

Supplementary Methods

Supplementary Table 1. The List of Towns Excluded for Donor Pool

Island Towns, Prefecture and Tokyo	Awashimaura, Sado (Niigata), Okinoshima (Shimane), Kamijima (Ehime), Tonosho, Shodoshima (Kagawa), Amagi, Amami, China, Iriomotejima, Isen, Kikai, Minamitane, Mishima, Nakatane, Setouchi, Tatsugo, Tokunoshima, Toshima, Uken, Yakushima, Yamato, Yoron, Wadomoari (Kagoshima), Okinawa, Tokyo
Missing Data	Minami-Ise, Kihoku (Mie), Hokkaido
Tottori Seibu (2000)	Daisen (Tottoti), Tonosho (Kagawa)
Geiyo (2001)	Hirao, Tabuse (Yamaguchi)
Noto Hanto (2007)	Hodatasu-Shimizu, Suzu (Ishikawa)
Surugawan (2009)	Higashi-Izu, Kawazu, Matsuzaki, Minami-Izu, Shimoda (Shizuoka)
Tohoku (2011)	Hashikami (Aomori), Hirono, Yamada (Iwate), Onagawa (Miyagi), Tomioka (Fukushima), Oarai (Ibaraki)
Awajishima (2013)	Minamiawaji (Hyogo)
Kumamoto (2016)	Ashikita, Minamata (Kumamoto)
Tottori Chubu (2016)	Kotoura, Yurihama, Kitasakae (Tottori)

The earthquakes that caused damage to housing equal to one or more instances of houses being half-destroyed are used to identify towns excluded for the donor pool. Disasters that hit inland areas and those that overlap with areas affected by other disasters are not considered. The list is compiled from the Japan Meteorological Agency¹.

Migration Destinations

A closer look at the migration statistics, specifically the destinations of migration from four towns that were most severely affected by the earthquake and tsunami, provides several key insights. Supplementary Table 2 and 3 summarize migration destinations using net out-migration: that is, the excess of out-migration to a given destination over in-migration from it. For example, net out-migration from Minamisanriku to Tome City is calculated by subtracting migration from Tome to Minamisanriku from migration from Minamisanriku to Tome. All figures use totals from 2012 to 2016. The results show that even when evacuees chose to leave their hometowns, more than half relocated to neighboring towns. In Supplementary Table 2,

71.99% of net out-migration from Minamisanriku went to neighboring Tome City, while just over 50% from Otsuchi went to neighboring Kamaishi City. Supplementary Table 3 reveals the same pattern in Yamamoto (the fourth most affected town in Miyagi), where just over 50% of net out-migration went to neighboring Watari Town.

These patterns indicate that the majority of evacuees seek to live near their hometowns if they are not able to return to their original location. Evacuees from Onagawa who relocated to the neighboring Ishinomaki city explained during an interview, “I thought I had let go of my attachment to my hometown, but I became aware that for Onagawa natives, the center of the world is Onagawa. I want to go back in the future”². Second, evacuees tended to migrate to the most populous neighboring towns. As shown in Supplementary Tables 2 and 3, the top migration destinations, i.e., Watari Town for Yamamoto, Tome City for Minamisanriku, and Kamaishi City for Otsuchi, are each the largest or second-largest neighboring town by population. This is intuitive: for evacuees who have endured extraordinary hardship, relocating to a more populous nearby city offering better access to essential services, employment, and schools would be a natural choice.

Third, 20 to 30% of evacuees migrated to the prefectural capitals: Morioka City for Iwate and Sendai City for Miyagi. Some may assume that evacuees from towns in Iwate could have also chosen to relocate to Sendai, the most populated area in the Tohoku region with more than one million residents. Such assumptions are inaccurate, as some 30% of evacuees in Otsuchi migrated to Morioka and only 6.58% of them migrated to Sendai. While some 20% of the displaced population from Rikuzentakata relocated to Sendai, residents in towns at the southern tip of Iwate that share a border with Miyagi Prefecture may not perceive various hurdles to crossing the prefectural border as strongly as the majority of evacuees in Iwate.

The descriptive statistics and testimony align with six general principles of migrant destination selection¹⁶. Three of these principles, linked to migration driven by environmental change, are particularly relevant to post-disaster migration in the Tohoku context. First, displaced evacuees prefer to rebuild in their hometowns (immobility). Second, those who do relocate tend to move only short distances (short distance). Third, evacuees do not migrate to the most attractive cities overall, but rather to the most attractive towns near their hometowns (intervening opportunity).

Supplementary Table 2. Excess of Out-migrants by Destination: Minamisanriku and Otsuchi

Minamisanriku	(2012-2016)	Otsuchi	(2012-2016)
Destination	Number (%)	Destination	Number (%)
Tome	892 (71.99)	Kamaishi	247 (56.01)
Sendai	280 (22.6)	Morioka	131 (29.7)
Ishinomaki	47 (3.79)	Sendai	29 (6.58)
Kesennuma	20 (1.61)	Hanamaki	17 (3.85)
		Kitakami	15 (3.4)
		Miyako	2 (0.45)
Total	1,239 (100)	Total	441 (100)

Supplementary Table 3. Excess of Out-migrants by Destination: Yamamoto and Rikuzentakata

Yamamoto	(2012-2016)	Rikuzentakata	(2012-2016)
Destination	Number (%)	Destination	Number (%)
Watari	569 (51.35)	Morioka	108 (29.26)
Sendai	269 (24.27)	Sendai	83 (22.49)
Iwanuma	148 (13.36)	Ofunato	76 (20.6)
Natori	64 (5.78)	Ichinoseki	49 (13.28)
Kakuda	32 (2.89)	Oshu	21 (5.69)
Shibata	26 (2.35)	Kitakami	18 (4.88)
Soma	2 (0.18)	Takizawa	6 (1.63)
		Kesennuma	5 (1.36)
		Hanamaki	3 (0.81)
Total	1,110 (100)	Total	369 (100)

While the table shows two different patterns of migration destinations, more importantly, there is a large difference in the absolute size of migration out of towns relative to their

population between towns in Iwate and Miyagi. Although the various metrics of Otsuchi and Minamisanriku indicate that these towns share some similarities, the excess of out-migration amounts to 441 in Otsuchi and 1,239 in Minamisanriku, which is 2.81 times larger than Otsuchi. The same goes for Yamamoto, which also shares similarities with Otsuchi, with an excess of out-migration amounting to 1,110, 2.52 times larger than Otsuchi. Even when many major indicators are held constant, the extent of depopulation through migration differs, indicating that the existence of more populous towns nearby drives depopulation in Miyagi.

Supplementary Table 4 summarizes the population of towns in March 2010, a year before the disaster, followed by a paragraph with each section providing an overview of the population in each region. Taken together, the existence of populated cities and the resulting difference in population between evacuees' hometowns and cities of regional centers impact the composition of migration destinations from affected towns (relative term) and the number of migration flows (absolute term).

Supplementary Table 4. Population by Municipality Grouped by Area as of 2010

Miyagi		Iwate	
Area/Town	Population	Area/Town	Population
Sendai Plain			
Sendai	1,045,902	Morioka	298,348
Southern Greater Sendai		Kamaishi Area	
Natori	73,138	Kamaishi	39,574
Iwanuma	44,170	Otsuchi	15,267
Watari	34,812		
Yamamoto	16,708		
Kenhoku Area			
Tome	83,956		
Minamisanriku	17,431		
Ishinomaki Area			
Ishinomaki	160,692		
Onagawa	10,052		

Sendai Plain, Miyagi (Sendai & Southern Greater Sendai): Among five towns in the Sendai Plain, a town that is located at the southern tip of Greater Sendai, Yamamoto experienced the most severe depopulation because evacuees from Yamamoto migrated out to the town of Watari, its northern neighbor, as shown in Supplementary Table 3. The population of Watari was only two times larger than Yamamoto. However, four towns and cities in southern Greater Sendai, listed from north to south as, Natori, Iwanuma, Watari, and Yamamoto, consist of residential areas for Sendai, drawing more population from Yamamoto to Watari, one town closer to Sendai.

Kenhoku Area, Miyagi (Northern Miyagi): The Kenhoku area consists of one city and one town, Tome City and Minamisanriku Town. Tome's population is 83,956, amounting to 4.81 times that of neighboring Minamisanriku. Evacuees from Minamisanriku migrated out to Tome City, as shown in Supplementary Table 2.

Ishinomaki Area, Miyagi (Ishinomaki & Onagawa): Similarly, the Ishinomaki area consists of one city and one town, Ishinomaki City and Onagawa Town. There is a larger population difference between Ishinomaki and Onagawa. Ishinomaki was home to 160,692 residents, the second-largest population among towns in Miyagi, amounting to a population 16 times larger than Onagawa.

Kamaishi Area, Iwate (Kamaishi & Otsuchi): The Kamaishi area also consists of one city and one town, Kamaishi City and Otsuchi Town. In comparison with towns in Miyagi, Kamaishi in Iwate has a population of 39,574, only 2.6 times larger than Otsuchi. Kamaishi is not a populated city itself, nor a gateway to a larger city, and thus Kamaishi was not as appealing as a post-disaster relocation destination for displaced residents in Otsuchi.

Supplementary Table 5. Calculation of the Population Advantage of the Neighbor (PAN)

Municipality	POP_2010	Identified Neighbor	POP_2010	PAN
Miyako	59,636	Yamada	18,810	0.32
Ofunato	40,219	Rikuzentakata	24,128	0.6
Kuji	37,979	Hirono	19,189	0.51
Rikuzentakata	24,128	Kesennuma	73,363	3.04
Kamaishi	39,464	Ofunato	40,219	1.02
Otsuchi	15,979	Kamaishi	39,464	2.47
Yamada	18,810	Miyako	59,636	3.17
Iwaizumi	11,080	Miyako	59,636	5.38

Tanohata	3,931	Iwaizumi	11,080	2.82
Fudai	3,052	Iwaizumi	11,080	3.63
Noda	4,757	Kuji	37,979	7.98
Hirono	19,189	Kuji	37,979	1.98
Sendai	1,011,592	Natori	72,350	0.07
Ishinomaki	161,636	Higashimatsushima	42,277	0.26
Shiogama	57,266	Tagajo	62,289	1.09
Kesenuma	73,363	Rikuzentakata	24,128	0.33
Natori	72,350	Sendai	1,011,592	13.98
Tagajo	62,289	Sendai	1,011,592	16.24
Iwanuma	43,903	Natori	72,350	1.65
Higashimatsushima	42,277	Ishinomaki	161,636	3.82
Watari	35,211	Iwanuma	43,903	1.25
Yamamoto	15,946	Watari	35,211	2.21
Matsushima	15,340	Rifu	34,859	2.27
Shichigahama	20,675	Tagajo	62,289	3.01
Rifu	34,859	Sendai	1,011,592	29.02
Onagawa	9,698	Ishinomaki	161,636	16.67
Minamisanriku	17,063	Tome	85,611	5.02
Soma	37,568	Minamisoma	70,516	1.88
Shinchi	8,277	Soma	37,568	4.54

Model Specification for OLS

First, because the distributions of regressors and the regressand are all right-skewed, we transformed the data with the natural log to induce a normal distribution. Second, considering that the municipalities that experienced large damage from the disaster tend to receive larger reconstruction investment, we ran a correlation matrix of regressors and checked the VIF for

each model. Variables are centered at their means to reduce the inflation of VIF caused by the inclusion of interaction terms. Third, we used robust standard errors to estimate our models because models analyzing population dynamics often produce heteroskedastic errors.

The pairwise correlation matrix shows that the correlation of each regressor to another is $|r| < 0.8$, lower than the conventional threshold indicating potential multicollinearity. We proceeded to check the VIF after mean-centering the variables, which showed that all regressors are independent, with $VIF < 5$.

Correlation Matrix

	<i>NET_MGR₀₀₁₀</i>	<i>RIPC</i>	<i>HDR</i>	<i>PAN</i>
<i>NET_MGR₀₀₁₀</i>	1.0000000	-0.4453257	0.1412695	0.2405831
<i>RIPC</i>	-0.4453257	1.0000000	0.61019427	0.01511215
<i>HDR</i>	0.1412695	0.61019427	1.0000000	0.002672352
<i>PAN</i>	0.2405831	0.01511215	0.002672352	1.0000000

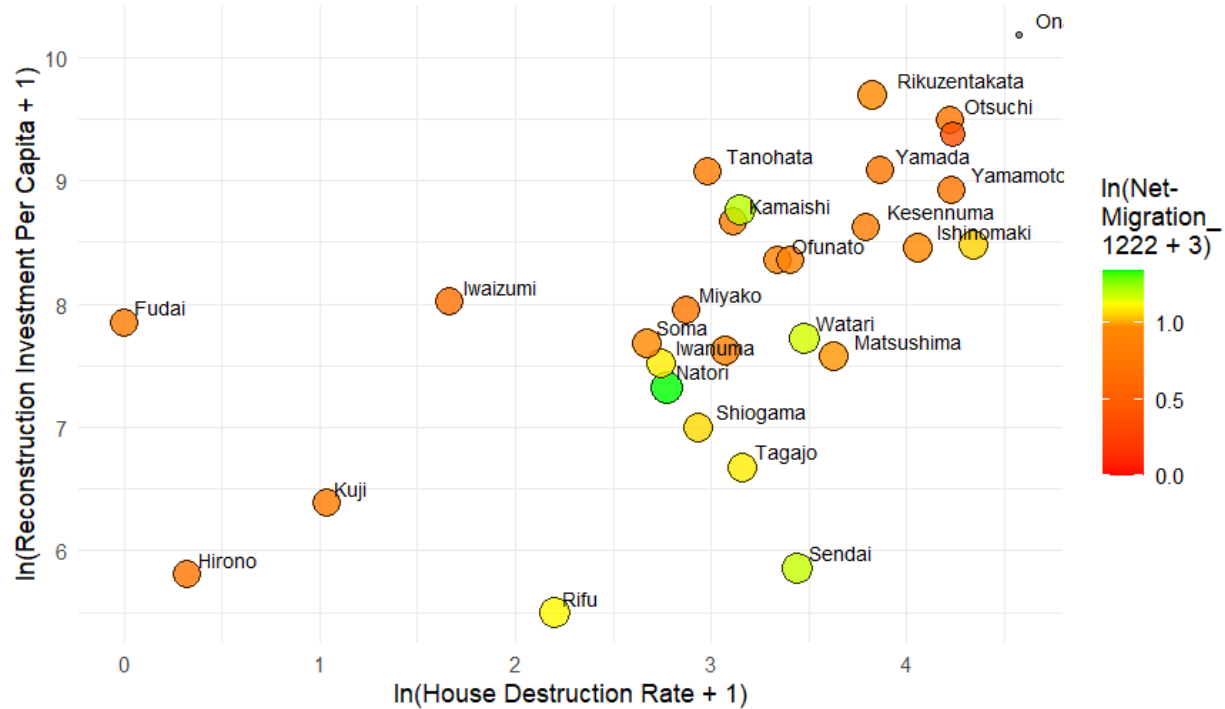
VIF Table (Natural Log-Centered Variables)

	<i>NET_MGR₀₀₁₀</i>	<i>RIPC</i>	<i>HDR</i>	<i>PAN</i>	<i>RIPC*PAN</i>	<i>HDR*PAN</i>
<i>Model 1</i>	2.53	3.16	2.63	1.25	1.55	NA
<i>Model 2</i>	2.57	3.19	2.60	1.17	NA	1.29
<i>Model 3</i>	2.63	3.19	2.63	1.57	3.00	2.49

The Results of Breusch–Pagan Test to Check for Heteroskedasticity

	<i>BP Test</i>	<i>df</i>	<i>p</i>
<i>Model 1</i>	16.1	5	0.007
<i>Model 2</i>	17.9	5	0.003
<i>Model 3</i>	16.7	6	0.01

Scatterplot of the House Destruction Rate and the Reconstruction Investment per Capita with Points Adjusted to the Average Net-migration from 2012 to 2022



Robustness Check: Using the Total of Reconstruction Investments (RIT)

	Model 1	Model 2	Model 3
Intercept	0.86	0.87	0.91
$\ln (NETMGR_{0010}+3)$	1.17***	0.96***	0.97***
$\ln (RIT+1)$	-0.07	-0.07	-0.07
$\ln (HDR+1)$	-0.04	-0.02	-0.02
$\ln (PAN+1)$	-0.12	-0.17*	-0.17***
$\ln (RIT+1)*\ln (PAN+1)$	-0.04		0.09
$\ln (HDR+1)*\ln (PAN+1)$		-0.17*	-0.28**
Model Statistics			
Residual Standard Error	0.26	0.23	0.22
Multiple R^2	0.58	0.67	0.71
Adjusted R^2	0.49	0.60	0.62

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$, $N=29$, All models are statistically significant with Model 1: ($F(5, 23) = 8.93$, $p < 0.001$), Model 2: ($F(5, 23) = 8.17$, $p < 0.001$), and Model 3: ($F(6, 22) = 7.34$, $p < 0.001$).

Supplementary References

1. Japan Meteorological Agency. Earthquakes occurred around Japan after 1996. <https://www.data.jma.go.jp/eqev/data/higai/higai1996-new.html> (2025).
2. Mainichi Shimbun. Out-migration in Onagawa, Miyagi, cannot wait for rebuilding hometown. <https://mainichi.jp/articles/20150309/mog/00m/040/007000c> (2015).