Essays on Fiscal and Macroprudential Policy

Thesis submitted to the University of Nottingham for the degree of
Doctor of Philosophy, October 2024.

Hun Jang

20258066

Supervised by

Dr. Margarita Rubio
Dr. Atsuyoshi Morozumi

School of Economics

University of Nottingham

Summary

Since the Global Financial Crisis of 2008-09, pursuing appropriate policy measures to achieve macroeconomic stability has been a primary concern for academia and policymakers. Given this focus, this thesis presents three studies conducted to analyze the effects of fiscal and macroprudential policies and offer pertinent policy implications.

Chapter 2, "How should fiscal policies be used as a macroprudential tool?", conducts a theoretical investigation into the impact of property taxes and mortgage deductions on house prices and household indebtedness, which are key macroeconomic aggregates in macroprudential policy operations. The study pays particular attention to how tax revenues are used and examines the side effects of combined tax and spending policies on economic output and household welfare, shedding light on how fiscal policies should be utilized as macroprudential tools. The results indicate that while such tax measures help curb increases in house prices and credit levels, they tend to have adverse effects on output in the short term due to a decrease in residential investment. Furthermore, these fiscal measures carry significant equity implications, particularly undermining the welfare of borrowers. The adequate allocation of tax revenues is crucial to mitigate such negative consequences. Public investment spending, to the extent that public and private capital are complementary, can expedite recovery by fostering the accumulation of private capital and thus minimize harm to the welfare of borrowers.

Chapter 3, "Debt Finance Bias and Macroprudential Policy," discusses how proper macroprudential policy operations can address distortions arising from tax design that could potentially damage macroeconomic stability. Previous studies have indicated that corporate income tax (CIT) systems that allow interest payments to be deductible but not for dividends contain a bias towards debt, inducing firms to have excessive leverage and making them vulnerable to shocks. Using a dynamic stochastic general equilibrium model with a banking sector and corporate finance structure that entails both debt and equity financing, the study first shows that without time-varying capital requirements, an economy with higher corporate income tax rates and greater debt deductibility is characterized by a more substantial debt finance bias, leading to larger financial and macroeconomic volatility. It then demonstrates that volatility can be reduced by imposing a countercyclical capital buffer, whereby the bank's capital-to-debt ratio is significantly more responsive to deviations of the credit-to-GDP ratio from the steady state.

Finally, Chapter 4 (co-authored with Dr. Atsuyoshi Morozumi), "Liquidity Constraints and the Consumption Effects of Recurrent Property Taxes," empirically examines the impact of recurrent property taxes on consumer spending. We identify unexpected changes in these taxes by exploiting a unique feature of the South Korean property tax system. Specifically, while the governments annually reassess residential properties to update the recurrent tax base, their assessment methods are unknown to homeowners, such that each year's recurrent tax liability inevitably contains an unexpected component for homeowners. We then show that an unexpected increase in recurrent taxes generally has an insignificant consumption effect. However, it reduces liquidity-constrained homeowners' spending in particular, which happens primarily through a fall in their spending on durable goods. The results thus offer support for utilizing recurrent taxes as a means of raising revenue, provided that arrangements are made for liquidity-constrained homeowners to alleviate the unequal consumption effects.

Acknowledgements

First and foremost, I would like to express my greatest gratitude to my supervisors, Dr. Margarita Rubio and Dr. Atsuyoshi Morozumi, who provided me with immense support and valuable advice. Without their patience and guidance, I could not have completed my PhD thesis.

I also want to thank Dr. George Bratsiotis and Dr. Marta Aloi for their constructive feedback in improving my thesis and for serving as examiners. I am also indebted to Kevin Lee and the faculty members of the School of Economics, as I was able to obtain enlightening comments that refined my project. I am thankful to my fellow doctoral students, especially Yoocheol Noh and Junggie Lee. They helped me settle well in Nottingham, shared their feelings and ideas, and assisted me in relieving stress and concerns. I am also grateful to other students, those who shared the office (B58 SCGB) with me, and others I encountered every day. It was always interesting to chat with everyone, and it helped me sort out my ideas.

I also benefited from communications with conference participants at numerous locations, including the 7th International Conference on Applied Theory, Macro and Empirical Finance (Thessaloniki), the 10th Annual Money, Macro and Finance Society PhD Conference (Sheffield), the Asian Economic Development Conference (Asian Development Bank, Tokyo), the Royal Economic Society (RES) PhD Conference 2023 (Glasgow), and the RES Annual Conference 2024 (Belfast). I was pleased and honored to have these opportunities to present my work and receive useful insights.

I am also deeply grateful to Paul Walker for his generous scholarship during my PhD, which allowed me to focus on my studies without financial concerns. I also extend my thanks to the Bank of Korea for supporting me during my master's and allowing me an extended leave to pursue my doctoral degree.

Finally, I am sincerely grateful to my family members, my parents, and my beloved wife Gaeun, for their patience and love.

Contents

Summary i

Acknowledgements iii

List of Tables vii

List of Figures viii

Chapter 1 General introduction 1

Chapter 2 How should fiscal policies be used as a macroprudential tool? 6

2.1 Introduction 7

2.2 Related literature 10

2.3 The model 12

2.4 Quantitative analysis 26

2.5 Robustness check 43

2.6 Concluding Remarks 48

2.7 Appendix 50

Chapter 3 Debt Finance Bias and Macroprudential Policy 73

3.1 Introduction 74

3.2 Related Literature 77

3.3 Stylized facts 79

3.4 The model 81

3.5 Calibration and Estimation 93

3.6 Quantitative Analysis 95

3.7 Sensitivity analysis and further results 105

3.8 Concluding Remarks 109

3.9 Appendix 110

Chapter 4 Liquidity Constraints and the Consumption Effects of Recurrent Property Taxes 119

4.1 Introduction 120

4.2 Hypotheses development 126

4.3 Background 128

4.4 Empirical Framework 132

4.5 Data 137

4.6 Results 140

4.7 Concluding Remarks 157

4.8 Appendix 158

Bibliography 177

List of Tables

2.1 Parameter values 24
2.2 Comparison of the steady state value and Data 25
2.3 Policy effectiveness: Comparison of two tax measures 30
2.4 Consumption equivalents (Λ_i) 40
2.5 Comparison of consumption equivalents (Λ_i) 48
2.6 Data used for the estimation ζ 57
2.7 Estimation results for substitutability parameters 58
2.8 Parameter values (Model for nominal rigidity) 64
2.9 Parameter values (Model for housing tenure choice) 70

3.1 Calibrated parameters 94
3.2 Steady-state value and model fit 95
3.3 Estimated parameters 95
3.4 Standard deviations of variables across macroeconomic shocks in each fiscal system 101
3.5 Optimal CCyB parameters within each fiscal regime across various types of shocks 105
3.6 Performance analysis 106
3.7 Optimal CCyB parameters within each fiscal regime across various types of shocks: using the degree of corporate debt deviation from its steady state as a reference 107
3.8 Optimal CCyB and Bank tax rates parameters within each fiscal regime across various types of shocks 109

4.1 Recurrent tax base (assessed value), rate, and liability 129
4.2 Descriptive statistics 140
4.3 Results of first-step regression 141
4.4 Unconditional effects of recurrent tax shocks on consumption 143
4.5 Role of liquidity constraints in consumption effects 144
4.6 Role of liquidity constraints in consumption effects: Interaction approach 146
4.7 Robustness check: Using the 33rd percentile as a threshold 149
4.8 Placebo test on unexpected recurrent tax shocks 151
4.9 Comparing means between liquidity constrained and unconstrained households 153
4.10 Relevance of liquidity constraints: Taking account of housing tenure status 154
4.11 Household balance sheet and variables 168
4.12 Unconditional effects of recurrent tax shocks on consumption 171
4.13 Robustness check: Using the median as a threshold 172
4.14 Robustness checks: Interaction approach 173
4.15 Consumption effects of recurrent tax shocks on durable spending . . 174
4.16 Consumption effects of recurrent tax shocks on durable spending: Interaction approach 175
4.17 Tax effects: Using other conditional factors 176

List of Figures

1.1 Macroprudential policy operations (LTV, DTI and Taxes) 2

2.1 Dynamics of the variables after policy shocks 29
2.2 Dynamics of the variables after tax rate adjustment 33
2.3 Dynamics of the variables by households after tax rate adjustment (by households) 35
2.4 Dynamics of the variables after reducing mortgage deductibility . . 36
2.5 Dynamics of the variables by households after reducing mortgage deductibility (by households) 37
2.6 Dynamics of the variables after tax rate adjustment and increases in public investment 43
2.7 Dynamics of the variables by households after tax rate adjustment combined with public investment 45
2.8 Dynamics of the variables by households after reducing mortgage deductibility combined with public investment 47
2.9 Ratios of Hand-to-Mouth households in Korea 57
2.10 Dynamics of the variables after tax rate adjustment 1 64
2.11 Dynamics of the variables after tax rate adjustment 2 65
2.12 Dynamics of the variables after mortgage deductibility adjustment 1 65
2.13 Dynamics of the variables after mortgage deductibility adjustment 2 66
2.14 Dynamics of the variables after tax rate adjustment 1 70
2.15 Dynamics of the variables after tax rate adjustment 2 71
2.16 Dynamics of the variables after mortgage deductibility adjustment 1 71

2.17 Dynamics of the variables after mortgage deductibility adjustment 2 72

3.1 Volatility of corporate debt-to-GDP and corporate income tax rates 80
3.2 The structure of the model 82
3.3 Impulse-responses after productivity shock 98
3.4 Impulse-responses after financial shock 99
3.5 Impulse-responses after demand shock 101
3.6 Loss function across different types of shocks and policy parameters (HH Economy) 108
3.7 Loss function across different types of shocks and policy parameters (LL Economy) 108
3.8 Volatility of corporate debt-to-GDP and corporate income tax rates (with outliers) 111
3.9 Densities of the priors and posteriors of the estimated parameters . 116

4.1 Share of recurrent property taxes in tax revenue at the general government level 120
4.2 Timeline: Determination of recurrent taxes in South Korea 131
4.3 Boxplots of household consumption expenditures 139
4.4 Unexpected recurrent tax shocks (Unit: 10,000 KRW) 142
4.5 Marginal effects of the recurrent tax shocks on household consumption 147
4.6 Effects of tax shocks on total consumption: Taking account of housing tenure status 155
4.7 Durable goods 169
4.8 Non-durable goods 170
4.9 Robustness checks: Liquidity constraint and effects on total consumption 174

Chapter 1

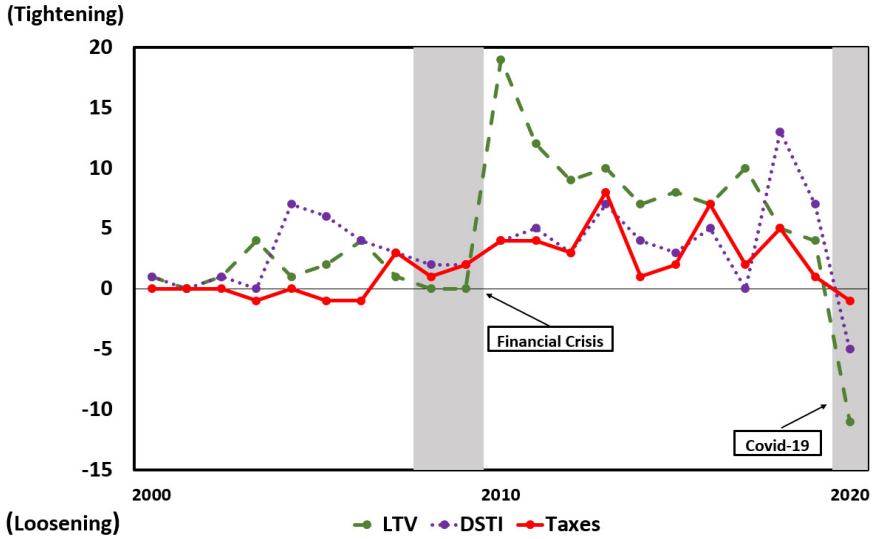
General introduction

The Global Financial Crisis (GFC) of 2008-09 illustrates the importance of appropriate policy engagement in maintaining macroeconomic stability. The Great Moderation, marked by stable inflation and economic growth before the GFC, masked significant imbalances in the asset (housing) market and financial sectors. The accumulation of these imbalances within the financial system, characterized by excessive bank leverage associated with steep increases in house prices, ultimately led to a major macroeconomic crisis in the form of the GFC. Such harrowing ordeal reshaped policymakers' perceptions, leading to a consensus on the need for preemptive policy interventions to mitigate risks associated with high leverage or overheating asset markets. Consequently, this necessitates the implementation of appropriate measures, regulatory tools, or macroprudential policies, which differ from monetary policy, as the latter is too blunt to address such imbalances (Blanchard et al., 2010). Examining better policy operations has thus become a primary concern for researchers and policymakers, encompassing discussions on their effectiveness, the costs associated with specific tools due to unintended side effects, and the interactions among various macroeconomic policies to ensure financial stability.

Against this background, the importance of fiscal (tax) tools in promoting financial

stability has been widely emphasized for two reasons: (1) They can significantly influence households' leverage levels, and (2) an improperly designed tax system can result in greater susceptibility to adverse macroeconomic shocks (Schuberth, 2013). Regarding the former, tax measures have consistently been utilized in pursuit of financial stability, often in conjunction with other macroprudential policies, such as caps on Loan-to-Value (LTV) and Debt-Service-to-Income (DSTI) ratios (Figure 1.1). Since the crisis unfolded, an increasing number of tightening measures, including tax tools, were introduced. However, during COVID-19, these measures were simultaneously relaxed to counteract the economic downturn and support financial markets. Despite the burgeoning discussion on the use of macroprudential policy over the past decade, many questions regarding the adequate implementation of fiscal tools to achieve macro-financial stability remain unanswered.

Figure 1.1: Macroprudential policy operations (LTV, DTI and Taxes)



Sources: Author's calculation using data from Integrated Macroprudential Policy Database by Alam et al. (2019). This is a simple sum of dummy-type indicators, with "+1" meaning tightening the measures and "-1" meaning loosening the measures.

By highlighting this gap in scholarly work, Chapter 2, "How should fiscal policies be used as a macroprudential tool?" theoretically explores the effectiveness of housing-related fiscal tools on key macroeconomic aggregates for financial stability, including house prices and household indebtedness. Importantly, the chapter also examines

their unintended side effects, such as reducing output levels or causing heterogeneous welfare changes among agents, motivated by prior works on the effectiveness of macroprudential policies (Alam et al., 2019; Richter et al., 2019; Kim et al., 2023).

This chapter's main contribution lies in that it examines the intended and unintended impacts of different tax policies as a macroprudential tool while paying close attention to how these revenues are used. In particular, the chapter considers the effects of the tax policies in combination with various spending policies such as investment in public infrastructure, government consumption, transfers and debt restructuring. This is critical, simply because, in light of the government budget constraints, any change in tax policies has to be accompanied by a change in other component(s) of the constraint, and the tax effects are naturally different depending on which component(s) changes. However, this simple aspect has often been overlooked in the prior literature (including Alpanda and Zubairy, 2016, 2017), resulting in there is little consensus on how exactly fiscal policies should be used as a macroprudential tool to achieve financial stability while minimizing unintended impacts. In summary, the chapter demonstrates that housing-related tax tools can suppress household credit growth and house price increases but may lead to an economic downturn in the short run due to reduced investment in new residential properties, causing losses to borrowers' welfare. To minimize these negative impacts, it is necessary to direct the revenues from tightened tax measures toward investment in public infrastructure, provided that private and public capital are sufficiently complementary.

Next, the thesis concentrates on the perspective that the tax system can magnify the impact of economic shocks and worsen the adverse effects of crises. Specifically, many corporate tax systems in the world offer favorable tax incentives for debt finance than equity finance, i.e., debt bias, and concerns about debt bias in the tax system have been continuously raised. Such unequal treatment significantly affects corporate leverage and debt ratios (Borio et al., 2023; Dallari et al., 2020),

ultimately undermining macroeconomic stability (IMF, 2016). In response to this issue, Claessens (2014) has called for studies on appropriate macroprudential policy engagement to address these distortions, including discussions on the interaction between fiscal and macroprudential policies. Nevertheless, formal analyses on this topic—differences in the tax system and the appropriate operation of macroprudential policy—have been significantly overlooked.

To fill in this gap in the literature, Chapter 3, "Debt Finance Bias and Macroprudential Policy," examines macroeconomic volatility, particularly the corporate debt-to-GDP ratio, which is a main target of macroprudential policy operations, across different corporate income tax (CIT) systems. It discusses how the counter-cyclical capital buffer (CCyB) can provide remedies for such flaws in corporate tax design. Using a DSGE model that incorporates corporate finance structure and the banking system, it shows that CIT systems with a higher debt bias experience greater volatility due to lower investment incentives and higher debt repayment burdens. To reduce this volatility and alleviate financial stability concerns, macroprudential authorities in pro-debt finance tax systems should use CCyB more stringently. Specifically, compared to alternative systems where the debt bias is negligible, a much more significant adjustment (about 4 times larger) of the capital requirement should be made when the debt-to-GDP ratio deviates from its steady-state level.

Finally, the thesis focuses on the heterogeneous consumption effects of recurrent property taxes. After the GFC, the proper design of the tax system became a significant concern for policymakers, as it is necessary to facilitate a quicker recovery and ensure stable revenues for public finance. In this context, it is argued that recurrent taxes on immobile property have been underutilized despite being the least distortionary in terms of economic growth (Johansson et al., 2008; Arnold et al., 2011; Acosta-Ormaechea et al., 2019) and providing steadier resources to the government than other types of taxes, regardless of business cycles (Norregaard, 2013). It is becoming more significant for public finance by considering the growing

international mobility of labor and capital (OECD, 2022). However, since previous literature analyzing the impact of recurrent taxes used country-level data and aggregate variables, it could not address who would bear most of the costs of tax impositions, although the impact of fiscal policies is heterogeneous and may vary across household balance sheet conditions (Cloyne and Surico, 2017; Andrés et al., 2022). Discussing these potential heterogeneous effects is crucial as it can reveal the merits and demerits of utilizing such taxes more clearly and provide implications for policymakers regarding the distributional consequences related to household characteristics. However, little is known about the non-uniformity of recurrent tax effects (Surico and Trezzi, 2019).

Motivated by these concerns, Chapter 4, "Liquidity Constraints and the Consumption Effects of Recurrent Property Taxes," examines the consumption effects of recurrent property taxes using South Korean household panel data. By considering the opaque nature of the Korean residential property tax base assessment practice, unexpected recurrent tax shocks are identified, and their impact on household consumption is estimated. While an unexpected increase in recurrent taxes generally has an insignificant impact on consumption, the result masks heterogeneous tax effects: (1) households under liquidity constraints are more negatively affected by such taxes; (2) affected households reduce spending on durable goods more than on non-durable goods. The results imply that offering households proper arrangements, such as tax deferral when their liquidity conditions are constrained, would be useful in reducing the affected households' welfare losses.

Overall, the three chapters aim to fill gaps in academic debates on the effects of fiscal and macroprudential policies. Additionally, they seek to offer both practical policy recommendations and considerations for improved policy implementations to ensure macroeconomic stability.

Chapter 2

How should fiscal policies be used as a macroprudential tool?

Abstract This paper theoretically investigates the impact of property taxes and mortgage deductions on key macroeconomic aggregates relevant to financial stability, including house prices and household indebtedness. We pay particular attention to how tax revenues are allocated and examine the side effects of combined tax and spending policies on economic output and household welfare, shedding light on how fiscal policies should be utilized as macroprudential tools. We find that while such tax measures help curb increases in house prices and credit levels, they tend to have adverse effects on output in the short term. Furthermore, these fiscal measures carry significant equity implications, particularly exacerbating the welfare of borrowers. The adequate allocation of tax revenues is crucial to mitigating such negative consequences. Public investment spending, to the extent that public and private capital are complementary, can expedite recovery by fostering the accumulation of private capital and thus minimize harm to the welfare of borrowers.

2.1 Introduction

Taming household indebtedness to prevent it from reaching unsustainable levels has emerged as a primary objective of macroprudential policy operations. Previous studies, such as those by Müller and Verner (2023) and Jordá et al. (2016), have pointed out the significance of household debt levels as a precursor of financial crises, particularly concerning real estate activities and the mortgage market. As a result, policy authorities endeavor to manage private debt levels associated with the housing sector not only through borrower-side prudential tools, such as Loan-to-Value (LTV) and Debt Service-to-Income (DSTI) ratio regulations, but also through fiscal tools, as previously illustrated in Figure 1.1. This corresponds to the claims made by Borio et al. (2023) regarding the significant influence of the tax system on an economy's overall leverage.

Although fiscal tools have been increasingly utilized to promote financial stability, there remains a significant gap in understanding their optimal use to minimize the potential costs associated with such measures. Specifically, while reducing households' leverage ratios could be the primary objective of these tools, careful consideration needs to be given to their unintended consequences, adverse impacts on output levels, and equity issues, which could become sources of macroeconomic instability. For instance, although higher property taxes might effectively curb household indebtedness, they could also suppress housing investment and have a disproportionately negative impact on households with diverse balance sheet conditions. Since fiscal policies naturally take various forms, encompassing different types of expenditures, taxes, and public debt strategies subject to the government budget constraint (GBC), it is crucial to discern the most effective policy mix that enhances financial stability while mitigating potential adverse effects. This necessitates a comprehensive assessment of tax effects, paying explicit attention to how an adjustment in other fiscal components might offset a tax increase in accordance with GBC. To my

knowledge, prior literature has largely overlooked such critical issues surrounding the deployment of fiscal policies as macroprudential tools.

Motivated by these concerns, the study addresses the following questions: (1) What is the effectiveness of housing-related fiscal policies in influencing house prices and household indebtedness, which are key variables for financial stability? (2) What unintended side effects may arise from employing fiscal tools to enhance financial stability, and to what extent do they occur? (3) Do tax policies vary in effectiveness across different fiscal expenditure regimes? (4) Which combination of contractionary revenue-side policies and fiscal expenditures is preferable in order to minimize potential negative impacts? To provide answers, this paper employs a quantitative framework. Specifically, it constructs a dynamic general equilibrium model incorporating the housing market and fiscal tools for government intervention. This includes housing-related tax measures, such as recurrent property taxes and mortgage deductions, which are predominantly used by OECD countries. The model also considers various government expenditure schemes while accounting for public debt levels. Additionally, it introduces three distinct household groups who differ in asset holdings and credit constraints, à la Kiyotaki and Moore (1997), and thus in their access to the lending market. Through this approach, the study analyzes how the impacts of housing-related tax policies may vary with different combinations of taxes and expenditures. For model calibration, South Korea is selected as the reference economy since it uses both tax tools.

This paper presents several findings: First, it demonstrates that reductions in mortgage deductibility curtail house prices and household indebtedness more than increases in property tax rates. Although both policies influence these variables through the same mechanism by deterring housing demand due to the increased real cost of housing, the impact of reducing mortgage deductibility is more significant. This is because it directly regulates the behavior of impatient households, who value housing stocks more highly than others since these properties serve as collateral.

This is also why the adverse impacts, such as economic downturns in the short run, are more pronounced with reductions in mortgage deductibility, as they lead to decreased housing production by lowering house prices. Second, the effectiveness of such policies crucially depends on how the revenues are directed towards public spending. In particular, using the revenues for public investment can stimulate the production of non-housing goods, thereby improving household factor incomes. As a result, house prices and credit are less affected since higher income helps sustain housing demand. Moreover, this is the only way the government can quickly recover the economy's output level, contingent upon public infrastructure sufficiently complementing private capital. Third, patient households and renters experience relatively higher welfare gains (or fewer losses) when mortgage deductions are adjusted, compared to changes in property taxes. This is because patient households can purchase more houses from impatient households at a lower price. This enhances not only the amount of owner-occupied housing for patient households but also the rental housing services they provide. In contrast, impatient households suffer welfare losses in this process. Fourth, using revenues for investment in public infrastructure is the most desirable in terms of minimizing social welfare loss. However, the most preferable method of public spending combined with revenue-side adjustments is not identical for each household. Public investment, which boosts the economy by improving the productivity of the non-housing goods sector, brings the most welfare gains to patient households since they own private capital. It also benefits impatient households by allowing them to increase consumption of non-housing goods in the end. On the contrary, transfer payments are most beneficial for renters' welfare since they value immediate consumption, and such direct rebates can be used to promote it.

This paper is structured as follows. In Section 2.2, a review of the related literature is provided. Section 2.3 introduces the model used for the main analysis. Quantitative policy experiments conducted using the model, along with their respective results,

are presented in Section 2.4. Section 2.5 provides robustness checks on the main results. Finally, concluding remarks are presented in Section 2.6.

2.2 Related literature

This paper is related to existing studies that examine the macroeconomic impact of housing-related fiscal tools, especially on house prices and household indebtedness, using a general equilibrium framework. For instance, Mora-Sanguinetti and Rubio (2014) demonstrated that increases in VAT and the elimination of deductions on home purchases reduce real house prices but have a negative short-run impact on GDP. Further, Alpanda and Zubairy (2017) compared the effectiveness of various macroeconomic policies—including housing-related taxes and regulatory loan-to-value ratios—highlighting their efficacy in reducing mortgage debt and house prices at the expense of lower residential investment. These findings align with the analysis provided by Alpanda and Zubairy (2016), which discusses the impact of various tax tools related to the housing sector on the macroeconomy. Complementary studies by Asimakopoulos and Asimakopoulos (2019) and Ghiaie and Rouillard (2022) focus on the role of financial intermediaries during tax reforms, suggesting that banks can act as shock absorbers by enhancing capital adequacy ratios, thus mitigating negative spillovers. Furthermore, there are investigations on country-specific housing-related fiscal tools, such as Guo and Jiang (2021), which analyzed the impact of the implicit residential land tax in China. They find that the land tax increase would result in higher house prices and household indebtedness, proving to be more distortionary than property taxes due to its detrimental effects on social welfare. Rabanal (2018)'s counterfactual simulation on Hong Kong SAR's Stamp Duty taxes indicated significant potential increases in house prices and household indebtedness in the absence of these measures.

Despite these ample discussions on the effects of housing-related taxes, previous studies largely overlook the balancing role of fiscal spending components. As underscored by Kneller et al. (1999), it is crucial for evaluating fiscal policy effectiveness to consider both government financing methods and public spending while taking into account the GBC. Acosta-Ormaechea and Morozumi (2017) further emphasize that allocating resources into different categories can lead to contrasting outcomes. Even though some previous works discuss the effect of revenue-neutral tax reforms, which emphasize the advantages of increasing recurrent property taxes as an alternative to income tax reductions, by taking either an empirical (e.g., Arnold et al., 2011; Acosta-Ormaechea et al., 2019) or theoretical approach (e.g., Stähler, 2019; Bielecki and Stähler, 2022), the impact of housing-related taxes combined with varying public expenditures remains unaddressed. Conducting an analysis on this topic is significant in seeking ways to minimize the negative consequences of tightening housing-related tax measures for macroprudential purposes. Therefore, the current paper makes a clear contribution to the existing literature by (1) taking a more comprehensive approach that accounts for diverse public expenditure methods in the discussion, which has not been explored much, and (2) drawing useful policy recommendations when the government uses housing-related tax tools as a macroprudential measure. In this context, the current study relates to the theoretical discussions on the mixes of taxes and government expenditures by Economides et al. (2022) and Li and Lin (2023). However, it is distinctive from theirs because the former focuses on (labor, capital, and corporate) income taxes and social contributions, and the latter only allows for one type of spending, education expenditure, even though they consider property taxes. Moreover, these two studies pay attention to intergenerational welfare implications by adopting a representative household, whereas we focus on the different types of households with varying degrees of indebtedness and asset holdings, which are the direct targets of macroprudential operations.

Finally, this paper is also related to previous studies that examine the distributional consequences of macroeconomic policy implementations, particularly among economic agents differing in their balance sheet conditions. Although research in this field is expanding, not much evidence has yet been accumulated (Colciago et al., 2019). Selected examples on this topic are Georgescu and Martín (2021), which use household survey data to figure out the impact of macroprudential policy; Rubio and Unsal (2020), which compares the heterogeneous welfare implications of different types of macroprudential policy operations; Hohberger et al. (2020), which measures wealth inequality due to quantitative easing between agents differing in liquid asset holdings; Andrés et al. (2022), which analyzes the welfare implications of fiscal policy operations among households differing by balance sheet conditions; and McManus et al. (2021), which seeks the least adverse fiscal austerity plan by examining welfare changes of economic agents. As these analyses have not explored housing-related fiscal tools, our analysis is distinct, and we additionally suggest proper policy engagement to reduce distributional concerns.

2.3 The model

The model is based on Iacoviello and Neri (2010), as it contains the housing market and includes housing production in a closed economy. There are three types of representative households: patient households, impatient households and renters. The patient households act as savers and provide rental housing services. However, the impatient households are indebted every period and are subject to collateral constraints. Renters are unable to own housing stocks and thus reside in rental housing, as in Alpanda and Zubairy (2016). Since they cannot own collateral (housing stocks), renters are excluded from the financial market and therefore spend all of their labor income in the current period.[1] There is a government that intervenes

[1]Thus, this type of household represents the 'Poor Hand-to-Mouth', defined by Kaplan et al. (2014). Allowing for the existence of this type of household is connected with findings in Park

in the housing market using housing-related tax tools, such as property taxes and mortgage deductions. It conducts fiscal expenditure operations that are divided into four parts: First, it allocates tax resources for fiscal consolidation purposes; second, it increases government consumption; third, it invests in public capital accumulation; and fourth, it provides transfers to each household. The public infrastructure established by the government is used as a production factor in non-housing goods production, which uses a CES-type production function, as in Baier and Glomm (2001). A more detailed description of the model is provided below.

2.3.1 Household

Patient households

The patient household has a utility function in the following form[2]:

$$\max E_0 \sum_{t=0}^{\infty} \beta_P^t \left[\log(C_{P,t}) + j \log(H_{P,t}) - \frac{\left[N_{P,t}^{\gamma} + N_{hP,t}^{\gamma}\right]^{\eta/\gamma}}{\eta} \right] \tag{2.1}$$

where β_P is their discount factor, assumed to be $0 < \beta_P < 1$, C_P is non-housing consumption, H_P is owner-occupied housing stock, and N_P and N_{hP} are their labor supplies to the non-housing goods and housing production sectors, respectively. The parameter $j \in (0, 1)$, a common factor across households, governs the relative importance of housing services in their flow utility. η denotes the inverse of the Frisch labor supply elasticity plus 1, and γ represents the elasticity of substitution between labor supplies for each production sector. It is also assumed that η and γ are homogeneous across households.

(2017), which show that the number of 'Poor Hand-to-Mouth' households is non-trivial in South Korea. This is similar to the way of decomposing the types of households used in Andrés et al. (2022).

[2]Note that variables denoted with the subscript h are related to the housing production side throughout the discussion.

The patient household's budget constraint is given as:

$$\begin{aligned}
&C_{P,t} + I_t + I_{h,t} + P_{L,t}L_t + b_t + B_t^g + (1+\tau^{tc})q_t(H_{P,t} + H_{RR,t}^s) \\
&= R_{t-1}b_{t-1} + R_{t-1}^g B_{t-1}^g + W_{P,t}N_{P,t} + W_{hP,t}N_{hP,t} + r_t K_{t-1} + r_{h,t}K_{h,t-1} + r_{L,t}L_{t-1} \\
&- \tau_S(W_{P,t}N_{P,t} + W_{hP,t}N_{hP,t} + r_t K_{t-1} + r_{h,t}K_{h,t-1} + r_{L,t}L_{t-1}) \\
&+ P_{L,t}L_{t-1} + (1-\delta_H - \tau_t^p)q_t(H_{P,t-1} + H_{RR,t-1}^s) + (1-\tau_{RR})RR_t H_{RR,t}^s + TR_{P,t}
\end{aligned} \tag{2.2}$$

The budget constraint (2.2) clearly shows that patient households act as lenders to impatient households (b) and the government (B^g). They receive interest income in the next period with gross interest rates R and R^g, respectively. The patient household also accumulates housing stock for their utility maximization (H_P) and for providing rental housing services to renters (H_{RR}^s, at a rental rate RR). The variable q denotes the relative housing price to non-housing goods. The household must pay transaction taxes (τ^{tc}) when they purchase new housing stock valued at $q_t(H_{P,t}+H_{RR,t}^s)$, and recurrent property taxes (τ_p) applied to their previous holdings, computed at current year prices of $q_t(H_{P,t-1}+H_{RR,t-1}^s)$.[3] It is assumed that changes in τ_t^p from the initial steady state tax rate ($\tau^{p,o}$) are unanticipated.

Given the households' utility function and budget constraint, owning housing stock has two motives. It provides the household with residential services and serves as a store of value, so that the household expects capital gains from its sale. The patient household is also assumed to own land (L), which is normalized to 1, thereby receiving a rental fee (r_L) from the housing constructor. Furthermore, they receive labor income from non-housing goods and housing production, with wage rates W_P and W_{hP}, respectively. Finally, the patient households decide the level of investment in capital for non-housing (I) and housing (I_h) sectors. Each capital, K and K_h, is

[3]It is assumed that τ^{tc} is constant and that the government does not adjust this tax rate. The taxes are incorporated to enhance the stability of the model by ensuring a certain amount of government revenue, which guarantees that government debt remains non-negative.

accumulated by the law of motion below, subject to adjustment costs, $\frac{\psi}{2}\left(\frac{I_t}{I_{t-1}}-1\right)^2$ and $\frac{\psi_h}{2}\left(\frac{I_{h,t}}{I_{h,t-1}}-1\right)^2$.

$$K_t = (1-\delta)K_{t-1} + I_t\left[1-\frac{\psi}{2}(\frac{I_t}{I_{t-1}}-1)^2\right] \tag{2.3}$$

$$K_{h,t} = (1-\delta_h)K_{h,t-1} + I_{h,t}\left[1-\frac{\psi_h}{2}(\frac{I_{h,t}}{I_{h,t-1}}-1)^2\right] \tag{2.4}$$

Since capital is employed as a production factor, non-housing goods producers and housing constructors pay capital rental rates, r and r_h, to the patient households each period. Factor and rental incomes are subject to taxation. The patient households must pay taxes on their factor income at a tax rate τ_S. The tax rate on their rental income is τ_{RR}. On the other hand, they receive transfer payments TR_P from the government. All first-order conditions for the patient household's utility maximization problem are given in the appendix.[4]

Impatient households

The impatient households maximize their lifetime utility, which is identical to that of the patient households except for the discount factor (β_{IM}), with the assumption that $\beta_P > \beta_{IM}$. Additionally, the impatient households are subject to an endogenous collateral constraint whereby their total debt repayment ($R_t b_t$) is bounded by the LTV requirement times the future housing (collateral) values. In other words, they choose their non-housing consumption (C_{IM}), housing (H_{IM}), and labor supply (N_{IM}, N_{hIM}), subject to the budget constraint and the collateral constraint below:

$$\begin{aligned} &C_{IM,t} + R_{t-1}b_{t-1} + (1+\tau^{tc})q_t H_{IM,t} = W_{IM,t}N_{IM,t} + W_{hIM,t}N_{hIM,t} \\ &- \tau_{IM}(W_{IM,t}N_{IM,t} + W_{hIM,t}N_{hIM,t} - \kappa_{B,t}R_{t-1}b_{t-1}) \\ &+ b_t + (1-\delta_H - \tau_t^p)q_t H_{IM,t-1} + TR_{IM,t} \end{aligned} \tag{2.5}$$

[4]All the maximization conditions for all agents in the model are also provided in the appendix.

$$R_t b_t \leq LTV_t E_t q_{t+1} H_{IM,t} \tag{2.6}$$

Here, W_{IM} and W_{hIM} are the real wage rates of the impatient households' labor supply, and TR_{IM} represents transfer payments from the government. Like the patient households, the impatient households must pay income taxes at a rate of τ_{IM} and housing-related taxes. However, the impatient households' mortgage payments are partially deductible for income tax purposes at a rate of $\kappa_{B,t}$. Specifically, the partial deduction reduces their income tax base by subtracting an amount equal to $\kappa_{B,t}$ multiplied by the mortgage payment from their total labor income. Allowing such a deduction is similar to the provision of interest payment subsidies to mortgage holders in Bratsiotis and Gloria (2024). Again, any changes in $\kappa_{B,t}$ from its initial steady state (κ_B^o) are unanticipated, as assumed for τ_t^p.

Using the assumption on the discount factor, $\beta_P > \beta_{IM}$, and equation (2.40) in the appendix, the following condition holds at the steady state.

$$\lambda_b = \frac{1}{C_{IM}}(1 - \frac{\beta_{IM}}{\beta_P}(1 - \kappa_B \tau_{IM})) \tag{2.7}$$

Equation 2.7 is positive since $\beta_P > \beta_{IM} > \beta_{IM}(1 - \kappa_B \tau_{IM})$, $\kappa_B < 1$ and $\tau_{IM} < 1$. It implies that the borrowing constraint is binding in any steady state. Given that the size of the policy shock, which will be discussed later, is small enough, the constraint (2.6) would be binding over the transition dynamics and is assumed to be always binding. Therefore, the impatient household borrows up to its credit limit every period.

Renter

We consider housing renters as described in Alpanda and Zubairy (2016), Guo and Jiang (2021), and Ghiaie and Rouillard (2022). They share the same utility function as the other two types of households, deriving utility from non-housing goods

and housing services while experiencing disutility from labor. However, they cannot own housing stock, and housing services are generated exclusively by rental housing supplied by the patient households. Additionally, they are assumed to neither save nor borrow, which makes them similar to the 'poor hand-to-mouth' households described by Kaplan et al. (2014). Consequently, their current after-tax income must equal their current total consumption expenditure on non-housing goods and rental housing services. Since the renters' maximization problem is non-intertemporal, the discount factor does not affect the model's optimality conditions. However, it influences the welfare implications of each policy experiment, and we assume they have the same discount factor as the impatient households, as in Ghiaie and Rouillard (2022). Accordingly, renters determine the level of non-housing consumption (C_R), rental housing services (H_R^d), and labor supply (N_R, N_{hR}) under the following budget constraint.

$$C_{R,t}+RR_tH^d_{RR,t} = W_{R,t}N_{R,t}+W_{hR,t}N_{hR,t}-\tau_R(W_{R,t}N_{R,t}+W_{hR,t}N_{hR,t})+TR_{R,t} \quad (2.8)$$

The renter must pay labor income taxes at a rate of τ_R to the government and pay rental housing fees (RR) to the patient household. Transfer payments (TR_R) are also provided to them.

2.3.2 Production sector

Non-housing goods producer

A representative firm produces non-housing goods by employing labor from each household and capital from patient households. The firm can access public infrastructure (Gk) without paying any cost. The firm's production technology is given

as follows:

$$Y_t = A(\chi G k_{t-1}^{1-\zeta} + (1-\chi)K_{t-1}^{1-\zeta})^{\frac{\omega}{1-\zeta}}(N_{P,t}^{\alpha_P} N_{IM,t}^{\alpha_{IM}} N_{R,t}^{1-\alpha_P-\alpha_{IM}})^{(1-\omega)} \tag{2.9}$$

where $\zeta \geq 0$, $0 < \chi < 1$, and $0 < \omega, \alpha_P, \alpha_{IM}, \alpha_R < 1$. A is the total factor productivity, which is assumed to be 1. The CES-type production function (2.9) allows the interaction between private and public capital, and the form is identical to that of Baier and Glomm (2001). To elaborate further, $1-\zeta$ represents the elasticity of substitution between the two types of capital. Note that as ζ approaches zero, the two types of capital become close to perfect substitutes, and as ζ approaches infinity, the capital inputs become close to perfect complements. In the special case of $\zeta \approx 1$, the production function converges to the Cobb-Douglas function. Additionally, parameters α_P, α_{IM}, and α_R are the labor income shares of each household, and ω represents the capital income share. Accordingly, the firm maximizes the profit function as follows:

$$\Pi_t = Y_t - (r_t K_{t-1} + W_{P,t} N_{P,t} + W_{IM,t} N_{IM,t} + W_{R,t} N_{hR,t}) \tag{2.10}$$

Housing production

Housing production operates under perfectly competitive conditions as in Iacoviello and Neri (2010). Like the non-housing production side, the housing production firm employs labor from each household and utilizes private capital (K_h) specific for housing construction. Additionally, the firm must use a fixed production factor, land (L), which is assumed to be 1.[5] The housing production-specific technology parameter B is set to 1. In its operations, the firm maximizes profit. The detailed

[5]The existence of the fixed production factor functions as an adjustment cost in housing investment as in Iacoviello and Neri (2010). Also, we exclude the possibility of using public capital as a production factor to reflect relatively heavier regulations on this industry than on other sectors.

production function and profit are given below.

$$IH_t = BK_{h,t-1}^{\mu_h} L^{\mu_L} (N_{hP,t}^{\alpha_P} N_{hIM,t}^{\alpha_{IM}} N_{hR,t}^{\alpha_R})^{1-\mu_h-\mu_L} \tag{2.11}$$

$$\Pi_{h,t} = q_t IH_t - (r_{h,t}K_{h,t-1} + W_{hP,t}N_{hP,t} + W_{hIM,t}N_{hIM,t} + W_{hR,t}N_{hR,t} + r_{L,t}L) \tag{2.12}$$

New housing production in a given period contributes to the accumulation of housing stock in the economy. At the same time, the existing housing depreciates every period at the rate of δ_H. Therefore, the law of motion of total housing stocks (H_t) in the economy is given by $H_t = IH_t + (1 - \delta_H)H_{t-1}$. The housing stock in the economy will be traded and distributed among the households.

2.3.3 Macroeconomic policies

Fiscal policies

The government conducts fiscal policies and accrues tax revenues. The government tax revenues (GR) are given below.

$$\begin{aligned} GR_t \equiv\ & \tau^{tc} q_t (H_{P,t} + H_{IM,t} + H_{RR,t}) + \tau_t^p q_t (H_{P,t-1} + H_{IM,t-1} + H_{RR,t-1}) \\ & + \tau_S (W_{P,t}N_{P,t} + W_{hP,t}N_{hP,t} + r_t K_{t-1} + r_{h,t}K_{h,t-1} + r_{L,t}L_{t-1}) \\ & + \tau_{IM} (W_{IM,t}N_{IM,t} + W_{hIM,t}N_{hIM,t} - \kappa_{B,t}R_{t-1}b_{t-1}) \\ & + \tau_R (W_{R,t}N_{R,t} + W_{hR,t}N_{hR,t}) + \tau_{RR} RR_t H_{RR,t} \end{aligned} \tag{2.13}$$

Using these tax revenues, the government conducts expenditure-side fiscal policies, categorized into four types. Specifically, the government can use the revenues for debt repayment. Alternatively, they can use the resources to buy final goods (G), invest (GI) in accumulating public infrastructure (Gk), a production factor for non-

housing goods production, or rebate their tax revenues to each household as transfer payments (TR). In the case where transfer payments are made, each household i will receive $TR_i = \lambda_i TR$ under the assumption that $\lambda_i = \frac{1}{3}$. The level of government expenditures for each category follows the rule below:

$$\frac{EX_t}{Y_t} = \left(\frac{EX_{t-1}}{Y_{t-1}}\right)^{\rho_{EX}} \left(\frac{EX'}{Y}\left(\frac{B^G_{t-1}}{B^{G'}}\right)^{-\rho_{BG,EX}} \left(\frac{GDP_t}{GDP_{t-1}}\right)^{-\rho_{GDP,EX}}\right)^{1-\rho_{EX}} \tag{2.14}$$

Here, EX_t is either G_t, GI_t, or TR_t. The fiscal rule shows that the government primarily adjusts each public expenditure considering the predetermined public debt level, to avoid explosive debt accumulations and guarantee the stability of the model, governed by $\rho_{BG,EX}$. ρ_{EX} represents the persistence of each expenditure, and $\rho_{BG,EX}$ and ρ_{EX} are assumed to be identical across the types of public spending. However, as in Alpanda and Zubairy (2016), it is assumed that allocation to transfer payments is affected by business cycles, thus $\rho_{GDP,TR}$ is positive, while $\rho_{GDP,G}$ and $\rho_{GDP,GI}$ are equal to zero. Here, $\frac{EX'}{Y}$ is the public spending to non-housing goods ratio, which will be discussed later in Section 2.3.6, and $B^{G'}$ stands for the steady-state public debt level.

Government investment enhances public infrastructure. The law of motion of public capital is given as follows:

$$Gk_t = GI_t + (1 - \delta_g)Gk_{t-1} \tag{2.15}$$

where $0 < \delta_g < 1$. Also, since the government issues a one-period government debt that is purchased by patient households, it must satisfy the flow budget constraint as follows:

$$B^G_t = R_{t-1}B^G_{t-1} + G_t + GI_t + TR_t - GR_t \tag{2.16}$$

Equation (2.16) shows that the aggregate tax revenues and government debt must be sufficient to cover the repayment of the debt issued in period $t-1$ and total

expenditures.[6]

Loan-to-Value ratio rule

As in Iacoviello (2005) and Rubio and Carrasco-Gallego (2014), the collateral constraint is determined by credit growth considerations, so it is time-varying around the steady state LTV level (LTV_{ss}). Thus, the constraint becomes tighter with steeper credit growth whereas it is more permissive with lower credit growth. ϕ_b^{LTV}, assumed to be larger than 0, represents the counter-cyclicality of policy actions. Overall, the LTV rule is given by:

$$LTV_t = LTV_{ss} \left(\frac{b_t}{b_{t-1}} \right)^{-\phi_b^{LTV}} \tag{2.17}$$

2.3.4 Market clearing conditions

The non-housing goods market clears when its production satisfies the demand side, including private consumption and investments in capital accumulation for both production sectors, investment adjustment costs, and government consumption and investments. Thus, the non-housing goods market clearing condition is as follows.

$$Y_t = C_{P,t} + C_{IM,t} + C_{R,t} + I_t + I_{h,t} + G_t + GI_t + adj.cost_t \tag{2.18}$$

Similarly, the housing market clears when the number of existing housing stock (H_t) is equal to the housing demand ($H_{P,t} + H_{IM,t} + H_{RR,t}$) where $H^d_{RR,t} = H^s_{RR,t} = H_{RR,t}$. In addition, as we have already specified, the law of motion of the housing stock accumulation needs to be met for all periods. The housing market clearing

[6] As given in the appendix, the two equations, from the patient households' maximization problem, that determine the government debt and household debt are identical. Thus, the two interest rates must be the same.

conditions are given below.

$$H_{S,t} + H_{B,t} + H_{RR,t} = H_t \tag{2.19}$$

$$H_t - (1 - \delta_H)H_{t-1} = IH_t \tag{2.20}$$

As there are two production sectors in the economy, the total output, GDP_t, is defined in a manner consistent with the National Income and Product Accounts, such that $GDP_t = Y_t + q_t IH_t + RR_t H_t$. Thus, the economy's total output consists of non-housing consumption, capital investments for each production sector, government consumption and public infrastructure formation, housing investment, and rental services, including imputed rents. Also, all factor markets—each household's labor, private capital, and land—are cleared when their demands and supplies are equal. Thus, the conditions (2.44) - (2.47) and (2.48) - (2.52) in Appendix 2.7.1 have to be fulfilled.

2.3.5 Equilibrium

The equilibrium consists of the dynamics of 46 endogenous variables with 46 equations. The endogenous variables are:

$$\{C_{P,t}, H_{P,t}, N_{P,t}, N_{hP,t}, I_t, I_{h,t}, P_{L,t}, b_t, q_t, R_t, W_{P,t}, W_{hP,t}, r_t, K_t, r_{h,t}, K_{h,t}, r_{L,t}, RR_t,$$
$$TR_{P,t}, C_{IM,t}, H_{IM,t}, N_{IM,t}, N_{hIM,t}, W_{IM,t}, W_{hIM,t}, TR_{IM,t}, LTV_t, C_{R,t}, H_{R,t},$$
$$N_{R,t}, N_{hR,t}, W_{R,t}, W_{hR,t} TR_{R,t}, Y_t, IH_t, GR_t, G_t, GI_t, TR_t, H_t, Gk_t, \mu_t, \mu_{h,t}, GDP_t\}_{t=0}^{\infty}$$

The infinite sequence of the variables satisfies first-order conditions (2.26) - (2.52) given in Appendix 2.7.1, each household's budget constraints (2.2), (2.5), (2.8), laws of motion (2.3), (2.4), (2.15), (2.20), collateral constraint (2.6), the LTV rule (2.17), production functions (2.9), (2.11), government total revenues (2.13), government

spending (2.14, for G_t, GI_t and TR_t, respectively), the GBC (2.16), market clearing conditions (2.18), (2.19), and the definition of GDP ($= Y_t + q_t IH_t + RR_t H_t$).

2.3.6 Calibration

The parameters in the model were calibrated to match the Korean economy between 2002 and 2019.[7] Table 2.1 shows the meaning of each parameter and its values. Table 2.2 compares the model fit to the data. To explain, first, the patient household's discount factor is set to 0.9932 to match the annual risk-free interest rate of 2.76%, which is equal to 1.0068 quarterly. Thus, $1/\beta_P$ is set to 1.0068, and one period in the model represents a quarter. The borrower's discount factor was chosen to be 0.985, which is less than 0.9932, to make the borrowers relatively impatient and ensure the collateral constraint holds in equality. Since their discount factor influences the steady-state values, particularly for housing stocks and GDP, the number was chosen to reflect those values as well.

The parameters for the labor income shares of the patient and the impatient households were selected as 0.6 and 0.3, respectively. These numbers are derived from Figure 2.9 and are also suggested by Park (2017), which shows the proportions of 'wealthy hand-to-mouth (HtM)' households that share similar features with the patient households. As suggested in the same literature, the share of 'poor HtM,' which is similar to the renter in the model, is 0.1. Accordingly, α_{IM} is 0.3, α_P is 0.6, and $\alpha_R = 1 - \alpha_P - \alpha_{IM} = 0.1$. The capital income share of the non-housing goods sector, $\omega = 0.54$, was calibrated to match the investment-to-GDP ratio at the steady state. All the depreciation rates of capital and housing stocks were selected to align with the private investment-to-GDP ratio as well. The capital and land income shares in the housing production sector were chosen using Korean National Accounts data. μ_h is set to 0.17 to match the shares of operating surpluses in the

[7]The South Korean government started actively engaging in the housing market by using appropriate macroprudential policy tools in 2002.

value added of the construction sector, and $\mu_L = 0.06$ was chosen to match 1− the sum of shares of operating surplus and labor income of the same sector.

Table 2.1: Parameter values

Description	Parameter	Value
Patient household's discount factor	β_P	0.9932
Impatient household's and renter's discount factor	β_{IM}, β_R	0.985
1 + Inverse of the Frisch labor supply elasticity	η	1.5
1 + Elasticity of substitution between labor supplies	γ	2.0
Patient household's relative income share	α_P	0.60
Impatient household's relative income share	α_{IM}	0.30
Renter's relative income share	α_R	0.10
Capital income share in the non-housing goods production	ω	0.54
Relative weights on public capital for non-housing goods prod.	χ	0.39
1 - Elasticity of subs. public capital and private capital	ζ	0.726
Capital income share in the housing production sector	μ_h	0.17
Land income share in the housing production sector	μ_L	0.06
Depreciation rate of capitals	δ, δ_h, δ_g,	0.1
Depreciation rate of housing stocks	δ_H	0.085
Investment adjustment cost	ψ, ψ_h	7.7
Response of the LTV to credit growth	ϕ_b^{LTV}	1.0
Steady state level of LTV requirement	LTV_{ss}	0.525
Housing preference parameter	j	0.15
Persistence of the government expenditure shocks	$\rho_G, \rho_{GI}, \rho_{TR}$	0.5
Fiscal reactions to the government debt increases	$\rho_{BG,G}, \rho_{BG,TR}, \rho_{BG,GI}$	0.07
Degree of counter-cyclical operations of transfer payment	$\rho_{GDP,TR}$	0.43
Patient household's income tax rate	τ_S	0.379
Rental income tax rate	τ_{RR}	0.28
Impatient household's income tax rate	τ_{IM}	0.30
Renter's income tax rate	τ_R	0.20
Housing-related tax rate	$\tau^{p,o}$, τ^{tc}	0.02
Mortgage deductibility	κ_B^o	0.24

The fiscal policy operations parameters, especially for the reaction of fiscal variables to government debt, $\rho_{BG,G}$, $\rho_{BG,TR}$, and $\rho_{BG,GI}$, were set to 0.07. This approach, as used by Alpanda and Zubairy (2016), ensures the stability of the model and prevents government debt from dominating the transition dynamics throughout the analyses. G'/Y and TR'/Y were determined to exactly match the related government

Table 2.2: Comparison of the steady state value and Data

Description	Symbol	Model	Data
Private consumption to GDP	$(C + RR \cdot H)/GDP$	0.58	0.53
Non-housing goods consumption to GDP	C/GDP	0.47	0.42
Imputed rent to GDP	$RR \cdot H/GDP$	0.10	0.09
Imputed rent to private consumption	$RR \cdot H/(C + RR \cdot H)$	0.18	0.18
Private investment to GDP	$(I + I_h + q \cdot IH)/GDP$	0.25	0.26
Residential investment to GDP	$q \cdot IH/GDP$	0.05	0.05
Capital investment to GDP	$(I + I_h)/GDP$	0.20	0.21
Residential investment to Private investment	$q \cdot IH/(I + I_h + q \cdot IH)$	0.19	0.19
Government consumption to GDP	G/GDP	0.15	0.15
Government investment to GDP	GI/GDP	0.03	0.05
Transfer payment to GDP	TR/GDP	0.11	0.11
Government debt to GDP	$BG/4 \cdot GDP$	0.47	0.47
Mortgage debt to total housing value	$b/q \cdot H$	0.16	0.16

expenditure-to-GDP ratios, and factor income tax rates (τ_S, τ_{IM}, and τ_R), housing-related tax rates and mortgage deductibility (τ^p, τ^{tc}, and κ_B), rental income tax rates (τ_{RR}), and GI'/Y were set to align the model with data on private investment-to-GDP, relative residential investment-to-total investment, imputed rent-to-GDP, imputed rent-to-total consumption ratio, and government debt-to-GDP ratio as closely as possible. The steady-state values of LTV and housing preference parameters were chosen as 0.525 and 0.15, respectively, to match the mortgage debt-to-total housing value ratio.

An important parameter that provides policy implications is ζ, which determines the substitutability between private and public capital in non-housing goods production. This parameter can determine the effectiveness of public investment, as discussed. To pin down the benchmark level of ζ, we estimated it using South Korean data and referring to the method in An et al. (2019). The detailed estimation method and results are given in Appendix 2.7.4. As a reference point, we set $\zeta = 0.726$, estimated from the regression. In addition, the estimated value of χ from the regression was used, setting it to 0.39.

Other parameters that do not have exact data references were borrowed from pre-

vious literature on South Korea. For parameters on labor supply decisions (η and γ), Bayesian estimation results from Hwang and Jung (2014) were used. For parameters on time-varying LTV operations (ϕ_b^{LTV}), we referred to Jung and Mok (2019), which analyzes optimal macroeconomic policy. Finally, for parameters on investment adjustment costs (ψ and ψ_h), the values from Bae (2013) were adopted.

2.4 Quantitative analysis

2.4.1 Policy experiments

By using the model, we analyze the effects of housing-related fiscal policies. Specifically, we conduct perfect foresight simulations involving changes in housing tax rates and the degree of mortgage deductibility. The permanent tax-side policy shock, which was unanticipated, occurs at time $t = 1$. The transition period (T) to the new steady state is 500 quarters. Through these exercises, we first compare the effectiveness of each policy on the macroeconomy, especially for the macroprudential target variables, the level of house prices and household indebtedness. For the analysis, we chose the degree of policy changes (shocks) to generate the same level of additional tax revenues in the new steady state, i.e., $\tau^{p,\nu} qH = \kappa_B^{\nu} \tau_{IM} Rb$ where $\tau^{p,\nu}$ and κ_B^{ν} denote the level of adjustment for the tax rate and deductibility, respectively. Specifically, the tax rate is increased by 0.0022 from the initial level of 0.02. This means that each household will face $\tau^{p,o} + \tau^{p,\nu} = 0.0222$ from $t = 1$. For the mortgage deductibility, it is decreased by 0.05, so it will be $\kappa_B^o - \kappa_B^{\nu} = 0.19$. These changes generate additional tax revenues of 0.0017 in the new steady state, which is around 0.4% of the total government revenues of the initial steady state.

The tax-side policy changes generate tax revenues associated with those adjustments. Formally, the additional tax revenues, GR^{ν}, after $t = 1$, are defined as

follows:

$$GR_t^{\nu} = \begin{cases} \tau^{p,\nu} q_t H_{t-1} & \text{if the property tax rate is adjusted;} \\ \kappa_B^{\nu} \tau_{IM} R_{t-1} b_{t-1} & \text{if the mortgage deductibility is adjusted} \end{cases} \tag{2.21}$$

The two tax revenue scenarios presented in Eq. 2.21 are formulated to explain the corresponding tax revenues generated by adjusting policy variables, namely property tax rates and mortgage deductibility, respectively. Our approach for both tax tools closely follows that of Li and Lin (2023), who experimented with increasing property taxes and using the additional revenues to enhance government education expenditures. Although Li and Lin (2023) focused mainly on property tax adjustments, we adopted a similar approach to conduct experiments on adjusting mortgage deductibility in our analysis. The government then determines how to use those revenues. They could be used either for a fiscal consolidation plan or to increase one category of expenditures. At time $t = 1$, each agent learns the government's expenditure plan concerning the tax revenues from the tax rate or deductibility adjustments.

Policy effects under public debt restructuring

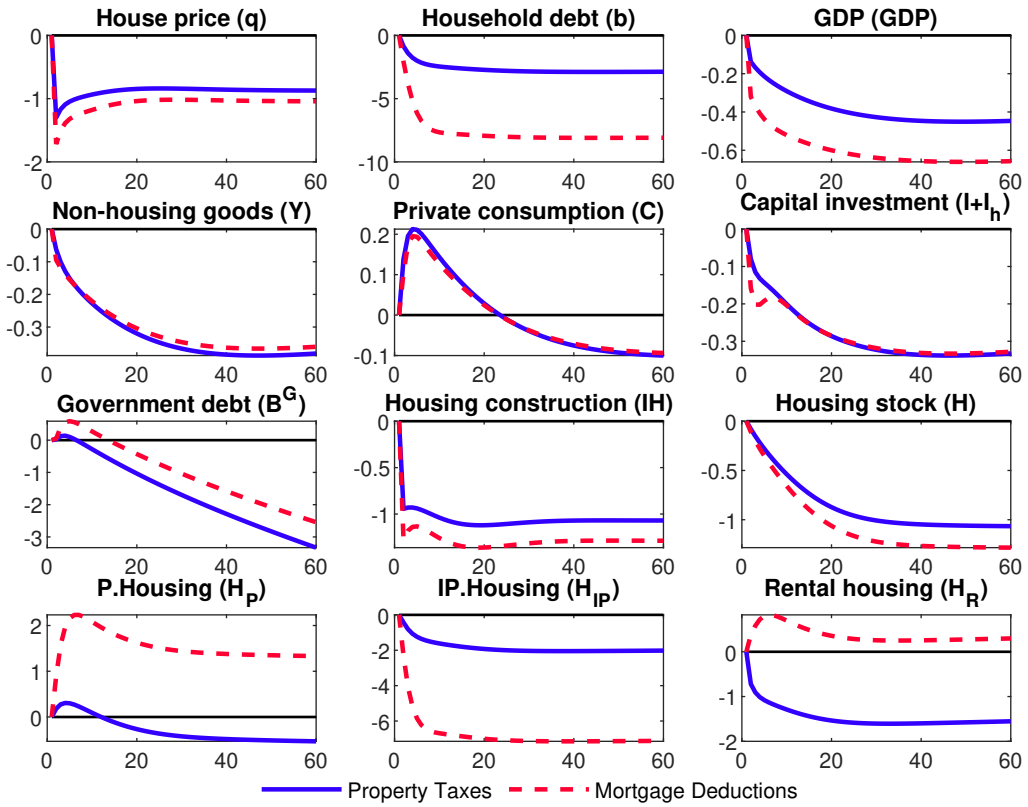
For this exercise, we assume that the government use all additional revenues (GR_t^{ν}) to reduce public debt levels. Therefore, the left-hand side of the GBC (2.16) is decreased by GR_t^{ν}. The spending plan is identical to that in Alpanda and Zubairy (2016). The analysis, therefore, will offer an opportunity to compare the results with those from the closely related previous study.

The dynamics of the macroeconomic variables after policy shocks are given in Figures 2.1. It can be easily observed that each contractionary policy shock causes an early reduction in both house prices and household indebtedness. However, adjustments to mortgage deductibility are more impactful in affecting those variables. This

is because impatient households value one unit of housing stock more than other economic agents under collateral constraints. Accordingly, as given in Equation (2.39), the benefit of possessing housing stock today is increased by $\lambda_{b,t} LTV_t E_t \left(\frac{q_{t+1}\pi_{t+1}}{R_t}\right)$. This is why impatient households show a relatively higher imputed rent-to-total consumption ratio (23.0%) than that of other types of households (18.8% for patient households and 13.0% for renters). However, a higher tax burden immediately disincentivizes the property-holding motives of impatient households since it tightens their budget constraints. Thus, they begin to sell off housing stock, causing downward pressure on house prices. This leads to a limitation in the credit availability for impatient households through two distinct channels: reduced collateral values (house prices) and disposal of the collateral (housing properties). Therefore, changes in mortgage deductibility have a more significant impact on credit levels. Additionally, the sale of housing by impatient households leads to acquisitions by patient households, both for their owner-occupied housing and for rental housing supply, resulting in increased housing services for patient households and renters. The reduction in housing prices leads to less housing construction through profit maximization, thereby adversely affecting the economy's total output level (GDP).

The effectiveness of tax rate changes is less powerful than that of mortgage deductibility reductions. Contrary to the latter, which directly affects impatient households, property tax increases influence both types of households. Therefore, the burdens of the tax shock are shared by the patient households, who can better handle the negative consequences of the tax shock. To explain, although taxes on housing property holding could tighten patient households' budget constraints, they are less susceptible because they have diverse asset portfolios, including financial assets (loans to impatient households and government) and non-financial assets (private capital and housing stock), compared to the impatient households (housing stock only). These assets help patient households sustain their demand for housing even if

Figure 2.1: Dynamics of the variables after policy shocks



Notes: Impulse responses to each housing-related revenue-side fiscal policy shock combined with public debt restructuring. 'P' refers to patient households. 'IP' refers to impatient households. 'R' means renter. The left-axis represents the percentange change from the initial steady state.

there is inevitable downward pressure on house prices. Accordingly, house prices decrease less, and the degree of household deleveraging is not as strong as in the case of mortgage deductibility adjustments. This causes a negative impact on housing construction and GDP, but it is less severe than that caused by mortgage deductibility reductions. Finally, the tax rate increases result in a reduction in owner-occupied housing by patient households and a lower supply of rental housing services as their budget constraints are more restrictive than before. This demonstrates that the tax burdens are more fairly split among the agents compared to the case of reducing mortgage deductibility.

Table 2.3 summarizes the quantitative effects of such tax measures. It compares their differences in effectiveness by measuring the present values of changes in each

variable.[8] The table clearly shows that both tools not only have significant effects on house prices and household indebtedness but also cause losses in the real economy, especially in the housing production sector. Furthermore, mortgage deductions generate a more pronounced effect on house prices and household indebtedness, being 1.18 and 2.93 times stronger, respectively. The adverse impact on the real economy is also more severe, being 1.75 times larger, particularly for GDP.

Table 2.3: Policy effectiveness: Comparison of two tax measures

	q	b	GDP	Y	IH
Property taxes (A)	-1.12	-3.29	-0.40	-0.32	-1.35
Mortgage deductions (B)	-1.32	-9.63	-0.70	-0.31	-1.59
B/A	1.18	2.93	1.75	0.97	1.18

Notes: The present value of changes in each variable after housing-related tax measures are adjusted. The present value of changes is the infinite sum of the rate of change from the initial steady state, multiplied by the discount factor of patient households at time t ($\frac{1}{v_{ss}} \sum_{t=0}^{\infty} \beta_P^t (v_t - v_{ss})$).

The results above are similar to previous literature, such as Alpanda and Zubairy (2016), which assumes that tax revenues are mainly used for retiring public debt. Thus, the dynamics of variables after property tax rate and/or mortgage deductibility adjustments are substantially similar to those of Alpanda and Zubairy (2016), especially for household indebtedness and each type of household's housing consumption. However, in comparison with Alpanda and Zubairy (2016), in our framework, decreases in residential investment are more rapid, and the reduction in household indebtedness is more pronounced due to the combination of the LTV constraint and the long-term decline in house prices, since we allow for a separate housing construction sector employing each production factor.[9]

[8] This follows the method in Alpanda and Zubairy (2016), where the present value of changes in variable v is equal to $\frac{1}{v_{ss}} \sum_{t=0}^{\infty} \beta_P^t (v_t - v_{ss})$, with v_{ss} indicating the initial steady-state value of the variable v.

[9] To explain, first, the level of residential investment is determined by the employment of production factors, as in Iacoviello and Neri (2010). Thus, lower house prices due to reduced housing demand by households diminish the housing construction firm's profitability. Consequently, the firm reduces the level of production factors employed to prevent losses, resulting in an immediate decrease in residential investment. This is not the case in Alpanda and Zubairy (2016), where residential investment is only governed by an adjustment cost, leading to more gradual declines in housing construction. Second, related to this point, the relative housing price returns to unity in the long run in Alpanda and Zubairy (2016). Accordingly, long-run residential investment steadily decreases over time to meet $q = 1$. However, in our framework, household labor supply to hous-

Policy effects with fiscal stimulus

The policy experiments previously discussed considered the case in which revenues from tighter tax impositions were only used for fiscal austerity. Thus, the findings are comparable to those of Alpanda and Zubairy (2016), where the government uses revenues to reduce its debts. Now, we analyze how policy effectiveness could be altered if taxation is directed towards fiscal stimulus, government consumption, investment in public infrastructure, or transfer payments to households.[10] Such possibilities and pertinent analyses have been overlooked by Alpanda and Zubairy (2016, 2017). Thus, the analyses presented below are distinct from theirs and complement these previous studies. This can offer insights into the best ways to minimize the potential adverse impacts of policy operations, such as GDP declines and/or unequal welfare changes. During the following exercises, the size of shocks is maintained at 0.0022 for property tax rates and 0.05 for mortgage deductibility. However, the usage of GR_t^ν differs from the previous analysis. These are as follows.

1. Government Consumption ($GR_t^\nu = G_t^\nu$): The total public consumption is $G_t + G_t^\nu$, representing government purchases of non-housing goods. Thus, G_t^ν is added to the market clearing condition on the non-housing goods sector, which is given by Equation (2.18).

2. Public Investment ($GR_t^\nu = GI_t^\nu$): The total public investment is $GI_t + GI_t^\nu$, which builds up public infrastructure. Therefore, GI_t^ν is added to the right-

ing construction increases after the initial declines following the policy adjustment. This increase occurs to mitigate the negative income effects caused by higher tax rates and reduced mortgage deductibility, helping to maintain residential investment at a certain level, approximately 1% below the original steady state, and preventing house prices from reverting to their initial level.

[10]One caveat is that we did not consider the allocation of tax revenues across multiple fiscal spending categories or time-varying allocations, where revenues are assigned to different categories in different periods. We acknowledge that reflecting on such possibilities could provide additional insights into optimal policy implementation. However, given the scope of our research, we follow a similar approach to that of previous literature, such as Li and Lin (2023) and Bielecki and Stähler (2022), which experiment with adjusting one component of the government budget constraint as a financial source for increasing another single component. Additionally, the selection of representative policy experiments, as we have done, is inevitable due to feasibility considerations, as the number of all possible combinations is infinite.

hand side of the law of motion of public capital (2.15). Also, GI_t^ν is added to the market clearing condition of the non-housing goods sector, given by Equation (2.18).

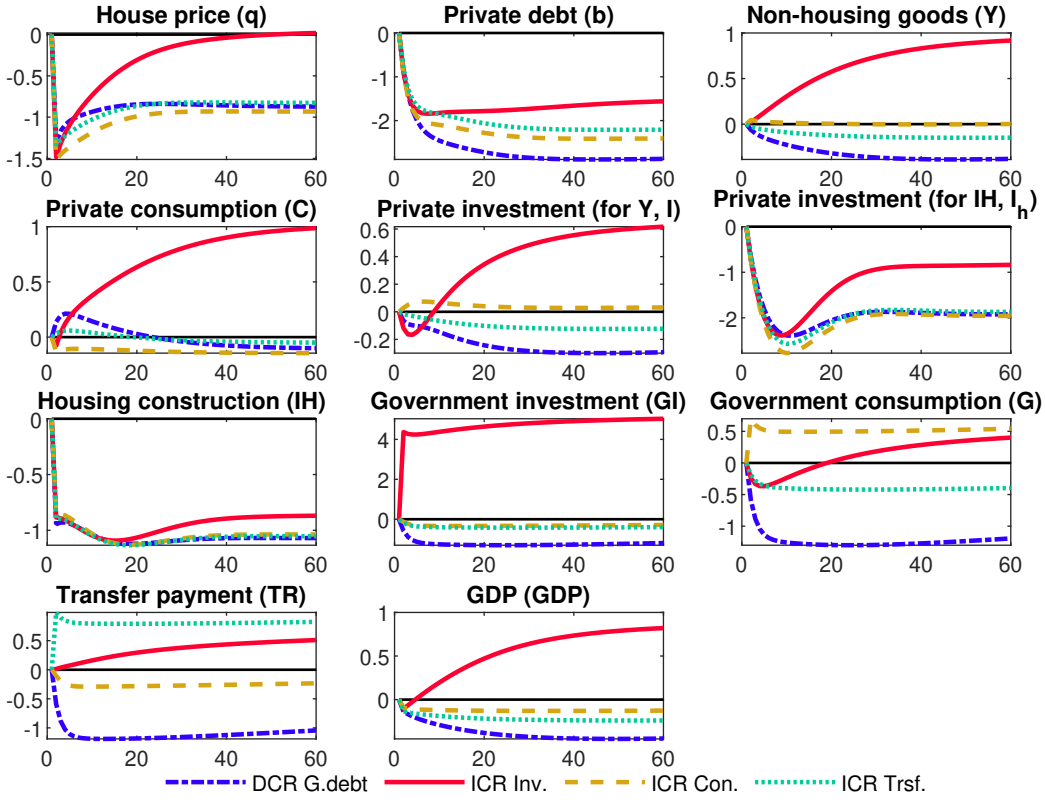
3. Transfer Payments ($GR_t^\nu = TR_t^\nu$): The total transfer payments to each household is $TR_t + TR_t^\nu$. This means that the boosted transfer payments TR_t^ν are distributed equally among the three types of households. Thus, $\frac{1}{3}TR_t^\nu$ is added to each households' budget constraint, (2.2), (2.5), and (2.8), respectively.

For any fiscal stimulus, the GBC (2.16) is unaffected as GR_t^ν and public spending exactly offset each other.

Property taxes Figure 2.2 presents the macroeconomic dynamics after the tax shock under different types of expenditure. The figure shows that the tax rate increase reduces both house prices and credit levels for all cases, albeit to different degrees. Overall, the higher tax rate raises the cost of housing for the patient and impatient households, thereby suppressing the demand for owner-occupied housing. This leads to an initial decrease in house prices, incentivizing firms to reduce new housing production. Due to the reduced house prices, the funds available to the impatient households, who are under the collateral constraint, decline. However, such effects become least significant around 8-9 quarters after the policy implementation in the case of increasing public investment as a stimulus since it improves the productivity of non-housing goods production, positively impacting each household's income level. The effects are stronger with patient households' investment in capital, as they reallocate resources saved from reducing loans to impatient households to more profitable opportunities. Accordingly, the demand for housing stock can be sustained despite the shrinkage in additional housing investment, resulting in a return of house prices to the initial steady-state level. This causes private indebtedness to be affected the least, as higher price levels help the impatient households

by alleviating their collateral constraints. Thus, the level of private indebtedness under public investment stimulus is 1.01 times larger than the average of the three other cases in the long run. In addition, such substantial positive effects on the non-housing goods sector provoke a rapid recovery of the economy's output level. This recovery phase is impossible with other stimuli, such as dissipative consumption or transfer payments, since they do not significantly improve non-housing goods production, although they help the economy overcome a certain degree of adversity compared to decreasing government debt.

Figure 2.2: Dynamics of the variables after tax rate adjustment



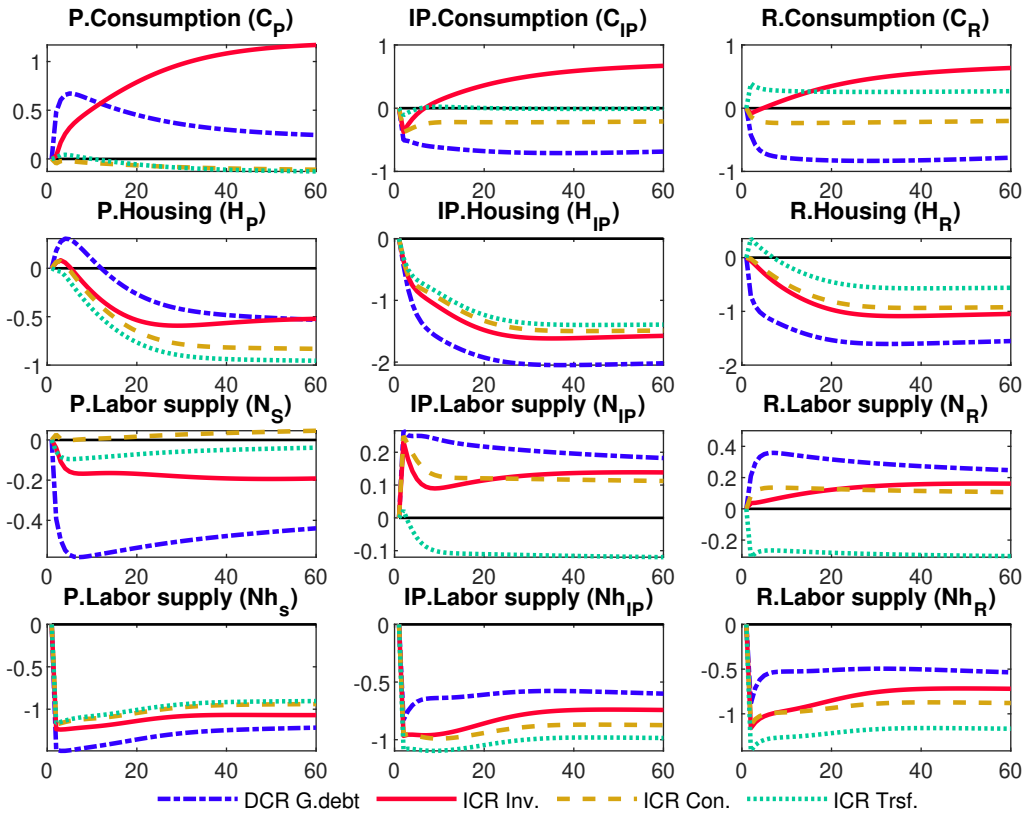
Notes: Impulse responses to property tax shocks combined with each expenditure method. 'DCR' refers to 'decreasing' and 'ICR' refers to ''increasing', respectively. The left-axis represents the percentage change from the initial steady state.

In addition, the mix of fiscal spending with housing tax rate increases would have equity implications. As shown in Figure 2.3, the patient household's consumption level can be improved much more than that of others when the government uses

its tax revenues for public infrastructure construction. This is because the patient household owns private capital and thus benefits the most from such fiscal policy operations. On the other hand, transfer payments would be most helpful for renters, as they can improve their consumption and rental housing levels and reduce the disutility from supplying labor. For impatient households, transfer payments are the most beneficial stimulus scheme because they would be able to sustain their non-housing consumption level and minimize their welfare loss due to declines in housing stock. It is also notable that impatient households significantly improve their consumption level of non-housing goods when public investment increases. A more detailed quantitative discussion on inequality and welfare changes resulting from tax policy changes will be given later in section 2.4.2.

Mortgage deductions The dynamics of macroeconomic variables are presented in Figure 2.4. As shown in the figure, the policy impact of reducing mortgage deductibility is stronger than that of property tax rate adjustments. Specifically, there was around a 2% fall in house prices right after the policy shock for all expenditure methods, which is higher than that observed for tax rate adjustments, where house prices fell by approximately 1.5%. After this initial adjustment in house prices, the economy approaches a steady-state level of house prices, which is lower than that resulting from the tax rate adjustments. As already discussed, this is because the decrease in mortgage deductibility only affects the impatient households, who have a higher valuation of owner-occupied housing since it can function as collateral and offer housing services. This leads to a more sizable recession in housing production, thus, the economy's GDP experiences a longer downturn than in the case of property tax increases when the government uses their additional tax revenues for productive purposes. The other types of stimulus help the economy sustain its non-housing goods output level by directly purchasing it (government consumption) or indirectly supporting it through transfer payments to households. However, the ef-

Figure 2.3: Dynamics of the variables by households after tax rate adjustment (by households)

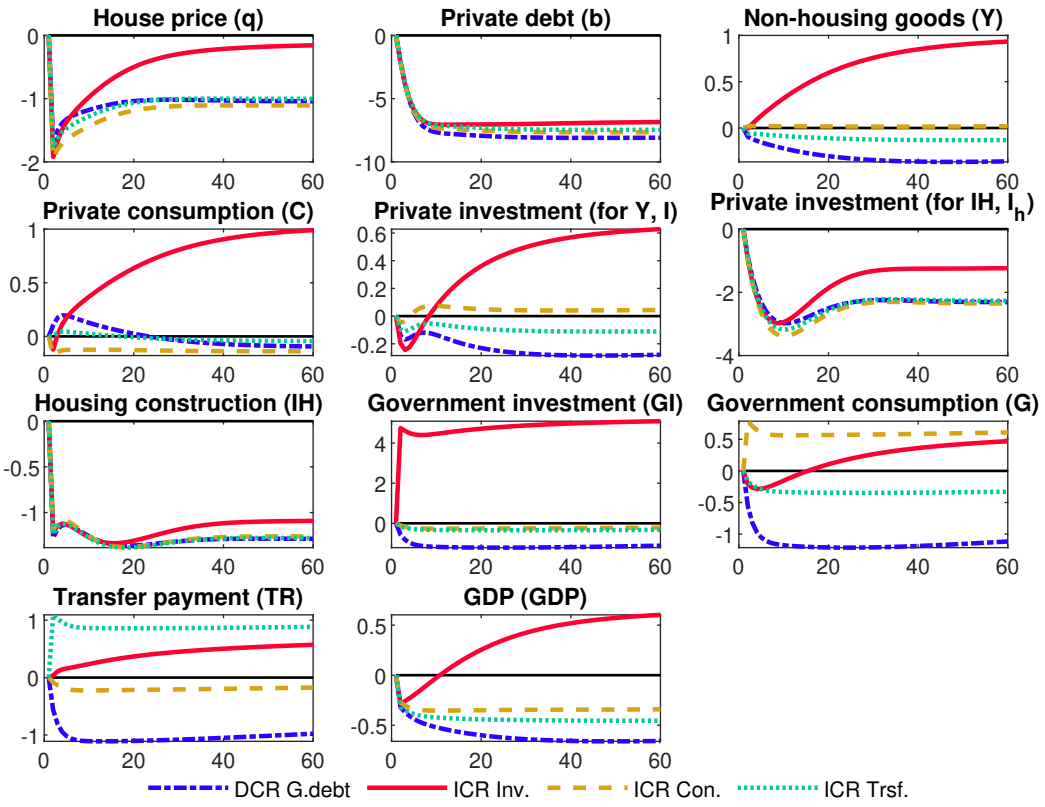


Notes: Impulse responses to property tax shocks combined with each expenditure method. 'P' refers to patient households. 'IP' refers to impatient households. 'R' means renter. 'DCR' refers to 'decreasing' and 'ICR' refers to ''increasing', respectively. The left-axis represents the percentage change from the initial steady state.

fects are insufficient to overcome the recession phase after the mortgage deductibility is adjusted.

It is obvious that the impatient households' welfare is highly disadvantaged, especially regarding their level of owner-occupied housing, since they lose the opportunity to obtain loans using their housing stock as collateral. On the other hand, the policy benefits the patient households and renters, as it increases the level of housing services through the general equilibrium effect. Since the impatient households' collateral constraint is tightened due to lower property prices and reduced availability

Figure 2.4: Dynamics of the variables after reducing mortgage deductibility

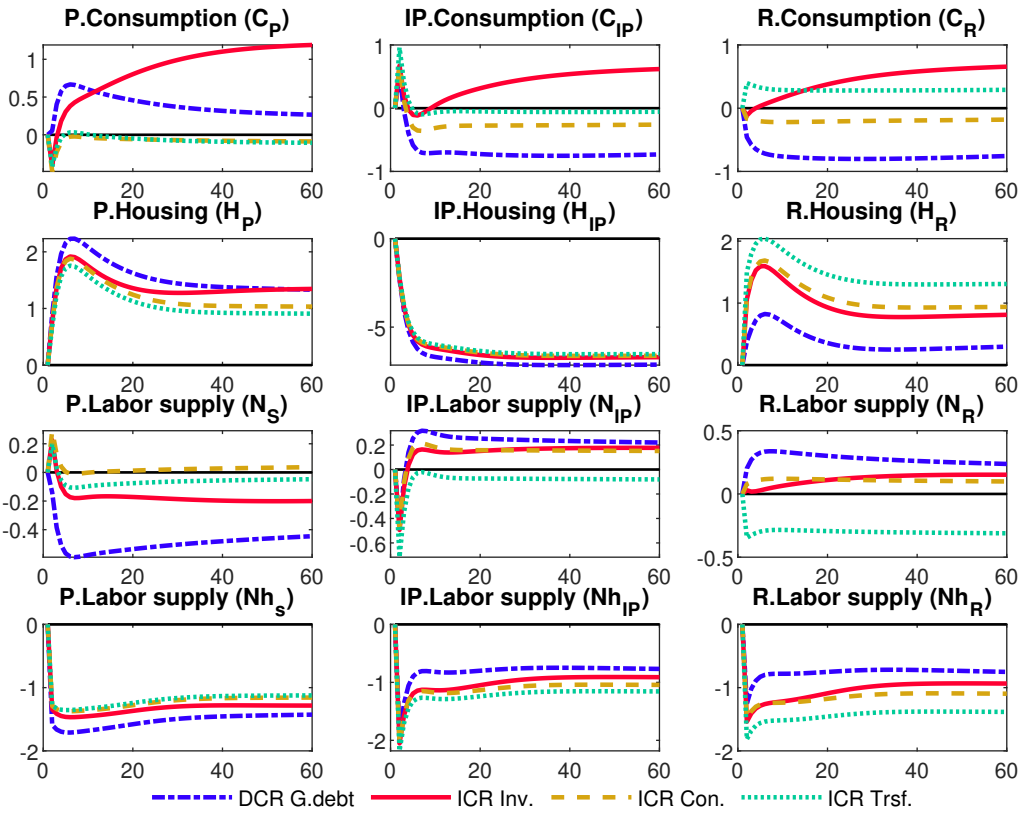


Notes: Impulse responses to mortgage deductability shock combined with each expenditure method. 'DCR' refers to 'decreasing' and 'ICR' refers to ''increasing', respectively. The left-axis represents the percentage change from the initial steady state.

of housing stock, they cannot achieve the same amount of housing services they enjoyed before. Meanwhile, the housing stock disposed of by the impatient households provides more purchasing opportunities for the patient households. Consequently, the savers increase rental service supplies. When the government uses the revenues for public infrastructure, all types of households can achieve a higher level of non-housing goods consumption in the new steady state, with the patient households benefiting the most, as they own the physical capital.

To sum up, the impact of housing-related taxes is not homogeneous; it highly depends on how the government uses the related revenues. Focusing on output recovery—which is one of the main reasons for objections to using such tax tools to influence financial stability variables—our results are clearly different from those of

Figure 2.5: Dynamics of the variables by households after reducing mortgage deductibility (by households)



Notes: Impulse responses to mortgage deductability shock combined with each expenditure method. 'P' refers to patient households. 'IP' refers to impatient households. 'R' means renter. 'DCR' refers to 'decreasing' and 'ICR' refers to ''increasing', respectively. The left-axis represents the percentage change from the initial steady state.

Alpanda and Zubairy (2016), which argue that the output level cannot be restored to its initial level since it only implicitly considers using revenues for public debt restructuring. Our experiment demonstrates that the economy recovers its GDP level within approximately 8-9 quarters and 12-13 quarters in the cases of property tax rate increases and decreases in mortgage deductibility, respectively, if the government directs tax revenues to public investment. Regarding using revenues for increasing government consumption or transfer payments, previous figures indicate that the degree of adverse effects is less critical than using revenues for reducing public debt. Accordingly, in terms of the speed of output recovery, using additional revenues for government investment is the optimal allocation that achieves the high-

est economic rebound after a short-run downturn. Notably, the policy's effectiveness on house prices diminishes in the long run when revenues are directed to government investment. Therefore, a combination of housing-related tax tightening and increased public investment is recommended if policymakers seek to reduce private indebtedness and minimize the duration of economic downturn.

2.4.2 Welfare analysis

The divergent dynamics of each household's consumption, housing services, and labor supplies imply that policy measures would have heterogeneous effects on household welfare. This impact would be particularly negative for impatient households that rely on the value of housing properties. Therefore, it is reasonable to question how much they are negatively affected by the fiscal policies relative to other groups of households and to explore the best options for mitigating such negative consequences. Accordingly, we quantitatively analyze the welfare effects of these fiscal tools and examine how changes in housing tax policies affect each household's welfare level, with explicit consideration of the diverse expenditure methods.

As Alpanda and Zubairy (2016) and Andrés et al. (2022) discuss, computing consumption equivalents in fiscal policy operations illustrates how much welfare gain or loss would occur after policy changes. Suppose C_i and H_i are the levels of non-housing consumption and housing service, and N_i and N_{hi} are the labor supplies to the non-housing goods production and housing production sectors, respectively, for each household type $i \in P, IM, R$ in the initial steady state, all of which are constant before the policy adjustment occurs. Then, the welfare level for household i in the steady state can be specified as W_i such that:

$$W_i = \sum_{t=0}^{\infty} \beta_i^t \left[\log(C_{i,ss}) + j \log(H_{i,ss}) - \left(\frac{N_{i,ss}^{\gamma} + N_{hi,ss}^{\gamma}}{\eta} \right)^{\eta/\gamma} \right] \tag{2.22}$$

Now we can define the lifetime utility W_i^* that is expected to be obtained during the transitions and in the new steady state after housing-related policy changes as:

$$W_i^* = \sum_{t=0}^{\infty} \beta_i^t \left[\log(C_{i,t}) + j \log(H_{i,t}) - \left(\frac{N_{i,t}^{\gamma} + N_{hi,t}^{\gamma}}{\eta} \right)^{\eta/\gamma} \right] \tag{2.23}$$

Here, $C_{i,t}$ and $H_{i,t}$ are the non-housing consumption and housing stock levels, and $N_{i,t}$ and $N_{hi,t}$ are the labor supplies to the non-housing goods production and housing production sectors, respectively, for household i at time t. Now define a constant value Λ_i that shows how much addition or deduction is needed to the initial steady-state level of non-housing consumption to achieve W_i^*. Then, W_i^* can be written as follows:

$$W_i^* = \sum_{t=0}^{\infty} \beta_i^t \left[\log((1+\Lambda_i) C_{i,ss}) + j \log(H_{i,ss}) - \left(\frac{N_{i,ss}^{\gamma} + N_{hi,ss}^{\gamma}}{\eta} \right)^{\eta/\gamma} \right] \tag{2.24}$$

Therefore, by using the expressions for W_i and W_i^*, we can rewrite Λ_i in the following way:

$$\Lambda_i = 100 \times (\exp((1-\beta_i)(W_i^* - W_i)) - 1) \tag{2.25}$$

The value of Λ_i represents the consumption equivalent, indicating the welfare gain or loss resulting from changes in housing policies. By comparing the Λ_i values across different scenarios for each household type, we can identify equity issues arising from welfare changes. Additionally, we include the aggregate welfare changes by following the approach of Bielecki and Stähler (2022) and Stähler (2019), who compute the weighted average of the consumption equivalent for each household.[11] The results are presented in Table 2.4 below.

[11] In Bielecki and Stähler (2022) and Stähler (2019), the weights represent the share of each type of household. Since we assumed the proportions of households were identical, we assigned equal weight.

Table 2.4: Consumption equivalents (Λ_i)

Revenue	Expenditure	Agg.	P	IM	R
Property taxes	DCR Debt.	-1.59%	+0.39%	-0.97%	-1.01%
	ICR Inv.	+1.68%	+1.08%	+0.26%	+0.34%
	ICR Con.	-0.95%	-0.22%	-0.42%	-0.31%
	ICR Trsf.	+0.19%	-0.21%	-0.02%	+0.42%
Mortgage deductions	DCR Debt.	-1.76%	+0.70%	-1.75%	-0.71%
	ICR Inv.	+1.51%	+1.39%	-0.53%	+0.65%
	ICR Con.	-1.13%	+0.09%	-1.21%	-0.01%
	ICR Trsf.	+0.02%	+0.10%	-0.81%	+0.73%

Notes: Consumption equivalents across different combinations of revenue and expenditure side policies. 'DCR' refers to 'decreasing' and 'ICR' refers to 'increasing', respectively. 'Agg.', 'P', 'IM', and 'R' stand for aggregate level, patient households, impatient households, and renters, respectively.

First, when the housing taxes were increased, the welfare of impatient households declined unless the increase was combined with public investment. The welfare decreases range from -0.02% to -0.97% measured in non-housing goods consumption equivalents. The lower level of housing stock had a negative impact on the impatient households' welfare by limiting their participation in the financial market, as predicted. However, such negative effects could be fully compensated with significant increases in non-housing consumption if the government uses the revenues for public infrastructure formation. This approach would be the most preferable in terms of social welfare, as no one would be disadvantaged, although most of the benefit would be distributed to the private capital owners (patient households). In addition, transfer payments are favorable for impatient households' and renters' welfare levels. Higher transfer payments help households sustain their consumption of non-housing and housing goods, as well as reduce the disutility of labor supply through substitution effects. Thus, when the policy that increases transfer payments is implemented, the renters will benefit the most, and the impatient households' welfare loss will be negligible, almost identical to zero. That is to say, fiscal austerity that reduces government debt with tax revenues is most damaging for two types of households—impatient households and renters—since the debt restructur-

ing inevitably involves declines in transfer payments to them. Finally, increasing the government consumption level would be most adverse for each household's welfare since it crowds out their non-housing consumption.

In addition, when the government decides to reduce the level of mortgage deductibility, it will definitely have an adverse impact on the impatient households' welfare, varying from -0.53% to -1.75%. As we have discussed, this policy limits the credit available for this type of household more directly, and they are the only type of household that should face higher tax burdens. In this case, using public investment as a primary fiscal stimulus does not help achieve the full recovery of their welfare level. Still, public infrastructure formation is the best option to minimize the reduction of impatient households' welfare. On the other hand, the patient households benefit from all types of expenditure schemes as they are private capital owners, and they derive higher utility from housing stock levels. The renters, again, achieve the highest welfare gain with transfer payments for the reasons mentioned above.

Overall, the contractionary operations of the housing-related fiscal tools redistribute lifetime wealth from the mortgagors (the impatient households) to the savers (the patient households). Using tax revenues to enhance public infrastructure would be useful not only for helping the macroeconomy rebound from the short-run recession but also for resulting in the least harmful welfare effects for all types of households. Following Mankiw et al. (2009); Nakatani (2022), who suggest maximizing social welfare as the criterion for optimal policy, we find that the optimal mix of taxes and fiscal expenditures involves increasing public investment regardless of which tax tools are adjusted, as this approach can achieve the highest aggregate consumption equivalents in both cases. In particular, the combination of increasing the property tax rate and allocating revenues solely to government investment is most preferable in terms of 'Pareto improvement', as no one is disadvantaged by the policy implementations. This does not apply to the case of reducing mortgage deductibil-

ity, as impatient households experience significant welfare losses. Therefore, there is a conflict of interest for the policy authority, as adjusting mortgage deductibility is a more efficient tool to impact house prices and household indebtedness, but it inevitably has adverse impacts on impatient households.

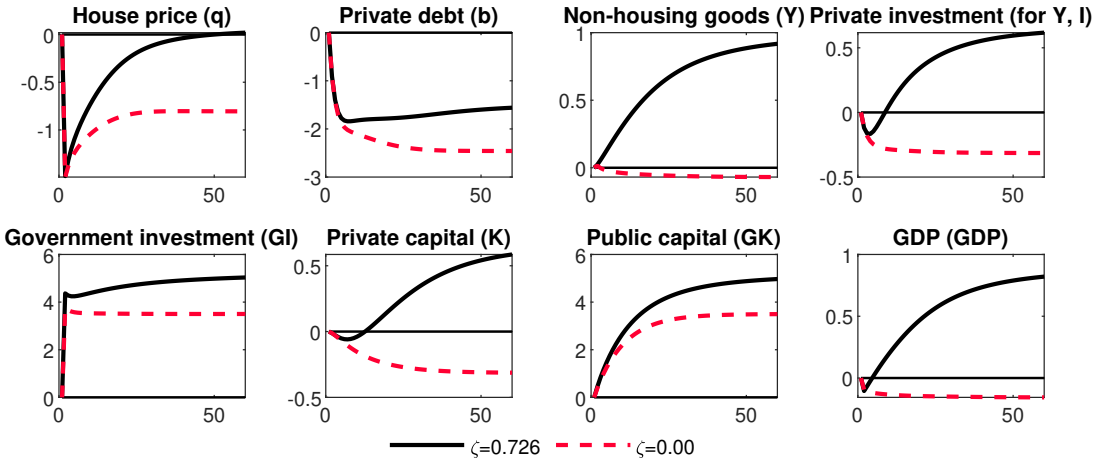
2.4.3 Discussion - Complementarity between private and public capital

One of the decisive parameters in determining the results is ζ, the complementarity between private and public capital. Throughout our exercises, we used the value of ζ estimated in Appendix 2.7.4 as a benchmark. The estimation is based on the time period between 1960 and 2019, which covers a longer horizon than the years used for the main calibration. Considering this limitation, we examine the validity of the main results and discuss how the results would differ if we used an alternative value of ζ. Intuitively, it is expected that a low degree of ζ could lead to a slower recovery phase, even if the government uses revenues for productive purposes, since the induced capital accumulation by the private sector could be less. To investigate this hypothesis, we conducted perfect foresight simulations by choosing an extreme ζ value of 0, which represents perfect substitution between the two types of capital.

Figure 2.6 shows the dynamics of variables after the tax rate adjustment combined with public investment. As can be seen from the figure, the tax measure dampens house prices and credit levels when ζ is zero. However, the degree of this effectiveness is relatively greater than when ζ is 0.726. This is because the stimulus effects on non-housing goods production are limited; public capital cannot induce investment by patient households, as the two types of capital are perfect substitutes. Instead, it crowds out private capital investment. Consequently, household income levels do not recover during the transition dynamics, leading to prolonged negative impacts on the housing market. In other words, the total output level (GDP) cannot recover even in

the medium run. Efforts to minimize the negative consequences of housing-related fiscal tools are, therefore, only effective when ζ is sufficiently large to stimulate private investment. These results suggest a clear policy implication for developing countries, which generally show lower levels of ζ, as evidenced by An et al. (2019). They should be cautious when managing household indebtedness through housing-related fiscal policies, as the economy might not recover even if fiscal expenditures are directed towards the productive sector.

Figure 2.6: Dynamics of the variables after tax rate adjustment and increases in public investment



2.5 Robustness check

We now investigate the robustness of the key results suggested earlier. This section explains the nature of the robustness check and presents the relevant findings.

2.5.1 Nominal rigidity

As noted in D'Auria (2015), a fiscal spending shock, particularly for productive spending such as public investment, would have different implications for the macroeconomy if there is nominal rigidity in the firm's price adjustments. Motivated by these findings, we incorporate price stickiness in non-housing goods production and explore its implications for the results. To add these features, we adjusted the model as follows:[12]

1. There are numerous intermediate goods producers, $z \in (0, 1)$, operating under monopolistic competition, who set their prices to maximize their lifetime profits. They are not able to adjust their prices every period; only a certain proportion $(1 - \theta)$ of firms can do so.[13] They use identical production technology as given by (2.9).

2. Non-housing goods suppliers purchase intermediate goods from producers and repackage them using a Dixit-Stiglitz aggregator.

3. There is a central bank sets the interest rate according to the Taylor rule, where the interest rate applied to loans to impatient households is a function of the inflation rate and the economy's output level.

All other features of the model are maintained as in the main analysis. After considering nominal rigidity, the results mentioned earlier were generally sustained, although there are discrepancies, particularly in the initial response of each variable and their dynamics, as shown in Figure 2.7.[14] To explain, fiscal stimulus through public investment is more effective in enhancing output because increased demand

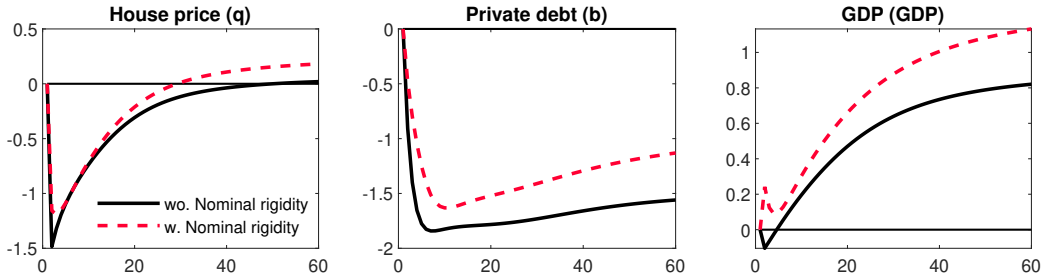
[12] A detailed description of the model with nominal rigidity is provided in Appendix 2.7.5.

[13] θ was chosen based on the survey results from Park and Song (2013) showing that Korean firms adjust their prices once a year, and the elasticity of substitution between goods, ϵ, was set to achieve a steady-state markup rate of 20%.

[14] The relevant impulse-response functions are given in Appendix 2.7.5.

for non-housing goods by the public sector raises the output level under the New Keynesian Phillips Curve (2.60). Consequently, in this case, the economy does not experience a short period of output recession. As the policy immediately improves the income level of impatient households, their housing demand is less suppressed compared to the case with price flexibility. Thus, the impact of such a policy on house prices is less significant. Accordingly, it results in smaller declines in household indebtedness as well. Overall, with nominal rigidity, using housing-related fiscal tools would be less effective for macroprudential purposes, although an economic downturn would be avoidable.

Figure 2.7: Dynamics of the variables by households after tax rate adjustment combined with public investment



Notes: The left-axis represents the percentage change from the initial steady state.

2.5.2 Housing tenure choice

There are three motivations for considering housing tenure choice. First, as argued by Rubio (2019), the transmission of macroeconomic shocks depends on the relative extent of the rental market, as it influences the degree of the financial accelerator mechanism. Second, in reality, patient and impatient households use rental housing services and own second homes as assets. During the years 2002-2019, the owner-occupancy rates of these types of households in South Korea were 51% and 94%, respectively, rather than 100% as implicitly assumed in the model.[15] Third, allow-

[15]The same dataset used for constructing Figure 2.9 was utilized to determine the owner-occupancy rates.

ing housing tenure choice has implications for welfare. It is natural to consider that higher housing-related tax burdens may prompt households to change their housing tenure status. For instance, patient households may desire to move to rental housing properties offered by others when property tax liabilities become heavier than before. The model employed for the main investigation could not account for this possibility. One of the most closely related studies, Alpanda and Zubairy (2016), also acknowledged that their welfare analysis might be overestimated because it does not consider housing tenure choice. To address these concerns, we modify the model to incorporate housing tenure choice as in Rubaszek and Rubio (2020), Sun and Tsang (2017), and Forster and Sun (2022). More concretely, the following features are incorporated into the main model:[16]

1. Both patient and impatient households gain utility not only from owner-occupied housing but also from rental housing services. This utility is modeled using a CES-type aggregator of the two housing services.

2. Rental housing services are offered by another type of agent, the buy-to-let investor, who purchases housing stock and lets it into the rental market without incurring any additional cost when providing rental services. They only gain utility from the consumption of non-housing goods and are subject to rental income taxes.

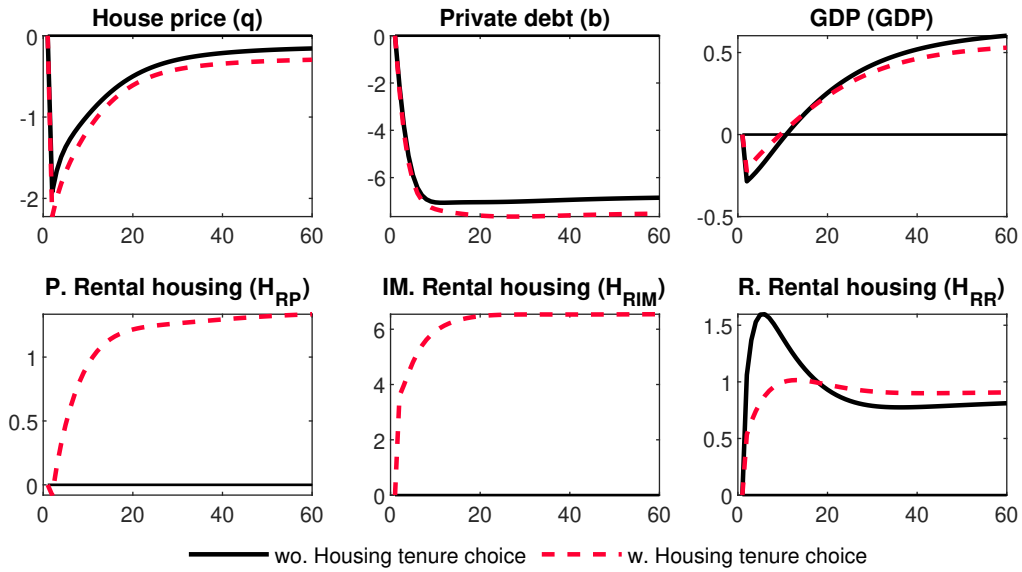
All other characteristics of the model are maintained. Overall, the key results previously discussed were generally sustained.[17] However, the policy effects are not exactly identical to those in the main analysis, and tax measures have a slightly larger impact on house prices and household indebtedness. Figure 2.8 illustrates this implication by showing the effects of lower mortgage deductibility combined with increased public investment. This is because tighter tax measures encourage

[16] A detailed description of the features is given in Appendix 2.7.6.
[17] All impulse-response functions are given in Appendix 2.7.6.

impatient households to choose rental housing services to sustain their welfare levels. This implies that the demand for housing stock by these households is more depressed than in the scenario without housing tenure choice, thereby intensifying the dampening effects. Such increased expenditures on rental housing services help the economy experience a less severe downturn in the short run, but the economy achieves a lower output level in the end, as housing investment is adversely affected by reduced demand for owner-occupied housing.

Table 2.5 compares the welfare changes of households based on whether the model allows housing tenure choice. Overall, the welfare of impatient households is disadvantaged (Panel B), but it is slightly less severe.

Figure 2.8: Dynamics of the variables by households after reducing mortgage deductibility combined with public investment



Notes: Impulse responses to a mortgage deductibility shock. 'P' refers to patient households. 'IM' refers to impatient households. 'R' means renter.

Table 2.5: Comparison of consumption equivalents (Λ_i)

	Expenditure	Agg.	P	IM	R
Panel A:	DCR Debt.	-1.76%	+0.70%	-1.75%	-0.71%
wo. Housing tenure choice	ICR Inv.	+1.51%	+1.39%	-0.53%	+0.65%
	ICR Con.	-1.13%	+0.09%	-1.21%	-0.01%
	ICR Trsf.	+0.02%	+0.10%	-0.81%	+0.73%
Panel B:	DCR Debt.	-1.38%	+0.64%	-1.48%	-0.54%
w. Housing tenure choice	ICR Inv.	+1.44%	+1.25%	-0.43%	+0.62%
	ICR Con.	-0.91%	+0.11%	-1.04%	+0.02%
	ICR Trsf.	+0.10%	+0.12%	-0.69%	+0.67%
Difference (B-A)	DCR Debt.	+0.38	-0.06	+0.27	+0.17
	ICR Inv.	-0.07	-0.13	+0.10	-0.03
	ICR Con.	+0.22	+0.02	+0.17	+0.03
	ICR Trsf.	+0.08	+0.02	+0.12	-0.06

Notes: Consumption equivalent across different combinations of the revenue and expenditure side policies.'DCR' refers to 'decreasing' and 'ICR' refers to 'increasing', respectively. 'Agg.', 'P', 'IM', and 'R' stand for aggregate level, patient households, impatient households, and renters, respectively.

2.6 Concluding Remarks

Despite the growing utilization of housing-related fiscal tools as a means to achieve financial stability, their optimal deployment has been insufficiently explored. Previous studies often overlook the interplay between tax increases and the components of public spending, a critical factor in determining the efficacy of these fiscal tools. Recognizing this gap, this study undertakes a comprehensive analysis of how such tools influence economic output and household welfare, as well as their effectiveness in implementing macroprudential policy objectives. Employing a dynamic general equilibrium model incorporating the housing market and government interventions, this research scrutinizes the effects of contractionary measures such as recurrent property tax increases, reductions in mortgage deductions, and various public expenditures.

The analysis confirms that increasing property tax rates or decreasing mortgage

deductibility suppresses house prices and household indebtedness. Although these measures facilitate the reallocation of resources towards capital formation for the non-housing goods production sector, they dampen residential investment, leading to economic downturns. Due to such changes, the collateral-constrained borrowers particularly experience adverse welfare effects since their financial availability is reduced with the depreciation of the housing stock values, and their housing services are negatively affected. Such negative consequences closely align with findings by Alpanda and Zubairy (2016), where the government primarily uses revenues from adjusting housing-related tax measures to reduce government debt. However, unlike Alpanda and Zubairy (2016), we show that the outcomes depend significantly on how additional tax revenues are allocated. Specifically, the recovery from the short-run downturn is accelerated when tax revenues are redirected towards public infrastructure investments, as this boosts non-housing goods production, contingent upon sufficient complementarity between public and private capital. Moreover, the enhancements in public infrastructure spending can mitigate the borrowers' welfare disadvantages by bolstering output levels in non-housing goods sectors.

This framework establishes a foundation for subsequent investigations. While the present model exogenously determines the types of agents and their proportions within the economy based on existing data, future studies could consider endogenizing these aspects. Additionally, incorporating potential demographic shifts and household decision-making processes related to age could yield further insights. Empirical investigations using microdata to support and supplement the theoretical findings of this study would be highly valuable, providing a more nuanced understanding of the impacts of housing-related fiscal policies.

2.7 Appendix

2.7.1 Main Equations

Patient household

$$(1-\tau_S)W_{P,t} = C_{P,t}N_{P,t}^{\gamma-1}(N_{P,t}^{\gamma}+N_{hP,t}^{\gamma})^{\frac{\eta}{\gamma}-1} \tag{2.26}$$

$$(1-\tau_S)W_{hP,t} = C_{P,t}N_{hP,t}^{\gamma-1}(N_{P,t}^{\gamma}+N_{hP,t}^{\gamma})^{\frac{\eta}{\gamma}-1} \tag{2.27}$$

$$\frac{j}{H_{P,t}} = \frac{1}{C_{P,t}}(1+\tau^{tc})q_t - E_t\beta_P\left(\frac{1}{C_{P,t+1}}(1-\delta_H-\tau_{t+1}^{p})q_{t+1}\right) \tag{2.28}$$

$$(1+\tau^{tc})q_t = E_t\beta_P\frac{C_{P,t}}{C_{P,t+1}}(1-\delta_H-\tau_{t+1}^{p})q_{t+1} + (1-\tau_{RI,t})RR_t \tag{2.29}$$

$$\frac{1}{C_{P,t}} = \beta_P E_t\frac{1}{C_{P,t+1}}R_t \tag{2.30}$$

$$\frac{1}{C_{P,t}} = \beta_P E_t\frac{1}{C_{P,t+1}}R_t^G \tag{2.31}$$

$$\frac{\mu_t}{C_{P,t}} = \beta_P E_t\frac{1}{C_{P,t+1}}((1-\tau_S)r_{t+1}+\mu_{t+1}(1-\delta)) \tag{2.32}$$

$$\frac{\mu_{h,t}}{C_{P,t}} = \beta_P E_t\frac{1}{C_{P,t+1}}((1-\tau_S)r_{h,t+1}+\mu_{h,t+1}(1-\delta_h)) \tag{2.33}$$

$$\begin{aligned}1 = {} & \mu_t\left(1-\frac{\psi}{2}\left(\frac{I_t}{I_{t-1}}-1\right)^2-\psi\frac{I_t}{I_{t-1}}\left(\frac{I_t}{I_{t-1}}-1\right)\right)\\ & +\beta_P E_t\frac{C_{P,t}}{C_{P,t+1}}\mu_{t+1}\left(\frac{I_{t+1}}{I_t}\right)^2\psi\left(\frac{I_{t+1}}{I_t}-1\right)\end{aligned} \tag{2.34}$$

$$\begin{aligned}1 = {} & \mu_{h,t}\left(1-\frac{\psi_h}{2}\left(\frac{I_{h,t}}{I_{h,t-1}}-1\right)^2-\psi_h\frac{I_{h,t}}{I_{h,t-1}}\left(\frac{I_{h,t}}{I_{h,t-1}}-1\right)\right)\\ & +\beta_P E_t\frac{C_{P,t}}{C_{P,t+1}}\mu_{h,t+1}\left(\frac{I_{h,t+1}}{I_{h,t}}\right)^2\psi_h\left(\frac{I_{h,t+1}}{I_{h,t}}-1\right)\end{aligned} \tag{2.35}$$

$$P_{L,t} = \beta_P E_t\frac{C_{P,t}}{C_{P,t+1}}\left(P_{L,t+1}+(1-\tau_S)r_{L,t+1}\right) \tag{2.36}$$

Impatient household

$$(1-\tau_{IM})W_{IM,t} = C_{IM,t}N_{IM,t}^{\gamma-1}(N_{IM,t}^{\gamma}+N_{hIM,t}^{\gamma})^{\frac{\eta}{\gamma}-1} \tag{2.37}$$

$$(1-\tau_{IM})W_{hIM,t} = C_{IM,t}N_{hIM,t}^{\gamma-1}(N_{IM,t}^{\gamma}+N_{hIM,t}^{\gamma})^{\frac{\eta}{\gamma}-1} \tag{2.38}$$

$$\frac{j}{H_{IM,t}} = \frac{1}{C_{IM,t}}(1+\tau^{tc})q_t - E_t\beta_{IM}\left(\frac{1}{C_{IM,t+1}}(1-\delta_H-\tau_{t+1}^{p})q_{t+1}\right) - \lambda_{b,t}LTV_tE_t\left(\frac{q_{t+1}}{R_t}\right) \tag{2.39}$$

$$\frac{1}{C_{IM,t}} = \beta_{IM}E_t\frac{1}{C_{IM,t+1}}R_t\left(1-\kappa_{B,t+1}\tau_{IM}\right)+\lambda_{b,t} \tag{2.40}$$

Renter

$$\frac{j}{H_{RR,t}} = \frac{1}{C_{R,t}}RR_t \tag{2.41}$$

$$(1-\tau_R)W_{R,t} = C_{R,t}N_{R,t}^{\gamma-1}(N_{R,t}^{\gamma}+N_{hR,t}^{\gamma})^{\frac{\eta}{\gamma}-1} \tag{2.42}$$

$$(1-\tau_R)W_{hR,t} = C_{R,t}N_{hR,t}^{\gamma-1}(N_{R,t}^{\gamma}+N_{hR,t}^{\gamma})^{\frac{\eta}{\gamma}-1} \tag{2.43}$$

Non-housing goods producer

$$W_{P,t} = \frac{\alpha_P(1-\omega)Y_t}{N_{P,t}} \tag{2.44}$$

$$W_{IM,t} = \frac{\alpha_{IM}(1-\omega)Y_t}{N_{IM,t}} \tag{2.45}$$

$$W_{R,t} = \frac{(1-\alpha_P-\alpha_{IM})(1-\omega)Y_t}{N_{R,t}} \tag{2.46}$$

$$r_t = \left(\frac{(1-\chi)K_{t-1}^{1-\zeta}}{\chi G K_{t-1}^{1-\zeta}+(1-\chi)K_{t-1}^{1-\zeta}}\right)\omega\frac{Y_t}{K_{t-1}} \tag{2.47}$$

Housing Producer

$$N_{hP,t} = \frac{q_t\alpha_P(1-\mu_h-\mu_L)IH_t}{W_{hP,t}} \tag{2.48}$$

$$N_{hIM,t} = \frac{q_t\alpha_{IM}(1-\mu_h-\mu_L)IH_t}{W_{hIM,t}} \tag{2.49}$$

$$N_{hR,t} = \frac{q_t \alpha_R (1 - \mu_h - \mu_L) I H_t}{W_{hR,t}} \tag{2.50}$$

$$r_{h,t} = \frac{q_t \mu_h I H_t}{K_{h,t-1}} \tag{2.51}$$

$$r_{L,t} = \frac{q_t \mu_L I H_t}{L_{t-1}} \tag{2.52}$$

2.7.2 Derivations of the main equations

1. Patient households' problem

$$\begin{aligned}
\mathcal{L} = E_0 \sum_{t=0}^{\infty} \beta_P^t [\log(C_{P,t}) + j \log(H_{P,t}) - (N_{P,t}^{\gamma} + N_{hP,t}^{\gamma})^{\frac{\eta}{\gamma}} \eta^{-1} \\
+ \lambda_{P,t} [R_{t-1} b_{t-1} + R_{t-1}^g B_{t-1}^g + W_{P,t} N_{P,t} + W_{hP,t} N_{hP,t} + r_t K_{t-1} + r_{h,t} K_{h,t-1} + r_{L,t} L_{t-1} \\
- \tau_S (W_{P,t} N_{P,t} + W_{hP,t} N_{hP,t} + r_t K_{t-1} + r_{h,t} K_{h,t-1} + r_{L,t} L_{t-1}) \\
+ P_{L,t} L_{t-1} + (1 - \delta_H - \tau_t^p)(q_t H_{P,t-1} + H_{RR,t-1}^s) + TR_{P,t} \\
- (C_{P,t} + I_t + I_{h,t} + P_{L,t} L_t + b_t + B_t^g + (1 + \tau^{tc})(q_t H_{P,t} + H_{RR,t}^s)) \\
+ \mu_t ((1 - \delta) K_{t-1} - K_t + I_t (1 - (\psi/2)(I_t / I_{t-1} - 1)^2) \\
+ \mu_{h,t} ((1 - \delta) K_{h,t-1} - K_{h,t} + I_{h,t} (1 - (\psi_h/2)(I_{h,t} / I_{h,t-1} - 1)^2)]
\end{aligned}$$

$\Rightarrow \frac{\partial L}{\partial C_{P,t}} = \beta_P^t \frac{1}{C_{P,t}} + \beta_P^t \lambda_{P,t}(-1) = 0, \therefore \lambda_{P,t} = \frac{1}{C_{P,t}}$

$\Rightarrow \frac{\partial L}{\partial H_{P,t}} = \beta_P^t (\frac{j}{H_{P,t}} + \lambda_{P,t}(1 + \tau^{tc})(-q_t)) + E_t \beta_P^{t+1} \lambda_{P,t+1}(1 - \delta_H - \tau_{t+1}^p) q_{t+1} = 0$
and $\lambda_{P,t} = \frac{1}{C_{P,t}}$

$\therefore \frac{j}{H_{P,t}} = \frac{1}{C_{P,t}}(1 + \tau^{tc}) q_t - E_t \beta_P \left(\frac{1}{C_{P,t+1}} (1 - \delta_H - \tau_{t+1}^p) q_{t+1} \right)$

$\Rightarrow \frac{\partial L}{\partial N_{P,t}} = \beta_P^t N_{P,t}^{\gamma-1} (N_{P,t}^{\gamma} + N_{hP,t}^{\gamma})^{\frac{\eta}{\gamma}-1} + \beta_P^t \lambda_{P,t}(1 - \tau_S) W_{P,t} = 0$ and $\lambda_{P,t} = \frac{1}{C_{P,t}}$,
$\therefore (1 - \tau_S) W_{P,t} = C_{P,t} N_{P,t}^{\gamma-1} (N_{P,t}^{\gamma} + N_{hP,t}^{\gamma})^{\frac{\eta}{\gamma}-1}$

$\Rightarrow \frac{\partial L}{\partial N_{hP,t}} = \beta_P^t N_{hP,t}^{\gamma-1} (N_{P,t}^{\gamma} + N_{hP,t}^{\gamma})^{\frac{\eta}{\gamma}-1} + \beta_P^t \lambda_{P,t}(1 - \tau_S) W_{hP,t} = 0$ and $\lambda_{P,t} = \frac{1}{C_{P,t}}$,
$\therefore (1 - \tau_S) W_{hP,t} = C_{P,t} N_{hP,t}^{\gamma-1} (N_{P,t}^{\gamma} + N_{hP,t}^{\gamma})^{\frac{\eta}{\gamma}-1}$

$\Rightarrow \frac{\partial L}{\partial b_t} = \beta_P^t (-\lambda_{P,t}) + E_t \beta_P^{t+1} \lambda_{P,t+1} \frac{R_t}{\pi_{t+1}} = 0$ and $\lambda_{P,t} = \frac{1}{C_{P,t}}, \therefore \frac{1}{C_{P,t}} = \beta_P E_t \frac{1}{C_{P,t+1}} \frac{R_t}{\pi_{t+1}}$

$\Rightarrow \frac{\partial L}{\partial B_t^g} = \beta_P^t(-\lambda_{P,t}) + E_t\beta_P^{t+1}\lambda_{P,t+1}\frac{R_t^g}{\pi_{t+1}} = 0$ and $\lambda_{P,t} = \frac{1}{C_{P,t}}$, $\therefore \frac{1}{C_{P,t}} = \beta_P E_t \frac{1}{C_{P,t+1}}\frac{R_t^g}{\pi_{t+1}}$

$\Rightarrow \frac{\partial L}{\partial K_t} = \lambda_{P,t}\mu_t(-1)\beta_P^t + E_t\beta_P^{t+1}\lambda_{P,t+1}((1-\tau_S)r_{t+1} + \mu_{t+1}(1-\delta)) = 0$ and $\lambda_{P,t} = \frac{1}{C_{P,t}}$, $\therefore \frac{\mu_t}{C_{P,t}} = \beta_P E_t \frac{1}{C_{P,t+1}}((1-\tau_S)r_{t+1} + \mu_{t+1}(1-\delta))$

$\Rightarrow \frac{\partial L}{\partial K_{h,t}} = \lambda_{P,t}\mu_{h,t}(-1)\beta_P^t + E_t\beta_P^{t+1}\lambda_{P,t+1}((1-\tau_S)r_{h,t+1} + \mu_{h,t+1}(1-\delta_h)) = 0$ and $\lambda_{P,t} = \frac{1}{C_{P,t}}$, $\therefore \frac{\mu_t}{C_{P,t}} = \beta_P E_t \frac{1}{C_{P,t+1}}((1-\tau_S)r_{h,t+1} + \mu_{h,t+1}(1-\delta_h))$

$\Rightarrow \frac{\partial L}{\partial I_t} = \beta_P^t(\lambda_{P,t}(-1) + \lambda_{P,t}\mu_t(1 - \frac{\psi}{2}(\frac{I_t}{I_{t-1}} - 1)^2 - \psi(\frac{I_t}{I_{t-1}} - 1)\frac{I_t}{I_{t-1}})$
$+ E_t\beta_P^{t+1}(\lambda_{P,t+1}\mu_{t+1}\psi\frac{I_{t+1}^2}{I_t^2}(\frac{I_{t+1}}{I_t} - 1)) = 0$ and $\lambda_{P,t} = \frac{1}{C_{P,t}}$

$$\therefore \quad 1 = \mu_t\left(1 - \frac{\psi}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 - \psi\frac{I_t}{I_{t-1}}\left(\frac{I_t}{I_{t-1}} - 1\right)\right)$$
$$+ \beta_P E_t \frac{C_{P,t}}{C_{P,t+1}}\mu_{t+1}\left(\frac{I_{t+1}}{I_t}\right)^2\psi\left(\frac{I_{t+1}}{I_t} - 1\right)$$

$$\Rightarrow \frac{\partial L}{\partial I_{h,t}} = \beta_P^t(\lambda_{P,t}(-1) + \lambda_{P,t}\mu_{h,t}(1 - \frac{\psi_h}{2}(\frac{I_{h,t}}{I_{h,t-1}} - 1)^2 - \psi_h(\frac{I_{h,t}}{I_{h,t-1}} - 1)\frac{I_{h,t}}{I_{h,t-1}}) + E_t\beta_P^{t+1}(\lambda_{P,t+1}\mu_{h,t+1}\psi_h\frac{I_{h,t+1}^2}{I_{h,t}^2}(\frac{I_{h,t+1}}{I_{h,t}} - 1)) = 0$$

and $\lambda_{P,t} = \frac{1}{C_{P,t}}$

$$\therefore 1 = \mu_{h,t}\left(1 - \frac{\psi_h}{2}\left(\frac{I_{h,t}}{I_{h,t-1}} - 1\right)^2 - \psi_h\frac{I_{h,t}}{I_{h,t-1}}\left(\frac{I_{h,t}}{I_{h,t-1}} - 1\right)\right)$$
$$+ \beta_P E_t \frac{C_{P,t}}{C_{P,t+1}}\mu_{h,t+1}\left(\frac{I_{h,t+1}}{I_{h,t}}\right)^2\psi_h\left(\frac{I_{h,t+1}}{I_{h,t}} - 1\right)$$

$\Rightarrow \frac{\partial L}{\partial L_t} = -\beta_P^t\lambda_{P,t}P_{L,t} + \beta_P^{t+1}(\lambda_{P,t+1}(1-\tau_S)r_{L,t+1} + P_{L,t+1}) = 0$

and $\lambda_{P,t} = \frac{1}{C_{P,t}}$, $\therefore P_{L,t} = \beta_P E_t \frac{C_{P,t}}{C_{P,t+1}}(P_{L,t+1} + (1-\tau_S)r_{L,t+1})$

2. Impatient households' problem

$$\mathcal{L} = E_0\sum_{t=0}^{\infty}\beta_{IM}^t[\log(C_{IM,t}) + j\log(H_{IM,t}) - (N_{IM,t}^{\gamma} + N_{hIM,t}^{\gamma})^{\frac{\eta}{\gamma}}\eta^{-1}$$
$$+ \lambda_{d,t}[W_{IM,t}N_{IM,t} + W_{hIM,t}N_{hIM,t} + b_t + (1 - \delta_H - \tau_t^p)q_tH_{IM,t-1} + TR_{IM,t}$$
$$- \tau_{IM}(W_{IM,t}N_{IM,t} + W_{hIM,t}N_{hIM,t} - \kappa_{B,t}R_{t-1}b_{t-1})$$
$$- (C_{IM,t} + R_{t-1}b_{t-1} + (1+\tau^{tc})q_tH_{IM,t}) + \lambda_{b,t}(LTV_tq_{t+1}H_{IM,t}\frac{1}{R_{t+1}} - b_t)]$$

$\Rightarrow \frac{\partial L}{\partial C_{IM,t}} = \beta_{IM}^t \frac{1}{C_{IM,t}} + \beta_{IM}^t \lambda_{d,t}(-1) = 0, \therefore \lambda_{d,t} = \frac{1}{C_{IM,t}}$

$\Rightarrow \frac{\partial L}{\partial H_{IM,t}} = \beta_{IM}^t (\frac{j}{H_{IM,t}} + \lambda_{d,t}(1+\tau^{tc})(-q_t) + \lambda_{b,t} E_t LTV_t q_{t+1} \frac{1}{R_{t+1}}) + E_t \beta_{IM}^{t+1} \lambda_{d,t+1}(1-\delta_H - \tau_{t+1}^p) q_{t+1} = 0$ and $\lambda_{d,t} = \frac{1}{C_{IM,t}}$

$\therefore \frac{j}{H_{IM,t}} = \frac{1}{C_{IM,t}}(1+\tau_t^{tc}) q_t - E_t \beta_{IM} \left(\frac{1}{C_{IM,t+1}} (1 - \delta_H - \tau_{t+1}^p) q_{t+1} \right) - \lambda_{b,t} LTV_t E_t \left(\frac{q_{t+1}}{R_t} \right)$

$\therefore \frac{j}{\tilde{H_{IM,t}}^{(\epsilon_h - 1)/\epsilon_h}} (1 - \omega_{IM})^{1/\epsilon_h} H_{RIM,t}^{-1/\epsilon_h} = \frac{RR_t}{C_{IM,t}} (1 - \tau_{IM} \kappa_{R,t})$

$\Rightarrow \frac{\partial L}{\partial N_{IM,t}} = \beta_{IM}^t N_{IM,t}^{\gamma-1} (N_{IM,t}^\gamma + N_{hIM,t}^\gamma)^{\frac{\eta}{\gamma}-1} + \beta_{IM}^t \lambda_{IM,t}(1-\tau_{IM}) W_{IM,t} = 0$ and $\lambda_{IM,t} = \frac{1}{C_{IM,t}}, \therefore (1-\tau_{IM}) W_{IM,t} = C_{IM,t} N_{IM,t}^{\gamma-1} (N_{IM,t}^\gamma + N_{hIM,t}^\gamma)^{\frac{\eta}{\gamma}-1}$

$\Rightarrow \frac{\partial L}{\partial N_{hIM,t}} = \beta_{IM}^t N_{hIM,t}^{\gamma-1} (N_{IM,t}^\gamma + N_{hIM,t}^\gamma)^{\frac{\eta}{\gamma}-1} + \beta_{IM}^t \lambda_{IM,t}(1-\tau_{IM}) W_{hIM,t} = 0$ and $\lambda_{IM,t} = \frac{1}{C_{IM,t}}, \therefore (1-\tau_{IM}) W_{hIM,t} = C_{IM,t} N_{hIM,t}^{\gamma-1} (N_{IM,t}^\gamma + N_{hIM,t}^\gamma)^{\frac{\eta}{\gamma}-1}$

$\Rightarrow \frac{\partial L}{\partial b_t} = \beta_{IM}^t (-\lambda_{b,t} + \lambda_{d,t}) + E_t \beta_{IM}^{t+1} \lambda_{d,t+1} (\tau_{IM} \kappa_{B,t+1} \frac{R_t}{\pi_{t+1}} - \frac{R_t}{\pi_{t+1}}) = 0$ and $\lambda_{d,t} = \frac{1}{C_{IM,t}}, \therefore \frac{1}{C_{IM,t}} = \beta_{IM} E_t \frac{1}{C_{IM,t+1}} \frac{R_t}{\pi_{t+1}} (1 - \kappa_{B,t+1} \tau_{IM}) + \lambda_{b,t}$

3. Renters' problem

$$\begin{aligned}\mathcal{L} = E_0 \sum_{t=0}^{\infty} \beta_R^t [\log(C_{R,t}) + j \log(H_{RR,t}) - (N_{R,t}^\gamma + N_{hR,t}^\gamma)^{\frac{\eta}{\gamma}} \eta^{-1} \\ + \lambda_{R,t} [W_{R,t} N_{R,t} + W_{hR,t} N_{hR,t} + TR_{R,t} - C_{R,t} - RR_t H_{RR,t} \\ - \tau_R (W_{R,t} N_{R,t} + W_{hR,t} N_{hR,t})]\end{aligned}$$

$\Rightarrow \frac{\partial L}{\partial C_{R,t}} = \beta_R^t \frac{1}{C_{R,t}} + \beta_R^t \lambda_{R,t}(-1) = 0, \therefore \lambda_{R,t} = \frac{1}{C_{R,t}}$

$\Rightarrow \frac{\partial L}{\partial H_{RR,t}} = \beta_R^t (\frac{j}{H_{RR,t}} + \lambda_{R,t}(-RR_t)) = 0$ and $\lambda_{R,t} = \frac{1}{C_{R,t}}, \therefore \frac{j}{H_{RR,t}} = \frac{RR_t}{C_{R,t}}$

$\Rightarrow \frac{\partial L}{\partial N_{R,t}} = \beta_R^t N_{R,t}^{\gamma-1} (N_{R,t}^\gamma + N_{hR,t}^\gamma)^{\frac{\eta}{\gamma}-1} + \beta_R^t \lambda_{R,t}(1-\tau_R) W_{R,t} = 0$ and $\lambda_{R,t} = \frac{1}{C_{R,t}}, \therefore (1-\tau_R) W_{R,t} = C_{R,t} N_{R,t}^{\gamma-1} (N_{R,t}^\gamma + N_{hR,t}^\gamma)^{\frac{\eta}{\gamma}-1}$

$\Rightarrow \frac{\partial L}{\partial N_{hR,t}} = \beta_R^t N_{hR,t}^{\gamma-1} (N_{R,t}^\gamma + N_{hR,t}^\gamma)^{\frac{\eta}{\gamma}-1} + \beta_R^t \lambda_{R,t}(1-\tau_R) W_{hR,t} = 0$ and $\lambda_{R,t} = \frac{1}{C_{R,t}}, \therefore (1-\tau_R) W_{hR,t} = C_{R,t} N_{hR,t}^{\gamma-1} (N_{R,t}^\gamma + N_{hR,t}^\gamma)^{\frac{\eta}{\gamma}-1}$

4. Non-housing goods producer's problem

$$\Pi_t = Y_t - (W_{P,t}N_{P,t} + W_{IM,t}N_{IM,t} + W_{R,t}N_{R,t} + r_tK_{t-1})$$

$$\Rightarrow \frac{\partial \Pi_t}{\partial N_{P,t}} = -W_{P,t} + (\alpha_P(1-\omega)A(\chi Gk_{t-1}^{1-\zeta} + (1-\chi)K_{t-1}^{1-\zeta})^{\frac{\omega}{1-\zeta}} N_{P,t}^{\alpha(1-\omega)-1} N_{IM,t}^{\alpha_{IM}(1-\omega)} N_{R,t}^{(1-\alpha_P-\alpha_{IM})(1-\omega)}) = 0$$

$$\therefore W_{P,t} = \alpha_P(1-\omega)Y_t/N_{P,t}$$

$$\Rightarrow \frac{\partial \Pi_t}{\partial N_{IM,t}} = -W_{IM,t} + \Phi_t(\alpha_{IM}(1-\omega)A(\chi Gk_{t-1}^{1-\zeta} + (1-\chi)K_{t-1}^{1-\zeta})^{\frac{\omega}{1-\zeta}} N_{P,t}^{\alpha(1-\omega)} N_{IM,t}^{\alpha_{IM}(1-\omega)-1} N_{R,t}^{(1-\alpha_P-\alpha_{IM})(1-\omega)}) = 0$$

$$\therefore W_{IM,t} = \alpha_{IM}(1-\omega)Y_t/N_{IM,t}$$

$$\Rightarrow \frac{\partial \Pi_t}{\partial N_{R,t}} = -W_{R,t} + (\alpha_R(1-\omega)A(\chi Gk_{t-1}^{1-\zeta} + (1-\chi)K_{t-1}^{1-\zeta})^{\frac{\omega}{1-\zeta}} N_{P,t}^{\alpha(1-\omega)} N_{IM,t}^{\alpha_{IM}(1-\omega)} N_{R,t}^{(1-\alpha_P-\alpha_{IM})(1-\omega)-1}) = 0$$

$$\therefore W_{R,t} = (1-\alpha_P-\alpha_{IM})(1-\omega)Y_t/N_{R,t}$$

$$\Rightarrow \frac{\partial \Pi_t}{\partial K_{t-1}} = -r_t + (\frac{\omega}{1-\zeta}(1-\chi)(1-\zeta)K_{t-1}^{1-\zeta-1}A(\chi Gk_{t-1}^{1-\zeta} + (1-\chi)K_{t-1}^{1-\zeta})^{\frac{\omega}{1-\zeta}-1} N_{P,t}^{\alpha(1-\omega)} N_{IM,t}^{\alpha_{IM}(1-\omega)} N_{R,t}^{(1-\alpha_P-\alpha_{IM})(1-\omega)}) = 0$$

$$\therefore r_t = (\frac{(1-\chi)K_{t-1}^{1-\zeta}}{\chi GK_{t-1}^{1-\zeta} + (1-\chi)K_{t-1}^{1-\zeta}})\omega\frac{Y_t}{K_{t-1}}$$

5. Housing producer's problem

$$\max \Pi_{h,t} = q_tBK_{h,t-1}^{\mu_h}L^{\mu_L}(N_{hP,t}^{\alpha_P}N_{hIM,t}^{\alpha_{IM}}N_{hR,t}^{\alpha_R})^{1-\mu_h-\mu_L} - (r_{h,t}K_{h,t-1} + W_{hP,t}N_{hP,t} + W_{hIM,t}N_{hIM,t} + W_{hR,t}N_{hR,t} + r_{L,t}L)$$

$$\Rightarrow \frac{\partial \Pi_{h,t}}{\partial N_{hP,t}} = q_tBK_{h,t-1}^{\mu_h}L^{\mu_L}(N_{hP,t}^{\alpha_P}N_{hIM,t}^{\alpha_{IM}}N_{hR,t}^{\alpha_R})^{1-\mu_h-\mu_L}\alpha_P(1-\mu_h-\mu_L)N_{hP,t}^{-1} - W_{hP,t} = 0$$

$$\therefore W_{hP,t} = \frac{q_t\alpha_P(1-\mu_h-\mu_L)IH_t}{N_{hP,t}}$$

$$\Rightarrow \frac{\partial \Pi_{h,t}}{\partial N_{hIM,t}} = q_tBK_{h,t-1}^{\mu_h}L^{\mu_L}(N_{hP,t}^{\alpha_P}N_{hIM,t}^{\alpha_{IM}}N_{hR,t}^{\alpha_R})^{1-\mu_h-\mu_L}\alpha_{IM}(1-\mu_h-\mu_L)N_{hIM,t}^{-1} -$$

$W_{hIM,t} = 0$

$\therefore W_{hIM,t} = \frac{q_t \alpha_{IM}(1-\mu_h-\mu_L)IH_t}{N_{hIM,t}}$

$\Rightarrow \frac{\partial \Pi_{h,t}}{\partial N_{hR,t}} = q_t B K_{h,t-1}^{\mu_h} L^{\mu_L} (N_{hP,t}^{\alpha_P} N_{hIM,t}^{\alpha_{IM}} N_{hR,t}^{\alpha_R})^{1-\mu_h-\mu_L} \alpha_R (1-\mu_h-\mu_L) N_{hP,t}^{-1} -$

$W_{hP,t} = 0$

$\therefore W_{hR,t} = \frac{q_t \alpha_R(1-\mu_h-\mu_L)IH_t}{N_{hR,t}}$

$\Rightarrow \frac{\partial \Pi_{h,t}}{\partial K_{h,t-1}} = q_t B K_{h,t-1}^{\mu_h} L^{\mu_L} (N_{hP,t}^{\alpha_P} N_{hIM,t}^{\alpha_{IM}} N_{hR,t}^{\alpha_R})^{1-\mu_h-\mu_L} \mu_h K_{h,t-1}^{-1} - r_{h,t} = 0$

$\therefore r_{h,t} = \frac{q_t \mu_h IH_t}{K_{h,t-1}}$

$\Rightarrow \frac{\partial \Pi_{h,t}}{\partial L} = q_t B K_{h,t-1}^{\mu_h} L^{\mu_L} (N_{hP,t}^{\alpha_P} N_{hIM,t}^{\alpha_{IM}} N_{hR,t}^{\alpha_R})^{1-\mu_h-\mu_L} \mu_L L^{-1} - r_{L,t} = 0$

$\therefore r_{L,t} = \frac{q_t \mu_L IH_t}{L}$

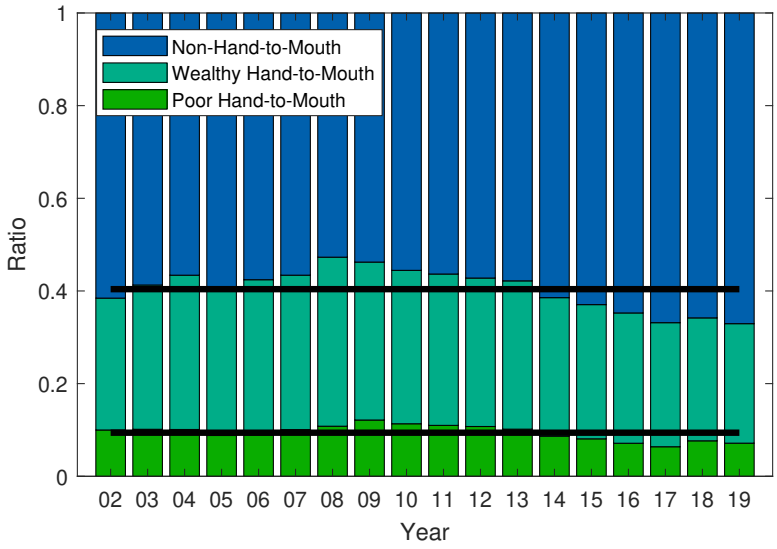
2.7.3 Ratios of Hand-to-Mouth households in Korea

Identifying the ratios of each type of household is completed by referring to the methods outlined in Park (2017). The Korean Labor and Income Panel Study (KLIPS) from the Korea Labor Institute is used. This is an annual survey of approximately 5,000 households with a repeated sample. The computed values are adopted for model calibration.

2.7.4 Auxiliary regression for capital substitutability parameters

The parameter ζ, representing the substitutability between private capital and public infrastructure, has been estimated using Korean data from 1960 to 2019. All data are in real terms. The regression model is based on An et al. (2019), which estimated the substitutability between private and public capital in a CES production

Figure 2.9: Ratios of Hand-to-Mouth households in Korea



function. Specifically, the following model has been estimated, and the data used for the regression are provided in Table 2.6.

$$ln(\frac{Y_t}{Y_{t-1}}) = \lambda + (1-\omega)ln(\frac{N_t}{N_{t-1}}) + \frac{\omega}{1-\zeta}ln(\frac{\chi Gk_t + (1-\chi)K_t}{\chi Gk_{t-1} + (1-\chi)K_{t-1}}) + v_t \quad (2.53)$$

Table 2.6: Data used for the estimation ζ

Variables	Data	Sources
Y	GDP	Bank of Korea
N	Number of persons engaged	Penn World Table, version 10.0
Gk	General government capital stocks	IMF
K	Private capital stocks	IMF

Note that v_t is the error term. Although the calibrated parameters were chosen to describe the Korean economy between 2002 and 2019, data from a longer time horizon were selected for ζ estimation. This was done to increase the number of observations and achieve a more reliable regression outcome. As conducted by An et al. (2019), the estimation using 2-year, 3-year, and 5-year averaged data was also performed. By doing so, the potential effects of business cycles could be mitigated.

The estimation results, obtained by non-linear least squares, are given in Table 2.7. The table shows that the estimated ζ varies from 0.718 to 0.727 and is statistically significant only when 5-year averaged data is used. Other parameters show minor discrepancies among each other and are statistically insignificant except for the intercept. The estimated parameter with 5-year averaged data, which showed statistical significance, was chosen as the benchmark case for the main analysis.

Table 2.7: Estimation results for substitutability parameters

	(1)	(2)	(3)	(4)
PARAMETERS	Level	2 yr. Avg.	3 yr. Avg.	5 yr. Avg.
λ	0.080**	0.080**	0.082***	0.083***
	(0.031)	(0.023)	(0.019)	(0.014)
ω	-0.003	-0.003	-0.003	-0.003
	(0.007)	(0.005)	(0.004)	(0.003)
ζ	0.720	0.727	0.718	0.726**
	(0.865)	(0.589)	(0.473)	(0.132)
χ	0.289	0.314	0.286	0.322
	(2.869)	(2.138)	(1.550)	(1.159)
Observations	59	58	57	55
R-squared	0.584	0.701	0.781	0.874

Notes: Standard errors are in parentheses. ***, **, and * indicate 1%, 5%, and 10% statistical significance, respectively. The table shows the non-linear least squares estimation results of the model (2.53). Columns (1), (2), (3), and (4) refer to each case of using level, 2-year averaged, 3-year averaged, and 5-year averaged data of the dependent and independent variables for estimation, respectively.

2.7.5 The model with nominal rigidity

All features of the model in the main analysis remain unchanged unless stated otherwise below.

Non-housing goods supplier In a competitive market, a representative non-housing goods supplier (Y_t) operates, purchasing all intermediate goods ($Y_t(z)$) for

repackaging. They aggregate the intermediate goods using the production function in (2.54), with an elasticity of substitution between the intermediate goods greater than 1 ($\epsilon > 1$).

$$Y_t = [\int_0^1 Y_t(z)^{\frac{\epsilon-1}{\epsilon}} dz]^{\frac{\epsilon}{\epsilon-1}} \tag{2.54}$$

The non-housing goods supplier maximizes its profit in each period. Operating in a competitive market, they take the price of each intermediate good as given. Thus, their maximization problem can be expressed as follows. This static problem yields the demand function for intermediate goods as $Y_t(z) = Y_t \left(\frac{P_t(z)}{P_t}\right)^{-\epsilon}$, where $P_t = [\int_0^1 P_t(z)^{1-\epsilon} dz]^{\frac{1}{1-\epsilon}}$.

$$\max_{Y_t(z)} P_t Y_t - \int_0^1 p_t(z) Y_t(z) dz \tag{2.55}$$

Intermediate goods producers Intermediate goods producers, z, operate under monopolistic competition. They utilize the following production function:

$$Y_t(z) = A(\chi G k_{t-1}^{1-\zeta} + (1-\chi) K_{t-1}(z)^{1-\zeta})^{\frac{\omega}{1-\zeta}} (N_{P,t}(z)^{\alpha_P} N_{IM,t}(z)^{\alpha_{IM}} N_{R,t}(z)^{1-\alpha_P-\alpha_{IM}})^{(1-\omega)} \tag{2.56}$$

Each z minimizes its cost of production as follows:

$$\begin{aligned} \min_{N_{P,t}(z), N_{IM,t}(z), K_{t-1}(z)} & W_{P,t} N_{P,t}(z) + W_{IM,t} N_{IM,t}(z) + W_{R,t} N_{R,t}(z) + r_t K_{t-1}(z) \\ & + \Phi_t(z)[Y_t(z) - A(\chi G k_{t-1}^{1-\zeta} + (1-\chi) K_{t-1}(z)^{1-\zeta})^{\frac{\omega}{1-\zeta}} \\ & * (N_{P,t}(z)^{\alpha_P} N_{IM,t}(z)^{\alpha_{IM}} N_{R,t}(z)^{1-\alpha_P-\alpha_{IM}})^{1-\omega}] \end{aligned} \tag{2.57}$$

where $\Phi_t(z)$ is the Lagrange multiplier related to the real marginal cost of producing $Y_t(z)$. The real marginal cost is derived as $MC_t(z) = \Phi_t(z) * (1 - \omega + \omega V_t(z))$ where $V_t(z) = \frac{(1-\chi) K_{t-1}(z)^{1-\zeta}}{\chi G k_{t-1}^{1-\zeta} + (1-\chi) K_{t-1}(z)^{1-\zeta}}$.

In addition to the cost minimization problem, the intermediate goods producers set prices following the Calvo-Yun framework. In this framework, each producer can reset their price with a probability of $1-\theta$ in each period. This is done to maximize the lifetime cash flow of the intermediate goods firms, given the demand for their goods. Thus, their problem for this maximization is not static. The maximization problem is expressed as follows.

$$\max_{P_t^*(z)} \sum_{k=0}^{\infty} \theta^k E_t \left[M_{t,t+k} \left(\frac{P_t^*(z)}{P_{t+k}} Y_{t+k}(z) - MC_{t+k}(z) Y_{t+k}(z) \right) \right] \tag{2.58}$$

$$s.t. Y_t(z) = Y_t \left(\frac{P_t(z)}{P_t} \right)^{-\epsilon} \tag{2.59}$$

Here, $M_{t,t+k}$ represents the stochastic discount factor. The solution to the maximization problem above can be used to derive the New-Keynesian Phillips curve presented below.[18]

$$\hat{\pi_t} = \beta_P E_t \hat{\pi}_{t+1} + \frac{(1-\theta)(1-\theta\beta_P)}{\theta} \hat{MC}_t \tag{2.60}$$

Since the intermediate goods producers operate under monopolistic competition, they generate a positive profit each period. This profit is denoted as F_t, and it is assumed to be distributed to the patient households. By definition, the profit is expressed as follows.

$$F_t = Y_t - W_{P,t} N_{P,t} - W_{IM,t} N_{IM,t} - W_{R,t} N_{R,t} - r_t K_{t-1} = Y_t (1 - MC_t) \tag{2.61}$$

Central bank There exists a central bank that operates monetary policy according to the standard Taylor rule. The central bank responds to inflation (ϕ_π^R) and

[18] The variable written with a hat ˆ denotes the percentage deviation from the steady state, i.e., $\hat{x} = \frac{x - x_{ss}}{x_{ss}}$.

the growth of non-housing goods (ϕ_y^R). However, we set $\phi_y^R = 0$, meaning that the central bank conducts monetary policy solely to stabilize the inflation rate. The monetary policy rule is expressed as follows.

$$R_t = R_{t-1}^{\rho} \left(\pi_t^{1+\phi_\pi^R} \left(\frac{Y_t}{Y_{t-1}} \right)^{\phi_y^R} R \right)^{1-\rho} \tag{2.62}$$

Derivation of the equations

1. Non-housing goods supplier's problem

   The objective function is $P_t Y_t - \int_0^1 P_t(z) Y_t(z) dz = P_t (\int_0^1 Y_t(z)^{\frac{\epsilon-1}{\epsilon}} dz)^{\frac{\epsilon}{\epsilon-1}} - \int_0^1 P_t(z) Y_t(z) dz$.

   Taking the derivative of the above expression with respect to $Y_t(z)$,

   $\Rightarrow P_t Y_t^{1/\epsilon} Y_t(z)^{-1/\epsilon} = P_t(z), \therefore Y_t(z) = Y_t \left(\frac{P_t(z)}{P_t} \right)^{-\epsilon}$

2. Intermediate goods producers' problem

   (1) Cost minimization: $\mathcal{L} = W_{P,t} N_{P,t}(z) + W_{IM,t} N_{IM,t}(z) + W_{R,t} N_{R,t}(z) + r_t K_{t-1}(z) + \Phi_t(z)(Y_t(z) - A(\chi G k_{t-1}^{1-\zeta} + (1-\chi) K_{t-1}(z)^{1-\zeta})^{\frac{\omega}{1-\zeta}}$
   $N_{P,t}(z)^{\alpha_P(1-\omega)} N_{IM,t}(z)^{\alpha_{IM}(1-\omega)} N_{R,t}(z)^{(1-\alpha_P-\alpha_{IM})(1-\omega)})$

$$\Rightarrow \frac{\partial L}{\partial N_{P,t}(z)} = W_{P,t} + \Phi_t(z)(-\alpha_P(1-\omega) A(\chi G k_{t-1}^{1-\zeta} + (1-\chi) K_{t-1}(z)^{1-\zeta})^{\frac{\omega}{1-\zeta}} N_{P,t}(z)^{\alpha(1-\omega)-1} N_{IM,t}(z)^{\alpha_{IM}(1-\omega)} N_{R,t}(z)^{(1-\alpha_P-\alpha_{IM})(1-\omega)}) = 0$$

$$\therefore W_{P,t} = \frac{\Phi_t(z)\alpha_P(1-\omega) Y_t(z)}{N_{P,t}(z)}$$

$$\Rightarrow \frac{\partial L}{\partial N_{IM,t}(z)} = W_{IM,t} + \Phi_t(z)(-\alpha_{IM}(1-\omega) A(\chi G k_{t-1}^{1-\zeta} + (1-\chi) K_{t-1}(z)^{1-\zeta})^{\frac{\omega}{1-\zeta}} N_{P,t}(z)^{\alpha(1-\omega)} N_{IM,t}(z)^{\alpha_{IM}(1-\omega)-1} N_{R,t}(z)^{(1-\alpha_P-\alpha_{IM})(1-\omega)}) = 0$$

$\therefore W_{IM,t} = \frac{\Phi_t(z)\alpha_{IM}(1-\omega)Y_t(z)}{N_{IM,t}(z)}$

$$\Rightarrow \frac{\partial L}{\partial N_{R,t}(z)} = W_{R,t} + \Phi_t(z)(-\alpha_R(1-\omega)A(\chi G k_{t-1}^{1-\zeta} + (1-\chi)K_{t-1}(z)^{1-\zeta})^{\frac{\omega}{1-\zeta}} N_{P,t}(z)^{\alpha(1-\omega)} N_{IM,t}(z)^{\alpha_{IM}(1-\omega)} N_{R,t}(z)^{(1-\alpha_P-\alpha_{IM})(1-\omega)-1}) = 0$$

$\therefore W_{R,t} = \frac{\Phi_t(z)(1-\alpha_P-\alpha_{IM})(1-\omega)Y_t(z)}{N_{R,t}(z)}$

$$\Rightarrow \frac{\partial L}{\partial K_{t-1}(z)} = r_t + \Phi_t(z)(-\frac{\omega}{1-\zeta}(1-\chi)(1-\zeta)K_{t-1}(z)^{1-\zeta-1} A(\chi G k_{t-1}^{1-\zeta} + (1-\chi)K_{t-1}(z)^{1-\zeta})^{\frac{\omega}{1-\zeta}-1} N_{P,t}(z)^{\alpha(1-\omega)} N_{IM,t}(z)^{\alpha_{IM}(1-\omega)} N_{R,t}(z)^{(1-\alpha_P-\alpha_{IM})(1-\omega)}) = 0$$

$\therefore r_t = \Phi_t(z)(\frac{(1-\chi)K_{t-1}(z)^{1-\zeta}}{\chi G K_{t-1}^{1-\zeta}+(1-\chi)K_{t-1}(z)^{1-\zeta}})\omega\frac{Y_t(z)}{K_{t-1}(z)}$

(2) To maximize discounted lifetime profit, the objective function of the intermediate goods producers is as follows: $\sum_{k=0}^{\infty}\theta^k E_t M_{t,t+k}(\frac{P_t^*(z)}{P_{t+k}}Y_{t+k}(z) - MC_{t+k}Y_{t+k}(z))$ s.t $Y_{t+k}(z) = Y_{t+k}(\frac{P_t^*(z)}{P_{t+k}})^{-\epsilon}$ and $MC_{t+k} = \Phi_{t+k}(z) * (1-\omega+\omega V_{t+k}(z))$

Taking the derivative of the above expression with respect to $P_t^*(z)$,

$\Rightarrow \sum_{k=0}^{\infty}\theta^k E_t M_{t,t+k}Y_{t+k}(\frac{1}{P_{t+k}^{1-\epsilon}}(1-\epsilon)P_t^*(z)^{-\epsilon} + MC_{t+k}(\frac{1}{P_{t+k}})^{-\epsilon}\epsilon P_t^*(z)^{-\epsilon-1}) = 0$

$\Rightarrow \sum_{k=0}^{\infty}\theta^k E_t M_{t,t+k}Y_{t+k}(1-\epsilon)(\frac{P_t^*(z)}{P_{t+k}})^{-\epsilon}(\frac{P_t^*(z)}{P_{t+k}} - \frac{\epsilon}{\epsilon-1}MC_{t+k}) = 0$

$\Rightarrow \sum_{k=0}^{\infty}\theta^k E_t M_{t,t+k}Y_{t+k}(\frac{P_t^*(z)}{P_{t+k}})^{-\epsilon}(\frac{P_t^*}{P_{t+k}} - \frac{\epsilon}{\epsilon-1}MC_{t+k}) = 0$ ($\because 1-\epsilon$ is a constant)

$\Rightarrow \sum_{k=0}^{\infty}\theta^k E_t M_{t,t+k}Y_{t+k}(z)(\frac{P_t^*(z)}{P_{t+k}} - \frac{\epsilon}{\epsilon-1}MC_{t+k}) = 0$ ($\because Y_{t+k}(z) = Y_{t+k}(\frac{P_t^*(z)}{P_{t+k}})^{-\epsilon}$)

$\Rightarrow \sum_{k=0}^{\infty}\theta^k E_t M_{t,t+k}Y_{t+k}(\frac{P_t^*}{P_{t+k}} - \frac{\epsilon}{\epsilon-1}MC_{t+k}) = 0$ ($\because$ all intermediate goods producers are symmetric)

$\Rightarrow \sum_{k=0}^{\infty}(\theta\beta_s)^k E_t \Lambda_{t,t+k}Y_{t+k}(\frac{P_t^*}{P_{t+k}} - \frac{\epsilon}{\epsilon-1}MC_{t+k}) = 0$ ($\because M_{t,t+k} = \beta_P^k\left(\frac{C_{P,t}}{C_{P,t+k}}\right)$ and define $\Lambda_{t,t+k} = \frac{C_{P,t}}{C_{P,t+k}}$)

After log-linearization around the steady state with zero net inflation ($P = P^*$), $\Rightarrow \sum_{k=0}^{\infty}(\theta\beta_P)^k E_t \Lambda Y(1+\hat{\Lambda}_{t,t+k}+\hat{Y}_{t+k})(\frac{P^*}{P}(1+\hat{P}_t^*-\hat{P}_{t+k})-MC\frac{\epsilon}{\epsilon-1}(1+\hat{MC}_{t+k}))=0$

$\Rightarrow \sum_{k=0}^{\infty}(\theta\beta_P)^k E_t(1+\hat{\Lambda}_{t,t+k}+\hat{Y}_{t+k}+\hat{P}_t^*-\hat{P}_{t+k}) = \sum_{t=0}^{\infty}(\theta\beta_P)^k E_t MC\frac{\epsilon}{\epsilon-1}(1+\hat{\Lambda}_{t,t+k}+\hat{Y}_{t+k}+\hat{MC}_{t+k})$ ($\because \Lambda Y$ is a constant)

$\Rightarrow E_t \sum_{k=0}^{\infty}(\theta\beta_P)^k \hat{P}_t^* = E_t \sum_{k=0}^{\infty}(\theta\beta_P)^k(\hat{P}_{t+k}+\hat{MC}_{t+k})$ ($\because MC\frac{\epsilon}{\epsilon-1}=1$)

$\Rightarrow \hat{P}_t^* E_t \sum_{k=0}^{\infty}(\theta\beta_P)^k = E_t \sum_{k=0}^{\infty}(\theta\beta_P)^k(\hat{P}_{t+k}+\hat{MC}_{t+k})$

$\Rightarrow \hat{P}_t^* = (1-\theta\beta_P)(\hat{P}_t+\hat{MC}_t)+(1-\theta\beta_P)E_t\sum_{k=1}^{\infty}(\theta\beta_P)^k(\hat{P}_{t+k}+\hat{MC}_{t+k})$

$\Rightarrow \hat{P}_t^* = (1-\theta\beta_P)(\hat{P}_t+\hat{MC}_t)+\theta\beta_P(1-\theta\beta_P)E_t\sum_{k=1}^{\infty}(\theta\beta_P)^k(\hat{P}_{t+k+1}+\hat{MC}_{t+k+1})$

$\Rightarrow \hat{P}_t^* = (1-\theta\beta_P)(\hat{P}_t+\hat{MC}_t)+\theta\beta_P E_t\hat{P}_{t+1}^*$

($\because E_t\hat{P}_{t+1}^* = (1-\theta\beta_P)E_t\sum_{k=1}^{\infty}(\theta\beta_P)^k(\hat{P}_{t+k+1}+\hat{MC}_{t+k+1})$)

$\Rightarrow \hat{P}_t^*-\hat{P}_t = (1-\theta\beta_P)\hat{MC}_t+\theta\beta_P E_t(\hat{P}_{t+1}^*-\hat{P}_{t+1}+\hat{\pi}_{t+1})$ ($\because \hat{\pi}_{t+1}=\hat{P}_{t+1}-\hat{P}_t$ and Denote it as $\mathcal{F}_1$)

Also, $P_t = [\int_0^1 P_t(z)^{1-\epsilon}dz]^{\frac{1}{1-\epsilon}} = (\theta P_{t-1}^{1-\epsilon}+(1-\theta)P_t^{*1-\epsilon})^{\frac{1}{1-\epsilon}} \Rightarrow P_t^{1-\epsilon} = (1-\theta)P_t^{*1-\epsilon}+\theta P_{t-1}^{1-\epsilon}$

$\Rightarrow P^{1-\epsilon}(1+(1-\epsilon)\hat{P}_t) = (1-\theta)P^{1-\epsilon}(1+(1-\epsilon)\hat{P}_t^*)+\theta P^{1-\epsilon}(1+(1-\epsilon)\hat{P}_{t-1})$ (By log-linearization)

$\Rightarrow \hat{P}_t = (1-\theta)\hat{P}_t^*+\theta\hat{P}_{t-1}$ ($\because P^{1-\epsilon} = (1-\theta)P^{1-\epsilon}+\theta P^{1-\epsilon}$ in steady state)

$\Rightarrow \hat{P}_t^*-\hat{P}_t = \frac{\theta}{1-\theta}\hat{\pi}_t$ ($\because \hat{\pi}_t = \hat{P}_t-\hat{P}_{t-1}$) (Denote it as $\mathcal{F}_2$)

$\therefore \hat{\pi}_t = \beta_P E_t\hat{\pi}_{t+1}+\frac{(1-\theta)(1-\theta\beta_P)}{\theta}\hat{MC}_t$ (By $\mathcal{F}_1$ and $\mathcal{F}_2$)

Parametric values Table 2.8 provides the values of the parameters introduced. ϵ is calibrated to achieve a steady-state markup rate of 20%. The value of θ is adopted from Park and Song (2013). The values of ρ, ϕ_π^R, and ϕ_y^R are derived from Jung and Mok (2019).

Table 2.8: Parameter values (Model for nominal rigidity)

Description	Parameter	Value
Elasticity of substitution between intermediate goods	ϵ	6
1-Probability of adjusting prices	θ	0.75
Interest rate smoothing parameter	ρ	0.9
Response of the interest rate to inflation	ϕ_{π}^{R}	1.5
Response of the interest rate to output growth	ϕ_{y}^{R}	0.0

Dynamics of the variables

Figure 2.10: Dynamics of the variables after tax rate adjustment 1

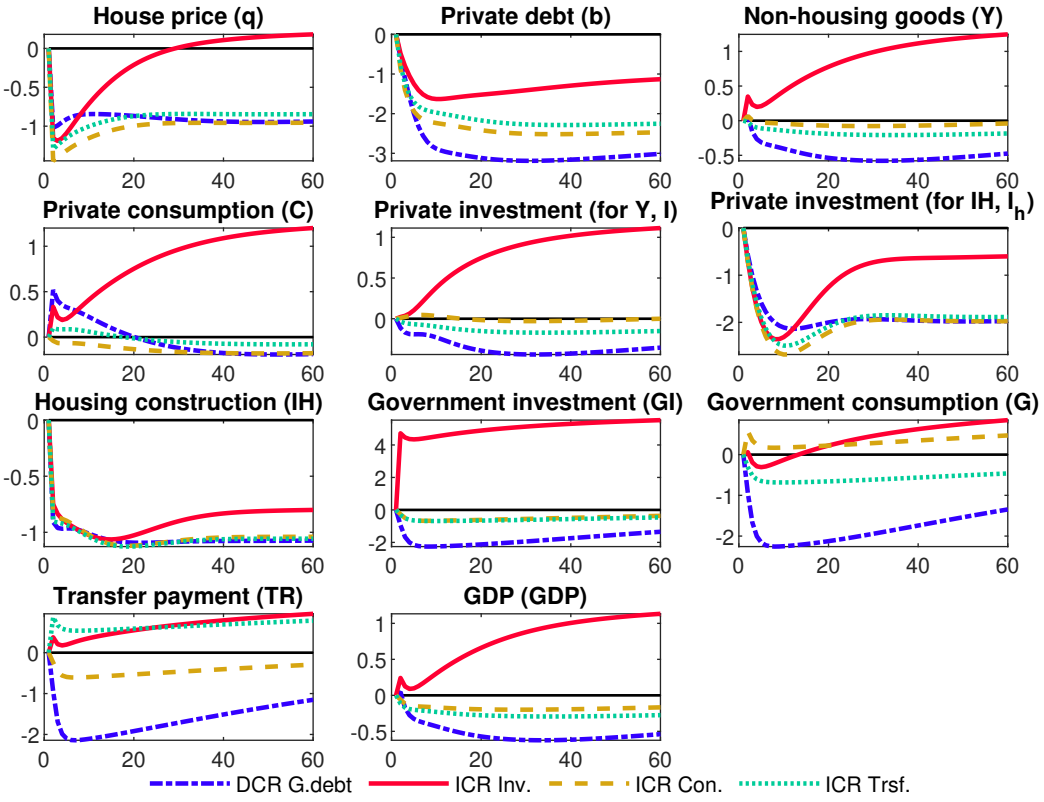


Figure 2.11: Dynamics of the variables after tax rate adjustment 2

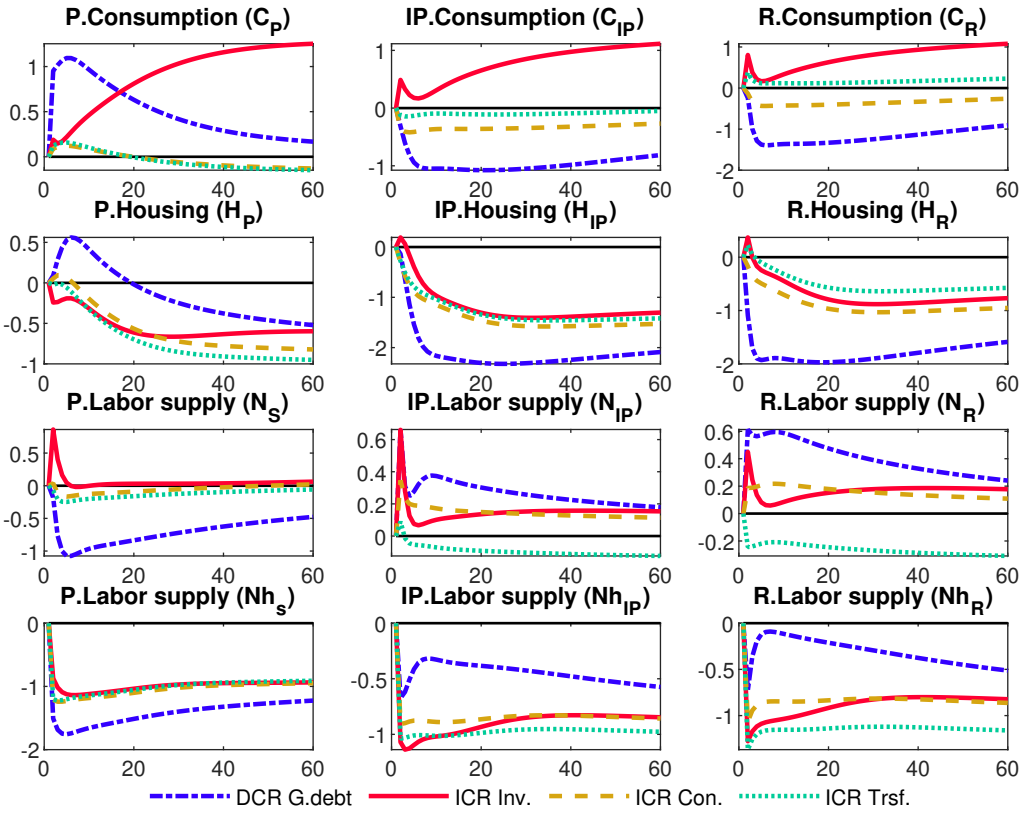


Figure 2.12: Dynamics of the variables after mortgage deductibility adjustment 1

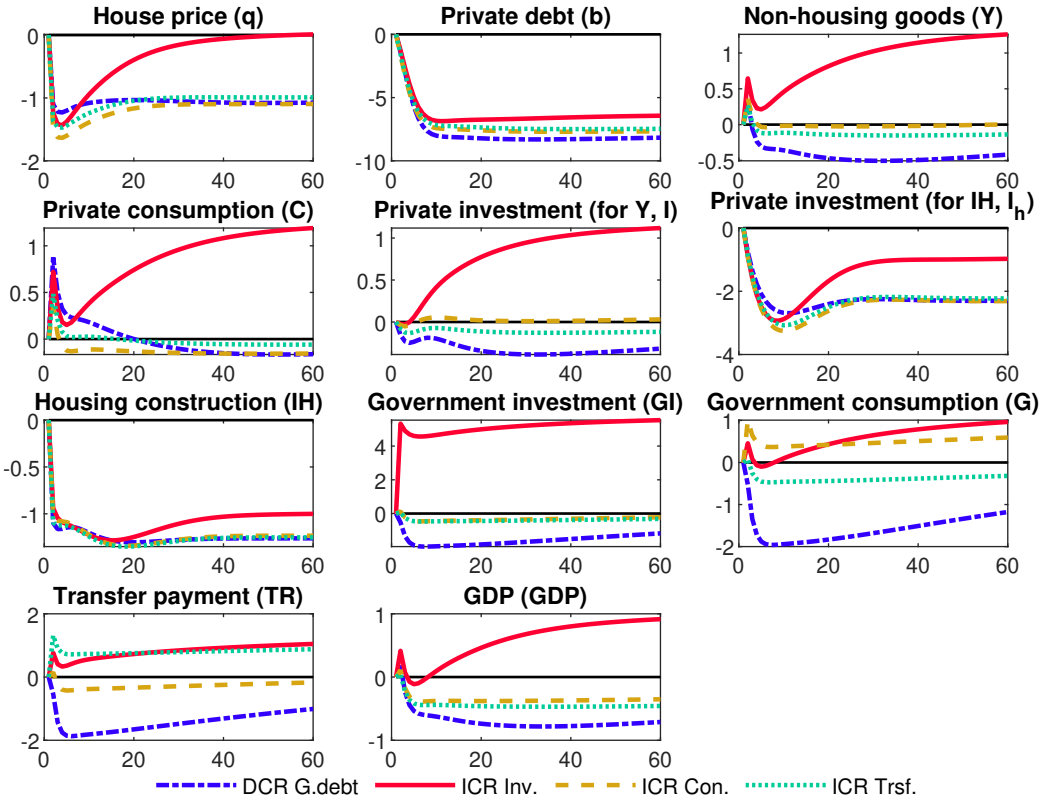
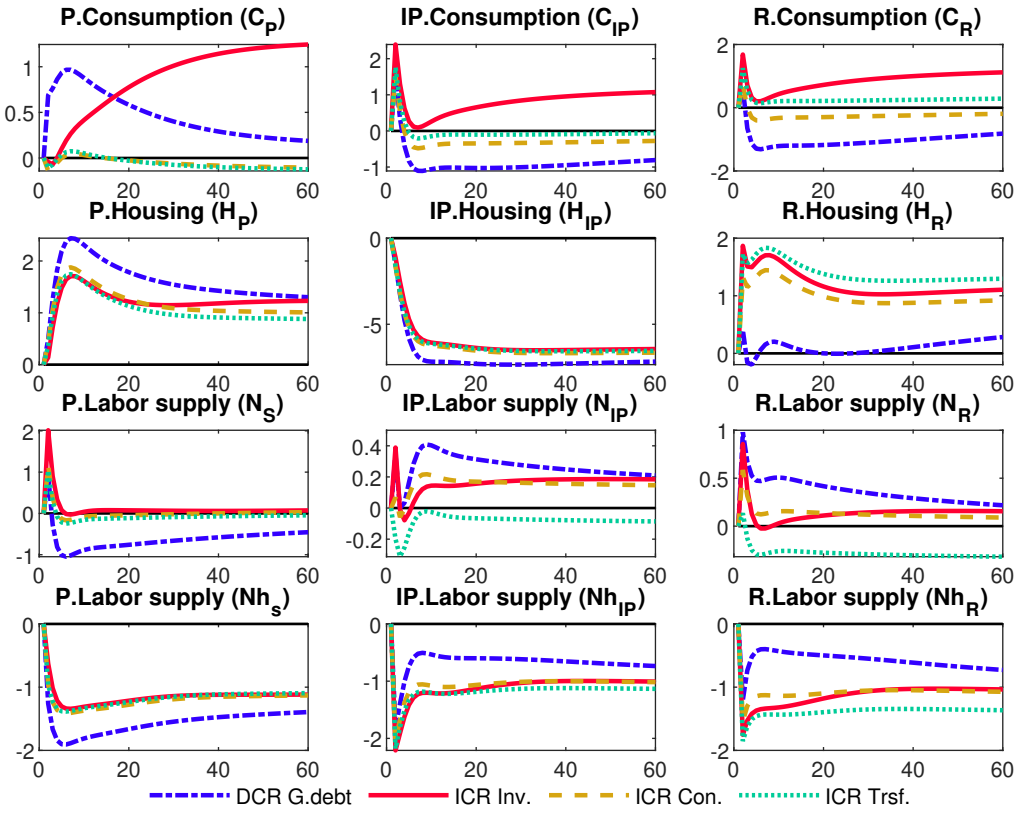


Figure 2.13: Dynamics of the variables after mortgage deductibility adjustment 2



2.7.6 The model with housing tenure choice

The features of the model are identical to those given in the main context unless explicitly stated otherwise below.

Patient households The patient households maximize their lifetime utility by solving the problem below. All other aspects are identical to the model in the main analysis, but now they derive utility from rental housing services (H_{RP}) and pay a rental rate (RR) to the buy-to-let investors. Note that the subscript 'O' refers to owner-occupied housing and 'R' represents rental housing services.

$$\max E_0 \sum_{t=0}^{\infty} \beta_P^t \left[\log(C_{P,t}) + j \log(\tilde{H_{P,t}}) - \frac{[N_{P,t}^{\gamma} + N_{hP,t}^{\gamma}]}{\eta}^{\eta/\gamma} \right] \tag{2.63}$$

$$\tilde{H_{P,t}} = (\omega_P^{1/\epsilon_h} H_{OP,t}^{(\epsilon_h-1)/\epsilon_h} + (1-\omega_P)^{1/\epsilon_h} H_{RP,t}^{(\epsilon_h-1)/\epsilon_h})^{\epsilon_h/(\epsilon_h-1)} \tag{2.64}$$

$$\begin{aligned} s.t\ & C_{P,t} + I_t + I_{h,t} + P_{L,t}L_t + b_t + B_t^g + (1+\tau^{tc})q_t H_{OP,t} + RR_t H_{RP,t} \\ &= R_{t-1}b_{t-1} + R_{t-1}^g B_{t-1}^g + W_{P,t}N_{P,t} + W_{hP,t}N_{hP,t} + r_t K_{t-1} + r_{h,t}K_{h,t-1} + r_{L,t}L_{t-1} \\ &- \tau_S(W_{P,t}N_{P,t} + W_{hP,t}N_{hP,t} + r_t K_{t-1} + r_{h,t}K_{h,t-1} + r_{L,t}L_{t-1} - \kappa_R RR_t H_{RP,t}) \\ &+ P_{L,t}L_{t-1} + (1-\delta_H - \tau_t^p)q_t H_{OP,t-1} + F_t + TR_{P,t} \end{aligned} \tag{2.65}$$

Impatient households The same adjustment applies to the impatient households, and their utility maximization problem is given below.

$$\max_{C_{IM,t}, H_{IM,t}, N_{IM,t}} E_0 \sum_{t=0}^{\infty} \beta_{IM}^t \left[\log(C_{IM,t}) + j \log(\tilde{H_{IM,t}}) - \frac{[N_{IM,t}^{\gamma} + N_{hIM,t}^{\gamma}]}{\eta}^{\eta/\gamma} \right] \tag{2.66}$$

$$\tilde{H_{IM,t}} = (\omega_{IM}^{1/\epsilon_h} H_{OIM,t}^{(\epsilon_h-1)/\epsilon_h} + (1-\omega_{IM})^{1/\epsilon_h} H_{RIM,t}^{(\epsilon_h-1)/\epsilon_h})^{\epsilon_h/(\epsilon_h-1)} \tag{2.67}$$

$$\begin{aligned} s.t\ & C_{IM,t} + R_{t-1}b_{t-1} + (1+\tau^{tc})q_t H_{OIM,t} + RR_t H_{RIM,t} \\ &= W_{IM,t}N_{IM,t} + W_{hIM,t}N_{hIM,t} \\ &- \tau_{IM}(W_{IM,t}N_{IM,t} + W_{hIM,t}N_{hIM,t} - \kappa_{B,t}R_{t-1}b_{t-1} - \kappa_R RR_t H_{RIM,t}) \\ &+ b_t + (1-\delta_H - \tau_t^p)q_t H_{OIM,t-1} + TR_{IM,t} \end{aligned} \tag{2.68}$$

$$E_t R_t b_t \leq LTV_t E_t q_{t+1} H_{OIM,t} \tag{2.69}$$

Buy-to-let investors The buy-to-let investors offer rental housing services to each household. They trade houses for rental purposes and to secure capital gains. They receive the rental rate, RR, from each household for one unit of rental service.

It is assumed that they offer rental services, denoted as H_z, equal to the amount of housing they own in the current period without incurring any cost of providing these services. The operator is also subject to paying housing taxes and income taxes. Income taxes are levied on the total rental income $RR_t H_{Z,t}$ at a rate of τ_Z. Their utility maximization problem is as follows.

$$\max_{C_{Z,t}} E_0 \sum_{t=0}^{\infty} \beta_Z^t \left[\log(C_{Z,t})\right] \tag{2.70}$$

$$s.t\, C_{Z,t} + (1+\tau^{tc}) q_t H_{Z,t} = (1-\delta_H - \tau_t^p) q_t H_{Z,t-1} + (1-\tau_Z) RR_t H_{Z,t} \tag{2.71}$$

Derivation of the equations The first-order conditions related to the housing tenure choices are provided below.

1. Patient households problem

$$\begin{aligned}
\mathcal{L} = E_0 \sum_{t=0}^{\infty} \beta_P^t [\log(C_{P,t}) + j\log(\tilde{H_{P,t}}) - (N_{P,t}^{\gamma} + N_{hP,t}^{\gamma})^{\frac{\eta}{\gamma}} \eta^{-1} \\
+\lambda_{P,t}[R_{t-1}b_{t-1} + R_{t-1}^g B_{t-1}^g + W_{P,t}N_{P,t} + W_{hP,t}N_{hP,t} + r_t K_{t-1} + r_{h,t}K_{h,t-1} + r_{L,t}L_{t-1} \\
- \tau_S(W_{P,t}N_{P,t} + W_{hP,t}N_{hP,t} + r_t K_{t-1} + r_{h,t}K_{h,t-1} + r_{L,t}L_{t-1} - \kappa_R RR_t H_{RP,t}) \\
+ P_{L,t}L_{t-1} + (1-\delta_H - \tau_t^p) q_t H_{OP,t-1} + F_t + TR_{P,t} \\
- (C_{P,t} + I_t + I_{h,t} + P_{L,t}L_t + b_t + B_t^g + (1+\tau_t^{tc}) q_t H_{OP,t} + RR_t H_{RP,t}) \\
+ \mu_t((1-\delta)K_{t-1} - K_t + I_t(1 - (\psi/2)(I_t/I_{t-1} - 1)^2) \\
+ \mu_{h,t}((1-\delta)K_{h,t-1} - K_{h,t} + I_{h,t}(1 - (\psi_h/2)(I_{h,t}/I_{h,t-1} - 1)^2)]
\end{aligned}$$

$\Rightarrow \frac{\partial L}{\partial H_{OP,t}} = \beta_P^t(\frac{j}{\tilde{H_{P,t}}^{(\epsilon_h-1)/\epsilon_h}} \omega_P^{1/\epsilon_h} H_{OP,t}^{-1/\epsilon_h} + \lambda_{P,t}(1+\tau_t^{tc})(-q_t)) + E_t \beta_P^{t+1} \lambda_{P,t+1}(1 - \delta_H - \tau_{t+1}^p) q_{t+1} = 0$ and $\lambda_{P,t} = \frac{1}{C_{P,t}}$

$\therefore \frac{j}{\tilde{H_{P,t}}^{(\epsilon_h-1)/\epsilon_h}} \omega_P^{1/\epsilon_h} H_{OP,t}^{-1/\epsilon_h} = \frac{1}{C_{P,t}}(1+\tau_t^{tc}) q_t - E_t \beta_P \left(\frac{1}{C_{P,t+1}}(1-\delta_H - \tau_{t+1}^p) q_{t+1}\right)$

$\Rightarrow \frac{\partial L}{\partial H_{RP,t}} = \beta_P^t(\frac{j}{\tilde{H_{P,t}}}(1-\omega_P)^{1/\epsilon_h} H_{RP,t}^{-1/\epsilon_h} + \lambda_{P,t} RR_t(1 - \tau_S \kappa_R) = 0$ and $\lambda_{P,t} = \frac{1}{C_{P,t}}$

$\therefore \frac{j}{\tilde{H_{P,t}^{(\epsilon_h-1)/\epsilon_h}}}(1-\omega_P)^{1/\epsilon_h}H_{RP,t}^{-1/\epsilon_h} = \frac{RR_t}{C_{P,t}}(1-\tau_S\kappa_R)$

2. Impatient households' problem

$$\mathcal{L} = E_0\sum_{t=0}^{\infty}\beta_{IM}^t[\log(C_{IM,t}) + j\log(\tilde{H_{IM,t}}) - (N_{IM,t}^{\gamma}+N_{hIM,t}^{\gamma})^{\frac{\eta}{\gamma}}\eta^{-1}$$
$$+\lambda_{d,t}[W_{IM,t}N_{IM,t}+W_{hIM,t}N_{hIM,t}+b_t+(1-\delta_H-\tau_t^p)q_tH_{OIM,t-1}+TR_{IM,t}$$
$$-\tau_{IM}(W_{IM,t}N_{IM,t}+W_{hIM,t}N_{hIM,t}-\kappa_{B,t}R_{t-1}b_{t-1}-\kappa_R RR_tH_{RIM,t})$$
$$-(C_{IM,t}+R_{t-1}b_{t-1}+(1+\tau_t^{tc})q_tH_{OIM,t}+RR_tH_{RIM,t})+\lambda_{b,t}(LTV_tq_{t+1}H_{OIM,t}\frac{1}{R_{t+1}}-b_t)]$$

$\Rightarrow \frac{\partial L}{\partial H_{OIM,t}} = \beta_{IM}^t(\frac{j}{\tilde{H_{IM,t}^{(\epsilon_h-1)/\epsilon_h}}}\omega_{IM}^{1/\epsilon_h}H_{OIM,t}^{-1/\epsilon_h}+\lambda_{d,t}(1+\tau_t^{tc})(-q_t)+\lambda_{b,t}E_tLTV_tq_{t+1}\frac{1}{R_{t+1}})+$
$E_t\beta_{IM}^{t+1}\lambda_{d,t+1}(1-\delta_H-\tau_{t+1}^p)q_{t+1}=0$ and $\lambda_{d,t}=\frac{1}{C_{IM,t}}$

$\therefore \frac{j}{\tilde{H_{IM,t}^{(\epsilon_h-1)/\epsilon_h}}}\omega_{IM}^{1/\epsilon_h}H_{OIM,t}^{-1/\epsilon_h} = \frac{1}{C_{IM,t}}(1+\tau_t^{tc})q_t - E_t\beta_{IM}\left(\frac{1}{C_{IM,t+1}}(1-\delta_H-\tau_{t+1}^p)q_{t+1}\right)-$
$\lambda_{b,t}LTV_tE_t\left(\frac{q_{t+1}}{R_{t+1}}\right)$

$\Rightarrow \frac{\partial L}{\partial H_{RIM,t}} = \beta_{IM}^t(\frac{j}{H_{IM,t}}(1-\omega_{IM})^{1/\epsilon_h}H_{RIM,t}^{-1/\epsilon_h}+\lambda_{IM,t}RR_t(1-\tau_{IM}\kappa_{R,t})=0$ and
$\lambda_{d,t}=\frac{1}{C_{IM,t}}$

$\therefore \frac{j}{\tilde{H_{IM,t}^{(\epsilon_h-1)/\epsilon_h}}}(1-\omega_{IM})^{1/\epsilon_h}H_{RIM,t}^{-1/\epsilon_h} = \frac{RR_t}{C_{IM,t}}(1-\tau_{IM}\kappa_{R,t})$

3. Buy-to-let investor's problem

$\mathcal{L} = E_0\sum_{t=0}^{\infty}\beta_Z^t[log(C_{Z,t})+\lambda_{Z,t}[(1-\delta_H-\tau_t^p)q_tH_{Z,t-1}+(1-\tau_Z)RR_tH_{Z,t}-$
$C_{Z,t}-(1+\tau_t^{tc})q_tH_{Z,t}]$

$\Rightarrow \frac{\partial L}{\partial C_{Z,t}} = \beta_Z^t\frac{1}{C_{Z,t}}+\beta_Z^t\lambda_{Z,t}(-1)=0, \therefore \lambda_{Z,t}=\frac{1}{C_{Z,t}}$

$\Rightarrow \frac{\partial L}{\partial H_{Z,t}} = \beta_Z^t\lambda_{Z,t}((1-\tau_Z)RR_t-(1+\tau_t^{tc})q_t)+E_t\beta_Z^{t+1}\lambda_{Z,t+1}(1-\delta_H-\tau_{t+1}^p)q_{t+1}=0$
and $\lambda_{Z,t}=\frac{1}{C_{Z,t}}, \therefore \frac{RR_t}{C_{Z,t}}(1-\tau_Z)=\frac{q_t}{C_{Z,t}}(1+\tau_t^{tc})-\beta_ZE_t\frac{q_{t+1}}{C_{Z,t+1}}(1-\delta_H-\tau_{t+1}^P)$

Parametric values The parametric values are provided in Table 2.9. ϵ_h, ω_P, and ω_{IM} are calibrated to precisely match the data for each household's owner-occupancy rate (patient: 0.51, impatient: 0.94). τ_Z corresponds to the rental income

tax rate applied in the main model, and β_Z is assumed to be the same as that of the patient households.

Table 2.9: Parameter values (Model for housing tenure choice)

Description	Parameter	Value
Elasticity of substitution between the housing services	ϵ_h	1.8
Patient household's relative preference on owner-occupied housing	ω_P	0.365
Impatient household's relative preference on owner-occupied housing	ω_{IM}	0.835
Tax rates on rental income	τ_Z	0.28
Discount factor of buy-to-let investors	β_Z	0.9932

Dynamics of the variables

Figure 2.14: Dynamics of the variables after tax rate adjustment 1

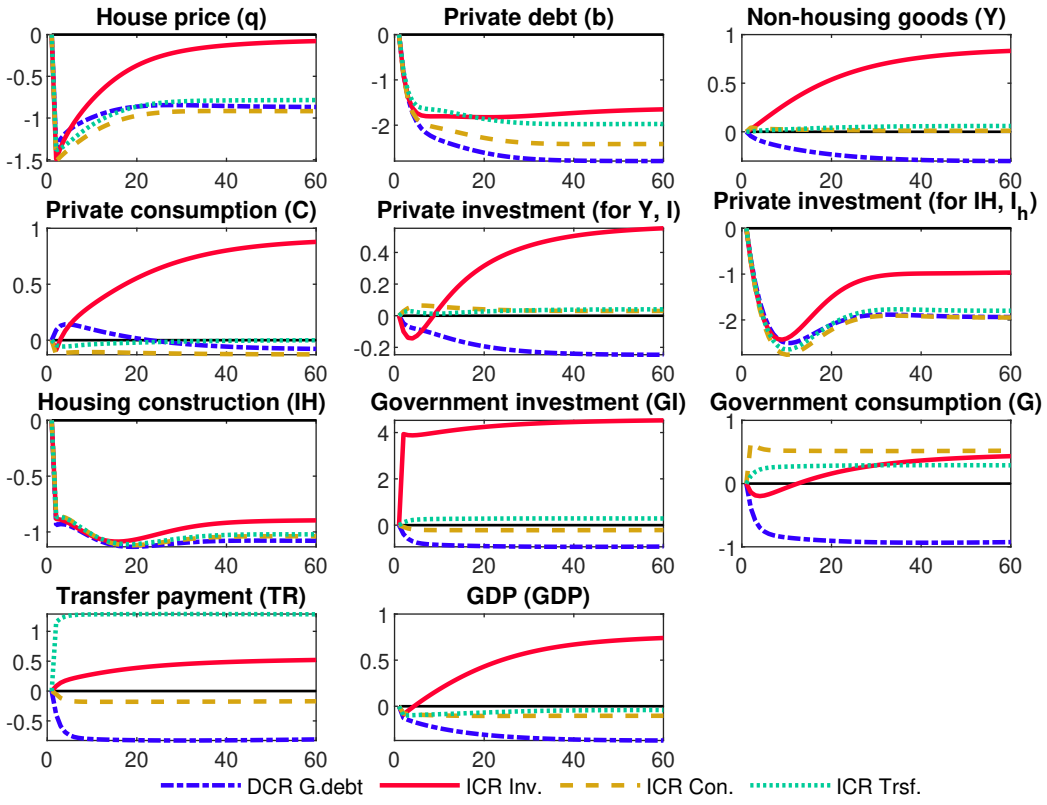


Figure 2.15: Dynamics of the variables after tax rate adjustment 2

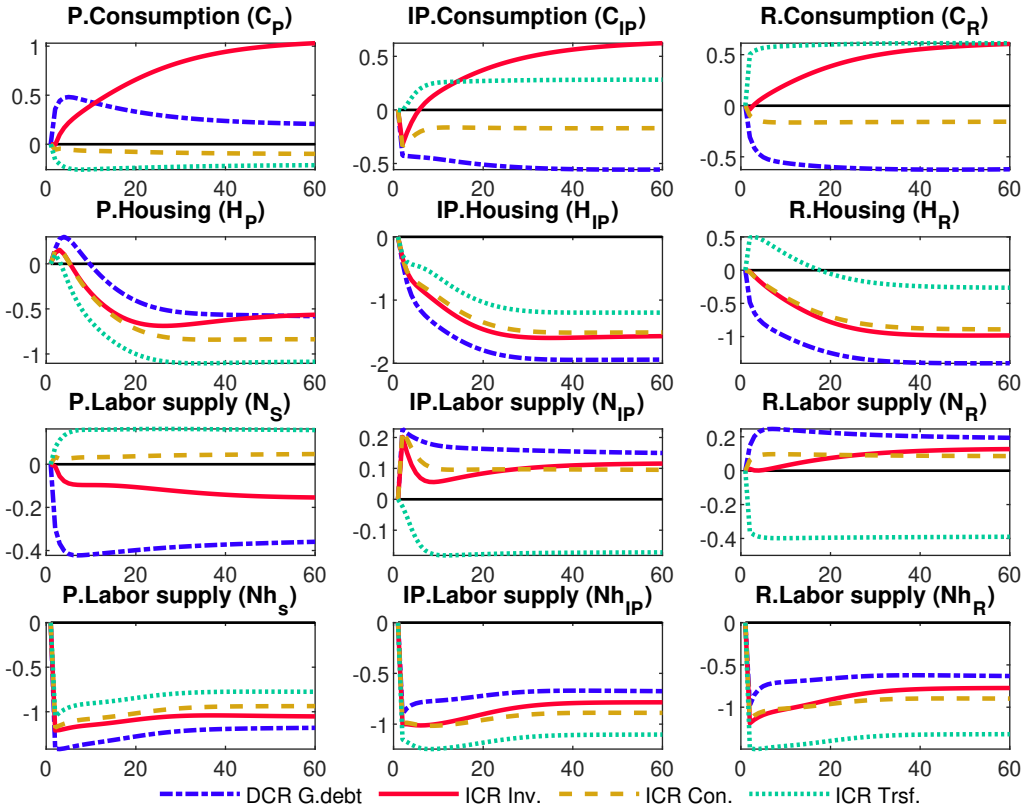


Figure 2.16: Dynamics of the variables after mortgage deductibility adjustment 1

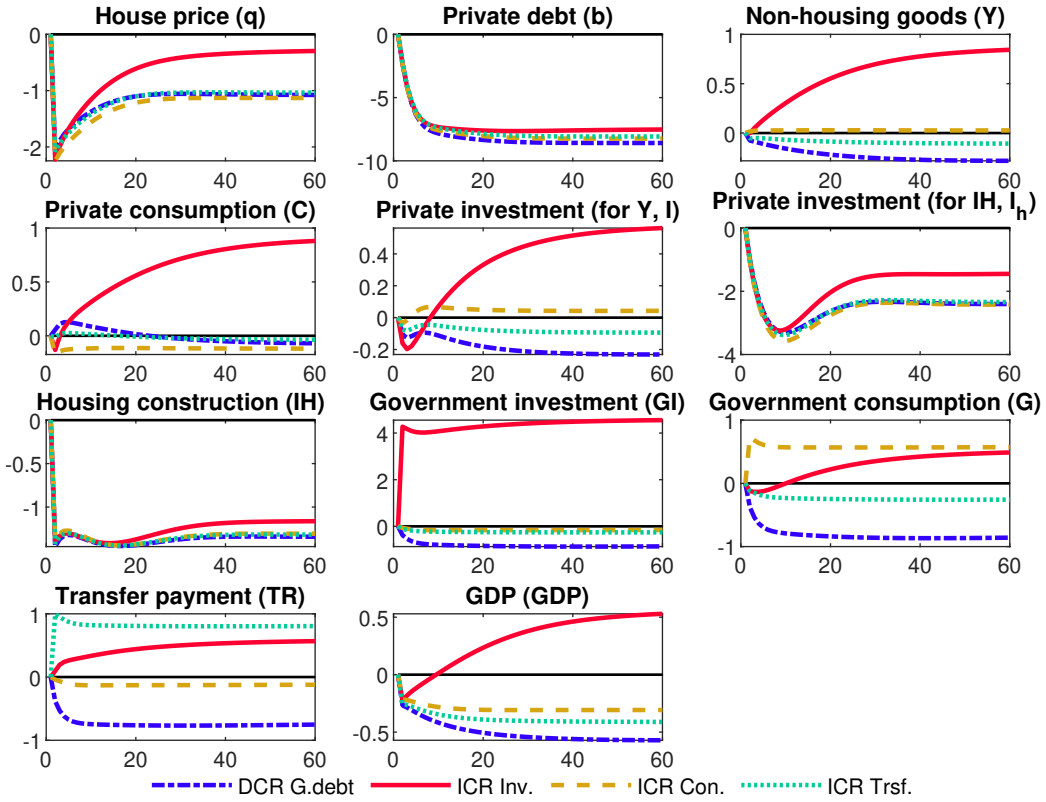
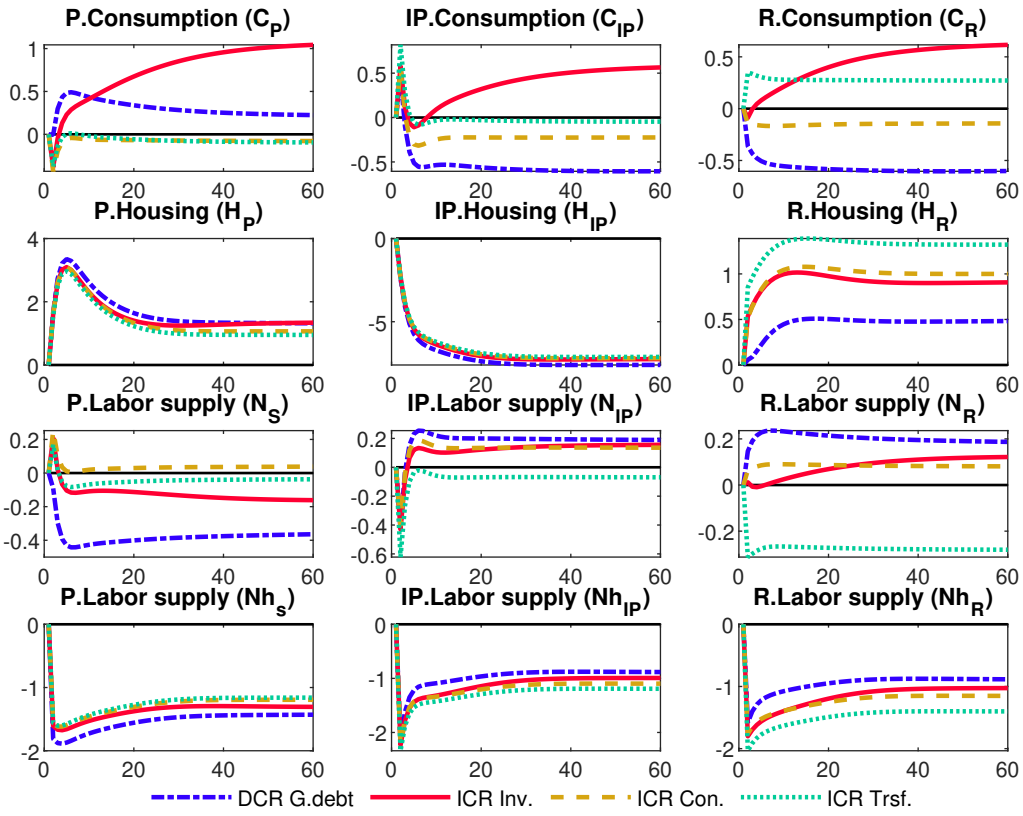


Figure 2.17: Dynamics of the variables after mortgage deductibility adjustment 2



Chapter 3

Debt Finance Bias and Macroprudential Policy

Abstract Previous studies have indicated that corporate income tax (CIT) systems that allow interest payments to be deductible but not dividends contain a bias toward debt, inducing firms to have excessive leverage and making them vulnerable to shocks. This paper examines theoretically how macroprudential policies, particularly capital requirements for banks, can moderate instability caused by CIT systems. Specifically, using a dynamic stochastic general equilibrium model with a banking sector and a corporate finance structure that entails both debt and equity financing, we first show that without time-varying capital requirements, an economy with higher corporate income tax rates and greater debt deductibility is characterized by a more substantial debt finance bias, leading to greater financial and macroeconomic volatility. We then demonstrate that under such a CIT system, volatility can be reduced by imposing a countercyclical capital buffer (CCyB), whereby the bank's capital-to-debt ratio is significantly more responsive to deviations of the credit-to-GDP ratio from the steady state.

3.1 Introduction

The corporate tax system varies significantly across countries, with divergent corporate income tax (CIT) rates and differences in the extent of corporate debt deductibility. As evidenced by de Mooji and Hebous (2018), high tax rates combined with more lenient debt deductibility—without offering preferential tax treatment for equity financing—encourage firms to rely heavily on debt financing. This reliance, however, could conflict with other macroeconomic policy objectives, particularly those aimed at ensuring financial stability. Such a debt bias in the tax system potentially fosters excessive borrowing, making the economy more vulnerable to adverse shocks and amplifying volatility (Borio et al., 2023; IMF, 2016; Bremus and Huber, 2016).

The possibility that the CIT system could influence financial stability often leads to calls for reforms such as the "Debt-equity bias reduction allowance (DEBRA)."[1] However, such reforms typically require substantial time to be enacted due to legislative and constitutional processes. Given this prolonged implementation lag, policy intervention through alternative measures with shorter implementation periods, such as macroprudential policy, can be useful for addressing immediate issues in enhancing macroeconomic stability. In this context, this paper theoretically explores how macroprudential tools, particularly the countercyclical capital buffer (CCyB) for banks, can be used to mitigate macroeconomic and financial instability that may arise from the CIT system.

Specifically, we construct a dynamic stochastic general equilibrium (DSGE) model that incorporates the banking sector and the corporate finance structure where firms choose between debt and equity as funding sources. Corporate income is subject to

[1]The European Parliament is currently in the legislative process of adopting a new corporate tax structure, "Debt-equity bias reduction allowance (DEBRA)," which introduces tighter limits on debt deductibility as a key aspect of the reform.

taxation, but CIT liabilities are reduced by the deductibility of debt repayment to the banking sector. The deductibility of debt repayments incentivizes firms to prefer debt financing over equity financing. This incentive is further amplified by high corporate tax rates, as firms can reduce their tax liabilities through increased debt financing. Meanwhile, the macroprudential authority imposes a CCyB rule by adjusting bank capital requirements. It does so to minimize the loss function, which includes the following three variables: the variance of the credit-to-GDP ratio, output volatility, and variabilities in capital requirement adjustments. Parameter values of the model are calibrated to align with the characteristics of the Euro area or estimated using the Euro area data. Using the model, we first examine how, across different CIT systems, macroeconomic shocks create greater volatility in financial and macroeconomic variables. We then study how, across those systems, the macroprudential authority uses a CCyB rule to minimize the loss function.

The main findings can be summarized as follows. Due to limited incentives for capital investment and the burden of debt repayment, the CIT system with a stronger preference for debt finance (characterized by a high CIT rate and deductibility) exhibits higher volatility than a tax system with a lower debt bias when macroeconomic shocks occur. Accordingly, the credit-to-GDP ratio, the primary target of macroprudential operations, shows greater fluctuations in this type of corporate tax system. Appropriately adopting the time-varying CCyB rule helps this economy reduce fluctuations in financial and macroeconomic volatility. The policy operation parameter, applied to deviations of the credit-to-GDP ratio from its steady-state level, should be set approximately 3-5 times larger in an economy with a relatively higher degree of debt bias, as measured by the amount of taxes deducted as a ratio of GDP—10 percentage points greater than in an economy with less debt bias. Such proactive macroprudential policy operations remain crucial for CIT systems that encourage debt finance, even if a different variable, such as the level of corporate debt, is used as an indicator of the CCyB rule or higher static capital requirements

are imposed.

The study makes clear contributions, particularly by offering immediate policy implications. First, it is one of the few studies that examine the interaction between fiscal and macroprudential policy. This subject has not been extensively explored despite its importance for ensuring financial stability, as highlighted by Claessens (2014). Most existing studies focus on the optimal mixes of monetary and macroprudential policy but neglect the fiscal side, except for Malmierca (2023), which deals with the combination of public spending and macroprudential policy. However, little discussion is given to the tax system and macroprudential policy. Second, it will contribute to a timely debate on the role of policy authorities in macroeconomic stabilization amid increasing economic uncertainty, which could be materialized by various types of shocks. The study is also relevant to the discussion on the proper usage of macroprudential policy following tax reforms in the real world, such as "DEBRA." Finally, from a technical perspective, the study proposes a DSGE framework for quantitative discussion on the effectiveness of macroeconomic policy by combining corporate finance decisions and the banking industry, which are respectively offered in seminal works by Jermann and Quadrini (2012) and Gerali et al. (2010), and properly integrating the public sector into the model.

The rest of the paper is organized as follows. Section 3.2 reviews related existing studies. Section 3.3 provides relevant stylized facts. Section 3.4 introduces the conceptual framework built for the primary analysis. Section 3.5 describes the choice of model parameters, presents the estimated parameters, and explains the estimation method. Section 3.6 contains the main results of the analysis and explores the optimal macroprudential policy rule under each fiscal regime. Robustness checks on the main results are provided in Section 3.7. Finally, Section 3.8 wraps up the discussion and provides a conclusion.

3.2 Related Literature

This study closely relates to empirical evidence on the debt bias in taxation structures and the indebtedness of firms or countries. Existing literature investigates the positive relationships between corporate tax rates or debt deductibility and debt-to-income or debt-to-asset ratios. For instance, de Mooji (2011) conducted a meta-analysis showing that a one percentage point increase in the tax rate is associated with an increase in the debt-to-asset ratio of entities by 0.17 to 0.28. This evidence is further supported by another meta-analysis on this topic, conducted by Feld et al. (2013). de Mooji and Hebous (2018) take a further step by considering both debt deductibility and corporate tax rates. They investigate whether limitations on debt deductibility, such as the 'Thin Capitalisation Rule (TCR),' reduce firms' debt-to-asset ratios, which are positively associated with corporate tax rates. Their study shows that the TCR is effective when its application is not limited to certain types of debt, and its effectiveness varies with the share of tangible assets, which can be used as collateral held by a firm. Similar findings are given by Dallari et al. (2020), suggesting that higher corporate taxes are related to greater total liabilities-to-asset ratios.

These findings extend to the analysis of issues related to financial stability. Several studies examine how debt bias in the tax system increases systemic risk or incurs the cost of banking crises. de Mooij et al. (2015) measure how the likelihood of a financial crisis increases with a rise in the corporate income tax rate. They found that a one percentage point increase in the corporate tax rate is associated with a significantly higher probability of a financial crisis, ranging from 0.1 to 5.22 percentage points, particularly when the banking sector's leverage ratio exceeds 96 percent. Langedijk et al. (2015) report similar findings from a microsimulation of the European banking sector. The study suggests that bank losses during a financial crisis could be substantially reduced as the corporate tax rate decreases. For example,

in France, a ten percentage point reduction in the tax rate could lead to a cost reduction of almost 2.5% of GDP in adverse scenarios. Using the same microsimulation method, Fatica et al. (2020) found that abolishing the debt finance bias in a coordinated way among European countries reduces the cost of a banking crisis by 0.4-1.3% of total bank assets. Consequently, the literature clearly demonstrates that the tax system plays a significant role in ensuring financial stability, and that reducing debt bias offers significant advantages in this context. However, employing a more comprehensive approach, such as a general equilibrium model, would be beneficial for further supporting these results, as previous studies do not consider potential spillovers and impacts on other macroeconomic variables.

Moreover, this paper relates to existing studies, both empirical and theoretical, on corporate finance structures and their implications for the propagation of macroeconomic shocks. For instance, using country-level data, Grjebine et al. (2018) illustrate that economies with a higher proportion of bond financing compared to bank debt recover more quickly from recessions, with faster investment recovery. Holm-Hadulla and Thürwächter (2021) also indicate that economies with a low bond-to-debt ratio respond more adversely to monetary policy tightening. Dees et al. (2022) confirm these results by using a semi-structural model, showing that incorporating the firm's finance decision rule into the model captures a stronger negative response in investment to interest rate shocks. These findings can be interpreted in light of De Fiore and Uhlig (2015) and Jermann and Quadrini (2012), who suggest that access to alternative funding sources beyond debt finance is crucial in mitigating the adverse effects of macroeconomic shocks.

Another body of literature related to this study is the design of the macroprudential policy, particularly the capital requirement rule. There has been a burgeoning of literature on this topic as new regulations in the banking sector have been adopted since the GFC. Due to the limited real-world experiences, the subject has been explored using conceptual frameworks such as DSGE models. Previous studies differ

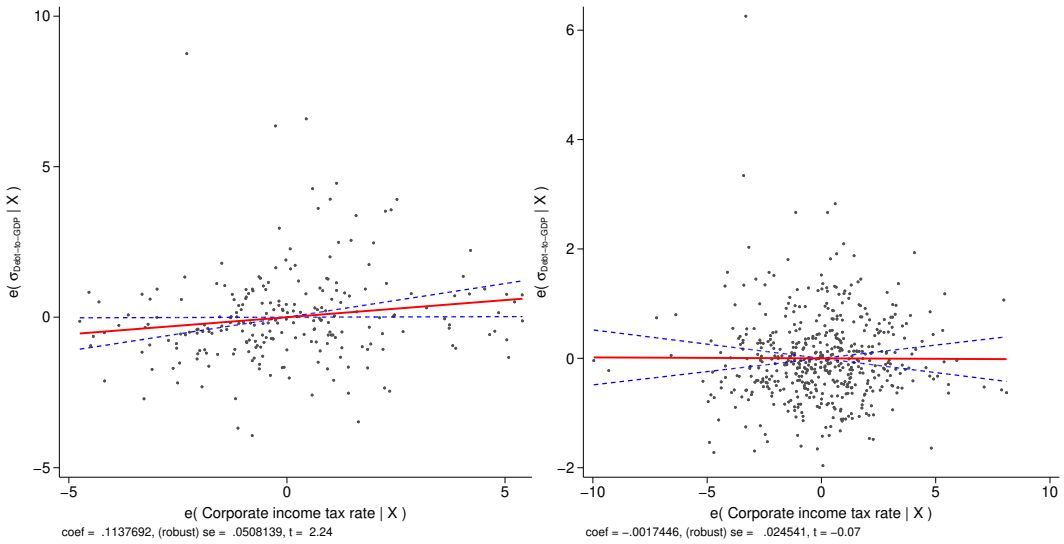
in their detailed research questions but examine optimal macroprudential policy under various circumstances. Examples include Angelini et al. (2014), Bratsiotis and Pathirage (2023), Aikman et al. (2023), and Agénor and Jackson (2022) on the interaction between monetary and macroprudential policy, and Rubio and Yao (2020), on the optimal capital requirement rule at the zero lower bound. In addition, Gebauer and Mazelis (2023) and Xiang (2022) explore the implications of non-bank financial institutions in the operations of the capital requirement rule. Lozej et al. (2023) investigate the best policy operations by examining the effectiveness of an alternative CCyB rule that takes into account house price changes. Also, Binder et al. (2018) examine a robust optimal CCyB rule by employing various structural models. While all these studies draw meaningful policy implications, there is no formal analysis of the interaction between the fiscal side, such as tax systems, and macroprudential policy. Thus, this paper will delve into this realm and contribute to the existing literature and better policy operations.

3.3 Stylized facts

The CIT system is crucial in determining corporate indebtedness, as indicated by the empirical findings reviewed in Section 3.2. Before proceeding with the formal analysis, we present empirical evidence more directly related to the CIT system and macro-financial stability, which motivates our analysis. This evidence includes: (1) higher corporate income tax rates are positively associated with greater volatility in the corporate debt-to-GDP, and (2) this varies depending on CIT systems, as countries that have adopted rules to limit debt deductibility do not exhibit a significant relationship between these two variables. To investigate this, we regress the volatility of corporate debt-to-GDP (measured as the standard deviation of quarterly data) on the statutory CIT rate and its interaction with macroprudential policy measures, controlling for country-specific characteristics and time-fixed ef-

fects. The analysis uses panel data from 43 countries between 2000 and 2019.[2] The countries are grouped into two categories based on whether they adopted any rules limiting debt deductibility during the sample period.[3]

Figure 3.1: Volatility of corporate debt-to-GDP and corporate income tax rates



Notes: Added-variable plot of fixed-effect regressions of the volatility of quarterly corporate debt-to-GDP on statutory corporate income tax rates, its interactions with Macroprudential policy measures $(t-1)$ constructed by using the indexes from Alam et al. (2019), time fixed effects and country-specific characteristics. Only non-financial corporations' debts are counted. A balanced panel of data for 43 countries of the years 2000-2019 was used. See Appendix 3.9.1 for the list of countries. The countries were categorized into two groups, those that never adopted any rules that limit the debt deductibility or the allowance for corporate equity (left) and those that employed such policies during a certain year of the sample period (right).

Figure 3.1 presents evidence on the relationship between statutory CIT rates and the volatility of corporate debt-to-GDP across two groups of countries, differentiated by the extent of debt deductibility.[4] The left subfigure shows the relationship

[2]See Appendix 3.9.1 for the list of countries. The macroprudential policy measure is the simple sum of indexes, taking values of 1 (for tightening actions), 0, or -1 (for loosening actions) for each prudential tool, available from Alam et al. (2019).

[3]Such rules include Fixed debt-equity rule, Arm's-length rule, and Interest-stripping rule, as outlined by de Mooji and Hebous (2018). The information provided in de Mooji and Hebous (2018) was used to determine whether a country adopted such rules. We also classify a country as employing the rule if it has a history of using the 'Allowance for Corporate Equity (ACE),' which grants the same level of deductions to equity finance. Although the types of rules, the extent of debt influenced, and the degree (threshold) of the rules vary among countries, we use a subsample analysis approach as these rules tend to remain consistent over time once introduced (de Mooji and Hebous, 2018).

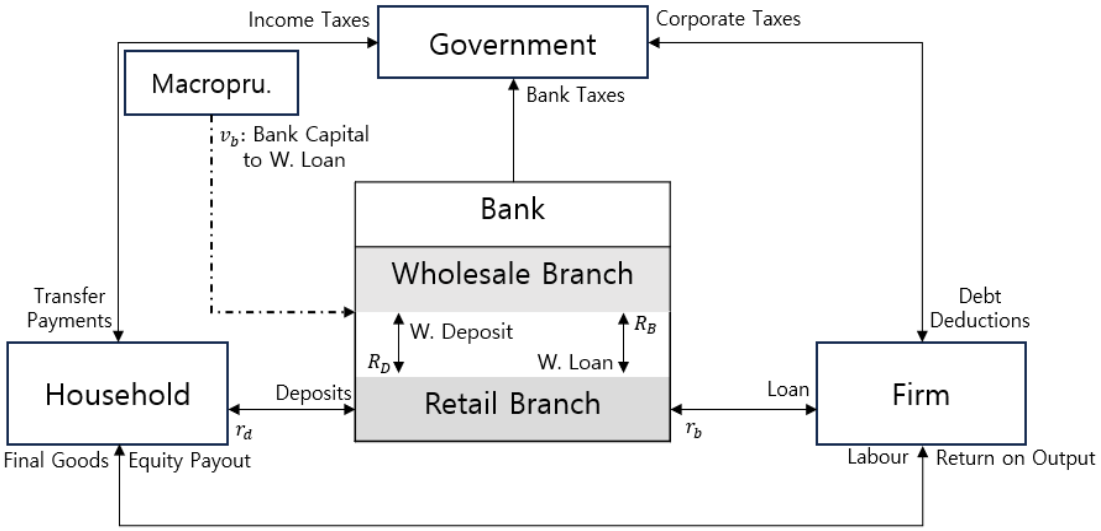
[4]Two obvious outliers in volatility, which exceeded 10, were excluded. See Figure 3.8 in the Appendix for these outliers.

between these two variables for countries that never adopted any measures to limit debt deductibility, while the right subfigure provides this relationship for countries that adopted such measures, even for a single year. The left subfigure suggests that countries with higher CIT rates tend to experience greater volatility in the corporate debt-to-GDP ratio. In contrast, the relationship between the two variables becomes insignificant in countries that have adopted any rules to limit debt deductibility. This indicates that countries with a debt bias are prone to experience greater volatility in corporate debt-to-GDP ratio, highlighting the need for appropriate policy interventions to address such distortions.

3.4 The model

The model is built on the seminal work by Jermann and Quadrini (2012), which examines the role of financial shocks in explaining US business cycles. We incorporate the firm's financial structure into our model based on their framework. Jermann and Quadrini (2012) present a corporate finance structure grounded in the pecking order theory, which posits that firms favor debt finance over equity finance due to tax advantages associated with debt. However, there are differences from Jermann and Quadrini (2012). While Jermann and Quadrini (2012) modeled the incentive for debt finance by applying a deduction to the net real interest rate, we explicitly incorporate specific deductions on corporate income tax when the firm is indebted to the bank. Furthermore, our framework includes a financial intermediary, the bank, which was absent in Jermann and Quadrini (2012). Consequently, the flow of funds between the firm and the household occurs entirely through the banking sector, which operates under monopolistic competition. This closely resembles the frameworks of Gerali et al. (2010) and Gebauer and Mazelis (2023). Before the detailed introduction of the model, it is summarized in Figure 3.2.

Figure 3.2: The structure of the model



3.4.1 Household

There exists a representative household that lives infinitely in this economy. To maximize lifetime utility, the household selects the consumption level (c_t) and labor supply (n_t), treating the wage rate (w_t) as given. Total wage income is subject to labor income taxes at a rate of τ_H. The household holds financial assets in the form of bank deposits. It determines the level of deposits (d_t), and accordingly, receives interest income ($r^d_{t-1}d_{t-1}$) from the bank. Additionally, the household obtains transfer payments from the government (TR_t) and equity payouts (x_t) from the representative firm, which will be elaborated upon later. The household's utility maximization problem, subject to its budget constraint, is as follows.

$$\max \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{\Xi_t (c_t - \alpha c_{t-1})^{1-\sigma}}{1-\sigma} - \frac{n_t^{1+\phi}}{1+\phi} \right] \tag{3.1}$$

$$s.t\ (1-\tau_H) w_t n_t + (1 + r^d_{t-1}) d_{t-1} + x_t + TR_t \geq d_t + c_t \tag{3.2}$$

Upon solving the utility maximization problem, the first-order conditions for c_t, n_t, and d_t are obtained as follows:[5]

$$\Xi_t(c_t - \alpha c_{t-1})^{-\sigma} - \beta\alpha\,\mathbb{E}_t\,\Xi_{t+1}(c_{t+1} - \alpha c_t)^{-\sigma} = \lambda_{Ht} \tag{3.3}$$

$$\Xi_t(c_t - \alpha c_{t-1})^{-\sigma} - \beta\alpha\,\mathbb{E}_t\,\Xi_{t+1}(c_{t+1} - \alpha c_t)^{-\sigma} = \frac{n_t^{\phi}}{(1-\tau_H)w_t} \tag{3.4}$$

$$\lambda_{Ht} = \beta(1 + r_t^d)\,\mathbb{E}_t\,\lambda_{Ht+1} \tag{3.5}$$

Here, Ξ_t exogenously affects the household's demand for final goods consumption. Put differently, it represents a demand shock in the economy. Ξ_t follows an AR(1) process, expressed as:

$$log(\Xi_t) = (1 - \rho_\Xi)log(\Xi_{ss}) + \rho_\Xi log(\Xi_{t-1}) + \varepsilon_{\Xi_t} \tag{3.6}$$

where ε_{Ξ_t} is assumed to follow a normal distribution $\mathcal{N}(0, \sigma_\Xi^2)$, and $\Xi_{ss} = 1$.

Building on the banking industry structure from Gerali et al. (2010), we incorporate imperfect competition in the financial market. It is assumed that there are multiple bank branches j within the interval $[0, 1]$, each possessing some degree of market power in setting interest rates. Given their market power in setting their deposit interest rate $r_t^d(j)$, the representative household allocates deposit demand across each branch j to maximize total interest payments, combining them using a Dixit-Stiglitz aggregator to meet their total demand for deposits. Thus, the household solves the following maximization problem:

[5] All derivation steps are given in Appendix 3.9.2.

$$\max_{r_t^d(j)} \int_0^1 r_t^d(j) d_t(j)\, dj \qquad s.t \left[\int_0^1 d_t(j)^{\frac{\epsilon_d - 1}{\epsilon_d}} dj \right]^{\frac{\epsilon_d}{\epsilon_d - 1}} \geq d_t \tag{3.7}$$

The solution to the maximization problem yields the relative deposit demand function for branch j:

$$d_t(j) = \left[\frac{r_t^d(j)}{r_t^d} \right]^{-\epsilon_d} d_t \qquad where \quad r_t^d = \left[\int_0^1 r_t^d(j)^{1-\epsilon_d}\, dj \right]^{\frac{1}{1-\epsilon_d}} \tag{3.8}$$

3.4.2 Production (Firm) Sector

A representative firm produces and supplies final goods. Since the household holds the firm's equity, the firm aims to maximize its lifetime valuation. Its production technology is $y_t = z_t k_{t-1}^{\theta} n_t^{1-\theta}$, and to produce final goods (y_t), the firm employs labor (n_t) and determines the level of investment (i_t) to accumulate capital (k_{t-1}), following the law of motion: $k_t = i_t + (1-\delta)k_{t-1}$. The firm is assumed to have corporate income tax liabilities applied to its EBITA (Earnings Before Interest, Taxes, Depreciation and Amortization), $y_t - w_t n_t$, at a tax rate of τ_F. Additionally, we adopt the framework in Jermann and Quadrini (2012) to properly incorporate the firm's financial structure. Thus, the firm can raise funds for business operations through debt (b_t) from banks or equity finance by lowering the level of payout (x_t), which is subject to the adjustment cost $\kappa(x_t - \overline{x})^2$ when x_t deviates from the steady-state level of equity payout ($\overline{x}$). Hence, the firm would prefer increasing the debt level instead of changing x_t unless κ is zero.[6] The firm's obligation of debt repayment

[6]The parameter κ represents friction in substituting the firm's finance structure from debt finance to equity finance (Jermann and Quadrini, 2012).

in period t is $(1 + r^b_{t-1})b_{t-1}$. The total amount of debt repayment is considered for a corporate income tax deduction, differing from Jermann and Quadrini (2012). Specifically, $\kappa_b(1+r^b_{t-1})b_{t-1}$ is deductible from the tax base $(y_t - w_t n_t)$. Consequently, the settled corporate income taxes, when the firm has a non-zero amount of debt, becomes $\tau_F(y_t - w_t n_t - \kappa_b(1 + r^b_{t-1})b_{t-1})$. The parameter κ_b, combined with the corporate tax rate τ_F, determines the degree of debt bias in the economy, enabling relevant analysis of the tax system and its implications for macroprudential policy.

The other corporate finance structures are the same as in Jermann and Quadrini (2012). First, it is assumed that there is a mismatch between the timing of selling their output (y_t) and receiving the revenues. The firm must cover all operational outflows—labor costs, corporate taxes, interest and principal repayment net of new loans, equity payout and its adjustment cost, and physical capital investment expenses—before receiving revenues. Because of this mismatch between costs and revenue, the firm must take an intra-temporal loan (l_t) to cover these costs. Additionally, l_t is assumed to be repaid by the end of period t at a zero interest rate. In summary, the required l_t is expressed as follows:

$$l_t = w_t n_t + \tau_F(z_t k^{\theta}_{t-1} n_t^{1-\theta} - w_t n_t) + (1 - \tau_F \kappa_b)(1 + r^b_{t-1})b_{t-1} - b_t + x_t + \kappa(x_t - \overline{x})^2 + i_t \tag{3.9}$$

Alternatively, the firm may default and refuse to repay l_t. In such a case, the wholesale branch of the banking sector can liquidate the firm's capital k_t with a probability of ζ_t, reflecting uncertainty about the value of the liquidated capital. As a result, with a probability of $1 - \zeta_t$, the bank receives nothing in the event of default. To avoid default, the enforcement constraint (3.12) should be satisfied.[7] Therefore, ζ can be interpreted as a financial shock influencing the firm's borrowing capacity. To summarize, the firm's problem can be written in a recursive form under the budget

[7]For a more detailed explanation, see Jermann and Quadrini (2012).

and enforcement constraints.

$$V(z,\zeta;k,b) = \max_{x,n,k',b'}\{x + \mathbb{E}\, m' V(z',\zeta';k',b')\} \tag{3.10}$$

$$s.t\ (1-\delta)k+(1-\tau_F)(zk^{\theta}n^{1-\theta}-wn)+b' = (1-\tau_F\kappa_b)(1+r^b)b+x+\kappa(x-\overline{x})^2+k' \tag{3.11}$$

$$\zeta(k'-b') \geq l \tag{3.12}$$

Here, $m_{t,t+j}$ is the stochastic discount factor defined as $m_{t,t+j} = \beta^j \frac{\lambda_{Ht+j}}{\lambda_{Ht}}$. Additionally, as shown in Appendix 3.9.3, we can verify that $l_t = y_t$ by combining Equations (3.9) and (3.11). By solving the problem (3.10) for x, n, k', and b' under the budget constraint (3.11) and enforcement constraint (3.12), and applying the envelope conditions, we derive the following first-order conditions. Here, μ_{ct} and μ_{et} are the Lagrange multipliers for conditions (3.11) and (3.12), respectively.

$$\mu_{ct} = \frac{1}{1+2\kappa(x_t-\overline{x})} \tag{3.13}$$

$$(1-\theta)z_t k_{t-1}^{\theta} n_t^{-\theta} = \left(\frac{1-\tau_F}{1-\tau_F-\mu_{et}/\mu_{ct}}\right) w_t \tag{3.14}$$

$$\mathbb{E}_t\, m_{t,t+1}\frac{\mu_{ct+1}}{\mu_{ct}}\left(1-\delta+(1-\tau_F)(\frac{\theta}{1-\theta})(\frac{w_{t+1}n_{t+1}}{k_t})\right) = 1-\zeta_t\frac{\mu_{et}}{\mu_{ct}} \tag{3.15}$$

$$-\mathbb{E}_t\, m_{t,t+1}\frac{\mu_{ct+1}}{\mu_{ct}}(1-\tau_F\kappa_b)(1+r_t^b) = -1+\zeta_t\frac{\mu_{et}}{\mu_{ct}} \tag{3.16}$$

We assume the enforcement constraint (3.12) always binds. Additionally, productivity z_t and the financial condition ζ_t follow the AR(1) processes:

$$log(z_t) = (1-\rho_z)log(z_{ss}) + \rho_z log(z_{t-1}) + \varepsilon_{zt} \tag{3.17}$$

$$log(\zeta_t) = (1 - \rho_\zeta) log(\zeta_{ss}) + \rho_\zeta log(\zeta_{t-1}) + \varepsilon_{\zeta t} \tag{3.18}$$

It is assumed that ε_{zt} and $\varepsilon_{\zeta t}$ are distributed as $\mathcal{N}(0, \sigma_z^2)$ and $\mathcal{N}(0, \sigma_\zeta^2)$, respectively, with $z_{ss} = 1$ and $\zeta_{ss} = 0.45$.

The bank branch j also decides the amount of debt they supply to the firm under monopolistic competition, as in Gerali et al. (2010). The structure mirrors that of the deposit side. Once the firm determines its total debt (b_t), it allocates loans across retail branches j to minimize total repayment costs. Thus, the formal minimization problem is as follows.

$$\min_{r_t^b(j)} \int_0^1 r_t^b(j) b_t(j)\, dj \qquad s.t \left[\int_0^1 b_t(j)^{\frac{\epsilon_b - 1}{\epsilon_b}} dj \right]^{\frac{\epsilon_b}{\epsilon_b - 1}} \geq b_t \tag{3.19}$$

This yields the relative demand for loans from branch j:

$$b_t(j) = \left[\frac{r_t^b(j)}{r_t^b} \right]^{-\epsilon_b} b_t \qquad where \quad r_t^b = \left[\int_0^1 r_t^b(j)^{1-\epsilon_b}\, dj \right]^{\frac{1}{1-\epsilon_b}} \tag{3.20}$$

3.4.3 Banking Sector

The banking sector plays a crucial role in macroprudential policy operations. This sector closely follows the framework established in previous literature, particularly by Gerali et al. (2010) and Gebauer and Mazelis (2023), which analyzed the European banking industry. The banking sector consists of two main components: the wholesale branch and the retail branch. The wholesale branch oversees the overall banking business by determining the available funds for the retail branches and

imposing enforcement constraints on the firm. It also manages the total level of bank capital. In contrast, the retail branches handle regular business operations, acting as a financial intermediary between the firm and the household. Each branch operates in a monopolistic competitive environment. A more formal explanation is as follows.

Wholesale Branch The wholesale branch manages the overall banking sector and the operations of the retail branches. First, it negotiates with the firm over potential default and liquidation of capital, thereby incentivizing the firm to comply with the enforcement constraint (3.12) as discussed above. Additionally, it determines the total level of loans and deposits, following the capital requirement regulation imposed by the macroprudential authority, to maximize the available resources for the bank's operations. In other words, the wholesale branch supplies funds (B_t) for debt issuance by each retail branch in return for interest payments at the rate of R_t^b. Furthermore, the wholesale branch receives deposits (D_t) from each retail branch at the interest rate of R_t^d. The wholesale branch also manages the level of bank capital (K_t) in line with the capital requirement imposed by the macroprudential authority. Specifically, it must cover the cost when the bank capital-to-debt ratio ($\frac{K_t^b}{B_t}$) deviates from the required level (v_t^b), proportional to the level of discrepancy. For all these management processes, the wholesale branch must satisfy the balance sheet condition: Assets (B_t) = Liabilities (D_t) + Capital (K_t). The evolution of bank capital will be discussed later. Consequently, the wholesale branch's maximization problem is as follows.

$$\max_{B_t, D_t} \mathbb{E}_0 \sum_{t=0}^{\infty} m_{0,t}[(1+R_t^b)B_t - B_{t+1} + D_{t+1} - (1+R_t^d)D_t + (K_{t+1}^b - K_t^b) - \frac{\kappa_{Kb}}{2}\left(\frac{K_t^b}{B_t} - v_t^b\right)^2 K_t^b] \tag{3.21}$$

$$s.t\ B_t = D_t + K_t^b \tag{3.22}$$

The balance sheet condition (3.22) simplifies the dynamic maximization problem (3.21) into a static problem:

$$\max_{B_t, D_t} R_t^b B_t - R_t^d D_t - \frac{\kappa_{Kb}}{2}\left(\frac{K_t^b}{B_t} - v_t^b\right)^2 K_t^b \tag{3.23}$$

Then, the first-order condition of the maximization problem (3.23) provides an equation for the spread between the wholesale deposit and loan rates, as shown in (3.24). This indicates that the loan rate is determined by subtracting the wholesale branch's capital-related cost from the deposit rate.

$$R_t^b = R_t^d - \kappa_{Kb}\left(\frac{K_t^b}{B_t} - v_t^b\right)\left(\frac{K_t^b}{B_t}\right)^2 \tag{3.24}$$

Retail Branches As previously mentioned, multiple retail branches operate under monopolistic competition, and there are two distinct entities: loan branches and deposit branches. Each loan branch, j, determines the level of loans to firms ($b_t(j)$) using funds sourced from wholesale loans $B_t(j)$ at an interest rate R_t^b. The branches receive interest payments from the firm at a rate of $r_t^b(j)$, but they incur adjustment costs when adjusting interest rates. In short, the loan branches face the following maximization problem.

$$\max_{r_t^b(j)} \mathbb{E}_0 \sum_{t=0}^{\infty} m_{0,t}\left[r_t^b(j) b_t(j) - R_t^b B_t(j) - \frac{\psi_b}{2}\left(\frac{r_t^b(j)}{r_{t-1}^b(j)} - 1\right)^2 r_t^b b_t\right] \tag{3.25}$$

$$s.t. \quad b_t(j) = \left[\frac{r_t^b(j)}{r_t^b}\right]^{-\epsilon_b} b_t$$

Solving the problem (3.25) above, with the condition that $b_t(j) = B_t(j)$, yields the following condition (3.26) in the symmetric equilibrium, where decisions made by each branch j are identical. This condition demonstrates how the interest rate on corporate debt is determined by the wholesale debt rate, the degree of substitutability among loans from each branch j, adjustment costs, and the total level of corporate debt.

$$1 - \epsilon_b + \frac{R_t^b}{r_t^b}\epsilon_b - \psi_b \left(\frac{r_t^b}{r_{t-1}^b} - 1 \right) \frac{r_t^b}{r_{t-1}^b} + \mathbb{E}_t \, \beta \frac{\lambda_{Ht+1}}{\lambda_{Ht}} \psi_b \left(\frac{r_{t+1}^b}{r_t^b} - 1 \right) \left(\frac{r_{t+1}^b}{r_t^b} \right)^2 \frac{b_{t+1}}{b_t} = 0 \tag{3.26}$$

Additionally, numerous deposit branches exist. They place their wholesale deposits and earn interest from the wholesale branch. As mentioned earlier regarding the representative household, they collect deposits from the household and pay interest. In summary, deposit branches face the following profit maximization problem.

$$\max_{r_t^d(j)} \mathbb{E}_0 \sum_{t=0}^{\infty} m_{0,t} \left[R_t^d D_t(j) - r_t^d(j) d_t(j) - \frac{\psi_d}{2} \left(\frac{r_t^d(j)}{r_{t-1}^d(j)} - 1 \right)^2 r_t^d d_t \right] \tag{3.27}$$

$$s.t. \quad d_t(j) = \left[\frac{r_t^d(j)}{r_t^d} \right]^{-\epsilon_d} d_t$$

Analogously, as with the loan branches, solving the problem (3.27), under the condition that $d_t(j) = D_t(j)$, yields the following condition in the symmetric equilibrium. This condition determines the interest rates on household deposits.

$$-1 + \epsilon_d - \frac{R_t^d}{r_t^d}\epsilon_d - \psi_d \left(\frac{r_t^d}{r_{t-1}^d} - 1 \right) \frac{r_t^d}{r_{t-1}^d} + \mathbb{E}_t \, \beta \frac{\lambda_{Ht+1}}{\lambda_{Ht}} \psi_d \left(\frac{r_{t+1}^d}{r_t^d} - 1 \right) \left(\frac{r_{t+1}^d}{r_t^d} \right)^2 \frac{d_{t+1}}{d_t} = 0 \tag{3.28}$$

Finally, the inflows of resources to the consolidated banking sector are determined

by three components. The sector earns interest on corporate debt ($r^b_{t-1}b_{t-1}$) incurred at $t-1$, pays interest on household deposits ($r^d_{t-1}d_{t-1}$), and covers the cost arising from deviations in the required capital level ($\frac{\kappa_{Kb}}{2}\left(\frac{K^b_t}{B_t} - v^b_t\right)^2 K^b_t$). These inflows are taxed at a tax rate τ_B, so the final earnings retained by the banking sector in year t are A^b_t:

$$A^b_t = (1-\tau_B)\left(r^b_{t-1}b_{t-1} - r^d_{t-1}d_{t-1} - \frac{\kappa_{Kb}}{2}\left(\frac{K^b_t}{B_t} - v^b_t\right)^2 K^b_t\right) \tag{3.29}$$

Retained earnings (A^b_t) contribute to the accumulation of bank capital (K^b_t). A portion of bank capital depreciates each period at a rate δ^b to cover the bank's overall operation costs. Thus, the level of bank capital (K^b_t) at time t is as follows:

$$K^b_t = (1-\delta^b)K^b_{t-1} + A^b_t \tag{3.30}$$

3.4.4 Macroprudential Authority

The macroprudential authority regulates the capital requirement rule. As previously explained, the banking sector must comply with this rule, incurring a fine if it fails to do so. The macroprudential authority uses this rule to stabilize the economy. Thus, macroprudential policy operates counter-cyclically, taking into account the credit-to-GDP ratio.

$$log(v^b_t) = log(v^b_{ss}) + \rho_{By} log\left(\frac{B_t/y_t}{\overline{B}/\overline{y}}\right) \quad where \quad \frac{\overline{K^b}}{\overline{B}} = v^b_{ss} \tag{3.31}$$

3.4.5 Government and Market Clearing Condition

The government balances tax revenues and government spending in each period. As previously discussed, the government has three revenue sources: labor income taxes, corporate income taxes, and banking taxes. Therefore, the total tax revenues are as follows.

$$\underbrace{\tau_H w_t n_t}_{\text{Labor income taxes}} + \underbrace{\tau_F(z_t k_{t-1}^{\theta} n_t^{1-\theta} - w_t n_t)}_{\text{Corporate income taxes}} + \underbrace{\tau_B \left(r_{t-1}^b b_{t-1} - r_{t-1}^d d_{t-1} - \frac{\kappa_{Kb}}{2} \left(\frac{K_t^b}{B_t} - v_t^b \right)^2 K_t^b \right)}_{\text{Banking taxes}} \tag{3.32}$$

Based on the total revenues in Equation (3.32), the government adjusts corporate income taxes by considering the firm's debt level. To ensure total revenues align with government expenditures, the government makes transfer payments (TR_t) to the household using the remaining revenues after corporate tax deductions. Equation (3.33) represents total government spending.

$$\tau_F \kappa_b (1 + r_{t-1}^b) b_{t-1} + TR_t \tag{3.33}$$

Finally, the total production of final goods (y_t) in the economy must equal the sum of all demand components: final goods consumption, capital investment, banking sector operational costs, and total adjustment costs ($adj.cost_t$). Adjustment costs include payments made by the firm for adjusting equity payouts, fines for non-compliance with capital requirements, and costs associated with changing interest rates by the retail branches.

$$y_t = c_t + k_t - (1 - \delta) k_{t-1} + \delta^b K_{t-1}^b + adj.cost_t \tag{3.34}$$

3.4.6 Equilibrium

The competitive equilibrium of this economy is defined as a set of time paths:

$$\{r_t^d, R_t^d, R_t^b, r_t^b, v_t^b, w_t, n_t, c_t, B_t, K_t^b, A_t^b, D_t, b_t, d_t, k_{t-1}, y_t, l_t, i_t, \mu_{ct}, \mu_{et}, \lambda_{Ht}, x_t, TR_t\}_{t=0}^{\infty} \tag{3.35}$$

which satisfies the household's utility maximization problem, the production sector's problem, the wholesale and retail branches' maximization problems, the government's budget constraint, and the market clearing condition, subject to the macroprudential authority's capital requirement rule (3.31).

3.5 Calibration and Estimation

The model is designed to replicate the features of the European economy in the steady state. When obtaining values from the data is challenging, we primarily referred to existing literature that discusses macroeconomic policy effectiveness within a DSGE framework. These parameters include the household's risk aversion (σ), the capital income share (θ), and the depreciation rate of bank capital (δ^b), with each value sourced from Hohberger et al. (2020) and Gerali et al. (2010). Other parameters were calibrated to match the model and data between Q1 2000 and Q4 2019. These were set to align the model with the quarterly average data of the European economy. For instance, $\beta = 0.9959$ was selected to achieve a quarterly average short-term interest (policy) rate of 0.4% for the European economy. The quarterly average deposit and loan interest rates were 0.52% and 0.97%, respectively, leading us to set ϵ_d and ϵ_b to -3.661 and 2.187. Additionally, tax rates, debt deductibility, and capital depreciation rate were jointly calibrated to ensure the model's steady-state values, such as the Credit-to-GDP ratio, consumption, and investment ratios,

with the empirical data.[8] To clarify, the total debt repayment $(1 + r_{t-1})b_{t-1}$ is deductible, with a deductibility of $\kappa_b = 0.1$, as reflected in the tax liabilities previously presented in Section 3.4 by $\tau_F(y_t - w_t n_t - \kappa_B(1 + r^b_{t-1})b_{t-1})$. Further details will follow in Section 3.6.

Table 3.1: Calibrated parameters

Param.	Description	Value	Source & Target
σ	Risk aversion	1.54	Hohberger et al. (2020)
δ^b	Bank capital depreciation rate	0.1049	Gerali et al. (2010)
β	Household's discount factor	0.9959	ECB (Policy rate)
ϵ_d	Elasticity of substitution between deposits	-3.661	ECB (Deposit rate)
ϵ_b	Elasticity of substitution between loans	2.187	ECB (Loan rate)
τ_H	Tax rate on labor income	0.2	Eurostat $(c/(c+i))$
τ_F	Tax rate on corporate income	0.3	ECB, Eurostat (B/y)
τ_B	Tax rate on bank profit	0.35	ECB, Eurostat (B/y)
κ_b	Debt deductibility in reducing the corporate tax base	0.1	ECB, Eurostat (B/y)
θ	Capital income share	0.27	Eurostat $(c/(c+i))$
δ	Physical capital depreciation rate	0.051	Eurostat $(i/(c+i))$
ρ_z	Persistence of the productivity shock	0.94	Gerali et al. (2010)
σ_z	Standard deviation of the productivity shock	0.006	Gerali et al. (2010)

The parameters determining short-run economic fluctuations were primarily estimated. However, where appropriate, we used values from existing literature, such as ρ_z and σ_z from Gerali et al. (2010). If suitable values were unavailable, we estimated them. Besides productivity shocks, the economy experiences two other types of shocks: demand and financial. Thus, we employed two quarterly series—consumption and corporate loan data—to estimate the AR(1) coefficient, the size of each shock, and parameters related to adjustment costs and household decisions. The priors for the Bayesian estimation were selected based on studies closely related in terms of topics and methods, such as Gebauer and Mazelis (2023), Bratsiotis and Pathirage (2023), Gerali et al. (2010), and Hohberger et al. (2020). The estimation was conducted using the Metropolis-Hastings algorithm with 100,000 draws. The estimated

[8]The model fit shown in Table 3.2 remains unchanged due to the estimation results. This is because r^d, r^b, and R^d depend solely on the calibrated parameters. Even though the consumption, investment, corporate debt, and output levels are affected by the estimation results, the consumption (investment) ratios and debt-to-GDP ratios remain constant since these are also determined solely by the calibrated parameters. See Appendix 3.9.5

parameters are presented in Table 3.3.

Table 3.2: Steady-state value and model fit

Target	Model	Data
Deposit interest rate (r^d)	0.0041	0.0041
Corporate loan rate (r^b)	0.0097	0.0097
Wholesale interest rate (R^d)	0.0053	0.0053
Share of private consumption ($c/(c+i)$)	0.70	0.72
Share of investment ($i/(c+i)$)	0.30	0.28
Credit-to-GDP ratio (B/y)	3.51	3.57

Table 3.3: Estimated parameters

		Prior distribution			Posterior distribution		
	Parameter	Dist.	Mean	St.dev.	Mean	5%	Median	95%
α	Habit coefficient	Beta	0.50	0.10	0.39	0.24	0.39	0.53
ϕ	Inv. Frisch	Gamma	1.00	0.50	1.88	0.71	1.80	3.20
κ_{kb}	Adj. cost K^b	Gamma	10.00	5.00	10.41	2.17	9.64	20.55
ψ_b	Adj. cost r_b	Gamma	3.00	2.50	3.22	0.02	2.57	8.61
ψ_d	Adj. cost r_d	Gamma	10.00	2.50	9.91	5.09	9.65	14.66
ρ_ζ	Persistence of fin. shock	Beta	0.85	0.10	0.73	0.53	0.74	0.92
ρ_Ξ	Persistence of demand shock	Beta	0.85	0.10	0.83	0.66	0.84	0.97
σ_ζ	St.dev. fin. shock	IGamma	0.010	0.050	0.021	0.017	0.021	0.026
σ_Ξ	St.dev. demand shock	IGamma	0.010	0.050	0.006	0.004	0.005	0.008

3.6 Quantitative Analysis

Using the constructed model, this section examines macroeconomic instability across two different CIT systems and the optimal deployment of macroprudential policy. To this end, we postulate two distinct fiscal policy regimes: "HH" (High tax rates and High deductibility) and "LL" (Low tax rates and Low deductibility). By definition, debt finance deductibility refers to the extent to which a firm can deduct total debt payments from its CIT tax base. A higher deductibility encourages the firm to finance through debt rather than equity because it reduces its overall tax burden. The "HH" economy represents the current state of the European macroeconomy, as calibrated and estimated earlier. In this system, high CIT rates combined with

high debt finance deductibility encourages debt financing, resulting in a relatively higher debt-to-GDP ratio than the "LL" economy, which will be elaborated upon later. This is consistent with findings from several empirical studies. For instance, de Mooji (2011) and Dallari et al. (2020) provide evidence that higher tax rates increase firms' debt-to-asset ratios, given the same degree of deductibility. Additionally, de Mooji and Hebous (2018) shows that limitations on debt deductibility (e.g., thin-cap rules) reduce firms' levels of indebtedness. Conversely, the "LL" economy is a hypothetical scenario characterized by low CIT rates and low debt finance deductibility, leading to a lower debt-to-GDP ratio. In this system, the firm has less incentive to take loans to reduce its tax burden. This could be a potential outcome for the European fiscal system if the Euro area successfully implements "DEBRA". Alternatively, it characterizes the group of countries listed in the right sub-figure of Figure 3.1 which have adopted rules limiting debt deductibility.

To illustrate these discrepancies quantitatively, the "HH" economy assumes $\tau_F = 0.3$ and $\kappa_b = 0.1$, as shown in Table 3.1. Meanwhile, the "LL" economy assumes $\tau_F = 0.08$ and $\kappa_b = 0.05$. Consequently, the Credit-to-GDP ratio of the "LL" economy is 2.18, significantly lower than that of the "HH" economy, which stands at 3.51. Additionally, taxes deducted as a ratio of GDP in the steady state of the "HH" economy are 11%, whereas in the "LL" economy, they are only 1%. Thus, the "LL" economy's debt deductibility is 10 percentage points lower.[9]

After establishing the two fiscal regimes, we investigate the following: First, we will demonstrate how a macroeconomic shock propagates differently by comparing two distinct tax systems with the same macroprudential policy parameter. In this exercise, we set both economies to have the same countercyclical capital requirement parameter, ρ_{By}, at 0. Second, we will examine the optimal countercyclical capital

[9]Using the formulae in Appendix 3.9.5, the steady-state levels of consumption and labor can be easily obtained, and the "LL" economy shows slightly lower values for both variables. However, the long-run welfare differences between the two regimes are almost negligible, as the "LL" economy achieves a slightly higher welfare level by only 0.1%, measured in consumption equivalents.

requirement policy across different fiscal systems and types of shocks. For these exercises, we set up the size of the shock to cause a 1% decrease in each related variable: productivity (z), corporate debt availability (ζ), and consumer preference (Ξ).

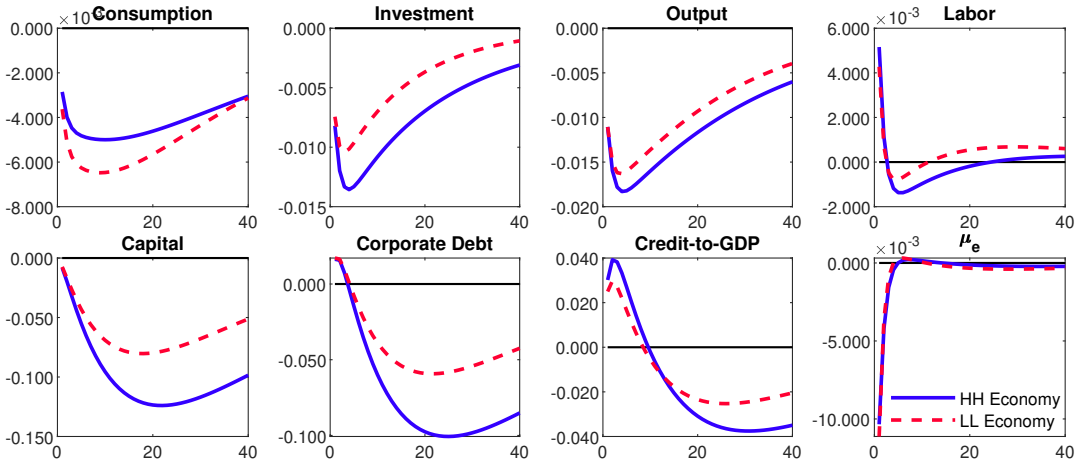
3.6.1 Volatility of variables across CIT regimes

Productivity shock First, Figure 3.3 presents the impulse-response function after the productivity shock. A decrease in z_t instantaneously worsens the current output level and tightens the firm's financial condition. Facing debt repayment pressures, as indicated in the budget constraint (3.11), the firm is incentivized to decrease the level of k_t and increase b_t for the next period. The firm may reduce the equity payout x_t today, but this would not be a much viable option as long as the adjustment cost parameter κ is non-zero. Since $l_t = y_t$, the lower output today due to the negative productivity shock can alleviate the enforcement constraint (3.12), reducing μ_{et}, which puts downward pressure on the capital level for the next period and gives the firm more room to issue intertemporal loans. As μ_{et} decreases, the marginal cost of increasing k_t rises, leading to a decrease in k_t through Equation (3.15), which drives investment and capital to deviate downward from the steady state. Accordingly, the output level declines, and the economy goes into recession. Meanwhile, as discussed earlier, the firm seeks to sustain its operations by increasing corporate loans. The benefit of an additional unit of loan increases due to the lower level of μ_{et}. To satisfy Equation (3.16), r_t^b must rise, reflecting higher demand for corporate loans. Thus, b_t increases, and the bank, which has a certain degree of market power, raises the interest rate.

Both the "HH" and "LL" economies exhibit similar initial responses, but the "HH" economy displays greater volatility. The reasons are as follows. First, the higher corporate tax rate in the "HH" economy leads to more substantial adverse effects

on the firm's budget constraint. Thus, the firm seeks to cut back further on investment, worsening output. Second, the debt-favorable tax system, characterized by higher debt financing deductibility, results in a relatively higher debt level at the steady state in the "HH" economy. The cumulative negative effect of depressed investment worsens the firm's debt repayment burden in the "HH" economy, which is inherently more indebted, leading to a steeper deleveraging phase. This exerts additional negative pressure on the economy. Consequently, the "HH" economy inevitably experiences more severe fluctuations in investment, capital, output, and the credit-to-GDP ratio compared to the "LL" economy. Consumption is less volatile in the "HH" economy because consumption and investment compete for resources. Therefore, a sharp decline in investment in the "HH" economy can lead to a relatively minor reduction in consumption.

Figure 3.3: Impulse-responses after productivity shock



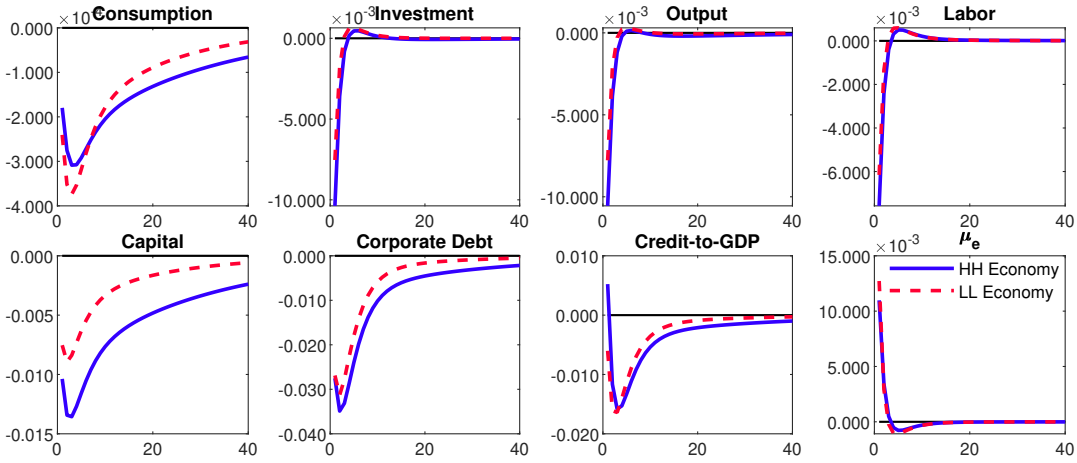
Notes: The impulse response functions after the 1% productivity shocks. The y-axis shows the deviation from the steady state. The solid blue lines refer to the "High tax rates and high deductibility" economy, while the dotted red lines represent the "Low tax rates and low deductibility" economy.

Financial shock Second, the dynamics of the economy after the financial shock are illustrated in Figure 3.4. The fluctuation originates from the enforcement constraint (3.12). A lower possibility (ζ_t) of recovering the firm's capital in the event of

default tightens the constraint, leading to an increase in μ_{et}. Equation (3.14) gives the firm's labor demand. As shown, a higher μ_{et} raises the real cost of labor, forcing the firm to reduce the level of employment. The firm may opt to reduce the level of equity payout (x_t), but this would be costly due to adjustment costs. Consequently, n_t declines, adversely impacting the output level. Additionally, a lower ζ_t immediately reduces capital investment through Equation (3.15). The demand for the intertemporal loan increases through Equation (3.16), but it cannot be raised further as the enforcement constraint (3.12) must be met. As long as ζ and y_t decrease by the same degree, b_t should be smaller as k_t lowers to satisfy the condition (3.12). Thus, k_t and b_t decline following a negative financial shock.

The reason for the high volatility in the "HH" economy is nearly identical to that of productivity shock. A high tax rate suppresses investment, leading to a more significant downward deviation in capital from the steady state. This lowers the economy's income level and increases the debt repayment burden. As a result, investment, output, capital, and the credit-to-GDP ratio experience greater fluctuations in the "HH" economy.

Figure 3.4: Impulse-responses after financial shock



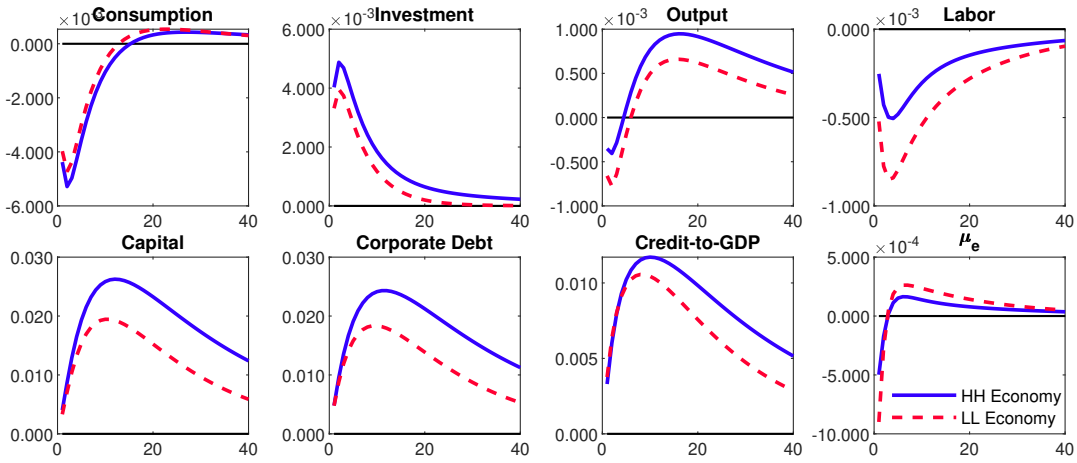
Notes: The impulse response functions after the 1% financial shocks. The y-axis shows the deviation from the steady state. The solid blue lines refer to the "High tax rates and high deductibility" economy, while the dotted red lines represent the "Low tax rates and low deductibility" economy.

Demand shock Finally, the impulse-response functions following the demand shock are illustrated in Figure 3.5. As household consumption demand decreases, more resources become available to increase investment. Thus, capital investment rises immediately following the demand shock. As the demand for final goods decreases, the household's labor supply incentive declines through Equation (3.4). This results in an initial reduction in output, but the output level surges as capital accumulates through increased investment. As the level of capital deviates positively from the steady state, the enforcement constraint (3.12) loosens, allowing the firm to secure additional loans. Thus, b_t increases.

In this context, the "HH" economy has a stronger incentive to pursue debt financing due to its higher debt deductibility. Therefore, the corporate debt level in the "HH" economy rises more than in the "LL". This enables the firm in the "HH" economy to accumulate more capital and mitigate the negative impact on labor supply, as higher capital levels increase the marginal productivity of labor. Consequently, in the short run, the "HH" economy achieves a higher output *level* than the "LL" economy. However, the heavier tax burden in the "HH" economy hampers the accumulation of physical capital *relative to* debt levels, causing corporate debt to grow faster than GDP. This leads to a more significant debt-to-GDP gap in the "HH" economy. Therefore, even though the direction of the deviation differs from previous shocks, the volatility in the "HH" economy is greater in response to the demand shock.

Table 3.4 summarizes the results discussed above, focusing on variables related to the financial and business cycles, namely the debt-to-GDP ratio (B/y), corporate debt (B), and GDP (y). The table clearly shows that the "HH" economy is more volatile, as measured by the standard deviation of each variable, across all types of

Figure 3.5: Impulse-responses after demand shock



Notes: The impulse response functions after the 1% demand shocks. The y-axis shows the deviation from the steady state. The solid blue lines refer to the "High tax rates and high deductibility" economy, while the dotted red lines represent the "Low tax rates and low deductibility" economy.

shocks. This reflects the impulse-response analysis, demonstrating that the "HH" economy deviates more and for a longer period from its steady state when maintaining the same ρ_{By} parameter as the "LL" economy. Focusing on financial stability concerns, the "HH" economy experiences greater fluctuations in the credit-to-GDP ratio, with a standard deviation approximately 1.1 to 1.6 times higher than that of the "LL" economy. This necessitates a more proactive role for the macroprudential authority under this fiscal system. In the next section, we will explore the role of macroprudential policy in more detail.

Table 3.4: Standard deviations of variables across macroeconomic shocks in each fiscal system

	High τ_F & High κ_b (A)			Low τ_F & Low κ_b (B)			A/B		
Shock	B/y	B	y	B/y	B	y	B/y	B	y
All	0.262	0.656	0.082	0.165	0.354	0.067	1.582	1.854	1.227
Prod.	0.252	0.639	0.081	0.155	0.338	0.067	1.626	1.889	1.222
Fin.	0.036	0.079	0.011	0.033	0.063	0.008	1.084	1.264	1.395
Dem.	0.060	0.126	0.005	0.047	0.083	0.003	1.266	1.513	1.531

3.6.2 Time-varying capital requirement rule

The previous section demonstrates that the CIT system favoring debt finance leads to greater volatility, particularly in the debt-to-GDP ratio. Based on the findings of Drehmann et al. (2010), which show that the debt-to-GDP ratio is the most effective proxy for financial stability as it can capture banking crisis, and considering that excessive credit growth, misaligned with economic fundamentals like GDP, provokes systemic risk, this outcome raises concerns about financial stability. Therefore, this calls for appropriate policy intervention using the static capital requirements and the CCyB to manage the volatility of the debt-to-GDP ratio. Here, we propose how the capital requirements should be used to mitigate such concerns. In this discussion, we use the modeled dynamic bank capital requirement (3.31), which is adjusted when the debt-to-GDP ratio deviates from the steady state. In brief, the mechanism works such that the bank capital requirement increases when the economy's credit-to-GDP ratio rises, indicating that credit levels are excessive relative to the economy's fundamentals (output). The higher required capital level deters the bank from issuing additional corporate loans.

Under this framework, the specific question we aim to investigate is: "What is the optimal operation of macroprudential policy (CCyB) under different CIT regimes across various macroeconomic shocks?" To answer this question, we followed the "revealed-preference approach", as outlined by Angelini et al. (2014) and Binder et al. (2018). This approach explicitly considers the primary concern of the macroprudential authority, such as proxies for financial stability (Hecker et al., 2023), and postulates a loss function based on this concern.[10] Thus, we adopt the loss function

[10]Unlike monetary policy which aims to achieve price stability (stable inflation), defining a single objective for financial stability is challenging (Patel, 2017). However, previous studies have used the variability of the credit-to-GDP ratio as a primary indicator, as suggested by Drehmann et al. (2010).

for the macroprudential policy authority (3.36) below.

$$L = \sigma^2_{B/y} + c_y\sigma^2_y + c_{\Delta v}\sigma^2_{\Delta v} \tag{3.36}$$

The loss function is similar to those used by macroprudential policy authorities in the previous literature, such as Angelini et al. (2014), Rubio and Carrasco-Gallego (2014), and Hecker et al. (2023). As we can see, the policy authority's loss function is a linear combination of the volatility in the debt-to-GDP ratio, output fluctuation, and the variability of adjustments in the required capital level. In other words, the financial stability authority's primary concern is stabilizing the debt-to-GDP ratio, but they also take into account the variability of the real economy as long as $c_y \neq 0$. For our main analysis, we set $c_y = 0.5$.[11] The final term represents a type of penalty applied in the case of drastic policy operations, ensuring the level of adjustment of the policy tool remains within a reasonable range (Angelini et al., 2014). This also takes into account the real practice of CCyB operations. In reality, the size of adjustment by policy authorities does not exceed more than 0.5 percentage points. Thus, similar to Angelini et al. (2014), we assign 0.1 to $c_{\Delta v}$. Now, considering the loss function (3.36), we can formally present the financial stability authority's optimization problem for each fiscal regime $j \in \{HH, LL\}$:

$$\min_{\rho_{By}} \sigma^2_{B/y,j} + c_y\sigma^2_{y,j} + c_{\Delta v}\sigma^2_{\Delta v,j} \tag{3.37}$$

$$s.t.\ log(v^b_t) = log(v^b_{ss}) + \rho_{By} log\left(\frac{B_t/y_t}{\overline{B}/\overline{y}}\right)$$

$$\mathbb{E}_t\left[f_j(Y_{t+1,j}, Y_{t,j}, Y_{t-1,j}, U_{t,j}, \Theta_j)\right] = 0$$

Here, Y, U, and Θ represent the endogenous variables, exogenous shocks, and parameters, respectively. By solving the problem (3.37), we find the optimal capital

[11] We experimented with different weights on the output gap, ranging from 0 to 1, but this did not alter the results in Table 3.5.

requirement rule across two different fiscal regimes and three types of shocks, as previously described. For this, we set a grid for the capital requirement parameter, ρ_{By} of Equation (3.31), ranging from 0 to 16 with a step size of 0.25.[12] Then, we compute the policy authority's loss across parametric values in the grid and obtain the optimal level of ρ_{By} that minimizes the loss.

Table 3.5 summarizes the results. The main findings presented in Table 3.5 are as follows: First, stronger responses from the countercyclical capital buffer are required in response to both productivity shocks and demand shocks for both fiscal systems. As observed in Section 3.6.1, the deviation period from the steady state is more prolonged with these shocks; thus, a sufficiently high level of parameters is necessary for stabilization. Second, a sufficiently proactive operation of macroprudential policy is crucial in a debt-favoring fiscal system. As indicated in the previous impulse-response analysis, an economy with a high debt level is more susceptible to excessive fluctuations when macroeconomic shocks occur. Thus, it is reasonable for the fiscal system to adopt a more aggressive macroprudential policy to minimize the loss function. In this context, the "HH" economy requires a response 3.8-4.6 times larger to deviations in the credit-to-GDP ratio from its steady state to achieve its policy objectives. Finally, it is more appropriate for both systems to remain inactive in response to financial shocks. This is because the volatility of the credit-to-GDP ratio in both systems is lower than with other shocks and swiftly converges back to steady state values. Additionally, the duration of a non-zero output gap is considerably short when a financial shock occurs.

To quantify the benefit of implementing an optimal capital requirement rule in each scenario, we conduct a performance analysis. This is measured by the following equation (3.38), where $j \in \{HH, LL\}$, k represents types of shocks, $Loss_{0,j}$ refers to the loss of the macroprudential policy authority when the capital requirement

[12]This ensures that the upper bound of the CCyB rate is 2.5%, which is an internationally agreed standard for the upper bound of the CCyB as suggested in Bank of England (2016).

Table 3.5: Optimal CCyB parameters within each fiscal regime across various types of shocks

	High τ_F & High κ_b		Low τ_F & Low κ_b		
Shocks	Loss	ρ_{By} (A)	Loss	ρ_{By} (B)	A/B
Productivity shock	0.0606	5.75	0.0258	1.25	4.60
Financial shock	0.0014	0.00	0.0011	0.00	-
Demand shock	0.0032	9.50	0.0022	2.50	3.80

rule is time-invariant, and $Loss_{opt,j}$ is the loss under the optimal rule.

$$Benefit_k = (\frac{Loss_{0,j} - Loss_{opt,j}}{Loss_{0,j}})_k * 100 \tag{3.38}$$

As shown in Table 3.6, economies with more pro-debt financing fiscal systems experience relatively higher losses when facing each type of shock. Accordingly, setting an optimal rule that minimizes the policy authority's loss function could improve welfare by reducing the variability of the economy, particularly against productivity shocks and demand shocks. Thus, the gains of the optimal CCyB are more extensive in fiscal regimes that encourage debt financing. In contrast, the loss reduction in the "Low tax rates and low deductibility" fiscal system is less substantial, confirming that the tax system matters for macroprudential policy affairs. As the tax regime offers less incentive for firms to depend on debt, there is also less need for the financial stability authority to intervene in the financial market to achieve its policy objectives.

3.7 Sensitivity analysis and further results

3.7.1 Alternative time-varying capital requirement rules

The credit-to-GDP gap serves as the indicator that the financial stability authority used to set the CCyB rule in our primary analysis. However, there are studies that

Table 3.6: Performance analysis

	High τ_F & High κ_b	Low τ_F & Low κ_b
Losses under time-invariant rule		
Productivity shock	0.0668	0.0262
Financial shock	0.0014	0.0011
Demand shock	0.0036	0.0022
Benefits		
Productivity shock	9.29%	1.47%
Financial shock	0.00%	0.00%
Demand shock	10.12%	2.04%

Notes: The benefits from setting optimal CCyB rules are measured by the percentage reduction in the macroprudential authority's loss compared to having a static capital requirement rule.

consider the variability of debt, its growth rate, or deviation from the steady state in their investigation of the effectiveness of the capital requirement rule, such as Rubio and Yao (2020). Motivated by their approach, we applied an alternative CCyB rule (3.39) in solving the financial stability authority's problem (3.37):

$$log(v_t^b) = log(v_{ss}^b) + \rho_{By} log\left(\frac{B_t}{\overline{B}}\right) \tag{3.39}$$

The optimal parameters derived by using Equation (3.39) are given in Table 3.7. It shows that a slightly larger ρ_{By} is required to counter consumer demand shocks if the policy authority operates with rule (3.39). Meanwhile, the optimal ρ_{By} is substantially larger if the prudential authority reacts to productivity shocks. This is because the deviation of corporate debt from its steady state is much larger than that of the credit-to-GDP ratio after a productivity shock (Figure 3.3). In other words, the deviation of corporate debt from its steady state is almost -0.1 around the twenty-second period after the productivity shock, which is nearly 3-4 times greater than that of the debt-to-GDP ratio. Therefore, a more aggressive policy response is required to counteract a more volatile variable. Still, a proactive response by the macroprudential authority must be in implemented under the debt-

favorable tax system, around 3-3.5 times greater than that under the opposite fiscal regime, consistent with the key results discussed earlier.

Table 3.7: Optimal CCyB parameters within each fiscal regime across various types of shocks: using the degree of corporate debt deviation from its steady state as a reference

	High τ_F & High κ_b		Low τ_F & Low κ_b		
Shocks	Loss	ρ_{By} (A)	Loss	ρ_{By} (B)	A/B
Productivity shock	0.0449	16.00	0.0242	4.75	3.37
Financial shock	0.0014	0.25	0.0011	0.00	-
Demand shock	0.0031	10.50	0.0022	3.00	3.50

3.7.2 Alternative banking tax rates and capital requirements

The level of capital requirements in the steady state is determined by Equation (3.44) in the appendix. It indicates that as the government reduces banking tax rates, the required bank capital-to-asset ratio increases. Thus, by setting $\tau_B = 0$, the highest $v^b = 0.055$ can be obtained in the steady state, assuming the other parameters remain the same. We consider the relationship between the bank tax rate and the static capital requirement level and investigate the best combination of τ_B (v^b) and ρ_{By}. Figures 3.6 and 3.7 show that the macroprudential authority's losses decrease as τ_B decreases (v^b increases) at the given ρ_{By} level. The best ρ_{By} varies across τ_B, but it decreases slightly as τ_B declines. The figures also suggest that the lowest bank tax rate, combined with an appropriate level of the time-varying capital requirement parameter is optimal for both corporate tax systems.

Figure 3.6: Loss function across different types of shocks and policy parameters (HH Economy)

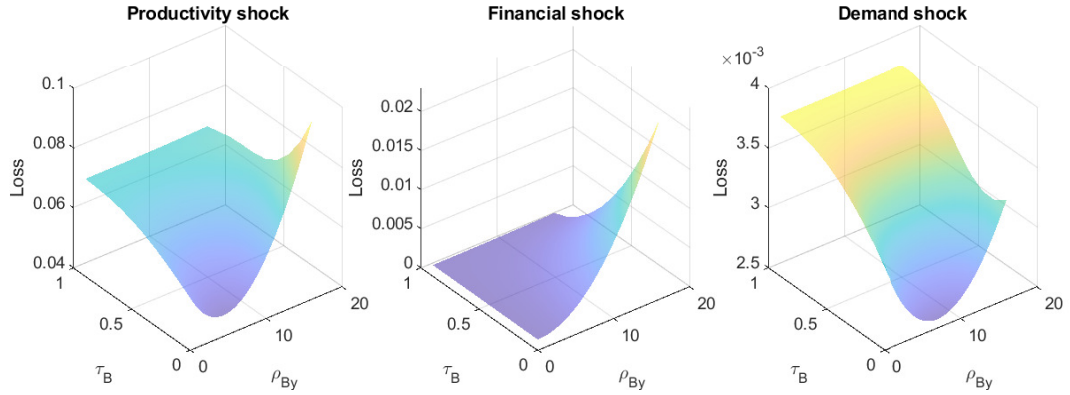


Figure 3.7: Loss function across different types of shocks and policy parameters (LL Economy)

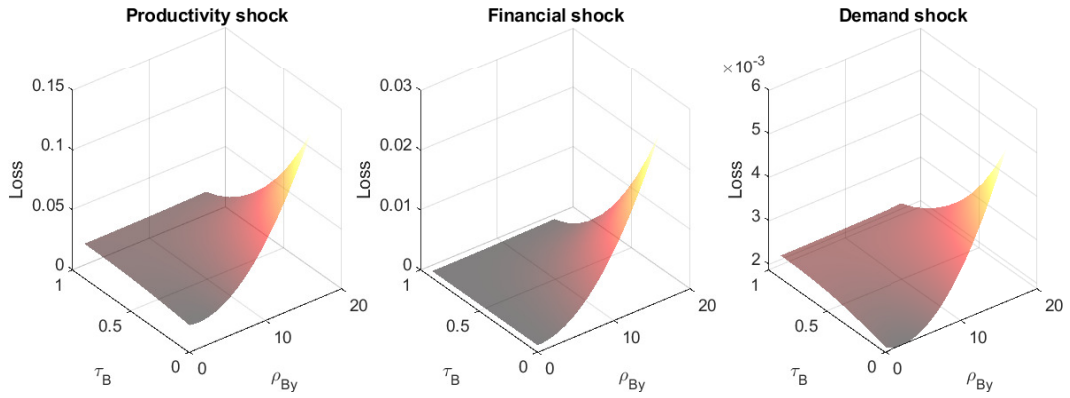


Table 3.8 clearly presents the optimal combination of τ_B and ρ_{By}. When a tighter static requirement rule is implemented with $\tau_B = 0$, the financial stability authority would achieve its policy objectives with a lower level of ρ_{By}, compared to our benchmark case, when a productivity or consumer demand shock hits the economy. Nevertheless, the debt-favoring fiscal regime must set relatively tighter rules for the time-varying parameters than its counterparts. In the face of a financial shock, the optimal $\rho_{By} = 0$ is maintained as discussed earlier, and there is no need to trigger time-varying capital requirements.

Table 3.8: Optimal CCyB and Bank tax rates parameters within each fiscal regime across various types of shocks

	High τ_F & High κ_b			Low τ_F & Low κ_b			
Shocks	Loss	τ_B	ρ_{By} (A)	Loss	τ_B	ρ_{By} (B)	A/B
Productivity shock	0.0470	0.00	3.75	0.0216	0.00	0.75	5.00
Financial shock	0.0013	0.00	0.00	0.0011	0.00	0.00	-
Demand shock	0.0026	0.00	6.50	0.0019	0.00	1.75	3.71

3.8 Concluding Remarks

Despite its importance in promoting financial stability, the interaction between the corporate tax system and the optimal operation of macroprudential policy has received limited attention. Motivated by this gap in formal discussion, this paper explores how macroeconomic volatility, particularly for financial stability-related variables such as the debt-to-GDP ratio, differs across two tax systems that vary in their inclination towards debt financing. By using a general equilibrium model that incorporates corporate finance, tax structure, and the banking sector, the study demonstrates that an economy with high corporate tax rates combined with high debt deductibility experiences greater volatility due to stronger incentives for deleveraging and weaker incentives for capital accumulation. To address financial stability concerns, the macroprudential authority in the economy with favorable tax treatment of debt financing should set its CCyB coefficient to be 3 to 5 times more sensitive to deviations of the debt-to-GDP ratio from its steady state, compared to an economy where both debt deductibility and corporate income tax rates are low, providing fewer incentives for debt financing, with total tax deductions as a share of GDP being ten percentage points lower. This has clear policy implications. For future research, it would be interesting to extend the conceptual framework to include multinational firms, which can shift their tax burden to branches in other economies that offer stronger debt-financing incentives. Additionally, incorporating heterogeneous firms with varying degrees of equity and debt financing would pro-

vide valuable insights into proper policy intervention. We leave these aspects for follow-up studies.

3.9 Appendix

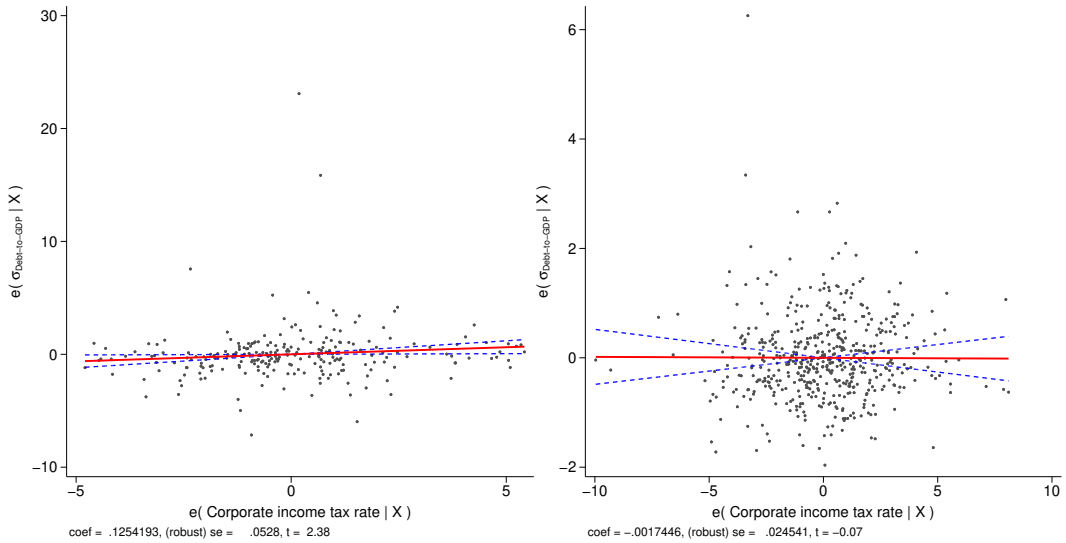
3.9.1 List of countries for empirical background (Section 3.3)

To draw the added-variable plot in Figure 3.1, we used data from the 43 countries that publish their corporate debt-to-GDP ratio in BIS statistics. The list of countries is as follows.

- Argentina, Austria, Australia, Belgium, Brazil, Canada, Switzerland, Chile, China, Colombia, Czech, Germany, Denmark, Spain, Finland, France, United Kingdom, Greece, Hong Kong SAR, Hungary, Indonesia, Ireland, Israel, India, Italy, Japan, South Korea, Luxembourg, Mexico, Malaysia, Netherland, Norway, New Zealand, Poland, Portugal, Russia, Saudi Arabia, Sweden, Singapore, Thailand, Turkey, United States, South Africa

Only non-financial corporate debts are counted. Each country's statutory corporate income tax rates were obtained from the OECD statistical database, and the Macroprudential policy dataset constructed by Alam et al. (2019) was used. The yearly standard deviation of the quarterly debt-to-GDP ratio is computed and used as the dependent variable for Figure 3.1. Information provided by de Mooji and Hebous (2018) was referenced for grouping countries. The results, including outliers, are given in Figure 3.8.

Figure 3.8: Volatility of corporate debt-to-GDP and corporate income tax rates (with outliers)



3.9.2 Derivation of the main equations

1. Household's problem

   (a) Consumption, leisure and saving decisions:

$$\mathcal{L} = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t [\frac{\Xi_t (c_t - \alpha c_{t-1})^{1-\sigma}}{1-\sigma} - \frac{n_t^{1+\phi}}{1+\phi} + \lambda_{H,t}[(1-\tau_H) w_t n_t + (1+r_{t-1}^d) d_{t-1} + x_t + TR_t - c_t - d_t]]$$

$$\Rightarrow \frac{\mathcal{L}}{\partial c_t} = \beta^t \Xi_t (c_t - \alpha c_{t-1})^{-\sigma} - \beta^t \lambda_{Ht} - \beta^{t+1} \alpha \, \mathbb{E}_t \, \Xi_{t+1} (c_{t+1} - \alpha c_t)^{-\sigma} = 0$$

$$\therefore \Xi_t (c_t - \alpha c_{t-1})^{-\sigma} - \beta \alpha \, \mathbb{E}_t \, \Xi_{t+1} (c_{t+1} - \alpha c_t)^{-\sigma} = \lambda_{Ht}$$

$$\Rightarrow \frac{\mathcal{L}}{\partial n_t} = -\beta^t n_t^{\phi} + \beta^t \lambda_{Ht} (1-\tau_H) w_t = 0$$

$$\therefore \Xi_t (c_t - \alpha c_{t-1})^{-\sigma} - \beta \alpha \, \mathbb{E}_t \, \Xi_{t+1} (c_{t+1} - \alpha c_t)^{-\sigma} = \frac{n_t^{\phi}}{(1-\tau_H) w_t}$$

$\Rightarrow \frac{\mathcal{L}}{\partial d_t} = -\beta^t \lambda_{Ht} + \beta^{t+1}\lambda_{Ht+1}(1 - r_t^d) = 0 \therefore \lambda_{Ht} = \beta(1 + r_t^d)\,\mathbb{E}_t\,\lambda_{Ht+1}$

(b) Deposit demand on bank branch j:

$$\mathcal{L} = \int_0^1 r_t^d(j) d_t(j) dj + \psi_{Ht}[d_t - (\int_0^1 d_t(j)^{\frac{\epsilon_d - 1}{\epsilon_d}}\, dj)^{\frac{\epsilon_d}{\epsilon_d - 1}}]$$

$\Rightarrow \frac{\mathcal{L}}{\partial d(j)} = r_t^d(j) + \psi_{Ht}(-[\int_0^1 d_t(j)^{\frac{\epsilon_d - 1}{\epsilon_d}}\, dj]^{\frac{1}{\epsilon_d - 1}} d_t(j)^{\frac{-1}{\epsilon_d}}) = 0$

$\therefore r_t^d(j) = \psi_{Ht}([\int_0^1 d_t(j)^{\frac{\epsilon_d - 1}{\epsilon_d}}\, dj]^{\frac{1}{\epsilon_d - 1}} d_t(j)^{\frac{-1}{\epsilon_d}})$

The condition above should hold for all other bank branches k, accordingly the following condition also holds:

$r_t^d(k) = \psi_{Ht}([\int_0^1 d_t(k)^{\frac{\epsilon_d - 1}{\epsilon_d}}\, dk]^{\frac{1}{\epsilon_d - 1}} d_t(k)^{\frac{-1}{\epsilon_d}})$

$\Rightarrow$ Thus, $r_t^d(j) d_t(j)^{\frac{1}{\epsilon_d}} = r_t^d(k) d_t(k)^{\frac{1}{\epsilon_d}}$

$\Rightarrow$ It can be written as $d_t(j) = d_t(k)(\frac{r_t^d(j)}{r_t^d(k)})^{-\epsilon^d}$

Plugging the equation above into the constraint of the maximization problem (3.7) when the equality condition holds yields the following:

$d_t = (\int_0^1 (d_t(k)(\frac{r_t^d(j)}{r_t^d(k)})^{-\epsilon^d})^{\frac{\epsilon_d - 1}{\epsilon_d}}\, dj)^{\frac{\epsilon^d}{\epsilon^d - 1}}$

$\Rightarrow d_t = d_t(k) r_t^d(k)^{\epsilon_d} (\int_0^1 r_t^d(j)^{1-\epsilon_d} dj)^{\frac{\epsilon_d}{\epsilon_d - 1}}$

$\therefore d_t(k) = d_t r_t^d(k)^{-\epsilon_d} (\int_0^1 r_t^d(j)^{1-\epsilon_d} dj)^{\frac{-\epsilon_d}{\epsilon_d - 1}}$

This condition should hold for bank branch j and

denote $r_t^d = (\int_0^1 r_t^d(j)^{1-\epsilon_d} dj)^{\frac{1}{1-\epsilon_d}}$.

$\therefore d_t(j) = \left[\frac{r_t^d(j)}{r_t^d}\right]^{-\epsilon_d} d_t \qquad where \quad r_t^d = \left[\int_0^1 r_t^d(j)^{1-\epsilon_d}\, dj\right]^{\frac{1}{1-\epsilon_d}}$

2. Firm's problem

(a) Equity payout, labor demand, capital investment and borrowing decisions:

To solve the problem (3.10), differentiation with respect to x, n, k' and b', respectively, gives us the following first-order conditions:

- x: $1 + \mu_c(-2\kappa(x - \overline{x})) = 0$

  $\therefore \mu_{ct} = \frac{1}{1+2\kappa(x_t - \overline{x})}$

- n: $\mu_c(1-\tau_F)((1-\theta)zk^\theta n^{-\theta} - w) - \mu_e(1-\theta)(zk^\theta n^{-\theta}) = 0$

  $\therefore (1-\theta)z_t k_{t-1}^\theta n_t^{-\theta} = \left(\frac{1-\tau_F}{1-\tau_F - \mu_{et}/\mu_{ct}}\right) w_t$

- k': $\mathbb{E}\, m' V_{k'}(k', b') - \mu_c + \mu_e \zeta = 0$

  Denote $y_t = F(z, k, n)$.

  Then, applying the envelope theorem, we get:

  $V_k(k, b) = \mu_c(1 - \delta + (1-\tau_F)F_k) - \mu_e F_k$ which can replace $V_{k'}(k', b')$ by iterating it forwards by one period.

  $\rightarrow \mathbb{E}\, m' \mu_c'(1 - \delta + (1-\tau_F)F_{k'} - \frac{\mu_e'}{\mu_c'} F_{k'}) = \mu_c - \mu_e \zeta$

  $\rightarrow \mathbb{E}\, m' \frac{\mu_c'}{\mu_c}(1 - \delta + [(1-\tau_F) - \frac{\mu_e'}{\mu_c'}]F_{k'}) = 1 - \frac{\mu_e}{\mu_c}\zeta$

  Using the first-order condition of n, we know $\frac{\mu_e'}{\mu_c'} = (1-\tau_F)(1 - \frac{w'}{F_n'})$

  $\therefore \mathbb{E}_t\, m_{t,t+1} \frac{\mu_{ct+1}}{\mu_{ct}} \left(1 - \delta + (1-\tau_F)(\frac{\theta}{1-\theta})(\frac{w_{t+1} n_{t+1}}{k_t})\right) = 1 - \zeta_t \frac{\mu_{et}}{\mu_{ct}}$

- b': $\mathbb{E}\, m' V_{b'}(k', b') + \mu_c + \mu_e(-\zeta) = 0$

  Again, applying the envelope theorem, we get:

  $V_b(k, b) = -\mu_c(1 - \tau_F \kappa_b)(1 + r^b)$

  By iterating it forward by one period,

  $\rightarrow \mathbb{E}\, m'(-\mu_{c'}(1 - \tau_F \kappa_b)(1 + r^{b'})) = -\mu_c + \mu_e \zeta$

  $\therefore -\mathbb{E}_t\, m_{t,t+1} \frac{\mu_{ct+1}}{\mu_{ct}}(1 - \tau_F \kappa_b)(1 + r_t^b) = -1 + \zeta_t \frac{\mu_{et}}{\mu_{ct}}$

(b) Cost minimization in borrowing:

$$\mathcal{L} = \int_0^1 r_t^b(j) b_t(j) dj + \psi_{Ft}(b_t - [\int_0^1 b_t(j)^{\frac{\epsilon_b - 1}{\epsilon_b}} dj)^{\frac{\epsilon_b}{\epsilon_b - 1}}]$$

Then, the same procedures and logic are applied for a symmetric equilibrium.

$\therefore b_t(j) = \left[\frac{r_t^b(j)}{r_t^b}\right]^{-\epsilon_b} b_t \qquad where \quad r_t^b = \left[\int_0^1 r_t^b(j)^{1-\epsilon_b}\, dj\right]^{\frac{1}{1-\epsilon_b}}$

3. Banking sector

   (a) Wholesale branch:

   Plugging (3.22) into the maximization problem (3.23) and taking derivative with respect to B_t yields the following condition:

   $R_t^b - R_t^d + \kappa_{Kb}(\frac{K_t^b}{B_t} - v_t^b)(\frac{K_t^b}{B_t})^2 = 0$

   $\therefore R_t^b = R_t^d - \kappa_{Kb}\left(\frac{K_t^b}{B_t} - v_t^b\right)\left(\frac{K_t^b}{B_t}\right)^2$

   (b) Retail branch:

   Plugging $b_t(j) = \left[\frac{r_t^b(j)}{r_t^b}\right]^{-\epsilon_b} b_t$ and $b_t(j) = B_t(j)$ into the maximization problem (3.25) and taking the derivative with respect to $b_t(j)$ yields the following condition:

   $m_{0,t}[(1-\epsilon_b)b_t(\frac{r_t^b(j)}{r_t})^{-\epsilon_b} + \epsilon_b R_t^b b_t \frac{r_t^b(j)^{-\epsilon_b-1}}{r_t^{-\epsilon_b}} - \psi_b(\frac{r_t^b(j)}{r_{t-1}^b(j)} - 1)b_t\frac{r_t^b}{r_{t-1}^b(j)}]$

   $+ \mathbb{E}_t\, m_{0,t+1}[\psi_b(\frac{r_{t+1}^b(j)}{r_t^b(j)} - 1)r_{t+1}^b r_{t+1}^b(j)\frac{b_{t+1}}{r_t^b(j)^2}] = 0$

   Then, by dividing the above condition by $m_{0,t}$ and b_t and applying the condition for getting a symmetric equilibrium (i.e., $r_t^b(j) = r_t^b$), we will have the following:

   $\rightarrow 1-\epsilon_b+\epsilon_b\frac{R_t^b}{r_t^b} - \psi_b(\frac{r_t^b}{r_{t-1}^b} - 1)\frac{r_t^b}{r_{t-1}^b} + \beta\,\mathbb{E}_t\,\frac{\lambda_{Ht+1}}{\lambda_H t}[\psi_b(\frac{r_{t+1}^b}{r_t^b} - 1)(\frac{r_{t+1}^b}{r_t^b})^2(\frac{b_{t+1}}{b_t})] = 0$

   The same procedure is employed to address the maximization problem presented in (3.27).

3.9.3 Proof of $l_t = y_t$

It is possible to express the budget constraint (3.12) using time notation t:

$(1-\delta)k_{t-1} + (1-\tau_F)(z_t k_{t-1}^\theta n_t^{1-\theta} - w_t n_t) + b_t = (1-\tau_F\kappa_b)(1+r_{t-1}^b)b_{t-1} + x_t + \kappa(x_t - \overline{x})^2 + k_t$

By subtracting $(1-\delta)k_{t-1}$ and b_t from both sides of the equation and using the definition of i_t, where $i_t = k_t - (1-\delta)k_{t-1}$, the following is obtained:

$(1-\tau_F)(z_t k_{t-1}^\theta n_t^{1-\theta} - w_t n_t) = (1-\tau_F\kappa_b)(1+r_{t-1}^b)b_{t-1} - b_t + x_t + \kappa(x_t - \overline{x})^2 + i_t$

Now, it is possible to replace $(1-\tau_F\kappa_b)(1+r^b_{t-1})b_{t-1}-b_t+x_t+\kappa(x_t-\overline{x})^2+i_t$ in Eq. (3.9) using the expression above, yielding the following:
$l_t = w_t n_t + \tau_F(z_t k^{\theta}_{t-1} n_t^{1-\theta} - w_t n_t) + (1-\tau_F)(z_t k^{\theta}_{t-1} n_t^{1-\theta} - w_t n_t)$

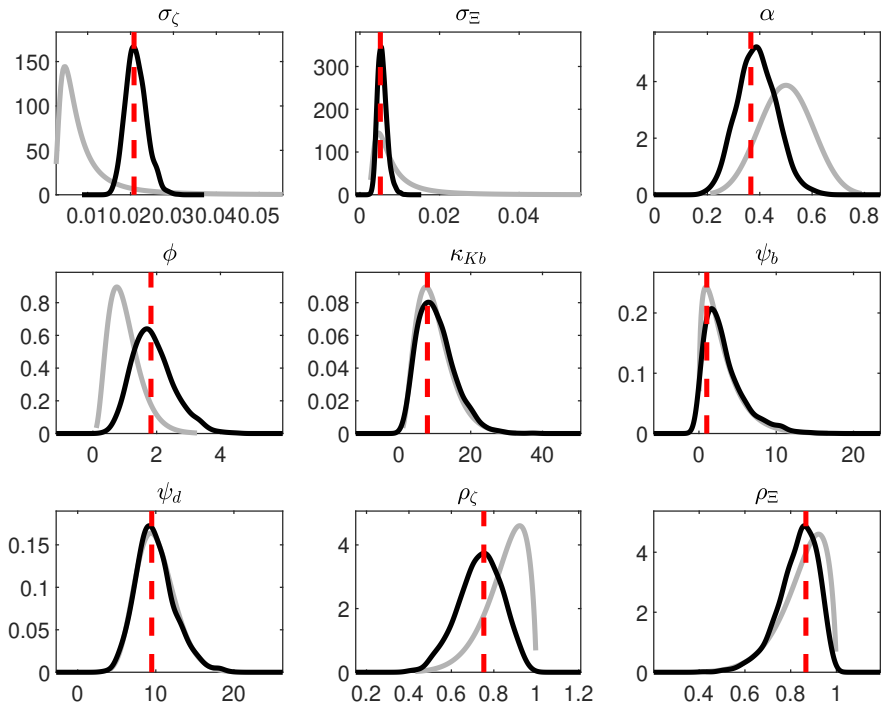
Since $y_t = z_t k^{\theta}_{t-1} n_t^{1-\theta}$, l_t can be expressed as $l_t = w_t n_t + \tau_F(y_t - w_t n_t) + (1-\tau_F)(y_t - w_t n_t)$. Here, the terms $\tau_F(y_t - w_t n_t)$ and $(1-\tau_F)(y_t - w_t n_t)$ combine and cancel each other out because their sum equals $(y_t - w_t n_t)$. Similarly, the $-w_t n_t$ terms also cancel out due to the opposite signs of the corresponding $w_t n_t$ terms. As a result, only y_t remains on the right-hand side.

$\therefore l_t = y_t$.

3.9.4 Estimation of the parameters

To estimate the parameters, two quarterly data series—final consumption expenditures and non-financial corporations' loans—from the Euro area (20 countries) for the period between Q1 2000 and Q4 2019 were employed. The final consumption expenditures of households and NPISH are chain-linked volumes and seasonally adjusted series accessible from Eurostat. The non-financial corporations' loans are provided as non-seasonally adjusted data, and only nominal values are compiled. Thus, the series was divided by an appropriate deflator (Harmonised Index of Consumer Prices) and then seasonally adjusted using X-13ARIMA-SEATS. Additionally, the trends of the two series were removed using the (one-sided) Hodrick-Prescott filter with a smoothing parameter of 1600. Figure 3.9 graphically presents the priors and posteriors of the estimated parameters.

Figure 3.9: Densities of the priors and posteriors of the estimated parameters



Notes: The densities of the priors and posteriors of the estimated parameters are illustrated. The gray solid line depicts the prior density. The black solid line represents the posterior density. The red dotted line indicates the posterior mode.

3.9.5 Steady state of the economy

The 23 equations, including (3.2), (3.3), (3.4), (3.5), (3.11), (3.12), (3.13), (3.14), (3.15), (3.16), (3.22), (3.24), (3.26), (3.28), (3.29), (3.30), (3.31), (3.34), the law of motion of capital ($k_t = i_t + (1-\delta)k_{t-1}$), the production function ($y_t = z_t k_{t-1}^{\theta} n_t^{1-\theta}$), the government's budget constraint (eq. 3.32 = eq. 3.33) and the equilibrium conditions for transactions between the wholesale and retail branches ($B_t = b_t$ and $D_t = d_t$), and 3 exogenous shock processess (3.6, 3.17 and 3.18) can be represented as follows:

$$\mathbb{E}_t \left[f(Y_{t+1}, Y_t, Y_{t-1}, U_t, \Theta) \right] = 0 \tag{3.40}$$

Here, Y represents 23 endogenous variables, U refers to three exogenous shocks, and Θ denotes the parameter of the model. Note that the control variables determined at period t are written as k_t, b_t and d_t. Thus, Y_{t-1} represents the predetermined variables. Then, the steady state of the model economy is characterized by $\overline{Y}$, such that $f(\overline{Y}, \overline{Y}, \overline{Y}, 0, \Theta) = 0$. In other words, solving the simultaneous equations by assuming zero means for the exogenous shocks and setting the endogenous variables with no time variation can derive the steady state. The solution of the simultaneous equations, representing the steady state of the economy, can be given as follows.

$$r^d = \frac{1}{\beta} - 1 \tag{3.41}$$

$$R^d = r^d \frac{(\epsilon_d - 1)}{\epsilon_d} = R^b \tag{3.42}$$

$$r^b = R^b \frac{\epsilon_b}{(\epsilon_b - 1)} \tag{3.43}$$

$$v^b = \frac{(1 - \tau_B)(r^b - r^d)}{\delta^b - (1 - \tau_B) r^d} \tag{3.44}$$

$$w = \left[(1-\theta) z (\frac{1}{N_1})^{\theta} (1 - \frac{1 - \beta(1 - \delta + (1 - \tau_F)\frac{\theta}{1-\theta}) N_1)}{\zeta(1 - \tau_F)}) \right]^{\frac{1}{1-\theta}} \tag{3.45}$$

$$n = \left[\frac{1}{N_5 N_3} \right]^{\frac{\sigma}{\sigma + \phi}} \tag{3.46}$$

$$c = \frac{n^{-\frac{\phi}{\sigma}}}{N_3} \tag{3.47}$$

$$B = N_4 n \tag{3.48}$$

$$K^b = v^b B \tag{3.49}$$

$$A^b = K^b \delta^b \tag{3.50}$$

$$D = B - K^b \tag{3.51}$$

$$b = B \tag{3.52}$$

$$d = D \tag{3.53}$$

$$k = \frac{wn}{N_1} \tag{3.54}$$

$$y = zk^{\theta}n^{1-\theta} \tag{3.55}$$

$$l = \zeta(k - b) \tag{3.56}$$

$$i = \delta k \tag{3.57}$$

$$\mu_c = 1 \tag{3.58}$$

$$\mu_e = (1 - \tau_F)(1 - \frac{w}{(1-\theta)z(\frac{k}{n})^{\theta}}) \tag{3.59}$$

$$\lambda_H = c^{-\sigma}(1-\alpha)^{-\sigma}(1-\beta\alpha) \tag{3.60}$$

$$x = (1 - \tau_F)(y - wn) - \delta k - b(r^b - \tau_F\kappa_b(1 + r^b)) \tag{3.61}$$

$$TR = \tau_H wn + \tau_F(y - wn) + \tau_B(r^b b - r^d d) - \tau_F\kappa_b(1 + r^b) \tag{3.62}$$

Here $N_1 = ((1-\tau_B\kappa_b)(1+r^b)-(1-\delta))(\frac{1-\theta}{\theta})(\frac{1}{1-\tau_F})$, $N_2 = \frac{w}{N1}$, $N_3 = ((1-\tau_H)w\Xi(1-\beta\alpha)(1-\alpha)^{-\sigma})^{\frac{-1}{\sigma}}$, $N_4 = N_2 - (\frac{z}{\zeta})N_2^{\theta}$ and $N_5 = (\zeta - \delta)N_2 - (\delta^b v^b + \zeta)N_4$.

Using the above equations, we can also derive the following equations:

$$\frac{c}{c+i} = \frac{1}{\frac{\delta w}{N_1 N_5} + 1} \tag{3.63}$$

$$\frac{B}{y} = \frac{N_4}{z\left(\frac{w}{N_1}\right)^{\theta}} \tag{3.64}$$

This shows that $\frac{c}{c+i}$ and $\frac{B}{y}$ are not functions of any estimated parameters in the steady state.

Chapter 4

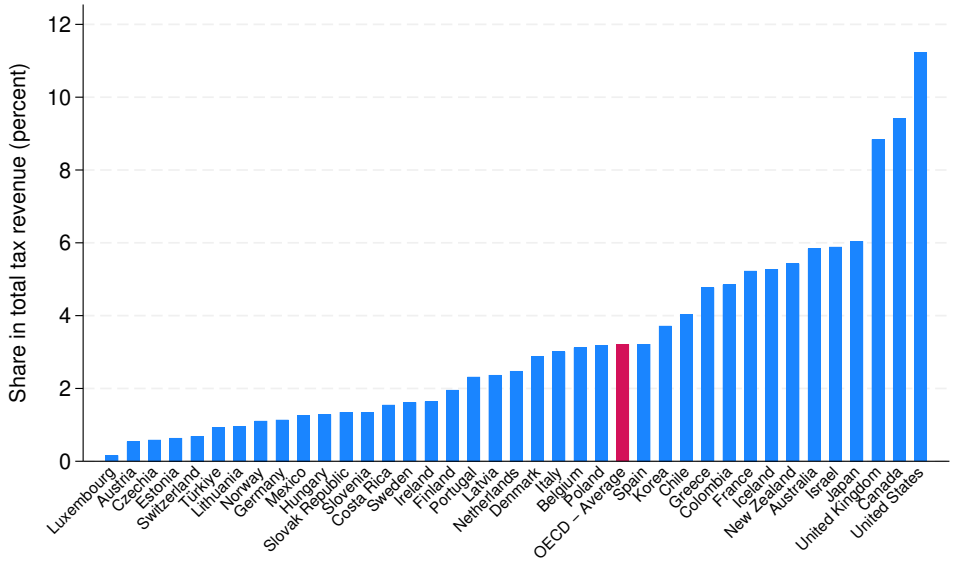
Liquidity Constraints and the Consumption Effects of Recurrent Property Taxes

Abstract We explore how recurrent property taxes, levied regularly on immovable property, affect homeowners' consumption behavior. Using household panel survey data from South Korea, we first identify unexpected exogenous changes to these taxes. This is achieved by exploiting a rare feature of the South Korean recurrent tax system, where the governments annually reassess residential properties to update the recurrent tax base, but their assessment methods are unknown to homeowners, meaning that each year's recurrent tax liability inevitably contains an unexpected component for homeowners. We then show that while an unexpected increase in recurrent taxes generally has an insignificant consumption effect, it reduces liquidity-constrained homeowners' spending, particularly through a reduction in their durable goods expenditures. These findings support the use of recurrent taxes as a revenue-raising tool, provided measures are taken to alleviate the unequal consumption effects on liquidity-constrained homeowners.

4.1 Introduction

In advanced economies, recurrent property taxes levied regularly on immobile property generally account for a relatively small share of total tax revenues at the general government level. For example, in OECD countries, recurrent taxes accounted for, on average, 3.21% of total tax revenue at the general government level in 2020. However, such an average figure hides substantial heterogeneity across countries. Figure 4.1 illustrates that recurrent taxes tend to be underutilized in the total tax revenue composition in a number of OECD countries. On the one hand, in countries such as the United States, Canada, and the United Kingdom, the share of recurrent taxes in the total tax revenue is about 10 percent, but in other countries like Luxembourg, Austria and Czech Republic, it is well below 1 percent.

Figure 4.1: Share of recurrent property taxes in tax revenue at the general government level



Notes: Shares of recurrent taxes on immovable property in total taxes at the general government levels in 2020 (in percent). Source: OECD's Global Revenue Statistics Database.

Meanwhile, recurrent taxes, more generally property taxes, have drawn special attention in the literature on tax composition and economic outcomes.[1] This is pri-

[1]In OECD countries, recurrent taxes, on average, represent a major share (62%) of total property tax revenues in 2020, followed by taxes on financial and capital transactions that include transactions on housing (OECD, 2022).

marily because recurrent taxes, in particular, are viewed as one of the least distortionary taxes, having a small impact on decisions to supply labor and to invest and innovate relative to other taxes such as income taxes (Johansson et al., 2008; Norregaard, 2013). Consistent with this view, Arnold et al. (2011) find empirically that in OECD countries, recurrent taxes are the least damaging taxes for long-run GDP, followed by consumption taxes.[2] Bielecki and Stähler (2022) show theoretically that a budget-neutral increase of recurrent taxes offset by lower labor income taxes has positive long-run effects on GDP and consumption, and the positive effects are even larger than a consumption tax increase offset by a labor tax reduction. Accordingly, it is often recommended that recurrent taxes should be utilized more in the tax composition (European Commission, 2013; OECD, 2015; IMF, 2019). In light of these recommendations, Paetzold and Tiefenbacher (2018) examine the distributional effects of a revenue-neutral tax shift to recurrent taxes from social insurance contributions (SIC) for Germany where the former taxes are underused (e.g., 9th from the bottom in Figure 4.1). They show that such a tax shift would have a very marginal effect on an income inequality measure such as the Gini or Atkinson index, although the exact effects depend on how SIC is reduced to offset an increase in recurrent taxes.[3]

To better understand the merits and demerits of utilizing recurrent taxes in the tax mix, this paper investigates the effects of recurrent taxes on household consumption. Specifically, we examine empirically (1) how recurrent taxes generally affect household spending on durable and non-durable goods, and (2) how the effects may differ depending on their liquidity constraints. These questions can be motivated

[2]McNabb (2018) and Acosta-Ormaechea et al. (2019), albeit not focusing on recurrent taxes per se, also offer support for property taxes as one of the least distortionary taxes for economic growth in high-income countries. Further, Akgun et al. (2017) echo Arnold et al. (2011) in that a change in the tax mix towards higher reliance on recurrent taxes is associated with larger long-term output. However, Baiardi et al. (2019) cast doubt on the robustness of the results of Arnold et al. (2011), indicating that the long-run output effect of recurrent taxes is still debatable empirically.

[3]An impact on economic outcomes aside, recurrent taxes are known for their revenue stability. This is due to the fact that the tax base is highly immobile, so the revenue tends to be predictable. Besides, the visibility of the property, along with the immobility, implies that the taxes are difficult to evade (Johansson et al., 2008; Norregaard, 2013).

as follows. First, although several prior works show that recurrent taxes tend to have a benign impact on output, examining their effects on consumption is crucial as it is generally a key factor that directly determines the utility of households. The decomposition of spending into the one on durable and non-durable goods is relevant because they affect household utility differently: higher consumption of non-durables increases utility immediately, whereas households benefit from service flows of durable goods not only today but also into the future.[4] Second, even if the taxes generally have an insignificant impact on consumption, they may have unequal effects across households to unintentionally create winners and losers. Here, liquidity constraints are a natural household characteristic to consider, based on the vast literature on consumption response to income changes that highlight the role of liquidity constraints (Zeldes, 1989; Parker et al., 2013; Jappelli and Pistaferri, 2014; Agarwal and Qian, 2014; Baker, 2018; Kreiner et al., 2019; Ganong and Noel, 2020).

To estimate recurrent tax effects on household consumption, a key empirical challenge is to identify *unexpected* variations in the taxes, which enable us to avoid biases in estimation that stem from the fact that people often change their present behavior in anticipation of future tax changes. We overcome this challenge by exploiting a rare feature of South Korean recurrent tax systems: unlike most of the OECD countries, the South Korean government annually updates the recurrent tax base by reassessing values of residential properties throughout the country, whereas their assessment methods are unknown to homeowners.[5,6] This feature *inevitably* creates

[4]It is acknowledged that housing consumption per se differs from non-housing goods, and accounting for such spending would yield different theoretical predictions regarding consumption effects. However, we focus exclusively on non-housing consumption, consisting of durable and non-durable goods, as our empirical analysis centers on the effects of *recurrent* property taxes rather than transaction taxes. As discussed later, the *recurrent* nature of these taxes is crucial for identifying unanticipated tax shocks, requiring us to focus on homeowners who have not relocated (i.e., those whose housing consumption has remained unchanged) during the sample period to accurately track those paying recurrent taxes on the same property.

[5]In only 4 countries among the OECD countries (South Korea, Hungary, Mexico, and Netherlands), governments evaluate properties annually to re-calculate recurrent tax bases (OECD, 2021).

[6]To be precise, a reform in South Korea in November 2020 made the assessment system more transparent relative to prior years. Acknowledging this, our analysis focuses on the years prior to

an unexpected component in the government's assessed value of the property, i.e., the tax base, each year from the homeowner's perspective. Then, assuming that households form an expectation of the assessed value by using the current market value of the property, we decompose the assessed value into the expected and unexpected components after controlling for various property- and region-specific characteristics. We do this by using household panel data from the "National Survey of Tax and Benefits (NaSTaB)" (conducted by the Korean Institute of Public Finance) that tracks both the government valuation and the market value of the property for individual homeowners during the 2014-19 period. With recurrent tax rates being known to the public, once an unexpected part of the tax base has been identified, we are able to calculate the unexpected part of recurrent tax payments. This, in turn, is used to estimate the consumption effects of recurrent taxes, highlighting the importance of liquidity constraints. Utilizing rich balance sheet information from the NaSTaB on the same households, we measure liquidity constraints by the liquid asset balance ratio, defined as the total value of liquid assets minus the total value of short-term debt liabilities, divided by disposable income.

Our main findings are as follows. An unexpected change in recurrent taxes generally has an insignificant effect on household spending on consumption goods. This is in line with the view that recurrent taxes are less distortionary than other taxes, such as labor income taxes, that have a direct impact on household labor-leisure decisions. However, this result masks important heterogeneity in the consumption effects. Specifically, while an unexpected increase in recurrent taxes has an insignificant impact on spending by liquidity-unconstrained households, it significantly reduces spending by constrained households. Further, we show that liquidity-constrained households reduce spending on durable goods more than on non-durable goods, such that they effectively re-balance consumption toward non-durable goods. A simple model of household consumption behavior (based on Chah et al., 1995 and Cerletti

the reform.

and Pijoan-Mas, 2012) indicates that when liquidity-constrained households are unable to smooth consumption in the face of higher recurrent taxes, they minimize utility loss by reducing today's expenditure on durable goods disproportionately, as these items bring most of the utility gain in the future. The importance of household liquidity as a source of heterogeneous consumption effects is robust even after taking into account the housing tenure status, namely the distinction between mortgagors and outright owners. Overall, while the results offer (further) support for utilizing recurrent taxes as a means to raise revenue, it is important to realize that the taxes have unequal effects depending on their liquidity constraints. This is where a measure such as tax deferrals for constrained homeowners can potentially be justifiable, allowing them to delay some of their tax payments to future periods when they have a greater ability to pay.

This paper is closely related to the literature on consumption response to income changes that highlights the relevance of household balance sheets. Several studies argue the importance of household liquidity conditions or indebtedness. For instance, Agarwal and Qian (2014) measure the consumption effect of a sudden fiscal stimulus announcement using Singaporean individual-level data. They find the policy effects are more significant, particularly for individuals with low checking account balances. Consistently, Jappelli and Pistaferri (2014) show that the effectiveness of fiscal stimulus is critically determined by households' liquidity. Meanwhile, Ogawa and Wan (2007) investigate the impact of household debt on consumption during and after the financial bubble in Japan (the late 1980s to 1990s), whereas Dynan (2012) examines the relevance of household leverage to consumption patterns around the time of the Global Financial Crisis in the US (between 2007 and 2009). They both show that household indebtedness results in limited consumption growth. Relatedly, Baker (2018) show that households' consumption response is more sensitive to the income shock when households have higher debt. However, they highlight that what matters to household consumption is not household balance sheet per se,

but rather the diminished liquidity that follows these excessively high debt levels. Similarly, Ganong and Noel (2020) find that providing households with liquidity as a remedial measure under adverse macroeconomic circumstances has a greater impact on household consumption than reducing debt principal as an alternative.

This paper is also related to works that examine tax effects on consumer spending using microdata. For instance, Cashin and Unayama (2021) discuss the impact of the anticipated VAT tax shock in Japan on the different categories of consumer goods, namely non-storable, storable, and durable goods. Cloyne and Surico (2017) examine the consumption effects of income taxes in the UK, showing that the taxes have a stronger impact on the consumption of households with mortgage debt relative to outright homeowners. More closely related to the present paper, Surico and Trezzi (2019) investigate the consumption effects of property taxes in Italy. They show that recurrent property taxes on the main dwelling can cause a substantial decline in household consumption expenditure, and this effect is greater for mortgagors than outright owners. While our results complement theirs, we focus explicitly on household liquid asset balance (as the ratio of liquid asset minus short-term debt to disposable income), rather than housing tenure status, as an indicator of household liquidity. Further, methodologically we identify an unexpected exogenous change to recurrent property tax payments (to avoid biases from an anticipation effect of the taxes), by exploiting the aforementioned unique feature of Korean tax system.[7]

The rest of the paper is organized as follows. Section 4.2 builds testable hypotheses related to the consumption effect of the recurrent taxes. Section 4.3 provides the institutional background of the Korean recurrent tax system. Section 4.4 elaborates an identification strategy. Section 4.5 describes the data, and Section 4.6 presents and discusses main results. Last, Section 4.7 concludes.

[7]Their estimation utilizes an unexpected reform of the Italian recurrent property tax system in 2011. Specifically, they identify the consumption effects of recurrent property taxes by comparing the difference in consumption spending for property taxpayers before and after the 2011 reform to the difference in spending for non-property taxpayers over the 2010-12 period.

4.2 Hypotheses development

This section presents hypotheses on the consumption effects of recurrent taxes conditional on household liquidity constraints. Because recurrent taxes are paid by homeowners, and not by renters, a household and a homeowner mean the same thing for the purpose of this paper (unless clarified otherwise). The hypotheses are derived from a simple theoretical model. In the model, households optimally choose a dynamic path of expenditures on durable and non-durable goods subject to a borrowing (liquidity) constraint that can prohibit them from smoothing consumption in the face of adverse shocks to recurrent taxes. The model is a simplified version of Chah et al. (1995) and Cerletti and Pijoan-Mas (2012), although we endogenize the household's labor supply decision unlike them. For brevity, we here focus on the intuition behind hypotheses about the consumption behavior of liquidity-unconstrained and constrained households. A formal derivation of those hypotheses with model solutions is found in Appendix 4.8.1.

First, when households are not liquidity constrained, the model yields the following hypothesis.

> **Hypothesis 1.** *When households are not liquidity constrained, an unexpected transient increase in recurrent taxes has a negligible effect on their consumption spending.*

Intuition for this hypothesis is primarily twofold. First, consistent with the aforementioned view that recurrent taxes are one of the least distortionary taxes, they do not affect the household's labor-leisure decisions. Specifically, an increase in recurrent taxes, unlike an increase in income taxes, do not discourage households from working in exchange for more leisure. Instead, a fall in disposable income from the tax increase encourages households to work more, mitigating the loss of income and thus consumption. Second, when liquidity constraints do not bind, households that

are hit by a transient adverse shock can smooth consumption via borrowing, such that the effects of the shock on consumption become even smaller. Overall, the total consumption effects remain rather negligible. With such insignificant overall effects, unconstrained households do not need to change, i.e., re-balance, the composition of spending between non-durable and durable goods.

Next, turning to liquidity-constrained households, our hypothesis about the consumption effects of recurrent taxes is the following.

> **Hypothesis 2.** *When households are liquidity constrained, an unexpected transient increase in taxes reduces their consumption, primarily via a fall in spending on durable goods.*

When the adverse recurrent taxes reduce the disposable income of constrained households, the fall in purchasing power still encourages them to increase hours of work, somewhat mitigating the loss of income. However, when the liquidity constraint binds, they have no liquid assets to use to smooth consumption. In this situation, households minimize the utility loss by reducing expenditure on durable rather than non-durable goods because they benefit from the durable spending primarily in the future with enhanced service flows from the increased stock that lasts over time, whereas expenditure on non-durable goods increases utility immediately. This re-balancing effect implies that there is a fall in total consumption spending, driven mainly by a fall in durable spending.

Those two hypotheses motivate the subsequent empirical analysis to focus on the role of liquidity constraints in the consumption effects of unexpected changes in recurrent taxes. The theory also highlights the relevance of disaggregating household spending into the ones on non-durables and durables. To note, similar hypotheses (and intuition) can be developed in the case of an unexpected *decrease* in recurrent taxes. Specifically, in that case liquidity-constrained households are predicted to increase durable spending rather than non-durable spending, such that their to-

tal spending increases primarily due to the former. Meanwhile, the tax decrease has a rather negligible effect on non-constrained households' consumption, without inducing the re-balancing effect.[8]

4.3 Background

We start an empirical investigation into the consumption effects of recurrent taxes by explaining key features of the South Korean recurrent tax system. We exploit these features to identify unexpected exogenous changes (i.e., shocks) to recurrent taxes. These shocks are subsequently used to estimate a causal effect of recurrent taxes on household consumption.

4.3.1 South Korean Recurrent Tax System

In South Korea, the government re-assesses the value of residential properties under its jurisdiction every year. This means a complete annual update of recurrent tax base throughout the country.[9] Among OECD countries, governments of only 3 other countries (Hungary, Netherlands, and Mexico) conduct re-assessment of the property as frequently as Korea. To elaborate, Australia, Japan, New Zealand, and Portugal conduct assessments every 3 years, and Chile, Lithuania, and Norway even less frequently (every 4, 5, 10 years, respectively), whereas several countries (such as Germany, UK, Estonia, France, Belgium, and Luxembourg) have not conducted

[8] One caveat in the case of an unexpected decrease in recurrent taxes is that to the extent that such a shock is 'large,' the borrowing (liquidity) constraint may not bind anymore. Therefore, the results in this case are applicable primarily for relatively small shocks.

[9] As of 2020, the government samples about 5.3% of detached houses and uses assessed values of the sampled houses as a reference to evaluate out-of-sample detached houses. Meanwhile, it conducts a complete reassessment of 13.83 million apartment houses (or multi-unit dwellings) within the country. The evaluation process is simplified by the fact that apartments in a 'complex' (16,770 complexes in total) tend to be similar in terms of their structures and features and share the same living environment. In practice, the appraisal is done with the help of certified appraisers from 'Korea Real Estate Board'.

Table 4.1: Recurrent tax base (assessed value), rate, and liability

(a) Tax base, rates and liabilities	
Tax base (TB, in 1,000 KRW)	Tax liability (in 1,000 KRW)
$TB \leq 100,000$	$(0.6 * TB) * 0.0014 + (0.6 * TB) * 0.001$
$100,000 < TB \leq 250,000$	$60 + (0.6 * TB) * 0.0014 + (0.6 * TB - 60,000) * 0.0015$
$250,000 < TB \leq 500,000$	$195 + (0.6 * TB) * 0.0014 + (0.6 * TB - 150,000) * 0.0025$
$500,000 < TB$	$570 + (0.6 * TB) * 0.0014 + (0.6 * TB - 300,000) * 0.0040$
(b) Tax base and tax limits	
Tax base (TB, in 1,000 KRW)	Tax limit
$TB \leq 300,000$	1.05 * Recurrent taxes paid $(t-1)$
$300,000 < TB \leq 600,000$	1.10 * Recurrent taxes paid $(t-1)$
$600,000 < TB$	1.30 * Recurrent taxes paid $(t-1)$

Notes: 1,000 KRW approximately equals 0.76 US dollars. The tax rates and tax limits were set in 2009, and maintained till 2020. They were public information throughout.

property re-evaluations for several years or even decades (OECD, 2021). Several other countries index the assessment values to other price indicators.

Once the government's "assessed value" (i.e., tax base) has been finalized, a relevant tax rate is applied, and the recurrent tax liability is determined. Panel (a) of Table 4.1 provides exact rules on how different assessed values are translated into the tax liabilities with respective tax rates. There are three thresholds above which different tax rates are applied: 100,000, 250,000, and 500,000 thousand South Korean Won (KRW), corresponding to about 76,000, 190,000, 380,000 US dollars.[10] At the threshold values of 100,000 (250,000, 500,000) thousands, the annual recurrent tax payments are 144 (405, 990) thousand KRW, i.e., 109 (308, 752) US dollars. Additionally, to avoid a large increase in tax burden across years, tax limits are applied relative to the previous year's liability. Specifically, the growth rate of tax liability shall not exceed 5% to 30%, with the cap becoming less tight as the tax base rises (Panel (b) of Table 4.1). The actual tax paid by a homeowner is the tax liability as calculated in Panel (a) or the limit as in Panel (b), whichever is lower.

The institutional element that we exploit for the identification of recurrent tax shocks is that the government's appraisal method is *not* known to homeowners. To explain, while the government's assessed value, as in the market value, is supposed

[10]The exchange rate used is: 1 KRW equals 0.00076 US dollars.

to depend on factors such as property features (e.g., size, type, and age) and proximity to key facilities (e.g., schools, amenities, and stations), it is not known how the government uses such information to evaluate the property. Besides, the fact that different government entities assess properties of different types and locations suggests the co-existence of varying appraisal methods within the government.[11] The government's assessment system is thus a black box from homeowners' perspectives.[12] To clarify, since the tax rates and limits have been published in advance (Table 4.1), the only source of uncertainty for homeowners is the assessed value, i.e., tax base.

4.3.2 Timeline of the government's assessment process

Figure 4.2 presents the exact timeline of the government's assessment process for years $t-1$ and t. To impose recurrent taxes in year t, the government starts its assessment process in year $t-1$. Specifically, after creating a plan for the evaluation process in July of year $t-1$, they conduct an appraisal of residential property values between August of the year and mid-January of year t. The government then determines the assessed value internally, and notifies the homeowner of it at the end of April of year t. Although the assessment system allows homeowners to make a formal objection between April and June, it is extremely unlikely that the initially announced value is overturned due to the objection.[13] The key indication is thus that because the tax liability automatically follows the assessed value (Tables 4.1), the final tax liability imposed in July of year t is effectively finalized in April, based primarily on the information the government gathered in year $t-1$ to assess the

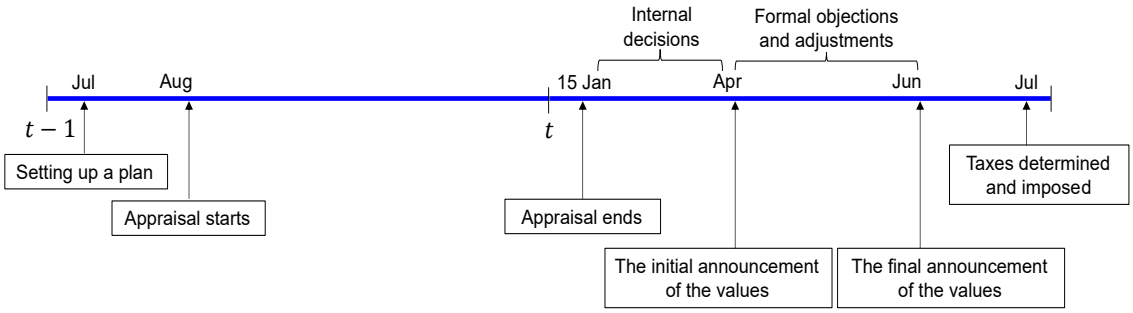
[11]The Ministry of Land, Infrastructure, and Transport leads the appraisal of apartments, whereas each one of 226 local governments (under 17 metropolitan governments including Seoul Special City and six metropolitan cities) evaluates other types of houses under the jurisdiction.

[12]Even when homeowners have some ideas on the formula used by the government, homeowners may not have easy access to certain information the government may use for assessment, making their expectation deviate even more from the eventual assessed value.

[13]Only 0.0093% of the initially-announced assessed values were changed between 2014 and 2020 due to the objection procedure, according to the government's annual reports on assessed values.

property value.

Figure 4.2: Timeline: Determination of recurrent taxes in South Korea



Notes: Timeline is applicable till 2020 (inclusive).

Homeowners know that the government's assessed values in year t will be based on information available in year $t-1$. They are thus likely to form expectations of the year t assessed value (and thus recurrent tax liability) using information available in year $t-1$, including the market value of the property that reflects the key features such as the type, location, and proximity to facilities. However, because, as explained, homeowners do not know the government's assessment method (i.e., how they use the year $t-1$ information), the homeowner's expected assessed value for the year t inevitably contains an *unexpected* element. Our identification of recurrent tax shocks exploits this very feature of the Korean recurrent tax system that every year the government's assessment system creates an unexpected, exogenous component in the recurrent tax liability paid by invidividual homeowners within the country.[14]

[14]To note, a major reform on the recurrent tax system in 2021 reset the way the government updates the assessed value. Specifically, in November 2020, the government announced that from 2021, it would increase the ratio of the assessed value to the market value by around 3 percentage points from the previous year's ratio. The key indication is that after the reform, it became possible for homeowners to accurately predict the coming assessment value and thus recurrent tax payments. This is why our analysis in this paper covers only until 2020.

4.4 Empirical Framework

Our empirical method follows a two-step approach. In the first step, we extract an unexpected component of recurrent taxes following the aforementioned principle, and in the second, we estimate the effects of the unexpected component, a recurrent tax shock, on household consumption conditional on liquidity constraints.[15]

4.4.1 First step: Identifying recurrent tax shocks

Before starting to describe the first-step procedure, it is worth highlighting that a key advantage of using household, as opposed to aggregate, data to assess the effects of taxes on consumption is that there is unlikely to be a two-way contemporaneous interdependence between them. That is, while taxes are likely to affect the household's consumption, it is unlikely that the tax policy is conducted in response to a contemporaneous change in consumption at the household level. In contrast, when considering tax effects on aggregate consumption, it is more likely that such two-way interdependence exists, thereby creating a reverse causality problem.[16]

However, even when the use of microdata mitigates the reverse causality concern, one important threat to identification is the role of expectations. Works such as Ramey (2011), Corsetti et al. (2012), and Miyamoto et al. (2018) emphasize the importance of taking account of expectations for estimating the effects of fiscal pol-

[15]A similar two-step approach whereby the first stage is used to extract an unexpected component of the key regressor is used by several prior papers. To our knowledge, Barro (1978) provides an early attempt in the context of the real effects of monetary policy shocks. Regarding fiscal policy effects, Corsetti et al. (2012) and Miyamoto et al. (2018) follow a similar approach, except that they use aggregate (not household-level) data.

[16]Typically, works on fiscal policies using aggregate data aim to address such reverse causality issues by using quarterly data. The key assumption, used after the lead of Blanchard and Perotti (2002), is that because of certain decision and implementation lags entailed in fiscal policies, it is unlikely that policymakers are able to respond to macroeconomic developments within a quarter. However, high-quality quarterly data on tax variables (that are free from interpolation), let alone decomposed taxes such as recurrent taxes, are often not available outside advanced economies, making it inherently difficult to use this strategy to address the endogeneity problem.

icy shocks. The rationale is that because forward-looking households may respond to part of future fiscal policy changes that have been anticipated, the estimated effect without removing the expected component can be biased. Acknowledging this, the objective of the first stage analysis is to isolate the unexpected component of recurrent taxes by exploiting the aforementioned feature of the South Korean recurrent tax system.

As explained, because it is not known how the South Korean government determines the year t assessed property values using the year $t-1$ information, there is inevitably an unexpected component for homeowners in the assessed value (tax base) and thus recurrent tax liability. To proceed, we assume that a homeowner forms an expectation about how much their property's assessed value in year t may deviate from the market value in year $t-1$. The rationale is that the market value itself reflects the key features of the property (such as proximity to facilities) in year $t-1$ that the government uses to determine the assessed value in year t. Having made this assumption, we first separate the ratio of assessed value in year t to the market value in year $t-1$, called the *assessment ratio*, into two components: expected and unexpected. The unexpected component thus reflects part of the deviation of the assessed value from the market value that is not systematic.

Specifically, we consider the following regression equation:

$$AR_{i,j,t} = \alpha_0 + \alpha_1 MV_{i,j,t-1} + \sum_{k=1}^{n} \delta_k Z_{i,j,k,t-1} + \eta_{j,t} + \theta_i + \nu_i t + \epsilon_{i,j,t}. \tag{4.1}$$

$AR_{i,j,t}$ ($\equiv AV_{i,j,t}/MV_{i,j,t-1}$) is the assessment ratio, where $AV_{i,j,t}$ is the government's assessed value of the property household i in region j resides in year t, and $MV_{i,j,t-1}$ is the property's market value in year $t-1$. The related literature suggests that this ratio is often negatively associated with the market value, making recurrent taxes regressive in that lower-valued houses are assessed at a greater proportion of their market value (e.g., McMillen and Weber, 2008). This observation motivates

us to control for $MV_{i,j,t-1}$, along with time-varying characteristics of the property, $Z_{i,j,k,t-1}$, such as the size (due to possible renovation of the property, particularly in the case of detached houses) and the household's satisfaction with residential conditions which may be relevant to the government's property assessment. Region-year fixed effects, $\eta_{j,t}$ are intended to reflect the possibility that different local governments who conduct an assessment of residential properties under the jurisdiction (see footnote 11 for details) may adopt different assessment strategies, and the strategies may vary year by year.[17] Household fixed effects, θ_i, reflect unobserved time-invariant characteristics of the property, such as their location and types (e.g., apartment or detached houses).[18] We further consider the household-specific time trends, $\nu_i t$, to control for the trend in the assessment ratio that is independent of the other property-specific characteristics. Last, $\epsilon_{i,j,t}$ reflects the unexpected part of the assessment ratio, i.e., the part that is not accounted for by the aforementioned factors.

Eq.4.1 enables us to decompose the assessment ratio into the fitted value of $\hat{AR}_{i,j,t}$ and the estimated residual of $\hat{\epsilon}_{i,j,t}$ as the expected and unexpected element. We then take the following steps to identify the unexpected component of recurrent taxes as a recurrent tax shock:

1. Obtain the expected assessed value (i.e., tax base) of property i in year t as $\hat{AR}_{i,j,t} * MV_{i,j,t-1}$.

2. Calculate the expected recurrent tax payment from the expected assessed value using Table 4.1, which is publicly available ex-ante.

3. Identify the recurrent tax shock as a difference between the actual and ex-

[17] As noted, there are 226 local governments in Korea, each of which is responsible for the assessment of residential properties (other than apartments). Since our region j corresponds to 16 metropolitan governments (Jeju-island, the 17th and final metropolitan government, is not covered) to which local governments are subordinate, the region-year fixed effects only partly reflect a possible heterogeneity in the assessment methods across the local governments.

[18] As noted below, we only consider households who did not move houses over the sample period.

pected payments.[19]

Overall, provided that Eq.4.1 delivers an accurate estimate of a systematic, expected deviation of the assessed value from the market value, the derived recurrent tax shock represents unexpected taxes that are purged of the household's expectations.

4.4.2 Second step: Consumption effects of recurrent taxes

The second step examines the impact of recurrent tax shocks on household spending on durable, and non-durable goods conditional on the household's liquidity constraints. The baseline regression equation is:

$$Y_{i,j,t} = \gamma_0 + \gamma_1 Tax\_shock_{i,j,t} + \sum_{k=1}^{n} \eta_k D_{i,j,k,t} + \rho_{j,t} + \zeta_i + u_{ijt}, \tag{4.2}$$

where $Y_{i,j,t}$ represents a dependent variable that is either spending on durable or non-durable goods of household i in region j in year t. Additionally, we consider the total spending (sum of durable and non-durable spending) as well as the ratio of durable to non-durable spending. The latter is to highlight the possible spending re-balancing effect. $Tax\_shock_{i,j,t}$ is the unexpected component of recurrent tax payment, as obtained from the first-step analysis. $D_{i,j,k,t}$ are time-varying control variables that represent households' economic or demographic features. These features include the expected component of recurrent taxes, annual disposable income, total value of the residential properties, the number of household members,

[19]To illustrate, suppose that the actual assessment ratio of a property in year t (i.e., "assessed value in year t"/"market value in year $t-1$") is 68%, with the assessed value in year t (market value in year $t-1$) being equal to 306,000 (450,000) in thousand KRW. Suppose further that the assessment ratio is decomposed into the expected part of 65% and unexpected part of 3%. Then, the expected assessed value of the property is 292,500 (=0.65*450,000), and the unexpected assessed value is 13,500. Next, following Panel (a) of Table 4.1, the expected payment is 504.45, whereas if we assume that recurrent tax payment in year $t-1$ was 500, the expected tax limit in year t is 525 (=1.05*500, see Panel (b)), meaning that the expected payment remains 504.45. Last, since the actual assessed value is 306,000, the actual payment in year t is 536.04, which is lower than the limit of 550 (=1.1*500). All in all, the unexpected recurrent tax payment is 31.59 (=536.04-504.45).

the number of household members under 18, and the number of household members above 65.[20] We further have region-year fixed effects, $\rho_{j,t}$, and household fixed effects, ζ_i, to control for the effects of any time-varying region-specific policies and unobserved time-invariant household characteristics, respectively.

To examine the role of liquidity constraints in the consumption effects of recurrent taxes, we categorize homeowners into constrained and unconstrained ones. The degree to which households are liquidity constrained is measured by "liquid asset balance ratio", calculated as the total value of liquid assets minus the total value of short-term debt liabilities, divided by their disposable income (elaborated in Section 4.5). To categorize households (homeowners), we average the liquidity asset balance (LAB) ratio for individual homeowners during the sample years, and regard ones with the average ratios below the 33rd (above the 67th) percentile as liquidity constrained (unconstrained) homeowners. We then estimate Eq.4.2 for liquidity constrained and unconstrained homeowners separately. We also consider an alternative threshold of the median of the LAB ratio, whereby homeowners with the average ratios during the sample period below (above) the median are regarded as liquidity constrained (unconstrained) ones.

We also estimate the following interaction model to check the robustness of the results:

$$Y_{i,j,t} = \gamma_0 + \gamma_1 Tax\_shock_{i,j,t} + \gamma_2 Tax\_shock_{i,j,t} * Liquidity_{i,t-1} + \gamma_3 Liquidity_{i,t-1} + \sum_{k=1}^{n} \eta_k D_{i,j,k,t} + \rho_{j,t} + \zeta_i + u_{ijt}, \tag{4.3}$$

where $Liquidity_{i,t-1}$ is liquidity constraint measured by the LAB ratio. We use the year $t-1$ value to ensure that it is a predetermined, not endogenous, variable. In this case, the coefficient on the interaction term, γ_2, gives an indication on the relevance

[20] When the dependent variable is the ratio of durable to non-durable spending, we replace the disposable income with the total consumption to disposable income ratio.

of liquidity constraint to the consumption effects of recurrent taxes. However, this model inherently yields rather extreme (thus implausible) consumption effects for households with very small (or large) LAB ratios, i.e., households with very large short-term debt relative to liquid assets (with large liquid assets relative to short-term debt). For this reason, our preferred approach is the sub-sample one explained above.

4.5 Data

Our primary data source is household-level data from the National Survey of Tax and Benefits (NaSTaB), conducted by the government-led research institute of the Korean Institute of Public Finance (KIPF). This is an annual survey that provides repeated observations at the household level, covering around 5,000 households each year. The survey, started in 2008 and has been ongoing without interruptions, provides a wide range of information, including households' consumption, income, tax payments, housing status (e.g., outright owners, mortgagors, vs renters), features of housing including the type (e.g., apartment vs detached house), and wealth. Appendix 4.8.2 explains details on the sampling method employed for NaSTaB.

The analysis below only uses a subset of the observations for various reasons. First, since we examine the consumption effects of recurrent taxes, our focus, among about 5,000 households surveyed in each year, is on those who reside in their own houses (homeowners), excluding those who live in rented houses (renters). Second, as explained above (Eq.4.1), analysis requires information to calculate the assessment ratio, namely both the government's assessed value and the market value of the property. Because the assessed value was not surveyed in 2013 and before, the analysis focuses on 6 waves between 2014 and 2019 (inclusive).[21] Third, we exclude

[21] Although data on 2020 are available, we only use the data for robustness checks in light of the effects of the COVID-19 pandemic.

outliers of the assessment ratio that are further more than three standard deviations from the mean.[22] Last, we only consider households that did not move houses over the sample period to keep track of households who paid recurrent taxes on the same property. The procedure, while acknowledging missing values (and dropping obvious misreporting, including 'negative' assessment ratios), leaves us with a sample of 6,739 observations in total for six years of an unbalanced panel for the first-step analysis.

The second-step analysis explores the effects of recurrent tax shocks on households' consumption by spending types—durable and non-durable. To define those aggregate consumption items, we use a "bottom-up" approach, summing up real expenditure on each durable or non-durable good.[23,24] Figure 4.3 shows boxplots for both durable and non-durable expenditures. It is more skewed for spending on durable goods since the acquisition of durable items happens infrequently such that most of the cases were recorded as zero. Atypical observations for both durable and non-durable goods spending, which fall outside the upper and lower whiskers of the boxplot, are excluded from our main analysis as outliers (Hubert and Vandervieren, 2008).[25]

As noted, the liquid asset balance ratio, a measure of household liquidity, is cal-

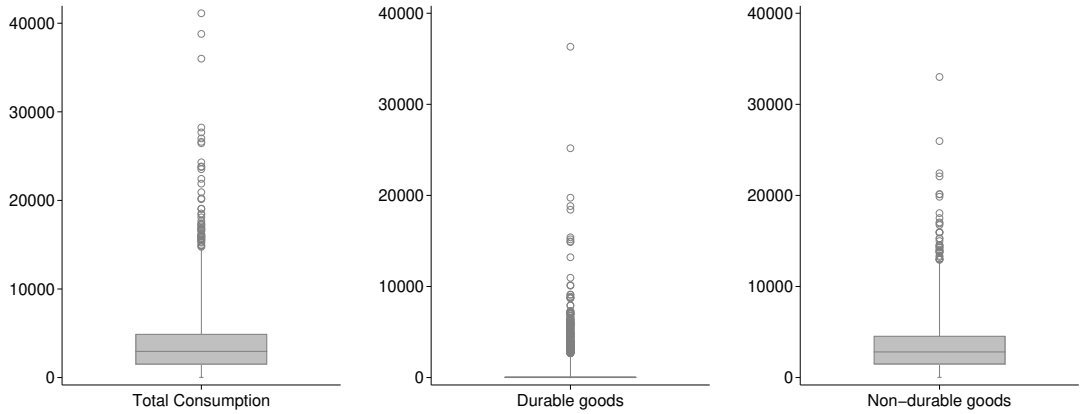
[22]The thresholds are 12.3% and 126.2%. Since the government implicitly aims to ensure that the assessed value does not exceed the market price, so the mean of the assessment value is well below 100%.

[23]We consider real consumption spending values by adjusting each item for inflation using the relevant consumer price index for each year.

[24]The NaSTaB surveys household expenditures for each consumption item under "The Classification of Individual Consumption by Purpose" (developed by the United Nations). Non-durable includes housing repair, eating out, public transportation, vehicle maintenance, communication service, expenditure for culture & leisure activities, rental for electronic devices, beauty treatment, travel, public education, private education, medical services, spending on family events such as funeral, housekeeping service, private insurance, apparel, dwelling expenses, grocery, alcohol, cigarette, cosmetics, sport equipment, fuel for cars. Durable goods are vehicles, electronic appliances, communication equipment, and furniture and others. See Appendix 4.8.4 for more detailed information.

[25]The method of Hubert and Vandervieren (2008) determines the upper and lower whiskers as $[Q_1 - 1.5exp(-4MC)IQR,\ Q_3 + 1.5exp(3MC)IQR]$ where Q_1, Q_3, IQR, and MC refer to the 25th percentile, the 75th percentile, interquartile range $(Q_3 - Q_1)$ and medcouple (a measure of skewness), respectively. This approach resulted in the removal of the top 3.8% of durable goods spending and the top 0.5% of non-durable goods spending.

Figure 4.3: Boxplots of household consumption expenditures



Notes: Based on a the method of Hubert and Vandervieren (2008) that adjusts a boxplot for skewed distributions. Dots outside whiskers indicate outliers.

culated as the total value of liquid assets minus the total value of short-term debt liabilities, divided by their disposable income. Here, 'liquid assets' include deposit and installment savings, funds, bonds, and bank trusts, while 'short-term debt' refers to unsecured debt such as credit loans and cash advances, excluding mortgage and student loans.[26] For information, Table 4.11 of Appendix 4.8.3 provides a full list of balance sheet variables available. The selection of liquid assets is based on the general definition, which includes cash or assets that can be monetized quickly. This definition is consistent with O'Brien (2007), who provides a list of liquid assets in compiling monetary aggregates. Only these short-term debts, which are more imminent in principal repayment than mortgage debt, are considered to construct the liquid asset balance ratio.[27] Similar to the case of the assessment ratio, outliers of the liquid asset balance ratio, which are outside of three standard deviations from the mean value, are excluded from the analysis. The descriptive statistics in Table

[26]The debt includes liabilities to financial institutions only. Although the NaSTaB surveys the amount of 'tenancy deposits' held by multi-house owners as part of the debt, we exclude this type of debt. This is because households that own the deposit did not actively borrow this money for utility maximization purposes. Instead, this is money received in return for offering a property for rent and is given to them as part of the tenancy agreement. Such tenancy deposits are generally excluded from aggregated household debt figures reported by related international institutions such as the OECD and BIS.

[27]While it is true that mortgage debt due within 1-2 years puts more pressure on households for principal repayment, leading to tighter liquidity conditions, the NaSTaB does not contain maturity information for different types of household debts. We thus are not able to consider this possibility when constructing our liquidity constraint measure.

Table 4.2: Descriptive statistics

	Mean	Std Dev	Min	Max
First stage analysis				
Assessment ratio	0.7	0.2	0.1	1.3
House prices (in 100 mil. KRW)	2.4	2.6	0.0	36.0
House size	87.2	33.9	11.7	514.8
Satisfaction with residential condition	2.3	0.6	1.0	5.0
Second stage analysis				
Recurrent taxes paid (in 10,000 KRW)	27.1	47.5	0.0	810.0
Spending on durable (in 10,000 KRW)	120.2	366.2	0.0	2666.1
Spending on non-durable (in 10,000 KRW)	3142.9	2173.1	46.6	12755.7
Spend on durable/spend on non-durable*100	3.7	12.8	0.0	226.2
Liquidity asset balance ratio $(t-1)$	0.9	2.0	-14.6	17.0
No. of household members	2.8	1.2	1.0	8.0
No. of household members under 18	0.5	0.9	0.0	4.0
No. of household members above 65	0.6	0.8	0.0	3.0
Disposable income (in 10,000 KRW)	4721.3	4109.3	9.4	108264.5
Total value of residential properties[(a)]	27864.7	34729.1	200.0	420000.0
Ratio of consumption to disposable income	0.9	3.1	0.0	186.4

Notes: An unbalanced panel data set with repeated observations at the household level over the 2014-19 period. The first (second) stage analysis covers 6,739 (6,067) observations spanning over the sample period. (a): Sum of values of properties held by household, including not only the main residence, but also the additional residence(s).

4.2 are based on the observations used for first and second-stage estimation, 6,739 and 6,067, respectively.

4.6 Results

This section first shows estimation results of the first-step regression (Eq.4.1) and reports unexpected recurrent taxes. We then turn to the results of the second-step regression (Eq.4.2) and discuss the relevance of liquidity constraints to the consumption effects of recurrent taxes.

4.6.1 Identification of unexpected recurrent taxes

Table 4.3 shows the results of the first-step analysis using Eq.4.1. Relative to the full model of Column (3), Column (1) considers the model without region-year fixed

effects and household-specific time trends, whereas Column (2) does without only the latter. The aim is to see the robustness of results to the inclusion of a battery of controls. The dependent variable is the assessment ratio, namely the share of the government's assessed value in year t to the market value in year $t-1$. The coefficient on the previous year's market value is negative and significant throughout, indicating that, in line with the prior literature (e.g., McMillen and Weber, 2008), lower-valued houses are assessed at a higher proportion of their market values, making recurrent taxes regressive. The house size and living environment satisfaction are positively related to the assessment ratios, but the effects are not robust (particularly for the former). The adjusted R-squared is highest in Column (3), indicating that region-year fixed effects and household-specific time trends substantially increase the model's explanatory power. Our focus below is thus on the full model of Column (3).

Table 4.3: Results of first-step regression

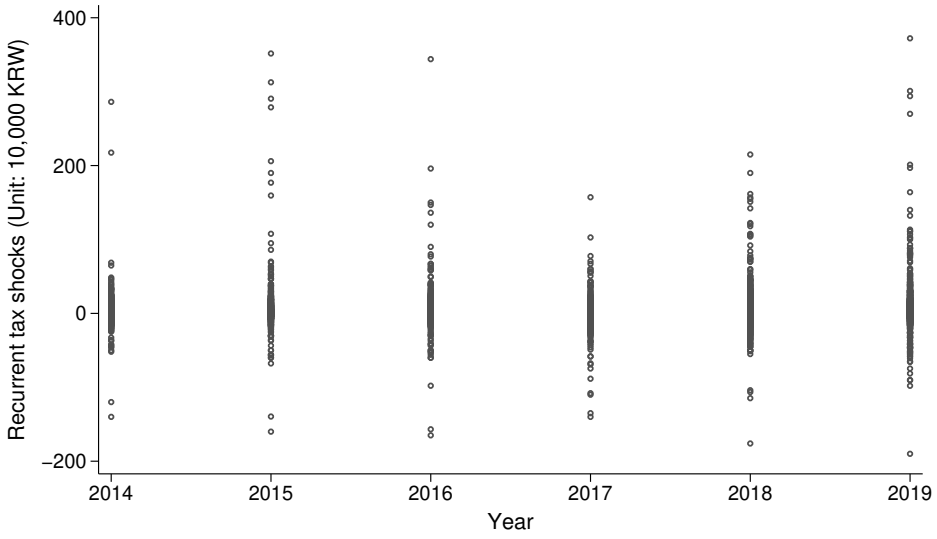
	(1)	(2)	(3)
*Dependent variable: Assessment ratio*100*			
Market value ($t-1$, unit: 1,000 KRW)	-0.006***	-0.005***	-0.012***
	(0.002)	(0.001)	(0.003)
Property size ($t-1$)	0.060**	0.053**	0.018
	(0.023)	(0.020)	(0.013)
Resident's satisfaction ($t-1$)	0.155	0.055	0.798
	(0.707)	(0.408)	(0.669)
Household Fixed Effects	Yes	Yes	Yes
Region-year Fixed Effects	No	Yes	Yes
Household-specific Time Trends	No	No	Yes
Observations	6,739	6,739	6,739
No. of households	2,066	2,066	2,066
Adj. R-squared	0.068	0.243	0.509

Notes: Fixed-effect estimations of Eq.4.1. Resident's satisfaction refers to the resident's satisfaction with the overall living environment which takes the value from 1 to 5, where the smaller value means higher satisfaction. Robust standard errors clustered by regions in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

The estimated residual of Eq.4.1 represents the part of the assessment ratio that is not accounted for by the model, whereas the fitted value of the assessment ratio can be seen as the expected part. As explained in Section 4.4.1, we then use the relationship between the assessed value as a tax base and recurrent taxes (Tables

4.1) to separate recurrent taxes into the expected and unexpected parts of recurrent taxes. Figure 4.4 plots the identified unexpected recurrent taxes for all households by year. The mean value of the unexpected recurrent tax shock is 35,000 KRW (27.5 USD), and ranging from -1,900,000 KRW (around -1,495 USD) to 3,722,000 KRW (around 2,929 USD). The correlation between the actual tax paid and its unexpected component is 0.47, indicating a tendency of the two series moving together, but not necessarily closely.

Figure 4.4: Unexpected recurrent tax shocks (Unit: 10,000 KRW)



Notes: Unexpected (and expected) recurrent taxes are calculated for each household from the unexpected (and expected) part of the assessment ratio estimated using Eq.4.1.

4.6.2 Liquidity constraints and consumption effects of recurrent taxes

Unconditional effects

We now examine the effects of recurrent tax shocks on household consumption. Provided that our first-step equation offers accurate estimates of unexpected recurrent taxes, these innovations help address a key source of estimation bias of tax

effects by controlling for anticipation effects. Before considering the role of liquidity constraints in the consumption effects, Table 4.4 estimates the unconditional consumption effects of recurrent taxes (Eq.4.2).[28] The estimates of the other household-level coefficients are found in Table 4.12 of Appendix 4.8.5. Starting with Column (2), the effect on spending on durable goods is negative and significant, indicating that an increase in recurrent taxes paid by a household by 1 KRW reduces durable spending by 0.69 KRW. However, Column (3) shows that the effect on non-durable goods expenditure is insignificant. Consistently, when having the ratio of durable spending to non-durable spending as a dependent variable (Column (4)), the coefficient on the tax shocks is negative, albeit insignificant. Back to Column (1), the effect on the total spending (i.e., the sum of durable and non-durable spending) is statistically insignificant. The overall indication is thus that, in general, recurrent taxes do not have an adverse effect on household consumption.

Table 4.4: Unconditional effects of recurrent tax shocks on consumption

Consumption	**Total**	**Durable (I)**	**Non-Durable (C)**	**I/C**
	(1)	(2)	(3)	(4)
Dependent variable: Spending (Columns 1 to 3), Ratio (Column 4)				
(Recurrent) tax shocks	-1.18	-0.69**	-0.48	-0.01
	(1.07)	(0.24)	(0.99)	(0.01)
Household Characteristics	Yes	Yes	Yes	Yes
Household Fixed Effects	Yes	Yes	Yes	Yes
Region-year Fixed Effects	Yes	Yes	Yes	Yes
Observations	6,067	6,067	6,067	6,067
No. of households	1,713	1,713	1,713	1,713
Adj. R-squared	0.13	0.00	0.15	0.00

Notes: Fixed-effect estimations of Eq.4.2. Effects of recurrent taxes on levels of expenditures are examined for total consumption, durable, non-durable goods, and ratios of spending on durable and non-durable. Recurrent tax shocks are estimated as estimated in Step 1 analysis (Figure 4.4). Coefficients on household characteristics are not shown for brevity. (See Table 4.12 of Appendix 4.8.5 for those coefficients.) Robust standard errors clustered by regions in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

The role of liquidity constraints

Table 4.5 shows estimation results for liquidity constrained and unconstrained

[28]Since we control for the household fixed effects, households that offer only one year of observation are disregarded.

homeowners separately. As explained, liquidity constraint is measured by the liquid asset balance (LAB) ratio, with the smaller (greater) value representing tighter (looser) constraint. Panel (a) reports coefficients on recurrent tax shocks using the threshold values of the 33rd and 67th percentile of the LAB ratio, whereby the liquidity constrained homeowners are the ones with the average LAB ratio (during the sample period) below the 33rd percentile, and unconstrained homeowners are the ones with the average ratio above the 67th percentile. The first (last) 4 columns show results for constrained (unconstrained) homeowners. Panel (b) uses the median as a threshold value to divide homeowners into constrained and unconstrained ones.

Table 4.5: Role of liquidity constraints in consumption effects

Liquidity	**Constrained**				**Unconstrained**			
Consumption	**Total**	**Durable (I)**	**Non-durable (C)**	**I/C**	**Total**	**Durable (I)**	**Non-durable (C)**	**I/C**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable: Spending (cols. 1-3 and 5-7), Ratio (cols. 4 and 8)								
(a) Below 33rd as constrained; Above 67th as unconstrained								
Tax shocks	-2.16**	-1.58***	-0.58	-0.03***	1.71	-0.27	1.98	-0.01
	(0.78)	(0.48)	(1.14)	(0.01)	(1.44)	(0.17)	(1.45)	(0.01)
Observations	1,963	1,963	1,963	1,963	2,044	2,044	2,044	2,044
No. of households	605	605	605	605	541	541	541	541
Adj. R-squared	0.09	0.01	0.10	0.01	0.17	0.02	0.19	0.02
(b) Below median as constrained; Above median as unconstrained								
Tax shocks	-2.77**	-1.11***	-1.65	-0.02**	-0.56	-0.59	0.03	-0.01
	(0.99)	(0.29)	(0.97)	(0.01)	(2.18)	(0.43)	(1.84)	(0.01)
Observations	2,979	2,979	2,979	2,979	3,088	3,088	3,088	3,088
No. of households	895	895	895	895	818	818	818	818
Adj. R-squared	0.11	0.00	0.13	0.01	0.18	0.01	0.19	0.00
H. characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region-year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Fixed-effect estimations of Eq.4.2. In Panel (a), bottom and top 33rd percentiles of the average liquid balance asset ratio were used as a cut-off for constrained households and unconstrained households, respectively. The liquid balance asset ratio is the total value of liquid assets minus the total value of short-term debt liabilities, divided by their disposable income. In Panel (b), the median is used as a cut-off instead. Coefficients on household characteristics are not shown for brevity. Robust standard errors clustered by regions in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Starting with Column (2) of Panel (a), the negative and significant coefficient on tax shocks indicates that an increase in recurrent taxes reduces durable consumption spending for liquidity constrained homeowners. The coefficient of -1.58 means that a 1 KRW increase in taxes reduces durable spending by 1.58 KRW. While this may seem too larger (particularly if one interprets the coefficient as the marginal propensity to consume), this is due to the down payment practice and credit-based payment method used in the acquisition of durable goods.[29] Meanwhile, Column (3) indicates that the effect on their non-durable spending is insignificant, albeit the sign is still negative. Column (4) then shows a clear indication that in the face of an increase in recurrent taxes, constrained homeowners re-balance spending towards non-durable from durable goods. Back to Column (1), recurrent taxes have a negative impact on their total consumption, driven by the reduction in their durable spending. Meanwhile, Columns (5) to (8) show that all the coefficients (on tax shocks) are statistically insignificant, suggesting that recurrent taxes do not have an impact on consumption behavior of unconstrained homeowners. Panel (b), where the median value of the LAB ratio is used as a threshold, conveys the same message, indicating the results are robust when using the alternative threshold.

To add, acknowledging the strong effect of recurrent taxes on durable spending for liquidity constrained homeowners, we further decompose durable spending into the ones on vehicles, electronic equipment, communication equipment, and furniture and others. Table 4.15 in Appendix 4.8.5 shows that recurrent taxes have significant effects, particularly on those constrained homeowners' spending on vehicles and electronic equipment, which are normally purchased by down payments, whereas the taxes have no impact on unconstrained homeowners' spending on any of the durable goods, regardless of the choice of the thresholds.[30]

[29]Suppose that a portion κ of 1 KRW is required as a down payment to purchase a durable good priced at 1 KRW, with the remaining balance paid later through credit. In this case, a tax increase of less than 1 KRW today can deter homeowner from purchasing the durable goods (priced at 1 KRW). A formal explanation of this point is provided by Aaronson et al. (2012).

[30]In South Korea, it is common that consumers purchase an electronic device using an installment plan with a small initial payment.

Interaction approach To check the robustness of the results, Table 4.6 examines the interaction model of Eq.4.3. Column (2) shows that the interaction coefficient is positive and significant, indicating that the tax effects on durable spending have a significantly more adverse effect as liquidity constraint becomes tighter.[31] The significant coefficient of -1.06 on recurrent tax shocks indicates that when the liquidity asset balance is zero, an increase in taxes by 1 KRW reduces households' spending on durable goods by 1.06 KRW. Meanwhile, Column (3) suggests that liquidity constraint may not be relevant to the tax effects on non-durable spending. Column (4) shows that the interaction effect is significantly positive, suggesting that in the face of a recurrent tax increase, the more liquidity constrained homeowners are, the more they re-balance spending to non-durable goods. Back to Column (1), the interaction coefficient is positive, albeit not significant.

Table 4.6: Role of liquidity constraints in consumption effects: Interaction approach

Consumption	**Total**	**Durable (I)**	**Non-Durable (C)**	**I/C**
	(1)	(2)	(3)	(4)
Dependent variable: Consumption (Columns 1 to 3), Ratio (Column 4)				
Tax shocks	-1.86**	-1.06***	-0.80	-0.02**
	(0.69)	(0.29)	(0.64)	(0.01)
Tax shocks * Liquid asset balance ratio $(t-1)$	0.53	0.28***	0.25	0.01***
	(0.44)	(0.04)	(0.44)	(0.00)
Liquid asset balance ratio $(t-1)$	-3.56	-2.34	-1.23	-0.12
	(8.34)	(4.07)	(6.40)	(0.15)
Household Characteristics	Yes	Yes	Yes	Yes
Household Fixed Effects	Yes	Yes	Yes	Yes
Region-year Fixed Effects	Yes	Yes	Yes	Yes
Observations	6,067	6,067	6,067	6,067
No. of households	1,713	1,713	1,713	1,713
Adj. R-squared	0.13	0.01	0.15	0.00

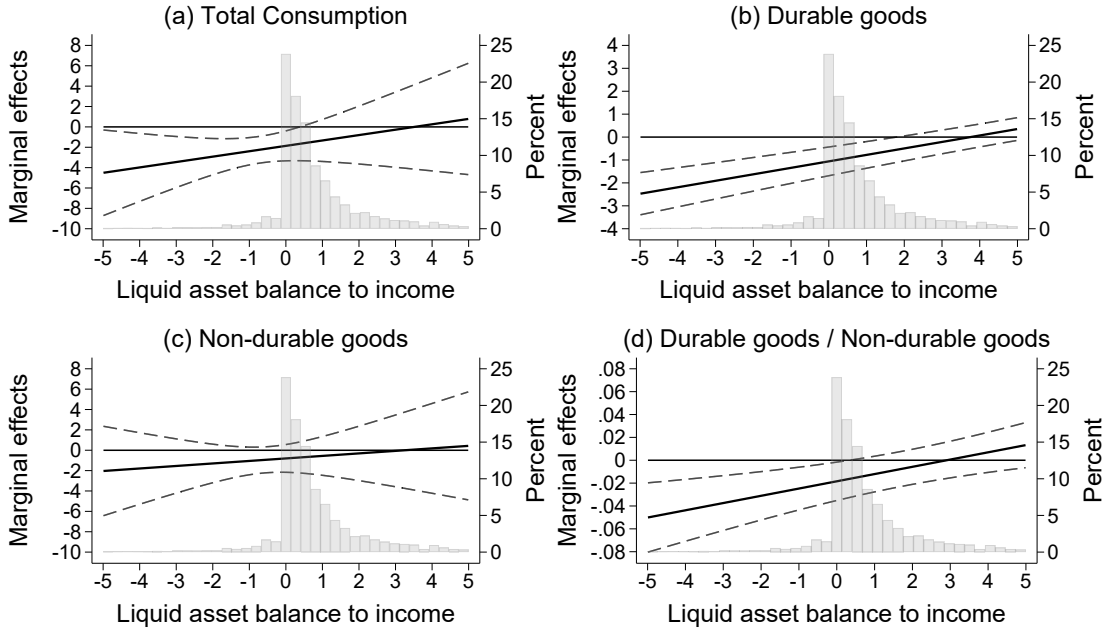
Notes: Fixed-effect estimations of Eq.4.3. Liquid asset balance ratio (in year $t-1$) is the total value of liquid assets minus the total value of short-term debt liabilities, divided by their disposable income. Robust standard errors clustered by regions in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Figure 4.5 explores the interaction results further by graphically showing the marginal

[31] As Table 4.16 in Appendix 4.8.5 shows, in line with the results from the sub-sample analysis, the interaction coefficients are positive and significant for vehicles and electronic equipment as specific durable goods. Here, the coefficient is also significantly positive for furniture and others.

effects of recurrent taxes on consumption spending, together with the 95% confidence intervals, across different LAB ratios. Panel (b) shows that the recurrent tax effect on durable spending is significantly negative for a large proportion of households, namely households whose LAB ratio is below 1.8. Panel (c) shows that the tax shock does not have any impact on non-durable spending regardless of the level of the LAB ratio. Combined, Panel (d) indicates that the re-balancing effect is significant for households whose LAB ratio is less than 1.0. Last, Panel (a) suggests that the tax shock has a negative impact on the total consumption, especially for households with an LAB ratio less than 0.8, driven primarily by the tax effects on durable spending.[32] Overall, although the interaction approach inevitably gives some apparently implausible consumption effects when the LAB ratio is very small (or large), the general message still provides strong support for the above results based on the sub-sample approach.

Figure 4.5: Marginal effects of the recurrent tax shocks on household consumption



Notes: Marginal effects of the recurrent tax shocks on consumption across liquid asset balance (LAB) ratio, corresponding to Table 4.6. The solid line represents the marginal effect, and the dotted lines are confidence intervals of 95% significance level. To improve visibility, the figures only covers the LAB ratio between -5 and 5 that covers the majority (about 95%) of households.

[32]This is the case despite the insignificant interaction term observed in Column (1) of Table 4.6.

Evaluating the hypotheses The results firmly support the hypotheses developed in Section 4.2. First, when households are not liquidity constrained, an unexpected transient increase in recurrent taxes has an insignificant effect on their spending. An intuition suggested by the theory is that this happens because unconstrained households can still smooth consumption, and also likely increase labor supply to mitigate the consumption loss. Second, when households are liquidity constrained, such an increase in recurrent taxes reduces total consumption, driven primarily by a fall in spending on durable goods. The intuition from the model is that this is to do with the lack of their ability to smooth consumption, and to mitigate the utility loss, they re-balance spending towards non-durable goods that increase utility immediately, as opposed to durable goods that they only receive utility benefit primarily in the future.

4.6.3 Robustness checks

This section conducts further robustness checks using the sub-sample approach with the 33rd and 67th percentiles of the liquid asset balance ratio as a threshold (cf. Panel (a) of Table 4.5).

Inclusion of observations in the year 2020 While the COVID-19 pandemic had substantial adverse effects on the economy as a whole, the effects were heterogeneous across consumer goods sectors. For example, in April 2020, service industry production, such as transportation, food, and leisure, exhibited a particularly large fall by 6.1 percent relative to the year before (Jung et al., 2020). To avoid complications from such heterogeneous impacts altogether, our main analysis above was conducted without using the 2020 data. Acknowledging the caveats, however, we here repeat the analysis utilizing the additional data available for 2020. Panel (a) of Table 4.7 shows that the results are robust. Recurrent taxes reduce liquidity con-

strained homeowners' durable spending in particular, which, in turn, reduces their total consumption. There is also some evidence that higher taxes prompt them to re-balance spending towards non-durable goods. Meanwhile, unconstrained homeowners' consumption patterns are effectively unaffected.

Table 4.7: Robustness check: Using the 33rd percentile as a threshold

	Constrained				**Unconstrained**			
Consumption	**Total**	**Durable (I)**	**Non-durable (C)**	**I/C**	**Total**	**Durable (I)**	**Non-durable (C)**	**I/C**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(a) Inclusion of the observations in the year 2020								
Tax shocks	-2.50**	-1.05***	-1.45	-0.00*	1.15	-0.05	1.20	-0.00
	(0.92)	(0.29)	(1.08)	(0.00)	(1.22)	(0.25)	(1.41)	(0.00)
Observations	2,484	2,484	2,484	2,484	2,566	2,566	2,566	2,566
No. of households	650	650	650	650	578	578	578	578
Adj. R-squared	0.10	0.02	0.12	0.02	0.18	0.03	0.19	0.01
(b) Exclusion of total value of residential properties from the control variables								
Tax shocks	-2.83***	-1.65***	-1.18	-0.03***	1.85	-0.29	2.14	-0.01
	(0.64)	(0.46)	(0.85)	(0.01)	(1.54)	(0.18)	(1.54)	(0.01)
Observations	1,963	1,963	1,963	1,963	2,044	2,044	2,044	2,044
No. of households	605	605	605	605	541	541	541	541
Adj. R-squared	0.09	0.01	0.10	0.01	0.17	0.02	0.19	0.02
(c) Substraction of the mortgage payments from the liquid asset balance								
Tax shocks	-0.33	-1.12**	0.79	-0.02**	1.02	-0.52**	1.54	-0.01
	(1.52)	(0.40)	(1.82)	(0.01)	(1.49)	(0.20)	(1.45)	(0.01)
Observations	1,962	1,962	1,962	1,962	2,045	2,045	2,045	2,045
No. of households	598	598	598	598	539	539	539	539
Adj. R-squared	0.08	0.01	0.09	0.01	0.17	0.02	0.18	0.02
H. characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region-year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Fixed-effect estimations of variants of Eq.4.2. Bottom and top 33rd percentiles of the average liquid balance asset ratio were used as a cut-off for constrained households and unconstrained households, respectively. The liquid balance asset ratio is the total value of liquid assets minus the total value of short-term debt liabilities, divided by their disposable income. Coefficients on household characteristics are not shown for brevity. Robust standard errors clustered by regions in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Exclusion of total value of residential properties from the control variables As Surico and Trezzi (2019) point out, recurrent property taxes on residential property may impact house prices, which would indirectly influence households'

consumption spending. This is because recurrent taxes can change the demand for housing properties by increasing the user cost of holding them, leading to changes in house prices (Kuttner and Shim, 2016; Zhang and Zoli, 2016). Then, to the extent that the market value of housing properties is affected, homeowners' total wealth is also affected, which, in turn, potentially causes a "second-round" effect on consumer spending through the wealth effect. Our main analysis above controls for the wealth effect, by having total value of residential properties as an independent variable (Eq.4.2). Here, to investigate whether our results are robust to the potential wealth effect, we repeat the analysis excluding housing prices from the control variables. Panel (b) of Table 4.7 confirms that the results are robust to the consideration of the wealth effect.

Counting mortgage payments in measuring the liquid asset balance Last, we construct an alternative measure of the liquidity constraint, revisiting the treatment of households' mortgage payments. In the main analysis above, we only subtracted short-term debt from liquid assets (and not subtracting the total value of mortgage interest and installment payments) to construct the liquidity constraint measure. We now use a measure that also subtracts those mortgage payments, thereby taking into account additional financial pressure on homeowners with mortgages. Panel (c) of Table 4.7 shows that the results are again robust to using this alternative liquidity measure.

Alternative liquidity threshold and interaction approach Tables 4.13 and 4.14 (along with Figure 4.9) of Appendix 4.8.5 present results of the above checks using the alternative threshold (median) of the liquidity asset balance ratio and the interaction approach, respectively. Those results provide further support for the main results.

4.6.4 Discussion

Are recurrent tax shocks really unexpected?

If we identify recurrent tax shocks that are really exogenous and unexpected, it is expected that tax shocks in year $t+1$ would not have significant effects on consumer spending in year t, after controlling for other factors related to household behavior in year t. Following this logic, we conduct a placebo test using the following equation:

$$Y_{i,j,t} = \gamma_0 + \gamma_1 Tax\_shock_{i,j,t+1} + \sum_{k=1}^{n} \eta_k D_{i,j,k,t} + \rho_{j,t} + \zeta_i + u_{ijt}, \tag{4.4}$$

where the only difference from Eq.4.2 is the timing of the recurrent tax shocks.

Table 4.8: Placebo test on unexpected recurrent tax shocks

	Constrained				**Unconstrained**			
Consumption	**Total**	**Durable (I)**	**Non-durable (C)**	**I/C**	**Total**	**Durable (I)**	**Non-durable (C)**	**I/C**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable: Consumption (Columns 1-3 and 5-7), Ratio (Columns 4 and 8)								
(a) Below 33rd as constrained; Above 67th as unconstrained								
Tax shocks	3.99	1.46	2.53	0.07	-2.01***	-0.83	-1.18	-0.00
	(2.59)	(1.50)	(2.30)	(0.06)	(0.64)	(0.69)	(1.23)	(0.02)
Observations	1,555	1,555	1,555	1,555	1,717	1,717	1,717	1,717
No. of households	533	533	533	533	512	512	512	512
Adj. R-squared	0.10	0.06	0.09	0.08	0.14	0.02	0.17	0.06
(b) Below median as constrained; Above median as unconstrained								
Tax shocks	1.86	0.92	0.94	0.05	0.07	-0.37	0.44	0.00
	(2.92)	(0.97)	(2.48)	(0.04)	(1.18)	(0.35)	(1.31)	(0.01)
Observations	2,379	2,379	2,379	2,379	2,602	2,602	2,602	2,602
No. of households	804	804	804	804	777	777	777	777
Adj. R-squared	0.10	0.03	0.11	0.04	0.15	0.01	0.18	0.05
H.Characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region-year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Fixed-effect estimations of Eq.4.4. In Panel (a), bottom and top 33rd percentiles of the average liquid balance asset ratio were used as a cut-off for constrained households and unconstrained households, respectively. The liquid balance asset ratio is the total value of liquid assets minus the total value of short-term debt liabilities, divided by their disposable income. In Panel (b), the median is used as a cut-off instead. Robust standard errors clustered by regions in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 4.8 shows the results.[33] Panel (a) ((b)) uses the 33rd and 67th percentiles (median) of the liquid asset balance ratio as a threshold. In both panels, the first (last) 4 columns report the consumption effects for liquidity constrained (unconstrained) homeowners. The results are largely consistent with our expectations, in that for liquidity-constrained homeowners, the significant effects on durable and total consumption, and the re-balancing effects (observed in Table 4.5) all disappear in both panels. Regarding unconstrained homeowners, as in Table 4.5, the effects are largely insignificant, except for Column (5) of Panel (a), where the effect on total consumption is significantly negative. However, the coefficients on durable and non-durable expenditures are insignificant on their own, which is what is expected to the extent that recurrent tax shocks identified are indeed unexpected.

Considering other conditional factors for consumption effects

The estimation results above indicate that the effects of recurrent taxes on consumer spending critically depend on the liquidity constraint. However, as reviewed in Section 4.1, the related literature examines various conditional factors broadly for consumption response to income changes. They include housing tenure status (Cloyne and Surico, 2017; Surico and Trezzi, 2019), debt-to-income ratio (Ogawa and Wan, 2007; Dynan, 2012), and the leverage ratio (Andrés et al., 2022). Realizing that those factors are often related to the degree of household liquidity constraint (shown below), we now examine whether liquidity constraint is still a relevant factor even after taking account of them.[34]

Specifically, we consider the following other factors.

[33]Since we lose one year (2019) of observations of the dependent variables, the sample size is reduced to 5,069.

[34]While the hand-to-month status is also shown to be an important conditional factor for consumption effects (Kaplan and Violante, 2014 and Guo et al. (2023)), we do not consider this factor here, because with our focus being on homeowners, a majority of them are not hand-to-month households.

- *Housing tenure status*: A dummy variable that takes the value of one if households never own mortgage debt during the sample period and thus are outright owners throughout, and the value of zero otherwise.

- *Debt-to-Income ratio*: The total value of household debt divided by disposable income.

- *Leverage ratio*: The total value of household debt balance divided by net worth (the total value of assets minus the total value of debt)

To check how these variables are related to liquidity constraint, Table 4.9 conducts a t test, comparing the means of these variables between liquidity-constrained and unconstrained households. Liquidity constrained (unconstrained) households are here defined as the ones with the average liquid asset balance ratio below the 33rd (above the 67th) percentile. The table shows that constrained households tend to be mortgagors, rather than outright owners, whereas they are relatively more indebted and leveraged. The differences between the two groups are statistically significant, as indicated by the p-value on the t-test, which is significant at the 1% level.

Table 4.9: Comparing means between liquidity constrained and unconstrained households

	Const.	**Unconst.**	**Diff.**	**Std. Dev.**	**P-value**
Below 33rd as constrained; Above 67th as unconstrained					
Outright owner dummy	0.29	0.81	-0.52	0.01	0.00
Debt-to-Income ratio	1.42	0.33	1.10	0.13	0.00
Leverage ratio	0.38	0.02	0.36	0.04	0.00

Notes: t test results on the equality of the sample means of the variables between the constrained and unconstrained homeowners. The 33rd and 67th percentiles of the liquid asset balance ratio as a threshold. The null hypothesis is that the difference between the means of the constrained and unconstrained households is zero.

We now examine the relevance of the alternative variables to the consumption effects of recurrent taxes. We here use the interaction approach (cf. Eq.4.3), which is convenient to consider below the importance of liquidity constraint relative to an alternative conditional factor. Table 4.17 of Appendix 4.8.5 suggests that the

housing tenure status (outright owner dummy), in particular, is a relevant conditional factor with expected signs. For example, a 1 KRW increase in the recurrent tax shock would decrease durable spending by 1.17 KRW for mortgagors (who tend to be liquidity constrained). For outright owners, the same shock causes a much smaller decrease in durable spending, namely by 0.04 KRW ($= 1.13 - 1.17$). Indeed, this result strongly echoes the results of Surico and Trezzi (2019). Meanwhile, the interaction terms of the debt-to-income ratio and leverage ratio are not statistically significant at the 5% level.

Table 4.10: Relevance of liquidity constraints: Taking account of housing tenure status

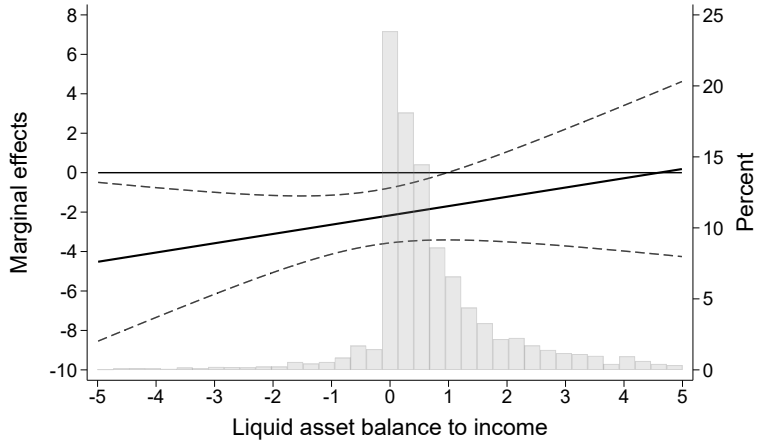
Consumption	**Total**	**Durable (I)**	**Non-Durable (C)**	**I/C**
	(1)	(2)	(3)	(4)
Tax shocks	-2.17***	-1.31***	-0.86	-0.03***
	(0.65)	(0.20)	(0.64)	(0.01)
Tax shocks * Liquidity constraint $(t-1)$	0.47	0.23***	0.24	0.00*
	(0.38)	(0.05)	(0.39)	(0.00)
Tax shocks * Outright owner dummy	0.89	0.73*	0.16	0.02
	(1.35)	(0.37)	(1.35)	(0.02)
Observations	6,067	6,067	6,067	6,067
No. of households	1,713	1,713	1,713	1,713
Adj. R-squared	0.13	0.01	0.15	0.00
Household characteristics	Yes	Yes	Yes	Yes
Household Fixed Effects	Yes	Yes	Yes	Yes
Region-year Fixed Effects	Yes	Yes	Yes	Yes

Notes: Fixed-effect estimations of variant of Eq.4.3. The liquid balance asset ratio is the total value of liquid assets minus the total value of short-term debt liabilities, divided by their disposable income. Outright owner dummy variable takes the value of one if households never own mortgage debt during the sample period and thus are outright owners throughout, and the value of zero otherwise. Robust standard errors clustered by regions in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Motivated by the relevance of the housing tenure status, we consider a model that includes not only the interaction between tax shocks and liquidity constraint (measured by the liquid asset balance) but also the interaction between tax shocks and the outright owner dummy. The idea is to examine the relative importance of liquidity constraint in the consumption effects of recurrent taxes. Table 4.10 shows

that the size of interaction coefficients for the outright owner (housing tenure status) dummy generally becomes smaller compared to Table 4.17. Meanwhile, the relevance of the liquidity measure appears robust. As before (Table 4.6), although the interaction is not significant when the dependent variable is total consumption (Column (1)), the marginal effect figure of Figure 4.6 shows that the effect of recurrent taxes still tends to be significantly negative when households are more liquidity constrained.

Figure 4.6: Effects of tax shocks on total consumption: Taking account of housing tenure status



Notes: Marginal effects of the recurrent tax shocks on consumption across liquid asset balance (LAB) ratio, corresponding to Column (1) of Table 4.10. The solid line represents the marginal effect, and the dotted lines are confidence intervals of 95% significance level. To improve visibility, the figures only covers the LAB ratio between -5 and 5 that covers the majority (about 95%) of households.

Further discussion of results and policy implications Upon a comprehensive review of the results and discussion above, we now draw the following insights on utilizing recurrent property taxes.

1. A more comprehensive assessment of homeowners' balance sheets is required: As previously discussed, a more crucial factor determining consumption effects is homeowners' liquid asset balance, rather than the housing tenure status suggested by Surico and Trezzi (2019). While our analysis aligns with Surico and Trezzi (2019) regarding the negative effects on constrained households and

reduced spending on durable goods, our approach reveals the quantitative differences in consumption effects based on liquid asset balance. As shown in Tables 4.5 and 4.6, a lack of liquid assets worsens the adverse effects, with a 0.28 KRW increase in negative effects for every 1-unit decrease in the liquid asset balance ratio. This highlights the need for a more comprehensive assessment of homeowners' balance sheets, rather than simply considering their housing tenure status, when preparing support for those adversely affected.

2. Re-balancing implies welfare disadvantages for constrained households: Surico and Trezzi (2019) do not provide a formal analysis of the re-balancing effects between durable and non-durable goods. Our primary results show that liquidity-constrained homeowners reallocate spending between durable and non-durable goods, relatively increasing non-durable expenditures to mitigate welfare losses. However, as long as their utility function is concave, as described in our model (Appendix 4.8.1), these consumption fluctuations suggest they are unable to smooth their spending, particularly in response to unexpected tax shocks. This creates welfare disadvantages compared to unconstrained homeowners.

3. Support for constrained homeowners is necessary: Related to the previous point, tax increases do not equally affect all homeowners. The unequal effects of tax increases across homeowners necessitate targeted support. One option is to allow tax deferrals when homeowners lack sufficient liquid assets to handle sudden tax increases. Another option is to provide installment payment plans for these constrained households. Recently, the Korean government introduced a three-month installment plan, and it is advisable to consider extending the installment period further to alleviate the burdens on constrained households.

4.7 Concluding Remarks

Recurrent property taxes are widely considered to be one of the least distortionary taxes, as evidenced in the context of taxes and economic growth. This argument, in turn, is often used as a basis for recommending that recurrent taxes should be utilized more in the tax composition. However, relatively little is known about their merits and demerits in the context of the effects on household consumption, a key factor that is directly relevant to household welfare. This paper aimed to fill this gap by examining the consumption effects of recurrent taxes while (1) differentiating between expenditures on durable and non-durable goods, and (2) considering household liquidity constraints as a key condition for the effects. To achieve this aim, we utilized an exceptionally rich Korean household-level panel dataset that enabled us to identify unexpected recurrent tax shocks in light of the unique feature of the South Korean tax system that the recurrent tax base is reassessed annually, yet the assessment method is publicly unknown.

We showed that recurrent taxes generally have an insignificant effect on household consumption. This is consistent with the view that the taxes are least distortionary. However, the taxes have unequal consumption effects across households depending on the degree to which they are liquidity constrained. Specifically, in the face of an increase in recurrent taxes, unconstrained homeowners do not incur consumption loss, whereas constrained owners do, particularly through the loss of consumption of durable goods. Intuitively, the total consumption of constrained households falls due to their inability to smooth spending, but they mitigate the utility loss by rebalancing consumption spending towards non-durable goods that offer immediate utility gains, unlike durable goods. Overall, the results provide further support for more active utilization of recurrent taxes in the tax mix, provided that the unequal consumption effects are alleviated by some measures (e.g., tax deferrals for constrained homeowners). A fruitful future research topic is to study the spillover

effects of recurrent taxes on renters who are not directly subject to the taxes. Such research would offer a deeper understanding of the distributional consequences between renters and homeowners.

4.8 Appendix

4.8.1 Theoretical motivation

Objective

The objective of the theoretical model is to help develop hypotheses about the role of liquidity constraints in the consumption effects of recurrent taxes. While acknowledging that introducing housing consumption could affect theoretical predictions, the model considers only non-housing goods consumption, as our empirical analysis focuses on recurrent property taxes and homeowners who have remained in the same properties throughout the sample period. In the model, households optimally choose a dynamic path of expenditures on durable and non-durable goods. The key feature of the model is that the household's expenditure decision is subject to a borrowing (liquidity) constraint. Thus, when the constraint binds, households may be prohibited from smoothing consumption in the face of shocks. The model below is essentially a simplified version of Chah et al. (1995) and Cerletti and Pijoan-Mas (2012), except that it endogenize the household's labor supply decision and explicitly considers the consumption effects of a transient shock to recurrent taxes.

The model

Starting with the household's utility optimization problem, the present discounted

value of lifetime utility of a household i is:

$$E_t \sum_{s=t}^{\infty} \beta^{s-t} U(C_s^i, D_s^i, L_s^i), \tag{4.5}$$

where

$$U(C_s^i, D_s^i, L_s^i) = \log C_s^i + \omega \log D_s^i - \frac{\kappa}{\gamma}(L_s^i)^{\gamma}. \tag{4.6}$$

In Eq.4.5, their flow utility in period t depends on the consumption of non-durable goods, C_t^i and the stock of durables at the end of period, D_t^i. Notice that it is service flows from the stock of durables that benefit the household. L_t^i is labor supply. β is a subjective discount factor. Eq.4.6 specifies the functional form of the flow utility. The law of motion for durables is

$$D_t^i = I_t^i + (1-\delta) D_{t-1}^i, \tag{4.7}$$

where δ is a depreciation rate, and I_t^i is expenditure on durable goods.

Next, the budget constraint is given as:

$$C_t^i + P D_t^i + A_{t+1}^i \leq \tilde{X}_t^i + W L_t^i, \tag{4.8}$$

where

$$\tilde{X}_t^i \equiv (1+r) A_t^i + P(1-\delta) D_{t-1}^i - (\eta^i + \epsilon_t^i) H^i. \tag{4.9}$$

In Eq.4.8, P is the price of durables in terms of non-durables, which is exogenous and time invariant. A_{t+1}^i is liquid assets at the end of period t. $\tilde{X}_t^i$ represents the exogenous (or predetermined) component of resource available during period t, which is the sum of liquid asset from period $t-1$ with a real interest rate, r, $(1+r)A_t^i$, and the undepreciated durables, $P(1-\delta)D_{t-1}^i$, minus recurrent taxes as the house price, H^i, multiplied by the sum of an expected and unexpected fractions, η^i, and

ϵ_t^i (Eq.4.9). ϵ_t^i is a serially uncorrelated shock such that $E(\epsilon_t^i) = 0$.[35] W is wage per hour of work (in terms of non-durables).

Households are further subject to the borrowing constraint of the following form:

$$(1+r)A_{t+1}^i + \theta(1-\delta)PD_t^i \geq 0. \tag{4.10}$$

Eq.4.10 says that the household's net worth at the end of the period needs to be non-negative. Here, we implicitly assume that durable goods (e.g., a car) can be used as a collateral, but the borrowing is allowed only up to a fraction $0 < \theta < 1$ of the undepreciated part of the goods. Accordingly, the smaller θ is, the tighter the borrowing constraint is.

Having specified the objective function and constraints, the timing of events within the period for household i is as follows:

1: They receive initial wealth, A_t^i, inclusive of the interest income.

2: Recurrent tax shock, ϵ_t^i, is realized.

3: They optimally choose (1) expenditure on nondurable goods, C_t^i, (2) expenditure on durable goods, I_t^i (thus D_t^i), (3) hours of work, L_t^i, and (4) asset, A_{t+1}^i, for the next period.

Optimal behavior of households

We now set up the Lagrangian to proceed. In what follow, we drop the individual subscript for the loss of generality. With the objective function (Eq.4.5) and the

[35] We do not specify the functional form of the distribution, but we assume that $\eta^i + \epsilon_t^i > 0$.

constraints (Eqs.4.8 and 4.10), we have:

$$L = E_t \sum_{s=t}^{\infty} \beta^{s-t} U(C_s, D_s, L_s) + E_t \sum_{s=t}^{\infty} \beta^{s-t} \mu_s (\tilde{X}_s + WL_s - C_s - PD_s - A_{s+1}) + E_t \sum_{s=t}^{\infty} \beta^{s-t} \lambda_s \left\{ A_{s+1} + \frac{\theta(1-\delta)}{1+r} PD_s \right\}. \tag{4.11}$$

Accordingly, the first order conditions (FOCs) are obtained as:

$$U_C(C_t, D_t, L_t) = \mu_t, \tag{4.12}$$

$$\beta(1+r)E_t\mu_{t+1} = \mu_t - \lambda_t, \tag{4.13}$$

$$W\mu_t = \kappa(L_t)^{\gamma-1}, \tag{4.14}$$

and

$$\frac{1}{P} U_D(C_t, D_t, L_t) + \beta(1-\delta)E_t\mu_{t+1} = \mu_t - \frac{\theta(1-\delta)}{1+r}\lambda_t \tag{4.15}$$

The Lagrange multiplier of μ_t reflects the shadow value of marginally adding resource, whereas λ_t reflects the shadow value of marginally relaxing the borrowing constraint. Since it is plausible to assume that the budget constraint always binds, we set $\mu_t > 0$. Regarding the borrowing constraint, however, we consider both cases where the constraint binds and does not bind. When it binds, $\lambda_t > 0$, while when it does not, $\lambda_t = 0$.

Next, by combining Eqs.4.12, 4.13, and 4.15, we obtain the expression for the marginal rate of substitution between the holding of durables and the consumption of non-durables:

$$\frac{U_D(C_t, D_t, L_t)}{U_C(C_t, D_t, L_t)} = P \frac{r + \delta + (1-\delta)(1-\theta)\frac{\lambda_t}{\mu_t}}{1+r}. \tag{4.16}$$

Further, by incorporating the utility function of Eq.4.6, Eq.4.16 becomes:

$$\frac{C_t}{D_t} = \frac{P}{\omega}\frac{r+\delta+(1-\delta)(1-\theta)\frac{\lambda_t}{\mu_t}}{1+r}. \tag{4.17}$$

When the borrowing constraint does not bind (i.e., $\lambda_t = 0$), Eq.4.17 reduces to:

$$\frac{C_t}{D_t} = \frac{P}{\omega}\frac{r+\delta}{1+r}. \tag{4.18}$$

Eqs.4.16 and 4.17 show that when the borrowing constraint binds ($\lambda_t > 0$), the ratio of consumption of non-durables to the stock of durables is greater (remember $\mu_t > 0$, $\delta < 1$ and $\theta < 1$). To understand why this is the case, notice that when the borrowing constraint binds, the household borrows up to the maximum to smooth consumption, such that households are liquidity constrained with no additional liquid asset available for present consumption. Intuitively, when the liquidity constraint limits consumption smoothing, households hold relatively more non-durable goods than durables, because the former generate utility immediately, while the latter generate most of the service flows only in the future periods.

Consumption effects of recurrent taxes

We now consider the consumption effects of recurrent taxes for the cases where households are liquidity unconstrained and constrained.

When liquidity constraint does not bind As mentioned, when households are not liquidity constrained, the FOCs give Eq.4.18. Combining it with the budget constraint (and also with $\delta = 0$ to lighten the notation), we have:

$$\left(1+\omega\frac{1+r}{r}\right)C_t + A_{t+1} = \tilde{X}_t + W^{1+\nu}(\kappa C_t)^{-\nu} \tag{4.19}$$

When an unexpected increase in recurrent taxes reduces the resource available, $\tilde{X}_t$, unconstrained households are still able to limit the fall in present consumption of non-durables, C_t, by reducing the asset accumulation for the next period, A_{t+1} (as well as by increasing hours of work). This suggests that a fall in present non-durable consumption is likely to be small. Further, Eq.4.18 indicates that as long as households can still smooth consumption, rebalancing of expenditures is not used as a way to mitigate the utility loss.[36] For a positive transient income shock due to the tax decrease, a similar logic applies. The following proposition summarizes the results (cf. Hypothesis 1 of the main text).

> **Proposition 1.** *When households are not liquidity constrained, an unexpected transient increase in recurrent taxes has a negligible effect on their consumption spending. A rebalancing effect between non-durable and durable expenditures is absent. Similarly, an unexpected fall in taxes causes a negligible increase in spending, without a rebalancing effect.*

When liquidity constraint binds In this case, combining the liquidity constraint with the budget constraint yields (see Eqs.4.8 and 4.10):

$$C_t + \left\{1 - \frac{\theta(1-\delta)}{1+r}\right\} PD_t = \tilde{X}_t + WL_t \tag{4.20}$$

Then, together with the labor supply function (Eqs.4.14) and the optimal share of non-durable to durable expenditures (4.17), Eq.4.20 becomes:

$$C_t \left[1 + \frac{\omega\left\{1 + r - \theta(1-\delta)\right\}}{r + \delta + (1-\delta)(1-\theta)\frac{\lambda_t}{\mu_t}}\right] = \tilde{X}_t + W^{1+\nu}(\kappa C_t)^{-\nu}, \tag{4.21}$$

where $\nu(= \frac{1}{\gamma - 1})$ is the elasticity of labor supply. Further, the consumption Euler equation (Eq.4.13), along with the flow utility function (Eq.4.6) enables us to

[36] Similar to footnote 37, a large adverse income shock possibly makes the constraint bound, suggesting that the results are applicable typically for small shocks.

express the ratio of the Lagrange multipliers as:

$$\frac{\lambda_t}{\mu_t} = 1 - \beta(1+r)\frac{C_t}{E_t C_{t+1}}. \tag{4.22}$$

Hence, substituting Eq.4.22 into Eq.4.21, and setting $\delta = 0$ to lighten the notation, we have:

$$C_t \left\{ 1 + \frac{\omega(1+r-\theta)}{r + (1-\theta)\left(1 - \frac{C_t}{E_t C_{t+1}}\right)} \right\} = \tilde{X}_t + W^{1+\nu}(\kappa C_t)^{-\nu}. \tag{4.23}$$

Consider now the case where recurrent taxes increase unexpectedly, i.e., $\epsilon_t > 0$. This corresponds to an unexpected decrease in the resource available during the current period, $\tilde{X}_t$. Eq.4.23 indicates that for given expected non-durable consumption in the next period ($E_t C_{t+1}$), current non-durable consumption, C_t has to fall. Intuitively, in the face of an adverse income shock, liquidity-constrained households need to be content themselves with a fall in the consumption of non-durables in the current period. To note, however, since a fall in non-durable consumption induces the household to cut back leisure, labor supply increases to mitigate the loss of income from the increase in recurrent taxes and thus the fall in current consumption. This mitigation effect is particularly strong when the labor supply elasticity, ν, is large.

Next, Eqs.4.17 and 4.22 yield (still with $\delta = 0$ for simplification):

$$\frac{C_t}{D_t} = \frac{P}{\omega}\frac{r + (1-\theta)\left(1 - \frac{C_t}{E_t C_{t+1}}\right)}{1+r}. \tag{4.24}$$

Observe that an unexpected transient increase in recurrent taxes, causing a fall in in the current non-durable consumption relative to the future expected consumption, $\frac{C_t}{E_t C_{t+1}}$, increases the ratio of non-durable consumption to the stock of durables, $\frac{C_t}{D_t}$. This suggests that even when the fall in non-durable consumption is small,

the stock of durables can fall substantially. Intuitively, when adverse transitory income shock hits liquidity-constrained households, they mitigate the utility loss by rebalancing expenditure towards non-durables that produce immediate utility gain unlike durables. When recurrent taxes decrease unexpectedly (i.e., $\epsilon_t < 0$), there is instead an increase in the level of non-durable consumption, together with the rebalancing of expenditure towards durables (so that there is a greater increase in the stock of durables).[37] The following proposition summarizes the results for liquidity-constrained households (cf. Hypothesis 2 of the main text).

> **Proposition 2.** *When households are liquidity constrained, an unexpected transient increase in recurrent taxes reduces their consumption, primarily via a fall in spending on durable goods (and stock of durables). In the case of an unexpected transient fall in taxes, the opposite happens, i.e., an increase in consumption, driven by an increase in durable spending.*

Comparison of recurrent taxes versus labor income taxes

Although the present paper does not empirically examine the consumption effects of labor income taxes, it is still useful to compare theoretically how they may differ from the consumption effects of recurrent taxes. Suppose now that the household must pay labor income taxes at a rate of $\tau_t = \tau + \epsilon_{w,t}$, where $E_t(\epsilon_{w,t}) = 0$. The budget constraint 4.8 is modified as follows:

$$C_t^i + PD_t^i + A_{t+1}^i \leq \tilde{X}_t^i + (1 - \tau_t)WL_t^i, \tag{4.25}$$

Accordingly, the first order condition of the labor supply decision (Eq.4.14) is altered.

$$(1 - \tau_t)W\mu_t = \kappa(L_t)^{\gamma-1}, \tag{4.26}$$

[37] As a caveat, in the case of an unexpected tax decrease, to the extent that such a shock is 'large', the borrowing constraint may not bind any longer. The results are thus applicable only for a small shock.

When liquidity constraint does not bind Eq. 4.19 is now adjusted as follows.

$$\left(1+\omega\frac{1+r}{r}\right)C_t + A_{t+1} = \tilde{X}_t + (1-\tau_t)WL_t \tag{4.27}$$

where $L_t = [(1-\tau_t)W]^{\nu}(\kappa C_t)^{-\nu}$.

In the face of an unexpected increase in labor income taxes (i.e., $\epsilon_{w,t} > 0$), unconstrained households can still mitigate a fall in consumption by reducing the level of liquid asset holding, A_{t+1}. However, an increase in labor income taxes would lead to a larger fall in consumption than the case of a recurrent tax increase, because the former not only reduces the resources available today, but also decreases labor supply through $L_t = [(1-\tau_t)W]^{\nu}(\kappa C_t)^{-\nu}$.

When liquidity constraint binds Using Eq. 4.26, Eq. 4.23 becomes:

$$C_t\left\{1+\frac{\omega(1+r-\theta)}{r+(1-\theta)\left(1-\frac{C_t}{E_tC_{t+1}}\right)}\right\} = \tilde{X}_t + (1-\tau_t)WL_t, \tag{4.28}$$

where $L_t = [(1-\tau_t)W]^{\nu}(\kappa C_t)^{-\nu}$.

Suppose labor income taxes increase unexpectedly. This would lead to a decrease in the resource available in time t, so that C_t falls. This is similar to the effect of an increase in recurrent taxes. However, despite a positive impact on labor supply due to the lower level of C_t (since $L_t = [(1-\tau_t)W]^{\nu}(\kappa C_t)^{-\nu}$), a higher τ_t negatively affects labor supply, weakening the positive effect. The implication is thus that consumption would decrease more than in the case of a recurrent tax increase. Regarding the re-balancing effect, a greater fall in C_t causes a higher downward pressure on $\frac{C_t}{E_tC_{t+1}}$. This means the right-hand side of Eq. 4.24 increases relatively more than the case of a recurrent taxes increase. Thus, the left-hand side, $\frac{C_t}{D_t}$, should rise more as well, indicating a stronger re-balancing effect, and a greater fall in durable goods consumption.

4.8.2 Details on NaSTaB sampling method

The KIPF adopts a stratified two-stage cluster sampling method, whereby it first selects 1,002 regions from the total 261,237 survey districts initially established by the Korean National Statistical Office for the 2005 Population and Housing Census. The 1,002 regions are within the 16 metropolitan governments that do not include the final, i.e., the 17th metropolitan government of Jeju-island (cf. footnote 17). The KIPF aimed to include sufficient numbers of households from both higher-income and lower-income groups by over-sampling.[38] Thus, they first selected 60 regions within Gangnam, Seocho, and Songpa in Seoul and Bundang in Seongnam, which are densely populated by higher-income earners, and another 60 regions from areas where recipients of basic living allowances reside. The remaining 882 regions were chosen through systematic sampling. Then, five households from each survey region were randomly selected.

The KIPF employs a private survey company to conduct face-to-face interviews with respondents on their behalf, ensuring the confidentiality of respondents and the sensitive information they provide. While the KIPF endeavors to conduct face-to-face interviews to ensure the accuracy of responses, in rare cases where this is not possible (e.g., due to private reasons or the need for the interviewee to check relevant documents), the surveyor is allowed to leave the questionnaire with households and collect it after completion. This principle was maintained for the surveys conducted in 2020 during the COVID-19 pandemic.[39]

[38]This is because the purpose of this survey was to assess the effectiveness of fiscal policies.

[39]This was possible because the Korean government did not implement national lockdown measures. All surveyors were required to strictly follow COVID-19 guidelines. In some exceptional cases, postal surveys (combined with the verification process via phone) were used. However, such instances were extremely rare, resulting in only one case in 2020.

4.8.3 Household balance sheet

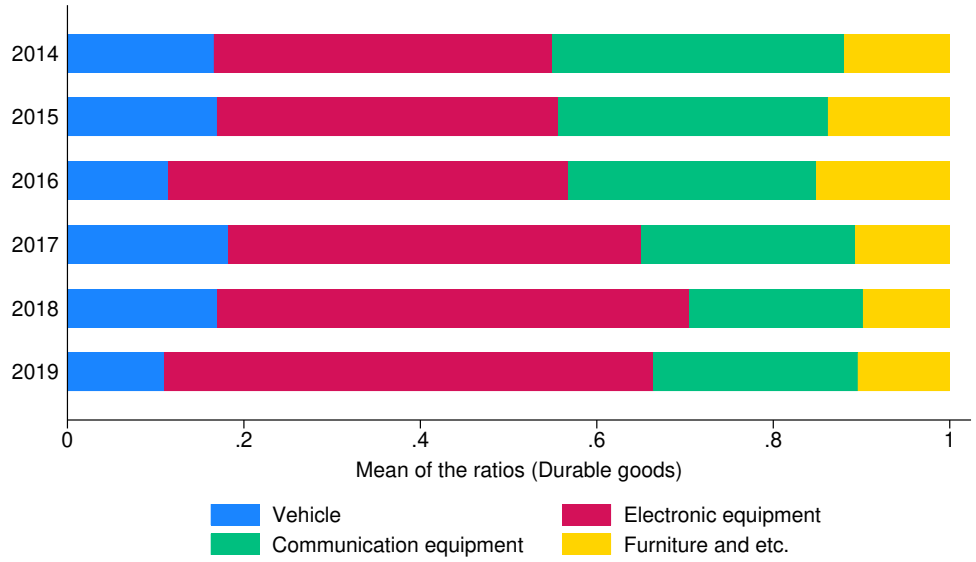
Table 4.11: Household balance sheet and variables

Asset	Liabilities
1. Financial assets • Deposits and Installment savings • Funds (Equity funds, MMF, ELS, etc.) • Bonds • Stocks • Savings insurance and Pension insurance • Registered retirement savings plan • Personal loan to acquaintances • Bank trust etc. 2. Non-financial assets • Main residential property • Residential properties other than the main residence • Real estate properties other than residences (Land, Offices, etc.) • Memberships (Golf courses, Condominium etc.) • Agricultural machines and Livestocks • Vessels and Construction equipments • Precious metals • Vehicles • Antiques, Art works etc.	• Government-funded mortgage loans or housing-related loans • Mortgage loans from financial institutions • Student loans • Loans from financial institutions other than mortgages • Loans related to credit card (Cash advances, Card loans etc.) • Loans from acquaintances etc. • Tenancy deposits

4.8.4 Consumption items

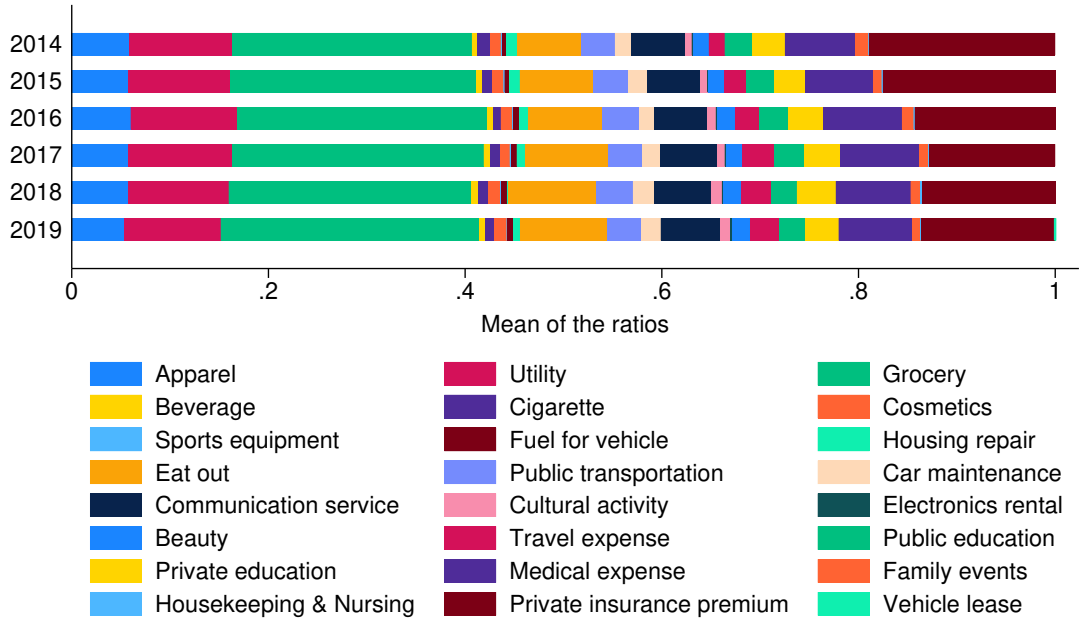
1. Durable goods: Vehicles, Electronic appliances, Communication equipments, Furniture and etc.

Figure 4.7: Durable goods



2. Non-durable goods: Utilities (Gas, Electricity, Water and etc), Groceries, Beverages, Cigarettes, Cosmetics, Apparel, Miscellaneous goods, Accessories, Sports equipment, and Fuel cost for vehicles, Housing repair costs, Spendings on eating out, Public Transportation, Costs for maintaining cars and bikes, Communication services charges, Expenses for cultural or physical activities, Rental costs for electronic devices, Costs for beauty treatments, Travel expenses, Public educations, Private educations, Medical expenditures, Expenses for family events and ceremonies (Wedding and Furneral), Housekeeping services, Private insurance premium, and Vehicle Lease

Figure 4.8: Non-durable goods



4.8.5 Supplementary results

Table 4.12: Unconditional effects of recurrent tax shocks on consumption

Consumption items	**Total**	**Durable (I)**	**Non-Durable (C)**	**I/C**
	(1)	(2)	(3)	(4)
Dependent variable: Consumption (in year t, Columns 1 to 2), Ratio (in year t, Column 4)				
Recurrent tax shocks	-1.18	-0.69**	-0.48	-0.01
	(1.07)	(0.24)	(0.99)	(0.01)
Expected recurrent taxes	-4.08***	-0.28	-3.81***	-0.01
	(0.86)	(0.16)	(0.91)	(0.01)
Disposable income	0.06***	0.01**	0.05***	
	(0.01)	(0.00)	(0.01)	
Consumption/Disposable income				0.09
				(0.06)
Value of the main residence	0.00	-0.00*	0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Number of Household members	660.11***	-4.91	665.02***	-0.99
	(53.85)	(16.49)	(49.80)	(0.61)
Number of U18	210.73**	12.93	197.79**	0.22
	(79.28)	(23.73)	(69.11)	(0.55)
Number of Above 65	-40.28	6.18	-46.46	-0.08
	(74.70)	(15.40)	(65.69)	(0.75)
Household Fixed Effects	Yes	Yes	Yes	Yes
Region-year Fixed Effects	Yes	Yes	Yes	Yes
Observations	6,067	6,067	6,067	6,067
No. of households	1,713	1,713	1,713	1,713
Adj. R-squared	0.13	0.00	0.15	0.00

Notes: Fixed-effect estimations of Eq.4.2. Effects of recurrent taxes on levels of expenditures are examined for total consumption, durable, non-durable goods, and ratios of spending on durable and non-durable. Recurrent tax shocks are estimated as estimated in Step 1 analysis (Figure 4.4). Robust standard errors clustered by regions in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 4.13: Robustness check: Using the median as a threshold

	Constrained				Unconstrained			
Consumption	**Total**	**I**	**C**	**I/C**	**Total**	**I**	**C**	**I/C**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(a) Inclusion of the observations in the year 2020								
Tax shocks	-2.51**	-0.77**	-1.75	-0.00	-1.31	-0.18	-1.13	0.00
	(0.86)	(0.28)	(1.06)	(0.00)	(1.40)	(0.23)	(1.44)	(0.00)
Observations	3,798	3,798	3,798	3,798	3,884	3,884	3,884	3,884
No. of households	974	974	974	974	882	882	882	882
Adj. R-squared	0.11	0.00	0.12	0.00	0.21	0.01	0.23	0.01
(b) Exclusion of total value of residential properties from the control variables								
Tax shocks	-2.84***	-1.17***	-1.67*	-0.02***	-0.56	-0.67	0.11	-0.01
	(0.95)	(0.30)	(0.92)	(0.01)	(2.39)	(0.45)	(2.02)	(0.01)
Observations	2,979	2,979	2,979	2,979	3,088	3,088	3,088	3,088
No. of households	895	895	895	895	818	818	818	818
Adj. R-squared	0.11	0.00	0.13	0.01	0.18	0.01	0.20	0.00
(c) Substraction of the mortgage payments from the liquid asset balance								
Tax shocks	-2.91***	-0.99***	-1.92**	-0.01**	-0.56	-0.66	0.10	-0.01
	(0.88)	(0.25)	(0.88)	(0.01)	(2.42)	(0.47)	(2.04)	(0.01)
Observations	2,978	2,978	2,978	2,978	3,089	3,089	3,089	3,089
No. of households	892	892	892	892	821	821	821	821
Adj. R-squared	0.11	0.00	0.12	0.00	0.19	0.01	0.20	0.00
H. Characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region-year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

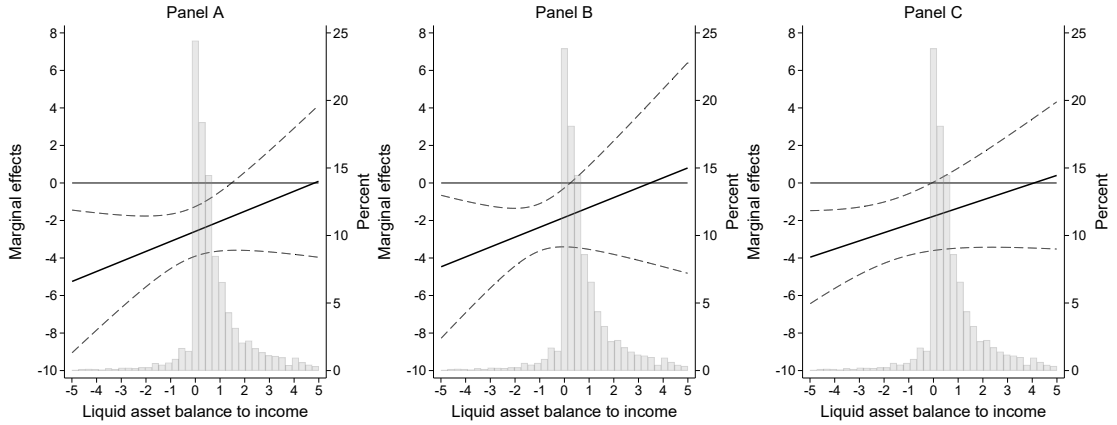
Notes: Fixed-effect estimations of variants of Eq.4.2. Median of the average liquid balance asset ratio was used as a cut-off for constrained households and unconstrained households. The liquid balance asset ratio is the total value of liquid assets minus the total value of short-term debt liabilities, divided by their disposable income. Coefficients on household characteristics are not shown for brevity. Robust standard errors clustered by regions in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 4.14: Robustness checks: Interaction approach

Consumption items	**Total**	**I**	**C**	**I/C**
	(1)	(2)	(3)	(4)
(a) Inclusion of the observations in the year 2020				
Tax shocks	-2.58***	-0.79***	-1.79**	-0.00**
	(0.62)	(0.20)	(0.67)	(0.00)
Tax shocks * Liquid asset balance ratio	0.53	0.27***	0.27	0.00***
	(0.35)	(0.02)	(0.35)	(0.00)
Observations	7,682	7,682	7,682	7,682
No. of households	1,856	1,856	1,856	1,856
Adj. R-squared	0.15	0.01	0.17	0.00
(b) Exclusion of total value of residential properties from the control variables				
Tax shocks	-1.83**	-1.12***	-0.72	-0.02**
	(0.74)	(0.30)	(0.66)	(0.01)
Tax shocks * Liquid asset balance ratio	0.53	0.29***	0.24	0.01***
	(0.43)	(0.04)	(0.43)	(0.00)
Observations	6,067	6,067	6,067	6,067
No. of households	1,713	1,713	1,713	1,713
Adj. R-squared	0.13	0.00	0.15	0.00
(c) Counting mortgage payments in measuring the liquid asset balance				
Tax shocks	-1.78*	-0.98***	-0.80	-0.01**
	(0.86)	(0.30)	(0.77)	(0.01)
Tax shocks * Liquid asset balance ratio	0.44	0.21***	0.23	0.00***
	(0.26)	(0.04)	(0.27)	(0.00)
Observations	6,067	6,067	6,067	6,067
No. of households	1,713	1,713	1,713	1,713
Adj. R-squared	0.13	0.00	0.15	0.00
Household Fixed Effects	Yes	Yes	Yes	Yes
Region-year Fixed Effects	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes

Notes: Fixed-effect estimations of Eq.4.3. Robust standard errors clustered by regions in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Figure 4.9: Robustness checks: Liquidity constraint and effects on total consumption



Notes: Marginal effects of the recurrent tax shocks on total consumption across liquid asset balance ratio. The solid line represents the marginal effect, and the dotted lines are confidence intervals of 95% significance level. These are visualization of results of Table 4.14.

Table 4.15: Consumption effects of recurrent tax shocks on durable spending

	Constrained				**Unconstrained**			
Consumption	**Vehicle**	**Elec.**	**Comm.**	**Furnit.**	**Vehicle**	**Elec.**	**Comm.**	**Furnit.**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(a) Below 33rd as constrained; Above 67th as unconstrained								
Tax shocks	-0.92**	-0.41***	-0.04	-0.22	-0.14	-0.16	0.05	-0.01
	(0.36)	(0.12)	(0.04)	(0.13)	(0.15)	(0.11)	(0.03)	(0.09)
Observations	1,963	1,963	1,963	1,963	2,043	2,043	2,043	2,043
No. of households	605	605	605	605	541	541	541	541
Adj. R-squared	0.00	0.02	0.02	0.03	0.02	0.02	0.06	0.02
(b) Below median as constrained; Above median as unconstrained								
Tax shocks	-0.58***	-0.37**	-0.01	-0.16	-0.36	-0.13	0.00	-0.09
	(0.19)	(0.13)	(0.03)	(0.12)	(0.38)	(0.11)	(0.04)	(0.13)
Observations	2,979	2,979	2,979	2,979	3,087	3,087	3,087	3,087
No. of households	895	895	895	895	818	818	818	818
Adj. R-squared	0.00	0.02	0.02	0.02	0.01	0.02	0.04	0.01
House controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household FEts	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region-year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Fixed-effect estimations of Eq.4.2. Robust standard errors clustered by regions in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 4.16: Consumption effects of recurrent tax shocks on durable spending: Interaction approach

Consumption	**Vehicle**	**Elec.**	**Comm.**	**Furnit.**
	(1)	(2)	(3)	(4)
Dependent variable: Consumption				
Tax shocks	-0.61*	-0.31***	-0.03	-0.18***
	(0.29)	(0.08)	(0.03)	(0.05)
Tax shocks * Liquid asset balance ratio	0.13***	0.10***	0.01	0.05***
	(0.03)	(0.01)	(0.01)	(0.02)
Liquid asset balance ratio	-0.79	-1.24	-0.11	0.03
	(2.86)	(1.19)	(0.32)	(0.88)
Household Characteristics	Yes	Yes	Yes	Yes
Household Fixed Effects	Yes	Yes	Yes	Yes
Region-year Fixed Effects	Yes	Yes	Yes	Yes
Observations	6,067	6,067	6,067	6,067
No. of households	1,713	1,713	1,713	1,713
Adj. R-squared	0.00	0.01	0.03	0.01

Notes: Fixed-effect estimations of Eq.4.3. Robust standard errors clustered by regions in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 4.17: Tax effects: Using other conditional factors

Consumption	**Total**	**Durable (I)**	**Non-Durable (C)**	**I/C**
	(1)	(2)	(3)	(4)
(a) Housing tenure				
Tax shocks	-1.90**	-1.17***	-0.73	-0.02***
	(0.72)	(0.17)	(0.68)	(0.00)
Tax shocks * Outright owner dummy	1.69	1.13***	0.57	0.03*
	(1.75)	(0.26)	(1.76)	(0.01)
Adj. R-squared	0.13	0.00	0.15	0.00
(b) Debt-to-Income ratio				
Tax shocks	-1.45	-0.70**	-0.75	-0.01
	(1.27)	(0.29)	(1.12)	(0.01)
Tax shocks * Debt-to-Income ratio $(t-1)$	-0.06	-0.03*	-0.03	-0.00**
	(0.04)	(0.01)	(0.04)	(0.00)
Adj. R-squared	0.13	0.00	0.15	0.00
(c) Leverage ratio				
Tax shocks	-1.22	-0.71**	-0.51	-0.01
	(1.11)	(0.24)	(1.03)	(0.01)
Tax shocks * Leverage ratio $(t-1)$	0.11	0.03	0.08	0.00
	(0.18)	(0.05)	(0.14)	(0.00)
Adj. R-squared	0.13	0.00	0.15	0.00
Observations	6,067(5)	6,067(5)	6,067(5)	6,067(5)
No. of households	1,713	1,713	1,713	1,713
Household characteristics	Yes	Yes	Yes	Yes
Household Fixed Effects	Yes	Yes	Yes	Yes
Region-year Fixed Effects	Yes	Yes	Yes	Yes

Notes: Fixed-effect estimations of variant of Eq.4.3. Observations for each estimation are 6,067, except for Panel (c) where observations are 6,065. Robust standard errors clustered by regions in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Bibliography

Aaronson, D., Agarwal, S., and French, E. (2012). The spending and debt response to minimum wage hikes. *The American Economic Review*, 102(7):3111–3139.

Acosta-Ormaechea, S. and Morozumi, A. (2017). Public spending reallocations and economic growth across different income levels. *Economic inquiry*, 55(1):98–114.

Acosta-Ormaechea, S., Sola, S., and Yoo, J. (2019). Tax composition and growth: A broad cross-country perspective. *German Economic Review*, 20(4):e70–e106.

Agarwal, S. and Qian, W. (2014). Consumption and debt response to unanticipated income shocks: Evidence from a natural experiment in singapore. *American Economic Review*, 104:4205–30.

Agénor, P.-R. and Jackson, T. P. (2022). Monetary and macroprudential policy coordination with biased preferences. *Journal of Economic Dynamics & Control*, 144:104519.

Aikman, D., Giese, J., Kapadia, S., and McLeay, M. (2023). Targeting financial stability: Macroprudential or monetary policy? *International Journal of Central Banking*, 19(1):159–241.

Akgun, O., Cournède, B., and Fournier, J.-M. (2017). The effects of the tax mix on inequality and growth. OECD Economics Department Working Papers No.1447.

Alam, Z., Alter, A., Eiseman, J., Gelos, G., Kang, H., Narita, M., Nier, E., and Wang, N. (2019). Digging deeper-evidence on the effects of macroprudential policies from a new database. IMF Working Paper 19/66.

Alpanda, S. and Zubairy, S. (2016). Housing and tax policy. *Journal of Money, Credit and Banking*, 48:458–512.

Alpanda, S. and Zubairy, S. (2017). Addressing household indebtedness: Monetary, fiscal or macroprudential policy? *European Economic Review*, 92:47–73.

An, Z., Kangur, A., and Papageorgiou, C. (2019). On the substitution of private and public capital in production. *European Economic Review*, 118:296–311.

Andrés, J., Boscá, J., Ferri, J., and Fuentes-Albero, C. (2022). Households' balance sheets and the effects of fiscal policy. *Journal of Money, Credit and Banking*, 54(4):737–778.

Angelini, P., Neri, S., and Panetta, F. (2014). The interaction between capital requirements and monetary policy. *Journal of Money, Credit and Banking*, 46(6):1073–1112.

Arnold, J. M., Brys, B., Heady, C., Johansson, Å., Schwellnus, C., and Vartia, L. (2011). Tax policy for economic recovery and growth. *Economic Journal*, 121:F59–F80.

Asimakopoulos, P. and Asimakopoulos, S. (2019). Fiscal policy with banks and financial frictions. *Journal of Financial Stability*, 40:94–109.

Bae, B. H. (2013). The role of financial factors in the business cycle and the transmission of monetary policy in korea (in korean). Working Papers. Economic Research Institute, Bank of Korea.

Baiardi, D., Profeta, P., Puglisi, R., and Scabrosetti, S. (2019). Tax policy and economic growth: Does it really matter? *International Tax and Public Finance*, 26:282–316.

Baier, S. L. and Glomm, G. (2001). Long-run growth and welfare effects of public policies with distortionary taxation. *Journal of Economic Dynamics & Control*, 25:2007–2042.

Baker, S. R. (2018). Debt and the response to household income shocks: Validation and application of linked financial account data. *Journal of Political Economy*, 126:4:1504–1557.

Bank of England (2016). The financial policy committee's approach to setting the countercyclical capital buffer. A Policy Statement.

Barro, R. (1978). Unanticipated money, output, and the price level in the united states. *Journal of Political Economy*, 86(4):549–580.

Bielecki, M. and Stähler, N. (2022). Labor tax reductions in europe: The role of property taxation. *Macroeconomic Dynamics*, 26(2):419–451.

Binder, M., Lieberknecht, P., Quintana, J., and Wieland, V. (2018). Robust macroprudential policy rules under model uncertainty. VfS Annual Conference 2018 (Freiburg, Breisgau): Digital Economy, Verein für Socialpolitik / German Economic Association.

Blanchard, O., Dell'ariccia, G., and Mauro, P. (2010). Rethinking macroeconomic policy. *Journal of Money, Credit and Banking*, 42(s1):199–215.

Blanchard, O. and Perotti, R. (2002). An empirical characterization of the dynamic effects of changes in government spending and taxes on output. *Quarterly Journal of Economics*, 117(4):1329–1368.

Borio, C., Farag, M., and Zampolli, F. (2023). Tackling the fiscal policy-financial stability nexus. BIS Working Papers No. 1090.

Bratsiotis, G. J. and Gloria, M. (2024). Pandemic shocks and macroprudential policy. *Oxford Economic Papers*, page gpae040. Available at: https://doi.org/10.1093/oep/gpae040.

Bratsiotis, G. J. and Pathirage, K. D. (2023). Monetary and macroprudential policy and welfare in an estimated four-agent new keynesian model. *Journal of Money, Credit and Banking*.

Bremus, F. and Huber, J. (2016). Corporate taxation, leverage, and macroeconomic stability. DIW Roundup: Politik im Fokus 93, DIW Berlin, German Institute for Economic Research.

Cashin, D. and Unayama, T. (2021). The spending and consumption response to a vat rate increase. *National Tax Journal*, 74(2):313–346.

Cerletti, E. A. and Pijoan-Mas, J. (2012). Durable goods, borrowing constraints and consumption insurance. CEMFI Working Paper No.1206.

Chah, E. Y., Ramey, V. A., and Starr, R. M. (1995). Liquidity constraints and intertemporal consumer optimization: Theory and evidence from durable goods. *Journal of Money, Credit and Banking*, 27(1):272–287.

Claessens, S. (2014). An overview of macroprudential policy tools. IMF Working Paper.

Cloyne, J. S. and Surico, P. (2017). Household debt and the dynamic effects of income tax changes. *Review of Economic Studies*, 84:45–81.

Colciago, A., Samarina, A., and de Haan, J. (2019). Central bank policies and income and wealth inequality: A survey. *Journal of Economic Surveys*, 33:1199–1231.

Corsetti, G., Meier, A., and Müller, G. J. (2012). What determines government spending multipliers? *Economic Policy*, 27:521–565.

Dallari, P., End, N., Miryugin, F., and Tieman, A. F. (2020). Pouring oil on fire: interest deductibility and corporate debt. *International Tax and Public Finance*, 27:1520–1556.

D'Auria, F. (2015). The effects of fiscal shocks in a new keynesian model with useful government spending. *Macroeconomic Dynamics*, 19(6):1380–1399.

De Fiore, F. and Uhlig, H. (2015). Corporate debt structure and the financial crisis. *Journal of Money, Credit and Banking*, 47:1571–1598.

de Mooij, R., Keen, M., and Orihara, M. (2015). Taxation, bank leverage, and financial crises. In de Mooij, R. and Nicodème, G., editors, *Taxation and Regulation of the Financial Sector*. The MIT Press, Cambridge, MA.

de Mooji, R. A. (2011). The tax elasticity of corporate debt: A synthesis of size and variations. IMF Working Paper.

de Mooji, R. A. and Hebous, S. (2018). Curbing corporate debt bias: Do limitations to interest deductibility work? *Journal of Banking and Finance*, 96:368–378.

Dees, S., Gebauer, S., Goncalves, T., and Thubin, C. (2022). The financing structure of non-financial corporations and macro-financial implications in france. Banque de France, Working Paper 880.

Drehmann, M., Borio, C., Gambacorta, L., Jiminez, G., and Trucharte, C. (2010). Countercyclical capital buffers: exploring options. BIS Working Papers No. 317.

Dynan, K. (2012). Is a household debt overhang holding back consumption. Brookings Papers on Economic Activity, Economic Studies Program, The Brookings Institution, vol. 43(1 (Spring), pages 299-362.

Economides, G., Park, H., Philippopoulos, A., and Sakkas, S. (2022). On the mix of government expenditure and tax revenues. *Macroeconomic Dynamics*, 26(1):1–48.

European Commission (2013). Communication from the commission: Annual growth survey 2014. SWD(2013) 800 final.

Fatica, S., Heynderickx, W., and Pagano, A. (2020). Banks, debt and risk: assessing the spillovers of corporate taxes. *Economic Inquiry*, 58:1023–1044.

Feld, L. P., Heckemeyer, J. H., and Overesch, M. (2013). Capital structure choice and company taxation: A meta-study. *Journal of Banking & Finance*, 37(8):2850–2866.

Forster, R. and Sun, X. (2022). Taming the housing crisis: An ltv macroprudential policy. *Economic Modelling*, 108:105761.

Ganong, P. and Noel, P. (2020). Liquidity versus wealth in household debt obligations: Evidence from housing policy in the great recession. *American Economic Review*, 110(10):3100–3138.

Gebauer, S. and Mazelis, F. (2023). Macroprudential regulation and leakage to the shadow banking sector. *European Economic Review*, 154:104404.

Georgescu, O.-M. and Martín, D. V. (2021). Do macroprudential measures increase inequality? evidence from the euro area household survey. Working Paper Series, European Central Bank.

Gerali, A., Neri, S., Sessa, L., and Signoretti, F. M. (2010). Credit and banking in a dsge model of the euro area. *Journal of Money, Credit and Banking*, 42(s1):107–141.

Ghiaie, H. and Rouillard, J.-F. (2022). Housing tax expenditures and financial intermediation. *Canadian Journal of Economics/Revue canadienne d'économique*, 55(2):937–970.

Grjebine, T., Szczerbowicz, U., and Tripier, F. (2018). Corporate debt structure and economic recoveries. *European Economic Review*, 101:77–100.

Guo, F., Kit-Ming Yan, I., Chen, T., and Hu, C.-T. (2023). Fiscal multipliers, monetary efficacy, and hand-to-mouth households. *Journal of International Money and Finance*, 130:102743.

Guo, S. and Jiang, Z. (2021). The welfare implications of housing-related tax policy in china. *International Review of Economics & Finance*, 72:135–153.

Hecker, D., Jang, H., Rubio, M., and Verona, F. (2023). Robust design of countercyclical capital buffer rules. Manuscript submitted for publication.

Hohberger, S., Priftis, R., and Vogel, L. (2020). The distributional effects of conventional monetary policy and quantitative easing: Evidence from an estimated dsge model. *Journal of Banking and Finance*, 113:105483.

Holm-Hadulla, F. and Thürwächter, C. (2021). Heterogeneity in corporate debt structures and the transmission of monetary policy. *European Economic Review*, 136:103743.

Hubert, M. and Vandervieren, E. (2008). An adjusted boxplot for skewed distributions. *Computational Statistics & Data Analysis*, 52(12):5186–5201.

Hwang, S. and Jung, W. (2014). 부동산시장 변화와 소비간의 관계 분석 (analysis on the relationship between changes in the real estate market and consumption, in korean). BOK Issue Note 2014-11.

Iacoviello, M. (2005). House prices, borrowing constraints, and monetary policy in the business cycle. *American Economic Review*, 95(3):739–764.

Iacoviello, M. and Neri, S. (2010). Housing market spillovers: Evidence from an estimated dsge model. *American Economic Journal: Macroeconomics*, 2(2):125–64.

IMF (2016). Tax policy, leverage and macroeconomic stability. IMF Policy Paper 16/151, International Monetary Fund, Washington, DC.

IMF (2019). Imf technical assistance report - reform options to strengthen tax policy: Maldives. IMF Country Report No.19/196.

Jappelli, T. and Pistaferri, L. (2014). Fiscal policy and mpc heterogeneity. *American Economic Journal: Macroeconomics*, 6(4):107–136.

Jermann, U. and Quadrini, V. (2012). Macroeconomic effects of financial shocks. *American Economic Review*, 102(1):238–71.

Johansson, Å., Heady, C., Arnold, J. M., Brys, B., and Vartia, L. (2008). Taxation and economic growth. OECD Economics Department Working Papers.

Jordá, Ó., Schularick, M., and Taylor, A. M. (2016). The great mortgaging: housing finance, crises and business cycles. *Economic Policy*, 31(85):107–152.

Jung, J., Lee, H., and Song, K.-h. (2020). Public finance responses to covid-19 in korea. *National Tax Journal*, 73(3):879–900.

Jung, Y. and Mok, J. (2019). Implementable, optimal macroprudential and monetary policies: Implications for house prices and household debt. *Journal of Economic Theory and Econometrics*, 30(1):33–58.

Kaplan, G. and Violante, G. L. (2014). A model of the consumption response to fiscal stimulus payments. *Econometrica*, 82(4):1199–1239.

Kaplan, G., Violante, G. L., and Weidner, J. (2014). The wealth hand-to-mouth. *Brookings Papers on Economic Activity*, 45(1):77–153.

Kim, S., Shim, S., and Chen, H. (2023). Effects and conduct of macroprudential policy in china. *Journal of Financial Stability*, 66:101124.

Kiyotaki, N. and Moore, J. (1997). Credit cycles. *Journal of Political Economy*, 105(2):211–248.

Kneller, R., Bleaney, M. F., and Gemmell, N. (1999). Fiscal policy and growth: evidence from oecd countries. *Journal of Public Economics*, 74:171–190.

Kreiner, C. T., Lassen, D. D., and Leth-Petersen, S. (2019). Liquidity constraint tightness and consumer responses to fiscal stimulus policy. *American Economic Journal: Economic Policy*, 11(1):351–379.

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

Langedijk, S., Nicodème, G., Rossi, A., and Pagano, A. (2015). Debt bias in corporate income taxation and the costs of banking crises. CEPR Discussion Papers.

Li, S. and Lin, S. (2023). Housing property tax, economic growth, and intergenerational welfare: The case of china. *International Review of Economics & Finance*, 83:233–251.

Lozej, M., Onorante, L., and Rannenberg, A. (2023). Countercyclical capital regulation in a small open economy dsge model. *Macroeconomic Dynamics*, 27(5):1230–1267.

Malmierca, M. (2023). Optimal macroprudential and fiscal policy in a monetary union. *Economic Modelling*, 122:106238.

Mankiw, N. G., Weinzierl, M., and Yagan, D. (2009). Optimal taxation in theory and practice. *Journal of Economic Perspectives*, 23(4):147–74.

McManus, R., Ozkan, F. G., and Trzeciakiewicz, D. (2021). Fiscal consolidations and distributional effects: which form of fiscal austerity is least harmful? *Oxford Economic Papers*, 73(1):317–349.

McMillen, D. P. and Weber, R. N. (2008). Thin markets and property tax inequities: A multinomial logit approach. *National Tax Journal*, 61(4):653–671.

McNabb, K. (2018). Tax structures and economic growth: New evidence from the government revenue dataset. *Journal of International Development*, 30:173–205.

Miyamoto, W., Nguyen, T. L., and Sergeyev, D. (2018). Government spending multipliers under the zero lower bound: Evidence from japan. *American Economic Journal: Macroeconomics*, 10(3):247–277.

Mora-Sanguinetti, J. S. and Rubio, M. (2014). Recent reforms in spanish housing markets: An evaluation using a dsge model. *Economic Modelling*, 44(S1):42–29.

Müller, K. and Verner, E. (2023). Credit allocation and macroeconomic fluctuations. *The Review of Economic Studies*, page rdad112.

Nakatani, R. (2022). Optimal fiscal policy in the automated economy. University Library of Munich, Germany, MPRA paper.

Norregaard, J. (2013). Taxing immovable property. IMF Working Paper 13/129.

O'Brien, Y.-Y. C. (2007). Measurement of monetary aggregates across countries. Staff working paper, Finance and Economics Discussion Series, Federal Reserve Board, Washington, D.C.

OECD (2015). Oecd economic surveys: Italy 2015. OECD Publishing, Paris, http://dx.doi.org/10.1787/eco_surveys-ita-2015-en.

OECD (2021). Making property tax reform happen in china: A review of property tax design and reform experiences in oecd countries, oecd fiscal federalism studies. OECD Publishing, Paris, https://doi.org/10.1787/bd0fbae3-en.

OECD (2022). Housing taxation in oecd countries. OECD Publishing, Paris, https://doi.org/10.1787/03dfe007-en.

Ogawa, K. and Wan, J. (2007). Households debt and consumption: A quantitative analysis based on household micro data for japan. *Journal of Housing Economics*, 16:127–142.

Paetzold, J. and Tiefenbacher, M. (2018). Distributional and revenue effects of a tax shift from labor to property. *International Tax and Public Finance*, 25:1215–1251.

Park, C. and Song, S. (2013). 기업단위 가격의 경직성 분석: 2012년 서베이 자료를 중심으로 (price rigidity in korea: Evidence

from firm-level data, in korean). Bank of Korea Working Paper 2013-16, Available at SSRN: https://ssrn.com/abstract=2579531 or http://dx.doi.org/10.2139/ssrn.2579531.

Park, K. Y. (2017). The wealthy hand-to-mouth households in south korea. *Global Economic Review*, 46(3):299–324.

Parker, J. A., Souleles, N. S., Johnson, D. S., and McClelland, R. (2013). Consumption spending and the economic stimulus payment of 2008. *American Economic Review*, 103(6):2530–2553.

Patel, N. (2017). Macroprudential frameworks: Communication. BIS papers No. 94.

Rabanal, P. (2018). An estimated dsge model to analyze housing market policies in hong kong sar. IMF Working Papers.

Ramey, V. A. (2011). Identifying government spending shocks: It's all in the timing. *Quarterly Journal of Economics*, 126(1):1–50.

Richter, B., Schularick, M., and Shim, I. (2019). The costs of macroprudential policy. *Journal of International Economics*, 118:263–282.

Rubaszek, M. and Rubio, M. (2020). Does the rental housing market stabilize the economy? a micro and macro perspective. *Empirical Economics*, 59:233–257.

Rubio, M. (2019). Rented vs. owner-occupied housing and monetary policy. *The B.E. Journal of Macroeconomics*, 19:1–16.

Rubio, M. and Carrasco-Gallego, J. A. (2014). Macroprudential and monetary policies: Implications for financial stability and welfare. *Journal of Banking & Finance*, 49:326–336.

Rubio, M. and Unsal, D. F. (2020). Macroprudential policy under incomplete information. *The European Journal of Finance*, 26(7-8):619–639.

Rubio, M. and Yao, F. (2020). Bank capital, financial stability and basel regulation in a low interest-rate environment. *International Review of Economics & Finance*, 67:378–392.

Schuberth, H. (2013). Tax policies and financial stability: Lessons from the crisis. In Braude, J., Eckstein, Z., Fischer, S., and Flug, K., editors, *The Great Recession: Lessons for Central Bankers*, pages 123–162. The MIT Press.

Stähler, N. (2019). Who benefits from using property taxes to finance a labor tax wedge reduction? *Journal of Housing Economics*, 46:1051–1377.

Sun, X. and Tsang, K. P. (2017). What drives the owner-occupied and rental housing markets? evidence from an estimated dsge model. *Journal of Money, Credit and Banking*, 49(2-3):443–468.

Surico, P. and Trezzi, R. (2019). Consumer spending and property taxes. *Journal of the European Economic Association*, 17(2):606–649.

Xiang, H. (2022). Corporate debt choice and bank capital regulation. *Journal of Economic Dynamics and Control*, 144:104506.

Zeldes, S. P. (1989). Consumption and liquidity constraints: An empirical investigation. *Journal of Political Economy*, 97:305–346.

Zhang, L. and Zoli, E. (2016). Leaning against the wind: Macroprudential policy in asia. *Journal of Asian Economics*, 42:33–52.