BANK FOR INTERNATIONAL SETTLEMENTS

BIS Working Papers

No 914

Demographic shifts, macroprudential policies, and house prices

by Jieun Lee and Hosung Jung

Monetary and Economic Department

December 2020

JEL classification: J11, J10, R31, E58, G10.

Keywords: Demographic structure, aging population, single-person households, macro-prudential policies, house price growth

This publication is available on the BIS website (www.bis.org).

ISSN 1020-0959 (print)
ISSN 1682-7678 (online)

Demographic Shifts, Macroprudential Policies, and House Prices*

Jieun Lee† Hosung Jung‡

December 15, 2020

Abstract

This paper investigates how recent demographic changes—population aging and the rising number of single-person households—affect house price growth using 95 district level data sources in Korea from Q1 2008 to Q4 2017. Based on a unique dataset that includes quantified macroprudential policy variables and various house price indices from real transaction data, our analysis yields three key findings. First, house price growth increases in districts with high age dependency ratios, suggesting that aging is unlikely to drive house prices downward. Second, house price growth falls in districts with a high proportion of single-person households, possibly due to their low level of income or delayed family formation. Third, macroprudential policies are generally effective, but not for elderly and single-person households. Overall, the evidence suggests that demographic shifts are an essential factor for determining house prices.

Keywords: Demographic structure, Aging population, Single-person households, Macroprudential policies, House price growth

JEL Codes: J11 J10 R31 E58 G10

*The authors would like to thank seminar participants at the Bank of Korea and the Bank for International Settlements for their helpful comments and suggestions. We are also grateful to Jong Chil Son, Euna Cho, Joon Seok Park, Boris Hofmann, Leonardo Gambacorta, Yavuz Arslan, Peter Lindner, and an anonymous referee. The views expressed here are those of the authors and do not necessarily represent those of the Bank of Korea

†Corresponding author, Economist, Economic Research Institute, Bank of Korea, jelee@bok.or.kr

‡Senior economist, Economic Research Institute, Bank of Korea, hschung@bok.or.kr

1 Introduction

What are the determinants of house prices? This has long been an essential and challenging question for households and policymakers because housing accounts for a large share of household wealth,[1] and because house price dynamics have a strong linkage with macroeconomics and financial stability as we learned from the global financial crisis (Alter et al. 2018; Claessens et al. 2012; Mankiw and Weil 1989). Numerous studies have investigated the fundamental drivers of house prices, suggesting population dynamics as one of the main demand-side factors (Capozza et al. 2002; Case and Shiller 2003; Glaeser and Gyourko 2005; Pitkin and Myers 1994; Égert and Mihaljek 2007; Hwang and Quigley 2006). However, only a few studies have examined its decomposition. The seminal paper by Mankiw and Weil (1989) projected that demographic transition would be a potential risk in the housing market, highlighting the importance of further investigating the relationship between demographic structures and house prices.

In the past decade, demographic structures have changed rapidly nearly everywhere in two ways: the population is aging,[2] and the number of single-person households is rising.[3] In particular, there have been some concerns that aging can drive house prices down. These concerns are supported by two hypotheses. The *asset meltdown hypothesis*, proposed by Mankiw and Weil (1989), suggests that house prices would drop substantially in response to a rapid fall in the adult population when the baby boomers retire. Another is the *life-cycle hypothesis* which posits that, to smooth lifetime consumption, young people tend to buy houses while the elderly tend to sell them. However, these hypotheses may not be valid as the elderly have a demand for housing, contributing to higher house prices. Presumably, their extended life expectancy would cause the elderly to respond by owning houses or further investing in them for rental purposes, leading to an increase in housing demand and thereby house prices. Even when older people need urgent funds for medical expenses, they will first sell financial assets in preference to non-financial assets (Berkowitz and Qiu 2006), implying that housing seems to be the last asset they would consider selling. On the other hand,

[1] As of the end of 2017, housing accounts for 40-60% of total household wealth in Europe, 20% in the United States, and about 70% in Korea.

[2] UN(2019) shows that the proportion of the elderly population aged 65 or over to the total population increased globally from 6% in 1990 to 9% in 2019.

[3] UN(2019) shows that the average household size has declined across the globe. Specifically, according to the U.S. Census Bureau, Euro Statistics and Statistics Korea, the ratios of single-person households to all households between 2010 and 2018 have increased from 27% to 28%, from 31% to 34%, and from 24% to 28% in the U.S., Europe, and Korea, respectively.

existing empirical evidence has been mixed. Some argue that an aging population has a negative effect on house price growth (Takáts 2012; Bakshi and Chen 1994; Chiyachantana et al. 2004; Levin et al. 2009) while others assert that it may not cause any substantial reduction in housing demand (Chiuri and Jappelli 2010; Eichholtz and Lindenthal 2014; Wang et al. 2018; Hort 1998). Therefore, further analysis regarding aging is warranted.

Moreover, few existing studies focus on the relationship between single-person households and house prices, despite their growing share of the housing market. Fisher and Graham (1974) show that one-person households led to new rental housing construction in the U.S. between 1969 and 1970. Yet they did not make a direct comparison between single-person households and house prices. This paper therefore proposes that a rise in the number of single-person households could lead to a fall in house prices for several reasons. First, single-person households are likely to have fewer incentives to buy a house than do multi-family households because people, in general, tend to purchase houses when they form their family (Krainer et al. 2005). Second, single-person households, perhaps especially poor households, may have different consumption or investment sets, excluding houses. Moreover, there are more challenging aspects for single-person households to own their homes, as there are not many favorable housing policies for single-person households in terms of interest rates or loan amounts.

To the best of our knowledge, little has been known about how demographic changes, related to age or the number of households, affect house prices. The existing studies are scarce, and their results, mostly from aggregated data, have been mixed, depending on countries and time-spans (Takáts 2012; Hiller and Lerbs 2016; Holland 1991). Although aggregate evidence can help to understand the changes that influence a substantial portion of the population, we can learn more from the disaggregated data. Since the housing market is known to be geographically localized, the results from the aggregated data may not capture the locally idiosyncratic factors (Piazzesi et al. 2020; Case et al. 1991). For instance, elderly people or single-person households may be concentrated in a few areas within a country so that house prices in those areas would fluctuate differently from other areas. Therefore, our goal in this paper is to assess empirically how the demographic shifts affect house prices, using disaggregated data from Korea, one of the most advanced emerging economies, and one that is experiencing rapid demographic shifts.[4] Specifically,

[4]Korea overcomes the critics Nishimura and Takáts (2012) who argue that the slow-changing nature of demo-

we ask the following questions: First, how does the age distribution of the population and the number of households affect house price growth? Second, how do the total dependency ratio and its decomposition–the youth dependency ratio and elderly dependency ratio– affect house price growth at the district-level? Third, does a rise in the number of single-person households have a significant effect on house price growth? Fourth, do macroprudential policies, such as limits on the debt-to-income ratio (DTI) and the loan-to-value ratio (LTV), influence the relationship between demographic structure and house price growth?

To illustrate the relationship between demographic variables and house price growth, we introduce an extensive panel data set for 95 districts covering Seoul metropolitan areas and five non-Seoul metropolitan cities in Korea over the period from Q1 2008 to Q4 2017. We first construct a variety of house price indexes from the real transaction data by applying the standard Case and Shiller repeat sales methodology (1987). Specifically, we estimate the district-level house price index as well as seven house price indexes based on property types, e.g., price-level, dwelling size, and housing age, at the district-level. We also calculate the total dependency ratio and the proportion of single-person households in this district. We further divide the total dependency ratio into an elderly dependency ratio and a youth dependency ratio: the youth dependency and elderly dependency ratios, respectively, represent the burden of children and the elderly on the working-age population. Additionally, we directly quantify the strength of the LTV and DTI limits at the district-level, focusing on the following six components: the targeted areas, types of regulated financial institutions, house types, dwelling size, house prices, and loan types. This is different from existing studies, which have mostly used the dummy for the implementation of the LTV and DTI limits (Igan and Kang 2011; Claessens et al. 2013; Kuttner and Shim 2016). After combining the demographic variables with the macroprudential policies and house price indexes at the district level, we carry out more fruitful analyses using the fixed-effects regression model. We find that our focal results are robust to the model specifications, the reversal causality, the changes in demographic variables, and the different sets of control variables.

graphic variables makes it difficult to conduct an analysis in a single-country. According to Statistics Korea, Korea is experiencing one of the fastest rates of demographic changes in recent years. First, Korea took 17 years to go from an "aging society" to an "aged society". In contrast, other countries like the U.S. and the U.K. are taking more than 100 years for this transition. Korea is also expected to be a "super-aged society" in 2026, where the proportion of the elderly population accounts for over 20% of the total population. Second, the ratio of single-person households in Korea increased rapidly from 23% to 28% between 2010 and 2018.

Our empirical evidence reveals the following key findings. First, as our preliminary test, we examine how the distribution of age and the number of households affects house price growth, and find that age and age squared describe a monotonic relationship with an inflection point, indicating that an increase in the rate of house price growth has gradually slowed with age (Engelhardt and Poterba 1991; Ohtake and Shintani 1996). That is, the age distribution of house price growth is shaped like an inverted U. Additionally, we show that an increase in the number of households leads to an increase in house price growth, but the relationship between the number of households squared and house price growth is insignificant.

Second, we investigate the effects of the total dependency ratio on house prices and find that its effects are insignificant. This does not seem to support the general conjecture that house prices are expected to fall with a high total dependency ratio because working-age adults tend to buy houses, while dependent people usually do not own or tend to sell houses. In fact, the total dependency ratio is composed of the elderly and the youth dependency ratio, having a different trend that the former tends to increase with rising life expectancy whereas the latter appears to decrease with a low fertility rate. We thus did further analyses, decomposing it into the elderly and the youth dependency ratio. We find a positive association between the elderly population and house price growth, showing that house price growth has increased in districts with a high representation of the elderly population aged 65 or over. This tendency is found to be strong, especially for older and medium-value houses, suggesting that the elderly tend to have preferences for living in those types of home. Our overall findings support the fact that due to extended life expectancy and improved health, the elderly tend to own or invest in the housing market to prepare for their future. This is in contrast to the life-cycle hypothesis or the asset meltdown hypothesis that the elderly would sell their assets when they retire. On the other hand, we find that house prices tend to fall in districts with a high youth dependency ratio. We interpret that households with children under the age of 15, on average, are likely to have difficulty in housing purchases because of the high cost of child-rearing and their low wealth accumulation. These differential effects from the elderly and youth dependency ratios appear to be driven by the fact that an increase in the youth dependent becomes more of a burden to the working-age population, different from the elderly who can own a house and live alone.

Third, we find evidence that single-person households are negatively related to house price growth. This is consistent with our conjecture that single households are likely to have less incentive to buy a house than does a multi-person household, probably due to their low-level of income, lifestyle changes or unfavorable housing policies for single-person households. Furthermore, the negative associations between single-person households and house price growth become weaker for low-priced, small-sized, and new houses only in Seoul, indicating that their preference for those types of homes leads to fewer reductions in those housing prices.

Lastly, our empirical results show that overall macroprudential policies, such as limits on the LTV and DTI ratios, are effective in that loosening policies lead to house price appreciation. However, the positive effect of the elderly on house prices becomes weaker with loosened LTV and DTI policies, whereas the negative association of the single-person households is stronger for the loosening policies. This result supports the idea that aged people and single-person households, unlike other groups, do not respond to macroprudential regulations as expected either because they may not be eligible for mortgage loans due to low or irregular incomes or because they may not need additional funding.

This paper contributes to the extant literature in several ways. First, we are, to our knowledge, the first to document the effect of recent demographic structure changes, such as an elderly population and a large number of single-person households, on house price growth in Korea by using disaggregated-level data. We provide an answer to an unsettled question regarding the relationship between aging and house housing prices, supporting previous papers (e.g., Wang et al. (2018); Hort (1998)) that assert that house housing prices increase with an elderly population. We further find a negative relationship between one-person households and house price growth in Korea. In fact, the UN (2019)[5] shows that such demographic shifts are global phenomena, but their speed tends to be more rapid among advanced countries. Despite its growing importance, the relationship between demographics and house prices has been much less explored. Our empirical evidence is thereby expected to provide implications for other countries experiencing demographic transitions similar to those in Korea, one of the highly developed and high-income countries.[6]

Second, we introduce a new set of house prices using real-transaction data that have the advantage of providing timely and accurate information compared to survey data. By combining

[5] World population ageing 2019

[6] As of 2017, Korea is the world's 10th largest economy in the world in terms of GDP (OECD).

demographic variables with house prices by property type, such as housing value, dwelling size, and house ages, all at the district level, we shed additional light on the preference of the elderly population and single-person households on their choices of housing.

Third, we contribute to the existing studies on macroprudential policies. Our findings are consistent with several recent studies, which suggest that macroprudential policies are effective in reducing credit growth and thereby constraining house prices (Allen et al. 2017; Akinci and Olmstead-Rumsey 2018; Bruno and Shin 2014; Cerutti et al. 2017; Claessens et al. 2013; Gambacorta and Murcia 2020; Igan and Kang 2011; Jung and Lee 2017; Revelo et al. 2020; Vandenbussche et al. 2015). We then investigate how the policies affect specific groups, which was examined less in past studies, and find that macroprudential policies are unlikely to be the main channel through which the elderly population or single-person households influence house prices.

Lastly, we show that our sample is appropriate for analyzing the relationship between demographic variables and house prices in a single country. Indeed, Korea experienced a rapid demographic transition over the past decade, which alleviates one of the concerns of Takáts (2012) that the slowness of demographics is inappropriate for a single-country study. Besides, our sample period (2008-2017) includes the time when the baby boomers in Korea, who were born between 1955 and 1963, began to retire. Despite their retirement, we do not find any significant drop in house prices in Korea, consistent with existing studies that do not support the asset meltdown hypothesis (Wang et al. 2018; Hort 1998).

The remainder of the paper is organized as follows. Section 2 provides an overview of the hypotheses. Section 3 describes the data and explains the empirical method used to examine the questions of interest, and Section 4 discusses the empirical results. Finally, Section 5 concludes the paper and provides some policy implications.

2 Hypothesis development

Past studies suggest that population is an essential factor in determining house price growth (Capozza et al. 2002; Mankiw and Weil 1989). In particular, Takáts (2012) shows that demographic size as well as its decomposition can affect house price growth. These studies imply that recent demographic changes– aging and a rise in the number of households, will have a potential effect on house price growth.

One of the central questions is how an aging or the elderly population affects house price growth. Previous studies suggested hypotheses on the relationship between aging and house prices. The seminal paper of Mankiw and Weil (1989) proposes the *asset meltdown hypothesis*. They argue that when a large cohort, e.g., baby boomers, retires and sells their assets to the next cohort made up of a smaller number of people, then house prices will drop because there are more sellers than buyers in the housing market at that time. In a similar vein, the *life-cycle hypothesis* suggests that individuals purchase houses when they are young and sell then when they are old in order to maximize their lifetime utility function, which relies on current and future consumption (Ando and Modigliani 1963; Samuelson 1958; Flavin and Yamashita 2002; Krainer et al. 2005). Both hypotheses suggest that aging can drive down asset prices. These hypotheses, however, are valid only when the elderly liquidate their wealth at the time of their retirement to smooth their future consumption. As life expectancy becomes longer and as people become healthier than before, the elderly may not dissave or sell assets at the moment of their retirement. Even if they have a problem with their health condition, they tend to use financial assets than non-financial assets for the medical expense (Berkowitz and Qiu 2006). A house, therefore, is likely to be the last resort sold by the elderly. Moreover, they may invest their retiring allowance in housing or financial assets to receive a regular rental income, rather than rely on their children after passing on their inheritance to their children, thereby causing housing demand as well as house prices to increase. Consequently, it is challenging to make conjectures about the relationship between population aging and house prices.

To empirically assess the relationship, we introduce a dependency ratio, the relative size of the dependent population to the working-age population. Working adults tend to buy houses, while the dependent population does not own or tend to sell houses. As the relative size of the dependent population to working adults increases, then house prices might be dampened. We, therefore, expect a negative relationship between the dependency ratio and house prices. We further divide the dependency ratio into the elderly dependency ratio and the youth dependency ratio. The main difference between the two is that the former has a purchasing power for houses, while the latter does not. The negative relationship between the youth dependency ratio and house prices would be maintained because many households with children under the age of 15 tend to have low wealth with the high cost of childcare.

On the other hand, an increase in the number of the elderly would lead to house price appreciation beyond offsetting the negative relationship between the dependency ratio and house prices since most of the elderly tend to own or invest in houses rather than depend on working adults after selling their houses. This is the first hypothesis we test in this paper.

Hypothesis 1. Districts with high elderly dependency ratios expect to experience house price appreciation due to the extended life expectancy.

Another demographic trend is a rise in the number of single-person households. Few studies, to the best of our knowledge, have investigated the effects of single-person households on house prices. The recent rise in the number of single-person households is mainly associated with unmarried or divorced segments of the population. Many young people tend to delay their marriage and live alone because of financial difficulties or lifestyle changes, mostly belonging to low-income groups. Statistic Korea (2018) releases information that indicates that the homeownership ratio in a single person household is about 30 percent, while that in multiple-person household accounts for over 55 percent in 2018, indicating that one-person households relative to multiple households are likely to have fewer incentives to purchase houses. This fact is consistent with Krainer (2005), documenting that people tend to buy houses when they form a family. Once family formation is delayed, housing purchases are likely to be postponed, as well. With such lifestyle changes, they tend to have a different consumption pattern, excluding house purchases. Moreover, single-person households are usually excluded from financial support or subsidies from the government for house purchases, e.g., a large amount of loans with low interest rates for multiple households, so it is far more difficult to possess their own home by taking out a loan from financial intermediaries. Therefore, we expect housing demand and house prices to decrease with a rise in the number of single-person households.

Hypothesis 2. Districts with a high number of single-person households are likely to face house price drops with reduced demand for housing, probably because of financial difficulties or delayed family formation.

Numerous studies have examined the effects of macroprudential policies on credit growth and house price growth, focusing on their overall effects on the economy (Claessens et al. 2013; Jung and Lee 2017; Bruno and Shin 2014; Cerutti et al. 2017). Theoretically, to cope with systemic risk, limits on LTV and DTI are expected to prevent a feedback loop between credit extension and house prices. If the regulations are effective, loosening LTV and DTI limits is expected to lead to house price appreciation, while tightening them is expected to contribute to house price depreciation.

However, few studies have examined how the changes in macroprudential policies affect specific groups, namely the elderly population and single-person households. Older people tend to have more wealth, but an irregular income, and single-person households, in general, are likely to belong to low-income groups. That is, those whose incomes are not regular or low may not be eligible for mortgages from financial intermediaries. Or those with extra funds or huge wealth, such as the elderly, might not need any additional mortgages. Consequently, unlike other groups, older and single-person households may not respond strongly to macroprudential policies once they cannot or do not need to take out mortgage. This leads to our third hypothesis, that the policies are not likely be the channel through which the elderly population or single-person households affect house prices.

Hypothesis 3. Macroprudential policies are unlikely to be the channel through which elderly or single-person households affect house prices.

Not only is it hard to conjecture the relationship between aging and house prices based on the hypotheses, but also the existing empirical evidence from aggregated data has been mixed depending on country and time-span. Moreover, studies about single-person households are rather scant. Therefore, further empirical studies about demographic structure are needed.

3 Data sources and variable measurements

The contributions of this paper are that it uses a unique dataset from which we can construct demographic variables, macroprudential measures and house price indexes at the disaggregated-level. We obtain quarterly data for the residential property sector, household leverage regulations, and demographic factors in 95 districts in Seoul metropolitan areas and five non-Seoul metropolitan cities around Korea over the period from Q1 2008 to Q4 2017.[7] Data on real estate transactions and prices are collected from the Ministry of Land Infrastructure and Transport (MOLIT). In this paper, we consider housing to be apartments, which account for about 70% of the national Korean housing supply. According to Korean housing laws, both buyers and sellers must report their transaction information, i.e., trading date, trading value, house address, housing types, housing age, square footage, floor or story in the building etc., to the government agency within 60 days of the conclusion of their contract. After collecting these data, the MOLIT publicly releases them on its website.[8] These real housing transaction data have the advantages that 1) they can minimize the sample bias with more accurate and timely information, relative to the survey data and 2) their extensive data coverage, including all transactions across the whole country, as well as the amount of trading information, enables us to estimate a house price index in different dimensions. Using this data, we estimate quarterly house price indexes based on the standard Case and Shiller (1987) repeat sales methodology at the district-level. We further construct a variety of house price indexes by property types, such as the price of the property, age, and dwelling size, applying the Case and Shiller methodology, as well. More specifically, we classify the transaction data into the following seven sub-groups: three groups based on house value [low-tier (below KRW 300 million), medium-tier (KRW 300-600 million) and high-tier (over KRW 600 million)], two groups based on dwelling sizes [small (below $85m^2$/915 sq.ft) and large (above $85m^2$)/915 sq.ft], and then two groups based on housing unit ages [new (below 10 years), and old (20-30 years)]. See Appendix B for a detailed explanation for the construction of house price indexes.

The demographic variables, the age distribution of the population and the number of households, are obtained from the Ministry of the Interior and Safety. According to OECD statistics, the dependent population is usually defined as the youth population (those under the age of 15) and the elderly population (those over the age of 64), and the working-age population is defined as those between the ages of 15 and 64. Following these definitions, we compute a total dependency ratio (DEPENDENCY), which is the ratio of the dependent population to the working-age population and also decompose the variable into an elderly dependency ratio (ELDERLY) and a youth

[7]The areas include the Seoul Metropolitan Areas – Seoul, Gyeonggi province, Incheon – as well as Busan, Daegu, Gwangju, Daejeon, and Ulsan. We merge some districts that have fewer transactions to neighboring districts. A total of seven districts were affected this way.

[8]http://rt.molit.go.kr

dependency ratio (YOUTH). The elderly dependency ratio is the ratio of the elderly population to the working-age population, and the youth dependency ratio is the ratio of the youth population to the working-age population. Such a decomposition is meaningful in that these two variables have shown distinctive trends: the youth ratio decreases with a low-fertility rate while the elderly ratio increases with extended life expectancy.

We gather information about the LTV and DTI regulations from the Financial Supervisory Service and the Financial Services Commission. To quantify the level of the LTV and DTI limits at district level, we compute them by considering different criteria such as type of financial institutions, apartment size, property value etc. The detailed computation of the LTV and DTI limits appears in Appendix C.

In addition, we use district and city characteristics or macroeconomic variables in our empirical tests. We collect district-level information about the number of unsold newly built houses (UNSOLD) from Real Estate 114 and city-level information about the gross regional domestic product (GRDP) from Statistics of Korea and the Jeonse price index from the Bank of Korea.[9] Macroeconomic data on mortgage loan rates (MORATE), the gross domestic product (GDP) and monetary growth (M2) are also obtained from the Bank of Korea. A detailed explanation for the variables is introduced in Appendix A.

3.1 Descriptive statistics

Table 1 provides summary statistics for our sample of 95 districts in Seoul metropolitan areas and non-Seoul metropolitan areas. All the real price indexes are constructed using the standard Case-Shiller (1987) repeat sales method. The quarterly mean, minimum and maximum of the district-level real house price index are 112.52, 77.97 and 182.40, respectively, and the mean of real house price growth is 0.24%. The mean of the house price growth among the low-, medium- and high-priced houses are 0.37%,-0.26%, -0.59%, respectively, indicating that houses below 300 million KRW have risen more than any other properties valued at over 300 million KRW between 2008 and 2017. The mean of the house price growth in the small and large houses is 0.46% and

[9] A Jeonse lease contract, unique to Korea, is a full up-front deposit, about 80% or so of the market price of the property, provided by the tenant to the landlord at the beginning of the contract period. The landlord is able to invest the deposit money and generate a return prior to repaying the original amount to the tenant at the end of the contract.

-0.19%, respectively, indicating that houses smaller than 85m^2 have increased in comparison to larger houses. The mean of the house price growth among the new and old houses is 0.05%, and 0.45%, respectively, implying that house price growth for old houses is greater than that for newer ones. In sum, we find that at the district level, house prices have risen substantially especially for low priced, small-sized, and old houses.

[Place Table 1 about here]

The table also provides information about demographic variables. The average number of households (HH) for each district is 144,274. Since the total number of households is about 20 million at the national level, HH in our sample accounts for about 69% [10] of total households. The average age per district is 38.39, with ages ranging between 31.47 and 47.44, and the average number of households per district is 2.53. The means of the dependency ratio is about 34.8%. The mean of the youth and elderly dependency ratio is 20% and 15%, respectively. The mean, minimum, and maximum of the proportion of the number of single households to the number of total households is 32.74%, 19.35%, and 52.27%, respectively. Additionally, the variables for the sources of financing are shown: the mean of the limit of the loan-to-value ratio (LTV) and debt-to-income ratio (DTI) is 65% and 78%, respectively, and the minimum (maximum) of the LTV and DTI is 40.86% (79.45%) and 40.72% (100%), respectively, indicating that the regulations controlling the LTV and DTI ratios appear to have been imposed differently across districts and time. The mean, minimum, and maximum of the mortgage rate (MORATE) is 4.3%, 2.72%, and 7.27%, respectively.

3.2 Univariate results: graphical illustration

In this subsection, we investigate the time-series trends in demographic structures, macroprudential policies, and house price growth. Figure 1 shows the demographic changes, namely, aging and the rise in single-person households in our sample, covering Seoul and other metropolitan areas in Korea from 2008 to 2017. Panel (A) shows the trends of the dependency ratio, the youth dependency ratio, and the elderly dependency ratio. The dependency ratio is quite stable at around 35%. However, its decomposition exhibits a distinctive trend. The youth dependency ratio decreases from 24% to

[10] 144,274*95(districts)/20$million$

17% with a low fertility rate, whereas the old dependency ratio increases from 12% to 18% with the extended life expectancy. This graph supports the fact that the population has been aging in Korea, given that the share of the working-age population is almost constant.

[Place Figure 1 about here]

Panel (B) exhibits the trend of the ratio of single-person households in Korea, showing an increase from 30% to 35% between 2008 and 2017. Statistic Korea released the information showing that the ratio of the single-person households in 2017 was about 28.6%. The reason why the ratio is higher in our sample than at the national-level is because we focus only on metropolitan areas. This indirectly suggests that single-person households seem to congregate in big cities.

Figure 2 shows the evolution of house prices in Korea. Panel (A) shows that the real house price index, on average, has nationally risen by approximately 15%, but quite volatile throughout the period from Q1 2008 to Q4 2017. While house prices seem to have increased in the long-term, house price return in the short-term has been quite volatile. Panel (B) shows that quarterly changes in real house prices ranged from -4.5% to 3%, indicating high fluctuations at the national level. This is clearly the case when it comes to housing that the pace of house price growth varies across house value, size, and age.

[Place Figure 2 about here]

Figure 3 depicts the house price index in levels and quarterly returns separated by property type such as housing value, dwelling size, and house age. Regardless of house prices, all seven series have shown similar trends in that they appear to have increased since 2014 when the macroprudential policies were relaxed, and when interest rates fell to low levels. However, the pace of the series is different according to the prices of different types of houses. Notably, we can see that house prices have increased more rapidly, especially for low-priced, small-sized, and old houses relative to other segments that have higher volatility. These results indicate that the effect of demographic variables on high price growth would vary with the type of houses.

[Place Figure 3 about here]

Figure 4 presents the changes in macroprudential and monetary policies. Korea is a country where macroprudential policies have been actively implemented since the introduction of LTV and DTI limits in 2002 and 2005, respectively. Panel (A) shows the trends of the levels of LTV and DTI limits, indicating that the regulations were repeatedly eased and strengthened at the district level over the sample period. For example, LTV and DTI regulations were eased at the same time in August 2014 to standardize regulations across all districts, and thus reduce any regulatory arbitrage. Then, the regulations were strengthened again in 2018 to stabilize excessive house price inflation.

[Place Figure 4 about here]

In panel (B), policy rates in Korea dropped from 5% to 2% during the global financial crisis (2008-2009). Since 2010, police rate hikes and cuts have been repeated. Mortgage interest rates have moved in tandem with policy rates, although the level is higher than the policy rate moving between 8% and 3%. In sum, these graphs indicate that macroprudential and monetary policies have been changed frequently in Korea over the sample period.

4 Empirical results

In this section, we conduct regression analyses to examine how house prices are related to demographic variables, macroprudential policies, and to various district/city attributes. In the first set of regressions, we analyze how population age and the number of households affect house price growth as a preliminary test for the in-depth understanding of their distributional effects. In the second set, we focus on the dependency ratio and on single-person households. Notably, we examine whether the elderly dependency ratio or the proportion of single-person households have any significant effect on house price growth. In the third set, we see how macroprudential policies affect the associations between the demographic variables and house price growth. In other words, we analyze how elderly and single-person households respond to macroprudential regulations.

4.1 Demographic structures and house price growth

In order to understand the distribution of population age segments and the number of houses at the district-level, we examine the direct relationship between the age, age squared, and house price growth as well as between the number of households, the number of households squared, and house price growth as our preliminary test after controlling for variables such as the cost of financing, housing supply, and macroeconomic variables. Referring to Takáts (2012), Kuttner and Shim (2016), and Favara and Imbs (2015), we set up the regression model, including the relationship between demographic variables, macroprudential policies and house price growth. The specific regression models for population ages are as follows:

$$
\begin{aligned}
dlog(HPI)_{it} &= b_0 + b_1 AGE_{it-1} + b_2 AGE^2_{it-1} + b_3 LTV + b_4 DTI \\
&+ b_5 dMORATE_{t-1} + b_6 dlog(HH)_{it-1} + b_7 JTP_{ct-1} + b_8 dlog(GRDP)_{ct-1} \\
&+ b_9 dlog(SUPPLY)_{it-1} + b_{10} UNSOLD_{it-1} + b_{11} dlog(M2)_{t-1} + b_{12} dlog(GDP)_{t-1} + e_{it}
\end{aligned} \tag{1}
$$

where the subscript i denotes district, c denotes city, and t denotes quarter. The dependent variable, dlog(HPI), is the log changes in house price index at the district level. The regression includes house price growth, not house price level due to unit root in the series.[11] The control variables are used with lagged one or two period to mitigate possible endogeneity problems: LTV and DTI are estimated at the different scales and time lags because the policy has a typical lag with implementation: dlog(LTV) and dlog(DTI) are the log changes in LTV and DTI, respectively; LTV and DTI are the level in LTV and DTI, respectively; dMORATE is the change in mortgage loan interest rate; JTP is the Jeonse-to-price ratio; dlog(HH) is the log changes in the number of households; dlog(GRDP) is the log changes in gross regional domestic product; dlog(SUPPLY) is the log changes in supply, which is the sum of the number of permissions and the number of constructions; UNSOLD is the ratio of unsold newly-built housing inventory relative to the total number of households; dlog(M2) is the log changes in the monetary aggregate (M2); dlog(GDP) is the log changes in the gross domestic product. To reduce any possible endogeneity, we take lags for all independent variables. One and two lagged HPIs are included to capture the effects of autocorrelations for the model of the pooled OLS regression. The detailed variable explanations are in Appendix A. e_{it} is the stochastic error term of district i at time t. The district fixed effects control for unobserved time-invariant differences across districts. To reduce identification concerns,

[11] We find that the hypothesis on panel unit root is not rejected for the level of log house prices (P-value for the Levin-Lin-Chu unit-root test for log(HPI): 0.26, P-value for the Im-Pesaran-Shin unit-root test for log(HPI): 0.53), but it is rejected for the difference in log house prices. Since the series on log house prices are non-stationary, we choose the log difference in house price index as our main dependent variable.

we introduce city-by-year fixed effects in all regressions to control for unobserved, time-varying differences across cities such as city-level business cycles or housing demand. Clustered standard errors at the district level are estimated from 3,553 district-quarter observation (Petersen 2009).

Regression equation (2) is similar to equation (1) except that it contains the number of family members and their square instead of age and age squared. The specific regression equation is as follows:

$$\begin{aligned} dlog(HPI)_{it} &= b_0 + b_1 NFAM_{it-1} + b_2 NFAM^2_{it-1} + b_3 LTV + b_4 DTI \\ &+ b_5 dMORATE_{t-1} + b_6 dlog(HH)_{it-1} + b_7 JTP_{ct-1} + b_8 dlog(GRDP)_{ct-1} \\ &+ b_9 dlog(SUPPLY)_{it-1} + b_{10} UNSOLD_{it-1} + b_{11} dlog(M2)_{t-1} + b_{12} dlog(GDP)_{t-1} + e_{it} \end{aligned} \tag{2}$$

where NFAM is the number of family members, and $NFAM^2$ is the number of family members squared. All other variables are the same as defined in equation (1).

Table 2 shows the results when the average age and age squared variables are included as demographic variables. Column (1) is the results when we include an average age per district, and columns (2) through (4) are the results when we add an age and a quadratic polynomial in age. To determine the number of lags where LTV and DTI regulations become effective, we use different lags together with different scales. Columns (1) and (5) show the results when we use the changes in one lagged log differences in LTV and DTI values, columns (2) through (4), (6) and (7) are the changes in two lagged log differences in LTV and DTI value.

[Place Table 2 about here]

Columns (1) through (4) show that the regression coefficients on AGE are positive and significant across model specifications, and the coefficients on AGE^2 are all negative and significant in columns (2) through (4), indicating an inverted U shape. That is, the direct effect of age is to increase house price growth up to about the age of 49[12] after which it appears to level off or even decline (column (3)).

We find that the regression coefficients on the one lagged log differences in LTV and DTI are negative and significant (columns (1) and (5)), while the coefficients on the two lagged differences in LTV and DTI are positive and significant (columns (2), (3), (4), (6), and (7)). Increases in LTV

[12] 2.075/(2*0.021)=49

and DTI values are regarded as loosening policies. We, therefore, expect a positive relationship between the policies and house prices if the regulations are effective. Our results show that the implementation of LTV and DTI regulations on house prices become effective after two quarters ((2), (3), (4), (6), and (7)), not one quarter (columns (1) and (5)). This is consistent with previous studies that show that the effect of macroprudential policies on house prices become effective after six months in Korea (Jung and Lee 2017; Igan and Kang 2011), indicating that house prices do not appear to respond immediately. We thus choose two lags of macroprudential policy variables as our primary control variables in the later analyses.[13]

We control for the other factors that are associated with house price growth and find that most of the variables appear to have the expected signs. We find the negative coefficients on interest rate (dMORATE), supporting the idea of Bernanke and Blinder (1992), Pavlov and Wachter (2011) and Bernanke et al. (2010) that short-term interest rates might therefore be just as important fundamentals for house prices as longer term rates because an increase in the mortgage interest rate has a negative effect on house price growth. We also show results that demand factors, such as the coefficients on dlog(HH) and dlog(GRDP), are positive and significant, indicating that an increase in the demographic size and household income tend to increase in house price growth, consistent with previous studies(Capozza et al. 2002). The supply factors, the coefficients on dlog(SUPPLY) and UNSOLD, are negative and significant, supporting the idea that an increase in supply or in unsold apartment leads to a downward drive in house prices. The coefficients on the rental-to-price (JTP) are positive and significant, probably indicating that an increases in Jeonse prices leads to house price increases since the easing of residential funding seems to outweigh the risk of not returning a deposit.[14] Columns (1), (4), and (7) show the presence of the positive autocorrelations of the house price growth. We confirm that these results are qualitatively similar to those excluding lagged house price growth. Lastly, the coefficients on GDP, the business cycle, are positive and significant, consistent with existing papers, showing that house prices tend to increase during boom

[13]We conduct the same analyses using the levels of LTV and DTI instead of the log differences, and find the qualitatively similar results. We therefore choose the log differences in LTV and DTI as our independent variables.

[14]If the Jeonse-to-price ratio is high, purchasing a house requires less funding, and the demand for housing increases through 1) a Jeonse tenant becoming a homeowner or 2) buyer purchasing a tenant occupied unit currently under Jeonse contract directly from the homeowner, i.e., making a gap investment. A high Jeonse-to-price ratio leads to easier funding for homeowners and has a positive effect on house prices. However, a high ratio can also indicate a risk in the housing market as house prices can easily fall below Jeonse prices, and tenants may not get a full refund on their deposit at the end of the contract. This can ultimately have a negative effect on house prices

periods (Agnello and Schuknecht 2011).

Columns (5) through (7) exhibit results when the average number of households and their squared variables are included. Columns (5) and (6) are the results when we include an average number of households per district, and column (7) is the results when we add the number of households and a quadratic polynomial in the number of households. The results show that the coefficients on NFAM are positive, but significant only in columns (5), indicating that the results depend on the model specifications. We also find that the coefficient on $NFAM^2$ in column (7) is insignificant, implying that no inflection point exists. We interpret these results as meaning that house price growth tends to increase monotonically with family size.

4.2 Dependency ratios, single-person households, house price growth

In our preliminary analysis, we confirm that our empirical results show that house prices tend to increase with a diminishing rate of age, indicating the presence of an inflection point. Although we find that an increase in house price growth begins to slow down with age, it has a still possibility that the elderly have a positive effect on house price growth. On the other hand, house price growth tends to increase weakly with family size, while the squared terms are insignificant. These earlier results do not explicitly provide evidence about how the elderly population and single-person households, respectively, affect house price growth.

In this subsection, to more directly estimate the direct demographic effects that are caused by specific groups, we introduce the dependency ratio and its decomposition — the elderly and youth dependency ratios and the proportion of single-person households, referring to Takáts (2012).

$$dlog(HPI)_{it} = b_0 + b_1 DEPENDENCY_{it-1} + b_2 SINGLE_{it-1} + b_j X_{it-1} + e_{it} \quad (3)$$

$$dlog(HPI)_{it} = b_0 + b_1 ELDERLY_{it-1} + b_2 YOUTH_{it-1} + b_3 SINGLE_{it-1} + b_j X_{it-1} + e_{it} \quad (4)$$

where DEPENDENCY is the percentage of those aged between 0 and 14 and over 65 to the total population; ELDERLY is the percentage of those aged over 65, YOUTH is the percentage of those aged between 0 and 14, $X = \{dlog(LTV)_{it-2}, dlog(DTI)_{it-2}, dMORATE_{it-1}, dlog(HH)_{it-1}, JTP_{ct-1}, dlog(GRDP)_{ct-1}, dlog(SUPPLY)_{it-1}, UNSOLD_{it-1}, dlog(M2)_{t-1}, dlog(GDP)_{t-1}\}$, and all other variables (X) are the same defined in regression equation (1).

Columns (1) and (2) in Table 3 show the results when we include the total dependency ratios in the regression. Columns (3) through (6) show the results when we include the youth and elderly dependency ratios instead of the total dependency ratio.[15] Columns (5) and (6) show the results when we add the ratio of single-person households to the youth and elderly dependency ratios. Columns (2), (4), and (6) show the results when we add the lagged dependent variable to control for the possible momentum of house price growth to the regression equations (3) and (4).

[Place Table 3 about here]

At first glance, we expect a negative relationship between the dependency ratio and house price growth because the higher the dependency ratio, the more the number of dependents, those supported by the working-age population. The working-age groups, therefore, are unlikely to be able to afford houses, causing house prices to fall. However, different from our expectations, we find that the regression coefficients on the dependency ratio (DEPENDENCY) are insignificant (columns (1) and (2)).

We further break the total dependency ratio into an elderly and a youth dependency ratio because they have different time-trends (see Figure 2), which can lead to different conclusions. While the elderly can form an independent household and buy a house by themselves, young people cannot. As a result, the elderly, compared to the youth dependents, are likely to be less of a burden to the working-age adults. We, therefore, expect district with high youth dependency ratios to reduce house price growth due to the burden on the working-age population to raise children ($b_1 < 0$). However, the effect of aging on house price growth is ambiguous. Previous studies have shown contradictory results on the relationship between aging population and house price growth. Some argue that an aging population has a negative effect on house price growth (Takáts 2012; Chiuri and Jappelli 2010) while others assert that it may not cause substantial decreases in housing demand (Eichholtz and Lindenthal 2014; Wang et al. 2018). If more older people are buying houses than are selling them, they could lead to an increase in house prices. Consistent with our conjecture regarding the youth dependency ratio, we find that the coefficients for YOUTH are negative, implying that house price growth tends to decrease in the district with

[15] There are two representative measures to estimate the extent of aging–the elderly ratio and the elderly dependency ratio. The difference between the two arises from the denominator. One is the population, and the other is the working- age population. In the unreported table, we confirm that our results are robust to the elderly ratio.

the high youth dependency ratio (columns (5) and (6)). On the other hand, the coefficients for ELDERLY are positive and significant regardless of the model specifications (columns (3) through (6)). Specifically, a 1 percentage point increase in the elderly dependency ratio is associated with a 0.2-0.3 percentage point increase in the growth rate of house prices. From the earlier section, we confirm that an increase in the rate of house price growth begins to slow down after the age of 49. However, we still find that the elderly aged 65 and over leads to house price growth because they are likely to prepare for their future by either purchasing houses or by delaying their sale along with their extended life expectancy. More specifically, as the elderly become healthier than before, they do not need to sell their houses right after retirement to pay for sickness or death. Even if they face a health shock, it would lead to a larger decline in financial assets than in non-financial wealth for the medical expense (Berkowitz and Qiu 2006). This indicates that the elderly are likely to see the sale of a house with low liquidity as their last resort. Furthermore, they may invest in more housing to get a regular rental income. As a result, we conclude that older adults continuously contribute to increases in housing demand by accumulating, rather than liquidating, their wealth due to their lengthened life expectancy, and that this helps to increase house prices. That is, this evidence is in contrast to the life-cycle hypothesis that the elderly sell their houses immediately when they retire to smooth their future consumption. In addition, Figure 5 supports our conclusion. Specifically, the report from Statistic Korea shows that 1) the homeownership ratio and the number of homeowners of those ages over 60 or 70 increased during the period between 2010 and 2018; 2) Their net worth tends to have a similar increasing trend with those aged between 40 and 49. Overall, our result suggests that the aging population is not likely to dampen the current Korean housing market because the elderly in our sample period have experienced Korea's dramatic economic development and because they have a chance of accumulating their wealth. Note that our results do not indicate that aging would not be a potential risk in the future as well because we do not differentiate between cohort effect and aging effect due to the short sample period in this study.

Additionally, the results show that the coefficients on SINGLE are negative and significant (columns (5) and (6)). Notably, we find that a 1 percentage point increase in the ratio of single-person households is related to a 0.3-0.4 percentage point decrease in the growth rate of house prices. This evidence supports Hypotheses 2, which posits that an increase in the number of single-person households leads to house prices down because they have less incentive to buy houses than do multi-person households. Overall, our analyses indicate that demographic changes are an essential factor in explaining house price changes.

4.3 Demographic variables and house prices growth by property types

In the earlier sub-sections, we find that housing price growth tends to increase in districts with large elderly populations and decrease in districts with a large number of children or single-person households. As shown in Figure 4, the pace of house price change differs depending on the property type such as value, size, and age, which can lead to different results. For example, the elderly population may tend to live in the same area or in the same apartment with a strong preference for older houses. Or households with budget constraints may respond to changes in the financing conditions by purchasing smaller or lower-priced houses.

To assess this possibility, we conduct the fixed effect regression analyses,[16] using our various house price indexes by property type, such as housing value, dwelling size, and house age. We specifically analyze whether the presence of the elderly or single-person households affect house prices differently depending on house type. Table 4 shows the results regarding the effects of the elderly and youth dependency ratios and the proportion of single-person households on various house prices. Columns (1), (2), and (3) show the results when the dependent variable is the log changes in the house price index by low-priced, medium-priced, and high-priced tiers, respectively and columns (4) and (5) show the results when the dependent variable is the house price index by low-sized and large-sized tiers, respectively and columns (6) and (7) show the results when the dependent variable is the house price index by new and old houses, respectively. Panels A, B and C show the results for the whole country, Seoul–the capital city, and Non-Seoul areas, respectively.

[Place Table 4 about here]

In Panel A of Table 4, we find that, regardless of property types, the coefficients for YOUTH are negative and significant for all types except for middle- and high-valued houses, and that the coefficients for ELDERLY are positively and significantly related with house price growth for all types except for the low-valued houses. Additionally, the coefficients for SINGLE are significant

[16] We run the regression analyses after adding the lagged dependent variables in our main regression models. In the unreported tables, the results are qualitatively similar to our main result.

and negative for all types except for the expensive housing. Overall, these results support the earlier findings that the districts with a high number of single-person households experience house price depreciation whereas the district with a high number of elderly people see house price appreciation regardless of the type of housing.

More specifically, we compare the coefficients within the same types of houses. We find that the elderly tend to live in expensive housing (columns (1) through (3)) and older rather than newer housing (columns (6) and (7)). Probably, the greater effects of the elderly on those houses can be explained by the redevelopment of the old houses where many aged people live. In contrast, single-person households are found to have no significant difference within the same types in the whole country.

We carry out the same analyses in Seoul and non-Seoul areas, including Gyeonggi province and Incheon. Seoul is the capital city in Korea, where 20% of the total population live, and house prices are skyrocketing compared to other cities, which may lead to different results from those in non-Seoul areas. Both Panels B and C show the qualitatively similar conclusions regarding the elderly population. We find that regardless of cities, they tend to live in low and medium valued houses or old houses, leading to price appreciation in those houses. In contrast, the effects of the ratio of single-person households vary with the city. The adverse effects of single-person households are weaker for low-valued, small-sized, and new houses in Seoul, but stronger for those in non-Seoul areas. Probably, this difference arises from the age of single-person households. Among single-person households, younger people, who have lower incomes, tend to live in Seoul rather than in outside the Seoul areas. Therefore, they are likely to prefer to live in low-value, small-sized, and new houses, indicating that the effects on those houses are likely to be smaller. On the other hand, older and widowed single persons tend to live more in outside the Seoul areas, keeping or buying homes, which may reduce demand demand for low-value, small-sized, and new houses. In sum, our empirical evidence suggests that changes in demographic structures play a crucial role in explaining house price dynamics, and their effects vary across property types.

4.4 Interaction between demographic variables and macroprudential policies

Previous studies have focused on the effectiveness of macroprudential policies such as limits on LTV and DTI ratios in the overall economy (Cerutti et al. 2017; Claessens et al. 2013; Vandenbussche et al. 2015). Yet it is unknown how the polices affect specific groups. We thus examine how macroprudential policies affect the elderly population and single-person households by focusing on their responses to the policies. The objective of macroprudential policy is to minimize systemic risk and to constrain financial booms so as to reduce the cost that financial instability can have on the overall economy. Specifically, policymakers focus on preventing excessive credit growth, and, thereby, the build-up of asset price bubbles that can cause an economic recession. As a result, tightening regulations on LTV and DTI ratios is generally expected to lower house price growth, while loosening regulations is expected to boost house price growth by adjusting credit growth. Such macroprudential regulations are regarded as being effective if house prices move in the same direction as policy intentions. Although we confirm that the LTV and DTI regulations overall appear to be effective in Korea from the earlier empirical evidence (Tables 2 through 4), it is still unclear how elderly and single-person households respond to macroprudential policies. In order to establish their responses, we construct the interaction terms between demographic variables and macroprudential policy measures.

Table 5 shows the results of how the LTV and DTI regulations affect the relationship between demographic variables and house prices. The variables (A)*(B), (A)*(C), and (A)*(D) represent the interaction terms between demographic variables and policy variables. For example, column (1) shows the results when we add the interaction term between the youth dependency ratio ((A) YOUTH) and the LTV ratio ((B) dlog(LTV)), the interaction term between the youth dependency ratio ((A) YOUTH) and the DTI ratio ((C) dlog(DTI)), and the interaction term between the youth dependency ratio ((A) YOUTH) and the interest rate ((D) dMORATE)), expressed in (A)*(B), (A)*(C), and (A)*(D), respectively. Column (2) shows the results when we include the interaction term between the elderly dependency ratio and policy variables in the regression equation (4). Column (3) shows the results when we include the interaction term between the ratio of single-person households and policy variables. Since we estimate the levels of the LTV and DTI regulations, increases in the values imply loosening policies. In contrast, increases in mortgage rates indicate tightening regulations.

[Place Table 5 about here]

Column (1) shows that the coefficients on YOUTH are significantly and negatively related to house price growth, and their negative effect becomes weaker as limits on LTV and DTI ratios increase (the coefficients on (A)*(B) and (A)*(C)), indicating that house prices tend to decrease less in the districts with a high youth-dependent population when the regulations are loosened, indicating that working-age adults living with young children tend to respond strongly to policies. Column (2) shows that the coefficients for ELDERLY are significantly and positively related to house price growth, and that the coefficients on (A)*(B) and (A)*(C) are negative and significant, indicating that the positive effects of the elderly dependency ratios on house price growth become weaker with loosening LTV and DTI regulations, different from the policy intentions. In other words, the tendency of increasing house prices in districts with a high number of elderly people appears to decelerate despite loosening LTV and DTI regulations. Column (3) shows the response of single-person households to macro and monetary policies. We find that the coefficients for SINGLE are negative and significant, and the interaction term between (A)*(C) are positive and significant. This result indicates that negative effects of single-person households on house price growth becomes stronger, implying that house prices appear to fall further in districts with a high proportion of single-person households with a DTI loosening. Additionally, our results indicate that the interaction term between demographic variables and the mortgage rate ((A)*(D)) are all insignificant, except for column (2). The results in column (2) show that the positive effect of the elderly dependency ratio on house price growth becomes stronger as interest rates increase, different from policy expectations. Overall, our results support the idea that macroprudential policies have heterogeneous effects on demographic groups. The elderly population or single-person households are unlikely to respond to the desired policy directions, implying that they do not become subject to the LTV and DTI regulations effectively when purchasing houses. In contrast, working adults who have children tend to strongly respond to such macroprudential policies.

4.5 Changes in demographic variables and house price growth

Regression analyses using changes in variables are less likely to show spurious results than those using level variables. In this section, we test the robustness of the earlier findings using the changes in demographic variables. Specifically, we investigate whether future house price growth can be explained by changes in demographic variables or migration. Table 6 shows the result when the dependent variable is a district-level house price index, and columns (2), (3), and (4) show the results when the dependent variable is a house price index with low-, medium-, and high-valued houses, respectively, and columns (5) and (6) show the results when the dependent variable is a house price index with small and large-sized houses, respectively, and columns (7) and (8) show the results when the dependent variable is a house price index with new and old houses, respectively. We include quarter-to-quarter changes in the youth dependency ratio, elderly dependency ratio, and changes in the ratio of single-person households instead of the level of demographic variables in the regression equation (4).

[**Place Table 6 about here**]

The results indicate that the coefficients on the previous quarter's change in the youth dependency ratio (dYOUTH) are negative, although only price growth for old houses is significant while the coefficients on the previous quarter's change in the elderly dependency ratio (dELDERLY) are positive and significant for house price growth for all types of houses. The coefficients on dELDERLY are economically larger for house price growth with the medium-valued, large sized, and old houses, indicating that price appreciations in those houses tend to be greater as the elderly population increases. In addition, the coefficients on the previous quarter's change in the ratio of single-person households (dSINGLE) are all negative and significant except for high-valued and large-sized houses. These results suggest that single-person households lead to a fall in prices, especially for low-valued, small-sized and old-houses. Overall, our results suggest that an increase in changes in the elderly groups tends to contribute to house price appreciation, while those in single-person households lead to price depreciation, which is consistent with our earlier analyses.

4.6 Reverse causality

In the previous section, we confirm that house prices tend to increase in districts with a high elderly dependency ratio, while they tend to drop in districts with a higher youth dependency ratio and a higher proportion of single-person households. However, there is the possibility that this relationship could arise due to reverse causality. Referring to results in Table 1 that the average house price growth for the large houses is -0.19% while that for small houses is 0.46%, families with many children who need large flats or large houses may prefer to buy houses with low house price growth. On the other hand, the elderly populations who attempt to invest with retirement funds may prefer to buy houses with an increasing house prices, expecting higher returns on investment. Since reciprocal causality leads to biased estimations, we check this possibility for robustness.

$$DEMOGRAPHICS_{it} = b_0 + b_1 dlog(HPI)_{it-1} + b2dlog(HPI)_{it-2} + b_j X_{it-1} + e_{it} \quad (5)$$

where $\text{DEMOGRAPHICS}_{\text{it}} = \{\text{ELDERLY}_{\text{it}}, \text{YOUTH}_{\text{it}}, \text{SINGLE}_{\text{it}}\}$: ELDERLY is the elderly dependency ratio; YOUTH is the youth dependency ratio; and SINGLE is the ratio of the single-person households. The definitions of other variables are the same as in equation (1). As shown in equation (5), we use the demographic variables as dependent variables and the one and two lagged house price growth as independent variables after controlling for the variables that are used in the previous analyses. Columns (1) and (4) show the results when the youth dependency ratio is the dependent variable; Columns (2) and (5) show the results when the elderly dependency ratio is the dependent variable; Columns (3) and (6) show the results when the ratio of single-person households is the dependent variable. We also include the one or two lagged values of the log changes in the house price index as control variables.

[Place Table 7 about here]

The coefficients on one lagged house prices growth are insignificant for the youth and elderly dependency ratio (columns (1), (2), (4) and (5)). The coefficients on the two lagged house price growth are significantly and positively related to house price growth for the youth dependency ratio (columns (1) through (3)) and those are negatively and significantly related for the elderly population (columns (4) through (6)). In other words, the coefficients on $\text{dlog(HPI)}_{\text{it-1}}$ or $\text{dlog(HPI)}_{\text{it-2}}$ tend to be insignificant or to have an opposite sign as the earlier results. These results suggest that reciprocal causation does not seem to be an issue for the relationship of house price growth with the elderly and youth dependency ratios. In contrast, we find that the coefficients on SINGLE are negatively and significantly related with house price growth, suggesting the possibility of reverse causation. We therefore need to be cautious in interpreting any results from the regressions, including the ratio of single-person households because the estimates could be biased. We further check the robustness of the endogeneity and reverse causation in the next section, by employing the General Methods of Moment (GMM).

4.7 Alternative estimation methodology: GMM

To check the robustness of the earlier results, we use the traditional first-differenced GMM or one-step GMM estimator as proposed by Arellano and Bond (1991) for reducing potential endogeneity. The one-step GMM method requires lagged levels of the dependent variable as instrument variables in order to reduce the endogeneity and to remove any district fixed effects. Table 8 shows that our empirical results pass the Arellano-Bond criteria, testing the validity of model specification. Specifically, the values of our AR (2) are all valid at the 5% significance level. We also find that the Sargen test and the Hansen test of overriding restrictions and the difference-in-Hansen tests of exogeneity of instruments do not reject the hypothesis that the GMM instruments are exogeneous and valid for our model.

[**Place Table 8 about here**]

Table 8 also shows that the coefficients on YOUTH are all negatively and significantly related with house price growth whereas the coefficients on ELDERLY are positive and significant except for those for high-valued houses. In addition, the coefficients on SINGLE are negative and significant except, again, for high-valued houses. The results indicate that districts with high elderly dependency ratios experience house price appreciation while the districts with a high number of single-person households and high youth dependency ratio are found to lower house price growth. In summary, the effect of demographic variables on house price growth are robust regardless of the regression schemes used.

5 Conclusion

Recent demographic changes—an aging population and a rising number of single-person households—have been rapid. One of the central questions is how such a demographic shift affects house prices. Only a few studies have examined the issue, and even the existing empirical evidence, mainly from aggregated data, has been mixed. Consequently, the goal in this paper is to shed additional light on how elderly and single-person households affect house price growth, and how these specific groups respond to macroprudential policies such as loan-to-value (LTV) and debt-to-income (DTI) ratios.

This paper's main contribution is to use a unique set of data covering a variety of house price indexes from real-transaction data, quantified LTV and DTI limits, and demographic variables in 95 districts across Korea that is experiencing very fast demographic transitions, over the period from Q1 2008 to Q4 2017. Using this data, we analyze the relationship between the demographic structure and house prices at the disaggregated level.

Our key findings can be summarized as follows. First, house price growth tends to increase with age and the number of households, but an increase in the rate of house price growth has gradually slowed with aging. Second, we find that the effects of the total dependency ratio on house price growth are insignificant, but its decomposition has differential effects. House price growth tends to increase in districts with a high elderly dependency ratio, seemingly due to an extended life expectancy that induces the elderly to prepare for their future. This result indicates that aging is unlikely to drive house prices down in contrast to what *life-cycle hypothesis* and *asset meltdown hypothesis* would imply. On the other hand, we find that house price growth tends to decline in districts with a high youth dependency ratio. The negative relationship is likely to be driven by the fact that households with children below the age of 15 tend to have relatively lower levels of wealth and incur high costs for childcare. Third, we further show that single-person households tend to lower house prices with their low demand for housing, probably due to their low-income level, delayed family formation, or the absence of favorable housing policies for single households. The negative effects of single-person households become weaker for low-priced, small-sized, and new houses in Seoul, indicating the strong preference of such households for those types of home. Lastly, we find that macroprudential policies do not seem to be a channel through which the elderly or single-person households affect house prices because such households are unlikely to respond to the desired policy directions, possibly because of their ineligibility for loan requirements owning to their low incomes or because they have no need of additional funding.

In sum, our empirical evidence provides answers to some unsettled questions. Significant concerns that aging would adversely affect house prices have been raised by the life-cycle hypothesis or the asset meltdown hypothesis. Yet, this is unlikely to occur soon in Korea because our analysis shows a positive relationship between the elderly and house prices. This association will be maintained for a while in that our sample includes baby boomers in Korea who have started to retire. Furthermore, this paper provides implications regarding macroprudential and housing policies. More specifically, we need to take caution to design the macroprudential policy frameworks because the regulations may not influence certain groups like the elderly or single-person households despite their overall effectiveness. We also need to set favorable housing policies for single-person households, leading to house price drops. Overall, our findings suggest that demographic variables have a substantial effect on house prices in Korea. Since impending demographic changes are global phenomena, the topics similar to this study deserve further studies in other countries, which can serve as valuable information for policymakers, homeowners, and academia alike.

References

Agnello, L. and L. Schuknecht (2011). Booms and busts in housing markets: Determinants and implications. *Journal of Housing Economics 20*(3), 171–190.

Akinci, O. and J. Olmstead-Rumsey (2018). How effective are macroprudential policies? An empirical investigation. *Journal of Financial Intermediation 33*, 33–57.

Allen, J., T. Grieder, B. Peterson, and T. Roberts (2017). The impact of macroprudential housing finance tools in canada. *Journal of Financial Intermediation*, 100761.

Alter, A., A. X. Feng, and N. Valckx (2018). Understanding the macro-financial effects of household debt: A global perspective. *IMF Working Paper 1876*.

Ando, A. and F. Modigliani (1963). The life cycle hypothesis of saving: Aggregate implications and tests. *American Economic Review 53*(1), 55–84.

Arellano, M. and S. Bond (1991). Some tests of specification for panel data: Monte carlo evidence and an application to employment equations. *Review of Economic Studies 58*(2), 277–297.

Bakshi, G. S. and Z. Chen (1994). Baby boom, population aging, and capital markets. *Journal of Business*, 165–202.

Berkowitz, M. K. and J. Qiu (2006). A further look at household portfolio choice and health status. *Journal of Banking and Finance 30*(4), 1201–1217.

Bernanke, B. and A. S. Blinder (1992). The federal funds rate and the transmission of monetary policy. *American Economic Review 82*(4), 901–21.

Bernanke, B. S. et al. (2010). Monetary policy and the housing bubble: a speech at the annual meeting of the american economic association, atlanta, georgia, january 3, 2010. Technical report.

Bruno, V. and H. S. Shin (2014). Assessing Macroprudential Policies: Case of South Korea*: Assessing macroprudential policies. *Scandinavian Journal of Economics 116*(1), 128–157.

Capozza, D., P. Hendershott, C. Mack, and C. Mayer (2002). Determinants of Real House Price Dynamics. Technical Report w9262, National Bureau of Economic Research, Cambridge, MA.

Case, B., H. O. Pollakowski, and S. M. Wachter (1991). On choosing among house price index methodologies. *Real Estate Economics 19*(3), 286–307.

Case, K. E. and R. J. Shiller (1987). Prices of single-family homes since 1970: new indexes for four cities. *New England Economic Review*, 45–56.

Case, K. E. and R. J. Shiller (2003). Is there a bubble in the housing market? *Brookings Papers on Economic Activity 2003*(2), 299–362.

Cerutti, E., S. Claessens, and L. Laeven (2017). The use and effectiveness of macroprudential policies: New evidence. *Journal of Financial Stability 28*, 203–224.

Chiuri, M. C. and T. Jappelli (2010). Do the elderly reduce housing equity? an international comparison. *Journal of Population Economics 23*(2), 643–663.

Chiyachantana, C. N., P. K. Jain, C. Jiang, and R. A. Wood (2004). International Evidence on Institutional Trading Behavior and Price Impact. *Journal of Finance 59*(2), 869–898.

Claessens, S., S. R. Ghosh, and R. Mihet (2013). Macro-prudential policies to mitigate financial system vulnerabilities. *Journal of International Money and Finance 39*, 153–185.

Claessens, S., M. A. Kose, and M. E. Terrones (2012). How do business and financial cycles interact? *Journal of International Economics 87*(1), 178–190.

Égert, B. and D. Mihaljek (2007). Determinants of house prices in central and eastern europe. *Comparative Economic Studies 49*(3), 367–388.

Eichholtz, P. and T. Lindenthal (2014). Demographics, human capital, and the demand for housing. *Journal of Housing Economics 26*, 19–32.

Engelhardt, G. V. and J. M. Poterba (1991). House prices and demographic change: Canadian evidence. *Regional Science and Urban Economics 21*(4), 539–546.

Favara, G. and J. Imbs (2015). Credit Supply and the Price of Housing. *American Economic Review 105*(3), 958–992.

Fisher, R. M. and J. W. Graham (1974). Housing demand by one-person households. *Land Economics 50*(2), 163–168.

Flavin, M. and T. Yamashita (2002). Owner-occupied housing and the composition of the household portfolio. *American Economic Review 92*(1), 345–362.

Gambacorta, L. and A. Murcia (2020). The impact of macroprudential policies in latin america: An empirical analysis using credit registry data. *Journal of Financial Intermediation 42*, 100828.

Glaeser, E. L. and J. Gyourko (2005). Urban decline and durable housing. *Journal of Political Economy 113*(2), 345–375.

Hiller, N. and O. W. Lerbs (2016). Aging and urban house prices. *Regional Science and Urban Economics 60*, 276–291.

Holland, A. S. (1991). The baby boom and the housing market: Another look at the evidence. *Regional Science and Urban Economics 21*(4), 565–571.

Hort, K. (1998). The determinants of urban house price fluctuations in sweden 1968–1994. *Journal of Housing Economics 7*(2), 93–120.

Hwang, M. and J. M. Quigley (2006). Economic fundamentals in local housing markets: evidence from us metropolitan regions. *Journal of Regional Science 46*(3), 425–453.

Igan, D. and H. Kang (2011). Do loan-to-value and debt-to-income limits work? evidence from korea. *IMF Working Papers*, 1–34.

Jung, H. and J. Lee (2017). The effects of macroprudential policies on house prices: Evidence from an event study using Korean real transaction data. *Journal of Financial Stability 31*, 167–185.

Krainer, J. et al. (2005). Housing markets and demographics. *FRBSF Economic Letter*.

Kuttner, K. N. and I. Shim (2016). Can non-interest rate policies stabilize housing markets? evidence from a panel of 57 economies. *Journal of Financial Stability 26*, 31–44.

Levin, E., A. Montagnoli, and R. E. Wright (2009). Demographic change and the housing market: evidence from a comparison of scotland and england. *Urban Studies 46*(1), 27–43.

Mankiw, N. G. and D. N. Weil (1989). The baby boom, the baby bust, and the housing market. *Regional Science and Urban Economics 19*(2), 235–258.

Nishimura, K. G. and E. Takáts (2012). Ageing, property prices and money demand. *BIS working paper*.

Ohtake, F. and M. Shintani (1996). The effect of demographics on the japanese housing market. *Regional Science and Urban Economics 26*(2), 189–201.

Pavlov, A. and S. Wachter (2011). Subprime lending and real estate prices. *Real Estate Economics 39*(1), 1–17.

Petersen, M. A. (2009). Estimating standard errors in finance panel data sets: Comparing approaches. *The Review of Financial Studies 22*(1), 435–480.

Piazzesi, M., M. Schneider, and J. Stroebel (2020). Segmented housing search. *American Economic Review 110*(3), 720–59.

Pitkin, J. R. and D. Myers (1994). The specification of demographic effects on housing demand: avoiding the age-cohort fallacy. *Journal of Housing Economics 3*(3), 240–250.

Revelo, J. D. G., Y. Lucotte, and F. Pradines-Jobet (2020). Macroprudential and monetary policies: The need to dance the tango in harmony. *Journal of International Money and Finance*, 102–156.

Samuelson, P. A. (1958). An exact consumption-loan model of interest with or without the social contrivance of money. *Journal of Political Economy 66*(6), 467–482.

Takáts, E. (2012). Aging and house prices. *Journal of Housing Economics 21*(2), 131–141.

Vandenbussche, J., U. Vogel, and E. Detragiache (2015). Macroprudential Policies and Housing Prices: A New Database and Empirical Evidence for Central, Eastern, and Southeastern Europe. *Journal of Money, Credit and Banking 47*(S1), 343–377.

Wang, X., E. Hui, and J. Sun (2018). Population Aging, Mobility, and Real Estate Price: Evidence from Cities in China. *Sustainability 10*(9), 3140.

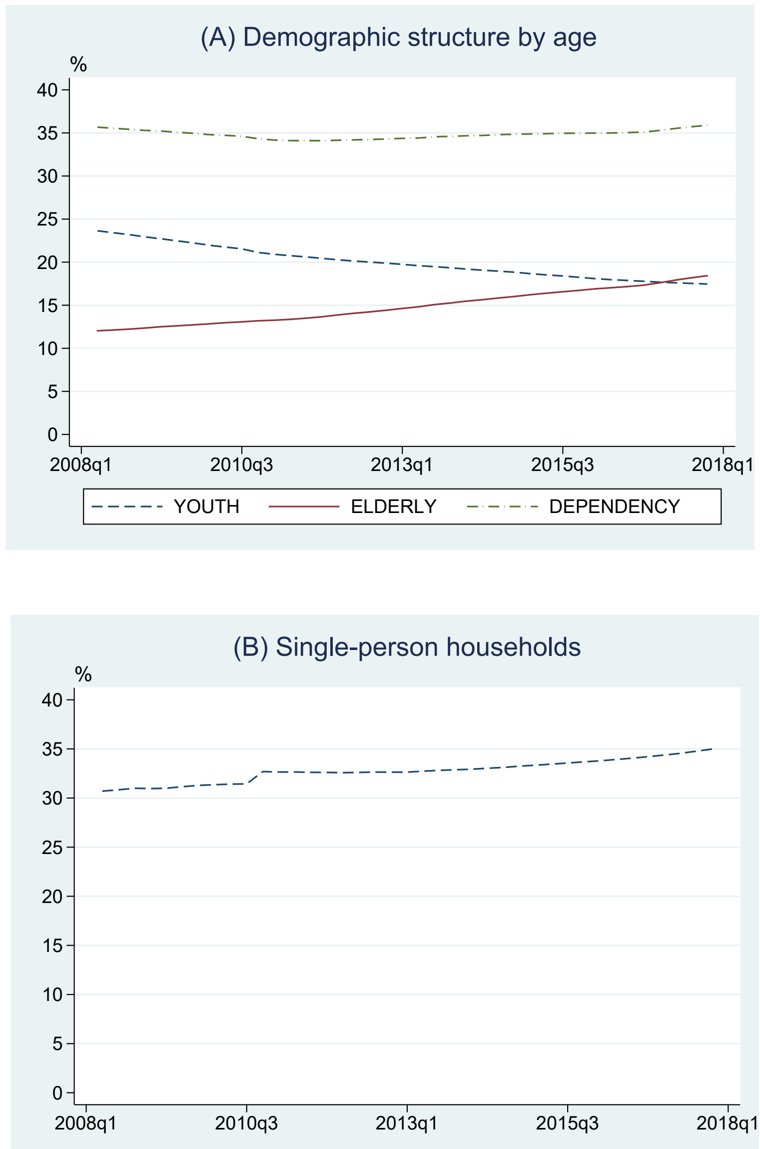

Figure 1: The recent demographic changes in Korea.
Panel (A) shows the dependency ratio (DEPENDENCY), the elderly dependency ratio (ELDERLY) and the youth dependency ratio (YOUTH). Panel (B) exhibits the ratio of single-person households to the total number of households over 2008-2017.

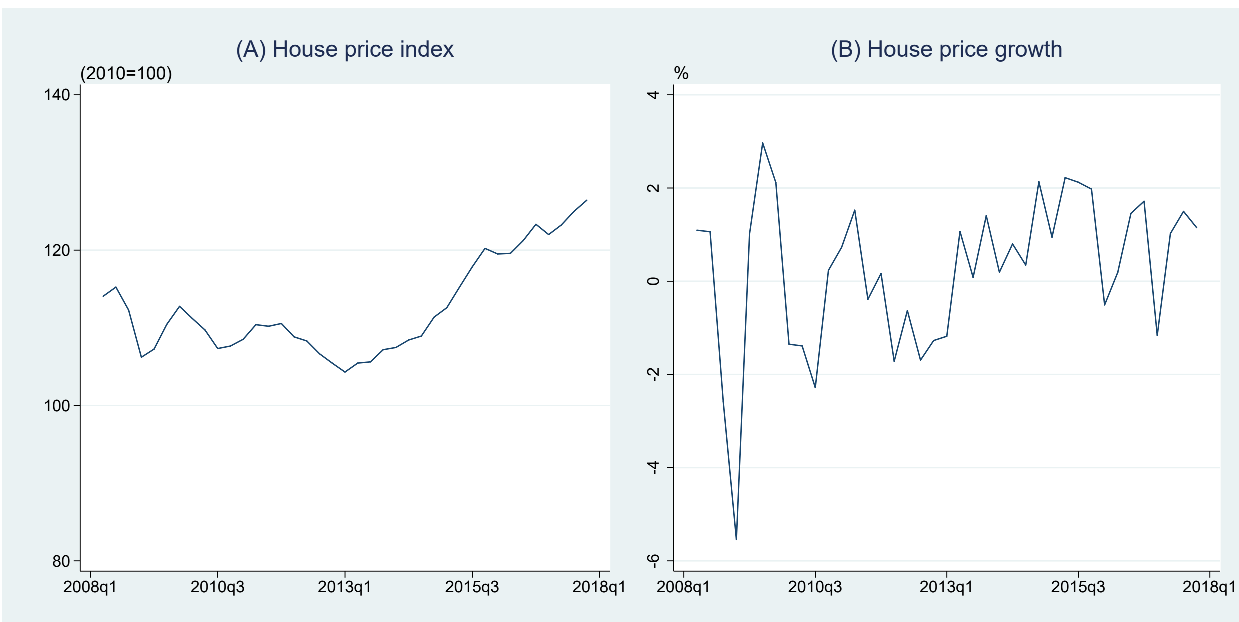

Figure 2: House prices in Korea.
Panel (A) shows the nationwide real house price index. The base year is 2010. Panel (B) shows the house price return computed by the quarter-on-quarter percent change in nationwide house prices. All series are based on the standard Case and Shiller (1987) repeat sales methodology.

Figure 3: House price index by property types.
Panels (A), (B), and (C) display the real house price indexes by property value, dwelling size, and the age of housing stock. The base year is 2010. Panels (D), (E), and (F) display the house price return by property value, dwelling size, and age. All series are based on the standard Case and Shiller (1987) repeat sales methodology.

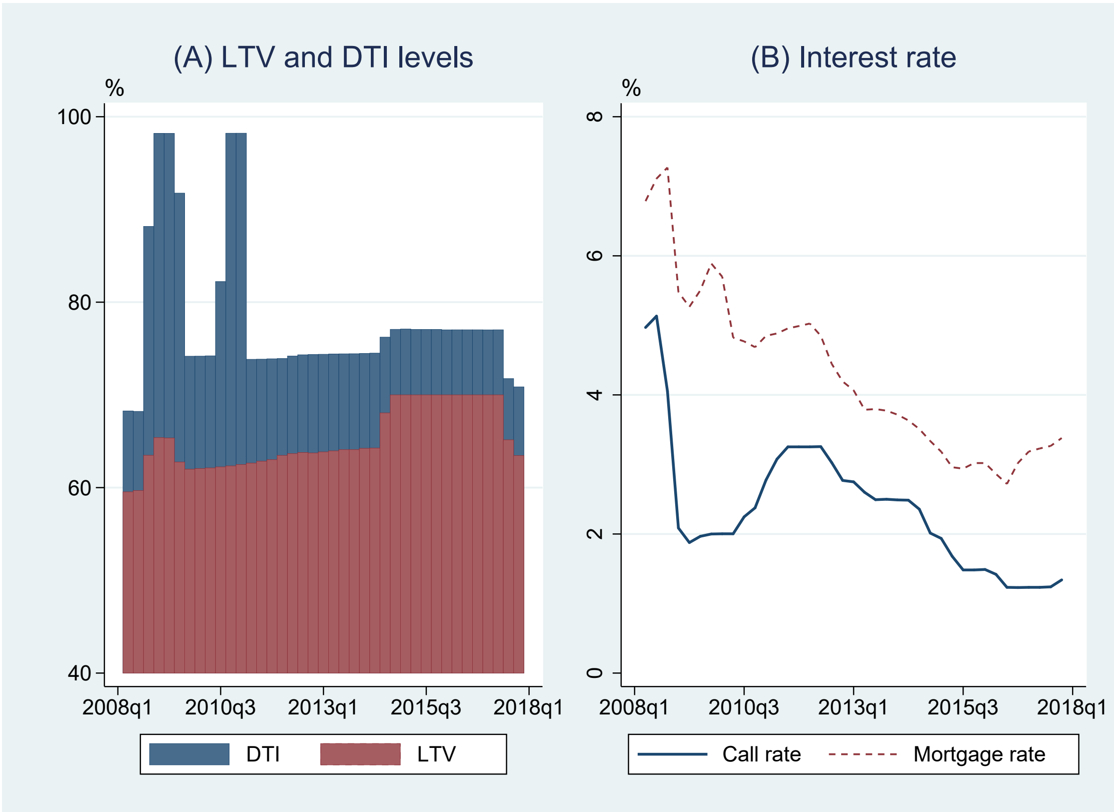

Figure 4: Macroprudential and monetary policies.
Panel (A) shows the limits placed on LTV and DTI ratios. Panel (B) shows the call rate and mortgage rate.

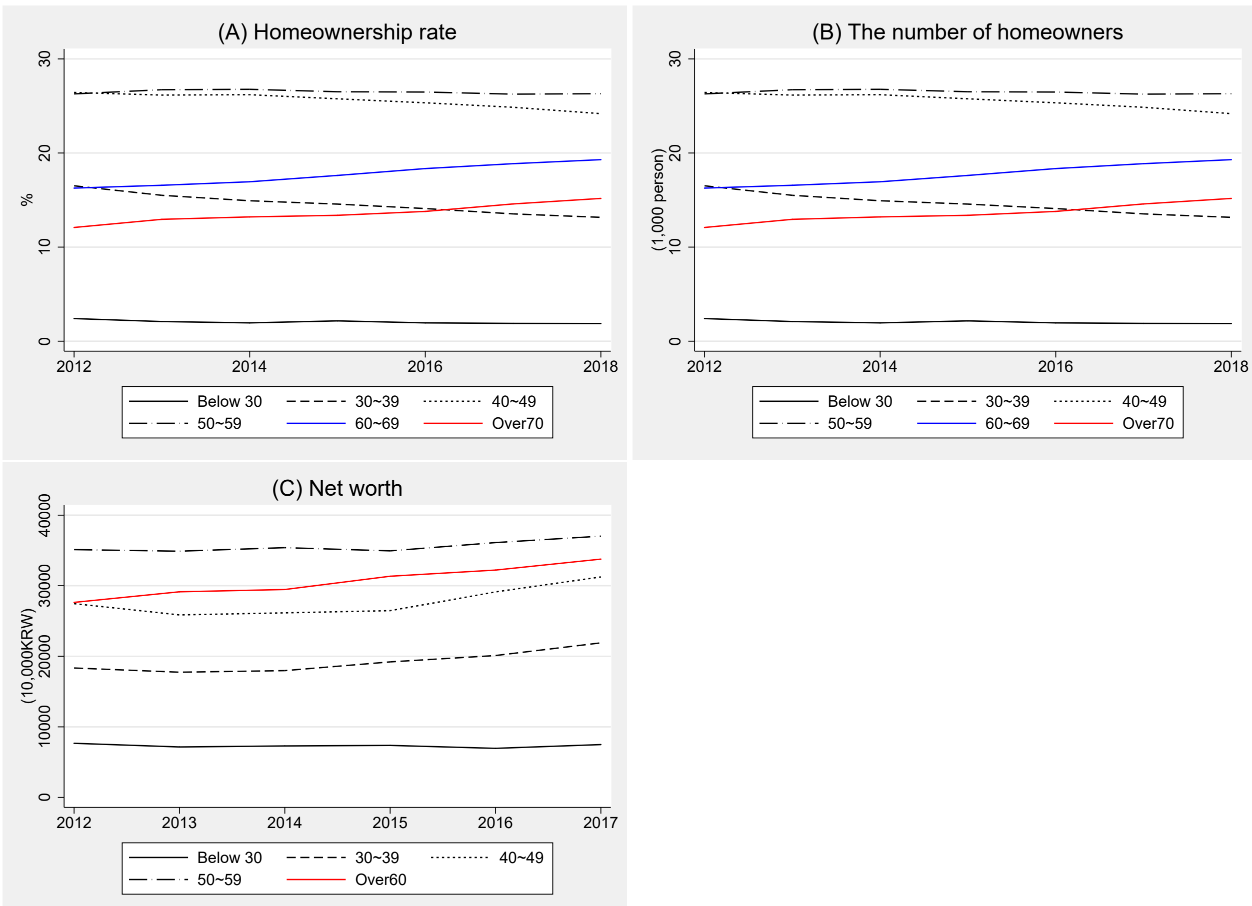

Figure 5: Home ownership and net wealth by age.
Panel (A) shows the home ownership rate by age groups at the national-level. Panel (B) exhibits the number of homeowners by age groups at the national-level. Panel (C) shows net worth per household.

Table 1: Summary statistics

The sample period is from Q1 2008 to Q4 2017. House price indexes are computed following the standard Case and Shiller (1987) repeat sales methodology. The detailed definitions of the variables are shown in Appendix A.

VARIABLES	(1) N	(2) MEAN	(3) SD	(4) MIN	(5) MAX
House price index					
HPI	3,705	112.52	19.58	77.97	182.40
dlog(HPI^{ALL})	3,705	0.24	2.70	-15.56	16.51
dlog(HPI^{LOW})	3,666	0.37	2.79	-19.05	25.22
dlog(HPI^{MED})	2,652	-0.26	2.69	-20.19	11.13
dlog(HPI^{HIGH})	1,014	-0.59	3.68	-21.07	14.00
dlog(HPI^{SMALL})	3,705	0.46	2.90	-29.50	20.65
dlog(HPI^{LARGE})	3,627	-0.19	3.26	-18.52	20.12
dlog(HPI^{NEW})	3,705	0.05	2.74	-14.12	18.49
dlog(HPI^{OLD})	2,964	0.45	4.01	-20.89	30.26
Demographic variables					
HH	3,705	144,274	78,226	29,224	482,695
AGE	3,684	38.39	2.59	31.47	47.44
NFAM	3,705	2.53	0.19	1.98	3.07
DEPENDENCY (%)	3,684	34.83	4.11	26.62	49.86
YOUTH (%)	3,684	19.99	4.22	10.48	37.41
ELDERLY (%)	3,684	14.84	4.41	5.87	33.61
SINGLE (%)	3,705	32.74	5.69	19.35	52.27
Source of financing					
LTV(%)	3,705	65.23	8.03	40.86	79.45
DTI(%)	3,705	78.09	20.12	40.72	100
MORATE(%)	3,705	4.30	1.20	2.72	7.27
Supply-side variables					
dlog(SUPPLY)	3,669	5.97	113.71	-553.95	541.26
NOSALE	3,705	467.01	940.22	0.00	8,117
City-level control variables					
GRDP	3,705	94.34	12.60	50.75	118.73
JTP(%)	3,705	62.78	12.30	38.36	78.86
Macroeconomic conditions					
CPI	3,705	96.13	5.11	86.00	103.21
M2	3,705	1.67	0.68	0.10	3.67

Table 2: Demographic structures and house price growth

This table reports the results of regressions with district dummies and clustered standard errors at the district level over the period from Q1 2008 to Q4 2017. *i*,*c* and *t* index district, city, and time, respectively. The dependent variable is $\text{dlog(HPI)}_{\text{it}}$, the log changes in the real house price index. The independent variables are as follows: $\text{AGE}_{\text{it-1}}$ and $\text{AGE}^2{}_{\text{it-1}}$ are the average age and the squared average age of each district; LTV and DTI are estimated at the different scale and time: dlog(LTV) and dlog(DTI) are the log changes in the LTV and DTI ratios, $\text{dMORATE}_{\text{ct-1}}$ is the changes in the mortgage loan interest rates; $\text{dlog(HH)}_{\text{it-1}}$ is the log changes in the number of households; $\text{JTP}_{\text{ct-1}}$ is the Jeonse-to-price ratio; $\text{dlog(GRDP)}_{\text{ct-1}}$ is the log changes in gross regional domestic product; $\text{dlog(SUPPLY)}_{\text{it-1}}$ is the log changes in supply, the number of housing starts and building permits; $\text{UNSOLD}_{\text{it-1}}$ is the ratio of unsold newly-built housing inventory relative to the total number of households; $\text{dlog(M2)}_{\text{t-1}}$ is the log changes in the monetary aggregate M2; $\text{dlog(GDP)}_{\text{t-1}}$ is the log changes in GDP and $\text{NFAM}_{\text{it-1}}$ is the average number of family members. The t-statistics are in parentheses, and *, ** and *** denote the significance levels of 10%, 5% and 1%, respectively.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)
AGE_{it-1}	0.298***	2.275**	2.075**	1.738**			
	(2.85)	(2.58)	(2.35)	(2.41)			
AGE^2_{it-1}		-0.022**	-0.021*	-0.017*			
		(-2.01)	(-1.90)	(-1.88)			
NFAM_{it-1}					4.358**	3.483	9.275
					(1.99)	(1.60)	(1.13)
NFAM^2_{it-1}							-1.384
							(-0.90)
dlog(LTV)_{it-1}	-0.082***				-0.093***		
	(-8.45)				(-10.24)		
dlog(DTI)_{it-1}	-0.020***				-0.027***		
	(-5.37)				(-9.59)		
dlog(LTV)_{it-2}		0.053***	0.060***	0.078***		0.062***	0.080***
		(2.96)	(2.95)	(3.75)		(3.07)	(3.85)
dlog(DTI)_{it-2}		0.031***	0.031***	0.029***		0.031***	0.028***
		(8.91)	(7.98)	(6.97)		(7.69)	(6.75)
dlog(HH)_{it-1}	0.220***	0.198**	0.060	0.121	0.198**	0.036	0.096
	(2.64)	(2.32)	(0.71)	(1.49)	(2.27)	(0.46)	(1.24)
JTP_{ct-1}	0.296***	0.339***	0.379***	0.406***	0.312***	0.424***	0.444***
	(11.80)	(10.85)	(10.85)	(12.00)	(11.57)	(12.34)	(13.00)
dlog(GRDP)_{ct-1}	-0.033***	-0.005	-0.013**	-0.026***	-0.028***	-0.014***	-0.028***
	(-5.28)	(-0.75)	(-2.38)	(-3.84)	(-5.67)	(-2.65)	(-4.06)
$\text{dlog(SUPPLY)}_{it-1}$	-0.002***	-0.001***	-0.001***	-0.002***	-0.001***	-0.001***	-0.002***
	(-5.46)	(-4.35)	(-4.12)	(-5.30)	(-4.58)	(-4.01)	(-5.21)
UNSOLD_{it-1}	-0.326***	-0.390***	-0.333***	-0.288***	-0.246**	-0.237**	-0.192**
	(-4.69)	(-4.56)	(-4.03)	(-4.19)	(-2.42)	(-2.39)	(-2.35)
dMORATE_{t-1}	-1.148***		0.045	-0.490	-0.842***	-0.041	-0.561*
	(-3.64)		(0.20)	(-1.50)	(-3.79)	(-0.17)	(-1.73)
dlog(M2)_{t-1}	-0.093		0.152	0.050	-0.049	0.109	0.017
	(-0.85)		(1.38)	(0.41)	(-0.52)	(1.02)	(0.14)
dlog(GDP)_{t-1}	0.371***		0.525***	0.424***	0.467***	0.554***	0.450***
	(4.38)		(8.25)	(4.88)	(7.59)	(8.97)	(5.27)
dlog(HPI)_{it-1}	0.160***			0.220***			0.219***
	(2.94)			(4.20)			(4.22)

Observations	3,553	3,553	3,553	3,553	3,574	3,574	3,574
Number of district	95	95	95	95	95	95	95
Adjusted R-squared	0.35	0.30	0.31	0.34	0.33	0.31	0.34
District FE	YES	YES	YES	YES	YES	YES	YES
CITY*YEAR FE	YES	YES	YES	YES	YES	YES	YES

Table 3: Demographic structures and house price growth

This table reports the results of regression with district dummies and clustered standard errors at the district level over the period from Q1 2008 to Q4 2017. *i,c* and *t* index district, city, and time, respectively. The dependent variable is $dlog(HPI)_{it}$, the log changes in the real house price index. The independent variables are as follows: $DEPENDENCY_{it-1}$ is the percentage of those aged between 0 and 14 and over 65 to the total population; $YOUTH_{it-1}$ is the percentage of those aged between 0 and 14; $ELDERLY_{it-1}$ is the percentage of those aged over 65; $SINGLE_{it-1}$ is the ratio of single-person households; $dlog(LTV)_{it-2}$ and $dlog(DTI)_{it-2}$ are the log changes in the LTV and DTI ratios; $dMORATE_{ct-1}$ is the changes in mortgage loan interest rates; $dlog(HH)_{it-1}$ is the log changes in the number of households; JTP_{ct-1} is the Jeonse-to-price ratio; $dlog(GRDP)_{ct-1}$ is the log changes in gross regional domestic product; $dlog(SUPPLY)_{it-1}$ is the log changes in supply, the number of housing starts and building permits; $UNSOLD_{t-1}$ is the ratio of unsold newly-built housing inventory relative to the total number of households; $dlog(M2)_{t-1}$ is the log changes in the monetary aggregate M2; and $dlog(GDP)_{t-1}$ is the log changes in GDP. The t-statistics are in parentheses, and *, ** and *** denote the significance levels of 10%, 5% and 1%, respectively.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
$DEPENDENCY_{it-1}$	0.025	0.019				
	(0.58)	(0.40)				
$YOUTH_{it-1}$			-0.075	-0.076	-0.220***	-0.194***
			(-1.45)	(-1.24)	(-3.39)	(-2.76)
$ELDERLY_{it-1}$			0.180**	0.168**	0.373***	0.325***
			(2.54)	(2.18)	(5.22)	(4.08)
$SINGLE_{it-1}$					-0.413***	-0.336***
					(-5.52)	(-3.69)
$dlog(LTV)_{it-2}$	0.061***	0.080***	0.060***	0.079***	0.059***	0.077***
	(2.98)	(3.79)	(2.96)	(3.76)	(2.91)	(3.67)
$dlog(DTI)_{it-2}$	0.031***	0.028***	0.031***	0.028***	0.032***	0.029***
	(7.75)	(6.92)	(7.79)	(6.98)	(7.87)	(7.11)
$dlog(HH)_{it-1}$	0.031	0.094	0.051	0.113	0.092	0.144*
	(0.39)	(1.27)	(0.62)	(1.52)	(1.15)	(1.91)
JTP_{ct-1}	0.421***	0.444***	0.394***	0.418***	0.366***	0.394***
	(12.13)	(12.97)	(11.68)	(11.41)	(10.36)	(10.85)
$dlog(GRDP)_{ct-1}$	-0.014**	-0.027***	-0.013**	-0.026***	-0.014**	-0.027***
	(-2.48)	(-4.45)	(-2.38)	(-4.33)	(-2.56)	(-4.37)
$dlog(SUPPLY)_{it-1}$	-0.001***	-0.002***	-0.001***	-0.002***	-0.001***	-0.002***
	(-4.01)	(-4.62)	(-4.12)	(-4.73)	(-4.04)	(-4.57)
$UNSOLD_{it-1}$	-0.286***	-0.238**	-0.375***	-0.323***	-0.272***	-0.242**
	(-2.99)	(-2.32)	(-4.60)	(-2.94)	(-3.06)	(-2.18)
$dMORATE_{t-1}$	0.002	-0.536**	0.026	-0.511**	0.061	-0.456*
	(0.01)	(-2.11)	(0.11)	(-2.03)	(0.27)	(-1.79)
$dlog(M2)_{t-1}$	0.116	0.017	0.134	0.034	0.155	0.057
	(1.07)	(0.14)	(1.22)	(0.28)	(1.41)	(0.46)
$dlog(GDP)_{t-1}$	0.552***	0.447***	0.530***	0.427***	0.528***	0.430***
	(8.93)	(6.23)	(8.39)	(5.96)	(8.31)	(5.99)
$dlog(HPI)_{it-1}$		0.223***		0.223***		0.212***
		(5.84)		(5.82)		(5.55)
Observations	3,553	3,553	3,553	3,553	3,553	3,553
Adjusted R-squared	0.31	0.35	0.31	0.36	0.32	0.36
CITY*YEAR FE	YES	YES	YES	YES	YES	YES

Table 4: Demographic structures and house price growth

This table reports the results of regressions with district dummies and clustered standard errors at the district level over the period from Q1 2008 to Q4 2017. *i*,*c* and *t* index district, city, and time, respectively. The dependent variable is $\text{dlog}(\text{HPI}^{\text{j}})_{\text{it}}$, the log changes in the real house price index by property types j, j={price-level (low, medium, high), dwelling size (small, large), and house age (new, old)}. The independent variables are as follows: $\text{YOUTH}_{\text{it-1}}$ is the percentage of those aged between 0 and 14; $\text{ELDERLY}_{\text{it-1}}$ is the percentage of those aged over 65; $\text{SINGLE}_{\text{it-1}}$ is the ratio of single-person households; $\text{dlog(LTV)}_{\text{it-2}}$ and $\text{dlog(DTI)}_{\text{it-2}}$ are the log changes in the LTV and DTI ratios; $\text{dMORATE}_{\text{ct-1}}$ is the changes in the mortgage loan interest rates; $\text{dlog(HH)}_{\text{it-1}}$ is the log changes in the number of households; $\text{JTP}_{\text{ct-1}}$ is the Jeonse-to-price ratio; $\text{dlog(GRDP)}_{\text{ct-1}}$ is the log changes in gross regional domestic product; $\text{dlog(SUPPLY)}_{\text{it-1}}$ is the log changes in supply, the number of housing starts and building permits; $\text{UNSOLD}_{\text{t-1}}$ is the ratio of unsold newly-built housing inventory relative to the total number of households; $\text{dlog(M2)}_{\text{t-1}}$ is the log changes in the monetary aggregate M2; and $\text{dlog(GDP)}_{\text{t-1}}$ is the log changes in GDP. The t-statistics are in parentheses, and *, ** and *** denote the significance levels of 10%, 5% and 1%, respectively.

Panel A. The whole country

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
		PRICE-LEVEL		SIZE		AGE	
VARIABLES	LOW	MED	HIGH	SMALL	LARGE	NEW	OLD
YOUTH_{it-1}	-0.240***	-0.136	-0.240	-0.173***	-0.186***	-0.147**	-0.230***
	(-4.03)	(-1.64)	(-0.71)	(-2.90)	(-2.92)	(-2.21)	(-3.30)
ELDERLY_{it-1}	0.284***	0.541***	0.826*	0.344***	0.366***	0.239***	0.469***
	(4.56)	(5.62)	(1.98)	(4.86)	(4.32)	(3.77)	(5.19)
SINGLE_{it-1}	-0.286***	-0.273***	-0.287	-0.390***	-0.381***	-0.327***	-0.405***
	(-4.08)	(-4.55)	(-1.22)	(-5.58)	(-4.92)	(-4.67)	(-5.04)
dlog(LTV)_{it-2}	0.068***	0.036	-0.049	0.057***	0.006	0.071***	0.026
	(3.65)	(1.63)	(-0.54)	(2.83)	(0.18)	(2.93)	(1.16)
dlog(DTI)_{it-2}	0.033***	0.021***	0.012	0.030***	0.025***	0.027***	0.030***
	(9.75)	(4.38)	(1.54)	(7.92)	(4.14)	(6.76)	(6.60)
dMORATE_{t-1}	0.100	-0.446	-1.638*	0.205	-0.194	-0.313	-0.100
	(0.54)	(-1.66)	(-1.78)	(0.85)	(-0.65)	(-1.41)	(-0.49)
dlog(HH)_{it-1}	-0.027	0.164*	0.651***	0.040	0.188*	0.147*	0.022
	(-0.35)	(1.80)	(3.05)	(0.47)	(1.85)	(1.87)	(0.26)
JTP_{ct-1}	0.328***	0.286***	0.143	0.356***	0.306***	0.350***	0.322***
	(10.28)	(5.85)	(1.16)	(10.39)	(6.56)	(8.78)	(8.05)
dlog(GRDP)_{ct-1}	-0.020***	-0.011**	-0.005	-0.022***	-0.019***	-0.007	-0.019***
	(-3.10)	(-2.15)	(-0.34)	(-3.48)	(-3.07)	(-1.10)	(-2.85)
$\text{dlog(SUPPLY)}_{it-1}$	-0.001**	-0.000	-0.002	-0.001***	-0.000	-0.001**	-0.001***
	(-2.61)	(-0.97)	(-0.95)	(-3.23)	(-0.68)	(-2.34)	(-3.46)
UNSOLD_{it-1}	-0.145	-0.334**	-0.439	-0.141	-0.436***	-0.129	-0.297***
	(-1.14)	(-2.25)	(-0.91)	(-1.20)	(-4.92)	(-1.32)	(-2.84)
dlog(M2)_{t-1}	0.255*	-0.170	-0.303	0.309**	-0.157	-0.107	-0.000
	(1.94)	(-1.59)	(-0.61)	(2.39)	(-0.99)	(-0.89)	(-0.00)
dlog(GDP)_{t-1}	0.559***	0.338***	0.097	0.545***	0.320***	0.404***	0.512***
	(8.96)	(5.04)	(0.53)	(8.66)	(3.25)	(4.86)	(6.87)
Observations	3,515	2,572	984	3,553	3,477	3,553	3,553
Number of district	94	68	26	95	93	95	95
Adjusted R-squared	0.26	0.29	0.25	0.30	0.24	0.23	0.25
Clustered by District	YES	YES	YES	YES	YES	YES	YES

Panel B. Seoul

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
			PRICE-LEVEL		SIZE		AGE	
VARIABLES	ALL	LOW	MED	HIGH	SMALL	LARGE	NEW	OLD
YOUTH_{it-1}	-0.261	-0.767***	-0.364**	0.119	-0.312	-0.215	-0.100	-0.521*
	(-1.39)	(-4.33)	(-2.73)	(0.43)	(-1.51)	(-1.28)	(-0.63)	(-2.07)
ELDERLY_{it-1}	0.625***	0.462***	0.769***	0.660	0.630***	0.603**	0.521**	0.955***
	(3.14)	(3.46)	(3.91)	(1.38)	(2.99)	(2.61)	(2.53)	(2.97)
SINGLE_{it-1}	-0.448***	-0.213	-0.357***	-0.202	-0.385***	-0.402**	-0.242*	-0.544***
	(-3.36)	(-1.54)	(-3.19)	(-0.94)	(-2.93)	(-2.69)	(-1.90)	(-3.07)
CONTROL	YES	YES	YES	YES	YES	YES	YES	YES
Observations	912	874	912	608	912	912	912	874
Number of district	24	23	24	16	24	24	24	23
Adjusted R-squared	0.38	0.17	0.37	0.32	0.37	0.35	0.27	0.29

Panel C. Non-Seoul

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
			PRICE-LEVEL		SIZE		AGE	
VARIABLES	ALL	LOW	MED	HIGH	SMALL	LARGE	NEW	OLD
YOUTH_{it-1}	-0.206***	-0.192***	-0.068	-1.653*	-0.155**	-0.167**	-0.148*	-0.286***
	(-2.85)	(-3.42)	(-0.77)	(-1.88)	(-2.31)	(-2.48)	(-1.94)	(-3.28)
ELDERLY_{it-1}	0.351***	0.282***	0.493***	1.470	0.329***	0.339***	0.223***	0.328***
	(4.59)	(4.11)	(4.61)	(1.67)	(4.20)	(3.89)	(3.32)	(3.04)
SINGLE_{it-1}	-0.425***	-0.381***	-0.283***	-0.899	-0.428***	-0.402***	-0.379***	-0.311***
	(-4.47)	(-4.97)	(-3.60)	(-1.38)	(-4.82)	(-3.96)	(-4.34)	(-3.09)
CONTROL	YES	YES	YES	YES	YES	YES	YES	YES
Observations	2,641	2,641	1,660	376	2,641	2,565	2,641	1,980
Number of district	71	71	44	10	71	69	71	53
Adjusted R-squared	0.31	0.31	0.25	0.15	0.28	0.21	0.22	0.22

Table 5: Interaction between demographic variables and macroprudential policies

This table reports the results of regressions with district dummies and clustered standard errors at the district level over the period from Q1 2008 to Q4 2017. i,c and t index district, city, and time, respectively. The dependent variable is dlog(HPI)$_{\text{it}}$, the log changes in the real house price index. The independent variables are as follows: YOUTH$_{\text{it-1}}$ is the percentage of those aged between 0 and 14; ELDERLY$_{\text{it-1}}$ is the percentage of those aged over 65; SINGLE$_{\text{it-1}}$ is the ratio of single-person households; dlog(LTV)$_{\text{it-2}}$ and dlog(DTI)$_{\text{it-2}}$ are the log changes in the LTV and DTI ratios; dMORATE$_{\text{ct-1}}$ is the changes in the mortgage loan interest rates; dlog(HH)$_{\text{it-1}}$ is the log changes in the number of households; JTP$_{\text{ct-1}}$ is the Jeonse-to-price ratio; dlog(GRDP)$_{\text{ct-1}}$ is the log changes in gross regional domestic product; dlog(SUPPLY)$_{\text{it-1}}$ is the log changes in supply, the number of housing starts and building permits; UNSOLD$_{\text{t-1}}$ is the ratio of unsold newly-built housing inventory relative to the total households; dlog(M2)$_{\text{t-1}}$ is the log changes in the monetary aggregate M2; and dlog(GDP)$_{\text{t-1}}$ is the log changes in GDP. The t-statistics are in parentheses, and *, ** and *** denote the significance levels of 10%, 5% and 1%, respectively.

VARIABLES	(1) (A)YOUTH	(2) (A)ELDERLY	(3) (A)SINGLE
(A) YOUTH$_{it-1}$	-0.252***	-0.258***	-0.052
	(-4.59)	(-4.66)	(-0.95)
(A) ELDERLY$_{it-1}$	0.461***	0.466***	0.262***
	(7.03)	(6.99)	(5.12)
(A) SINGLE$_{it-1}$	-0.359***	-0.355***	-0.358***
	(-5.96)	(-5.85)	(-5.97)
(B) dlog(LTV)$_{it-2}$	-0.171*	0.212***	0.194**
	(-1.74)	(2.81)	(1.99)
(C) dlog(DTI)$_{it-2}$	-0.014	0.066***	0.090***
	(-0.85)	(4.57)	(5.23)
(D) dMORATE$_{t-1}$	-0.856	-0.865	0.897
	(-0.97)	(-1.40)	(0.92)
(A)*(B)	0.012**	-0.010***	-0.003
	(2.51)	(-2.64)	(-1.19)
(A)*(C)	0.002**	-0.003***	-0.002***
	(2.47)	(-2.93)	(-3.67)
(A)*(D)	0.043	0.070*	-0.037
	(1.17)	(1.67)	(-1.16)
dlog(HH)$_{it-1}$	0.139**	0.141**	0.255***
	(2.08)	(2.15)	(3.19)
JTP$_{ct-1}$	0.304***	0.302***	0.057***
	(8.04)	(9.08)	(5.70)
dlog(GRDP)$_{ct-1}$	-0.009*	-0.008*	-0.011**
	(-1.86)	(-1.74)	(-2.15)
dlog(SUPPLY)$_{it-1}$	-0.001***	-0.001***	-0.001**
	(-4.72)	(-4.59)	(-2.18)
UNSOLD$_{it-1}$	-0.408***	-0.431***	-0.510***
	(-4.79)	(-5.17)	(-4.08)
dlog(M2)$_{t-1}$	-0.400***	-0.415***	-0.146**
	(-5.18)	(-5.37)	(-2.47)
dlog(GDP)$_{t-1}$	0.431***	0.433***	0.002
	(7.13)	(7.13)	(0.07)
Observations	3,459	3,459	3,459
CITY*YEAR FE	YES	YES	YES
Adjusted R-squared	0.38	0.39	0.19

Table 6: Changes in demographic variables and house price growth

This table reports the results of regressions with district dummies and clustered standard errors at the district level over the period from Q1 2008 to Q4 2017. i,c and t index district, city, and time, respectively. The dependent variable is dlog(HPI^{j})$_{it}$, the log changes in the real house price index by property types j, j={price-level, dwelling size, and house age}. The independent variables are as follows: $dYOUTH_{it\text{-}1}$ is the changes in percentage of those aged between 0 and 14; $dELDERLY_{it\text{-}1}$ is the changes in percentage of those aged over 65; $dSINGLE_{it\text{-}1}$ is the changes in the ratio of single-person households; dlog(LTV)$_{it\text{-}2}$ and dlog(DTI)$_{it\text{-}2}$ are the log changes in the LTV and DTI ratios; $dMORATE_{ct\text{-}1}$ is the changes in mortgage loan interest rates; dlog(HH)$_{it\text{-}1}$ is the log changes in the number of households; $JTP_{ct\text{-}1}$ is the Jeonse-to-price ratio; dlog(GRDP)$_{ct\text{-}1}$ is the log changes in gross regional domestic product; dlog(SUPPLY)$_{it\text{-}1}$ is the log changes in supply, the number of housing starts and building permits; $UNSOLD_{t\text{-}1}$ is the ratio of unsold newly-built housing inventory relative to the total number of households; dlog(M2)$_{t\text{-}1}$ is the log changes in the monetary aggregate M2; dlog(GDP)$_{t\text{-}1}$ is the log changes in GDP. The t-statistics are in parentheses, and *, ** and *** denote the significance levels of 10%, 5% and 1%, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
			PRICE-LEVEL		SIZE		AGE	
VARIABLES	ALL	LOW	MED	HIGH	SMALL	LARGE	NEW	OLD
$dYOUTH_{it-1}$	-0.390	-0.899	0.111	-1.211	-0.788	-0.148	-0.054	-2.439**
	(-0.51)	(-1.27)	(0.12)	(-0.59)	(-1.22)	(-0.17)	(-0.08)	(-2.17)
$dELDERLY_{it-1}$	4.527***	4.227***	4.872***	4.496**	3.701***	4.172***	3.327***	6.015***
	(5.91)	(6.28)	(5.35)	(2.07)	(3.88)	(4.32)	(4.00)	(3.98)
$dSINGLE_{it-1}$	-1.026***	-1.203***	-0.621*	-0.626	-1.087***	-0.166	-0.786***	-1.735***
	(-3.75)	(-5.01)	(-1.93)	(-0.88)	(-4.02)	(-0.39)	(-2.72)	(-2.96)
dlog(LTV)$_{it-2}$	0.058***	0.066***	0.036	-0.050	0.056***	0.010	0.069***	0.021
	(2.86)	(3.50)	(1.61)	(-0.55)	(2.74)	(0.30)	(2.83)	(0.55)
dlog(DTI)$_{it-2}$	0.033***	0.035***	0.023***	0.012	0.032***	0.024***	0.028***	0.031***
	(8.54)	(10.14)	(4.86)	(1.50)	(8.40)	(4.14)	(7.29)	(4.03)
$dMORATE_{t-1}$	0.092	0.139	-0.428	-1.691*	0.238	-0.207	-0.282	-0.016
	(0.41)	(0.74)	(-1.57)	(-1.92)	(0.98)	(-0.69)	(-1.26)	(-0.04)
dlog(HH)$_{it-1}$	0.338***	0.254**	0.326**	0.681***	0.280**	0.299**	0.327***	0.307
	(3.01)	(2.46)	(2.58)	(2.86)	(2.63)	(2.63)	(3.13)	(1.40)
JTP_{ct-1}	0.443***	0.403***	0.371***	0.283**	0.423***	0.387***	0.396***	0.456***
	(11.81)	(11.51)	(7.42)	(2.25)	(11.79)	(7.84)	(9.01)	(5.99)
dlog(GRDP)$_{ct-1}$	-0.010*	-0.016**	-0.008	-0.000	-0.018***	-0.016**	-0.004	-0.025**
	(-1.76)	(-2.37)	(-1.41)	(-0.00)	(-2.72)	(-2.51)	(-0.57)	(-2.23)
dlog(SUPPLY)$_{it-1}$	-0.001***	-0.001*	-0.000	-0.002	-0.001**	-0.000	-0.001*	0.000
	(-3.42)	(-1.92)	(-0.64)	(-0.86)	(-2.62)	(-0.52)	(-1.95)	(0.23)
$UNSOLD_{it-1}$	-0.313***	-0.166	-0.356**	-0.235	-0.192*	-0.471***	-0.190*	-0.488***
	(-3.39)	(-1.56)	(-2.19)	(-0.42)	(-1.84)	(-5.26)	(-1.93)	(-2.94)
dlog(M2)$_{t-1}$	0.109	0.218	-0.252**	-0.429	0.282**	-0.266*	-0.128	0.466**
	(0.99)	(1.65)	(-2.35)	(-0.88)	(2.15)	(-1.67)	(-1.05)	(2.26)
dlog(GDP)$_{t-1}$	0.594***	0.631***	0.392***	0.148	0.608***	0.315***	0.458***	0.740***
	(9.53)	(9.61)	(5.39)	(0.78)	(9.30)	(3.09)	(5.05)	(4.47)
Observations	3,552	3,514	2,572	984	3,552	3,476	3,552	2,854
Number of district	95	94	68	26	95	93	95	76
CITY*YEAR FE	YES	YES	YES	YES	YES	YES	YES	YES
Adjusted R-squared	0.32	0.26	0.29	0.24	0.30	0.24	0.23	0.24

Table 7: Reverse causality

This table reports the results of regression with district dummies and clustered standard errors at the district level over the period from Q1 2008 to Q4 2017. *i*,*c* and *t* index district, city, and time, respectively. The dependent variable is the demographic variable, YOUTH, ELDERLY and SINGLE: $\text{YOUTH}_{\text{it-1}}$ is the percentage of those aged between 0 and 14; $\text{ELDERLY}_{\text{it-1}}$ is the percentage of those aged over 65; $\text{SINGLE}_{\text{it-1}}$ is the ratio of single-person households. The independent variables are as follows: $\text{dlog(LTV)}_{\text{it-2}}$ and $\text{dlog(DTI)}_{\text{it-2}}$ are the log changes in the LTV and DTI ratios ; $\text{dMORATE}_{\text{ct-1}}$ is the changes in the mortgage loan interest rates; $\text{dlog(HH)}_{\text{it-1}}$ is the log changes in the number of households; $\text{JTP}_{\text{ct-1}}$ is the Jeonse-to-price ratio; $\text{dlog(GRDP)}_{\text{ct-1}}$ is the log changes in gross regional domestic product; $\text{dlog(SUPPLY)}_{\text{it-1}}$ is the log changes in supply, the number of housing starts and building permits; $\text{UNSOLD}_{\text{t-1}}$ is the ratio of unsold newly-built housing inventory relative to the total number of households; $\text{dlog(M2)}_{\text{t-1}}$ is the log changes in the monetary aggregate M2; $\text{dlog(GDP)}_{\text{t-1}}$ is the log changes in GDP; and $\text{dlog(HPI)}_{\text{it}}$ is the log changes in the real house price index. The t-statistics are in parentheses, and *, ** and *** denote the significance levels of 10%, 5% and 1%, respectively.

VARIABLES	(1) YOUTH	(2) ELDERLY	(3) SINGLE	(4) YOUTH	(5) ELDERLY	(6) SINGLE
dlog(HPI)_{it-1}	0.003	0.004	-0.030***	0.002	0.005	-0.027***
	(0.38)	(0.70)	(-3.84)	(0.26)	(0.90)	(-3.55)
dlog(HPI)_{it-2}				0.017**	-0.018***	-0.044***
				(2.46)	(-3.63)	(-6.80)
dlog(LTV)_{it-2}	-0.001	0.004	0.009*	0.001	0.003	0.005
	(-0.14)	(1.29)	(1.77)	(0.16)	(0.78)	(0.91)
dlog(DTI)_{it-2}	0.001	-0.000	0.004***	0.001*	-0.001*	0.002***
	(0.91)	(-0.78)	(5.51)	(1.76)	(-1.98)	(3.88)
dMORATE_{t-1}	0.081**	-0.092***	0.118***	0.050	-0.060**	0.196***
	(2.35)	(-4.03)	(3.67)	(1.14)	(-2.05)	(5.05)
dlog(HH)_{it-1}	0.103	-0.117**	0.022	0.108	-0.123**	0.009
	(1.18)	(-2.52)	(0.55)	(1.24)	(-2.60)	(0.25)
JTP_{ct-1}	-0.101***	0.096***	0.072***	-0.100***	0.095***	0.069***
	(-9.08)	(16.47)	(9.19)	(-8.91)	(16.17)	(9.37)
dlog(GRDP)_{ct-1}	0.000	-0.003***	-0.002	0.001**	-0.004***	-0.004***
	(0.45)	(-3.68)	(-1.53)	(2.10)	(-5.18)	(-4.11)
$\text{dlog(SUPPLY)}_{it-1}$	-0.000	0.000***	0.000**	-0.000	0.000***	0.000
	(-1.39)	(2.99)	(2.01)	(-1.15)	(2.76)	(1.40)
UNSOLD_{it-1}	-0.126	0.493***	0.479**	-0.124	0.491***	0.475**
	(-0.46)	(3.33)	(2.25)	(-0.45)	(3.30)	(2.22)
dlog(M2)_{t-1}	0.131***	-0.043***	-0.192***	0.127***	-0.039**	-0.182***
	(5.78)	(-2.72)	(-9.90)	(5.40)	(-2.32)	(-9.12)
dlog(GDP)_{t-1}	-0.064***	0.083***	0.021*	-0.066***	0.085***	0.024**
	(-3.10)	(7.00)	(1.73)	(-3.15)	(6.99)	(2.01)
Observations	3,554	3,554	3,574	3,554	3,554	3,574
Number of district	95	95	95	95	95	95
CITY*YEAR FE	YES	YES	YES	YES	YES	YES
Adjusted R-squared	0.84	0.90	0.77	0.84	0.90	0.78

Table 8: Alternative regression method: GMM

This table reports the results of regressions with district dummies and clustered standard errors at the district level over the period from Q1 2008 to Q4 2017. i,c and t index district, city, and time, respectively. The dependent variable is dlog(HPI^j)$_{it}$, the log changes in the real house price index by property types j, j={price-level, dwelling size, and house age}. The independent variables are as follows: $YOUTH_{it-1}$ is the percentage of those aged between 0 and 14; $ELDERLY_{it-1}$ is the percentage of those aged over 65; $SINGLE_{it-1}$ is the ratio of single-person households; dlog(LTV)$_{it-2}$ and dlog(DTI)$_{it-2}$ are the log changes in the LTV and DTI ; $dMORATE_{ct-1}$ is the changes in the mortgage loan interest rates; dlog(HH)$_{it-1}$ is the log changes in the number of households; JTP_{ct-1} is the Jeonse-to-price ratio; dlog(GRDP)$_{ct-1}$ is the log changes in gross regional domestic product; dlog(SUPPLY)$_{it-1}$ is the log changes in supply, the number of housing starts and building permits; $UNSOLD_{t-1}$ is the ratio of unsold newly-built housing inventory relative to the total number of households; dlog(M2)$_{t-1}$ is the log changes in the monetary aggregate M2; and dlog(GDP)$_{t-1}$ is the log changes in GDP. The t-statistics are in parentheses, and *, ** and *** denote the significance levels of 10%, 5% and 1%, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
			PRICE-LEVEL		SIZE		AGE	
VARIABLES	ALL	LOW	MED	HIGH	SMALL	LARGE	NEW	OLD
$YOUTH_{it-1}$	-0.243***	-2.068***	-5.477***	-4.241**	-0.238***	-2.782***	-3.262***	-2.993***
	(-4.23)	(-5.34)	(-5.37)	(-2.43)	(-3.65)	(-5.85)	(-7.43)	(-5.20)
$ELDERLY_{it-1}$	0.386***	2.045***	2.281***	1.590	0.397***	2.497***	2.570***	3.007***
	(6.95)	(6.46)	(3.08)	(1.56)	(5.36)	(5.42)	(6.40)	(5.87)
$SINGLE_{it-1}$	-0.303***	-1.800***	-1.028*	0.124	-0.345***	-1.643***	-1.776***	-2.387***
	(-4.88)	(-4.17)	(-1.74)	(0.08)	(-5.59)	(-3.08)	(-3.67)	(-3.40)
dlog(LTV)$_{it-2}$	0.128***	0.087***	-0.014	-0.069	0.068***	0.018	0.052**	0.018
	(5.53)	(4.40)	(-0.56)	(-1.35)	(3.24)	(0.64)	(2.59)	(0.39)
dlog(DTI)$_{it-2}$	0.030***	0.043***	0.031***	0.024***	0.029***	0.036***	0.036***	0.037***
	(7.43)	(8.11)	(3.37)	(2.85)	(7.81)	(4.24)	(6.76)	(4.20)
dlog(HH)$_{it-1}$	0.122	0.063	0.660***	1.017***	0.138	0.434	0.363**	0.436
	(1.63)	(0.53)	(4.70)	(2.90)	(1.55)	(1.63)	(2.55)	(1.43)
JTP_{ct-1}	0.424***	0.013	-0.547***	-0.223	0.363***	-0.193*	-0.241***	-0.139
	(11.67)	(0.16)	(-3.62)	(-1.41)	(11.33)	(-1.98)	(-2.77)	(-1.01)
dlog(GRDP)$_{ct-1}$	-0.029***	-0.007	0.005	0.012	-0.033***	-0.014	0.000	-0.005
	(-3.90)	(-0.65)	(0.29)	(0.57)	(-4.19)	(-1.26)	(0.01)	(-0.35)
dlog(SUPPLY)$_{it-1}$	-0.002***	-0.005***	-0.002*	-0.003*	-0.002***	-0.003***	-0.004***	-0.005***
	(-6.09)	(-7.26)	(-1.96)	(-1.96)	(-3.66)	(-2.95)	(-6.06)	(-4.18)
$UNSOLD_{it-1}$	-0.437***	-0.808	-0.037	1.640	-0.375***	0.119	-0.215	0.602
	(-4.63)	(-0.92)	(-0.05)	(0.86)	(-2.84)	(0.11)	(-0.28)	(0.31)
$dMORATE_{t-1}$	-0.496	0.525*	0.416	-1.164	-0.107	0.329	-0.086	-0.097
	(-1.36)	(1.86)	(0.53)	(-1.39)	(-0.31)	(0.71)	(-0.26)	(-0.16)
dlog(M2)$_{t-1}$	0.086	0.607***	0.286	-0.090	0.250*	0.002	0.013	0.056
	(0.58)	(3.35)	(1.27)	(-0.20)	(1.76)	(0.01)	(0.11)	(0.23)
dlog(GDP)$_{t-1}$	0.360***	0.342***	-0.175**	-0.297	0.396***	-0.043	-0.011	0.119
	(3.76)	(4.23)	(-2.05)	(-1.21)	(4.39)	(-0.29)	(-0.11)	(0.51)
dlog(HPI)$_{it-1}$	0.316***	0.130*	-0.060	0.046	0.178***	0.155	0.189***	0.194**
	(5.53)	(1.97)	(-0.28)	(0.46)	(2.76)	(1.53)	(3.05)	(2.54)
Observations	3,440	3,403	2,498	956	3,440	3,366	3,440	2,761
Number of district	95	94	68	26	95	93	95	76
P-value AR(1)	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
P-value AR(2)	0.223	0.079	0.117	0.316	0.133	0.522	0.306	0.486
CITY*YEAR FE	YES	YES	YES	YES	YES	YES	YES	YES

Appendix

Appendix A. Variable description

Variables	Comment	Data source
House price index: *dlog(HPI)*	Log changes in the real house price index, Log changes in the real house price indexes based on property types such as house price level (high (above 600 million KRW), medium (between 300 million KRW and 600 million KRW), low (below 300 million KRW)), dwelling size (large (greater than 85m2), small (smaller than 85m)), and age of house stock (new (below 10 years), medium (between 10 and 20 years), old (over 20 years))	Authors' calculation
Macroprudential policy measures : *dlog(LTV), dlog(DTI)*	Log changes in the LTV: the limit of loan-to-value ratio, Log changes in DTI: the limit of debt-to income ratio	Authors' calculation
Real disposable income: *dlog(GRDP)*	Log change in gross regional domestic product	Statistics of Korea
Mortgage rate: *dMORATE*	The changes in mortgage rate	Bank of Korea
Jeonse-to-Price ratio: *JTP*	The ratio of Jeonse price to house price	Bank of Korea
Household : *dlog(HH)*	log changes in the number of households	Ministry of the Interior and Safety
Dependency ratio: *DEPENDENCY*	The percentage of those aged between 0 and 14 and over 65 among the total population	Ministry of the Interior and Safety
Youth dependency ratio: *YOUTH*	The percentage of those aged between 0 and 14 among the total population	Ministry of the Interior and Safety
Elderly dependency ratio: *ELDERLY*	The percentage of those aged over 65	Ministry of the Interior and Safety
Single-person household: *SINGLE*	The percentage of single-person households	Ministry of the Interior and Safety
Supply: *SUPPLY*	Log changes in supply, which is the number of housing starts and building permits	Korea Appraisal Board
Unsold: *UNSOLD*	The ratio of unsold newly-built housing inventory relative to total number of households	Real Estate 114
Monetary aggregate: *dlog(M2)*	Log changes in M2	Bank of Korea
GDP: *dlog(GDP)*	Log changes in GDP	Bank of Korea

Appendix B. Constructing house price indexes

Using this real transaction data, we construct quarterly house price indexes based on the standard Case and Shiller (1987) repeat sales methodology at the district-level by normalizing the index so that the year 2010 has a value of 100. The sample for the repeat sales methodology includes trading which occurs at least once for the same housing unit. We treat apartments, located on the same floor, in the same building and of the same size to be the same units. We compute price changes between two arms-length sales of the same home, and construct the housing price index, using the robust interval and value-weighted arithmetic repeat sales indices (Robust IVWARS). We further construct a variety of house price indexes by property types, such as the price of the property, age, and dwelling size, applying the Case and Shiller methodology, as well. More specifically, we classify the transaction data into the following seven sub-groups: three groups based on house value [low-tier (below KRW 300 million), medium-tier (KRW 300-600 million) and high-tier (over KRW 600 million)], two groups based on dwelling sizes [small (below $85m^2$/915 sq.ft) and large (above $85m^2$)], and then two groups based on housing unit ages [new (below 10 years), and old (20-30 years)]. Each portfolio is formed based on criteria where the initial transactions were included. We do not rebalance portfolios every transaction because the Case and Shiller methodology requires a pair of sales of housing transactions for the same unit. That is, only houses with more than one transaction are included in our sample for estimating the house price indexes. More detail about our methodology can be found in Case and Shiller (1987).

Appendix C. Computing macroprudential policy measures

We quantify the strengths of macroprudential policies concerning the limits on loan-to-value (LTV) ratios and debt-to-income (DTI) ratios based on application ranges and areas. Since the introduction of LTV and DTI regulations in 2002 and 2005, respectively, the policies have been actively implemented in a very complicated manner. Detailed timelines of the implementation of macroprudential policies are shown in panels A and B of Appendix C. These indicate that the coverage of district is different depending on the time when the regulations are implemented. Furthermore, the regulations are applied differently at the district or neighborhood level based on the following six criteria: 1) an index for districts designated as speculative zones or overheated speculative prone zones; 2) the ratio of mortgage loan maturity; 3) the ratio of bank and non-banking institutions at the city-level; 4) the ratio of loans installments and straight loans at the national level; 5) the percentage of the apartments based on house prices, i.e., below 300 million KRW, between 300 and 600 million KRW, over 600 million KRW; and 6) the percentage of apartments below public apartment size. To compute the LTV and DTI ratio at the district-level, we first collect information on LTV and DTI limits under six categories. We then estimate the district-level LTV and DTI limits by multiplying the ratio or index with the LTV and DTI levels for each district and category and averaging them. We put the limits as 100 to be for districts where regulations have not been implemented.

Panel A. Changes in LTV regulations

Event Date	Description	No.of Dist.	Range of Application	Direction
200801	Designate speculative zones	4		Loosening
200811	Remove speculative zones	50	All financial institutions	Loosening
200907	Lower LTV ratio limit for Seoul metropolitan area (60%→ 50%)	3	Banks	Tightening
201205	Remove speculative zones	3		Loosening
201408	Raise LTV limit ratio	68	All financial institutions	Loosening
201611	Designate adjustment target zones	37		Tightening
201706	Lower LTV limit ratio		All financial institutions	Tightening
	Designate adjustment target zones	40		
201708	Designate speculative zones	27		

Panel B. Changes in DTI regulations

Event Date	Description	No. of Dist.	Range of Application	Direction
200801	Remove speculative zones	3		Loosening
200811	Remove speculative zones	58		Loosening
200909	Expand DTI regulated areas to non-speculative zones in Seoul metropolitan area	61		Tightening
201009	Raise DTI limit ratio	61		Loosening
201104	Lower DTI limit ratio	61		Tightening
201205	Remove speculative zones	3		Loosening
201408	Raise DTI limit ratio	25	All financial institutions	Loosening
201706	Lower DTI limit ratio		All financial institutions	Tightening

Previous volumes in this series

913 December 2020	Forecasting expected and unexpected losses	Mikael Juselius and Nikola Tarashev
912 December 2020	Regulatory capital, market capital and risk taking in international bank lending	Stefan Avdjiev and Jose Maria Serena
911 December 2020	Bilateral international investments: The Big Sur?	Fernando Broner, Tatiana Didier, Sergio L Schmukler and Goetz von Peter
910 December 2020	Recessions and mortality: a global perspective	Sebastian Doerr and Boris Hofmann
909 December 2020	Dealing with bank distress: Insights from a comprehensive database	Konrad Adler and Frederic Boissay
908 December 2020	Contagion Accounting	Iñaki Aldasoro, Anne-Caroline Hüser and Christoffer Kok
907 December 2020	Low price-to-book ratios and bank dividend payout policies	Leonardo Gambacorta, Tommaso Oliviero and Hyun Song Shin
906 November 2020	What share for gold? On the interaction of gold and foreign exchange reserve returns	Omar Zulaica
905 November 2020	Stablecoins: risks, potential and regulation	Douglas Arner, Raphael Auer and Jon Frost
904 November 2020	Housing booms, reallocation and productivity	Sebastian Doerr
903 November 2020	Bargaining power and the Phillips curve: a micro-macro analysis	Marco J Lombardi, Marianna Riggi and Eliana Viviano
902 November 2020	An early stablecoin? The Bank of Amsterdam and the governance of money	Jon Frost, Hyun Song Shin and Peter Wierts
901 November 2020	Inside the regulatory sandbox: effects on fintech funding	Giulio Cornelli, Sebastian Doerr, Leonardo Gambacorta and Ouarda Merrouche
900 November 2020	What can commercial property performance reveal about bank valuations?	Emanuel Kohlscheen and Előd Takáts

All volumes are available on our website www.bis.org.