The impact of macroprudential policy on inequality and implications for inclusive financial stability

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Abstract: A loan-to-value ratio (LTV) ceiling is a macroprudential policy that limits households' mortgage borrowing to a fraction of the value of a house. Our empirical evidence suggests that LTV ceilings have a significant impact on widening household wealth inequality. Using South Korean survey data from 9,844 households over the 2017-2019 period and a regression discontinuity design (RDD), we estimate that the tightening of the LTV ceiling by 10 percentage points reduced the average log net worth of the poorest quintile of households by 1.3 (a -73% change in net worth) over two years relative to the control households. Meanwhile, the measure did not affect the net worth of wealthier households.

Keywords: macroprudential policy, wealth inequality, household finance, inclusive financial stability, regression discontinuity design

JEL Classification Codes: G28, G51, E61, F65

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1. Introduction

In the aftermath of the financial crisis in 2008, policymakers in both advanced and developing economies adopted unprecedented measures to prevent future bubbles and meltdowns. One prominent class of such measures, macroprudential regulation, aims to maintain the general health of the financial system. Macroprudential regulation includes ceilings on loan-to-value (LTV) and debt-to-income (DTI) ratios for households (Galati and Moessner, 2013; Claessens, 2015; Kahou and Lehar, 2017). Under an LTV ratio ceiling, individuals may only take out mortgage loans up to a fixed proportion of the value of their houses. Under a DTI ratio ceiling, their repayments cannot be larger than a given proportion of their incomes.[1] These measures serve to reduce the number of nonperforming loans that are granted to households and to mitigate systemic risk.

Despite the possible benefits of these macroprudential measures, their costs have given rise to concerns. For example, measures of this kind may impose borrowing constraints on poor households, for whom housing is a key to wealth accumulation (Frost and van Stralen, 2018; Carpantier et al., 2018). Since more affluent investors are less likely to be affected by the constraints in question, the measures may widen the wealth gap.[2]

Motivated by these concerns, we examine the impact of macroprudential policies on wealth inequality between households.[3] We find empirical evidence that suggests that the LTV ceiling has a significant negative impact on the wealth of low-net-worth households. Using South Korean survey data from 9,844 households over the 2017-

[1] Both loan-to-value (LTV) ratio and debt-to-income (DTI) ratio ceilings directly limit borrowing. Other measures, such as those implemented through Basel III Standards since first announced in 2011, do so by placing restrictions on banks' balance sheets. One example, the *countercyclical capital buffer*, is an additional equity capital requirement levied uniformly to banks' risky assets during distressed periods.
[2] We illustrate this point formally in the Online Appendix. In a two-period model, households with different sizes of assets invest in houses while being constrained by their labor income and asset returns. LTV ratio regulation in this setting decreases the equilibrium value of assets in the second period. This negative impact is smaller for wealthier investors, worsening the wealth inequality.
[3] While income (flow) and wealth (stock) inequality are related, we focus on the latter for a few reasons. First, by design, borrowing constraints impact households' balance sheets more directly than their income and expenses. Moreover, wealth inequality is more severe than income inequality in most countries (Dabla-Norris et al., 2015). Finally, although measuring the impact on wealth inequality is often difficult due to limited data availability, it is possible in our study because our dataset contains households' detailed balance sheets.

2019 period, we estimate that reducing the LTV ceiling from 50% to 40% caused the average log net worth of the poorest-quintile households to decrease by 1.3 (a -73% change in net worth) over two years relative to the control households. Specifically, the log net worth of poorest-quintile households that were subject to the looser (higher) ceiling grew by approximately 0.9 on average, while that of households that were subject to the stricter (lower) ceiling shrank by 0.4. The impact of the change on the log net worth of other households is statistically indistinguishable from 0.

One channel that may explain this large negative impact is that the stricter LTV ceiling directly reduced the ability of the bottom-quintile households to purchase houses at the precise time when those households stood to gain the most from borrowing. In our sample, the bottom-quintile households in 2017 had the smallest wealth, the lowest share of homeowners (23%, compared to 88% overall), and the highest proportion of Seoul Metropolitan Area residents (48%, compared to 35% overall). Meanwhile, the two years that followed the tightening of the LTV ceiling coincided with a steep increase in house prices in Seoul (38%), the Seoul Metropolitan Area (26%), and South Korea as a whole (20%). Since house prices in Seoul and its surrounding area rose rapidly, it is plausible that the reduced ability of the poorest-quintile households to acquire homes in those localities severely inhibited their capability to gain wealth. This channel suggests that the impact of stricter LTV ceilings on households may depend crucially on the concurrent movement of house prices. The sign of the impact of stricter LTV ceilings may be reversed in a period of declining house prices.

To identify the causal effects of the LTV ceiling, we exploit the sharp discontinuity in government policy that was based on income levels. The South Korean government announced a new rule in August 2017 that imposed an LTV ceiling of 40% on mortgages granted to households, with exceptions for those whose incomes fell below certain thresholds. Households with annual incomes of less than 70 million Korean won (KRW; approximately USD 58,300) had to comply with an LTV ratio of 50% rather than 40%. In effect, the South Korean government applied an LTV ceiling that was stricter (lower) by 10 percentage points to households above the cutoffs. Those income-level cutoffs were unprecedented and unexpected, which makes the setup suitable for a regression discontinuity design (RDD).

We describe our contribution to the existing literature on macroprudential policy,

wealth inequality, and financial stability in Section 2. We then present the empirical evidence on the impact of macroprudential policy on wealth inequality in Section 3 before concluding in Section 4.

2. Macroprudential policy, wealth inequality, and financial stability

We contribute to the literature by providing an estimate of the impact of macroprudential policies on inequality, for which the evidence remains scarce and insufficient (Colciago et al., 2019). To date, there have been two relevant studies on the impact of LTV ceilings. First, Frost and van Stralen (2018) run panel regressions for 69 countries over the 2000-2013 period and find that the use of tighter (lower) LTV ceilings is associated with greater inequality in disposable income. Second, Carpantier et al. (2018) examine cross-sectional household survey data from 12 Eurozone countries in 2010 and find that households with higher LTV ratios have larger marginal contributions to wealth inequality. Given the absence of exogenous changes in the LTV ceilings, the authors of both papers acknowledge that identifying causal relationships is beyond their scope. In our work, in contrast, the discontinuity in South Korean LTV ceilings enables the identification of the causal effect of macroprudential policy on inequality, under the continuity assumption of a regression discontinuity design (RDD)[4].

Since LTV ceilings impose restrictions on household borrowing directly, our findings are also related to the literature on the impact of access to credit. The extant literature finds that the impact of access to small loans, such as payday loans, is mixed. Karlan and Zinman (2010) run a field experiment of payday loan applications that are approved at random. They find that expanding access to credit improves outcomes, such as employment and income, for borrowers. Zinman (2010) uses household survey data and a restriction on access to credit in Oregon from 2007. The restriction was found to be associated with a deterioration in the financial condition of households. In direct contrast with these studies, Melzer (2011) finds no evidence of payday loans alleviating economic hardship among low-income households. Unlike these studies, which focus on small, high-risk, and unsecured loans, our work

[4] We discuss the details of the discontinuity and the empirical design in Subsections 3.2 and 3.3.

provides evidence of the impact of restricting access to substantial secured credit in the form of mortgages. In this sense, our findings also add to the voluminous body of literature on finance and inequality, in which it is argued that financial development helps reduce inequality by expanding access to credit (Beck et al., 2007; Claessens and Perotti, 2007; Demirgüç-Kunt and Levine, 2009; Ang, 2010; Arora, 2012; Choudhary and Jain, 2017; Čihák and Sahay, 2020).

Assessing the impact of macroprudential policy on income and wealth inequality is important because rising inequality may affect financial stability. Rajan (2010), for example, argues that rising inequality led to a credit boom and eventually to the financial crisis in the United States. Meanwhile, drawing on a panel dataset that covers 14 advanced national economies over the 1920-2000 period, Bordo and Meissner (2012) find little evidence that income inequality leads to credit booms and financial instability. Instead, they argue that low interest rates and economic booms are the leading causes of crises. Kiyotaki and MoorFe (1997) show theoretically that temporary income shocks can cause persistent fluctuations in output and asset prices. This outcome may be observed when asset prices and credit limits interact because households use durable assets for production and as collateral.

Similarly, Kumhof, Ranciere, and Winant (2015) argue that significant crises, such as the Great Depression in the early 20th century and the Great Recession of 2008, were preceded by deepening income and wealth inequality and growing household debt. Using simulations from a calibrated model, they suggest that the rising income shares of affluent households (the top 5%) cause higher debt leverage among poor and middle-income households, eventually leaving them more vulnerable to financial crises. Due to their stronger preference for financial wealth, high-income households lend part of their additional income to poor and middle-income households. The expansion of the credit supply allows poor and middle-income households to sustain high consumption levels by borrowing, which increases the likelihood of a financial crisis.

In a related strand of the empirical literature, Perugini et al. (2016) use a panel dataset that covers 18 developed economies over the 1970-2007 period and find that income equality as measured by the top 1% income share has statistically significant positive effects on the size of credit relative to output. Hauner (2020) estimates a linear probability model with panel data for nine countries for the 1875-2014 period.

He reports that the probability of a financial crisis increases significantly as the share of the top 1% of wealth owners increases in step with the aggregate national wealth. Bazillier and Hericourt (2017) survey this literature that finds a strong relationship between inequality and credit. Furthermore, drawing on the United States data for the period between 1976 and 2006 and difference-in-differences estimation, Beck, Levine, and Levkov (2010) argue that bank deregulation and the elimination of restrictions on interstate branching narrowed the income gap by increasing relative wage rates and the working hours of unskilled workers. After examining data from 17 advanced economies for the top 1% and 10% income shares, total factor productivity, and financial crises between 1870 and 2013, Paul (2020) demonstrates that rising income inequality and low productivity growth are strong predictors of financial crises.

Building on this literature on inequality and its relationship to financial instability, Mitkov (2020) studies a model in which banks, a benevolent policymaker, and households of varying wealth decide on a deposit insurance policy to maximize the combined utility of households. He shows that, in equilibrium, the policymaker provides full insurance to poor households if their wealth is below a certain cutoff and only partial insurance to wealthier households. Thus, agents who hold wealth in excess of the cutoff have incentives to panic, which may precipitate bank runs and speculative behaviors that amplify financial crises. Therefore, growing inequality, which pushes more agents above the cutoff, is liable to cause the financial system to become fragile. In a similar context, Punzi and Rabitsch (2018), who use a DSGE model that features housing and mortgage markets, argue that wealthier speculative investors play a leading role in destabilizing the financial system. Observing that bank risks are higher in US regions with higher income inequality, Mitkov and Schuwer (2020) show that banks' endogenous shifting of risk into regions with greater inequality magnifies the risks in the sector.

Mian, Straub, and Sufi (2021), in their notable study, assume a non-homothetic utility function whereby savers have a lower marginal propensity to consume than borrowers. They demonstrate that, in this setup, rising inequality can result in both falling interest rates and the growing household debt that typified the recent financial crisis. In comparison, our paper is premised on a model (in the Online Appendix) whereby borrowers and savers differ in endowments rather than preferences, and we

show that the macroprudential policy restricting the loan-to-value ratio may widen the wealth gap.

Finally, our work fits into the rapidly developing literature on the general impact of macroprudential policies. Many recent studies examine extensive country-level panel data. The most comprehensive study to date is that by Alam et al. (2019). They use data from 134 countries over the 1990-2016 period and find that macroprudential instruments that target loans impact household credit significantly while exerting a milder impact on consumption. Cerutti et al. (2016) show that macroprudential policies can reduce credit expansion effectively. They draw on panel data from 119 countries over the 2000-2013 period. They find that macroprudential policies are less effective in countries that are more open and financially developed and in states whose financial markets are undergoing stress or crises. After examining data for 57 countries that cover 30 years, Kutter and Shim (2013) demonstrate that the supply of credit, especially of mortgages, is highly sensitive to LTV ceilings. Using data from 28 European Union countries for the 1990-2018 period, Poghosyan (2019) finds that lending restrictions, such as LTV ceilings, reduce house prices and credit growth. However, Arena et al. (2020) do not find significant evidence that such macroprudential policies cause house prices to fall or dampen credit growth in the European Union. Other studies use household-level survey data (Ampudia et al., 2016; Allen et al., 2020), loan-level data (de Araujo et al. 2020; Gambacorta and Murcia, 2020; Gómez et al., 2020), or quantitative macroeconomic models (Kiyotaki et al., 2021; Rubio and Unsal, 2020) to answer the same questions. The most recent survey of the literature is by Galati and Moessner (2018).

3. The impact of macroprudential policies on wealth inequality

3.1 Data

We use South Korean data from *the Survey of Household Finances and Living Conditions* that covers 9,844 households and the period between 2017 and 2019. Collected annually at the end of the first quarter of the year by Statistics Korea, Bank of Korea, and the Financial Supervisory Service, it surveys a rotating panel of 20,000 households. The survey focuses on financial and living conditions, including household assets, liabilities, incomes, and expenses. The survey's sample of households is selected so

Table 1. Summary Statistics of Household Finances in Year 0

Variable	Mean	SD	Percentile				
			0%	25%	50%	75%	100%
Panel A: Full sample							
Assets	373.3	581.1	0.0	80.3	218.3	450.1	16054.8
Financial	92.6	182.4	0.0	12.5	44.6	107.5	8080.0
Real estate	262.9	478.4	0.0	0.0	140.0	320.0	14600.0
Other real assets	17.8	50.5	0.0	0.0	5.4	18.0	1613.0
Liabilities	60.0	174.5	0.0	0.0	4.1	57.0	7400.0
Unsecured credit debt	5.0	23.1	0.0	0.0	0.0	0.0	610.0
Mortgage debt	32.2	125.2	0.0	0.0	0.0	16.0	6900.0
Other debt	22.8	85.4	0.0	0.0	0.0	5.6	2700.0
Net worth	313.3	485.8	0.0	65.2	181.5	379.3	9594.0
Annual Income	51.0	49.1	0.0	18.2	39.1	67.8	821.1
Loan-to-value ratio (%)	8.3	17.1	0.0	0.0	0.0	6.7	100.0
Panel B: Subsample							
Assets	468.8	425.0	2.9	217.3	350.9	566.4	3978.8
Financial	116.4	131.6	0.1	36.6	76.9	148.2	1501.8
Real estate	327.8	375.2	0.0	120.0	230.0	400.0	3400.0
Other real assets	24.6	46.1	0.0	5.4	13.0	26.1	715.0
Liabilities	82.8	141.5	0.0	0.0	30.0	102.2	1520.0
Unsecured credit debt	7.2	23.9	0.0	0.0	0.0	0.0	380.0
Mortgage debt	46.4	91.5	0.0	0.0	0.0	60.0	950.0
Other debt	29.2	82.3	0.0	0.0	0.0	12.8	1300.0
Net worth	386.0	371.9	0.3	170.6	284.9	468.6	3956.8
Annual Income	69.1	10.6	52.0	60.2	68.0	78.1	97.9
Loan-to-value ratio (%)	13.3	20.0	0.0	0.0	0.0	22.9	100.0

Note: This table shows the summary statistics of South Korean households' balance sheets and annual income reported in 2017 in the *Survey of Household Finances and Living Conditions*. The unit is a million South Korean won (KRW). A *loan-to-value ratio* is the size of a household's mortgage debt relative to the value of its real estate assets. Panel A is for the full sample of 9,844 households that had a positive net worth in 2017 (Year 0) and 2019 (Year 2). Panel B is for the subsample of 1,987 households. The subsample consists of (a) households whose annual income is between 52 and 88 million South Korean won (KRW) and have nonzero real estate assets, and (b) households whose annual income is between 62 and 98 million KRW and have zero real estate assets.

that it is representative of the entire South Korean population of about 20 million households. Each observation represents between 100 and 3,000 actual households, with an average of 1,000. There are 10,251 households present in the data in all three years between 2017 and 2019. Among these, 9,844 households have positive net worth in 2017 and 2019. To focus on the relative changes in household wealth in this period,

we select this group of households as our full sample.[5] We refer to years 2017, 2018, and 2019 as Year 0, Year 1, and Year 2, respectively.

Among the household finance variables in the survey, the two that are most important to our ends are (a) net worth and (b) annual income. Net worth in Year 1 and net worth in Year 2 are the primary dependent variables through which we assess the impact of the LTV ceilings on households. Annual income in Year 0 is the *running variable* of our RDD: the treatment, that is, the stricter LTV ceiling, depends on whether this variable is below or above a cutoff. The variable captures all income, be it from labor, business, property, or transfer payments, that was generated in 2016. Furthermore, we include additional balance-sheet variables, such as total outstanding assets, financial assets, real estate assets, unsecured credit loans, and mortgage loans.

Panel A of Table 1 reports the summary statistics of these variables as of Year 0. Its unit is a million Korean won (KRW), or 833 US dollars (USD) at an exchange rate of 1,200 won for the dollar. In rough terms, the median Korean household in our full sample earns an annual income of 39.1 million KRW (USD 32,600) and has total assets of 218.3 million KRW (USD 181,900). On average, 70% of the total assets are in the form of real estate. The median household has a total debt of 4.1 million KRW (USD 3,400) and a net worth of 181.5 million KRW (USD 151,300). While mortgages account for more than half of all household liabilities, they are concentrated in less than half of the households. The median household does not have any mortgages. The 75th percentile of household mortgage debt relative to real estate assets (that is, the LTV ratio) stands at 5.6%

Panel B of Table 1 shows the same summary statistics for a subsample of 1,987 households used in our regression discontinuity design. The subsample consists of (a)

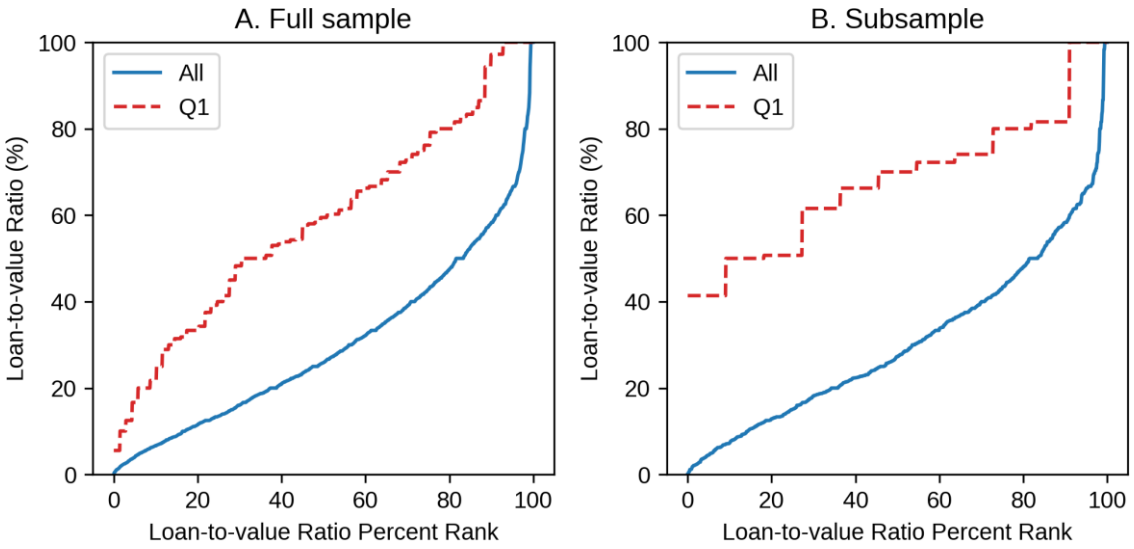
[5] Although we focus on the relative changes in household wealth, it may be important to estimate the effects of the LTV ceiling for households with both non-positive and positive net worth, for two reasons. First, households with non-positive net worth consist of a significant portion (about 4%) of all households, as there are 407 such households out of total 10,251. Second, because the loan-to-value ratio ceiling affects households' future wealth by restricting their debt, excluding households with large debt relative to their assets may lead to biased estimates of the effect of a stricter ceiling. For these reasons, we also estimate the effects of a stricter LTV ceiling on the *absolute* changes in household net worth, using a sample that includes households with non-positive net worth, in Subsection 3.4. For completeness, we include the summary statistics that include those households in the Online Appendix Tables B.1-B.4.

Table 2. Household Income, Wealth, and Mortgages in Year 0

Statistic	Net worth quintile in Year 0					All
	Bottom (poorest)	Second	Middle	Fourth	Top (wealthiest)	
Panel A: Full sample						
Observations	1,854	2,186	2,032	1,900	1,872	9,844
Mean annual income	20.8	33.5	45.9	60.9	96.7	51.0
Mean net worth	16.5	85.0	189.4	346.2	975.0	313.3
Mean real estate assets	6.3	67.1	154.7	289.9	836.0	262.9
% with real estate assets > 0	15.7	63.5	87.3	95.6	98.0	72.2
Mean mortgage debt	2.2	17.6	27.8	34.9	81.0	32.2
% with mortgage debt > 0	3.7	24.9	36.6	37.2	36.1	27.8
Mean loan-to-value ratio (LTV) among those with positive mortgage	58.5	41.5	32.4	24.3	20.8	29.9
% with LTV						
≥ 40%	75.4	52.1	34.1	16.9	13.9	29.3
≥ 50%	69.6	38.0	19.7	8.4	6.7	18.4
≥ 60%	49.3	21.8	6.6	3.3	3.1	9.0
≥ 70%	34.8	8.1	1.7	1.0	1.0	3.5
≥ 80%	23.2	4.2	1.2	0.6	0.6	2.0
≥ 90%	11.6	1.1	0.7	0.3	0.4	0.9
Panel B: Subsample						
Observations	65	274	537	624	487	1,987
Mean annual income	70.6	68.1	67.9	69.5	70.2	69.1
Mean net worth	25.1	93.5	193.7	349.1	858.0	386.0
Mean real estate assets	22.4	95.9	158.1	291.3	733.1	327.8
% with real estate assets > 0	23.1	69.7	87.2	95.5	97.3	87.8
Mean mortgage debt	15.8	40.9	39.7	43.6	64.7	46.4
% with mortgage debt > 0	16.9	43.8	50.8	45.2	35.3	43.2
Mean loan-to-value ratio (LTV) among those with positive mortgage	68.0	49.8	33.0	25.3	20.7	30.8
% with LTV						
≥ 40%	100.0	69.2	34.8	17.4	11.6	30.1
≥ 50%	90.9	51.7	19.4	7.8	7.0	18.5
≥ 60%	72.7	34.2	5.9	3.2	2.3	9.1
≥ 70%	54.5	12.5	0.7	0.4	1.2	3.0
≥ 80%	27.3	8.3	0.7	0.4	0.0	1.9
≥ 90%	9.1	4.2	0.4	0.4	0.0	0.9

Note: This table shows the summary statistics of South Korean households' income, wealth, and mortgages in 2017 in the *Survey of Household Finances and Living Conditions*. The unit for mean values is a million South Korean won (KRW). A *loan-to-value ratio* is the size of a household's mortgage debt relative to the value of its real estate assets. Panel A is for the full sample of 9,844 households that had a positive net worth in 2017 (Year 0) and 2019 (Year 2). Panel B is for the subsample of 1,987 households. The subsample consists of (a) households whose annual income is between 52 and 88 million South Korean won (KRW) and have nonzero real estate assets, and (b) households whose annual income is between 62 and 98 million KRW and have zero real estate assets.

Figure 1. Distribution of the Loan-to-value Ratio across Households in Year 0



Note: This figure shows the percentile values of South Korean households' loan-to-value ratios in Year 0, among households with positive outstanding mortgage debt. A household's loan-to-value ratio is the size of its mortgage debt relative to its real estate assets. "Q1" refers to the households in the bottom quintile (0-20%) of net worth in the whole population of households in Year 0. Panel A is for the full sample of 9,844 households that had a positive net worth in 2017 (Year 0) and 2019 (Year 2). Panel B is for the subsample of 1,987 households. The subsample consists of (a) households whose annual income is between 52 and 88 million South Korean won (KRW) and have nonzero real estate assets, and (b) households whose annual income is between 62 and 98 million KRW and have zero real estate assets.

households with nonzero real estate assets and an annual income of between 52 and 88 million KRW and of (b) households with zero real estate assets and an annual income of between 62 and 98 million KRW. [6] We explain the empirical design and the subsample selection in detail in Subsection 3.2 and Subsection 3.3. Since all of the households in the subsample have incomes that are higher than the average for the full sample (50 million KRW), it is not surprising that, on average, they have more assets, larger debts, and higher net worth. They are also more leveraged, with higher average LTV ratios than households in the full sample.

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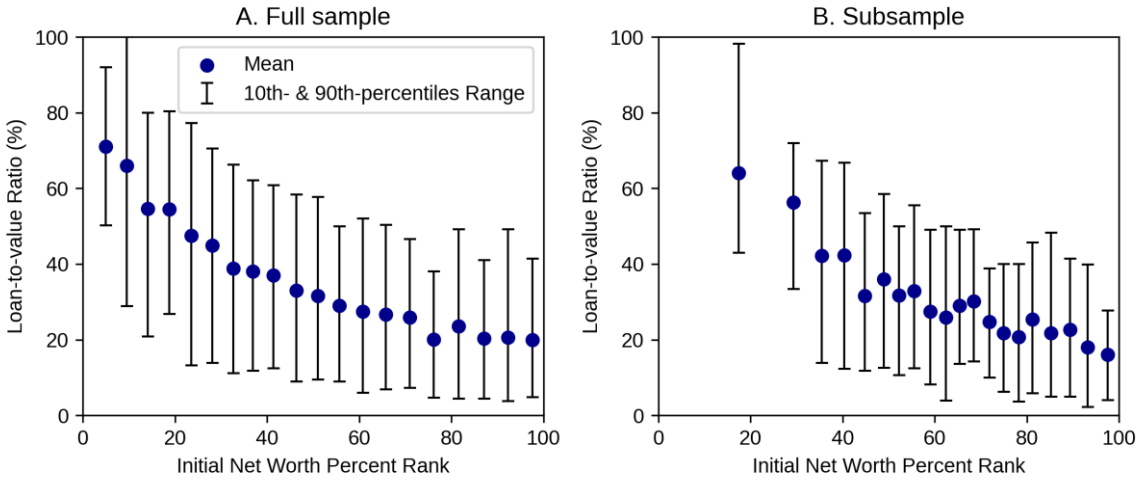
Table 2 displays Year-0 incomes, wealth, and mortgages in more detail for each quintile of households by net worth. The five quintiles, included in the original survey

[6] There are 2,025 households that meet these two conditions, out of 10,251 households that are present in all three years of data. Among them, 1,987 households have positive net worth in Year 0 and Year 2.

Figure 2. Initial Net Worth and the Distribution of Loan-to-value Ratios



Note: This figure shows the binned scatter plots of households' loan-to-value ratios in Year 0, among households with positive outstanding mortgage debt. Each dot and error bar indicate each mean and the 10th-to-90th percentile range of the loan-to-value ratios of the households in the corresponding bin. The bins are equally spaced across households with different initial net worth. The x-axis, the initial net worth percent rank, is the percent rank in the whole population of households. Panel A is for the full sample of 9,844 households that had a positive net worth in 2017 (Year 0) and 2019 (Year 2). Panel B is for the subsample of 1,987 households. The subsample consists of (a) households whose annual income is between 52 and 88 million South Korean won (KRW) and have nonzero real estate assets, and (b) households whose annual income is between 62 and 98 million KRW and have zero real estate assets.

data, are based on all 20,000 observations in the original survey as of Year 0, weighted by the number of households that each observation represents. We define them as the bottom quintile (0-20%), the second quintile (20-40%), the middle quintile (40-60%), the fourth quintile (60-80%), and the top quintile (80-100%). A cursory examination of the quintiles that are based on initial net worth reveals a striking pattern, in that different shares of households hold real estate. It is evident from Panel A that only 16% of households in the bottom quintile own a home. Most of the wealthier households own real estate. This gap is not significantly smaller in the subsample of higher-income households (Panel B), in which only 23% of the bottom-quintile households own real estate.

Table 2 also shows the share of households with positive outstanding mortgage debt ("mortgagers") and the distribution of the loan-to-value ratios among mortgagers. We see from Panel A that the bottom quintile households have the smallest share of mortgagers, at 4% compared to 28% in all quintiles. However, among

Table 3. Absolute Changes in Household Net Worth

Cumulative change in net worth from Year 0	Net worth quintile in Year 0					All
	Bottom (poorest)	Second	Middle	Fourth	Top (wealthiest)	
Panel A. Full Sample						
Year 1	8.9	15.5	15.3	17.4	43.5	19.9
	(31.8)	(96.7)	(83.3)	(99.8)	(277.3)	(142.6)
	[1,869]	[2,197]	[2,040]	[1,903]	[1,874]	[9,883]
Year 2	19.9	26.9	29.1	39.0	96.2	41.6
	(64.9)	(100.1)	(105.9)	(147.0)	(474.9)	(230.4)
	[1,854]	[2,186]	[2,032]	[1,900]	[1,872]	[9,844]
Panel B. Subsample						
Year 1	30.8	32.2	19.1	17.1	40.8	26.0
	(57.6)	(94.6)	(76.2)	(89.3)	(209.4)	(127.5)
	[64]	[276]	[539]	[625]	[489]	[1,993]
Year 2	49.3	55.8	39.6	44.3	92.9	56.7
	(77.4)	(124.4)	(109.2)	(132.6)	(493.6)	(266.7)
	[65]	[274]	[537]	[624]	[487]	[1987]

Note: This table shows the changes in households' net worth from Year 0 (2017) to Year 1 (2018) and Year 2 (2019). The unit is a million South Korean won (KRW). Net worth quintiles are from the whole population of households in Year 0. Numbers without brackets are mean values. The numbers in parentheses are standard deviations. Numbers in square brackets are the numbers of observations. The subsample consists of (a) households whose annual income is between 52 and 88 million South Korean won (KRW) and have nonzero real estate assets, and (b) households whose annual income is between 62 and 98 million KRW and have zero real estate assets.

the mortgagers, the bottom quintile has the highest loan-to-value ratios. About 75% of the bottom-quintile mortgagers have a somewhat high LTV of 40% or above, whereas only 29% of all mortgagers have such an LTV. About 23% of the bottom-quintile mortgagers have an extremely high LTV of 80% or above, whereas only 2% of all mortgagers have such a high LTV. This concentration of extremely high LTVs in the poorest households is as strong in the subsample (Panel B). The share of mortgagers with extreme LTVs (80% or above) in the bottom quintile is 27%, compared to 8% at most in the other quintiles. Figure 1 illustrates this distribution of LTVs among the bottom-quintile mortgagers and enables comparisons with the other quintiles. Figure 2 also shows that lower-net-worth mortgagers exhibit a higher and wider range of LTVs.

Table 4. Relative Changes in Household Net Worth

Cumulative change in log net worth from Year 0	Net worth quintile in Year 0					All
	Bottom (poorest)	Second	Middle	Fourth	Top (wealthiest)	
Panel A. Full Sample						
Year 1	0.245	0.045	0.022	0.012	0.027	0.068
	(1.102)	(0.531)	(0.392)	(0.314)	(0.223)	(0.600)
	[1,869]	[2,197]	[2,040]	[1,903]	[1,874]	[9,883]
Year 2	0.437	0.064	0.026	0.023	0.041	0.114
	(1.372)	(0.792)	(0.621)	(0.509)	(0.407)	(0.824)
	[1,854]	[2,186]	[2,032]	[1,900]	[1,872]	[9,844]
Panel B. Subsample						
Year 1	0.502	0.181	0.058	0.019	0.018	0.067
	(1.003)	(0.491)	(0.288)	(0.272)	(0.235)	(0.365)
	[64]	[276]	[539]	[625]	[489]	[1,993]
Year 2	0.747	0.298	0.107	0.068	0.028	0.123
	(1.257)	(0.624)	(0.495)	(0.353)	(0.425)	(0.524)
	[65]	[274]	[537]	[624]	[487]	[1,987]

Note: This table shows the changes in households' *log* net worth from Year 0 (2017) to Year 1 (2018) and Year 2 (2019). Numbers without brackets are mean values. Numbers in parentheses are standard deviations. Numbers in square brackets are the numbers of observations. The subsample consists of (a) households whose annual income is between 52 and 88 million South Korean won (KRW) and have nonzero real estate assets, and (b) households whose annual income is between 62 and 98 million KRW and have zero real estate assets.

Since household net worth is our key outcome variable, we report the summary statistics of its absolute and relative changes in Table 3 and Table 4. Table 3 shows the means and the standard deviations of cumulative changes in household net worth from Year 0 to Year 1 and Year 2. Table 4 is the same as Table 3, except that it displays relative changes, that is, *log* net worth rather than net worth. An important takeaway from the two tables is that households that were poorer at the outset (lower net worth in Year 0) made larger relative gains in net worth. For example, the bottom-quintile households in the full sample had an average net worth of 17 million KRW in Year 0 and gained 20 million KRW by Year 2. In comparison, the middle-quintile households in the full sample had an average net worth of 189 million KRW in Year 0 and gained 29 million KRW by Year 2. This tendency is even more pronounced in the subsample—on average, the bottom-quintile households accumulated greater amount of net worth than the middle-quintile households between Year 0 and Year 2.

Table 5. Share of Households by Demographic Groups: Subsample

Demographic Group	Net worth quintile in Year 0					All
	Bottom (poorest)	Second	Middle	Fourth	Top (wealthiest)	
Age						
18-29	4.6	4.4	1.1	0.8	0.0	1.3
30s	20.0	18.6	22.7	16.7	10.3	17.1
40s	30.8	29.2	30.4	34.6	22.0	29.5
50s	32.3	33.6	31.7	27.7	31.0	30.5
60 or above	12.3	14.2	14.2	20.2	36.8	21.5
Sex						
Male	83.1	87.2	89.6	93.4	90.1	90.4
Female	16.9	12.8	10.4	6.6	9.9	9.6
Education						
Elementary school	7.7	6.9	6.3	6.3	3.5	5.7
Middle school	12.3	12.4	7.6	5.8	6.8	7.6
High school	53.8	41.2	38.0	34.9	31.4	36.4
College or further	26.2	39.4	48.0	53.0	58.3	50.2
Household size						
1	4.6	2.9	2.6	2.1	3.7	2.8
2	21.5	18.6	18.8	16.3	27.3	20.2
3-4	58.5	66.8	67.4	69.6	60.2	65.9
5-6	15.4	11.7	11.0	11.5	8.2	10.7
7+	0.0	0.0	0.2	0.5	0.6	0.4
Housing type						
Own housing	18.5	60.2	75.2	86.5	88.1	78.0
Lump-sum deposit rent (*Jeonse*)	24.6	19.0	19.0	10.6	10.3	14.4
Monthly rent	41.5	13.5	3.9	1.6	0.6	4.9
Free housing	15.4	7.3	1.9	1.3	1.0	2.7
Location						
Seoul Metropolitan Area	47.7	33.9	27.7	34.1	42.5	34.9
Other	52.3	66.1	72.3	65.9	57.5	65.1
Employment type						
Regular	52.3	54.7	62.2	58.8	44.1	55.4
Temporary	26.2	15.7	6.7	6.1	4.1	7.8
Self-employed	15.4	24.8	25.1	27.4	35.9	28.1
Unemployed *etc*.	6.2	4.7	6.0	7.7	15.8	8.8
Annual income quintile in Year 0						
Bottom (0-20%)	0.0	0.0	0.0	0.0	0.0	0.0
Second (20-40%)	0.0	0.0	0.0	0.0	0.0	0.0
Middle (40-60%)	3.1	3.6	3.7	2.1	1.4	2.6
Fourth (60-80%)	83.1	85.0	81.4	83.2	81.1	82.4
Top (80-100%)	13.8	11.3	14.9	14.7	17.5	14.9
Observations	65	274	537	624	487	1,987

Note: This table shows the share of households by demographic groups for the subsample of 1,987 households that had a positive net worth in Year 0 and Year 2. The subsample consists of (a) households whose annual income is between 52 and 88 million South Korean won (KRW) and have nonzero real estate assets, and (b) households whose annual income is between 62 and 98 million KRW and have zero real estate assets. *Sex* refers to the sex of the householder. *Lump-sum deposit rent* (or, *Jeonse*) refers to a housing arrangement unique to Korea of having the tenant pay a large one-time deposit returned at the end of the lease. *Free housing* refers to free housing such as that provided by employers.

We also report the demographic characteristics of each initial-net-worth quintile. Table 5 shows the shares of households in the subsample that belong to various ages, sexes, education levels, household sizes, housing types, locations, employment types, and initial-income-quintile categories. It is apparent that the bottom quintile has the largest share of young individuals (between 18 and 29 years old), with 4.6%, and the largest share of single-person households, also at 4.6%. Only 18.5% of the bottom-quintile households were living in homes that they owned; the rest inhabited lump-sum-deposit-rent housing (*Jeonse*),[7] paying monthly rent, or availing themselves of free housing provided by the government or their employers. In contrast, most wealthier households were living in homes that they owned. Notably, the bottom quintile had a higher share of households that were based in the Seoul Metropolitan Area[8] than the other quintiles. These demographic patterns are also present in the full sample (Table A.1), albeit to a lesser degree.

An important limitation of our dataset is that it does not contain any information on the prices, quantitates, locations, or other characteristics of real estate assets—only total value can be observed. This absence of observable portfolio choices limits our ability to provide conclusive evidence on the mechanism that drives our results.

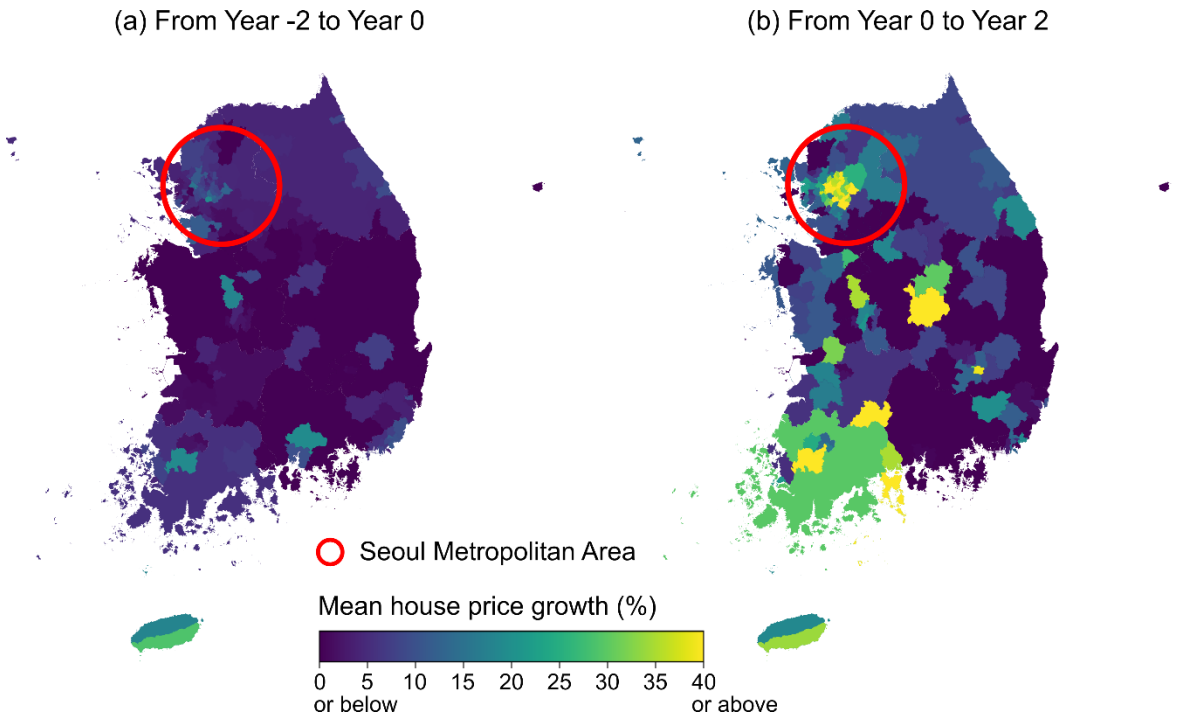
3.2 The South Korean LTV ceiling change of 2017

We exploit a sharp discontinuity in the South Korean LTV ceiling for mortgages in 2017. On August 2, 2017, the Ministry of Land, Infrastructure, and Transport (MOLIT), the Ministry of Economy and Finance (MOEF), and the Financial Services Commission (FSC) jointly announced the new rule, which would come into effect on August 23 of the same year, as part of their *Housing Market Stabilization Plan to Protect Actual Demand and Curb Speculation* ("the 8/2 Plan"). The announcement stipulated that the mortgage LTV ceiling for households would be 40%. In other words, financial

[7] The lump-sum deposit rent (or, *Jeonse*), is a uniquely Korean housing arrangement. Instead of paying regular rent, the tenant pays a one-time deposit typically from 50% to 80% of the house price for a two-year lease; the landlord profits by earning interest on the deposit or investing it elsewhere and pays it back at the end of the lease. This practice arose as an alternative means to finance house purchases when mortgage loans were not widely available in Korea.

[8] Seoul Metropolitan Area includes Seoul, Incheon, and Gyeonggi Province, and has a population of about 25 million. In comparison, South Korea's total population is about 52 million.

Figure 3. Rising House Prices in South Korea, 2015-2019



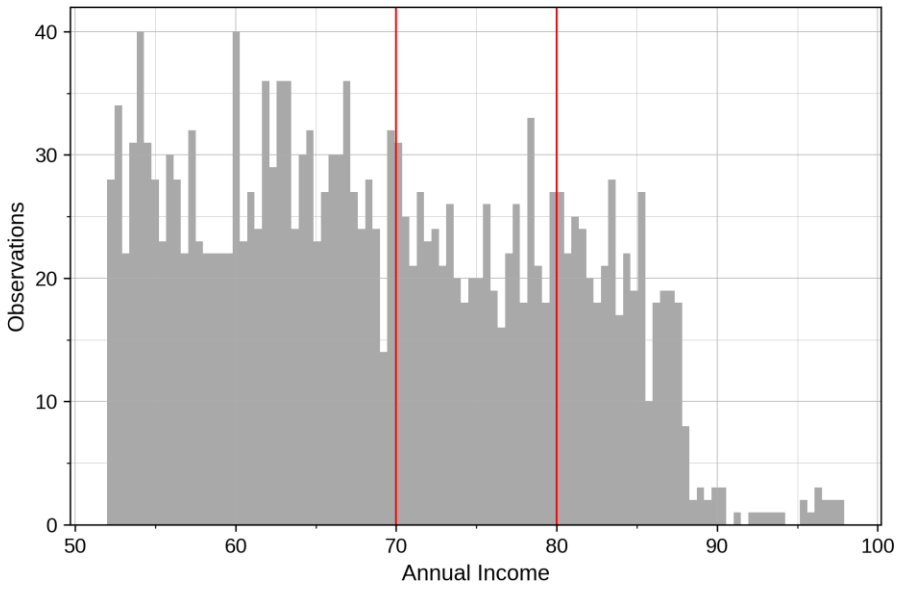
Note: This figure shows the relative changes in the average apartment sales prices in South Korea's administrative districts. *Seoul Metropolitan Area* refers to Seoul and its surrounding areas such as Incheon and Gyeonggi Province. It holds a population of 25 million, about half of the country's total population. Panel (a) is from July 2015 to July 2017. Panel (b) is from July 2017 to July 2019. The house price data are from Korea Real Estate Board (REB). The geographic shape data are from the GIS Developer (http://www.gisdeveloper.co.kr).

institutions would not be permitted to provide new mortgage loans for more than 40% of the value of a house. Representing a drastic tightening of the previous ceiling, which was 70%, the rule applied to all new house purchases in Seoul as well as in Gwacheon and Sejong, which had been designated as areas that attract speculative real estate investment by presidential decree. The policy, the government announced, would discourage speculation and stabilize house prices. The rule would apply to all new mortgage originations from the effective date, August 23. Existing borrowers did not have to repay their mortgages immediately to comply with the new ceiling.

It is worth noting that house prices rose more rapidly after the rule was announced, despite its policy objectives. Figure 3 shows the relative changes in the sales price of the average apartments[9] in the administrative districts of the country between 2015 to

[9] Apartments are the most common type of residential bui in South Korea. As of 2017, 49

Figure 4. Distribution of Household Annual Income: Subsample



Note: This figure displays the distribution of a subsample of 1,987 South Korean households' annual income reported in the *Survey of Household Finances and Living Conditions* in 2017. Annual income (x-axis) is in millions of South Korean won (KRW). The subsample contains (a) households whose annual income is between 52 and 88 million KRW. and have nonzero real estate assets, and (b) households whose annual income is between 62 and 98 million KRW and have zero real estate assets. The two vertical lines indicate 70 and 80 million KRW.

2019. Panel (a) displays mean house price growth in the two years before the policy change. The red circle denotes the Seoul Metropolitan Area, which holds about half of the population of South Korea. During the two years that preceded the tightening of the LTV ceiling, average apartment prices rose by 7.8% in Seoul, 5.7% in the Seoul Metropolitan Area, and 4.2% in the whole country. Panel (b) shows the growth of mean house prices over the two years that followed the policy change. Average apartment prices rose by 38% in Seoul, by 26% in the Seoul Metropolitan Area, and by 20% in the country.

There was an important discontinuity in the new rule, which enables our empirical design: the policy contained exceptions for low- and middle-income households. Households could borrow up to 50% of the value of a house, rather than 40%, if they

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percent of households lived in apartment buildings compared to houses (37%) and others (14%).

(a) had an annual income of 70 million KRW (USD 58,300) or less or (b) did not own any real estate and had an annual income of 80 million KRW (USD 66,700) or less.[10] In effect, the South Korean government applied an LTV ceiling that was stricter (lower) by 10 percentage points to households above the cutoffs of 70 or 80 million won.

This discontinuity in the LTV ceiling based on income was unprecedented and unexpected. Since their introduction in 2005 through the South Korean *Standards for Risk Management of Housing Mortgage Loans,* hard LTV ceilings[11] had been conditional only on house value and mortgage maturity. For example, before the government relaxed all LTV ceilings to 70% in 2014, the ceiling for apartment mortgages was 40% if (a) the remainder of the term of the loan was less than 10 years or (b) the market value of the house was larger than 600 million KRW. Otherwise, the ceiling was set at 60%. The rules had never referred to income cutoffs.

That the cutoffs were unexpected is further confirmed by the distribution of reported annual incomes before the policy change in 2017. Figure 4 presents a histogram of a subsample of households with annual incomes that were within 18 million KRW of the cutoffs. That sample contains 2,025 observations. Figure A.1 presents the same histogram for the full sample. Neither figure contains significant signs of bunching or clustering toward the cutoffs.

3.3 Empirical strategy

Our empirical strategy is to measure the heterogeneous causal effects of a stricter (lower) LTV ceiling by using a regression discontinuity design (RDD). Let $i = 1, 2, \ldots, N$ denote households, and let $t = 0, 1, 2$ denote Year 0, Year 1, and Year 2. Let y_{it} denote our primary dependent variable, the log net worth of household i in year t. Let D_i denote the treatment, with $D_i = 1$ if household i is being treated (subject to the stricter LTV ceiling) and $D_i = 0$ otherwise. The running variable that determines the treatment is the Year-0 annual income of household i. Let x_i denote the annual income of that household in millions of KRW, centered at the cutoff by subtracting 70 if the

[10] The ministries originally announced the cutoffs to be 60 and 70 million KRW on August 2. They adjusted them upward to 70 and 80 million KRW in an announcement two weeks later as well as in the final rule.

[11] Soft ceilings on loan-to-value ratios (LTV) were first introduced in 2002.

household had real estate assets in Year 0 or 80 otherwise. Thus,

$$D_i = \begin{cases} 0 & \text{if } x_i < 0, \\ 1 & \text{if } x_i \geq 0. \end{cases} \tag{1}$$

Our model is

$$y_{it} = y_{i0} + \beta_{kt} D_i + \rho_{kt} D_i x_i + \gamma_{kt} x_i + \delta_{kt} + \varepsilon_{it} \text{ for } t = 1, 2, \tag{2}$$

where ε_{it} is an error term, and $k \in K$ denotes the group that household *i* belongs to. The letter *K* denotes any set of groups of households that are mutually exclusive and exhaustive. For example, *K* may be the set of five initial-net-worth quintiles, i.e., {Q1, Q2, Q3, Q4, Q5}. As a further example, *K* may be the set of the two groups, homeowners and non-homeowners, in Year 0.

In writing the model as Equation (2), we are assuming that the treatment effect is the same across households in the same group.[12] We interpret the coefficient β_{kt} as the local average treatment effect (LATE) for households that belong to group *k* and are near the annual income cutoffs. We call them *heterogeneous* (local average) treatment effects to stress that the causal effect may differ across groups. We estimate the heterogeneous treatment effects separately for multiple possible groupings, such as the initial-net-worth quintiles and the groups that are based on homeownership status. As for the other coefficients, γ_{kt} is the effect of annual income for the control households in group *k*. The coefficient ρ_{kt} is the additional effect of annual income for the treated households in group *k*. The constant δ_{kt} is the expected change for the control households in group *k*. The time-invariant unobserved household heterogeneity of the dependent variable is captured by y_{i0}.

We rewrite Equation (2) equivalently as

$$y_{it} - y_{i0} = \sum_{k \in K} d_{ik} \left(\beta_{kt} D_i + \gamma_{kt} x_i + \rho_{kt} D_i x_i + \delta_{kt} \right) + \varepsilon_{it} \text{ for } t = 1, 2, \tag{3}$$

[12] Ideally, one would like to observe for each individual both the treatment and counterfactual control outcome, but that is not possible.

and estimate the coefficients of Equation (3) in two separate regressions for $t = 1, 2$. The dependent variable is the cumulative change in log net worth from Year 0 to Year t. The variable d_{ik} is an indicator that equals 1 if household i belongs to group k and 0 otherwise. Therefore, for each regression with $t = 1$ or $t = 2$, the number of estimated coefficients is four (β_{kt}, γ_{kt}, ρ_{kt}, and δ_{kt}) times the number of groups k in K.

Our identifying assumption is that the expected value of Equation (3) conditional on the running variable x_i and the treatment D_i is continuous in x_i, for both $D_i = 0$ and $D_i = 1$. That is, the assignment of the treatment status is as good as random, for households with income just below and just above the thresholds. Economically, it means that the households did not anticipate the discontinuity in the level of loan-to-value ratio ceilings and did not manipulate their reported incomes accordingly. As discussed in Subsection 3.2, South Korea's LTV ceiling change in 2017 appears arbitrary and unexpected, making the continuity assumption reasonable.

Given this design, we only use a local subsample around the cutoff, drawing on the optimal bandwidth choice algorithm by Imbens and Kalyanaraman (2012) for the entire sample of 10,251 households. The chosen bandwidth is 18 million KRW (USD 15,000), which leaves 2,025 observations.[13] In other words, we retain only the observations of house-owning households with annual incomes of between 52 and 88 million KRW (USD 43,300-73,300) and non-house-owning households with annual incomes of between 62 and 98 million KRW (USD 51,600-81,600). As discussed in Subsection 3.1, on average, the households in this subsample have higher incomes, more assets, and more debt than those in the full sample. We use weighted least squares, with weights w_i computed as

$$w_i = 1 - \left(\frac{x_i}{18} \right)^2 . \tag{4}$$

This weight is the Epanechnikov kernel function, which assigns larger weights to

[13] We use the same bandwidth for all groups to be consistent. An alternative way of estimating the coefficients is to run a separate regression for each group k while choosing the optimal bandwidth for each regression separately. For robustness, we report and discuss the results of this alternative method in Subsection 3.4 with Table A.6.

observations that are closer to the cutoff.[14]

3.4 Results

Our results reveal that a tighter (lower) LTV ceiling has a substantial negative impact on low-net-worth households. The estimated treatment effect for the bottom quintile of initial net-worth households is -1.3 in log net worth (about -73% in net worth) over two years relative to the control households. In comparison, the estimated treatment effects on the wealthier households are small and statistically indistinguishable from zero. We estimate that the average log net worth of the control households in the bottom quintile increased by 0.9 (approximately 146% in net worth) from Year 0 to Year 2, whereas that of the treated households in the bottom quintile decreased by 0.4 (approximately 33% in net worth).

Table 6 shows the estimated average impact of strict LTV ceilings on future log net worth. Households are not grouped into different categories. The first row shows the estimates of the treatment effect, that is, the coefficients β_{kt}, for years $t = 1, 2$, where k is the entire group of households. The other rows show the estimated coefficients of the indicated variables. Column (1) and Column (2) of Table 6 display our baseline point estimates of the average treatment effects: -0.046 in the first year and -0.069 in the second year. These figures represent -4.5% and -6.7% changes relative to the net worth that the households would have attained had they not faced the stricter LTV ceiling. In other words, these point estimates indicate that the stricter LTV ceiling caused households to lose, on average, about 4.5% of their wealth over two years, a nontrivial loss. Regardless of the economic impact of these coefficients, neither is statistically significant. The results do not change when we include controls for householder age, sex, education level, and residence in the Seoul Metropolitan Area in the regression equation. Columns (3)-(6) show that, for the most part, the estimates remain the same, although the addition of controls improves the fit.

Since the treatment effect is relative to the outcome for the control group, the negative estimates do not mean that the treated households lost wealth during Years 0-2. The estimated constants (δ_{kt} from Equation [3]) in the fourth row, under Column

[14] For robustness, we include results with an alternative, triangular kernel at the end of Subsection 3.4.

Table 6. Effects of Stricter LTV Ceiling on Household Log Net Worth

Independent Variable	*Dependent Variable:* Cumulative Change in Log Net Worth					
	(1)	(2)	(3)	(4)	(5)	(6)
	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
Stricter Loan-to-value	-0.046	-0.069	-0.047	-0.073	-0.048	-0.076*
Ratio Ceiling (*D*)	(0.037)	(0.047)	(0.036)	(0.046)	(0.036)	(0.046)
Centered Annual Income (x)	0.001	0.004	0.001	0.003	0.001	0.003
	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)
$D \times x$	0.002	-0.001	0.003	0.000	0.003	0.000
	(0.004)	(0.005)	(0.004)	(0.005)	(0.004)	(0.005)
Constant	0.082***	0.160***	0.104***	0.170***	0.095***	0.149***
	(0.024)	(0.027)	(0.031)	(0.037)	(0.031)	(0.038)
Controls						
Age, sex, & education			✓	✓	✓	✓
Residence in Seoul					✓	✓
Observations	1,993	1,987	1,993	1,987	1,993	1,987
Adjusted R-squared	0.000	0.000	0.007	0.013	0.007	0.016

Note: Numbers without parentheses represent estimates of regression coefficients on the independent variables of Equation (3). Stricter loan-to-value ratio ceiling (*D*) is a dummy variable that equals one if the household faces the LTV ceiling of 40% and 0 if it faces 50%. Centered annual income (*x*) is the household's annual income as of Year 0 minus its cutoff, in millions of South Korean won (KRW). The cutoff is (a) 70 million KRW if the household owns some real estate as of Year 0 and (b) 80 million KRW otherwise. The controls age, sex, and education refer to those of the householder. Residence in Seoul equals one if the household lives in Seoul Metropolitan Area and equals zero otherwise. Numbers in parentheses are heteroskedasticity-robust standard errors. Stars *, **, and *** indicate that the estimates differ significantly from zero with 90%, 95%, and 99% confidence.

(1) and Column (2), reveal that, on average, the net worth of the control households (those who did not face a stricter LTV ceiling) increased considerably over the period. The estimated intercepts are 0.082 for the first year and 0.160 for the second year. If the treatment effects are considered, the point estimates of the changes in the log net worth of the treated households are 0.082 – 0.046 = 0.036 by Year 1 and 0.160 – 0.069 = 0.091 by Year 2. Therefore, the treated households also made significant gains in net worth during the period in question. This large increase in overall household wealth is not too surprising because home prices rose rapidly over the period under observation (Figure 3) and because real estate assets account for about two-thirds of household assets (Table 1).

Table 7. Effects of Stricter LTV Ceiling on Household Log Net Worth by Initial Net Worth Quintile

	Dependent Variable: Cumulative Change in Log Net Worth					
Initial Net Worth Quintile and Stricter LTV Ceiling (*D*)	(1) Year 1	(2) Year 2	(3) Year 1	(4) Year 2	(5) Year 1	(6) Year 2
Bottom (poorest) × *D*	-1.070**	-1.289**	-1.051**	-1.249**	-1.054**	-1.248**
	(0.529)	(0.555)	(0.523)	(0.545)	(0.524)	(0.548)
Second × *D*	-0.033	0.027	-0.047	0.019	-0.050	0.013
	(0.169)	(0.194)	(0.170)	(0.196)	(0.169)	(0.196)
Middle × *D*	-0.017	-0.108	-0.016	-0.112	-0.017	-0.115
	(0.051)	(0.086)	(0.051)	(0.082)	(0.051)	(0.082)
Fourth × *D*	-0.050	-0.056	-0.041	-0.053	-0.041	-0.054
	(0.047)	(0.054)	(0.046)	(0.054)	(0.046)	(0.054)
Top (wealthiest) × *D*	0.018	0.016	0.011	0.003	0.010	0.001
	(0.048)	(0.077)	(0.049)	(0.077)	(0.049)	(0.077)
Bottom (poorest)	0.805**	0.906***	0.839***	0.943***	0.830***	0.920***
	(0.312)	(0.309)	(0.313)	(0.305)	(0.314)	(0.306)
Second	0.137**	0.207**	0.177***	0.237***	0.173***	0.226***
	(0.060)	(0.082)	(0.065)	(0.084)	(0.064)	(0.084)
Middle	0.088**	0.201***	0.122**	0.229***	0.117**	0.217***
	(0.042)	(0.048)	(0.049)	(0.054)	(0.048)	(0.054)
Fourth	0.028	0.080**	0.065*	0.116***	0.060	0.103**
	(0.035)	(0.035)	(0.038)	(0.042)	(0.038)	(0.042)
Top (wealthiest)	0.035	0.110**	0.075**	0.142***	0.067*	0.123***
	(0.032)	(0.043)	(0.036)	(0.046)	(0.037)	(0.047)
Controls						
Age, sex, & education			✓	✓	✓	✓
Residence in Seoul					✓	✓
Observations	1,993	1,987	1,993	1,987	1,993	1,987
Adjusted R-squared	0.087	0.101	0.095	0.113	0.095	0.114

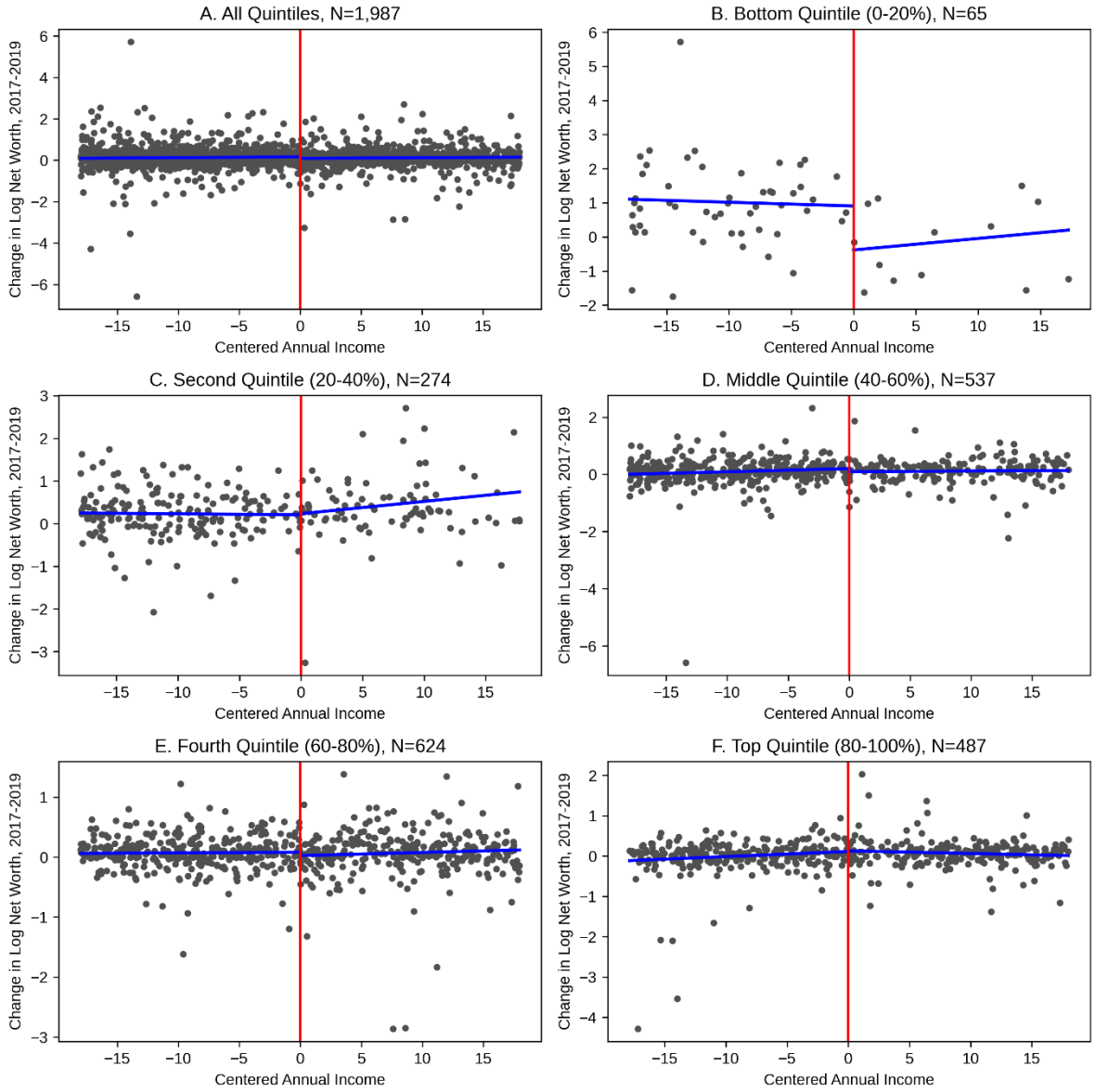
Note: Numbers without parentheses represent estimates of regression coefficients on the selected independent variables of Equation (3). Stricter LTV ceiling (*D*) is a dummy variable that equals one if the household faces the LTV ceiling of 40% and 0 if it faces 50%. The controls age, sex, and education refer to those of the householder. Residence in Seoul equals one if the household lives in Seoul Metropolitan Area and equals zero otherwise. Numbers in parentheses are heteroskedasticity-robust standard errors. Stars *, **, and *** indicate that the estimates differ significantly from zero with 90%, 95%, and 99% confidence.

Although most households had a positive net worth over the period under observation, households with zero or negative net worth may also have been affected meaningfully by the stricter LTV ceiling. Table A.2 shows the estimated coefficients of the regressions with the net-worth positivity of households (1 if positive; 0 otherwise) in Year 1 and Year 2 as a dependent variable. Columns (1)-(6) display the regressions for the subsample of households with zero or negative net worth in Year 0, whereas Columns (7)-(12) display the same regressions for households with a positive net worth in Year 0. It is evident from the insignificant estimates in the first row of Columns (1)-(6) that we fail to reject the null hypothesis, namely that a stricter LTV ceiling does not affect the probability of switching to positive net worth. The point estimates in the first rows of Columns (7)-(12) suggest that a stricter LTV ceiling could make maintaining a positive net worth less likely by 1% given a positive initial net worth. However, these estimates are statistically indistinguishable from zero or only significant with less than 90% confidence.

Table 7 shows our main result: the stricter LTV ceiling hurt the poorest households the most. The numbers in the first five rows of this table are estimates of the treatment effects β_{kt} for each initial-net-worth quintile k. The parameter estimates in each column are from a single regression of Equation (3). As before, non-positive-net-worth households are dropped from these regressions because the dependent variable is log net worth. We estimate that the LTV ceiling that was stricter by 10 percentage points reduced the log net worth of the bottom-quintile households by 1.070 over a year and by 1.289 over two years relative to the control households. In exponentiated terms, these findings mean that the treatment caused the poorest-quintile households to lose $1 - \exp(-1.070) = 65.7\%$ by Year 1 and $1 - \exp(-1.289) = 72.4\%$ by Year 2, relative to the net worth that they would have otherwise attained. Both estimates are statistically significant with 95% confidence.

In contrast, the negative impact of the stricter LTV ceiling on the remainder of the households seems much milder or nonexistent. For middle- and fourth-quintile households, the estimated impacts are -0.108 (-10.2%) and -0.056 (-5.4%), respectively, over two years. The estimates are slightly positive for the second and the top quintile, at 0.027 (2.7%) and 0.016 (1.6%), respectively. All of the estimates except those for the bottom quintile are statistically indistinguishable from zero. These results are robust to controls for demographic characteristics (age, sex, and education) and residence in the Seoul Metropolitan Area.

Figure 5. Heterogeneous Treatment Effects by Initial Net Worth Quintile



Note: Centered annual income (x-axis) is the household's annual income as of Year 0 minus its cutoff, in millions of South Korean won (KRW). The cutoff is (a) 70 million KRW if the household owns some real estate as of Year 0 and (b) 80 million KRW otherwise. Because the dependent variable (y-axis) is two-year changes in *log* net worth, the scattered plots only include households with a positive net worth in Year 0 and Year 2. The blue lines indicate the estimated regression lines from Table 6 and Table 7.

Since the estimated treatment effects are relative to the control groups, the very large negative treatment effect on the bottom-quintile households should be interpreted in the context of the overall changes in household net worth. The last five rows of Columns (1)-(2) in Table 7 show the intercepts—the estimated average cumulative change in the log net worth of the control households. From Year 0 to Year

2, the control households from the bottom quintile saw their log net worth grow by 0.906 (147%). Therefore, the log net worth of the treated households in the bottom quintile changed by 0.906 – 1.289 = – 0.383 (– 31.8%) from Year 0 to Year 2.

These large swings in the log net worth of the control and treated households in the bottom quintile are not unrealistic, given the negligible starting wealth of these households. Panel B of Table 2 from Subsection 3.1 shows that the sample in question had a tiny initial net worth of 6.6 million KRW (USD 5,500) on average. Yet, as seen from Panel B of Table 3, the same sample had a large and highly volatile change in net worth over two years with an average of 56 million KRW (USD 47,000) and a standard deviation of 143 million KRW (USD 119,000). In terms of log net worth, the average change over two years was 0.75 (112%) with a standard deviation of 1.26 (252%).

Next, as an illustration of our main results, we plot the individual data points and the estimated regressions. Figure 5 displays these plots. The dependent variable, that is, changes in log net worth over two years, is on the vertical axes. The horizontal axes represent the running variable, annual income minus cutoffs. Panel A shows the data and the regression for households across all initial-net-worth quintiles, as estimated in Columns (1)-(2) of Table 6. Consistent with the near-zero and insignificant treatment effects, the data points on the left side (control households) and the right side (treated households) of the cutoff show few signs of discontinuity. Panels B-E display the data points by initial-net-worth quintiles and the corresponding regressions of Equation (4), as reported in Table 4. All panels except Panel B reveal no evidence of discontinuity at the cutoff, suggesting little or no impact on households in the second and the top initial-net-worth quintiles. For the bottom-quintile households (Panel B), in contrast, the data points on the right side of the cutoff are, on average, located lower than those on the left side. The implication is that the treatment had a negative effect on the former, which is consistent with the result that we presented earlier.

One concern that emerges from this figure has to do with the small size of the bottom quintile of the sample. There are only 13 observations on the right side of the cutoff. The number of such households in the sample is small because of our empirical design—the analysis focuses on a subsample of households near the annual income cutoffs of 70 and 80 million KRW (approximately USD 58,300 and USD 66,700, respectively). Those households typically belong to the middle- and high-income

Table 8. Effects of Stricter LTV Ceiling on Household Net Worth by Initial Net Worth Quintile

	Dependent Variable: Cumulative Change in Net Worth					
Initial Net Worth Quintile and Stricter LTV Ceiling (*D*)	(1) Year 1	(2) Year 2	(3) Year 1	(4) Year 2	(5) Year 1	(6) Year 2
Bottom (poorest) × *D*	-70.9*	-160.4**	-69.0*	-164.5**	-71.2*	-172.0**
	(36.6)	(81.3)	(36.4)	(81.9)	(37.0)	(82.3)
Second × *D*	1.6	12.7	1.9	18.0	0.3	12.5
	(13.4)	(20.2)	(13.6)	(21.8)	(13.7)	(22.4)
Middle × *D*	-16.5	-22.2	-18.2	-31.3	-18.9	-33.5
	(18.0)	(27.2)	(18.1)	(25.8)	(18.2)	(25.7)
Fourth × *D*	-21.0	-12.8	-21.1	-19.1	-21.4	-20.2
	(14.5)	(20.4)	(14.4)	(21.5)	(14.4)	(21.6)
Top (wealthiest) × *D*	-27.1	125.5	-27.7	125.5	-28.3	123.5
	(51.8)	(169.3)	(51.9)	(166.5)	(51.8)	(165.7)
Bottom (poorest)	76.2**	166.1**	82.7**	196.2**	77.0**	176.9**
	(35.6)	(80.2)	(36.6)	(80.7)	(37.2)	(79.1)
Second	19.2**	32.5***	24.7**	56.6***	21.5**	45.7***
	(7.8)	(11.1)	(10.5)	(17.5)	(10.6)	(17.2)
Middle	34.8**	59.9***	39.6**	85.9***	35.9*	73.2***
	(17.0)	(17.7)	(19.9)	(23.2)	(19.2)	(21.6)
Fourth	21.7**	44.2***	26.7**	68.9***	23.1*	56.3***
	(10.1)	(12.2)	(11.7)	(17.4)	(11.8)	(16.6)
Top (wealthiest)	79.5**	156.5***	80.0***	156.8***	74.5**	138.1***
	(31.4)	(48.6)	(31.0)	(48.6)	(31.2)	(49.3)
Controls						
Age, sex, & education			✓	✓	✓	✓
Residence in Seoul					✓	✓
Observations	2,025	2,025	2,025	2,025	2,025	2,025
Adjusted R-squared	0.008	0.019	0.012	0.035	0.014	0.039

Note: Numbers without parentheses represent estimates of regression coefficients on the selected independent variables of Equation (3). Stricter LTV ceiling (*D*) is a dummy variable that equals one if the household faces the LTV ceiling of 40% and 0 if it faces 50%. The controls age, sex, and education refer to those of the householder. Residence in Seoul equals one if the household lives in Seoul Metropolitan Area and equals zero otherwise. Numbers in parentheses are heteroskedasticity-robust standard errors. Stars *, **, and *** indicate that the estimates differ significantly from zero with 90%, 95%, and 99% confidence.

groups. Since the initial-net-worth quintiles are assigned from the full household data (see Subsection 3.1), the number of households in the bottom quintile of that subsample is lower than the number of households in the other quintiles. However, despite the small sample, the point estimates and the heteroscedasticity-robust standard errors reveal that the null hypothesis of zero LATE is rejected with 95% confidence, as can be seen in Table 7.

Relatedly, given the small sample of bottom-quintile households, one may ask how sensitive the results are to the choice of initial-net-worth groups. If the stricter LTV ceilings hurt the poorest quintile of households the most, we should see the estimated impact grow smaller as we include more households in the bottom group. Table A.3, Table A.4, and Table A.5 show the results from the same regressions when households are grouped into initial-net-worth quartiles, terciles, and deciles. The estimated treatment effect on the bottom quartile (0-25%) of households is -0.751, which is only statistically significant with 90% confidence. The estimated treatment effect on the bottom tercile (0-33%) of households is -0.399, and it is not statistically significant. Meanwhile, the estimated treatment effects on the bottom decile and the second decile are -0.434 (not significant) and -1.527 (significant with 99% confidence), respectively.

The impact of the policy on the poorest-quintile households remains sizeable and negative even when actual net worth replaces log net worth as a dependent variable. This substitution allows us to retain the observations of non-positive-net-worth households in the sample. The first five rows of Table 8 show the estimated effects of the stricter LTV ceiling on the net worth of households in Year 1 and Year 2. The estimated impact over two years is -160 million KRW (USD -133,000) for the bottom-quintile households; it is small and insignificant for the households in the other quintiles. The estimated intercept for the bottom quintile is 166 million KRW, meaning that the control households in the bottom quintile gained this much wealth from Year 0 to Year 2. Therefore, most of the negative treatment effects may be attributed to the treated households' failure to gain wealth rather than losing existing wealth.

Furthermore, our results are robust to changes in estimation methods, such as (a) the kernel (weighting) function and (b) bandwidths to the subsample.[15] Table A.6

[15] We also run a placebo exercise using a false set of income cutoffs and do not find any significant treatment effects, as desired. Instead of the true annual income cutoffs of 70 (for

shows the estimated heterogeneous treatment effects by using Calonico et al.'s (2015) R package *rdrobust*. Each estimate is from a separate regression that uses the relevant sample with separately computed optimal bandwidth. We use Calonico et al.'s (2015) default method, which employs the triangular kernel function and the optimal bandwidth selection by Imbens and Kalyanaraman (2012). The resulting estimates are strongly consistent with our earlier result—the stricter LTV ceiling substantially reduced the future net worth of the poorest households without affecting others. Over two years, the estimated impact on the log net worth of the bottom-quintile households is -1.351 (-74.1% in net worth). The estimated impacts on the remaining households are small and insignificant.

Lastly, our results are robust to the possible presence of outliers: top-coding and bottom-coding extreme data points (or *winsorizing*) do not reduce the economic or statistical significance of our main estimate. Table A.7 shows the results of 1% winsorization for the dependent variable, changes in log net worth. The independent variables do not need to be winsorized because all of them are either categorical or restricted to a fixed bandwidth. With 1% winsorization, the estimated treatment effect for the bottom-quintile households is -1.364 (-74.4% in net worth), which is significant with 95% confidence. Table A.8 shows the results with 2% winsorization. The estimated treatment effect for the bottom-quintile households is -1.377 (-74.8% in net worth), which, too, is significant with 95% confidence.

3.5 Mechanism

In line with Frost and van Stralen (2018), Carpantier et al. (2018), and our model (Online Appendix), we hypothesize that the stricter LTV ceiling directly reduced the ability of low-net-worth households in South Korea to purchase houses. As seen in Subsection 3.2, the period from Year 0 to Year 2 coincided with a steep increase in real estate prices in Seoul (38%), the Seoul Metropolitan Area (26%), and South Korea as a whole (20%). It is plausible that this significantly suppressed wealth accumulation among the treated households, relative to the control group.

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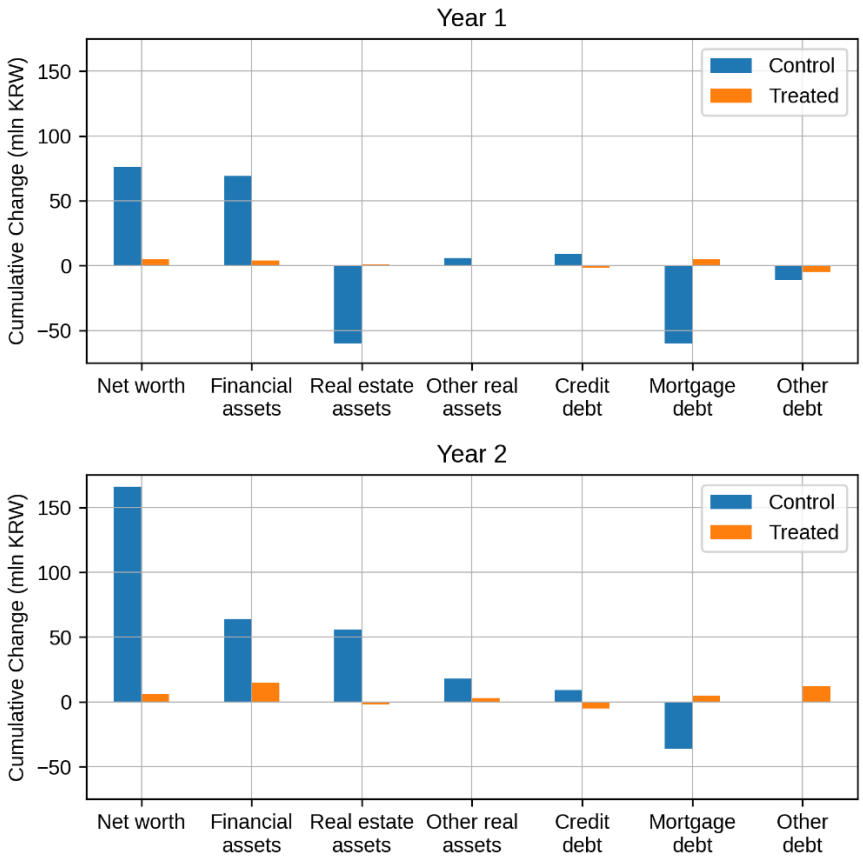
households with some real estate) and 80 (for households with no real estate) million KRW, we use the hypothetical cutoffs of 80 and 70 to assign the treatment status. We report the results in Table B.5 of the Online Appendix.

To assess this hypothesis, we decompose the estimated treatment effects on household net worth into more detailed balance-sheet items. If our hypothesis is correct, we should see a smaller gain in real estate ownership among treated households in the bottom quintile. Table A.9 displays the decomposition. Each number represents the estimated heterogeneous treatment effect for each of the dependent variables on the same row. For example, the numbers in Column (6) are the Year-2 treatment effects for the bottom quintile of households by net worth, financial assets, real estate assets, other real assets, unsecured credit debt, mortgage debt, and other debt. Although statistically insignificant, the point estimates suggest that real estate assets contributed the most to the large negative treatment effect that is observed for the bottom-quintile households. The Year-2 bottom-quintile treatment effect on real estate assets is -57.9 million KRW (USD 48,300); the whole treatment effect on net worth is -160.4 million KRW (USD 133,700).

We also decompose the intercepts to gauge the cumulative changes in different balance-sheet items for the control households. Table A.10 shows this decomposition. Each number represents the estimated intercept for each dependent variable in the same row. As in Table A.9, the numbers in Column (6) represent Year-2 cumulative changes in the net worth of the bottom-quintile control households as well as in their financial assets, real estate assets, other real assets, unsecured credit debt, mortgage debt, and other debt. The point estimates, although insignificant, suggest that financial and real estate assets contributed the most to the large increase in the wealth of those households.

Focusing on bottom-quintile households, we illustrate the results that are presented in Table A.9 and Table A.10 by plotting the estimated cumulative changes in the balance-sheet items for both the control and the treated households. Figure 6 displays this plot. Each blue bar indicates a Year-2 cumulative change in a balance-sheet item for the control households. Each orange bar indicates a cumulative change in a balance-sheet item for the treated households. Except for net worth in Year 2, the difference between the blue and the orange bar is not statistically significant. Still, across all of the balance-sheet items, the range of estimated changes is much wider for the control group, suggesting that those households may have had more room for maneuver.

Figure 6. Decomposition of the Estimated Average Cumulative Changes in Net Worth: Bottom (0-20%) Quintile Households in Initial Net Worth



Note: The bars for the control households represent the estimated intercepts of the regressions in Table A.10 for the bottom quintile households. The bars for the treated households represent the estimated intercepts for the control plus the estimated treatment effects in Table A.9 for the bottom quintile households. The treatment is a stricter loan-to-value ratio (LTV) ceiling by ten percentage points from 50% to 40%.

Another implication of our hypothesis is that the negative impact of the stricter LTV ceiling must have been smaller for households who already owned some real estate in Year 0. Recall that home prices in South Korea rose steeply between Year 0 and Year 2. A homeowner at Year 0 would have benefited from rising home prices during the observation period, even if their household was subject to the stricter LTV ceiling. In contrast, stricter borrowing constraints would have reduced the ability of non-homeowners to benefit from the price increase.

The estimated heterogeneous treatment effects for homeowners and non-homeowners are consistent with this prediction. Table 9 shows these estimates, and Figure 7 illustrates them. The estimated treatment effect on the log net worth of non-

Table 9. Effects of Stricter LTV Ceiling on Household Log Net Worth by Initial Home Ownership

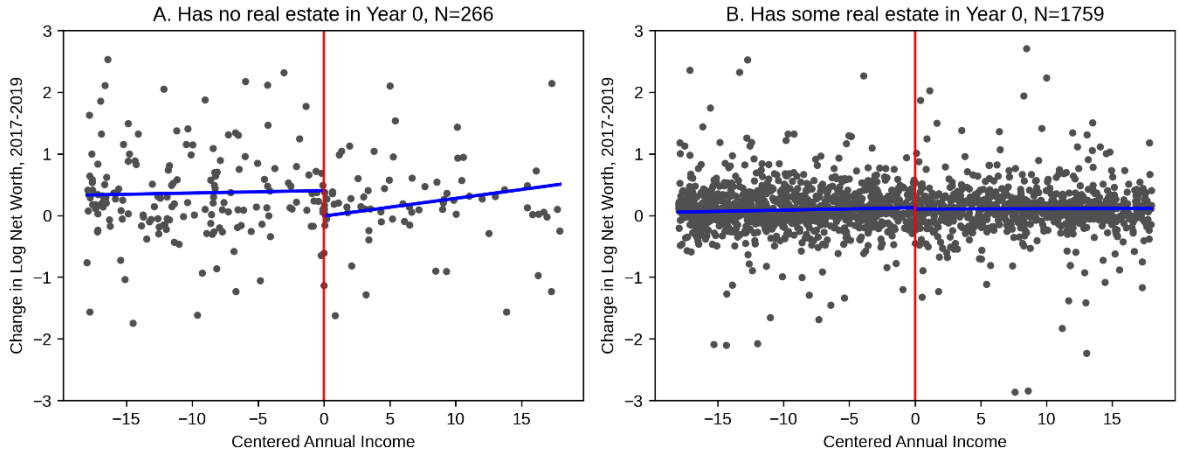
	Dependent Variable: Cumulative Change in Log Net Worth					
Initial Home Ownership and Stricter LTV Ceiling (*D*)	(1) Year 1	(2) Year 2	(3) Year 1	(4) Year 2	(5) Year 1	(6) Year 2
Non-homeowner × *D*	-0.213	-0.414**	-0.216	-0.415**	-0.215	-0.413**
	(0.188)	(0.206)	(0.187)	(0.205)	(0.187)	(0.206)
Homeowner × *D*	-0.025	-0.022	-0.024	-0.025	-0.024	-0.027
	(0.029)	(0.041)	(0.029)	(0.041)	(0.029)	(0.040)
Non-homeowner	0.239**	0.405***	0.255**	0.394***	0.245**	0.368***
	(0.111)	(0.120)	(0.117)	(0.125)	(0.118)	(0.126)
Homeowner	0.060***	0.127***	0.083***	0.139***	0.078***	0.125***
	(0.021)	(0.025)	(0.027)	(0.035)	(0.028)	(0.036)
Controls						
Age, sex, & education			✓	✓	✓	✓
Residence in Seoul					✓	✓
Observations	1,993	1,987	1,993	1,987	1,993	1,987
Adjusted R-squared	0.013	0.020	0.018	0.029	0.018	0.030

Note: Numbers without parentheses represent estimates of regression coefficients on the selected independent variables of Equation (3). Stricter LTV ceiling (*D*) is a dummy variable that equals one if the household faces the LTV ceiling of 40% and 0 if it faces 50%. A household is a *non-homeowner* if its real estate assets are zero in Year 0. A household is a *homeowner* if its real estate assets are positive in Year 0. The controls age, sex, and education refer to those of the householder. Residence in Seoul equals one if the household lives in Seoul Metropolitan Area and equals zero otherwise. Numbers in parentheses are heteroskedasticity-robust standard errors. Stars *, **, and *** indicate that the estimates differ significantly from zero with 90%, 95%, and 99% confidence.

homeowners is -0.414 (-33.9% in net worth) over two years, which is statistically different from 0 with 95% confidence.[16] In contrast, the estimated treatment effect for homeowners is economically and statistically insignificant. The estimated intercept indicates that the control homeowners accumulated 0.394 in log net worth (48%) over two years; the treated homeowners accumulated 0.394 - 0.414 = -0.020 (2% in net worth). Therefore, most of the negative treatment effects for homeowners may be

[16] The bottom two rows of Table A.6 show that this result is robust to the choices of bandwidth and kernel function.

Figure 7. Heterogeneous Treatment Effects by Initial Homeowner Status



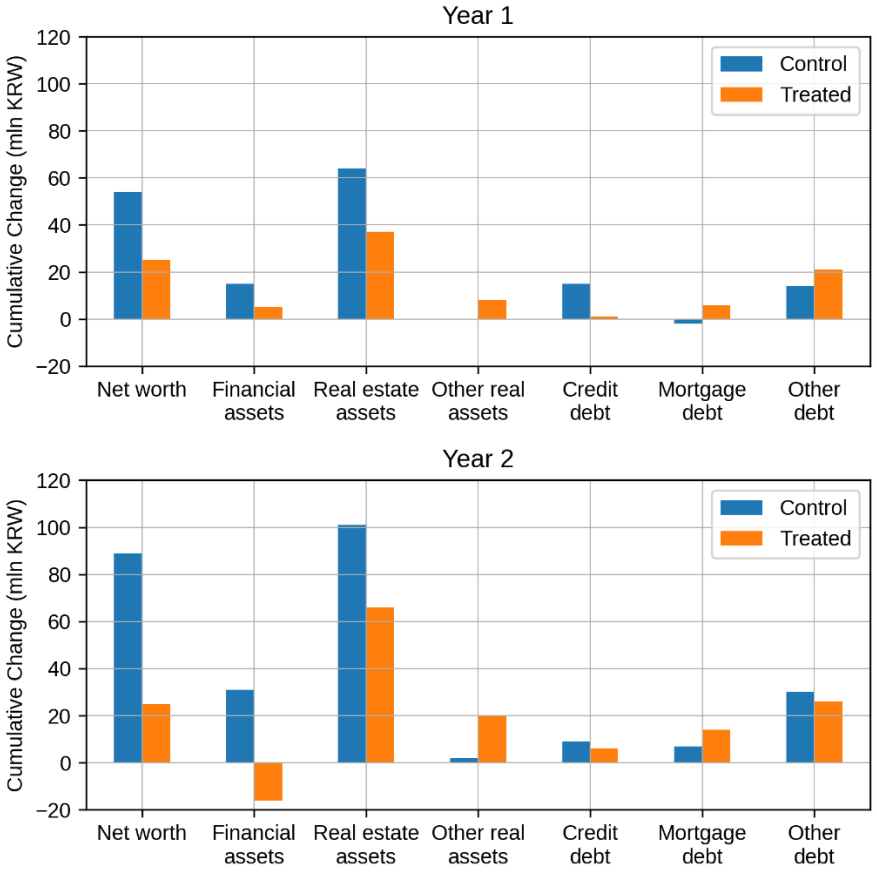
Note: Centered annual income (x-axis) is the household's annual income as of Year 0 minus its cutoff, in millions of South Korean won (KRW). The cutoff is (a) 70 million KRW if the household owns some real estate as of Year 0 and (b) 80 million KRW otherwise.

attributed to foregone opportunities to accumulate wealth. In comparison, the estimated log-net-worth intercept for homeowners is 0.139 (14.9% in net worth). Combined with the estimated treatment effect for homeowners, which is 0, this result means that those who owned homes at Year 0 increased their wealth by about 15%, irrespective of whether they were subject to the stricter LTV ceiling.

Following through with our earlier approach, we also estimate treatment effects and intercepts for net worth (instead of log net worth) for homeowners and non-homeowners. Table A.11 shows that the estimated treatment effect for non-homeowners is 65.2 million KRW (USD 54,300). That result is only significant with 90% confidence. Table A.12 and Table A.13 provide the decomposition of the estimated treatment effects and intercepts into detailed balance-sheet items. Figure 8 focuses on non-homeowners and illustrates the decomposition. It suggests that the difference between the growth of the value of real estate assets explains much of the gap in wealth accumulation between the control and the treatment groups.

To refine our analysis further, we examine the impact of the stricter LTV ceiling conditional on housing type. Examples of housing types are residing in a home that one owns and paying rent monthly. Table A.14 shows the estimated treatment effects and intercepts for households in different housing types at Year 0. None of the estimated treatment effects are statistically different from zero. Still, the point estimates suggest that the LTV restrictions have, on average, hurt those who live in

Figure 8. Decomposition of the Estimated Average Cumulative Changes in Net Worth: Households with No Real Estate in Year 0



Note: The bars for the control households represent the estimated intercepts of the regressions in Table A.13 for the non-homeowners. The bars for the treated households represent the estimated intercepts for the control plus the estimated treatment effects in Table A.12 for the non-homeowners. The treatment is a stricter loan-to-value ratio (LTV) ceiling by ten percentage points from 50% to 40%.

rented and free housing, whose log net worth was lower by 0.157 (14.5%) and 0.644 (47.5%), respectively. This result provides a supplementary explanation of how stricter LTV ceilings hurt the poorest households: most of the bottom-quintile households were living in rented or free housing, as can be seen from Table 5.

In light of these results, it is important to recall the demographics of the bottom-quintile households in our sample, which are displayed in Tables 2 and 5. The bottom-quintile households had the same annual income, on average, as the other households, at around 70 million KRW (USD 50,000). Despite this relatively high income, they had small initial net worth, on average at 25 million KRW (USD 21,000). The average for the entire sample is 386 million KRW (USD 322,000). The share of homeowners was

small (23%, compared to 88% overall). They had the largest share of residents in the Seoul Metropolitan Area (48%, compared to 35% overall) and the largest share of households that were living in rented or free housing (57%, compared to 8% overall). Since house prices in Seoul and the Seoul Metropolitan Area rose rapidly (38% and 26% over two years), it is possible that the reduced ability to purchase houses in those areas prevented the households' wealth from growing. Given their low initial net worth, this effect may have been exceptionally pronounced.

All in all, the auxiliary results and the discussion in this subsection do not constitute conclusive evidence for the proposition that the stricter LTV ceiling diminished the ability of bottom-quintile households to invest in real estate. The limited data on relocations and house prices for the poorest households prevent us from arriving at a more definitive conclusion. Nonetheless, the results above provide the context behind the large negative estimated treatment effect of -1.3 for log net worth.

3.6 Aggregate impact

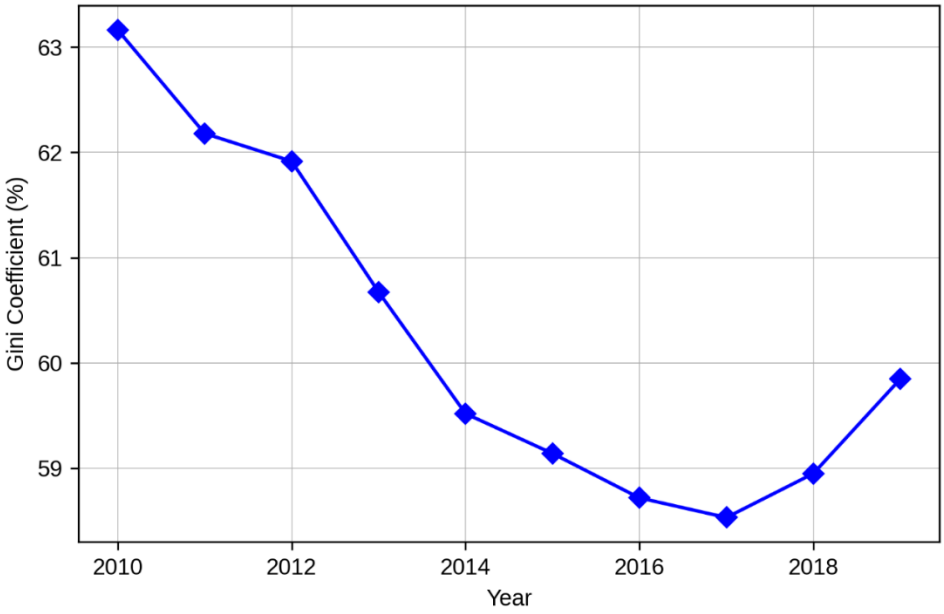
Our rough calculations suggest that the aggregate impact of a stricter LTV ceiling could be substantial. We make a crude assumption that the treatment effect is the same for all households that belong to the same initial-net-worth quintile in the full sample. We then use the estimated values β_{kt} of the heterogeneous treatment effects in Column (2) of Table 7 to compute the counterfactual distributions of net worth under the stricter and the looser LTV ceiling. In other words, we let

$$y_{i2}^1 = \begin{cases} y_{i2}, & \text{if } D_i = 1 \\ y_{i2} + \beta_{kt}, & \text{if } D_i = 0 \end{cases} \text{ and } y_{i2}^0 = \begin{cases} y_{i2} - \beta_{kt}, & \text{if } D_i = 1 \\ y_{i2}, & \text{if } D_i = 0 \end{cases} \tag{5}$$

for each *i* and its initial-net-worth quintile *k*. The counterfactual net-worth distribution under the stricter LTV ceiling is the vector $Y_1 = \left\{ y_{i2}^1 \right\}_{i=1,2,\ldots N}$. The counterfactual net-worth distribution under the looser LTV ceiling is the vector $Y_0 = \left\{ y_{i2}^0 \right\}_{i=1,2,\ldots N}$. Then, the aggregate impact is

$$\text{Aggregate Impact} = G(Y_1) - G(Y_0), \tag{6}$$

Figure 9. Wealth Inequality in South Korea, 2010-2019



Note: This figure shows the Gini coefficients of households' net worth computed with data from the *Survey of Household Finances and Living Conditions* from 2010 to 2019.

where $G(\bullet)$ is the standard formula for computing the Gini coefficient.

Following this definition, we compute the two-year aggregate impact on wealth inequality at 1.7 percentage points for the net-worth Gini coefficient. However, this result depends on the estimated local average treatment effects (LATEs) β_{kt}, with wide confidence intervals. Therefore, we interpret the result to imply only that the order of magnitude of the aggregate impact is 1 percentage point.

An aggregate impact of this order of magnitude is substantial in light of the historical data. Recall that South Korea lowered the LTV ceiling from 70% to 40% or 50% in 2017. Figure 9 shows the net-worth Gini coefficient of the country over the 2010-2019 period. That coefficient decreased steadily from approximately 63% in 2010 to a trough of 58.5% in 2017 before increasing to 60% in 2019. A one-percentage-point change may have accounted for a nontrivial part of the increase in wealth inequality since 2017.

3.7 Discussion

As with any study that employs a regression discontinuity design, there may be

concerns about the external validity of our findings. We assess four such concerns and discuss their implications. First, our estimates of the heterogeneous treatment effects may not be generalizable to households at different income levels. By design, our empirical strategy employs the discontinuity in the South Korean LTV ceiling at annual income cutoffs to identify the causal impact of the policy. Therefore, the estimated causal impact is the local average treatment effect (LATE) conditional on initial household net worth in the close neighborhood of those cutoffs. In particular, our estimate that the impact on the log net worth of the poorest-quintile households is -1.3 applies to households with prior annual incomes of around 70 million KRW (or, if the household did not own a house, of around 80 million KRW). The impact may have been smaller for households with significantly lower annual incomes, say 30 million KRW, in the same quintile: their ability to make real estate investments may be low regardless of the LTV ceiling. For analogous reasons, the impact may be larger for households whose incomes are further from the cutoffs. While our interpretation of the LATEs near the cutoff would still be valid in this case, the estimates of the aggregate impact on the Gini coefficient would be exaggerated.

Second, the estimated causal impact of tightening (lowering) the LTV ceiling by 10 percentage points, from 50% to 40%, may not be generalizable to other ratios. For example, the impact of reducing the LTV ratio ceiling by 10 percentage points from 60% or 70% may be different. On the one hand, the loss in maximum leverage is higher at 70% than at 50%, thus making the impact of the tightening from 50% larger than that from 70%. On the other hand, the LTV ceilings for households may bind less likely at 70% than at 50%, potentially making the impact of the tightening from 50% smaller than that from 70%.

Third, our estimates may be sensitive to the size of general equilibrium effects on house prices. Our estimates of the treatment effects rely on the fact that low- and middle-income earners in Year 0 were subject to an LTV ceiling of 50%, while the ceiling for other households was 40%. However, house prices would likely have been different if all households had been subjected to the same LTV ceiling, be it 50% or 40%. In particular, if all households had faced the more restrictive 40% ceiling, house prices after the policy change may have been lower than if only high-income households had been subject to the stricter policy. The return on real estate investment may have been lower under the uniform ceiling of 40%.

Fourth, more broadly, our estimates may not be readily generalizable to periods other than that between 2017 and 2019 and to countries other than South Korea. House prices in South Korea increased steeply over the period in question. Households that were constrained by the stricter LTV ceiling may have suffered more than they would have at a different time. This may have contributed to the large negative estimate of the LATE for households in the bottom quintile.

4. Concluding remarks

The empirical evidence suggests that tighter LTV ceilings have a significant negative impact on the wealth of low-net-worth households. Using South Korean survey data from 10,251 households over the 2017-2019 period, we estimated that the lowering of the LTV ceiling from 50% to 40% reduced the average log net worth of the poorest quintile of households by 1.3 (a -73% change in net worth) over two years relative to the control households. In contrast, the impact of that policy on the log net worth of the top quintile of households was statistically indistinguishable from zero. The differentiated LTV ceilings, which were based on household income, may have mitigated the potentially adverse impact of the general tightening of the LTV ratio on inequality in South Korea.

Our findings suggest that further research should be conducted on the relationship between macroprudential policy, inequality, and financial stability. While our findings provide clues about the link between macroprudential policy and inequality, the connection between inequality and financial stability is yet to be established clearly. Future studies on such connections would ultimately enhance the understanding of optimal macroprudential policy.

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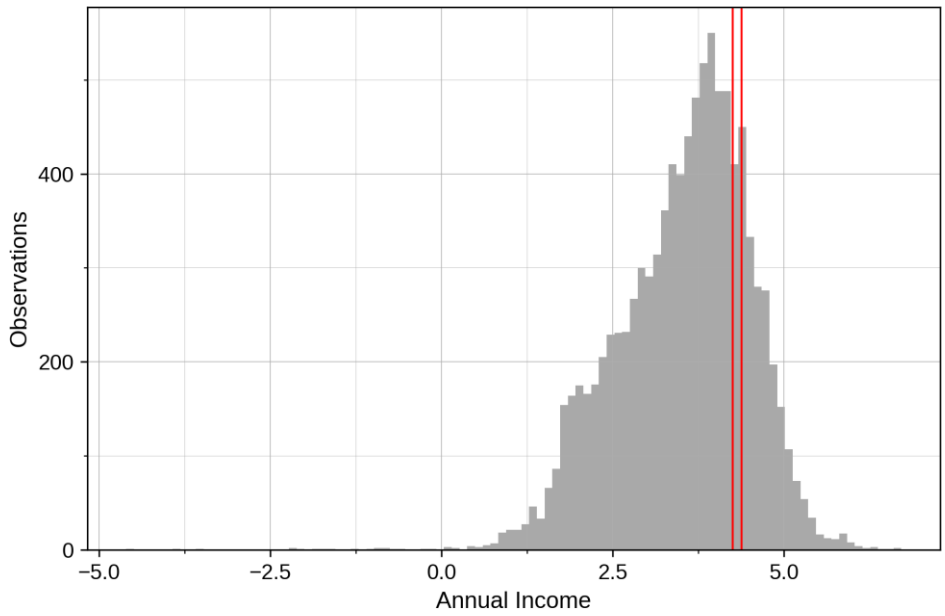
A. Appendix

Figure A.1. Distribution of Household Annual Income: Full Sample



Note: This figure displays the distribution of the full sample 9,844 South Korean households' annual income reported in the *Survey of Household Finances and Living Conditions* in 2017. The x-axis is the log of annual income in millions of Korean won (KRW). The two vertical lines indicate 70 and 80 million KRW.

Table A.1. Share of Households by Demographic Groups: Full Sample

Demographic Group	Initial (Year 0) net worth quintile					All
	Bottom (poorest)	Second	Middle	Fourth	Top (wealthiest)	
Age						
18-29	6.4	3.7	1.6	0.7	0.2	2.5
30s	11.4	17.2	17.7	13.6	6.0	13.4
40s	14.7	18.4	21.4	25.3	21.9	20.3
50s	20.1	19.5	24.2	24.4	32.1	23.9
60 or above	47.4	41.2	35.2	36.1	39.9	39.9
Sex						
Male	54.6	67.5	80.9	88.6	90.5	76.3
Female	45.4	32.5	19.1	11.4	9.5	23.7
Education						
Elementary school	35.8	27.4	17.5	12.4	6.4	20.1
Middle school	13.4	11.8	12.5	10.6	6.2	11.0
High school	33.7	34.6	33.6	33.2	27.7	32.6
Postsecondary school	17.1	26.3	36.3	43.8	59.7	36.3
Household size						
1	51.9	29.2	14.1	7.4	5.2	21.6
2	25.8	31.6	33.4	28.9	31.0	30.3
3-4	19.5	34.2	46.1	55.0	54.2	41.7
5-6	2.6	4.8	6.3	8.4	9.2	6.3
7+	0.1	0.1	0.1	0.3	0.3	0.2
Housing type						
Own housing	13.3	56.1	77.7	85.8	87.4	64.2
Lump-sum deposit rent	20.1	25.6	16.6	10.8	10.5	17.0
Monthly rent	43.3	12.7	3.4	1.5	0.6	12.1
Free housing	23.3	5.6	2.3	1.9	1.4	6.7
Location						
Seoul Metropolitan Area	30.3	31.2	28.0	32.5	44.3	33.1
Other	69.7	68.8	72.0	67.5	55.7	66.9
Employment type						
Regular	24.3	35.9	44.5	45.5	46.1	39.3
Temporary	21.5	18.8	10.2	6.4	2.8	12.1
Self-employed	12.2	21.1	26.9	31.2	30.9	24.4
Unemployed etc.	42.0	24.2	18.5	16.9	20.1	24.2
Annual income quintile in Year 0						
Bottom (0-20%)	55.6	31.1	17.1	9.6	5.1	23.7
Second (20-40%)	25.1	29.4	23.2	16.5	9.1	21.0
Middle (40-60%)	13.2	21.2	24.8	21.2	14.7	19.2
Fourth (60-80%)	5.3	13.8	23.5	27.9	21.2	18.3
Top (80-100%)	0.9	4.6	11.5	24.8	49.8	17.8
Observations	1,854	2,186	2,032	1,900	1,872	9,844

Note: This table shows the shares of households by demographic groups for the full sample of 9,844 households that had a positive net worth in Year 0 and Year 2. *Sex* refers to the sex of *Lump-sum deposit rent* (or, *Jeonse*) refers to a housing arrangement unique to Korea of having the tenant pay a large one-time deposit returned at the end of the lease. *Free housing* refers to free housing such as that provided by employers.

Table A.2. Effects of Stricter LTV Ceiling on Net Worth Positivity

	Dependent Variable: Net Worth Positivity (1 if positive, 0 otherwise)											
	Households with a negative net worth in Year 0						Households with a positive net worth in Year 0					
Independent Variable	(1) Year 1	(2) Year 2	(3) Year 1	(4) Year 2	(5) Year 1	(6) Year 2	(1) Year 1	(2) Year 2	(3) Year 1	(4) Year 2	(5) Year 1	(6) Year 2
Stricter LTV ceiling (D)	0.522	0.163	-0.286	0.879	-0.465	0.862	-0.007	-0.011*	-0.007	-0.01	-0.006	-0.009
	(0.415)	(0.230)	(0.757)	(0.728)	(0.417)	(0.756)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Centered Annual Income (x)	0.006	0.036	0.085	0.023	0.089	0.023	0.001*	0.001***	0.001*	0.001***	0.001*	0.001***
	(0.037)	(0.026)	(0.050)	(0.036)	(0.056)	(0.039)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$D \times x$	-0.118**	-0.090**	-0.143*	-0.143	-0.083	-0.138	-0.001	-0.002**	-0.001	-0.002**	-0.001	-0.002**
	(0.049)	(0.039)	(0.072)	(0.089)	(0.097)	(0.099)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Constant	0.486	0.901***	0.813	0.973***	1.061***	0.996***	1.000***	1.004***	1.000***	1.008***	1.003***	1.010***
	(0.356)	(0.207)	(0.479)	(0.173)	(0.269)	(0.182)	(0.003)	(0.002)	(0.005)	(0.004)	(0.004)	(0.005)
Controls												
Age, sex, & education			✓	✓	✓	✓			✓	✓	✓	✓
Residence in Seoul					✓	✓					✓	✓
Observations	19	19	19	19	19	19	2006	2006	2006	2006	2006	2006
Adjusted R-squared	0.065	-0.016	0.157	0.459	0.493	0.373	0.000	0.003	-0.002	0.002	0.000	0.003

Note: Numbers without parentheses represent estimates of regression coefficients on the independent variables of Equation (3). See Note for Table 6 for variable definitions. Stars *, **, and *** indicate that the estimates differ significantly from zero with 90%, 95%, and 99% confidence.

Table A.3. Effects of Stricter LTV Ceiling on Household Log Net Worth by Initial Net Worth Quartile

	Dependent Variable: Cumulative Change in Log Net Worth					
Initial Net Worth Quartile and Stricter LTV Ceiling (*D*)	(1) Year 1	(2) Year 2	(3) Year 1	(4) Year 2	(5) Year 1	(6) Year 2
Bottom (poorest) × *D*	-0.572	-0.751*	-0.564	-0.721*	-0.565	-0.718*
	(0.364)	(0.388)	(0.359)	(0.382)	(0.360)	(0.385)
Second × *D*	-0.071	0.011	-0.077	0.004	-0.079	-0.001
	(0.116)	(0.148)	(0.117)	(0.148)	(0.117)	(0.148)
Third × *D*	-0.025	-0.108**	-0.022	-0.116**	-0.022	-0.117**
	(0.038)	(0.050)	(0.038)	(0.049)	(0.038)	(0.049)
Top (wealthiest) × *D*	-0.003	0.012	-0.002	0.012	-0.003	0.009
	(0.044)	(0.064)	(0.045)	(0.065)	(0.045)	(0.064)
Bottom (poorest)	0.633***	0.736***	0.673***	0.766***	0.663***	0.743***
	(0.224)	(0.227)	(0.227)	(0.229)	(0.227)	(0.230)
Second	0.133**	0.230***	0.170***	0.259***	0.164***	0.245***
	(0.053)	(0.060)	(0.059)	(0.063)	(0.058)	(0.063)
Third	0.043	0.118***	0.082**	0.155***	0.076**	0.140***
	(0.029)	(0.033)	(0.035)	(0.042)	(0.035)	(0.043)
Top (wealthiest)	0.027	0.101***	0.071**	0.136***	0.063*	0.116***
	(0.028)	(0.037)	(0.033)	(0.042)	(0.034)	(0.043)
Controls						
Age, sex, & education			✓	✓	✓	✓
Residence in Seoul					✓	✓
Observations	1,993	1,987	1,993	1,987	1,993	1,987
Adjusted R-squared	0.076	0.076	0.082	0.088	0.083	0.090

Note: Numbers without parentheses represent estimates of regression coefficients on the selected independent variables in Equation (3). See Note for Table 7 for variable definitions. Stars *, **, and *** indicate that the estimates differ significantly from zero with 90%, 95%, and 99% confidence.

Table A.4. Effects of Stricter LTV Ceiling on Household Log Net Worth by Initial Net Worth Tercile

	Dependent Variable: Cumulative Change in Log Net Worth					
Initial Net Worth Tercile and Stricter LTV Ceiling (*D*)	(1) Year 1	(2) Year 2	(3) Year 1	(4) Year 2	(5) Year 1	(6) Year 2
Bottom (poorest) × *D*	-0.399	-0.458	-0.405	-0.451	-0.407	-0.453
	(0.277)	(0.306)	(0.278)	(0.307)	(0.279)	(0.309)
Middle × *D*	0.004	-0.052	0.001	-0.064	0.000	-0.065
	(0.040)	(0.064)	(0.040)	(0.063)	(0.040)	(0.063)
Top (wealthiest) × *D*	-0.035	-0.028	-0.032	-0.028	-0.034	-0.031
	(0.036)	(0.048)	(0.036)	(0.048)	(0.036)	(0.048)
Bottom (poorest)	0.372***	0.500***	0.411***	0.530***	0.402***	0.510***
	(0.129)	(0.144)	(0.133)	(0.148)	(0.133)	(0.149)
Middle	0.061*	0.141***	0.099**	0.174***	0.092**	0.157***
	(0.034)	(0.037)	(0.041)	(0.046)	(0.040)	(0.047)
Top (wealthiest)	0.045*	0.114***	0.086***	0.152***	0.079***	0.134***
	(0.023)	(0.029)	(0.029)	(0.035)	(0.030)	(0.036)
Controls						
Age, sex, & education			✓	✓	✓	✓
Residence in Seoul					✓	✓
Observations	1,993	1,987	1,993	1,987	1,993	1,987
Adjusted R-squared	0.058	0.057	0.065	0.071	0.066	0.073

Note: Numbers without parentheses represent estimates of regression coefficients on the selected independent variables in Equation (3). See Note for Table 7 for variable definitions. Stars *, **, and *** indicate that the estimates differ significantly from zero with 90%, 95%, and 99% confidence.

Table A.5. Effects of Stricter LTV Ceiling on Household Log Net Worth by Initial Net Worth Decile

	Dependent Variable: Cumulative Change in Log Net Worth					
Initial Net Worth Decile and Stricter LTV Ceiling (*D*)	(1) Year 1	(2) Year 2	(3) Year 1	(4) Year 2	(5) Year 1	(6) Year 2
Bottom (poorest) × *D*	-0.006	-0.434	-0.006	-0.518	-0.006	-0.514
	(0.006)	(0.617)	(0.006)	(0.615)	(0.006)	(0.613)
Second × *D*	-1.077**	-1.527***	-1.049**	-1.485***	-1.051**	-1.484***
	(0.532)	(0.560)	(0.525)	(0.548)	(0.526)	(0.551)
Third × *D*	-0.047	-0.039	-0.071	-0.056	-0.072	-0.058
	(0.435)	(0.457)	(0.445)	(0.472)	(0.446)	(0.474)
Fourth × *D*	-0.036	0.049	-0.043	0.050	-0.045	0.043
	(0.099)	(0.149)	(0.098)	(0.147)	(0.099)	(0.147)
Middle × *D*	-0.055	0.013	-0.057	0.001	-0.057	0.001
	(0.095)	(0.188)	(0.094)	(0.181)	(0.094)	(0.181)
Sixth × *D*	0.014	-0.156*	0.013	-0.162**	0.012	-0.165**
	(0.054)	(0.085)	(0.055)	(0.082)	(0.055)	(0.081)
Seventh × *D*	-0.020	-0.057	-0.020	-0.077	-0.019	-0.075
	(0.063)	(0.084)	(0.063)	(0.084)	(0.063)	(0.084)
Eighth × *D*	-0.076	-0.059	-0.057	-0.035	-0.058	-0.038
	(0.064)	(0.066)	(0.062)	(0.068)	(0.062)	(0.068)
Ninth × *D*	0.123*	0.094	0.124*	0.097	0.122*	0.093
	(0.066)	(0.093)	(0.066)	(0.095)	(0.066)	(0.095)
Top (wealthiest) × *D*	-0.075	-0.060	-0.086	-0.091	-0.086	-0.091
	(0.068)	(0.125)	(0.069)	(0.121)	(0.069)	(0.121)
Bottom (poorest)	2.088***	2.064***	2.161***	2.193***	2.144***	2.143***
	(0.323)	(0.617)	(0.315)	(0.615)	(0.315)	(0.613)
Second	0.852***	1.051***	0.884***	1.091***	0.877***	1.070***
	(0.316)	(0.297)	(0.317)	(0.289)	(0.317)	(0.290)
Third	0.122	0.094	0.167	0.133	0.163	0.120
	(0.127)	(0.157)	(0.130)	(0.155)	(0.130)	(0.154)
Fourth	0.149**	0.269***	0.189***	0.300***	0.187***	0.292***
	(0.065)	(0.095)	(0.069)	(0.097)	(0.069)	(0.097)
Middle	0.137*	0.250***	0.168**	0.276***	0.164*	0.264***
	(0.082)	(0.080)	(0.086)	(0.082)	(0.085)	(0.080)
Sixth	0.053	0.167***	0.090**	0.205***	0.087*	0.194***
	(0.041)	(0.058)	(0.046)	(0.064)	(0.046)	(0.065)
Seventh	0.026	0.067	0.067	0.110**	0.063	0.098*
	(0.051)	(0.051)	(0.052)	(0.055)	(0.053)	(0.056)
Eighth	0.029	0.097**	0.065	0.133***	0.061	0.121**
	(0.041)	(0.045)	(0.046)	(0.051)	(0.046)	(0.052)
Ninth	-0.039	0.053	-0.008	0.082	-0.013	0.066
	(0.050)	(0.056)	(0.052)	(0.060)	(0.052)	(0.061)
Top (wealthiest)	0.093**	0.165***	0.144***	0.205***	0.137***	0.187***
	(0.038)	(0.064)	(0.043)	(0.063)	(0.044)	(0.065)
Controls						
Age, sex, & education			✓	✓	✓	✓
Residence in Seoul					✓	✓
Observations	1,993	1,987	1,993	1,987	1,993	1,987
Adjusted R-squared	0.106	0.132	0.114	0.146	0.114	0.147

Note: Numbers without parentheses represent estimates of regression coefficients on the selected independent variables in Equation (3). See Note for Table 7 for variable definitions. Stars *, **, and *** indicate that the estimates differ significantly from zero with 90%, 95%, and 99% confidence.

Table A.6. Effects of Stricter LTV Ceiling on Household Net Worth by Initial Net Worth Quintile and Homeowner Status: Robustness to Bandwidth and Kernel Choices

	Dependent Variable: Log Net Worth							
	Year 1				Year 2			
Groups	Observa-tions	Band-width	Estimate	Std Err	Observa-tions	Band-width	Estimate	Std Err
All households	2,081	18.8	-0.049	0.037	1,936	17.6	-0.082	0.048
Net worth quintile in Year 0								
Bottom (poorest)	64	17.9	-1.096*	0.568	54	16.941	-1.351**	0.658
Second	595	31.7	0.052	0.127	211	14.379	-0.064	0.223
Middle	659	21.5	-0.014	0.046	622	20.433	-0.103	0.083
Fourth	789	22.6	-0.045	0.043	656	19.111	-0.064	0.054
Top (wealthiest)	559	20.5	0.017	0.049	599	21.950	0.031	0.073
Homeowner status in Year 0								
Non-homeowner	794	40.5	-0.176	0.134	412	26.4	-0.420**	0.179
Homeowner	2,088	21.2	-0.018	0.028	2,017	20.5	-0.015	0.041

Note: This table shows the estimated heterogeneous treatment effects using Calonico et al. (2015)'s R package *rdrobust*. Each estimate is from a separate regression using the relevant subsample of households by their initial net worth quintile and initial homeowner status. Each regression uses the optimal bandwidth choice algorithm by Imbens and Kalyanaraman (2012) and the triangular kernel function. Reported standard errors are heteroskedasticity-robust. Stars *, **, and *** indicate that the estimates differ significantly from zero with 90%, 95%, and 99% confidence using conventional confidence intervals.

Table A.7. Effects of Stricter LTV Ceiling on Household Log Net Worth by Initial Net Worth Quintile: 1% Winsorization

	Dependent Variable: Cumulative Change in Log Net Worth					
Initial Net Worth Quintile and Stricter LTV Ceiling (*D*)	(1) Year 1	(2) Year 2	(3) Year 1	(4) Year 2	(5) Year 1	(6) Year 2
Bottom (poorest) × *D*	-0.990**	-1.364**	-0.972**	-1.323**	-0.970**	-1.310**
	(0.459)	(0.544)	(0.455)	(0.536)	(0.458)	(0.540)
Second × *D*	0.028	0.041	0.016	0.036	0.013	0.031
	(0.123)	(0.183)	(0.124)	(0.185)	(0.124)	(0.184)
Middle × *D*	-0.013	-0.098	-0.013	-0.103	-0.013	-0.102
	(0.049)	(0.084)	(0.049)	(0.081)	(0.050)	(0.081)
Fourth × *D*	-0.047	-0.056	-0.039	-0.054	-0.04	-0.056
	(0.046)	(0.054)	(0.045)	(0.054)	(0.045)	(0.054)
Top (wealthiest) × *D*	0.018	0.02	0.013	0.009	0.012	0.008
	(0.048)	(0.077)	(0.049)	(0.077)	(0.049)	(0.076)
Bottom (poorest)	0.818***	0.981***	0.856***	1.022***	0.839***	0.985***
	(0.300)	(0.289)	(0.299)	(0.284)	(0.302)	(0.287)
Second	0.137**	0.207**	0.178***	0.237***	0.162**	0.207**
	(0.060)	(0.082)	(0.064)	(0.084)	(0.068)	(0.093)
Middle	0.085**	0.191***	0.119***	0.220***	0.097	0.179**
	(0.040)	(0.045)	(0.046)	(0.051)	(0.064)	(0.077)
Fourth	0.028	0.080**	0.065*	0.115***	0.042	0.072
	(0.035)	(0.035)	(0.038)	(0.042)	(0.055)	(0.067)
Top (wealthiest)	0.035	0.106**	0.071**	0.133***	0.044	0.083
	(0.032)	(0.042)	(0.036)	(0.045)	(0.052)	(0.069)
Controls						
Age, sex, & education			✓	✓	✓	✓
Residence in Seoul					✓	✓
Observations	1,993	1,987	1,993	1,987	1,993	1,987
Adjusted R-squared	0.095	0.105	0.102	0.118	0.103	0.119

Note: Numbers without parentheses represent estimates of regression coefficients on the selected independent variables in Equation (3). Stricter LTV ceiling (D) is a dummy variable that equals one if the household faces the LTV ceiling of 40% and 0 if it faces 50%. The controls age, sex, and education refer to those of the householder. Residence in Seoul equals one if the household lives in Seoul Metropolitan Area and equals zero otherwise. Numbers in parentheses are heteroske-dasticity-robust standard errors. Stars *, **, and *** indicate that the estimates differ significantly from zero with 90%, 95%, and 99% confidence.

Table A.8. Effects of Stricter LTV Ceiling on Household Log Net Worth by Initial Net Worth Quintile: 2% Winsorization

	Dependent Variable: Cumulative Change in Log Net Worth					
Initial Net Worth Quintile and Stricter LTV Ceiling (*D*)	(1) Year 1	(2) Year 2	(3) Year 1	(4) Year 2	(5) Year 1	(6) Year 2
Bottom (poorest) × *D*	-0.818**	-1.377**	-0.803**	-1.337**	-0.799**	-1.327**
	(0.364)	(0.536)	(0.362)	(0.528)	(0.364)	(0.533)
Second × *D*	0.052	0.09	0.043	0.087	0.041	0.082
	(0.105)	(0.150)	(0.106)	(0.151)	(0.106)	(0.151)
Middle × *D*	-0.008	-0.094	-0.008	-0.099	-0.007	-0.099
	(0.045)	(0.083)	(0.045)	(0.079)	(0.045)	(0.079)
Fourth × *D*	-0.045	-0.053	-0.038	-0.052	-0.039	-0.054
	(0.045)	(0.053)	(0.044)	(0.054)	(0.044)	(0.054)
Top (wealthiest) × *D*	0.020	0.028	0.015	0.019	0.015	0.017
	(0.048)	(0.076)	(0.049)	(0.076)	(0.049)	(0.075)
Bottom (poorest)	0.758***	0.994***	0.788***	1.038***	0.770***	1.003***
	(0.245)	(0.273)	(0.244)	(0.267)	(0.245)	(0.271)
Second	0.137**	0.206**	0.168***	0.237***	0.149**	0.211**
	(0.060)	(0.082)	(0.062)	(0.083)	(0.065)	(0.091)
Middle	0.080**	0.185***	0.105***	0.215***	0.08	0.180**
	(0.035)	(0.043)	(0.040)	(0.048)	(0.054)	(0.071)
Fourth	0.029	0.080**	0.057	0.115***	0.031	0.079
	(0.034)	(0.035)	(0.036)	(0.041)	(0.050)	(0.064)
Top (wealthiest)	0.032	0.099**	0.059*	0.123***	0.029	0.079
	(0.032)	(0.041)	(0.035)	(0.044)	(0.048)	(0.066)
Controls						
Age, sex, & education			✓	✓	✓	✓
Residence in Seoul					✓	✓
Observations	1,993	1,987	1,993	1,987	1,993	1,987
Adjusted R-squared	0.092	0.108	0.099	0.123	0.100	0.125

Note: Numbers without parentheses represent estimates of regression coefficients on the selected independent variables in Equation (3). Stricter LTV ceiling (D) is a dummy variable that equals one if the household faces the LTV ceiling of 40% and 0 if it faces 50%. The controls age, sex, and education refer to those of the householder. Residence in Seoul equals one if the household lives in Seoul Metropolitan Area and equals zero otherwise. Numbers in parentheses are heteroske-dasticity-robust standard errors. Stars *, **, and *** indicate that the estimates differ significantly from zero with 90%, 95%, and 99% confidence.

Table A.9. Decomposition of the Effects of Stricter LTV Ceiling by Initial Net Worth Quintile

	Year 1					Year 2				
Dependent Variable	Bottom	Second	Middle	Fourth	Top	Bottom	Second	Middle	Fourth	Top
Net Worth	-70.9*	1.6	-16.5	-21.0	-27.1	-160.4**	12.7	-22.2	-12.8	125.5
	(36.6)	(13.4)	(18.0)	(14.5)	(51.8)	(81.3)	(20.2)	(27.2)	(20.4)	(169.3)
Financial assets	-65.2*	-10.2	-2.0	-8.7	5.4	-49.2	-0.1	-18.3	-5.0	-9.7
	(34.9)	(9.2)	(7.5)	(11.2)	(29.5)	(38.6)	(13.1)	(16.0)	(12.8)	(32.6)
Real estate	61.1	14.9	-14.8	-5.6	-8.2	-57.9	0.2	-3.4	5.5	215.5
	(45.9)	(14.4)	(20.2)	(16.3)	(58.6)	(75.0)	(22.0)	(25.6)	(21.9)	(186.0)
Other real assets	-6.3	3.5	-5.4**	0.2	-1.1	-14.8	-1.6	-4.0	1.7	-38.5
	(6.8)	(3.9)	(2.6)	(3.2)	(9.4)	(11.9)	(4.3)	(5.5)	(4.9)	(55.1)
Unsecured credit debt	-10.5	-4.4	-4.3	1.8	-0.6	-14.5	-4.0	3.2	4.3	5.1
	(15.4)	(3.6)	(5.6)	(3.8)	(3.5)	(11.7)	(6.4)	(5.5)	(7.0)	(7.1)
Mortgage debt	65.1	9.3	3.8	3.8	12.9	40.6	7.8	8.3	3.5	11.1
	(51.6)	(7.6)	(5.7)	(6.8)	(16.1)	(26.0)	(11.7)	(9.9)	(9.2)	(16.5)
Other debt	5.9	1.6	-5.2	1.4	11.0	12.4	-18.0*	-14.9	7.1	25.6
	(31.8)	(3.8)	(6.1)	(5.7)	(15.6)	(43.4)	(10.8)	(10.7)	(7.5)	(33.3)
Observations	92	278	540	626	489	92	278	540	626	489

Note: Numbers without parentheses represent the estimated Year-1 and Year-2 treatment effects on the dependent variables of a stricter loan-to-value ratio (LTV) ceiling by ten percentage points, from 50% to 40%, conditional on the household's initial net worth quintile. Numbers in parentheses are heteroskedasticity-robust standard errors. Stars *, **, and *** indicate that the estimates differ significantly from zero with 90%, 95%, and 99% confidence.

Table A.10. Decomposition of the Intercepts for Control Households by Initial Net Worth Quintile

	Year 1					Year 2				
Dependent variable	Bot-tom	Second	Middle	Fourth	Top	Bottom	Second	Middle	Fourth	Top
Net Worth	76.2**	19.2**	34.8**	21.7**	79.5**	166.1**	32.3***	59.9***	44.2***	156.5***
	(35.6)	(7.8)	(17.0)	(10.1)	(31.4)	(80.2)	(11.1)	(17.7)	(12.2)	(48.6)
Financial assets	68.8**	10.1*	14.4**	5.3	17.6	64.1*	16.7**	33.5***	11.2	27.2
	(34.4)	(5.9)	(5.8)	(8.0)	(23.4)	(35.1)	(8.0)	(8.4)	(9.2)	(24.0)
Real estate	-60.0	1.8	28.3	17.0	64.0**	56.1	25.6*	31.6	30.2*	102.6
	(45.9)	(4.6)	(19.2)	(12.5)	(32.5)	(74.9)	(14.7)	(20.7)	(15.9)	(72.6)
Other real assets	5.8*	0.0	2.6**	0.1	7.9	18.4*	1.3	6.9***	3.4	62.2
	(3.1)	(1.7)	(1.3)	(1.5)	(8.4)	(11.2)	(2.6)	(2.2)	(2.3)	(54.1)
Unsecured credit debt	8.6	-0.6	4.4	3.2	5.8**	8.9	3.2	0.1	4.9	5.3*
	(14.5)	(1.9)	(5.5)	(2.3)	(2.6)	(10.6)	(4.3)	(4.6)	(5.4)	(3.2)
Mortgage debt	-59.7	-6.4***	-2.5	-2.4	-1.6	-36.3	-1.9	-5.2	-3.0	0.8
	(51.2)	(2.3)	(3.7)	(5.0)	(9.9)	(25.3)	(5.3)	(5.4)	(6.0)	(8.4)
Other debt	-10.6	-0.4	8.6*	-0.1	5.8	-0.1	9.8*	17.1***	-1.4	29.4*
	(31.0)	(1.6)	(4.8)	(2.3)	(9.8)	(39.0)	(5.8)	(6.2)	(3.9)	(15.4)
Observations	92	278	540	626	489	92	278	540	626	489

Note: Numbers without parentheses represent the estimated intercept for non-treated households on Year-1 and Year-2 cumulative changes in the dependent variable, conditional on the household's initial net worth quintile. The treatment is a stricter loan-to-value ratio (LTV) ceiling by ten percentage points from 50% to 40%. Numbers in parentheses are heteroskedasticity-robust standard errors. Stars *, **, and *** indicate that the estimates differ significantly from zero with 90%, 95%, and 99% confidence.

Table A.11. Effects of Stricter LTV Ceiling on Household Net Worth by Initial Home Ownership

	Dependent Variable: Cumulative Change in Net Worth					
Initial Home Ownership and Stricter LTV Ceiling (*D*)	(1) Year 1	(2) Year 2	(3) Year 1	(4) Year 2	(5) Year 1	(6) Year 2
Non-homeowner × *D*	-29.4	-64.1*	-29.4	-65.2*	-29.5	-65.8*
	(34.4)	(36.3)	(34.4)	(36.8)	(34.4)	(37.4)
Homeowner × *D*	-19.0	31.6	-19.4	28.0	-20.1	25.6
	(16.7)	(51.9)	(16.6)	(48.6)	(16.4)	(47.8)
Non-homeowner	53.6	88.8***	57.2	106.2***	48.7	77.8**
	(33.2)	(33.6)	(35.2)	(35.4)	(34.6)	(34.9)
Homeowner	39.7***	78.5***	45.2***	100.4***	40.4***	84.6***
	(10.2)	(15.7)	(11.7)	(20.2)	(11.8)	(19.2)
Controls						
Age, sex, & education			✓	✓	✓	✓
Residence in Seoul					✓	✓
Observations	2,025	2,025	2,025	2,025	2,025	2,025
Adjusted R-squared	0.001	0.003	0.006	0.022	0.008	0.028

Note: Numbers without parentheses represent estimates of regression coefficients on the selected independent variables in Equation (3). Stricter LTV ceiling (D) is a dummy variable that equals one if the household faces the LTV ceiling of 40% and 0 if it faces 50%. A household is a *non-homeowner* if its real estate assets are zero in Year 0. A household is a *homeowner* if its real estate assets are positive in Year 0. The controls age, sex, and education refer to those of the householder. Residence in Seoul equals one if the household lives in Seoul Metropolitan Area and equals zero otherwise. Numbers in parentheses are heteroskedasticity-robust standard errors. Stars *, **, and *** indicate that the estimates differ significantly from zero with 90%, 95%, and 99% confidence.

Table A.12. Decomposition of the Effects of Stricter LTV Ceiling by Initial Home Ownership

Dependent variable	Year 1		Year 2	
	Non-homeowner	Homeowner	Non-homeowner	Home-owner
Net Worth	-29.4	-19.0	-64.2*	31.6
	(34.4)	(16.7)	(36.3)	(51.9)
Financial assets	-10.1	-4.6	-47.2	-3.2
	(30.9)	(8.5)	(31.3)	(10.6)
Real estate	-27.2	-1.6	-34.5	65.1
	(45.6)	(18.2)	(50.5)	(56.3)
Other real assets	8.2	-3.0	18.1	-15.9
	(6.3)	(2.9)	(14.8)	(15.8)
Unsecured credit debt	-14.4	0.3	-3.2	3.5
	(9.2)	(2.2)	(8.1)	(3.7)
Mortgage debt	8.1	8.9	7.4	7.8
	(5.5)	(6.2)	(10.2)	(6.7)
Other debt	6.6	0.5	-3.8	3.2
	(18.9)	(4.4)	(20.4)	(10.5)
Observations	266	1759	266	1759

Note: Numbers without parentheses represent the estimated Year-1 and Year-2 treatment effects on the dependent variables of a stricter loan-to-value ratio (LTV) ceiling by ten percentage points, from 50% to 40%, conditional on the household's initial net worth quintile. A household is a *non-homeowner* if its real estate assets are zero in Year 0. A household is a *homeowner* if its real estate assets are positive in Year 0. Numbers in parentheses are heteroskedasticity-robust standard errors. Stars *, **, and *** indicate that the estimates differ significantly from zero with 90%, 95%, and 99% confidence.

Table A.13. Decomposition of the Intercepts for Control Households by Initial Home Ownership

	Year 1		Year 2	
Dependent variable	Non-homeowner	Home-owner	Non-home-owner	Homeowner
Net Worth	53.6	39.7***	88.8***	78.5***
	(33.2)	(10.2)	(33.6)	(15.7)
Financial assets	15.5	13.5*	31.3	22.5***
	(20.3)	(7.1)	(21.7)	(7.6)
Real estate	64.0	21.6**	101.5**	42.0*
	(40.2)	(10.6)	(43.1)	(21.8)
Other real assets	0.2	3.4	2.1	21.9
	(1.4)	(2.5)	(2.6)	(15.5)
Unsecured credit debt	14.6	2.3	9.0	2.9
	(8.9)	(1.7)	(7.0)	(2.5)
Mortgage debt	-2.1	-5.3	7.0	-5.2
	(3.1)	(4.3)	(6.2)	(3.8)
Other debt	13.5	1.8	30.2**	10.1**
	(10.5)	(3.2)	(12.3)	(5.1)
Observations	266	1,759	266	1,759

Note: Numbers without parentheses represent the estimated intercept for non-treated households on Year-1 and Year-2 cumulative changes in the dependent variable, conditional on the household's initial home ownership status. The treatment is a stricter loan-to-value ratio (LTV) ceiling by ten percentage points from 50% to 40%. Numbers in parentheses are heteroskedasticity-robust standard errors. Stars *, **, and *** indicate that the estimates differ significantly from zero with 90%, 95%, and 99% confidence.

Table A.14. Effects of Stricter LTV Ceiling on Household Log Net Worth by Housing Types

Housing Type and Stricter LTV Ceiling (*D*)	*Dependent Variable:* Cumulative Change in Log Net Worth					
	(1)	(2)	(3)	(4)	(5)	(6)
	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
Own housing × *D*	-0.053*	-0.044	-0.051*	-0.046	-0.052*	-0.048
	(0.028)	(0.040)	(0.028)	(0.040)	(0.028)	(0.040)
Lump-sum deposit rent (*Jeonse*) × *D*	0.000	(0.114)	0.001	(0.109)	0.001	(0.109)
	(0.121)	(0.149)	(0.122)	(0.148)	(0.121)	(0.148)
Monthly rent × *D*	0.059	(0.157)	0.058	(0.187)	0.059	(0.180)
	(0.283)	(0.310)	(0.276)	(0.303)	(0.276)	(0.305)
Free housing × *D*	-0.536	-0.644	-0.541	-0.634	-0.542	-0.639
	(0.635)	(0.712)	(0.627)	(0.706)	(0.630)	(0.711)
Own housing	0.084***	0.144***	0.108***	0.156***	0.102***	0.140***
	(0.019)	(0.024)	(0.026)	(0.035)	(0.026)	(0.036)
Lump-sum deposit rent (*Jeonse*)	0.108	0.331***	0.119	0.313***	0.106	0.281**
	(0.112)	(0.108)	(0.116)	(0.111)	(0.115)	(0.112)
Monthly rent	0.089	0.105	0.114	0.127	0.105	0.106
	(0.195)	(0.203)	(0.191)	(0.198)	(0.192)	(0.198)
Free housing	(0.059)	0.091	(0.036)	0.084	(0.042)	0.072
	(0.226)	(0.290)	(0.227)	(0.298)	(0.227)	(0.296)
Controls						
Age, sex, & education			✓	✓	✓	✓
Residence in Seoul					✓	✓
Observations	1,993	1,987	1,993	1,987	1,993	1,987
Adjusted R-squared	0.021	0.026	0.027	0.035	0.028	0.037

Note: Numbers without parentheses represent estimates of regression coefficients on the selected independent variables in Equation (3). Stricter LTV ceiling (D) is a dummy variable that equals one if the household faces the LTV ceiling of 40% and 0 if it faces 50%. "Lump-sum deposit rent" (or, *Jeonse*) refers to a housing arrangement unique to Korea of having the tenant pay a large one-time deposit returned at the end of the lease. "Free housing" refers to free housing such as that provided by employers. The controls age, sex, and education refer to those of the householder. *Residence in Seoul* equals one if the household lives in Seoul Metropolitan Area and equals zero otherwise. Numbers in parentheses are heteroskedasticity-robust standard errors. Stars *, **, and *** indicate that the estimates differ significantly from zero with 90%, 95%, and 99% confidence.

B. Online Appendix

Model of macroprudential policy and household wealth

To examine the possible effects of macroprudential policies on wealth inequality, we introduce a two-period model in which investors with different initial wealth decide housing investment and labor inputs. The constraints on their investment include the available loans subject to a loan-to-value ratio (LTV) ceiling, the house price in each period, and the financial costs of borrowing. These constraints over the two periods determine the impact on wealth inequality.

There are two types of investors with large and small amounts of initial wealth b_h and b_l. They maximize their utilities over two periods by choosing their consumption, leisure, and stocks of housing. The utility of an investor is:

$$U_{t,i} = \ln c_t + j_t \ln H_t - l_t^{\eta}/\eta + \beta_i \left(\ln c_{t+1} + j_{t+1} \ln H_t - l_{t+1}^{\eta}/\eta \right), \quad i \in \{h, l\} \tag{B.1}$$

where c_t denotes consumption in period *t*, j_t is the parameter representing the marginal utility from holding housing stock H_t in period *t*, and l_t is the labor input in period *t*. Therefore, the term $-l_t^{\eta}/\eta$ represents the utility of leisure. The constant β_i is investor *i*'s discount factor, for which $\beta_h > \beta_l$.

The budget constraint in each period is given as follows[17]:

$$\text{Period-1 constraint: } b_i + H_t p_t \theta + w_t l_t = c_t + p_t H_t, \tag{B.2}$$

$$\text{Period-2 constraint: } H_t p_{t+1} + w_{t+1} l_{t+1} = c_{t+1} + (1 + r_t) H_t p_t \theta, \tag{B.3}$$

where b_i is the initial wealth of investor *i*, H_t is the housing stock in period *t*, p_t is the unit house price in period *t*, θ is the loan-to-value (LTV) ratio set by the macroprudential authority, and $H_t p_t \theta$ is the amount of the mortgage loan. The

[17] A la Foley (1975), an investor's discrete decision at the end of each period is constrained by both the initial stock of wealth and the labor income flow.

variable w_t is the wage in period *t*, and l_t is the labor input in period *t*. Therefore, investors in the first period consume and invest in houses with their initial wealth, mortgage loans, and labor income. Then, in the second period, the investors pay back their mortgage with their house and labor income and consume the rest.[18]

Investors' speculation affects the growth rate $\pi(\theta)$ of the unit house price as a function of the loan-to-value ratio (LTV) ceiling θ where $p_{t+1}(\theta)/p_t = 1+\pi(\theta)$. The wage is assumed to grow at the same rate as inflation, as $w_{t+1}(\phi)/w_t = 1+\phi(\theta)$ where $\phi(\theta)$ is the inflation rate.[19]

Analysis

Governments can implement ceilings for loan-to-value ratios (LTV) in two fashions: as a fraction of (a) the current house value ($L_t = H_t p_t \theta$) or (b) the expected (or forecasted) future house value ($L_t = H_t p_{t+1} \theta$). As in most developed countries, we restrict mortgage borrowing relative to the current instead of the future house value to avoid the possibly complicated issue of forecasting. Investors take the maximum available mortgage under the ceiling; hence, the loan amount taken is not a strategic variable. Also, investors do not save through other means besides purchasing houses in the first period. Therefore, they spend all of their remaining resources on consumption after purchasing houses in the first period. After repaying their mortgages in the second period, they spend the rest on consumption.

Then the strategic variables are the house investment (H_t) and labor input in each period (l_t and l_{t+1}). The rest—such as the LTV ceiling (θ), the discount factor

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[18] Houses in this model play two roles: (i) providing housing services and (ii) enabling the intertemporal substitution of consumption. Similarly, in Mian et al. (2021), houses serve a critical dual role of providing direct utility (through what they call "warm-glow bequest motive") as well as constituting a pledgeable real asset. Likewise, Piazzesi et al. (2007) models houses both as a source of housing services and claims to future services streams. In contrast, Mitkov and Schwer (2020) model houses solely as the collateral for mortgage loans.

[19] Our earlier manuscript included an assumption that house prices react more sensitively than the inflation rate to changes in macroprudential policy ($\pi'(\theta) > \phi'(\theta)$). However, this assumption is not essential and is not included. In addition, the empirical evidence is weak; for example, Arena et al. (2020) find a mixed impact of macroprudential policies on house prices.

(β_i), and the initial wealth (b_i)—are exogenous. The first-order conditions for the investors' utility maximization are:

$$\frac{\partial L}{\partial H_t} = F^1(H_t, l_t, l_{t+1}; \theta, b_i, \beta_i) = \frac{P_t(\theta - 1)}{c_t} + \frac{j_t}{H_t} + \beta\left(\frac{(1+\pi-(1+r)\theta)P_t}{c_{t+1}} + \frac{j_{t+1}}{H_t}\right) = 0 \qquad \text{(B.4)}$$

$$\frac{\partial L}{\partial l_t} = F^2(H_t, l_t, l_{t+1}; \theta, b_i, \beta_i) = \frac{w_t}{c_t} - l_t^{\eta-1} = 0 \qquad \text{(B.5)}$$

$$\frac{\partial L}{\partial l_{t+1}} = F^3(H_t, l_t, l_{t+1}; \theta, b_i, \beta_i) = \beta\left(\frac{(1+\phi_t)w_t}{c_{t+1}} - l_{t+1}^{\eta-1}\right) = 0 \qquad \text{(B.6)}$$

We linearize the above first-order conditions for the three strategic variables by taking total derivatives:

$$\frac{\partial F^1}{\partial H_t}dH_t + \frac{\partial F^1}{\partial l_t}dl_t + \frac{\partial F^1}{\partial l_{t+1}}dl_{t+1} + \frac{\partial F^1}{\partial \theta}d\theta + \frac{\partial F^1}{\partial \beta_i}d\beta_i = 0, \qquad \text{(B.7)}$$

$$\frac{\partial F^2}{\partial H_t}dH_t + \frac{\partial F^2}{\partial l_t}dl_t + \frac{\partial F^2}{\partial l_{t+1}}dl_{t+1} + \frac{\partial F^2}{\partial \theta}d\theta + \frac{\partial F^2}{\partial \beta_i}d\beta_i = 0, \qquad \text{(B.8)}$$

$$\frac{\partial F^3}{\partial H_t}dH_t + \frac{\partial F^3}{\partial l_t}dl_t + \frac{\partial F^3}{\partial l_{t+1}}dl_{t+1} + \frac{\partial F^3}{\partial \theta}d\theta + \frac{\partial F^3}{\partial \beta_i}d\beta_i = 0. \qquad \text{(B.9)}$$

We can rewrite the linearized first-order conditions as

$$\begin{bmatrix} \frac{\partial F^1}{\partial H_t} & \frac{\partial F^1}{\partial l_t} & \frac{\partial F^1}{\partial l_{t+1}} \\ \frac{\partial F^2}{\partial H_t} & \frac{\partial F^2}{\partial l_t} & \frac{\partial F^2}{\partial l_{t+1}} \\ \frac{\partial F^3}{\partial H_t} & \frac{\partial F^3}{\partial l_t} & \frac{\partial F^3}{\partial l_{t+1}} \end{bmatrix} \begin{bmatrix} dH_t \\ dl_t \\ dl_{t+1} \end{bmatrix} = -\begin{bmatrix} \frac{\partial F^1}{\partial \theta}d\theta + \frac{\partial F^1}{\partial \beta_i}d\beta_i \\ \frac{\partial F^2}{\partial \theta}d\theta + \frac{\partial F^2}{\partial \beta_i}d\beta_i \\ \frac{\partial F^3}{\partial \theta}d\theta + \frac{\partial F^3}{\partial \beta_i}d\beta_i \end{bmatrix}.$$

(B.10)

Let us simplify the above matrix by substituting the values of the FOC's partial derivatives with respect to the endogenous variables as follows:

$$\begin{bmatrix} -\frac{(1+\beta)j_t}{H_t^2} & 0 & 0 \\ 0 & -(\eta-1)l_t^{\eta-2} & 0 \\ 0 & 0 & -\beta_i(\eta-1)l_{t+1}^{\eta-2} \end{bmatrix} \begin{bmatrix} dH_t \\ dl_t \\ dl_{t+1} \end{bmatrix} = -\begin{bmatrix} \frac{\partial F^1}{\partial \theta}d\theta + \frac{\partial F^1}{\partial \beta_i}d\beta_i \\ \frac{\partial F^2}{\partial \theta}d\theta + \frac{\partial F^2}{\partial \beta_i}d\beta_i \\ \frac{\partial F^3}{\partial \theta}d\theta + \frac{\partial F^3}{\partial \beta_i}d\beta_i \end{bmatrix}. \qquad \text{(B.11)}$$

Then the impact of the LTV ceiling on the equilibrium amount of house investment is determined to be positive:

$$\frac{dH_t}{d\theta} = -\frac{\begin{vmatrix} \frac{\partial F^1}{\partial \theta} & 0 & 0 \\ \frac{\partial F^2}{\partial \theta} & -(\eta-1)l_t^{\eta-2} & 0 \\ \frac{\partial F^3}{\partial \theta} & 0 & -\beta_i(\eta-1)l_{t+1}^{\eta-2} \end{vmatrix}}{\begin{vmatrix} -\frac{(1+\beta)j_t}{H_t^2} & 0 & 0 \\ 0 & -(\eta-1)l_t^{\eta-2} & 0 \\ 0 & 0 & -\beta_i(\eta-1)l_{t+1}^{\eta-2} \end{vmatrix}} = -\frac{\begin{vmatrix} \frac{P_t}{c_t} - \frac{\beta_i(1+r)P_t}{c_{t+1}} & 0 & 0 \\ 0 & -(\eta-1)l_t^{\eta-2} & 0 \\ \frac{\beta_i\phi' w_t}{c_{t+1}} & 0 & -\beta_i(\eta-1)l_{t+1}^{\eta-2} \end{vmatrix}}{-\frac{j_t\beta_i(1+\beta_i)(\eta-1)^2 l_t^{\eta-2}l_{t+1}^{\eta-2}}{H_t^2}}$$

$$= \frac{\left(c_{t+1} - c_t(1+r)\beta_i\right)P_t H_t^2}{c_t c_{t+1} j_t(1+\beta_i)} > 0 \qquad if\ r < (c_{t+1} - c_t\beta_i)/c_t\beta_i.$$

(B.12)

The above result shows that a looser (higher) loan-to-value ratio (LTV) ceiling increases the equilibrium housing investment as long as the mortgage rate is lower than a critical level. The impact of the LTV ceiling on the investors' budget constraints is larger when their initial wealth is smaller and vice versa. As a result, the elasticity of housing investment to LTV ceiling changes is lower for (initially) wealthier investors. Likewise, the impact of the LTV policy changes on the budget constraints is larger for poorer investors; consequently, they have a higher elasticity of housing investment to LTV ceiling changes: $\varepsilon_{H_t(b_h)\theta} < \varepsilon_{H_t(b_l)\theta}$.[20] Therefore, a tighter (lower) LTV

[20] The higher elasticity of housing investment to LTV ceiling changes for poor investors can be shown as follows:

ceiling—a stricter macroprudential policy—can widen wealth inequality. Proposition 1 summarizes this result.

Proposition 1. The tightening macroprudential policy of decreasing the loan-to-value ratio (LTV) can worsen wealth inequality further from the initial gap in endowments $b_h - b_l$.

Proof. The equilibrium wealth inequality in the second period is defined as follows:

Wealth Inequality (WI): $WI = P_{t+1}(\theta)H^*_{b_h}(\theta) - P_{t+1}(\theta)H^*_{b_l}(\theta)$

Then the impact of the LTV ceiling change on wealth inequality is determined as follows:

$$\begin{aligned}
\frac{\partial WI}{\partial \theta} &= \frac{\partial P_{t+1}(\theta)}{\partial \theta}\left(H^*_{b_h}(\theta) - H^*_{b_l}(\theta)\right) + P_{t+1}(\theta)\left(\frac{\partial H^*_{b_h}(\theta)}{\partial \theta} - \frac{\partial H^*_{b_l}(\theta)}{\partial \theta}\right) \\
&= \left(\frac{\partial P_{t+1}(\theta)}{\partial \theta}\frac{\theta}{P_{t+1}}\left(H^*_{b_h}(\theta) - H^*_{b_l}(\theta)\right) + P_{t+1}(\theta)\frac{\theta}{P_{t+1}}\left(\frac{\partial H^*_{b_h}(\theta)}{\partial \theta} - \frac{\partial H^*_{b_l}(\theta)}{\partial \theta}\right)\right)\frac{P_{t+1}}{\theta} \qquad \text{(B.13)} \\
&< \left(\frac{\partial P_{t+1}(\theta)/P_{t+1}}{\partial \theta/\theta} - \left(\frac{\partial H^*_{b_l}(\theta)/H^*_{b_l}(\theta)}{\partial \theta/\theta} - \frac{\partial H^*_{b_h}(\theta)/H^*_{b_h}(\theta)}{\partial \theta/\theta}\right)\right)\frac{P_{t+1}\left(H^*_{b_h}(\theta) - H^*_{b_l}(\theta)\right)}{\theta} < 0
\end{aligned}$$

if $\varepsilon_{H_{b_l}\theta} - \varepsilon_{H_{b_h}\theta} > \varepsilon_{P_{(t+1)}\theta}$.

The impact of the LTV ceiling changes on the budget constraints is larger for poorer investors. As a result, the housing investment for poorer investors is more elastic to the LTV ceiling changes: that is, $\frac{dH_t(b_h)/H_t(b_h)}{d\theta/\theta} < \frac{dH_t(b_l)/H_t(b_l)}{d\theta/\theta}$. Since wealthier investors are less sensitive to LTV ceiling changes and own a larger share of total houses, the change in the house price is limited. Therefore, a stricter (lower)

$$\varepsilon_{H_{b_l}\theta} - \varepsilon_{H_{b_h}\theta} = \frac{\partial H^*_{b_l}(\theta)/H^*_{b_l}(\theta)}{\partial \theta/\theta} - \frac{\partial H^*_{b_h}(\theta)/H^*_{b_h}(\theta)}{\partial \theta/\theta} = \frac{\partial H^*_{b_l}(\theta)}{\partial \theta}\frac{\theta}{H^*_{b_l}(\theta)} - \frac{\partial H^*_{b_h}(\theta)}{\partial \theta}\frac{\theta}{H^*_{b_h}(\theta)}$$

As assumed, the initial asset endowment of the wealthier is higher than the poor as follows: $b_h > b_l$. Then, the budget constraint for the two types of investors to invest in housing show the following asymmetry:

$$H_{b_l} = (b_l + w_t l_t - c_t)/p_t(1-\theta) < H_{b_h} = (b_h + w_t l_t - c_t)/p_t(1-\theta)$$

$$\begin{aligned}
\varepsilon_{H_{b_l}\theta} - \varepsilon_{H_{b_h}\theta} &= \frac{\partial H^*_{b_l}(\theta)/H^*_{b_l}(\theta)}{\partial \theta/\theta} - \frac{\partial H^*_{b_h}(\theta)/H^*_{b_h}(\theta)}{\partial \theta/\theta} = \frac{\partial H^*_{b_l}(\theta)}{\partial \theta}\frac{\theta}{H^*_{b_l}(\theta)} - \frac{\partial H^*_{b_h}(\theta)}{\partial \theta}\frac{\theta}{H^*_{b_h}(\theta)} \\
&= \left(\frac{\theta}{1-\theta}\right)\left(\frac{1}{b_l + w_t l_t - c_t} - \frac{1}{b_h + w_t l_t - c_t}\right) > 0 \quad \text{since } b_l < b_h.
\end{aligned}$$

LTV ratio worsens the existing wealth inequality when the elasticity $\varepsilon_{P_{(t+1)}\theta}$ of house price to LTV ceiling changes is lower than the difference $\varepsilon_{H_{b_l}\theta} - \varepsilon_{H_{b_h}\theta}$ between the poor and wealthy households' elasticities of housing investment to LTV ceiling changes. □

Given the initial inequality in endowments, stricter macroprudential policies such as a lower LTV ceiling have a more significant impact on poorer households, thus aggravating wealth inequality.

Wealthier investors have higher flexibility in the intertemporal decision of consumption and investment. That is, they have a higher discount factor $\beta_h > \beta_l$. Consequently, wealthier investors increase their housing investment in the first period, widening the wealth inequality in the following period since their relative weight of period-2 utility is higher than that of the poor. Corollary 1 summarizes this result.

Corollary 1. Since the discount factor is greater for the wealthy than the poor ($\beta_h > \beta_l$), the wealthy increase housing investment in response to a stricter LTV ceiling, resulting in increased wealth inequality.

References for Online Appendix

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Table B.1. Summary Statistics of Household Finances in Year 0

Variable	Mean	SD	Percentile				
			0%	25%	50%	75%	100%
Panel A: Full sample							
Assets	361.1	574.2	0.0	69.2	207.5	435.8	16054.8
Financial	89.6	179.4	0.0	11.3	41.7	103.9	8080.0
Real estate	254.0	472.3	0.0	0.0	130.0	310.0	14600.0
Other real assets	17.5	50.3	0.0	0.0	5.0	17.9	1613.0
Liabilities	60.2	174.6	0.0	0.0	5.0	57.0	7400.0
Unsecured credit debt	5.4	23.6	0.0	0.0	0.0	0.0	610.0
Mortgage debt	31.9	126.2	0.0	0.0	0.0	13.0	6900.0
Other debt	22.8	84.4	0.0	0.0	0.0	7.1	2700.0
Net worth	300.9	480.3	-280.1	54.0	170.4	368.0	9594.0
Annual Income	50.1	48.6	0.0	17.8	38.1	66.8	821.1
Loan-to-value ratio (%)	8.3	17.4	0.0	0.0	0.0	5.8	100.0
Panel B: Subsample							
Assets	465.1	426.8	2.9	212.7	347.0	563.5	3978.8
Financial	115.1	131.0	0.1	35.5	75.5	146.2	1501.8
Real estate	325.3	376.5	0.0	119.5	230.0	400.0	3400.0
Other real assets	24.7	47.7	0.0	5.2	13.0	26.0	715.0
Liabilities	85.3	153.7	0.0	0.0	30.0	104.5	2120.0
Unsecured credit debt	7.6	24.5	0.0	0.0	0.0	0.0	380.0
Mortgage debt	47.7	104.4	0.0	0.0	0.0	60.0	2000.0
Other debt	30.0	83.9	0.0	0.0	0.0	15.0	1300.0
Net worth	379.8	372.3	-270.8	164.0	280.6	464.8	3956.8
Annual Income	69.1	10.6	52.0	60.3	68.1	78.2	97.9
Loan-to-value ratio (%)	13.3	20.3	0.0	0.0	0.0	22.9	100.0

Note: This table shows the summary statistics of South Korean households' balance sheets and annual income reported in 2017 in the *Survey of Household Finances and Living Conditions*. The unit is a million South Korean won (KRW). A *loan-to-value ratio* is the size of a household's mortgage debt relative to the value of its real estate assets. Panel A is for the full sample of 10,251 households. Panel B is for the subsample of 2,025 households. Both the full sample and the subsample include households with non-positive net worth. The subsample consists of (a) households whose annual income is between 52 and 88 million South Korean won (KRW) and have nonzero real estate assets, and (b) households whose annual income is between 62 and 98 million KRW and have zero real estate assets.

Table B.2. Household Income, Wealth, and Mortgages in Year 0

Statistic	Net worth quintile in Year 0					All
	Bottom (poorest)	Second	Middle	Fourth	Top (wealthiest)	
Panel A: Full sample						
Observations	2,222	2,207	2,043	1,904	1,875	10,251
Mean annual income	22.0	33.6	45.9	60.9	96.6	50.1
Mean net worth	10.9	84.9	189.3	346.1	974.8	300.9
% with net worth > 0	87.9	100.0	100.0	100.0	100.0	97.4
Mean real estate assets	8.1	66.9	155.0	290.0	837.0	254.0
% with real estate assets > 0	14.6	63.4	87.3	95.6	98.0	69.9
Mean mortgage debt	4.6	17.7	28.1	35.0	82.1	31.9
% with mortgage debt > 0	4.4	25.0	36.6	37.2	36.2	27.1
Mean loan-to-value ratio (LTV) among those with positive mortgage	66.0	41.7	32.5	24.3	20.9	30.6
% with LTV						
≥ 40%	81.4	52.3	34.4	16.8	14.2	30.2
≥ 50%	76.3	38.3	19.9	8.3	6.9	19.4
≥ 60%	60.8	22.3	7.0	3.2	3.2	10.0
≥ 70%	44.3	8.3	1.7	1.0	1.2	4.2
≥ 80%	36.1	4.5	1.2	0.6	0.7	2.8
≥ 90%	25.8	1.3	0.7	0.3	0.4	1.5
Panel B: Subsample						
Observations	92	278	540	626	489	2,025
Mean annual income	71.7	68.1	67.9	69.5	70.2	69.1
Mean net worth	6.6	93.4	193.7	349.0	857.7	379.8
% with net worth > 0	79.3	100.0	100.0	100.0	100.0	99.1
Mean real estate assets	53.6	94.9	158.8	291.4	734.5	325.3
% with real estate assets > 0	23.9	69.1	87.2	95.5	97.3	86.9
Mean mortgage debt	47.1	40.7	40.0	43.5	65.8	47.7
% with mortgage debt > 0	16.3	43.5	50.7	45.2	35.6	42.8
Mean loan-to-value ratio (LTV) among those with positive mortgage	74.6	50.1	33.0	25.2	20.9	31.1
% with LTV						
≥ 40%	100.0	69.4	35.0	17.3	12.1	30.6
≥ 50%	93.3	52.1	19.3	7.8	7.5	19.0
≥ 60%	80.0	34.7	5.8	3.2	2.3	9.6
≥ 70%	66.7	13.2	0.7	0.4	1.1	3.6
≥ 80%	46.7	9.1	0.7	0.4	0.0	2.4
≥ 90%	26.7	4.1	0.4	0.4	0.0	1.3

Note: This table shows the summary statistics of South Korean households' income, wealth, and mortgages in 2017 in the *Survey of Household Finances and Living Conditions*. The unit for mean values is a million South Korean won (KRW). A *loan-to-value ratio* is the size of a household's mortgage debt relative to the value of its real estate assets. Panel A is for the full sample of 10,251 households. Panel B is for the subsample of 2,025 households. Both the full sample and the subsample include households with non-positive net worth. The subsample consists of (a) households whose annual income is between 52 and 88 million South Korean won (KRW) and have nonzero real estate assets, and (b) households whose annual income is between 62 and 98 million KRW and have zero real estate assets.

Table B.3. Absolute Changes in Household Net Worth

Cumulative change in net worth from Year 0	Net worth quintile in Year 0					All
	Bottom (poorest)	Second	Middle	Fourth	Top (wealthi-est)	
Panel A. Full Sample						
Year 1	9.3	14.6	14.9	17.2	42.9	19.2
	(38.5)	(97.8)	(83.9)	(100.1)	(278.1)	(141.1)
	[2,222]	[2,207]	[2,043]	[1,904]	[1,875]	[10,251]
Year 2	19.2	25.4	27.8	38.2	94.5	39.5
	(69.7)	(101.1)	(107.4)	(147.9)	(476.5)	(227.7)
	[2,222]	[2,207]	[2,043]	[1,904]	[1,875]	[10,251]
Panel B. Subsample						
Year 1	30.7	31.2	18.6	16.5	40.8	25.6
	(77.5)	(95.1)	(77.0)	(90.5)	(209.4)	(127.6)
	[92]	[278]	[540]	[626]	[489]	[2,025]
Year 2	56.4	53.3	38.2	43.0	88.4	54.7
	(142.6)	(125.1)	(110.6)	(134.5)	(497.7)	(268.3)
	[92]	[278]	[540]	[626]	[489]	[2,025]

Note: This table shows the changes in households' net worth from Year 0 (2017) to Year 1 (2018) and Year 2 (2019). The unit is a million South Korean won (KRW). Net worth quintiles are from the whole population of households in Year 0. Numbers without brackets are mean values. The numbers in parentheses are standard deviations. Numbers in square brackets are the numbers of observations. Panel A is for the full sample of 10,251 households. Panel B is for the subsample of 2,025 households. Both the full sample and the subsample include households with non-positive net worth. The subsample consists of (a) households whose annual income is between 52 and 88 million South Korean won (KRW) and have nonzero real estate assets, and (b) households whose annual income is between 62 and 98 million KRW and have zero real estate assets.

Table B.4. Share of Households by Demographic Groups: Subsample

Demographic Group	Net worth quintile in Year 0					All
	Bottom (poorest)	Second	Middle	Fourth	Top (wealthiest)	
Age						
18-29	6.5	4.3	1.1	0.8	0.0	1.4
30s	17.4	18.3	22.6	16.8	10.2	17.0
40s	28.3	29.1	30.4	34.7	22.1	29.4
50s	29.3	34.2	31.5	27.6	30.9	30.4
60 or above	18.5	14.0	14.4	20.1	36.8	21.7
Sex						
Male	82.6	87.4	89.3	93.5	90.2	90.2
Female	17.4	12.6	10.7	6.5	9.8	9.8
Education						
Elementary school	7.6	6.8	6.5	6.2	3.7	5.8
Middle school	13.0	12.2	7.8	5.8	6.7	7.8
High school	46.7	41.4	38.0	35.0	31.3	36.3
College or further	32.6	39.6	47.8	53.0	58.3	50.1
Household size						
1	6.5	2.9	2.6	2.1	3.7	2.9
2	15.2	18.3	19.1	16.3	27.2	19.9
3-4	62.0	67.3	67.2	69.5	60.3	66.0
5-6	16.3	11.5	10.9	11.7	8.2	10.8
7+	0.0	0.0	0.2	0.5	0.6	0.3
Housing type						
Own housing	18.5	59.7	75.0	86.6	88.1	77.1
Lump-sum deposit rent (*Jeonse*)	23.9	19.8	18.9	10.5	10.2	14.6
Monthly rent	42.4	13.3	3.9	1.6	0.6	5.4
Free housing	15.2	7.2	2.2	1.3	1.0	2.9
Location						
Seoul Metropolitan Area	45.7	33.8	28.0	34.3	42.7	35.1
Other	54.3	66.2	72.0	65.7	57.3	64.9
Employment type						
Regular	51.1	54.7	61.9	58.8	44.2	55.2
Temporary	21.7	15.5	6.9	6.2	4.1	7.9
Self-employed	20.7	25.2	25.4	27.3	36.0	28.3
Unemployed *etc*.	6.5	4.7	5.9	7.7	15.7	8.7
Annual income quintile in Year 0						
Bottom (0-20%)	0.0	0.0	0.0	0.0	0.0	0.0
Second (20-40%)	0.0	0.0	0.0	0.0	0.0	0.0
Middle (40-60%)	3.3	3.6	3.7	2.1	1.4	2.6
Fourth (60-80%)	78.3	85.3	81.3	83.2	81.0	82.2
Top (80-100%)	18.5	11.2	15.0	14.7	17.6	15.2
Observations	92	278	540	626	489	2,025

Note: This table shows the share of households by demographic groups. *Sex* refers to the sex of the householder for the subsample of 2,025 households. Both the subsample include households with non-positive net worth. The subsample consists of (a) households whose annual income is between 52 and 88 million South Korean won (KRW) and have nonzero real estate assets, and (b) households whose annual income is between 62 and 98 million KRW and have zero real estate assets. *Lump-sum deposit rent* (or, *Jeonse*) refers to a housing arrangement unique to Korea of having the tenant pay a large one-time deposit returned at the end of the lease. *Free housing* refers to free housing such as that provided by employers.

Table B.5. Effects of Stricter LTV Ceiling on Household Log Net Worth by Initial Net Worth Quintile: Placebo exercise

	Dependent Variable:					
	Cumulative Change in Log Net Worth					
Initial Net Worth Quintile and Stricter LTV Ceiling (*D*)	(1) Year 1	(2) Year 2	(3) Year 1	(4) Year 2	(5) Year 1	(6) Year 2
Bottom (poorest) × *D*	0.123	0.003	0.108	0.010	0.100	-0.006
	(0.410)	(0.540)	(0.409)	(0.537)	(0.409)	(0.539)
Second × *D*	-0.087	-0.124	-0.066	-0.082	-0.063	-0.082
	(0.152)	(0.185)	(0.152)	(0.184)	(0.150)	(0.180)
Middle × *D*	0.017	-0.054	0.028	-0.032	0.018	-0.047
	(0.051)	(0.102)	(0.050)	(0.102)	(0.051)	(0.103)
Fourth × *D*	0.002	-0.013	-0.008	-0.030	-0.006	-0.027
	(0.061)	(0.094)	(0.062)	(0.092)	(0.061)	(0.091)
Top (wealthiest) × *D*	-0.001	-0.029	-0.008	-0.043	-0.007	-0.039
	(0.040)	(0.053)	(0.042)	(0.055)	(0.042)	(0.054)
Bottom (poorest)	0.513	1.038**	0.582*	1.099**	0.576*	1.074**
	(0.327)	(0.466)	(0.338)	(0.486)	(0.336)	(0.483)
Second	0.322***	0.459***	0.353***	0.491***	0.309***	0.414***
	(0.102)	(0.118)	(0.106)	(0.121)	(0.104)	(0.121)
Middle	0.082**	0.163***	0.108***	0.185***	0.055	0.099
	(0.036)	(0.054)	(0.041)	(0.063)	(0.050)	(0.076)
Fourth	0.035	0.047	0.068	0.087	0.000	-0.020
	(0.042)	(0.065)	(0.050)	(0.070)	(0.059)	(0.083)
Top (wealthiest)	0.019	0.078**	0.043	0.107**	-0.027	-0.008
	(0.028)	(0.038)	(0.034)	(0.046)	(0.050)	(0.067)
Controls						
Age, sex, & education			✓	✓	✓	✓
Residence in Seoul					✓	✓
Observations	1,814	1,807	1,814	1,807	1,814	1,807
Adjusted R-squared	0.061	0.076	0.063	0.088	0.065	0.091

Note: This table shows the results of a placebo exercise of using hypothetical income cutoffs of 80 and 70 million KRW instead of 70 and 80. Numbers without parentheses represent estimates of regression coefficients on the selected independent variables in Equation (3). Stricter LTV ceiling (*D*) is a dummy variable that equals one if the household faces the LTV ceiling of 40% and 0 if it faces 50%. The controls age, sex, and education refer to those of the householder. Residence in Seoul equals one if the household lives in Seoul Metropolitan Area and equals zero otherwise. Numbers in parentheses are heteroskedasticity-robust standard errors. Stars *, **, and *** indicate that the estimates differ significantly from zero with 90%, 95%, and 99% confidence.