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Resilience Tested: Interplay between Mortgage Channels and Natural Disasters on Housing Price

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The existing body of literature on the interaction between mortgage channels and natural disasters on housing prices is limited. As a vast archipelagic nation, Indonesia is highly susceptible to natural disasters. Our research utilizes quarterly data from Indonesian provinces between 2012 and 2019, and employs panel regression to evaluate the influence of mortgage channels and natural disasters on housing prices. The results indicate varying impacts on housing prices based on the type and intensity of natural disasters, alongside regional development, which remain robust under various tests. Despite potential disruptions, the overall availability and effects of housing loans on housing prices remain relatively stable, thus highlighting the significant role of mortgage channels in shaping housing prices under different circumstances. This understanding has the potential to guide stakeholders in enhancing disaster management strategies and overseeing housing prices, and takes into consideration the distinct vulnerabilities found in each region. Due to the unpredictable nature of natural calamities, it is crucial to

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establish plans for pre-disaster strategies. Using risk-disaster clusters allows the government to customize housing policies based on particular vulnerability categorizations instead of utilizing a standardized approach nationwide. Additionally, the financial sector has the opportunity to integrate regional risk assessments in the decision-making process for the distribution of housing loans.

Keywords

Housing price, Mortgage channel, Natural disasters, Regional factors

1. Introduction

The disparity in regional house prices in Indonesia is significantly influenced by various regional factors. Indonesia, with a population exceeding 266.9 million, comprises 34 provinces spread across 16,766 islands, which encompasses an area of 1,916,906.77 square kilometers as of 2019 (Badan Pusat Statistik, 2024). Positioned within the "Ring of Fire", Indonesia is situated amidst three major tectonic plates: the Eurasian, Indo-Australian, and Pacific plates. Furthermore, as an archipelagic nation, Indonesia exhibits diverse geographical characteristics, which renders it susceptible to various natural disasters with severities that vary across regions due to its expansive size. Housing prices may reflect varying levels of disaster risk depending on the area and timing of the impact of the event (Montz, 1993; Samarasinghe and Sharp, 2010; Troy and Romm, 2004; Walsh and Mui, 2017). Consequently, the diverse geographic landscape of Indonesia contributes to significant variations in housing prices across regions, attributable to differences in accessibility, development, and demand.

House prices reflect the heterogeneity in beliefs on the risks of long-term climate change, where climate change can trigger a variety of natural disasters. One source of risk in real estate appraisal comes from natural disasters, such as floods, fires, and earthquakes (Baldauf et al., 2020). In addition, Bos et al. (2022) state that natural disasters can inflict substantial damage to residential properties, thus prompting homeowners to seek housing finance for repairs or reconstruction. This surge in demand for housing loans can exert pressure on house prices. Despite governmental regulatory measures, long-term risks persist within the housing market. The lessons learned from the subprime mortgage crisis underscore the importance of prudent policies in the housing sector, particularly concerning housing types vulnerable to credit risks, as defaults on loan repayments can precipitate market disruptions and financial losses for banks. Ultimately, such risks can precipitate drastic declines in housing prices and financial instability within the banking sector. The previous literature has studied how financially integrated banks respond to natural

disasters (Cortés and Strahan, 2017). Interest rate and credit are the most influential factors in the real sector, and housing is one of the real sectors. Besides that, based on the uniqueness of location, borrowers are free to continue or terminate their loan according to the terms and conditions agreed upon in the contract, such as changes in mortgage rates that affect the default and prepayment loan (Fang and Munneke, 2020; Kelly and O'Toole, 2018).

The mediating role of natural disasters in housing loans can impact the supply and demand dynamics in the housing market. In areas prone to disasters, the supply of available housing may decrease due to property damage or destruction. This is in line with the Indonesian government who implemented a policy to provide special treatment for sharia credit and financing from banks for debtors or projects located in natural disaster locations (Otoritas Jasa Keuangan, 2018). However, the demand for housing in these areas may persist or even increase, driven by various factors such as population growth, economic opportunities, and government support for rebuilding. This interplay between supply and demand can influence house prices. Mortgage availability is the most useful of home purchases in Indonesia, which are facilitated through mortgage arrangements, with approximately more than 70% of transactions utilizing this financing method in the last few decades (Haryono, 2024). This data underscores the significant reliance of the community on mortgages when it comes to property acquisition, which surpasses cash transactions and other payment alternatives. The Indonesian government oversees housing loans through the regulations of Bank Indonesia, which mandate that credit be extended based on the loan to value (LTV) scheme. This policy dictates the required down payment and installment amounts that banks can impose on buyers.

Similar regulations are commonplace in various countries, including Australia, Belgium, Canada, and New Zealand, which aim to govern the housing market (Armstrong et al., 2019; Bian et al., 2018; de Araujo et al., 2020; Kiarelly et al., 2016; Kinghan et al., 2019; Lim and Nugraheni, 2017; Qi and Yang, 2009; Sasikirono et al., 2019). The local housing characteristics lead to differences in the development of the housing market in each region (Hernández-Murillo et al., 2017; Tuzel and Zhang, 2017), and Indonesia as a country with thousands of islands also encounters problems in housing market development. There are two aspects in the housing demand discussion; the first is the total demand or number of housing units needed in the market, and the second is house characteristics, such as unit size, age, location, geographic conditions, and whether the units are planned to be sold or rented to consumers. Therefore, the housing market characteristics in Indonesia need to have a spatial or cluster analysis based on regional factors.

According to Rohmat et al. (2022), in alignment with the Indonesian National Board for Disaster Management (BNPB), Indonesia recorded 5,402 disaster events in 2021. These disasters included floods, landslides, hurricanes, droughts, forest and land fires, extreme tidal waves, earthquakes, and volcanic

eruptions. The capital city, Jakarta, is notably prone to flooding, with several studies indicating its high vulnerability to such events (Farid et al., 2019). While the primary cause of floods in Indonesia is the overtopping of riverbanks, this issue is exacerbated by the decreased hydraulic capacity of rivers, a consequence of both direct and indirect urbanization pressures (Asdak et al., 2018; Jones, 2017; Moe et al., 2017). For instance, urban centers such as Jakarta may exhibit distinct pricing dynamics compared to other metropolitan areas, which are considered high-risk climate-related disaster cities, particularly to floods (Nasution et al., 2022). Apart from floods, Indonesia is very vulnerable to earthquakes and volcanic eruptions because its geographical location is in the Pacific Ring of Fire zone, which is known for the most intense seismic and volcanic activity throughout the world. Along the west coast of Sumatra and Java, tectonic plate subduction activity often triggers earthquakes, which can cause sea level changes and tsunamis, thus causing inundation on the coast. In particular, from 2012 to 2019, Indonesia witnessed several noteworthy earthquakes, including the devastating Aceh earthquake in 2016, which generated a devastating tsunami. Indonesia has an extraordinary geological landscape, with more than 100 active volcanoes, which strengthen its position as one of the countries with the most active volcanoes in the world. Throughout the period of 2012 to 2019, several volcanoes, such as Mount Sinabung in North Sumatra, Mount Agung in Bali, and Mount Merapi in Central Java, experienced eruptions. The eruptions required residents to be evacuated, caused environmental damage, and disrupted air travel due to ash clouds and volcanic activity.

Proximity to disaster-prone areas translates into a greater reduction in house prices (Atreya and Ferreira, 2015; Bakkensen et al., 2019; Bin and Landry, 2008; Bin and Polasky, 2004; Cheung et al., 2018; Fekrazad, 2019; Masiero and Santarossa, 2020; Modica et al., 2021). Additionally, the duration of this price reduction can vary, either short-term or long-term, depending on the recovery period and the conditions of each region (Bakkensen et al., 2019; Jung and Yoon, 2018; Livy, 2023). Coulson et al. (2020) indicate that regional economic diversification can lessen the negative impacts of natural disasters on housing values.

We opt to explore how natural disaster risks influence housing prices through the mortgage channel, and how regional disasters can play a role in this process. Moreover, this examination contributes to understanding how susceptibility to disasters affects both the cost and demand for housing. Various elements such as geographical location, disaster preparedness measures, and environmental conditions significantly shape property values in regions prone to disasters. Additionally, public perceptions and attitudes toward disaster risks can influence the housing market dynamics, due to the differences in the overall resilience of the housing sector in affected regions.

2. Literature Review and Conceptual Model

Drawing on partial findings from earlier studies outlined in the previous section, it becomes evident that not all housing markets in Indonesia exhibit rapid growth. Various factors, such as regional economic conditions, local infrastructure, and susceptibility to natural disasters, contribute to this uneven growth. Research has shown that major housing purchases in Indonesia come from housing loans, while housing loans are one of the mortgage channels in the housing market. In addition, areas prone to natural disasters tend to experience slower growth in the housing markets due to the heightened perceived risk and potential financial losses.

This section will delve into several previous studies on mortgage financing channels that could help ease or reduce the impact of natural disaster risks on housing prices. Enhanced mortgage financing options, such as lower interest rates for properties with disaster-resilient features, can also incentivize investment in safer housing and reduce overall market volatility. Collectively, these studies indicate a negative impact of natural disasters on house prices.

2.1 Effects of Mortgage Channel on Housing Prices

The empirical relevance of the study shows that loans are the central topic of banking research and the subject is discussed in much of the existing literature. In line with Bos et al. (2022), the behavior of banks in response to adverse events, whether economic or non-economic, is of central importance to economic policymaking and financial stability. Furthermore, the effects of mortgage channels on housing prices can vary significantly across regions. Glaeser et al. (2014) emphasize the importance of local economic conditions, regulatory environments, and housing supply constraints. For instance, in high-demand cities with limited housing supply, even small changes in mortgage rates can lead to substantial price fluctuations. Albouy and Ehrlich (2018) and Saiz (2010) further expand on the findings of Glaeser et al. (2014), and examine how regional factors such as land use regulations and economic growth rates interact with mortgage market conditions to influence housing prices.

Since the early 2000s, macroprudential policies have increasingly become part of regulatory and supervisory frameworks. Likewise, the housing market has been at the center of debate on systemic financial risk management. Among the macroprudential tools, the purpose of the LTV ratio is to limit the loan size of housing loans (Morgan et al., 2019). In addition, the US housing boom was the result of lenders who erroneously rushed to provide housing loans, which ultimately led to the appreciation of house prices (Mian et al., 2015). Therefore, economic growth can be triggered because of house price shocks. These effects can have more impact on financially integrated regions, thus, house price shocks can increase economic volatility. Banks do reallocate funds to booming markets and as a result, local economic growth becomes negatively correlated

with external housing booms (Loutskina and Strahan, 2015). In general, the property sector is a leading sector for economic recovery, thus, it is expected to have a spillover effect on other sectors such as construction, industry, and services. The LTV ratio can be eased and tightened depending on the housing market conditions. The easing consists of down-payment reduction and reduction in ownership tiers for first-house, second-house, and so on and so forth.

Goodman and Mayer (2018) analyze the impact of government-backed mortgage programs, and find that they significantly increase homeownership rates and stabilize housing prices in distressed markets. Additionally, Mian et al. (2015) examine the effects of the Dodd-Frank Act on mortgage lending, and conclude that regulatory changes improve market transparency and reduce the likelihood of another housing bubble. Lending standards, including down payment requirements and credit score thresholds, directly impact mortgage accessibility. Dipasquale (1999) shows that relaxed lending standards in the early 2000s led to increased homeownership rates and elevated housing prices, a trend that reversed during the 2008 financial crisis when lending standards tightened. More recent work by Anenberg et al. (2019) explores the post-crisis period, and notes that stricter lending standards initially slowed price growth, but subsequent regulatory adjustments helped to stabilize the market. Moreover, interest rates are a primary determinant of mortgage affordability and, consequently, housing demand and prices. Miller et al. (2005) highlight that lower interest rates reduce the cost of borrowing, thus increasing housing affordability and driving up housing prices.

Natural disasters are also a factor that affects the amount of credit granted by banks (Albuquerque and Rajhi, 2019; Nguyen and Wilson, 2018), as studies have found that there is a significant decline in the total supply of credit disbursed to disaster-affected regions. It is common for banks to experience shock after a natural disaster, including a common disaster like flooding, such as when they have corporate customers in affected areas which requires banks to carefully consider local factors (Koetter et al., 2020). In conclusion, the relationship between mortgage channels and natural disasters is complex, with significant implications for housing prices and market stability. Effective mortgage financing options, supported by sound macroprudential policies and regulatory frameworks, are essential in mitigating the adverse effects of natural disasters on the housing market.

2.2 Effects of Natural Disasters on Housing Prices

The impact of natural disasters on price disparities in the housing market has become increasingly significant as the climate crisis exacerbates the risks associated with property purchases. Natural disasters cause substantial damage or destruction to houses, which in turn affects the broader economy (Johar et al., 2022). Regression analyses with individual, area, and time-fixed effects reveal that while natural disasters do not directly influence employment and

income, they considerably heighten financial distress and risk aversion. Using a group fixed effects estimator, predictors of financial vulnerability such as age, parenthood, illness, and social support have been identified.

In Mexico, earthquake damage is one of the most alarming risks perceived by homebuyers. Lara-Pulido et al. (2022) use data from real estate listing prices in cities before and after the 2017 Puebla earthquake with a magnitude of 7.1 and apply a spatial difference-in-differences model to find that prices for risky housing are discounted prior to the earthquake and increased in the short term following the incident. These findings highlight the importance of adequate risk awareness policies to protect potential consumers and mitigate market failures (Lara-Pulido et al., 2022).

A global study by Apergis (2021) confirms that natural disasters contribute to declines in house prices, with geological disasters having the most pronounced negative impact. Similarly, Adachi and Li (2023) examine the impact of natural disasters on residential property values in Australia, and reveal that property prices in affected areas decline, while regions with minimal disaster impacts initially see price increases, which later depreciate if a natural disaster occurred.

Repairing flood damage is notoriously expensive (Bin and Kruse, 2006; Posey and Rogers, 2010; Simmons and Sutter, 2007). Homes affected by flooding are costly to restore and likely to face similar risks in the future (Hennighausen et al., 2023; Nyce et al., 2015; Zhang et al., 2010). Despite these challenges, demand for properties in flood-prone areas remains strong. This phenomenon is partly due to the temporary nature of the drop in housing values in such areas. Over time, memories of floods fade, and property values recover (Jung and Yoon, 2018; Seo et al., 2021). Additionally, financial safety nets like flood insurance, despite high premiums, provide a sense of security and mitigate financial risks (Bin and Landry, 2008; Eves, 2004; Nyce et al., 2015), and financial assistance mechanisms also help to sustain the housing market in these regions. This interplay of short-term memory, financial support mechanisms, and the inherent resilience of the housing market helps to maintain demand for homes in flood-prone areas.

The geographically weighted regression (GWR) of the hedonic model on point data, which groups model coefficients to detect housing submarkets, is explored by Kopczewska and Ćwiakowski (2021) who examine spatio-temporal stability, and added novelty by comparing whether clusters move or remain stable by using the Rand Index and Jaccard Similarity to evaluate the stability of spatial structures. This approach quantitatively evaluates the stability of price determinants over time and location. Applying the standard error of the GWR coefficient tests the spatiotemporal stability of local heteroscedasticity. A case study of apartment transactions in Warsaw, Poland, from 2006 to 2015 shows relatively high spatiotemporal stability.

Income is not the sole measure of development in reducing mortality and disaster damage (Toya and Skidmore, 2007). Factors such as higher educational attainment, increased openness, a robust financial sector, and meticulous governmental attention are also pivotal in reducing mortality and disaster damage. Policymakers involved in disaster preparedness programs may find it valuable to gauge potential lives saved due to development efforts. Beyond direct disaster mitigation, policies aimed at minimizing and managing long-term disasters will have far-reaching impacts across all economic sectors. Income plays a pivotal role in shaping individual consumption habits. A rise in house prices can impact consumption through two mechanisms: increased perceived wealth which prompts more spending and eased borrowing constraints by using houses as collateral.

Sociodemographic and preference-based segmentations in the housing market reveal that even homogenous demographic groups can have varied housing preferences. Głuszak and Marona (2011) show through a housing demand analysis in Poland that both demographic and preference-based factors must be considered to accurately reflect consumer behavior. Preferences differ based on model, location, and proximity to public facilities, which simple demographic characteristics cannot fully explain (Głuszak and Marona, 2011).

The housing market is a complex system susceptible to various influences, including natural disasters like floods, volcanic eruptions, and earthquakes. These events inflict significant property damage, displace residents, and disrupt communities. The effect of natural disasters on housing markets is of particular interest due to its potential to disrupt local economies and alter property values. Beyond immediate devastation, natural disasters have a ripple effect on housing prices, often mediated through the mortgage channel.

In line with previous research, regional economic diversification significantly impacts the resilience of the housing market in the US, and shows substantial spatial and temporal variations. Coastal and urban centers show greater resilience in the social and infrastructure domains compared to hilly regions (Narieswari et al., 2022). Coulson et al., (2020) use natural disaster data as exogenous shocks to the regional economy, and find that both the magnitude and duration of disasters impact local housing market values.

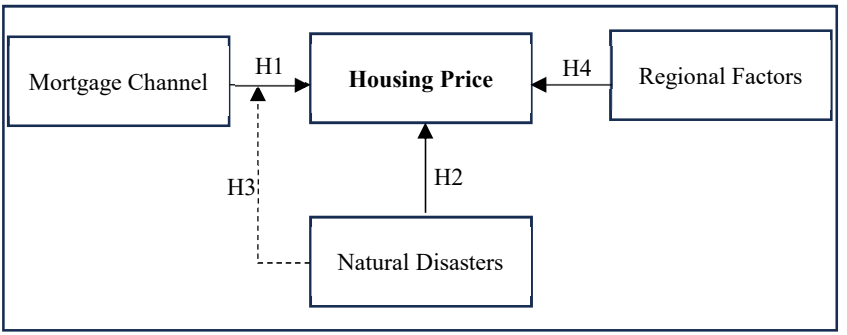
2.3 Conceptual Model: Mortgage Channel, Natural Disasters, and Regional Housing Prices

As the literature review suggests, the findings are inconsistent despite substantial research on the effects of natural hazards on housing price (Zhang et al., 2010). Moreover, most of the studies in the related literature indicate that the relationship between natural disasters and housing prices is negative. This aligns with the findings in Apergis (2020), who notes that countries affected by natural disasters tend to experience lower house prices, which can lead to

significantly reduced consumption and investment (the wealth effect), thus having further negative impacts on the real economy.

Most studies treat natural disasters or mortgage channels as a direct influence on housing prices, but there is evidence that the effect of mortgage channels is moderated by natural disasters and the magnitude of the influence of natural disasters depends on regional capabilities in each affected area. In addition, there is a different response to each type of natural disaster. Nevertheless, the foregoing discussion of the literature leads to a hypothetical conceptual model (Figure 1), which depicts the causal relationship among mortgage channels, natural disasters, regional factors, and housing price. In the model, the effect of the mortgage channel on housing price is moderated by natural disasters. This moderation implies two conditions. First, natural disasters should be significantly related to the mortgage channel. Second, the moderation also implies a slow-down effect of the mortgage channel on housing price.

Figure 1 Hypothesized Model of Relationship Among Natural Disasters, Mortgage Channel, Regional Factors, and Housing Price



The mortgage channel plays a crucial role in shaping the dynamics of housing prices. This channel refers to the system through which housing loans are issued and serviced, thus influencing the ability of borrowers to purchase property. In addition, it can be used as a proxy in terms of directly impacting the demand for housing, as it determines the affordability and accessibility of home ownership. Understanding this relationship helps to shed light on the broader economic implications of mortgage policy and interest rate adjustments.

Hypothesis 1a: Increased activity in the mortgage channel leads to higher housing prices.

Hypothesis 1b: Changes in mortgage interest rates significantly affect housing prices.

Natural disasters pose a significant threat to the stability of housing markets, often causing immediate and long-term disruptions. The impact of events such as floods, earthquakes, and eruptions can be devastating, thus resulting in property damage, loss of life, and economic instability. These disasters can drastically change housing prices, especially in the affected areas, and the extent of this impact can vary based on several factors, including the preparedness and resilience of the region.

Hypothesis 2a: Natural disasters (floods, earthquakes, and eruptions) have a negative impact on housing prices in the affected areas.

Hypothesis 2b: The effect of natural disasters (floods, earthquakes, and eruptions) on housing prices is moderated by the resilience and preparedness of the region.

The interplay between the mortgage channel and natural disasters introduces a complex layer of interaction that affects housing prices. Natural disasters can disrupt the normal functioning of mortgage markets by influencing both the supply and demand for housing loans. Additionally, the presence of a robust mortgage system might mitigate the negative impacts of such disasters on housing prices, thus highlighting the importance of financial stability in disaster-prone regions.

Hypothesis 3a: Natural disasters moderate the impact of a mortgage channel on housing prices.

Hypothesis 3b: Areas with more robust mortgage channels experience a less negative impact on housing prices following natural disasters (floods, earthquakes, and eruptions).

Regional factors encompass a variety of elements that influence housing prices, such as economic conditions, employment rates, and local government policies. These factors contribute to the unique economic environment of each region, which affect both the supply and demand for housing. By examining these influences, it becomes clear how regional disparities can lead to significant variations in housing market behavior.

Hypothesis 4a: Regional factors, such as economic growth, employment rates, and local policies, have a positive impact on housing prices.

Hypothesis 4b: Variations in regional factors cause significant disparities in housing prices.

Specifically, this study analyzes ten models to answer all of the hypotheses in this study, with each focusing on mortgage channels, regional factors, and a different natural disaster event (earthquakes, floods, or eruptions), as well as the potential moderating effects between housing loans and natural disasters.

The models include both main effects and interaction terms to capture the complexities of these relationships. The following section presents the results of our regression analysis, which highlight the key findings and their implications for understanding housing price dynamics.

3. Data and Method

The hypotheses are tested with the use of Indonesian data, which are obtained from a disaster-prone area. Moreover, hundreds of natural disasters pose natural hazards. Data are collected from five sources from 2012 to 2019 on a quarterly dataset. The first of which is financial data on mortgage channels from the Financial Services Authority (FSA) and Central Bank of Indonesia (BI). The second data source is the natural disaster data from the National Disaster Management Agency (BNPB), which are correlated with floods, earthquakes, and eruptions. Data of the other factors are collected from Statistics Indonesia (BPS) such as socio-economics and geographical data. The dataset utilized in our analysis may however have limitations in terms of its duration, as it is chosen deliberately to exclude post-COVID-19 data, thereby ensuring the impartiality of our findings and focusing solely on examining the constrained influence of natural disasters on housing prices. Besides that, the 16 provinces in Indonesia are chosen based on the availability of data from the BI, which only publishes information for a subset of provinces rather than covering the entire region.

The dataset is derived from a residential property price survey conducted by the BI in these 16 provinces, which are strategically chosen to represent the diverse characteristics of the islands of Indonesia. These regions encompass the five largest islands: Sumatera, Java, Bali, Kalimantan, and Sulawesi. Specifically, provinces such as North Sumatera, Riau, West Sumatera, Riau Island, South Sumatera, and Lampung are selected from Sumatra Island, while West Java, DI Yogyakarta, Central Java, and East Java are chosen from Java Island. Bali province represents Bali Island, while the West Kalimantan, South Kalimantan, and East Kalimantan provinces are from the Kalimantan Island, and the North Sulawesi and South Sulawesi provinces from the Sulawesi Island.

The dependent variable is housing price (*hp*) which is derived from an index constructed by using the chain index approach, and incorporates data of both the quantity of house units sold and house sales prices. This data is collected for both the current quarter of the house price survey and projected prices for the subsequent quarter. The research examines several independent variables, including housing loans (*loan*), gross regional domestic product (*grdp*), and natural disasters. Additionally, control variables considered in the analysis comprise mortgage rates (*r*), non-performing loans (*npl*), LTV ratios (*ltv*), income (*inc*), population density (*d*), and the open unemployment rate (*tpt*). This research focuses on three types of natural disasters, namely earthquakes,

floods, and volcanic eruptions, which are chosen based on their severity. The data are collected from several sources, for example, we employ *loan*, *r*, and non-performing-loan data from the Indonesian Financial Services Authority (OJK), *ltv* and house price data from the BI, natural disaster data from the BNPB, and data of other factors collected from BPS.

Our analysis considers natural disasters regardless of their severity. We define an area as "affected" if any natural disaster (major or minor) occurs within a three-month period that corresponds to the quarter being analyzed. This approach aligns with how previous studies have incorporated natural disaster data (Bin and Kruse, 2006; Bin and Polasky, 2004; Boustan et al., 2020; de Koning et al., 2018; Ewing et al., 2007; Troy and Romm, 2004). Since other control variables in our study are measured quarterly, we convert the natural disaster data to a quarterly format by assigning a value of "1" if at least one disaster happens within the relevant three-month period.

The *loan*, *r*, *npl*, and *ltv* variables are representative of the mortgage channels. Furthermore, the regional economics that represent regional characteristics, proxied by regional factors, consist of *grdp*, *inc*, *d*, and *tpt*. In addition, to represent the government size, we use investment, and for the natural disaster, we apply a dummy variable, 1 after the disaster happened and 0 before the disaster. The use of dummy variables for natural disasters is because, in this study, we want to focus on the impact after natural disasters occur, so natural disaster variables also act as moderating variables. To test this relationship, we test moderating estimation on *loan*, *grdp*, and *inv*, because these variables are the most influential in a pre-disaster strategy plan. Thus, we can determine how natural disasters can strengthen or weaken house prices.

This research employs the two baseline models based on the development of the hypotheses: the initial model evaluates the direct influence of individual mortgage channels, natural disasters, and regional factors on housing prices. The second model incorporates the interplay between the mortgage channels and natural disasters on house prices. The details of the baseline models to observe their effects are:

$$hp_{it} = \alpha + \beta_1 MC_{it} + \beta_2 ND_{it} + \beta_3 RF_{it} + e_{it} \quad (1)$$

where *hp* is the value of the house price index in province *i* at time *t*. Accordingly, *MC* is a vector of mortgage channels which consists of *loan, npl, ltv*, *ND* a vector of natural disasters, *RF* a vector of regional factors, and *e*, the error term. The initial model serves as the baseline, while the second model introduces the moderation effect of natural disasters on the relationship between mortgage channels and house prices. This moderation follows Troy and Romm (2004) who use an interaction dummy variable to indicate house transactions within the flood zone area. Meanwhile, this study uses housing loans as the moderator variable from the mortgage channel, which has a crucial role in this dynamic housing transaction. Furthermore, loans significantly influence the

speed and extent of market recovery, as evidenced by various studies (Cortés and Strahan, 2017; Mian et al., 2015; Toya and Skidmore, 2007). These findings underscore the importance of mortgage loans in mitigating the adverse effects of natural disasters on housing markets and promoting financial resilience.

$$hp_{it} = \alpha + \beta_1 MC_{it} + \beta_2 ND_{it} + \beta_3 RF_{it} + \beta_3 (loan * ND)_{it} + e_{it} \quad (2)$$

The descriptive statistics provided in Table 1 offer a comprehensive overview of the sample data, albeit limited by data availability constraints. The fluctuation in the number of observations presented in the table is attributed to the varying availability of data for each variable across different periods of time.

Table 1 Descriptive Statistics

Variable	Obs	Mean	Std. dev.	Min	Max
hp	478	203.96	56.11	100.00	348.15
loan	497	12,543.78	16,805.39	434.00	104,413.70
r	512	352.72	436.22	23.00	2,631.59
npl	497	99,712.62	100,578.50	13,208.24	425,191.80
ltv	512	79.71	6.96	70.00	89.50
grdp	512	10.36	0.78	8.68	11.34
inc	512	1,772,678.00	632,441.20	745,000.00	3,355,750.00
d	512	405.04	427.89	18.39	1,394.00
tpt	512	5.48	1.77	1.37	10.83
flood	512	0.37	0.48	-	1.00
earthquake	512	0.01	0.09	-	1.00
eruption	512	0.01	0.10	-	1.00

Notes: The type of natural disaster, such as floods, earthquakes, or eruptions, is a dummy variable where 1 is the natural disaster happening in quarter *t* and 0 otherwise.

Each region has different conditions, and a complex process of development in terms of the housing market (Hernández-Murillo et al., 2017; Nugroho et al., 2020; Tuzel and Zhang, 2017; Wu and Sharma, 2012). Therefore, we analyze the data by using a static data panel. Based on the descriptive statistics provided in Table 1, *loan*, *npl*, *grdp*, monthly *inc*, and *d* have a high standard deviation and thus, to address this problem, the natural logarithm of the variables is used in the regression estimation. After that, we compare the data between regions to find out more about the impact of natural disasters on housing prices in each region. Thus, we can see that the impact varies in each region based on the capabilities and resilience of the region.

4. Results and Discussion

This discussion paper delves into the nuanced dynamics of housing prices across different regions, particularly examining how natural disasters influence the relationship between regional characteristics and housing prices. Leveraging panel data regressions by using a fixed effect model, the study explores variations in the determinants of housing prices among the sample regions. The Chow, Hausman, and Lagrange multiplier tests are used to optimize methodological rigor and robustness. The findings reveal intriguing insights into the interplay among mortgage channels, regional factors, and natural disasters, thus shedding light on the complexities of housing market phenomena.

A base regression model that predicts housing prices is run and the results are shown in Table 2, where the analysis of the impact of mortgage channels and regional factors on house prices is shown in Model (1). This is followed by adding each natural disaster, that is, floods, earthquakes, and eruption events, to the regression in Models (2) to (4). All of the models have a substantial amount of variance in housing prices which have an R2 of around 70 percent, thus indicating that mortgage channels, regional factors, and natural disasters are important in determining housing prices.

Consistent with Hypothesis 1, the mortgage channel has a positive effect on housing prices; it leads housing prices with activity in the mortgage channel such as an increasing volume of housing loans and a rising *r*. In addition, the *ltv* is correlated with higher housing prices because it is a measure to stabilize housing prices, and the government can increase or reduce the ratio for the down payment in housing financing. Nevertheless, based on the result, the *ltv* does not have a significant impact on house price. So, this suggests that higher availability of mortgage financing drives up housing demand and prices which is in line with the findings in Agnello et al. (2019), Kim et al. (2018), and Zhu et al. (2017), where access to mortgage financing is a critical driver of housing market dynamics.

Hypothesis 2 alludes to the role of the direct impact of natural disasters on house price which is shown in the regression results based on Models (2), (3), and (4) in Table 2. Table 3 responds to Hypothesis 3 and shows how natural disasters impact house prices through mortgage channels. The difference between the two is that in Equation 2, we investigate floods as the natural disaster where Model (3) investigates earthquakes, and Model (4) examines eruptions. The inclusion of different natural disaster variables provides nuanced insights, which might have more local or less enduring effects on the housing market. The findings reveal that volcanic eruptions are the only disaster to negatively affect housing prices (Model 4). In contrast, floods (Model 2) and earthquakes Model (3) do not exhibit significant impacts on housing prices.

The distinction impact of natural disasters on house prices can differ with different regional conditions. From an economic region perspective, better economic conditions mean less impact from a disaster. The *grdp* and *inc* are also consistently significant, which indicate that higher regional economic output and personal income positively influence housing prices. The result of the impact of regional factors on house prices therefore supports Hypothesis 4.

Table 2 Regression Results of Mortgage Channel, Regional Factor, and Natural Disasters on House Price

Variable	(1) Before ND	(2) Floods	(3) Earthquakes	(4) Eruptions
loan	19.05*			
	(10.540)			
npl	7.321	7.445	7.478	7.645
	(9.674)	(10.720)	(10.680)	(10.640)
r	6.924**	7.106***	7.016***	6.986***
	(2.426)	(2.344)	(2.315)	(2.331)
ltv	0.106	0.283	0.291	0.290
	(0.400)	(0.470)	(0.460)	(0.459)
lgrdp	118.1**	142.3***	141.0***	141.3***
	(48.730)	(43.560)	(43.340)	(43.240)
inc	10.38*	11.95*	12.43*	11.98*
	(5.363)	(5.951)	(6.281)	(5.988)
ld	-0.798	0.840	0.665	1.122
	(47.370)	(47.160)	(46.870)	(46.400)
tpt	-3.520	-3.612	-3.552	-3.604
	(4.585)	(4.476)	(4.487)	(4.478)
fl		1.314		
		(1.890)		
eq			-4.642	
			(8.712)	
er				-9.042**
				(3.167)
Constant	-1,518***	-1,664***	-1,654***	-1,654***
	(452.4)	(417.2)	(412.8)	(411.6)
Observations	478	478	478	478
R-squared	0.718	0.706	0.706	0.707
Number of codes	16	16	16	16

Notes: ND denotes natural disaster. Estimates of the effect of regional factors and natural disasters on house prices are implemented by using a fixed-effects model in Models (1), (2) and (3). The results are robust against multicollinearity and autocorrelation problems. Standard errors (in parentheses) are robust. All regressions include time with significance at *** <1%, ** <5%, and * <10%.

Table 2 shows that the mortgage channel, economic output, and income levels drive housing prices, while natural disasters such as earthquakes, floods, and eruptions cause significant disruptions differently. The impacts of these factors on housing prices are examined, with a particular focus on the moderating effects of housing loans as the main part of the mortgage channel and natural disasters on housing prices. Then, an analysis of the six models in Table 3 reveals important insights into the factors that influence housing prices. By exploring these dynamics, we provide a comprehensive understanding of the interplay between mortgage channels and external shocks in the housing market.

Table 3 allows a comprehensive analysis of the factors that influence housing prices. Overall, the R-squared values are very similar across all of the models, which range from 0.718 to 0.720, thus indicating a consistent level of explanatory power. These high R-squared values suggest that the models explain for a substantial amount of the variability in housing prices. The consistency of certain key variables, such as *loan*, *grdp*, and *inc*, underscores their importance in understanding housing price dynamics. Additionally, the significant moderation effects of earthquakes and eruptions highlight the necessity of considering interaction terms to fully capture the impact of natural disasters on housing prices.

Across all models, mortgage channels have a strong impact on housing price. *loan* consistently shows a significantly positive impact on housing prices, which demonstrates the crucial role of mortgage availability in the housing market. In terms of *r*, the results show that they have a positive relationship with housing prices across all of the models. This could be because they reflect better economic conditions or more significant demand for housing, which in turn, drives up prices. The *ltv* and *npl* are not significant in any model, which suggest that these do not have a direct impact on housing prices within the context of the given models. This might be due to the *ltv* being a government treatment without considering natural disasters. Furthermore, the OJK has relaxed the credit scheme in areas affected by natural disasters, so that when a natural disaster occurs, the credit payment process does not affect the amount of the *npl*. For example, it was implemented in West Nusa Tenggara (NTB) and several other provinces where OJK provided credit restructuring to affected debtors and instructed banks in affected areas to provide new credit to debtors affected by natural disasters.

When examining the impact of natural disaster events, the results vary, which is in line with Apergis (2020). The relationship between natural disasters and house prices depends on the type of natural disaster. In Model (2), the earthquake dummy variable is significantly negative, thus indicating that earthquakes have a detrimental effect on housing prices, following Apergis (2020) and Naoi et al. (2009) who examine how earthquake hazards impact housing prices. Housing loans have the potential to mitigate the impact of earthquakes on housing prices by as much as 10 percent. In contrast to Models

(4) and (6), the flood interaction term is not significant, thus suggesting that floods do not have a moderated impact on housing prices through housing loans. For floods and earthquakes, the direct effects on housing prices are not significant in the models without moderation (Models 1 and 3). In Model (5), eruptions have a direct impact on house prices.

Table 3 Regression Result of the Interplay between Mortgage Channel and Natural Disaster on House Price

Variable	(1) eq	(2) mod eq	(3) fl	(4) mod fl	(5) er	(6) mod er
Loan	18.99*	18.44*	18.96*	18.45	18.85*	18.84*
	(10.52)	(10.48)	(10.62)	(11.33)	(10.49)	(10.50)
npl	7.317	7.642	7.290	7.391	7.464	7.483
	(9.652)	(9.584)	(9.670)	(9.616)	(9.638)	(9.667)
lgrdp	118.2**	119.4**	119.4**	119.4**	118.6**	118.7**
	(48.64)	(48.38)	(49.12)	(49.11)	(48.47)	(48.56)
ltv	0.0976	0.0743	0.0906	0.0875	0.0973	0.0974
	(0.395)	(0.392)	(0.399)	(0.399)	(0.394)	(0.393)
r	6.900**	6.911**	6.974**	6.912**	6.872**	6.869**
	(2.410)	(2.407)	(2.436)	(2.461)	(2.424)	(2.424)
inc	10.69*	10.80*	10.31*	10.32*	10.34*	10.34*
	(5.654)	(5.467)	(5.345)	(5.352)	(5.382)	(5.388)
d	-0.860	-0.598	-0.717	-0.498	-0.457	-0.514
	(47.37)	(47.59)	(47.60)	(47.58)	(46.96)	(47.05)
tpt	-3.528	-3.519	-3.577	-3.536	-3.574	-3.566
	(4.589)	(4.589)	(4.559)	(4.516)	(4.581)	(4.591)
eq	-3.587	-116.4***				
	(7.360)	(31.550)				
loan X *eq*		10.80***				
		(2.863)				
fl			1.088	-7.456		
			(1.972)	(24.47)		
Loan X *fl*				0.947		
				(2.551)		
er					-7.911**	-22.12
					(3.088)	(29.36)
loan X *er*						1.506
						(3.043)
Constant	-1,522***	-1,533***	-1,530***	-1,527***	-1,523***	-1,523***
	(452.8)	(451.5)	(458.0)	(457.5)	(450.4)	(450.9)
Observations	478	478	478	478	478	478
R-squared	0.718	0.720	0.719	0.719	0.719	0.719
Number of codes	16	16	16	16	16	16

Notes: Estimates of all models are made by using fixed-effects model. fl denotes floods, eq are earthquakes, er are eruptions, and mod is the result of the moderation effect. The results are robust against multicollinearity and autocorrelation problems. Standard errors (in parentheses) are robust. All regressions include time with significance at *** <1%, ** <5%, and * <10%.

While the impact of natural disasters on housing prices exhibits varying degrees of significance and moderation effects, the influence of regional economic factors remains consistently significant across all models. This contrast highlights the multifaceted nature of housing price determinants, where external shocks such as natural disasters can have immediate and sometimes moderated effects, whereas underlying economic conditions provide a more stable and persistent influence. Understanding these dynamics requires an integrated approach that considers both the short-term disruptions caused by natural events and the long-term contributions to regional economic health. In the following section, we delve deeper into the role of regional factors in shaping housing prices, by examining how variables such as *grdp*, *inc*, and *r* interact with and sometimes counterbalance the impacts of natural disasters.

In all of the models, gross domestic product and income emerge as strong positive determinants of housing prices. This consistency highlights the integral role of economic prosperity and household income in shaping housing market trends, which aligns with the conclusions drawn by Meen (2001), who emphasizes the importance of economic growth and income levels in influencing housing demand and prices. Conversely, *d* and *tpt* do not show significantly direct impacts on housing prices across our models. The negative but insignificant impact of *d* suggests that higher density does not necessarily lead to lower housing prices in these provinces, possibly due to varying urban development patterns and housing supply conditions. These findings are consistent with some of the previous studies that have found mixed results regarding the direct impact of these variables on housing prices (Adams and Füss, 2010)

As a result of the myriad of factors examined, mortgage channels significantly impact housing prices by facilitating the availability of housing loans, which makes it easier for individuals to purchase homes. This increased demand often drives up housing prices as more people can afford to buy, thus leveraging borrowed funds. However, this relationship can be moderated by extreme events such as volcanic eruptions. Eruptions create immediate and long-term uncertainties in affected areas, which lead to a decrease in housing demand and, consequently, housing prices. The fear of future eruptions, potential damage, and displacement concerns contribute to this decline, thus highlighting how natural disasters can change the typical dynamics between mortgage availability and housing prices.

In contrast, when considering floods and earthquakes as mediating factors, their impact on housing prices through the mortgage channel appears to be less significant. Floods are relatively common and often perceived as manageable compared to other disasters in Indonesia, so the effect of floods on house prices is positive but not significant. Many flood-prone areas are urban centers with high demand for housing. The economic opportunities and amenities in these areas can outweigh the flood risk, and maintain or even increase housing prices. Many areas have adapted to seasonal flooding, and residents might have

measures in place to mitigate the impact. There are established infrastructure and insurance systems so that housing markets recover more swiftly. As a result, while these events can cause temporary disruptions, they do not drastically change the overall availability and impact of housing loans on long-term housing prices. The resilience of the market and adaptive measures help to maintain a degree of stability even in the face of such disasters.

The analysis also incorporates dummy variables for natural disaster events, and reveals that the impact of earthquakes and floods on housing prices is not significant. However, eruptions have a negative and significant effect, thus highlighting the severe and lasting disruptions caused by volcanic eruptions on housing markets. Additionally, the moderation effects indicate that the interaction between *loan* and earthquake events has a positive and significant impact on housing prices, which suggests that post-disaster reconstruction efforts and increased borrowing can lead to higher housing prices. However, the interactions with flood and eruption events do not show significant impacts, thus implying that these moderations are not strong enough to significantly change housing price dynamics.

Overall, the influence of the mortgage channel on housing prices is substantial, but the extent of this influence is contingent on the nature of the moderating event. Volcanic eruptions are a unique, acute risk that significantly disrupts housing markets, whereas floods and earthquakes, although serious, are often mitigated through preparedness and recovery mechanisms, thus having a less profound long-term impact on housing prices. This distinction underscores the importance of considering the type and severity of natural events when analyzing housing market dynamics and the efficacy of the mortgage channel.

5. Conclusion

The findings reveal intriguing insights into the interplay among mortgage channels, regional factors, and natural disasters, thus shedding light on the complexities of housing market phenomena. The differential impact of natural disasters on house prices can vary due to regional conditions. In addition, natural disaster events exhibit varying degrees of significance and moderation effects. Earthquakes negatively affect housing prices, and this effect is further moderated by the size of housing loans. This highlights the complex interplay between natural disasters and financial factors in the housing market. Mortgage channels significantly impact housing prices by facilitating *loan,* increasing demand, and driving up prices. Higher *r*, which reflect better economic conditions or greater housing demand, are also positively correlated with housing prices. The *ltv* and *npl* do not have a direct impact on housing prices within the given models.

The influence of regional economic factors remains consistently significant across all of the models, which emphasizes the multifaceted nature of housing price determinants. Better economic conditions in a region tend to mitigate the impact of disasters. Understanding these dynamics requires an integrated approach that considers both short-term disruptions from natural events and long-term contributions to regional economic health. In all of the models, *grdp* and *inc* emerge as strong positive determinants of housing prices, which align with previous studies that emphasize the importance of economic growth and income levels in influencing housing demand and prices.

In conclusion, while mortgage channels significantly impact housing prices, the extent of this influence depends on the nature of the moderating event. Volcanic eruptions present a unique risk that significantly disrupts housing markets, whereas floods and earthquakes, although serious, are often mitigated through preparedness and recovery mechanisms. This distinction underscores the importance of considering the type and severity of natural events when analyzing housing market dynamics and the efficacy of mortgage channels. Therefore, location serves as a pivotal determinant in shaping housing market dynamics. The housing sector warrants government attention tailored to regional nuances. Government interventions should account for factors that either accelerate or decelerate housing price fluctuations, particularly in areas vulnerable to natural disasters while leveraging the competitive advantages inherent to those regions. Moreover, demographic factors within a locality exert a notable influence on housing demand within the market.

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