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From Ruin to Resilience: Post-Disaster Population Stability in Miyagi and Iwate

Abstract

The population of Japan has faced a demographic and population crisis greatly influenced by the triple disasters of March 11, 2011. These include the Great East Japan Earthquake, subsequent tsunami and Fukushima-Daiichi nuclear meltdown that resulted in immense loss of lives, displacement of persons, and economic damages. The lengthy recovery period that followed demonstrated the dissatisfaction among affected communities that feel that there is nothing to return to. This research paper demonstrates how the effectiveness of urban planning and rebuilding strategies can determine whether or not populations are maintained in disaster-affected towns. It seeks to identify factors that enable some towns to better retain their populations through an examination of housing destruction rates, tourism development, population density, reconstruction timelines and location. The statistical analyses and case studies show that changes in housing destruction rates and population density are significant drivers of population changes while factors such as city tax revenue are less important due to equitable distribution of national government reconstruction funds as well as international aid. Consequently, this study's findings highlight the

need for prioritization of residential and commercial reconstruction over disaster prevention infrastructure in order to minimize population decrease.

Intro

Japan, currently going through a well-documented demographic and population crisis, had its problems compounded by the triple disasters of March 11th, 2011. The Great East Japan Earthquake, which measured 9.0 on the Richter scale, triggered a tsunami that reached as high as 17m in some areas. The tsunami also compromised the Fukushima-Daiichi nuclear plant, and two nuclear reactors exploded in the coming days, releasing extreme amounts of toxic radiation. The disaster resulted in the deaths of over 16,000 residents, displaced over 300,000 residents, and led to over $300 billion in economic damages. The disaster, recognized as the costliest natural disaster in history, led to a decline of 47 basis points in Japan's GDP in the year following the disaster. This massive displacement pushed the limits of prefectural and federal government capacity, and Japan's recovery is still very much unfinished. A ten-year check-in survey found that "only 30 percent of Fukushima Prefecture residents say reconstruction has been sufficient." Time and time again, the sentiment that "there is nothing left for me to return home to" has been restated by local residents throughout the three affected prefectures.

As Miyagi, Iwate, and Fukushima continue to rebuild their communities over 14 years later, urban planners and city officials have been charged with finding a solution to the declining populations in rural towns. Cities in Miyagi and Iwate have, at best, experienced Compound Annual Growth Rates (CAGR) of ~1.3%, and, at worst, seen their populations shrink by more than 4.75%. As cities attempt to 'Build Back Better,' urban planners have been put to the test as they seek to entice old and new residents alike back to their community. As seen in Japan's past, disasters provide unique opportunities to spur societal and physical changes. For instance, the passage of universal male and female suffrage was greatly influenced by the 1923 Earthquake and events of World War II, respectively. Disasters have a unique ability to disrupt social fabrics, and the triple disasters of 2011 proved no exception. Evacuation orders scattered refugees across the country, and ever since, city planners have fought (sometimes futilely) to bring social and physical stability back to towns.

This struggle has spurred research and further examination into which factors play a role in maintaining populations after disasters. Throughout this paper, I will argue that cities that prioritize residential and commercial reconstruction projects rather than disaster prevention infrastructure find more success in mitigating population loss. I will examine the role of multiple factors, including destruction rate, tourism, population density, reconstruction timelines, and location, in determining why cities experience different levels of population change following disasters. Through statistical analysis and case studies, I will determine the impact of urban planning and design on a city's resilience to population changes. The results of the study highlight the necessity of timely housing solutions within broader urban planning and disaster recovery strategies. Housing reconstruction is essential for supporting a growing population, and prioritizing it can significantly aid in population maintenance post-disaster.

Alternative Explanations

Social scientists have begun to study the impact of urban design on disaster recovery, although little research has been done on the impact this has on population change. However, the prevailing belief is that urban spaces in 21st century Japan have been driven by the need to encourage tourism, rather than grow local populations.[1] While this was a common theme I heard in conversations with

[1] Horita, Yumiko. 2017. "Urban Development and Tourism in Japanese Cities." *Tourism Planning & Development* 15 (1): 26–39. doi:10.1080/21568316.2017.1313774.

city officials in rebuilding communities like Rikuzentakata and Onagawa, the on-the-ground reality plays out very differently.

Before the triple disasters, “tourism [had] gradually become a key activity reinforcing the Japanese economy.” This was a trend, “not only in the large metropolises, but also in small and medium-sized regional cities.”[2] Urban and suburban tourism has increasingly become important to Japan’s economy, and as the state continues to transition into the tertiary and quaternary sectors, vacationers become an increasingly important revenue stream. Some cities, like Onagawa town, have chosen not to build protective sea walls so as to not impede the views of the ocean that it claims would draw tourists to the small town. Rather than tourism, the lack of a sea wall has much more to do with the revival of the nearly $70 million fishing industry that the town boasted prior to March 2011.[3] Leaders from the Onagawa Tourist Association claim that the sea is an integral part of life, and for a city so reliant on the ocean for its economy, building a seawall would have been wildly unpopular with residents. While tourism serves as a reasonable explanation for urban development and population maintenance in large urban centers like Tokyo and Kyoto, the argument weakens significantly when applied to fishing villages on the Sanriku coast.

The reasoning that tourism cannot be used as an explanation for development and, by extension, population changes, is simple – tourists don’t come to places like Onagawa. Miyagi and Iwate rank among the lowest prefectures in terms of tourism rates, ranking 21st and 38th, respectively, in terms

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[2] Horita, Yumiko. 2017. “Urban Development and Tourism in Japanese Cities.” *Tourism Planning & Development* 15 (1): 26–39. doi:10.1080/21568316.2017.1313774.
[3] Cosson, Camille. 2020. “From a Tsunami-Devastated Zone to an Attractive Fishing Town: A Study on Onagawa’s Strategy for a Prompt Recovery.” *Urban Geography* 41 (5): 777–90. doi:10.1080/02723638.2020.1780054.

of visitors annually.[4] Between the two prefectures, they see less than 700,000 visitors annually, many of these are concentrated in Sendai, one of Japan's largest cities, boasting over one million residents.[5] Visitors that don't go to Sendai often spend their time in remote natural areas of the prefectures.[6] The combination of limited visitor numbers to Miyagi and Iwate, the concentration of tourists in Sendai, and the preference for remote nature vacations means that few tourists venture to the disaster-affected cities along the Sanriku coast. Unfortunately, while many cities have an optimistic belief that 'disaster tourism' will bring hoards of eager learners and spenders, the lack of transportation infrastructure and remote nature of these small towns means tourism cannot truly be counted on as a reliable revenue stream. Further, rural populations are declining as a whole as young people leave to major cities in search of better opportunities. This leaves towns like Onagawa with not only a declining population, but also an aging population.

While tourism has been touted as an explanation for the development of these towns, it is not an effective one. Japan's reconstruction process often takes into account the views of residents, and these residents rarely list "tourism" as a top priority for their rebuilding.[7] Ultimately, tourism plays a much smaller role in reconstruction than many city officials and social scientists believe, and should not be treated as a meaningful confounding variable when examining which factors influence population changes.

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[4] Arba, Alexandru. "Japan: Most Visited Prefectures by Foreign Tourists 2020." Statista, May 19, 2022. https://www.statista.com/statistics/657560/japan-most-visited-prefectures-by-foreign-tourists/.

[5] "Data List: 日本の観光統計データ." Japan Tourism Statistics | 日本の観光統計データ. Accessed July 21, 2024. https://statistics.jnto.go.jp/en/graph/.

[6] Murayama, Takatoshi, Graham Brown, Rob Hallak, and Kohsuke Matsuoka. 2022. "Tourism Destination Competitiveness: Analysis and Strategy of the Miyagi Zaō Mountains Area, Japan" *Sustainability* 14, no. 15: 9124. https://doi.org/10.3390/su14159124

[7] Basic Guidelines for Reconstruction from the Great East Japan Earthquake After The "Reconstruction and Revitalization Period." Accessed July 21, 2024. https://www.reconstruction.go.jp/english/topics/Laws_etc/2019Dec_basic-guidelines_full-text.pdf.

Literature Review

A comprehensive review of the literature on the subject reveals the methods of studying urban development and population changes throughout Japanese history. An analysis of the *Japanese Urban Systems 1970-1990,* an article by economics professor Susumu Osada who studies urban population shifts in Japan, uncovers important historical context about how Japanese cities have developed. Japan has gone through different periods of development where populations concentrate into specific areas. These areas, known as JFUA (Japanese Functional Urban Areas) [*Figure 1*], create a metric of analysis used to understand population changes over time. Historically, Japan experienced sharp postwar economic growth in the 1950s and 1960s. This process led to the industrialization and concentration of population into metropolitan areas – mainly Tokyo, Kansai, and Nagoya.[8] In later years, economic slowdown due to the global oil crisis depopulated the major urban centers and saw the rise of non-metropolitan areas.[9] Like many other developing countries, port cities thrived on the import and export of natural resources. However, industrial shifts away from the primary sector saw some of these cities lose their importance, although not completely.[10]

While the historical context of settlement patterns is useful in understanding population trends in an economic context (another influential factor to be further examined later), some issues arise when using this method to examine settlement patterns. Osada notes that spatial units, such as the JFUA, can be interpreted differently, and while terminology attempts to provide consistency, the

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[8] Susumu Osada, "The Japanese Urban System 1970–1990," *Science Direct* 59, no. 3 (March 28, 2003): 125–231, https://doi.org/10.1016/s0305-9006(02)00111-3.

[9] Takahashi, J., and N. Sugiura. "The Japanese Urban System in Transition." In *unpublished conference paper*. 1992.

[10] Susumu Osada, "The Japanese Urban System 1970–1990"

varying interpretations of JFUAs can lead to further inconsistency in levels of analysis and may require further examination. For purposes of this paper, however, they serve to build an important understanding of how population centers have, or haven't, evolved over time.

In the years leading up to 1990, non-JFUA regions show a relative declining population, further cementing the importance of metropolitan areas. As Osada puts it, "Although the population of non-JFUAs grew in absolute terms, it declined relative to the national total."[11] However, in later years, non-JFUAs declined in both absolute terms and relative terms. Much of this stems from changes in production focus as Japan's economy shifted from the primary sector to the secondary sector. The chart below [*Figure 2*] depicts the changes in sector employment over time. Japan's economic development post-1970, which, relative to other nations, occurred quite rapidly, had a large impact on population centers and their geographic distribution.

When zooming in on the Miyagi and Iwate prefectures, the population decline issues become even more apparent. Despite heavy subsidies and incentives from the government, including financial gifts to cover the cost of children, college educated students, marriage, and transportation, some cities saw population declines of more than 15% in the last decades.[12] In spite of these generous opportunities, individuals have left in droves as both push and pull factors bring them away from the small towns of the Sanriku coast. Stable jobs in major cities like Sendai and Tokyo have pulled people in, and peace of mind surrounding issues of safety and future disaster have pushed people to abandon their small villages and migrate towards metropolitan areas around the country.

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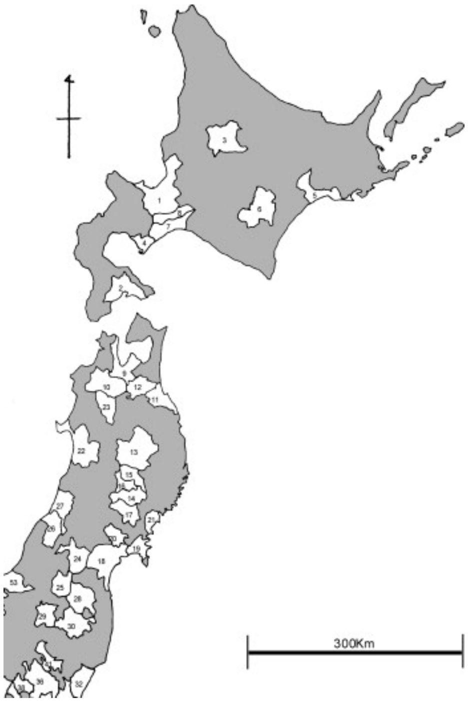
[11] Susumu Osada, Ibid.

[12] Daniel P. Aldrich, *Black Wave: How Networks and Governance Shaped Japan's 3/11 Disaster*, 118

Figure 1



Source: The Japanese Urban System 1970–1990

Description: This figure shows the distribution of JFUA throughout the country, with a clear lack of JFAUs in the Sanriku region.

Figure 2

Sector	1970 (Japan)	1990 (Japan)	2021 (Iwate/Miyagi)
Primary	19%	7%	1%
Secondary	34%	33%	17%
Tertiary+	47%	59%	81%

Source: The Japanese Urban System 1970–1990, Statistics Bureau of Japan

Description: This table captures Primary, Secondary, and Tertiary+ (tertiary, quaternary, etc.). Primary includes all jobs regarding the acquisition of natural resources: fishing, agriculture, mining, etc. The secondary sector includes all manufacturing and construction jobs, and Tertiary+ includes everything else: service work, IT, etc. This table shows the tail end of Japan's post-war industrialization and the shift at the beginning of the 21st century to service work and beyond, even in the more rural Iwate and Miyagi prefectures.

Disaster reconstruction in Japan is also an area that has garnered much academic attention. Rebuilding in the rural-urban fringe has been carefully studied, and ideas like the "Reconstruction Paradox" have emerged. The Reconstruction Paradox insists that despite rational thought that reconstruction efforts would encourage the population to stay or increase in size, a "larger number of population emigrates from the affected area if the municipality devotes itself to the larger recovery project with heavy reconstruction projects."[13] While this could be due to a myriad of factors, including noise, traffic, loss of hometown feel, or time, this paradox spurs many of the questions this study looks to answer. Considering the persistence of population decline amidst reconstruction projects, what can cities do to bring back old and bring in new residents?

The current state of reconstruction is one guided by a "top-down" decision tree, where "many decisions are deferred to higher levels in the hierarchy before municipal governments can act."[14] This can be partially attributed to two main factors. Firstly, the central government in Japan is more highly influenced by the government at the federal level than the local government at the prefecture level. The central government, which has funded nearly all of the reconstruction within prefectures, naturally has the most influence on how their dollars get spent. Second, many prefectures lack subject matter experts in individual towns, meaning that towns and local governments rely heavily on experts at the federal level to help them plan reconstruction projects. Towns that have strayed from the norm have chosen to ignore recommendations from regional and national governments and quickly institute their own vision; this is the exception, rather than the

[13] Shingo Nagamatsu, "Building Back a Better Tohoku after the March 2011 Tsunami: Contradicting Evidence," *Advances in Natural and Technological Hazards Research*, July 13, 2017, 37–54, https://doi.org/10.1007/978-3-319-58691-5_3.
[14] Kenji Muroi, "Post-Disaster Reconstruction in the Rural-Urban Fringe Following the Great East Japan Earthquake," *E3S Web of Conferences* 340 (2022): 03001, https://doi.org/10.1051/e3sconf/202234003001.

norm.[15] However, even cities that institute their own plans run into their own issues. Shingo Nagamatsu, public policy expert and economic recovery professor, suggests that cities that institute their own plans in this way tend to ignore voices and input from community members, leading to time consuming strife between officials and locals.[16] Because community members often feel ignored and left out of decision-making that directly impacts them,[17] it is important for a city to attempt to placate their communities by at least considering their input.

In review, the literature examined here highlights the multifaceted nature of urban development and population changes in Japan. The historical context provided by the analysis of Japanese Urban Systems from 1970 to 1990 underscores the significant shifts in population concentration driven by economic growth and subsequent slowdowns. The emergence and decline of Functional Urban Areas (JFUAs) offer a framework for understanding these trends, though the interpretation of spatial units can present challenges. Additionally, the review delves into the impact of Japan's economic transition on population distribution and examines the complexities of disaster reconstruction efforts. The "Reconstruction Paradox" and the top-down decision-making approach reveal the intricate dynamics between federal and local authorities, and the importance of community involvement in urban planning. Overall, this review underscores the need for a nuanced approach to understanding and addressing urban development and population changes in Japan.

[15] Daniel P. Aldrich, *Black Wave: How Networks and Governance Shaped Japan's 3/11 Disaster* (Chicago: The University of Chicago Press, 2020), xcii.
[16] Shingo Nagamatsu, "Building Back a Better Tohoku after the March 2011 Tsunami: Contradicting Evidence,"
[17] Daniel P. Aldrich, *Black Wave: How Networks and Governance Shaped Japan's 3/11 Disaster*, 12

Methods & Data

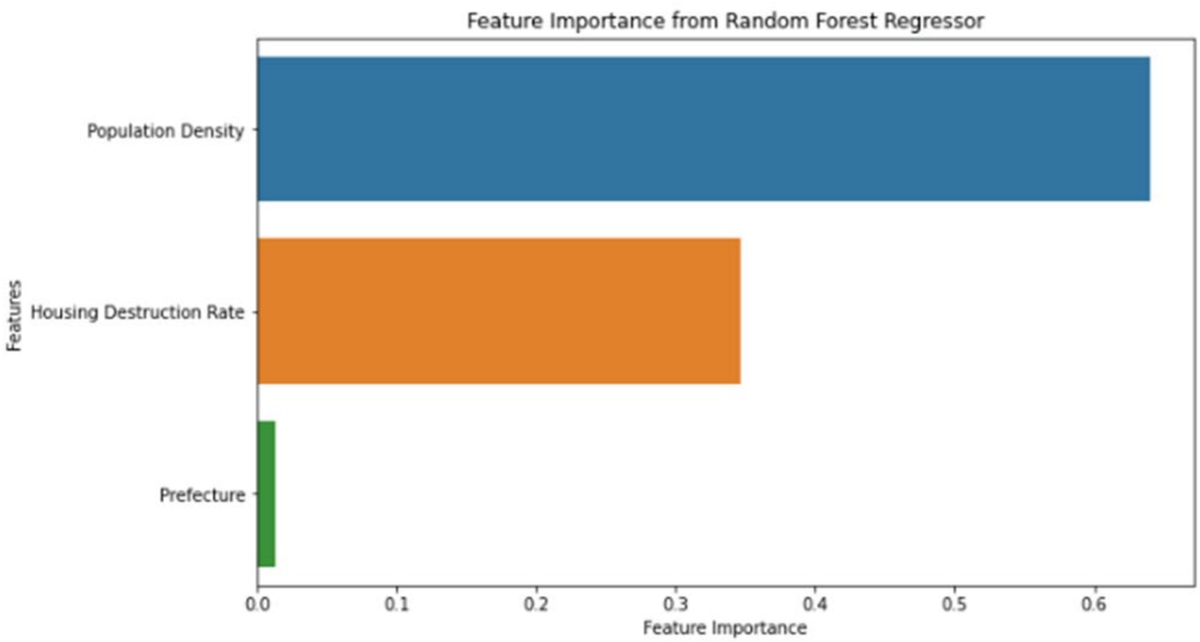
Quantitative

Machine-Learning, OLS Regression, and descriptive statistics and visualizations are used to uncover the reasoning and context behind population changes post-disaster.

The methodology of this study included a mixed-methods approach that includes both qualitative and quantitative analysis. I pulled housing, demographic, and population census from EStat Japan, and collected my own data via web scraping and local websites. To supplement this, I drew from conversations with local speakers and officials. In addition to descriptive statistics looking at housing reconstructions, population changes, and tsunami damage, I used machine learning models to begin to classify and predict population compound annual growth rate based on available data.

To capture the non-linear relationships between variables, I used a Random Forest Regressor, a boosted, ensemble machine-learning method used to predict continuous variables. This model, with an R^2 of 0.654 means that housing destruction rate, population density, and prefecture can account for 65% of the variance in Population CAGR. When predicting population growth or decline, population density accounted for ~65% of the model's performance, while housing damage made up the other ~30%. Prefecture, as aforementioned, was relatively insignificant in modeling. The breakdown of the variable performance is seen in [*Figure 4*]. However, one of the limitations of a supervised machine learning model like the Random Forest Regressor is that it is unable to provide coefficients and confidence values for each of the variables. While I believe the Random Forest Regressor does an accurate job predicting population CAGR with the given inputs, for my analysis, it is important to also understand the specific impact each variable has on CAGR, beyond simply examining covariance.

Figure 4



To achieve this aim, I decided to use an OLS Regression which seeks to relate independent and dependent variables linearly. A description of the scaling process and further details on variable covariance can be found in the appendix..

Firstly, I wanted to find if there is a statistically significant difference in CAGR between towns affected and not affected by tsunamis. An initial regression of "Impacted by Tsunami" on "CAGR" yields a p-value of 0.069, indicating that while it is close, there is not a statistically significant difference at a 95% confidence interval. However, I hypothesized that larger cities lose population at a relatively lower rate, and it is therefore important to control for population size when looking to see if there is a significant difference. Therefore, I created an "Adjusted CAGR," which accounts for population size within each municipality. A t-test looking at the impact of the tsunami on an adjusted CAGR yields a p-value of 0.031 - a statistically significant value. This means there is merit in further examining the difference between impacted and non-impacted municipalities. The boxplot showing the adjusted CAGR can be found in [Figure 13].

The results of the OLS Regression, shown in [Figure 6], depict an adjusted R^2 of 0.400, indicating that the model and independent variables account for 40% of the variance in adjusted Population CAGR. The regression was updated to exclude the "Impacted by Tsunami" variable, as it was found to exhibit multicollinearity with the "Housing Destruction Rate" variable, both capturing similar aspects of impact.

Figure 13

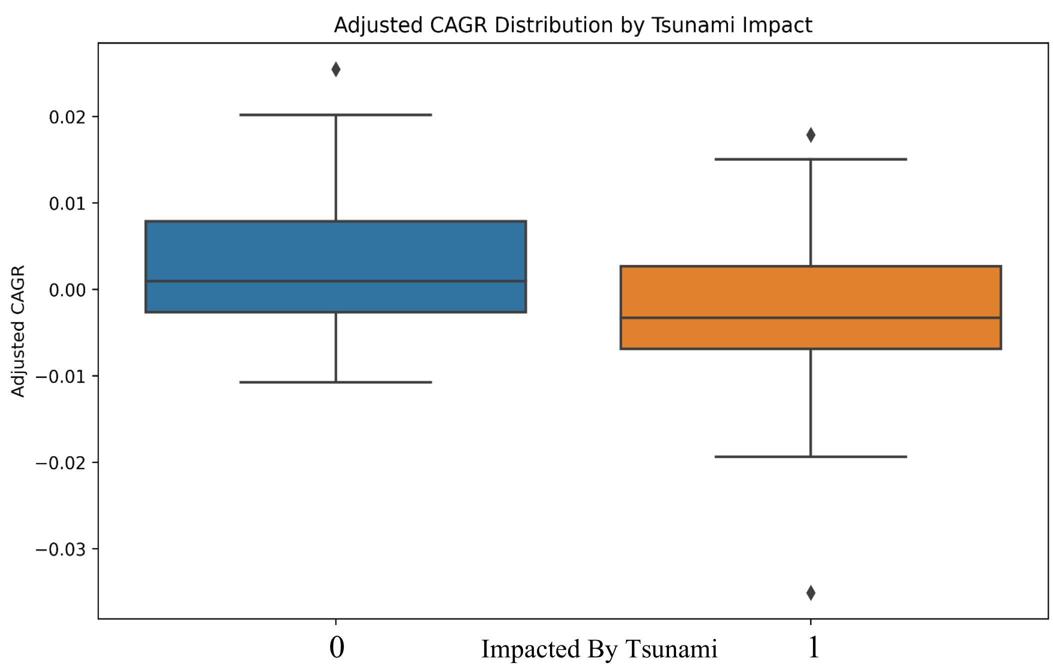


Figure 6

Variable	Coefficient (coef)	P-value (P>|t|)
Constant (const)	-1.247e-18	1.0
Prefecture	0.0021	0.067
Housing Destruction Rate	-0.0056	0.0
Population Density	0.0031	0.006
2011 Taxpayer per capita	-0.032	0.285
2021 Taxpayer per capita	0.0313	0.296

Statistic	Value
R-squared	0.448
Adj. R-squared	0.4
F-statistic	9.255
Prob (F-statistic)	1.71e-06

Key findings from the regression are as follows:

- **Prefecture:** This variable has a positive coefficient of 0.0021, suggesting a potential positive impact on CAGR. However, its p-value of 0.067 is slightly above the conventional significance level of 0.05, indicating that its effect may not be statistically significant at the 95% confidence level.
- **Housing Destruction Rate:** This variable has a negative coefficient of -0.0056, which is highly significant (p-value < 0.001). This suggests that an increase in the Housing Destruction Rate is associated with a significant decrease in CAGR. This makes intuitive sense with my understanding of disasters - the larger the damage, the more likely it is that residents are to leave and new residents are hesitant to move in. This could be because of the extended timeline of reconstruction projects or the feeling as if their community is no longer safe.

- **Population Density:** This variable shows a positive coefficient of 0.0031, which is statistically significant (p-value = 0.006). This indicates that higher population density is associated with an increase in CAGR.
- **2011 Taxpayer per capita:** This variable has a negative coefficient of -0.0320, but it is not statistically significant (p-value = 0.285). This suggests that there is no strong evidence that the 2011 Taxpayer per capita significantly impacts CAGR.
- **2021 Taxpayer per capita:** This variable has a positive coefficient of 0.0313, but it is not statistically significant (p-value = 0.296). This suggests that the number of taxpayers per capita in 2021 does not have a significant effect on CAGR.

[Figure 7] provides a clearer graphical interpretation of these results. It shows the relationship between each variable and the adjusted CAGR, with bounded confidence intervals.

The model yields a linear formula of statistically significant variables as follows:

$$\text{Adjusted\_Population\_CAGR} = -1.247 \times 10^{-18} + (0.0021 \times \textit{Prefecture}) - (0.0056 \times \textit{Housing Destruction Rate}) + (0.0031 \times \textit{Population Density})$$

The overall model's F-statistic is 9.255 with a p-value close to zero, confirming that the model is statistically significant. The diagnostics of the model show no evidence of heteroscedasticity (non-constant variance) and that the residuals are normally distributed, as indicated by the Omnibus and Jarque-Bera tests.

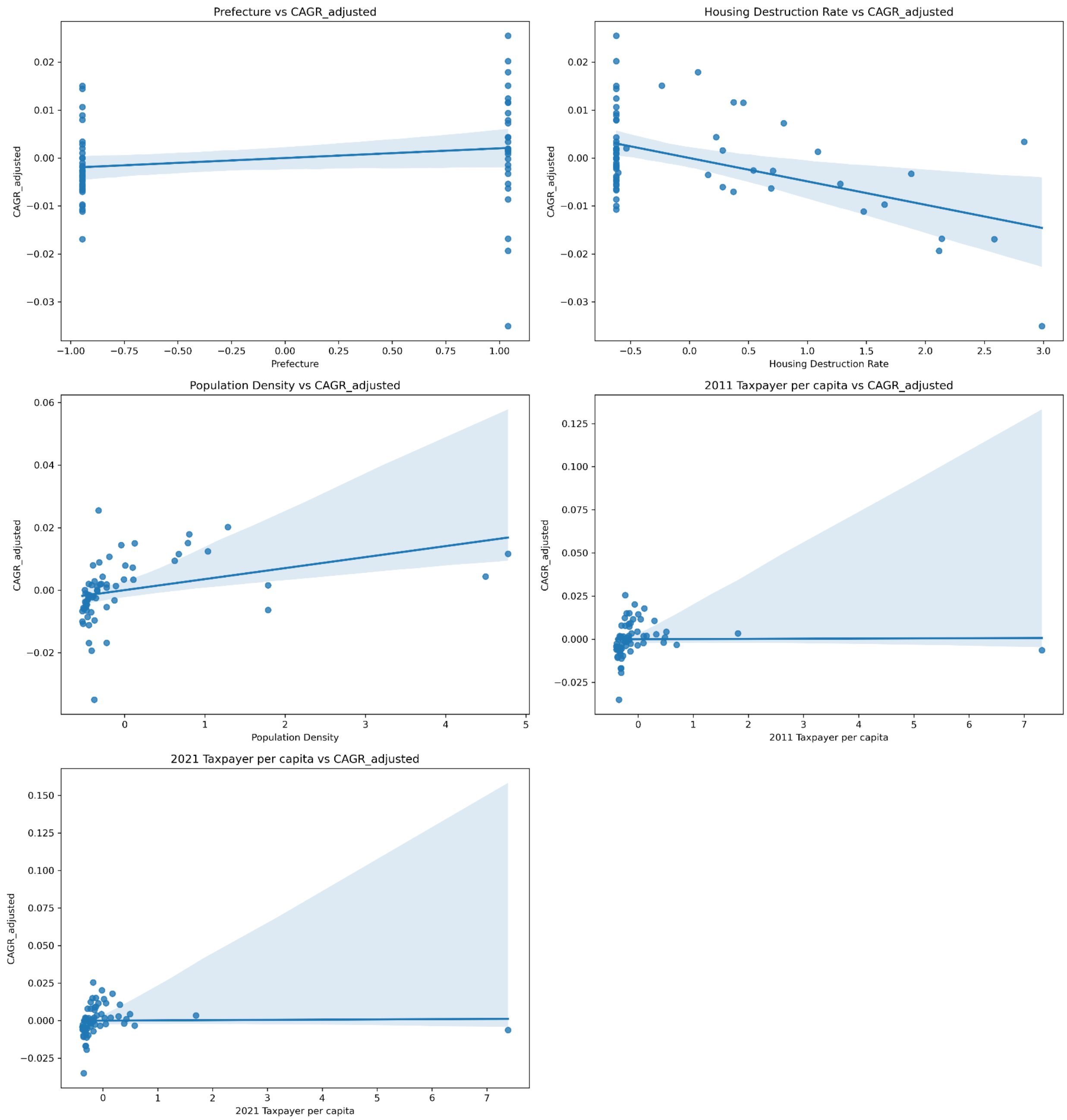
By removing the "Impacted by Tsunami" variable due to its multicollinearity with the "Housing Destruction Rate," the regression analysis now focuses on other factors influencing Population CAGR. The results reveal that while the prefecture variable has a marginally insignificant positive effect, Housing Destruction Rate and Population Density have significant effects on CAGR. The model fits the data reasonably well and provides valuable insights into the factors impacting Population CAGR. The regression performance can be seen in [Figure 14].

In addition to the OLS Regression and Random Forest Regressor, descriptive statistics are important in building context behind the extent of the damage, where damage occurred, why damage may have occurred in some places more than others, and what the scale of recovery looked like in the Miyagi and Iwate prefectures.

[*Figure 8*] shows the new dwellings constructed in Iwate and Miyagi as a percentage of total dwellings across Japan. The 31% increase in new dwellings post-disaster shows the scale and prioritization of residential projects in the recovery effort. The rate of residential construction can be viewed as a proxy for urban planning and development priorities. The largest spike occurs between late 2012 and early 2016, before the share begins to taper off to normal levels.

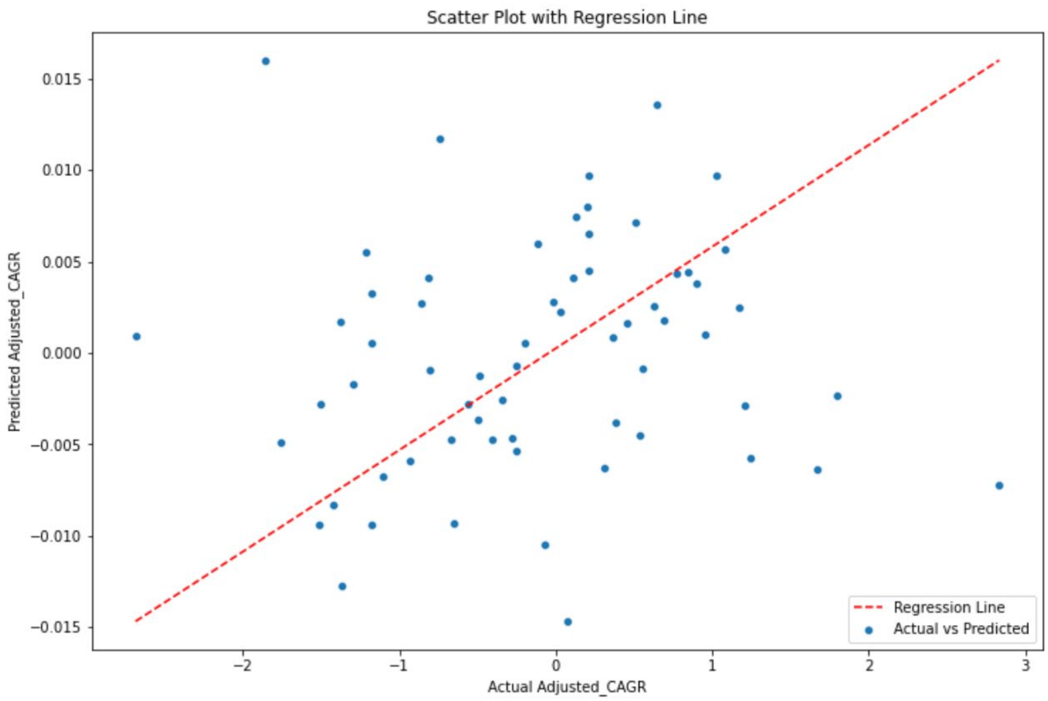
[*Figure 9*] compares towns based on their current population density and their population change between 2010 and 2020. Generally, towns with lower population densities experience higher rates of population decline, regardless of Tsunami status. Although there is limited data, it appears that those affected by tsunamis in the bottom 4 bands experience higher levels of population decline.

Figure 7



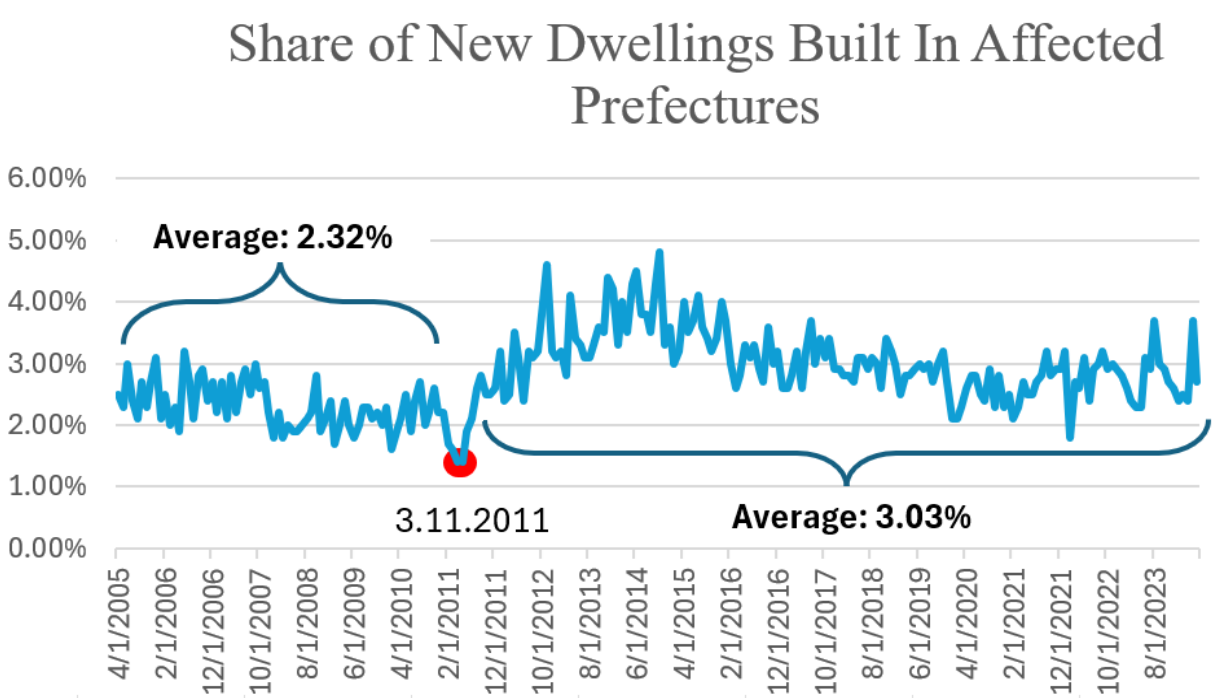
Prefecture vs CAGR_adjusted
CAGR_adjusted
Prefecture
Housing Destruction Rate vs CAGR_adjusted
CAGR_adjusted
Housing Destruction Rate
Population Density vs CAGR_adjusted
CAGR_adjusted
Population Density
2011 Taxpayer per capita vs CAGR_adjusted
CAGR_adjusted
2011 Taxpayer per capita
2021 Taxpayer per capita vs CAGR_adjusted
CAGR_adjusted
2021 Taxpayer per capita

Figure 14



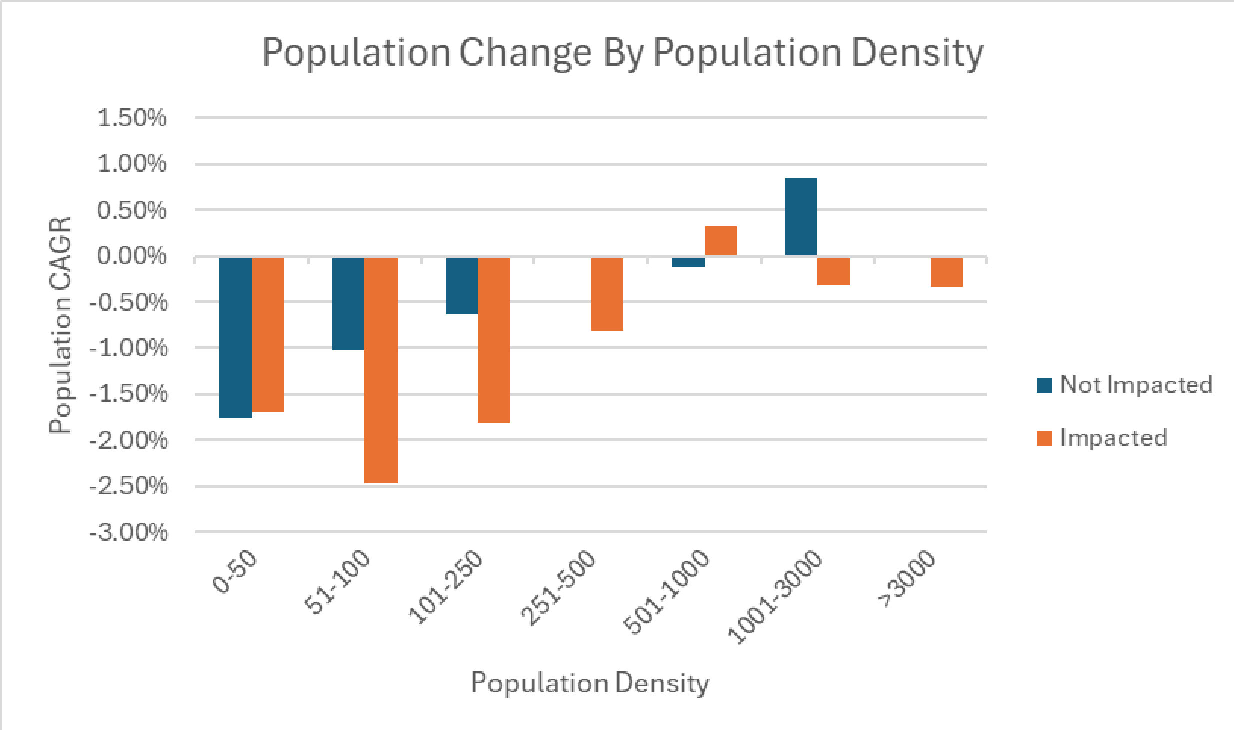
Source: Author
Description: Performance of regression model predicting adjusted CAGR

Figure 8



Source: Estat Japan
Description: Housing redevelopment over time, showing impact and scale of reconstruction

Figure 9



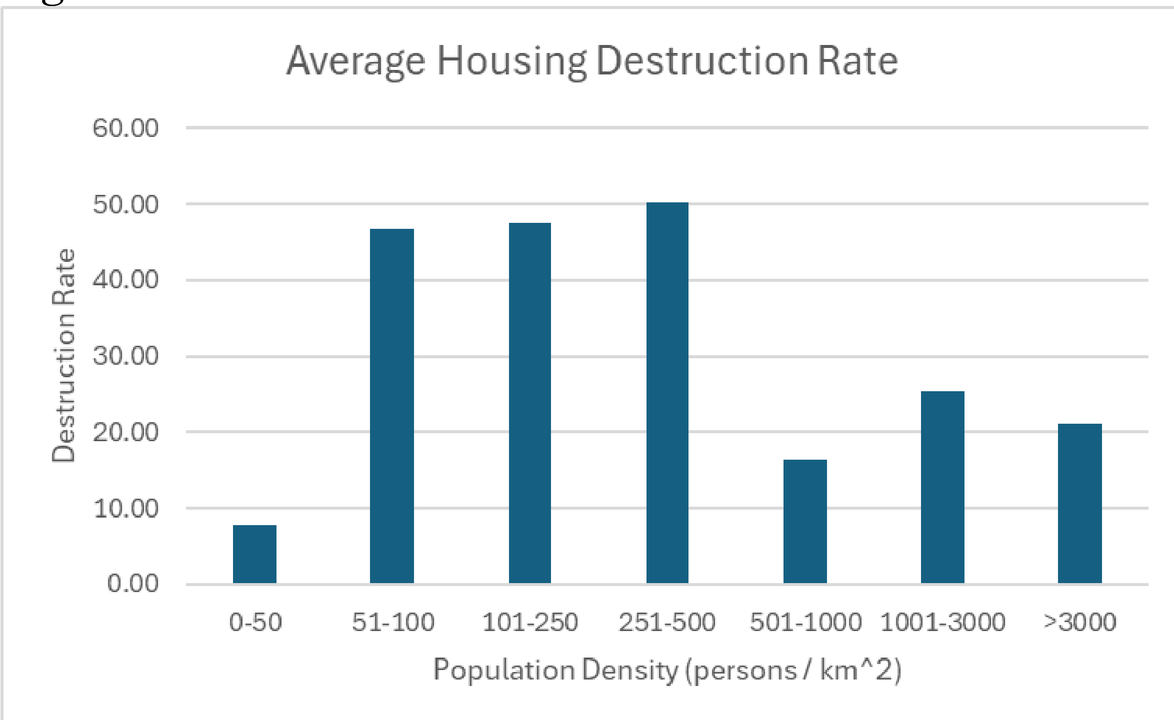
Source: Estat Japan
Description: Population change grouped by population density for cities in Iwate and Miyagi (merged) prefecture

[*Figure 10*] does not show a clear relationship between housing destruction rates and population density. At small N's, it is difficult to draw a clear conclusion. N = 22.

[*Figure 11*] Generally shows that, as the housing destruction rate increases, population change decreases. This negative relationship means that more destruction drives people away from a region. N = 27.

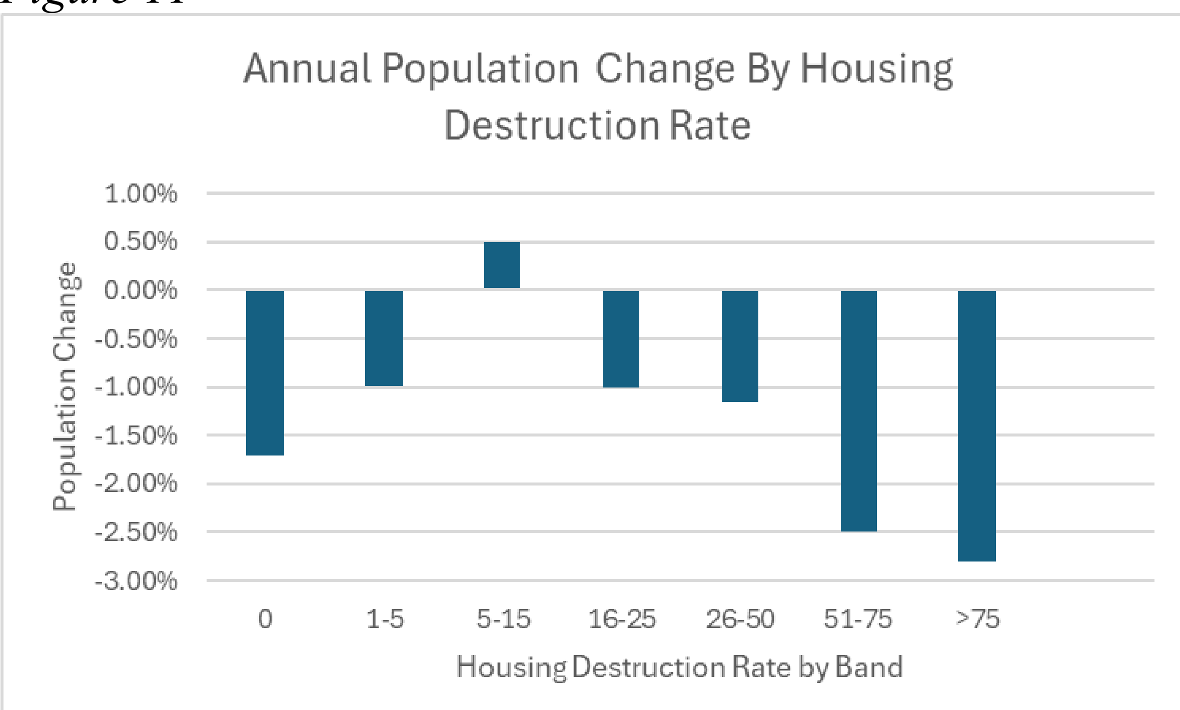
Further comparative case studies in cities such as Rikuzentakata and Onagawa will help to contextualize these findings and explore the nuances behind these variables' effects on population dynamics post-disaster.

Figure 10



Source: Estat Japan

Figure 11



Source: Estat Japan

Qualitative

Two case studies, looking at Onagawa and Rikuzentakata, seek to dive further into the regression results and uncover what other influences may exist in population changes.

Onagawa Town (女川町)

Onagawa, a small fishing village nestled in the Sanriku coast, boasts a strong agricultural fishing economy. The fishing industry, the main source of income for the town, "was worth almost $65 million before the disaster."[18] The other major industry in the town, the Onagawa Nuclear Power Plant, has been out of service for over 13 years, taking away a large portion of jobs from local residents.

The disaster, which effectively put the town on hold for a couple years, wasn't able to stop the thriving fishing industry. In fact, while "the number of town residents involved in fishing has dropped…total sales for [FY15] came to ¥5.5 billion, topping the figure of slightly less than ¥5 billion for the year preceding the disaster."[19] Their fishing recovery, largely aided by millions of dollars in aid from Qatari Foundations and prefecture aid, was also not without issue. Group subsidies, used to revive the fishing industry in many coastal prefectures, were not without stipulation, and have now become "shackles" for some businesses.[20]

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[18] Cosson, Camille. 2020. "From a Tsunami-Devastated Zone to an Attractive Fishing Town: A Study on Onagawa's Strategy for a Prompt Recovery." *Urban Geography* 41 (5): 777–90. doi:10.1080/02723638.2020.1780054.

[19] Kikuchi Masanori, "A Tōhoku Town Returns to Life," nippon.com, June 19, 2015, https://www.nippon.com/en/in-depth/a04302/.

[20] "東日本大震災13年 グループ補助金が被災企業の"足かせ"に: NHK: WEB特集." NHKニュース, July 10、 2024. https://www3.nhk.or.jp/news/html/20240308/k10014381371000.html.

When it comes to disaster recovery, Onagawa has served as both a poster-child and a grave warning to other municipalities. The town, which redeveloped its commercial area into a quaint, walkable, compact downtown serves tourists and local residents alike. Despite this success, Onagawa has seen their town's population drop at a staggering rate - 4.76% annually. This decline is the worst of any municipality in the Miyagi and Iwate prefectures. This forces the question: how can a city so highly lauded for revitalizing their downtown be struggling so greatly to attract old and new residents?

Onagawa attempted to rebrand their city based on a strong identity of architectural attractiveness and culinary tourism.[21] This, combined with Onagawa's natural beauty inspired the city to rebel against the Miyagi prefecture's advice – Onagawa has *no* seawall. With regard to urban design, they have maintained their identity of being a coastal fishing town, while also trying to attract tourists. Unfortunately, the aging population of the town's residents and their tourist aspirations often conflict. When I visited the quaint Onagawa downtown (which takes two hours to get to from the closest major city, Sendai), I was stunned! The downtown was beautiful - an incredible example of reconstruction - but empty, aside from my classmates and a handful of other tourists. I could probably count on one hand the number of local residents who made their way to the multi-million dollar project. In an effort to attract new residents, Onagawa's reconstruction heavily relied on the voices of younger residents. One of the testaments to this is the skatepark featured adjacent to Onagawa's city center.[22]

[21] Cosson, Camille. 2020. "From a Tsunami-Devastated Zone to an Attractive Fishing Town: A Study on Onagawa's Strategy for a Prompt Recovery."
[22] Okazaki, Manami. "From Rubble to Revival: The Story of Onagawa after the Tohoku Earthquake." Tokyo Weekender, April 10, 2024. https://www.tokyoweekender.com/travel/onagawa-revival-tohoku/.

Further, the focus on fishing revival and downtown beauty has been prioritized over housing reconstruction, which has fallen by the wayside and become victim to heavy delays. Onagawa has chosen to partake in Land Readjustment projects, which involve the digging up of mountains and land elsewhere to raise the land near the coast. This costly and time-consuming process was supposed to create 1,000 new housing units in Onagawa. However, the process has been delayed, leaving local residents stranded for extreme lengths of time away from their homes.[23] The length of these projects has pushed residents away in droves, and despite their best efforts to commercially revitalize the city, without housing infrastructure, populations are unable to return.

In Onagawa's case, the heavy destruction after the tsunami (82 Housing Destruction Score) meant that housing reconstruction projects would be costly and time consuming. Because of this, residents have chosen not to return. Couple the time, noise, and cost of housing reconstruction with the fact that Onagawa is hours away from major cities, and it is no surprise its population has seen a sharp decline. The unfortunate reality of Onagawa's population decline can be succinctly summed up by the quote of a local resident. In 2013, Yoshihide Abe noted, "In five to ten years, Onagawa will either turn into a ghost town or a lively town with no in between. If the rebuilding proposal on which we have worked for the past one or two years succeeds, I think we can bring back a relatively populated and vibrant town. If it fails, Onagawa will be deserted."[24] Population growth and decline is rarely linear. Cities benefit (and fall) due to the network effect – the value of the city is, at least partially, derived from the number of other users. Because of this, the

[23] Yoshiaki, Suda. "Rebuilding Onagawa." nippon.com, July 10, 2023. https://www.nippon.com/en/in-depth/a04305/.
[24] Cosson, Camille. 2020. "From a Tsunami-Devastated Zone to an Attractive Fishing Town: A Study on Onagawa's Strategy for a Prompt Recovery."

population often falls, and grows, exponentially. In Onagawa's case, while Abe's estimate of 10 years might be overly grave, it is unlikely Onagawa town, at its current pace, will exist by the end of this century.

Rikuzentakata (陸前高田市)

Rikuzentakata, like Onagawa, suffered heavy destruction (52 Housing Destruction Score). In its reconstruction, Rikuzentaka built a large seawall, and replanted its forest barrier as a method to protect the city from future tsunamis. Beyond the seawall, there is a designated "no-residential" zone, seen in [Figure 15], that prevents building of homes in the area deemed at high risk of a future tsunami. Like many cities, they decided to build the seawall on the recommendation of the Iwate prefecture. However, these seawalls often needed to be completed as 'prerequisites' to other projects such as housing, meaning, like with the case of Onagawa, housing construction was delayed.

Rikuzentakata utilized both mass relocation and land readjustment projects in its reconstruction. Despite Rikuzentakata only having 2 land readjustment projects, compared to 14 mass relocation projects, the land readjustment projects took longer and were significantly more expensive. City officials report statistics on the two land readjustment projects, Imaizumi District and Takata districts in [Figure 16]. The land readjustment projects handed land back to residents between 2017 and January 2021, nearly 10 years after the disaster. Considering residents in temporary housing often had to move multiple times, 10 years of waiting for their land was unfathomable.[25] Also in its reconstruction, Rikuzentakata officials aimed to create a "compact city." However, this, similar

[25] Daniel P. Aldrich, *Black Wave: How Networks and Governance Shaped Japan's 3/11 Disaster*, 39

to Onagawa, is misguided. Both downtowns *are* compact, but residential sprawl extends far from the epicenter of the cities. The population density numbers of the town rank in the bottom half of the prefecture. Residential "sprawl" is prevalent in both of these towns, and the residential area extends multiple kilometers out of the city center. In 2005, Rikuzentaka merged with Sumita and Takata, absorbing them into their city, as is quite common among small towns in Japan as they try to maintain populations and city capacity. This sprawl has led to the exact opposite of the compactness Rikuzentakata had set out to create.

Figure 15

Source: Author
Description: Highlights the zoning regulations in Rikuzentakata where housing is prohibited between the seawall and the main road. This buffer zone serves as greenspace for the community, and houses community athletic facilities. This zoning is an effective way to redistribute land, but could be a lengthy legal/community process because residents may be hesitant to give up their lands.

Across Onagawa and Rikuzentakata housing reconstruction projects, it becomes clear that higher levels of damage lead to longer wait times for housing reconstruction projects. This leads to instability for residents and likely influences them to seek permanent housing elsewhere. These cases help build upon the regression analysis and paint a clearer picture of why Tohoku towns affected by tsunamis have struggled, even relative to the rest of the prefecture, when it comes to population maintenance.

Figure 16

Project	Imaizumi District Land	Takata District
Area	112.4 ha	186.1 ha
Houses Constructed	617	1172
Population Services	1600	4300
Costs	89.11B Yen	76.63B Yen

Source: Rikuzentakata Government Official

Findings and Discussion

The OLS regression and case studies shed more light on some of the variables that influence population change. While I originally set out to find the impact of urban planning on population maintenance, data collection problems mentioned in [Limitations], forced the methodology and plan of the original project to shift slightly. I eventually decided to look at other variables, some of which influence urban design and reconstruction and might play a role in population maintenance. However, I still gathered minimal data from emailing municipalities. Responses from Kamaishi, Yahaba, and Kitakabi in the Iwate prefecture are seen below. For Yahaba and Kitakabi, neither of these cities were impacted by the tsunami, and therefore their reconstruction processes were not nearly as intensive as cities affected by the tsunami. This is a general trend seen throughout the two prefectures, demonstrated in [*Figure 17*].

Their responses are summarized as follows:

City	Housing Destruction Rate	Population Density	Population Growth (1-5)	Commerical Growth (1-5)	Development History	Development Classification	Impacted by Tsunami
Kamaishi	22.72	74.00	2.00	2.00	Urban areas form along riverbanks due to geographic constraints	Severe damage led to new regulations on residential land use	1
Kitakami	0.00	210.00	3.00	3.00	Mixed economy with strong transportation infrastructure	No change	0
Yahaba	0.00	400.00	3.00	3.00	Residential districts surrounding main transportation hub	No change	0

Development Classification asks how a town has changed their land-use and urban planning policies post-disaster. The response, "No Change," in Development Classification for the towns Kitakami and Yahaba makes sense when considering they were both unaffected by the tsunami. Therefore, they have had a much smaller-scale rebuilding process and their land use has stayed consistent. For Yahaba and Kitakami, their populations have grown at a rate of 0.29% and 0.01% respectively. Population and Commercial growth in the survey are measured on a 1 to 5 scale, where 1 is decreases significantly (>15%) and 5 is increases significantly (>15%) in the next 5 years. The response of 3, or no change, for commercial growth, however, comes as a slight surprise in Kitakami and Yahaba. The taxable income in Kitakami and Yahaba towns has grown at a rate of 2.18% and 2.37%, greatly outpacing the average across all municipalities of 1.64%.[26] Taxable income serves as a useful proxy to understand economic activity in a town. The per capita measurement does a good job separating economic growth from population growth, although they are likely intertwined. With historic population growth and strong taxable income growth, I would expect both Kitakami and Yahaba to have more positive forward looking statements concerning

[26] Estat Japan

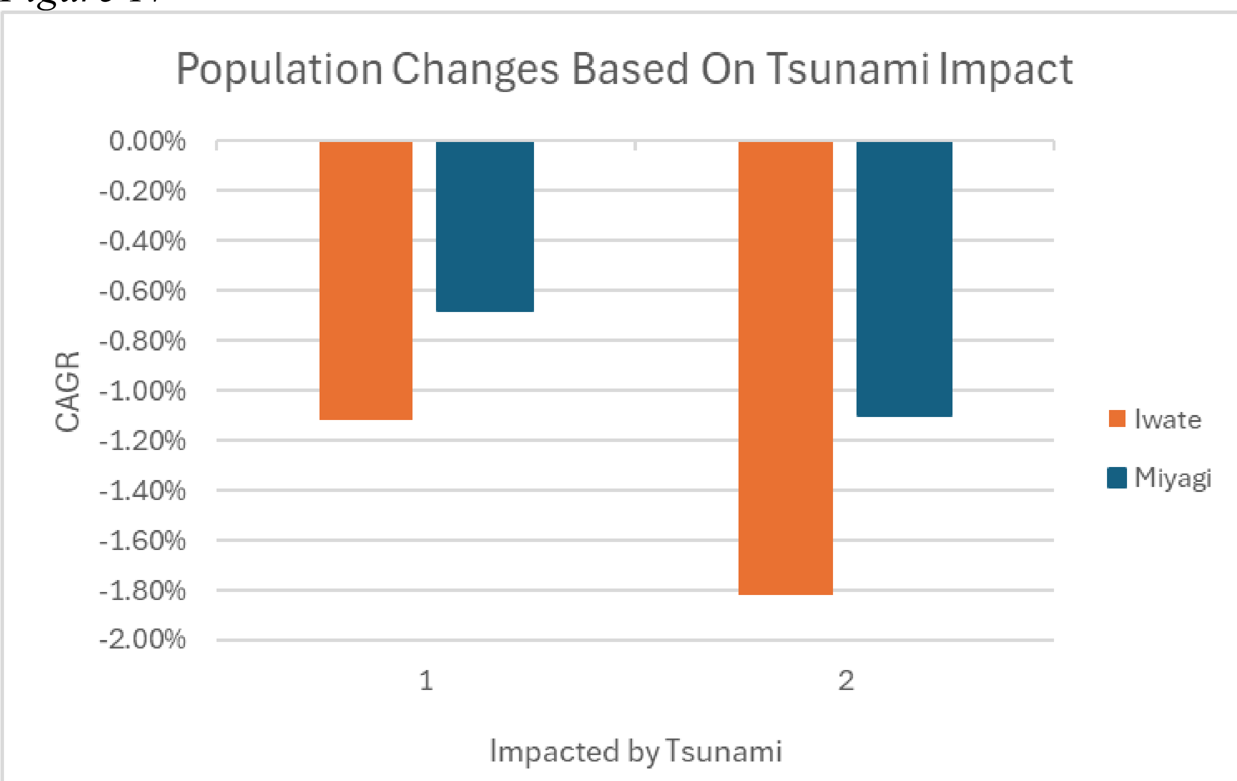
the state of their commercial affairs. For context, Onagawa ranks dead last among all municipalities with a real decline in taxable income of 1.22% annually.

Classifying Japanese towns based on their development is also challenging due to so much variation. Yahaba town has developed in a concentric ring model, where a central business district is the main commercial hub. Residential and agricultural land spreads out from the central business district as the land costs get cheaper the further you go from. Conversely, Kitakami towns development has been largely guided by unique geographic features, and their balanced economy takes advantage of agricultural and transportation sectors. These two cases highlight the difficulty of classifying Japanese towns because so much variation exists in the historical context of their development.

The opportunity to rebuild a town, essentially from the ground up, is a rare and exciting one for city planners. Many of the affected areas adopted mottos like “Build Back Better” as they attempted to rebuild in an innovative way. However, when rebuilding those unaffected did not get to take part in the opportunity or resources. This research also poses a difficult question to the central government. How should the central government distribute aid to affected communities? It appears that many towns will end up over invested relative to their population and the central government should focus investment on towns that are growing, not failing.

I also got a response from Kamaishi City, which was affected by the disaster. Although a small N, this response allows examination across impacted and not impacted municipalities. Kaimaishi expects both population and commercial decline slightly (5%-15%) over the next 5 years. I thought it interesting that all 3 towns are experiencing population decline, but only the town affected by the tsunami expects it to continue. Based on demographic trends, I expect all 3 towns to continue to face declining populations, but an area of further research I am interested in is finding out if towns affected have a different perception of the demographic crisis they expect to face in the coming years. Kamaishi, similar to Rikuzentakata, created "non-residential" zones where new housing development was prohibited. In its urban planning, Kamaishi has taken active steps to be more disaster conscious, including reshaping roads and thorough ways to be more evacuation savvy.[27] Despite this, Kamaishi's population has still declined at a rate of 1.89% annually, slightly below the average for municipalities affected by the disaster.

Figure 17



Source: Estat Japan
Note: 1 represents no impact from tsunami, 2 represents towns impacted by tsunami.

[27] Nakajima, Naoto. 2023. "Layers of Reconstruction: The Planning History of Disaster-Prone Kamaishi." *Planning Perspectives* 39 (1): 109–29. doi:10.1080/02665433.2023.2217425.

My findings reveal a novel relationship between how housing destruction rates, reconstruction timelines, and local factors all influence population decline. Many cities not in a JFAU have experienced population decline, but the 2011 tsunami has uniquely exacerbated population decline beyond the normal expectation. Qualitative analysis reveals future avenues for research that may reveal differences in perceptions and expectations surrounding population and commercial growth based on tsunami impact.

Limitations

As mentioned in the methodology of this paper, the initial goal was to collect data from each of the 63 municipalities within the Miyagi and Iwate prefectures. The email sent to the municipalities is shown in [*Figure 12*]. Using their disaster status (impacted by tsunami or not) as a control, the goal was to determine how land use and urban planning goals have shifted post disaster and what impact this has/will have on population and commercial activity in each respective municipality. Due to language barriers, this outreach was conducted via email, rather than telephone. Because of this, at the time of writing, I only received a 3% response rate on my outreach (N = 3). Two of the three municipalities were not impacted by the disaster, which makes it difficult to draw meaningful, comparative insights from their response.

Further data availability issues made it difficult to find information on project costs and precise details, also likely influenced by language challenges. Because of this, there likely remain confounding variables in my analysis that influence population changes.

Conclusion

This study explores the complex dynamics of population change in Miyagi and Iwate prefectures following the March 11, 2011, triple disaster. By combining quantitative and qualitative analyses of other towns in Japan, the research provides a comprehensive view of how the earthquake, tsunami, and nuclear meltdown have impacted demographic trends and urban development.

The quantitative analysis highlights that housing destruction and population density are significant factors influencing an adjusted population Compound Annual Growth Rate (CAGR). Specifically, a higher housing destruction rate correlates with a decrease in Population CAGR, while increased population density is associated with higher CAGR. The Random Forest Regressor and OLS regression models reveal that while prefecture-level factors play a minor role, housing destruction and population density are key drivers of population changes. Other factors like city tax revenue do not appear to play a major role, largely because much of the money for reconstruction came from the national government or equitably distributed international aid.

The qualitative case studies of Onagawa and Rikuzentakata further illustrate these findings. Onagawa's celebrated downtown redevelopment and fishing industry recovery have not prevented severe population decline due to delayed housing reconstruction and an aging population. In contrast, Rikuzentakata's extensive seawall and land readjustment projects, while crucial for disaster mitigation, have led to prolonged delays in housing availability, exacerbating residential instability.

These findings underscore the importance of integrating timely housing solutions with broader urban planning and disaster recovery strategies. Effective and prompt housing reconstruction is essential for supporting community resilience and population retention. Additionally, urban planning that emphasizes population density and accessibility can enhance the sustainability of affected communities.

While this study provides valuable insights, future research could benefit from more detailed and longitudinal data, as well as additional qualitative perspectives from a broader range of towns. Overall, the research offers practical implications for improving post-disaster urban planning and reconstruction efforts, contributing to a deeper understanding of the factors influencing population dynamics in the aftermath of major disasters.

Policy Recommendations

Based on the results of my research, several policy recommendations come to light which can be implemented to help cities better maintain population post-disaster. Especially in Japan, where rural populations are declining regardless of disaster status, these recommendations are crucial in ensuring the Sanriku coast maintains its population.

Prioritize Residential Reconstruction:

- Accelerate Housing Reconstruction: Delays in housing reconstruction decrease stability of a town's population and force residents to relocate more often, driving population decline. Intuitively, the longer residents are away, the less likely they are to return. The phenomena is an area of future research.

- Subsidies and Incentives: Financial support for residents to return, like seen in the Fukushima prefecture after the nuclear disaster, provides crucial resources necessary to return. Without funding, reconstruction becomes nearly impossible.

Enhance Urban Planning and Infrastructure:

- Integrated Urban Planning: Develop urban plans that encourage mixed-use developments and create more compact and walkable cities. Take residents' input into account as well. Zone based on proximity to disaster prone areas, like in the case of Rikuzentakata. Aim for a true "compact city." Flexible zone and land use restrictions are important in maintaining resident safety and city prosperity.
- Resilient Infrastructure: Invest in resilient infrastructure that not only prevents disasters but also sets a city up for a quick recovery. Ensure that infrastructure projects are balanced with immediate housing needs. Take for example, Onagawa's wooden downtown, which can be quickly and cheaply rebuilt in the case of a future disaster. It's important to maintain the integrity of the town's core cultural, geographic, and economic values.
- Land Readjustment Projects: Quickly complete land readjustment projects and have transparent timelines to ensure that reconstruction is aligned with local resident expectations. Simplify bureaucratic processes to speed up redevelopment to try and beat the "Reconstruction Paradox."

Reevaluate the Focus on Tourism:

- Balanced Development: While tourism can be beneficial to local economies, it should not be prioritized over the development of stable residential housing. Overemphasis on tourism may lead to short-term gains, but also tends to dissuade residents from coming back if they do not feel their values are reflected in urban planning efforts. Part of this may include "Sustainable Tourism" practices, where cities adopt strategies that complement, not compete with, the wishes of residents. Ishinomaki's aquarium attraction served as a great example of this pre-disaster.

By focusing on urban planning and residential reconstruction, while simultaneously tabling tourism aspirations, cities can strategically mitigate the population decline observed in disaster-affected areas. These policies aim to build "Build Back Better," by physically creating communities that are resilient to future challenges.

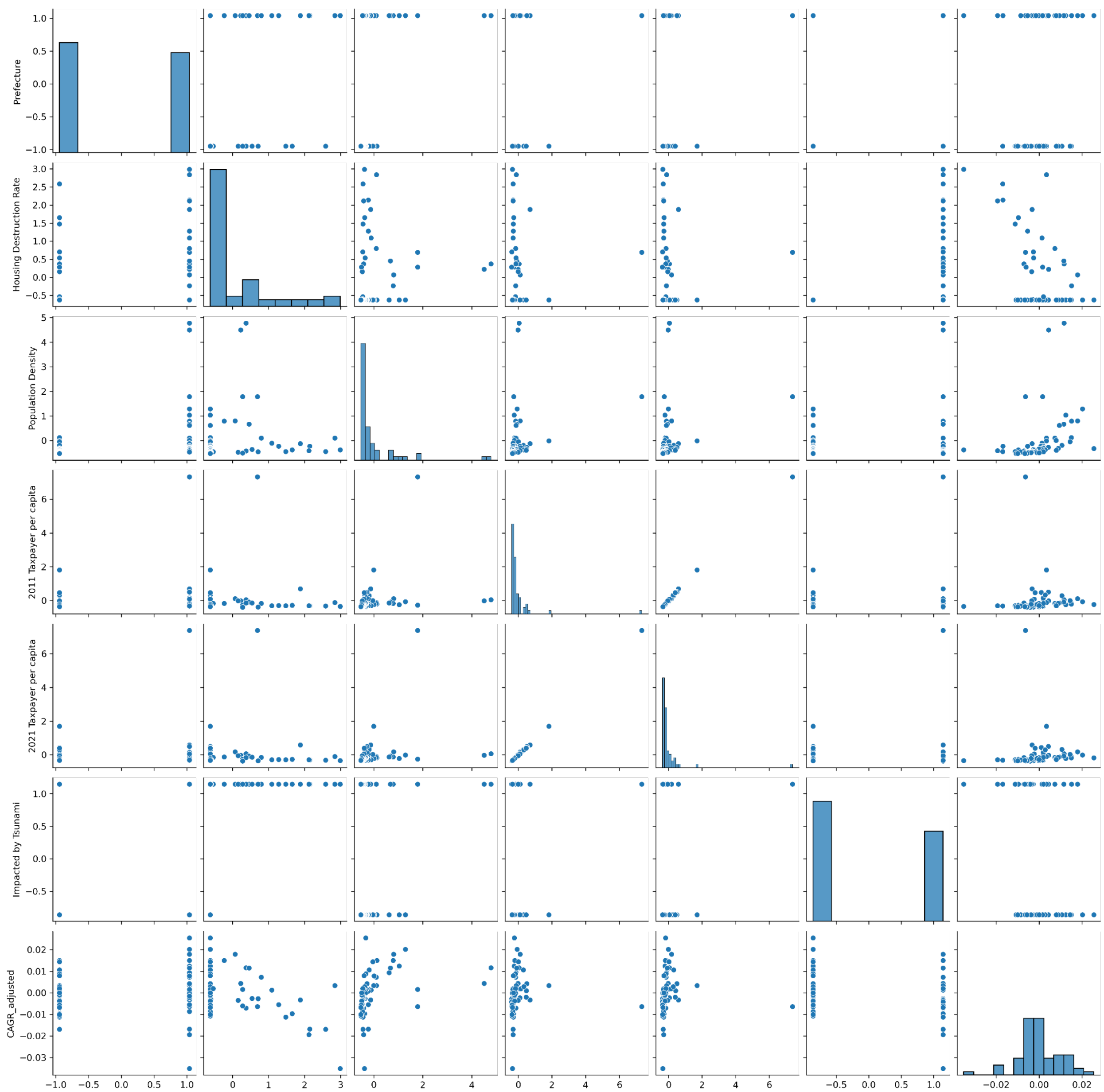
Works Cited

1. Aldrich, Daniel P. *Black Wave: How Networks and Governance Shaped Japan's 3/11 Disaster*. Chicago: The University of Chicago Press, 2020.
2. Arba, Alexandru. "Japan: Most Visited Prefectures by Foreign Tourists 2020." Statista, May 19, 2022. https://www.statista.com/statistics/657560/japan-most-visited-prefectures-by-foreign-tourists/.
3. Basic Guidelines for Reconstruction from the Great East Japan Earthquake After The "Reconstruction and Revitalization Period." Accessed July 21, 2024. https://www.reconstruction.go.jp/english/topics/Laws_etc/2019Dec_basic-guidelines_full-text.pdf.
4. "Data List: 日本の観光統計データ." Japan Tourism Statistics | 日本の観光統計データ. Accessed July 21, 2024. https://statistics.jnto.go.jp/en/graph/.
5. "Estat Japan." Statistics Dashboard - Time Series Tables. Accessed July 21, 2024. https://dashboard.e-stat.go.jp/en/timeSeries.
6. "Japan's 3.11 Triple Disaster and Its Impact 10 Years Later | MIT Center for International Studies." MIT Center for International Studies, September 16, 2021. https://cis.mit.edu/publications/magazine/japan%E2%80%99s-311-triple-disaster-and-its-impact-10-years-later.
7. Masanori, Kikuchi. "A Tōhoku Town Returns to Life." nippon.com, June 19, 2015. https://www.nippon.com/en/in-depth/a04302/.

8. Muroi, Kenji. “Post-Disaster Reconstruction in the Rural-Urban Fringe Following the Great East Japan Earthquake.” *E3S Web of Conferences* 340 (2022): 03001. https://doi.org/10.1051/e3sconf/202234003001.
9. Nagamatsu, Shingo. “Building Back a Better Tohoku after the March 2011 Tsunami: Contradicting Evidence.” *Advances in Natural and Technological Hazards Research*, July 13, 2017, 37–54. https://doi.org/10.1007/978-3-319-58691-5_3.
10. Nakajima, Naoto. 2023. “Layers of Reconstruction: The Planning History of Disaster-Prone Kamaishi.” Planning Perspectives 39 (1): 109–29. doi:10.1080/02665433.2023.2217425.
11. Okazaki, Manami. “From Rubble to Revival: The Story of Onagawa after the Tohoku Earthquake.” Tokyo Weekender, April 10, 2024. https://www.tokyoweekender.com/travel/onagawa-revival-tohoku/.
12. Osada, Susumu. “The Japanese Urban System 1970–1990.” *Science Direct* 59, no. 3 (March 28, 2003): 125–231. https://doi.org/10.1016/s0305-9006(02)00111-3.
13. Yoshiaki, Suda. “Rebuilding Onagawa.” nippon.com, July 10, 2023. https://www.nippon.com/en/in-depth/a04305/.
14. “東日本大震災13年 グループ補助金が被災企業の"足かせ"に: NHK: WEB特集.” NHKニュース、July 10、 2024. https://www3.nhk.or.jp/news/html/20240308/k10014381371000.html.

Appendix

Figure 3



Email Responses:

Yahaba Town, Iwate

Tatsuro Yamatani – Planning and Finance Division, Information Section

Q: In the next 5 years, how do you expect your population/commercial activity to change?

A: Population Change: No change

A: Commercial Change: No change

Q: How has your town historically developed? Have any patterns emerged or has your town's urban design followed any common development models?

A: A residential area has developed around Yahaba Station, with rural areas surrounding it.

Q: How has town land use changed post 3.11 disasters?

A: There has been no major change in land use, but we have improved disaster prevention centers such as evacuation centers and are working to strengthen voluntary disaster prevention organizations centered on the community.

Kitakami Town, Iwate

Yosuke Saito – Administrative Management Section, Policy Planning Division

Q: In the next 5 years, how do you expect your population/commercial activity to change?

A: Population Change: No change

A: Commercial Change: No change

Q: How has your town historically developed? Have any patterns emerged or has your town's urban design followed any common development models?

A: Our city has long been a key transportation hub, and has improved transportation convenience through the development of a high-speed transportation system. We have also developed a balanced mix of *agriculture*, which takes advantage of the fertile land where large rivers converge, and industry, which has been developed through active business attraction.

Q: How has town land use changed post 3.11 disasters?

A: No change

Kamaishi City, Iwate

Anna Ishikawa – General Affairs Planning Department, General Policy Division

Q: In the next 5 years, how do you expect your population/commercial activity to change?

A: Population Change: Decline (5-15%)

A: Commercial Change: Decline (5-15%)

Q: How has your town historically developed? Have any patterns emerged or has your town's urban design followed any common development models?

A: Nearly 90% of the total area of the city is occupied by forests, etc., and the habitable land area is less than 10% of the city area. Under these topographical constraints, urban areas as industrial cities have been formed mainly along the Koshigawa River basin, but now that major facilities are aging and there is a large amount of underutilized land due to the transformation of the industrial structure, we will promote the use of land in response to changes in the urban structure.

Q: How has town land use changed post 3.11 disasters?

A: Our city was severely damaged by the Great East Japan Earthquake and has been rebuilding houses while ensuring safety and security. The Great East Japan Earthquake has caused restrictions on land use, and there has been a significant change compared to before the earthquake, such as the need to raise the scale on a large scale.

Figure 12

私の名前はダリン・マターマンです。ノースイースタン大学の大学生です。日本に来て、都市開発と災害復興を学んでいます。Town name (Type name of Town in Alphabet or google Kanji/character Town name) 町に関するいくつかの質問に答えていただければ幸いです。

1. 今後 5 年間であなたの町の人口はどのように変化すると予想しますか?
   1. 大幅に減少する (15%以上)
   2. 減少する (5-15%)
   3. 変わらない
   4. 増加する (5-15%)
   5. 大幅に増加する (15%以上)

2. 今 後 5 年間であなたの町の商業活動はどのように変化すると予想しますか?
   1. 大幅に減少する (15%以上)
   2. 減少する (5-15%)
   3. 変わらない
   4. 増加する (5-15%)
   5. 大幅に増加する (15%以上)

3. 町がどのように発展してきたかを一文か二文で説明してください。発展の一般的な例は次のとおりです。

- 複数の
  - 成長を続ける都市部が合併して統合されることによって発生する可能性があります
- セクター モデル
  - このモデルでは、都市が産業別に分割されていると想定しています (中心業務地区の周囲に工業地区、小売地区、住宅地区が集中しています)
- 同心円モデル
  - 土地の不足とコストにより、貧困層向け住宅、上流階級け住宅、農業などのさまざまな「リング」が中心業務地区から広がっています

4. あなたの町の土地利用/開発は、3/11 災害の前後で変化しましたか? どのように変化しましたか?

お時間を割いていただき、ありがとうございました。
Darin Materman
ダリン・マターマン

Before my OLS Regression, I wanted to measure the relationships between variables and the strength of their correlation. In order to do this, I used z-score normalization. By subtracting each sample from the sample mean and dividing by the sample standard deviation, z-scores allow comparison across units that are unalike. After scaling the data appropriately, which is also an important step in preparing the data for machine learning models, I build a covariance matrix to measure the relationships between all the variables. This matrix can be found in [*Figure 5*], and displays the relationship between each variable. The closer to one or negative one, the stronger the correlation.

Figure 5

Features	Prefecture	Housing Destruction Rate	Population Density	2011 Taxpayer per capita	2021 Taxpayer per capita	Impacted by Tsunami	CAGR _ adjusted
Prefecture	1.000	0.246	0.418	0.135	0.138	0.138	0.002
Housing Destruction Rate	0.246	1.000	0.081	0.048	0.047	0.724	-0.005
Population Density	0.418	0.081	1.000	0.256	0.260	0.273	0.004
2011 Taxpayer per capita	0.135	0.048	0.256	1.000	0.999	0.086	0.000
2021 Taxpayer per capita	0.138	0.047	0.260	0.999	1.000	0.089	0.000
Impacted by Tsunami	0.138	0.724	0.273	0.086	0.089	1.000	-0.003
CAGR_adjusted	0.002	-0.005	0.004	0.000	0.000	-0.003	0.000

Description: This correlation matrix shows the relationships after each variable is z-score normalized. An absolute value closer to 1 represents a stronger relationship between two variables