Fukushima:** 376 billion yen (3.8 billion dollars)
  - **Ibaraki:** 617 billion yen (6.28 billion dollars)
  - **Tochigi:** 466 billion yen (4.74 billion dollars)
  - Gunma: 445 billion yen (4.53 billion dollars) Total of Four Prefectures: 1,904 billion yen (19.3 billion dollars)
- This is 1.5 times as much as the total estimate of rumor-related damage by the government panel, which calculated rumor-related damage based on the sales of the agricultural/forestry /fishery/food/tourism/ manufacturing/service sectors.

Policy Recommendation

- Distance-based communication is good!!!
- Distance-based communication is less likely to harm local economy in long-run unless the areas are set as restricted areas.
- It is not bad idea to start with the evacuation area with the larger radius, and then gradually shrink evacuation zones.
- “Over-react first policy” works for distance-based communication.

Policy Recommendation

- Our results suggest that the prefecture effects are significantly related to a reduction in land price as well as # of moving in/out and tourists after the accident.
- This means that we have to be VERY careful when we communicate with prefecture-based information to the public.
- Although health risk information based on prefecture has an obvious advantage of distilling large and complex risk information into a simple one, the government, media, and other organizations need to recognize and carefully examine the potential of misclassifying non-contaminated areas into contaminated prefectures, because economic loss due to the misclassification is quite large.
- “Fukushima Daiichi Nuclear Power plant” is bad name.

Discussion and Policy Recommendation

- Japanese government, mass media, and health researchers need to carefully examine the nature of distance-based and prefecture-based communications in the early stage of risk communication.
- Because it harms the local economy. We need to seek the way to protect people from the diaster “and” protect local economy from the unnecessary stigmatisation.

Thank you

year	move into adjacent	move into other sides	move out from adjacent	
2007	35658	90581	35363	86380
2008	35691	90340	36220	84473
2009	35033	86523	34777	80368
2010	32785	77278	32677	74686
2011	29935	76012	30608	74911
2012	29251	75207	32089	78724
2013	28915	69234	30488	72279
2014	28896	69731	30650	71665
2015	28856	68277	30132	69825

	2005-2010(Fukushima)	2010-2015(Fukushima)	2005-2010(Other Side)	2010-2015(Other Side)
From Other Prefectures	28657	26868	29067	26111
From Other Part of Fukushima	409	478	409	290
From evacuation area	1504	21506	64	698