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Sven Schnellbacher

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Contents

List of Abbreviations

ARDL	Autoregressive distributed lag
AUT	Austria
BEL	Belgium
BIS	Bank for International Settlements
BLev	Bank leverage
CBOE	Chicago board options exchange
CPI	Consumer price index
DEU	Germany
DSGE	Dynamic stochastic general equilibrium
ECB	European Central Bank
ESP	Spain
EST	Estonia
FIN	Finland
FINOP	Financial openness
FRA	France
FRED	Federal Reserve Economic Data
GDP	Gross domestic product
GRC	Greece
HLev	Household leverage
HP	Housing prices
IMF	International Monetary Fund
IR	Impulse response
IRF	Impulse response function
IRL	Ireland
ITA	Italy
KOF	Konjunkturforschungsstelle
LR	Long-term interest rate

MFI	Monetary financial institutions
NLD	Netherlands
OECD	Organisation for Economic Co-operation and Development
PCHVAR	Panel conditionally homogenous vector autoregressive
PRT	Portugal
SR	Short-term interest rate
SVAR	Structural vector autoregressive
VAR	Vector autoregressive
VIX	CBOE volatility index
WDI	World Development Indicators

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Summary

Large movements in asset prices can have severe consequences for the stability of the financial system and the macroeconomy. This confronts central banks with the question of which policy response is appropriate to address large swings in asset prices and stabilize macroeconomic fluctuations. Such monetary policy decisions are especially challenging in currency unions, such as the Eurozone, as changes in the monetary policy rate can impact the member economies differently. As highlighted by the academic literature, the asymmetric reactions to common monetary policy decisions depend on the underlying structural characteristics of the individual member economies including the structure of the financial system and sectoral differences (Assenmacher-Wesche and Gerlach 2008; Georgiadis 2014, 2015). However, such structural characteristics are not constant but may change over time. Over recent decades global economies experienced major increases in the leverage levels of the financial and household sector as well as in the degree of financial openness (Lane and Milesi-Ferretti 2007; Jordá et al. 2013, 2017; Schularick and Taylor 2012). This raises the question as to whether these developments have any sizable impact on the transmission of monetary policy.

Indeed, global economies experienced rapid surges in private as well as public debt over the past decades. According to a report published by the Centre for Economic Policy Research and the International Center for Monetary and Banking Studies, private and public debt in developed economies approached more than 250% of GDP. In developing economies private and public debt-to-GDP ratios have risen to 150% (Boone et al. 2022). These ever surging levels of debt raise concerns about their potentially destabilizing impact on global financial systems. The global financial crisis of 2007-2009 is an event of utmost importance in the more recent macroeconomic history. While the financial crisis of 2007-2009 was driven by extensive increases in private debt it revealed major imbalances in financial systems of advanced and emerging market economies around the world. These imbalances were driven by an increase in financial sector leverage which came about through a rise in lending activities of financial intermediaries. Indeed, research by Jordà et al. (2017) highlights the rise in credit-to-GDP ratios in major advanced economies over the second half of the twentieth and the beginning of the twenty-first century. Along similar lines, Schularick and Taylor (2012) refer to an increased importance of credit for the dynamics of the business cycle which is especially observable since the 1970s in which financial leverage began to increase steadily. Referring to the possible consequences for financial stability, they point to an increased probability of a financial crisis once credit growth has reached a threshold level beyond which it becomes unsustainable. This potentially destabilizing role of build-ups in credit is confirmed by Jordà et al. (2013) who show that credit expansions that lead to a financial crisis are followed by recessions that are deeper and last longer. Given this empirical evidence, it seems obvious that the role of credit for macroeconomic and financial stability has increased over recent decades.

The rise in financial sector leverage over the past decades has been accompanied by an increase in household leverage during the same time span. This increase in household debt is to a major extent driven by an increase in mortgage lending to private households (Jordà et al. 2017). The rise in mortgage debt reflects a larger scale change in lending practices of financial intermediaries. This change is characterized by a shift from business lending to real estate lending and has led to a change in the composition of bank balance sheets (Bezemer et al. 2020). The expansion in household debt and changes in lending practices of financial intermediaries entail risks to financial stability, however. As highlighted by Jordà et al. (2016) recessions preceded by an extensive expansion in mortgage lending tend to have more severe implications for the macroeconomy. Potential risks stemming from rising household leverage ratios include increased default risks after negative income shocks, declining collateral values due to decreasing housing prices as well as an increased vulnerability of the banking sector when household debt exceeds sustainable levels (Kuhn et al. 2020; Zinman 2015).

Besides surges in the leverage levels of the financial and household sectors, global economies have experienced a sharp rise in international financial integration with an especially pronounced upswing since the middle of the 1990s (Lane and Milesi-Ferretti 2007; Milesi-Ferretti and Tille 2011). Some years later, global capital flows increased rapidly in the run-up to the financial crisis of 2007-2009 and declined sharply during the crisis period (Forbes and Warnock 2012). This rapid rise in international capital flows led to elevated risks of financial fragility triggered by an increase in risk-aversion of international investors and a subsequent retrenchment of capital flows (Shin 2012). This retrenchment of capital flows brought about marked financial instabilities such as major declines in asset prices (Milesi-Ferretti and Tille 2011).

Over the last decades, the development, notably of advanced economies, is further characterized by a steady increase in public debt. Public debt levels experienced rapid surges particularly in times of crisis such as through the global financial crisis or the Covid-19 crisis (Boone et al. 2022; Eichengreen et al. 2021). In addition to public debt, income inequality in advanced economies has risen, too (Atkinson et al. 2011). Although developments in public debt and income distribution are closely linked to each other the academic literature offers only limited insights into a possible nexus between the two. Existing studies point out that a complete understanding of the interaction between public debt and income distribution requires an analysis based on a broader macroeconomic setting which includes factors such as interest rates and economic growth (Azzimonti et al. 2014; Hein 2018; You and Dutt 1996). This highlights the necessity to consider more recent macroeconomic trends. Slowing growth performance in major advanced economies triggered a renewed interest in the study of trends in aggregate saving and investment and its economic consequences (Summers 2014, 2015; Weizsäcker and Krämer 2021). It is argued that changing demographics and technological changes result in a higher propensity to save of private households driving a wedge between aggregate saving and investment decisions (Weizsäcker and Krämer 2021). This imbalance in aggregate saving and investment is said to lower the long-term path of equilibrium real interest rates in major advanced economies (Summers 2014). Whether and to what extent public debt has distributional consequences relies therefore, on factors such as saving and investment decisions and their impact on economic growth and interest rates (You and Dutt 1996).

As already noted, in addition to the above mentioned developments regarding debt levels in global economies, the past decades have further been characterized by an increase in the inequality of income distribution. Following insights by the World Inequality Report, the top 10% income earners of the global population own 52% of global income in the year 2021 (Chancel et al. 2022). This concentration of income at the top of the income distribution is the result of a longer term upward trend which is especially pronounced since the 1970s (Atkinson et al. 2011; Piketty and Saez 2007; Saez and Zucman 2020). The rise in income inequality has led to an increasing interest in the examination of its determinants and consequences. The growing academic literature can be divided into different strands each concerned with the interdependencies of income inequality and the broader macroeconomy. One such strand focuses on the interaction between income inequality and economic growth. The central question asked is whether income inequality promotes or hampers economic growth. While some studies highlight the growth enhancing effects of inequality (Forbes 2000; Li and Zou 1998; da Silva and Alves 2020) others point to the detrimental effects of inequality on economic growth (Alesina and Rodrik 1994; Perotti 1996; Persson and Tabellini 1994) which points out that the literature provides no clear conclusion regarding the growth inequality nexus (Neves and Silva 2014).

Besides this direct linkage between income inequality and economic growth, there is further interest in the impact of financial development on the distribution of income. For instance, Galor and Zeira (1993), Banerjee and Newman (1993) as well as Galor and Moav (2004) stress that more developed financial systems promote a reduction in income inequality. This reduction in income inequality is driven by an increased efficiency of financial services as well as a reduction of financial frictions for those parts of the society who were previously not part of the financial system, known as the *extensive margin* effect (Čihák and Sahay 2020). By contrast, Gimet and Lagoarde-Segot (2011), Seven and Coskun (2016) and Jauch and Watzka (2016) find that more developed financial systems increase income inequality. This increase in income inequality is based on the *intensive margin* effect as improvements in financial services benefit only those groups of the society who are already part of the financial system (Čihák and Sahay 2020). Additionally, the literature on the finance-inequality nexus offers evidence for a non-linear relationship between financial development and income inequality. Research by Brei et al. (2023) shows that financial development decreases income inequality up to a threshold level of financial development. Above that threshold income inequality increases. However, this non-linear relationship applies only to market based financing compared to bank based financing. Thus, as highlighted by Brei et al. (2023), the picture emerges that different forms of financial development exert a different impact on the distribution of income.

In addition to the examination of the link between financial development and income distribution, empirical and theoretical studies have further explored the interaction of financial development and economic growth. For instance, empirical evidence by King and Levine (1993) and Levine (2000) reveals a positive relationship between financial development and economic growth. On the other hand, Gantman and Dabós (2012) as well as Shan (2005) do not find empirical evidence for the growth enhancing effects of financial development. Further evidence by Rioja and Valev (2004) shows a non-linear relationship between financial development and economic growth. While financial development seems to have only a limited impact on economic growth in financially less developed countries, more developed financial systems seem to support economic growth, especially in middle-income countries (Rioja and Valev 2004).

Influenced by the above mentioned developments in the shorter macroeconomic history, the three chapters of this dissertation are guided by the following research questions:

- What impact do structural shifts in bank leverage, household debt and financial openness have on the transmission of monetary policy?
- What are the distributional effects of government debt?
- How do different types of financial development affect the interaction between economic growth and income inequality?

This dissertation contributes to the academic literature in three different ways. First, it provides empirical evidence for the relevance of household indebtedness, risk-taking by the banking sector and financial globalization for the monetary policy transmission mechanism. Second, it analyzes the nexus between government debt and income distribution by means of a comprehensive model-theoretic framework which takes interest rate and growth dynamics into account. Third, it empirically examines the impact of different types of financial development, such as easier access to and increased efficiency of financial services as well as a more liquid banking system and stock market, on the relationship between economic growth and income inequality.

The dissertation at hand uses time series data from multiple data sources. Chapter 1 draws on macroeconomic data on real gross domestic product, real housing prices and the short-term interest rate from the Organisation for Economic Co-operation and Development database. Banking sector leverage is computed with time series on equity, loans, currency and deposits as well as debt securities of monetary financial institutions in the Eurozone. The time series are obtained from the European Central Bank Data Warehouse. Household leverage is measured by the household credit-to-GDP ratio from the Bank for International Settlements statistics database. The financial globalisation subindex of the globalisation index by Gygli et al. (2019) provides a measure for financial openness. This index measures de facto financial globalization and includes a wide range of capital flows. Global risk aversion is measured by the VIX volatility index of the Chicago Board Options Exchange. The empirical examination in Chapter 3 relies on macroeconomic data from the World Bank. Income inequality is measured by the pre-tax Gini coefficient obtained from the Standardized World Income Inequality Database by Solt (2019). This index provides an average measure of income inequality and ranges from 0 (perfect equality) to 100 (perfect inequality). As the Gini coefficient underestimates changes at the tails of the income distribution (Atkinson 1970), additional data on income shares of the top 10% and bottom 10% of the income distribution from the World Bank is used. Moreover, a measure of the income share of the middle 60% of the income distribution is computed by subtracting the top 20% income share and the bottom 20% income share from 100. Financial development is measured by the Financial Development Index from Sahay et al. (2015). This index consists of several subindices measuring the depth, access to and efficiency of financial institutions and financial markets.

The vector autoregressive approach provides the methodological framework of the empirical chapters in this dissertation. Chapter 1 uses structural vector autoregressive models to examine the interaction between real GDP, real housing prices and the short-term interest rate. The shocks are identified recursively (Lütkepohl 2005). Additionally, the first chapter uses the panel conditionally homogenous vector autoregressive model developed by Georgiadis (2012). This modeling approach allows the estimated reduced form coefficients to vary according to unit-specific characteristics. Consequently, it is an appropriate methodology to measure heterogeneities in the underlying panel data that are due to unit-specific characteristics. The shocks are identified by a Choleski decomposition scheme (Lütkepohl 2005). The panel conditionally homogenous vector autoregressive model is also used in chapter 3 of this dissertation. Chapter 2 builds on the post-Keynesian model by You and Dutt (1996). This model provides a basic theoretical framework to analyze the distributional effects of government debt in a broader macroeconomic setting.

Chapter 1 of this dissertation sheds light on cross-country asymmetries in the transmission of monetary policy shocks in the context of a currency union. It builds on previous research by Georgiadis (2014) and Georgiadis (2015) which shows significant asymmetries in the transmission of monetary policy shocks across a panel of Eurozone economies due to country-specific structural characteristics regarding the manufacturing sector and the financial system. The chapter empirically examines the importance of household indebtedness, bank risk-taking and financial globalization for the transmission of monetary policy shocks to output and housing prices. It relies on panel data for twelve Eurozone economies ranging from 1999Q2 to 2018Q4. The econometric analysis shows that the intensity of the decrease in real housing prices after a contractionary monetary policy shock increases with the leverage levels of the banking and household sectors. Moreover, a higher level of financial openness induces a stronger contraction in real GDP growth and a larger fall in real housing prices after a contractionary monetary policy shock. A deeper empirical analysis reveals that the level of financial openness explains an average of 66% of the decline in real GDP growth and 55% of the fall in real housing prices. The level of bank leverage is responsible for 60% of the decline in real GDP growth and 55% of the fall in real housing prices. Furthermore, an average of 33% of the decrease in the growth rate of real GDP and 44% of the fall in real housing prices is attributable to the level of household leverage. These results show that financial globalization is a major determinant of the transmission of monetary policy shocks to the real economy. By contrast, the leverage level of the banking sector is an important factor in shaping the transmission of monetary policy shocks to the financial side of the economy.

Chapter 2 examines the linkages between income distribution and government debt. It draws on previous research by Pasinetti (1989) and You and Dutt (1996) which shows that economic growth and the interest rate are major determinants of this relationship. It also addresses the implications of variations in government spending, investment, tax rates and the real interest rate for the link between government debt and income distribution. The chapter extends the theoretical model of You and Dutt (1996) by assuming that not only capitalists but also workers save a fraction of their disposable income and hold government bonds. Additionally, compared to the previous literature, which focused the analysis on the functional distribution of income, the model in chapter 2 also includes the personal distribution of income. In addition, the model in chapter 2 takes the interest-growth differential into account. A comparative static analysis reveals that an increase in government spending increases the equilibrium rate of capacity utilization and the equilibrium rate of capital accumulation and raises the equilibrium public debt-to-capital ratio. An increase in investment also has expansionary effects but reduces the public debt-to-capital ratio in equilibrium. The consequences for income distribution are twofold. First, an increase in government spending increases income inequality in equilibrium as it increases the equilibrium public debt-to-capital ratio and the interest income of capitalists. Second, an increase in investment activity reduces income inequality in equilibrium as it increases the equilibrium capacity utilization rate. These effects are robust with respect to changes in the real interest rate.

Chapter 3 pays attention to the impact of financial development on the interaction between economic growth and income inequality. As a financial system can develop in different forms, such as through a better access of the population to financial services, through an increased liquidity of the financial system or through a reduction of financial frictions to increase the efficiency of financial institutions and markets, the focus lies on the relevance of different types of financial development for the growth-inequality-nexus (Sahay et al. 2015). The chapter uses different subcomponents of the financial development index from the IMF (Sahay et al. 2015) to measure multiple forms of financial development (access to, depth and efficiency of financial institutions and financial markets). The panel conditionally homogenous vector autoregressive model serves as the methodological framework to analyze a broad panel of annual macroeconomic data ranging from 1980 to 2016 and covering 110 advanced and emerging economies. The econometric results suggest that, in general, a higher level of financial development leads to a stronger reduction in income inequality after an increase in economic growth. By splitting the overall level of financial development into its subcomponents and using different income shares of the income distribution, the empirical analysis shows that economic growth increases the income share of the bottom 10% of the income distribution when financial institutions and financial markets are deeper and financial markets are more efficient. Further, an increase in the income share of the top 10% income earners exerts a stronger positive impact on economic growth when financial institutions are more efficient. Additionally, the chapter finds empirical support for the trickle-up hypothesis which states that increases in the income position of low income groups will be beneficial for economic development as aggregate demand increases (Thirlwall 1994). Further, albeit limited, evidence is found for the trickle-down mechanism, which highlights the positive impact of increases in top income shares for lower income classes through an enhancement of investment possibilities (Aghion and Bolton 1997).

Chapter 1

Leverage, Financial Openness, and the Transmission of Monetary Policy: Empirical Insights from the Euro Area[1]

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1.1 Introduction

Understanding the transmission of monetary policy shocks to the real and financial side of the economy is one of the most important fields in monetary economics. While the early empirical literature on monetary policy transmission used a single-country setup and often focused solely on the US economy (see e.g. Christiano et al. 1999), later studies such as Mihov (2001), Dedola and Lippi (2005) and Ciccarelli and Rebucci (2006) have undertaken a cross-country comparison of estimated single-country vector autoregressions. As pointed out by Peersman (2004), such comparisons are not always straightforward as the size of the monetary policy shocks and the reaction function of the monetary authority differ across countries.

The development of more appropriate vectorautoregressions facilitated a better understanding of the determinants of the monetary policy transmission mechanism by exploiting the cross-country dimension. This has led to further and more robust insights on the transmission mechanism in general, at the expense of cross-country insights, however. For instance, Assenmacher-Wesche and Gerlach (2008) use a panel vector autoregressive model estimated with data from seventeen advanced economies to study the role of financial structure, measured by indicators such as the level of the mortgage-debt-to-GDP ratio or the securitization of mortgages, in the transmission of monetary policy to output, inflation and asset prices. The findings reveal significant asymmetries in the transmission process between country-groups separated according to the above mentioned financial characteristics.

Recent studies, such as Georgiadis (2014) and Georgiadis (2015), have employed a cross-country setting to gain further insights into the transmission of monetary policy shocks. While focusing the empirical analysis on the euro area economies, they find significant asymmetries in the monetary policy transmission mechanism. These asymmetries arise because of cross-country differences in the composition of the manufacturing sector and the structure of the financial system. Short-run effects are driven by sectoral characteristics, whereas in the medium run labor market rigidities and financial structure seem to play a bigger role (Georgiadis 2014). Similarly, Mandler et al. (2021) use a Bayesian vector autoregressive model to study cross-country differences in monetary policy transmission across four large euro area countries. They find that, compared to the other countries, the stronger output response in Germany seems to be driven by the relative importance of the manufacturing sector, a higher share of exports in output, a less rigid labor market and a more fragmented banking sector.

Extensive research, e.g. by the European Central Bank, has highlighted the relative importance of the interest rate channel and the bank lending channel for the transmission of monetary policy shocks (Angeloni et al. 2003; Clements et al. 2001; Kashyap and Stein 1994). The relevance of the interest rate channel and the bank lending channel for the transmission mechanism depends on several characteristics underlying the economy. If interest sensitive sectors, like the manufacturing sector, contribute a higher share to domestic GDP, output and price dynamics seem to be shaped by the interest rate channel (Sala 2002). The significance of the bank lending channel is determined by the relative importance of bank funding compared to funding through capital markets (Bernanke and Gertler 1995).

By contrast, Borio and Zhu (2012) have highlighted the importance of the "risk-taking channel" of monetary policy transmission whereafter monetary policy affects the perceptions of risk and the resulting risk-taking behavior of financial intermediaries leading to fluctuations in the provision of liquidity. Bekaert et al. (2013) documents also the link between monetary policy and market risk measured by the VIX index. Adrian and Shin (2010) provide a possible explanation for the mechanism underlying the link between liquidity and market risk. Accordingly, changes in market risk are related to balance sheet adjustments by financial intermediaries which are due to changes in equity triggered by fluctuations in asset prices. In this sense, variations in financial leverage are procyclical. The risk-taking channel is not limited to the domestic economy, however. As argued by Bruno and Shin (2015) as well as Lee and Bowdler (2020), fluctuations in the leverage of financial intermediaries and the resulting variation in cross-border capital flows are central for spillovers of monetary policy shocks.

In the present paper, we use the panel conditionally homogenous vector autoregressive (PCHVAR) model from Georgiadis (2012) in order to contribute to recent findings. We condition the monetary policy transmission mechanism on the level of bank leverage, the level of household leverage and the degree of financial openness in order to study the significance of the risk-taking channel, the relevance of household indebtedness and the importance of cross-border capital flows in the transmission of monetary policy shocks to output and housing prices.

The remainder of this paper is organized as follows: Section 2 gives a brief overview on the choice of the conditioning variables. Section 3 outlines the methodological framework. Section 4 presents the empirical results along with several robustness checks. Finally, section 5 concludes.

1.2 On the Choice of the Conditioning Variables

Our choice of the conditioning variables is based on recent trends regarding structural changes of financial systems. The rise in cross-border capital flows observable over recent years has led to an increased interconnectedness of the economies around the world. As shown by Milesi-Ferretti and Tille (2011), such financial globalization is to a major extent driven by a rise in international bank flows between advanced economies, both through a rise in cross-border bank lending as well as through lending by foreign subsidiaries. This positive trend in financial integration was especially observable in the period preceding the global financial crisis, as European banks channeled liquidity to U.S. asset markets leading to the build-up of vulnerabilities in the real estate sector (Shin 2012). During the global financial crisis, the decline in gross capital flows was primarily driven by a reduction in cross-border bank flows. The intensity of the decline in capital inflows can be linked to macroeconomic factors such as the growth in the credit-to-GDP ratio and the level of gross external debt before the crisis (Eichengreen and Gupta 2017; Milesi-Ferretti and Tille 2011).

The high financial sector leverage experienced in recent decades is a possible threat for the stability of the macroeconomy. The evidence points to an increased importance of credit cycles for financial stability and an increasing role of credit in shaping the dynamics of the business cycle not only temporarily but as a recurrent phenomenon. Accordingly, the expansion in credit and the resulting rise in financial leverage results in a greater susceptibility of the financial system to shocks with severe negative implications for the real economy such as a decline in output and investment once financial instabilities unfold (Jordà et al. 2013; Schularick and Taylor 2012).

Regarding the composition of credit aggregates, it is observed that the importance of mortgage credit compared to business credit has risen over recent decades (Bezemer et al. 2016). This rise in the share of mortgage lending by financial intermediaries has led to a change in the composition of bank balance sheets and facilitated a change in banking practices (Jordà et al. 2016). The positive trend in mortgage lending was accompanied by rising household debt levels that exceeded the rise in asset values during the same time span leading to rising household leverage ratios (Jordà et al. 2017).

The expansion of household indebtedness and the rise of household leverage ratios have been a remarkable feature in most industrialized countries over the past decades (Zinman 2015). The rise in household debt poses several challenges for financial stability, however. First, if household debt exceeds sustainable levels, the risk of default after a negative income shock increases. Second, a negative shock to housing prices increases the fragility of the household sector as collateral values decline. Lastly, given the growing share of mortgages issued to private households on bank balance sheets, an increased fragility of the household sector diminishes the resilience of the banking sector as the quality of bank balance sheets declines (Jordà et al. 2016; Kuhn et al. 2020).

The left hand panel in the first row of figure 1.1 reveals considerable heterogeneities underlying the twelve euro area countries included in our empirical analysis with a decoupling of bank leverage in Ireland surrounding the financial crisis episode. A similar pattern is observable in the right hand panel of figure 1.1, which displays the level of household leverage in the twelve euro area countries. With Austria and Germany as an exception, it further shows a positive trend in household leverage until the beginning of the euro crisis. In addition to the high level regarding financial openness in the euro area, the panel in the second row of figure 1.1 shows a positive trend in financial globalization for the majority of the euro area countries until the start of the financial crisis period. Given these heterogeneities in the structural characteristics and their increasing role for the stability of the macroeconomy, we expect significant asymmetries in the transmission of monetary policy shocks across the individual euro area countries.

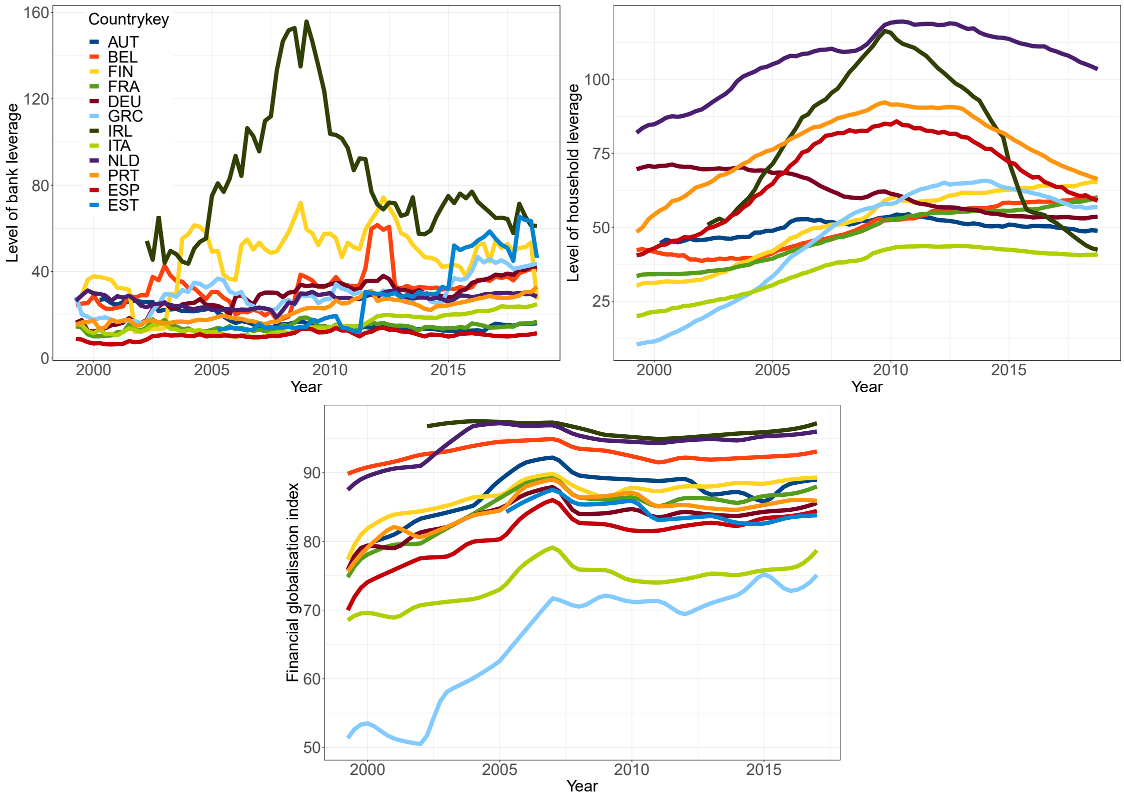

Figure 1.1: The left hand panel in row one plots the level of bank leverage measured as the ratio of financial assets over equity of monetary financial institutions in the twelve euro area countries included in the empirical analysis. The right hand panel in row one plots the level of household leverage measured as credit to households and non-profit institutions serving households to domestic GDP. The panel in row two plots the level of the KOF financial globalisation index.

1.3 Data and Methodology

1.3.1 Data Description

The data consists of quarterly time series of twelve euro area countries ranging from 1999Q2-2018Q4, which together account for 97% of euro area GDP.[2] Bank leverage is defined as the ratio of financial assets over equity of monetary financial institutions (MFI). Financial assets include currency and deposits, debt securities and loans (Lequiller and Blades 2014). Household leverage is measured by total credit to households and non-profit institutions serving households in relation to domestic GDP (Jordà et al. 2017).

According to the general convention in the literature, leverage and credit are endogenous. As we want to measure structural changes of the financial system, we need exogenous measures of bank leverage and the household credit-to-GDP ratio. In order to obtain weakly exogenous conditioning variables, we extract the trend component of the bank leverage and household credit-to-GDP time series by means of the Hodrick-Prescott filter. The underlying idea is that the trend component of the Hodrick-Prescott filter operates under a different frequency than the cyclical component. We assume that GDP and housing prices operate under the business cycle frequency. As we have quarterly time series, we choose a smoothing parameter of 1600. The resulting trend component of the bank leverage and household leverage time series should be roughly uncorrelated with the GDP growth and housing prices time series.

Financial openness is measured with the financial globalization subindex of the KOF Globalisation Index. The KOF financial globalization subindex is available for a wide range of economies. It covers a long time span ranging from 1970 to 2017 and is updated on a yearly basis. The subindex measures de facto financial globalization covering a wide range of capital flow categories. Specifically, the index comprises foreign direct investment, portfolio investment and debt flows as well as reserves and primary income payments (Gygli et al. 2019). The index is interpolated from yearly to quarterly frequency. The VIX index of the Chicago Board Options Exchange is included as a common exogenous variable and serves as a proxy for the degree of global risk aversion.

The real GDP and real housing prices series are measured in quarter-to-quarter percentage changes. Outliers larger than three times the interquartile range are replaced by the median value of the respective time series. The VIX index is in logs. The short-term interest rate, MFI leverage, household leverage and the KOF financial globalization index are in levels.

Table (1) summarizes the variables and their transformations. The augmented Dickey-Fuller, Philips-Perron and Kwiatkowski-Philips-Schmidt-Shin test results regarding the stationarity of the

[2] Table 1.3 in the appendix shows a complete list of countries included in the econometric analysis. The time series used including their sources and series keys are shown in table 1.4 in the appendix.

real GDP and real housing prices series are mixed. To keep interpretation simple, first differences are taken.

Table 1.1: Variables and transformations

Endogenous Variables	log	First Difference	Source
Real GDP	•	•	OECD
Real housing prices	•	•	OECD
Short-term interest rate			OECD
Conditioning Variables			
MFI leverage			ECB
KOF financial globalization index			KOF
Household credit-to-GDP ratio			BIS
Common Exogenous Variable			
VIX	•		CBOE

1.3.2 Country-Specific SVAR Models

As the first step of the empirical analysis we examine the dynamics of the short-term interest rate, real housing prices and real GDP in country-specific structural vector autoregressive (SVAR) models of the following form

$$\mathsf{A}y_t = \mathsf{A}c + \mathsf{A}_1^* y_{it-1} + \mathsf{A}_{\mathsf{q}}^* y_{t-q} + \nu_t \tag{1.1}$$

where y_t is a $(K \times 1)$ vector of endogenous variables, c a $(K \times 1)$ vector of constants, A is a $(K \times K)$ lower–triangular matrix, $\mathsf{A}_{\mathsf{j}}^* = \mathsf{A}\alpha_j$ for $j = 1, \ldots, q$ and $\nu_t = \mathsf{A}\varepsilon_t \sim (0, \Sigma_\nu = \mathsf{A}\Sigma_\nu \mathsf{A}')$ where ε_t for $t = 1, \ldots, t$ is a $(K \times 1)$ vector of white noise with $\varepsilon_t \sim (0, \Sigma_\varepsilon)$ a $(K \times K)$ positive definite matrix. The contemporaneous relationships between the endogenous variables are described by the matrix A. The shocks are recursively identified. Hence, the A-Matrix is constructed so that the first variable has a contemporaneous effect on the other variables, the second variable has a contemporaneous effect on all other variables except variable one, and so on. Thus, the following A-Matrix is prepared:

$$\mathsf{A} = \begin{pmatrix} a_{11} & 0 & 0 \\ a_{21} & a_{22} & 0 \\ a_{31} & a_{32} & a_{33} \end{pmatrix}$$

As we assume that real GDP is a slow moving variable, reacting to changes in real housing prices and the short-term interest rate with a time lag, we order it first. The short-term interest rate is ordered last, as we assume that it reacts contemporaneously to real GDP and real housing prices. Hence, the monetary authority observes real output and real housing prices before setting the interest rate (Christiano et al. 1999). Thus, the order of the endogenous variables in the country-specific SVAR models is as follows: (1) real GDP, (2) real housing prices, (3) short-term interest rate.

The decision on the optimal lag length is based on the Akaike information criterion, the Hannan-Quinn and the Bayesian information criterion. The information criteria suggest different lag lengths for each country. In theory, the optimal lag length should be chosen so that the residuals are white noise. As the sample size is rather small, we use the adjusted Portmanteau and the Breusch-Godfrey LM tests to assess whether the residuals are autocorrelated. The tests report mixed results for some countries in the panel. As the test results depend on the lag length of the SVAR models, we choose the optimal lag length in order to minimize the remaining autocorrelation in the residuals. Finally, we consider a lag length of two for every country-specific SVAR model except for Ireland, where a lag length of one is chosen.

1.3.3 The PCHVAR Model

The methodological framework of the panel conditionally homogenous vector autoregressive (PCHVAR) model, developed by Georgiadis (2012), allows the estimated reduced form coefficients to differ according to unit-specific properties. The model can be written in the following form

$$y_{it} = c_i + \Phi_p(\mathsf{z_{it}})y_{it-p} + \beta_q v_{t-q} + \varepsilon_{it} \tag{1.2}$$

where y_{it} is a $(K \times 1)$ vector of endogenous variables, Φ_i is a $(K \times K)$ matrix of coefficients, v_t a $(K \times 1)$ vector of common exogenous variables and ε_{it} a $(K \times 1)$ vector of white noise with $\varepsilon_{it} \sim (0, \Sigma_\varepsilon)$ a $(K \times K)$ positive definite matrix. The coefficient matrices Φ_p depend on the unit-specific vector $\mathsf{z_{it}}$. The coefficients $\phi_{j,nm}(\mathsf{z_{it}})$ with $j = 1, \ldots, p$, $n = 1, \ldots, K$ and $m = 1, \ldots, K$ in Φ_p are approximated by the following functional form

$$\phi_{j,nm}(\mathsf{z_{it}}) \simeq \pi(\mathsf{z_{it}})\gamma_{j,nm} \tag{1.3}$$

with $\pi(\mathsf{z_{it}}) = [\pi_1(\mathsf{z_{it}}), \pi_2(\mathsf{z_{it}}), \ldots, \pi_\tau(\mathsf{z_{it}})]$ being a $1 \times \tau$ vector of polynomials and $\gamma_{j,nm} = (\gamma_{j,nm1}, \gamma_{j,nm2}, \ldots, \gamma_{j,nm\tau})'$ a $\tau \times 1$ vector of polynomial coefficients.

The polynomial $\pi(\mathsf{z_{it}})$ is obtained by the following equation

$$\pi(\mathsf{z_{it}})\gamma_{j,nm} = [1, \pi_1(\mathsf{z_{1i,t-1}})] \times \gamma_{j,nm} \tag{1.4}$$

The coefficients in Φ_i are replaced by the polynomial approximations in equation (3).

$$\Phi_i(\mathsf{z_{it}}) = \begin{pmatrix} \pi(\mathsf{z_{it}})\gamma_{j,11} & \cdots & \pi(\mathsf{z_{it}})\gamma_{j,1K} \\ \vdots & \ddots & \vdots \\ \pi(\mathsf{z_{it}})\gamma_{j,K1} & \cdots & \pi(\mathsf{z_{it}})\gamma_{j,KK} \end{pmatrix}$$

$$= \begin{pmatrix} \gamma'_{j,11} & \gamma'_{j,12} & \cdots & \gamma'_{j,1K} \\ \vdots & \vdots & \ddots & \vdots \\ \gamma'_{j,K1} & \gamma'_{j,K2} & \cdots & \gamma'_{j,KK} \end{pmatrix} \times [I_K \otimes \pi'(\mathsf{z_{it}})]$$

$$= \Gamma \times [I_K \otimes \pi'(\mathsf{z_{it}})]$$

Equation (2) can be rewritten as follows

$$\begin{aligned} y_{it} &= c_i + \sum_{j=1}^{p} \Gamma_j \times [I_K \otimes \pi'(\mathsf{z_{it}})] y_{i,t-j} + \sum_{q=1}^{l} B_q \times v_{t-q} + \varepsilon_{it} \\ &= c_i + \sum_{j=1}^{p} \Gamma_j \times x_{i,t-j} + \sum_{q=1}^{l} B_q \times v_{t-q} + \varepsilon_{it} \\ &= c_i + \Gamma \times X_{i,t-j} + B \times V_{t-q} + \varepsilon_{it} \end{aligned} \tag{1.5}$$

with $X_{i,t-j} = (x'_{i,t-1}, x'_{i,t-2}, \ldots, x'_{i,t-j})'$, $\Gamma = (\Gamma_1, \Gamma_2, \ldots, \Gamma_p)$, $B = (B_1, B_2, \ldots, B_q)$ and $V_{t-q} = (v_{t-1}, v_{t-2}, \ldots, v_{t-q})$.

The estimation of the model in equation (5) occurs via ordinary least squares.

To compute the impulse responses, we start by writing the model in equation (2) in canonical form

$$\begin{bmatrix} y_{it} \\ y_{it-1} \\ \vdots \\ y_{it-p} \end{bmatrix} = \begin{bmatrix} c_1 \\ c_2 \\ \vdots \\ 0 \end{bmatrix} \times \begin{bmatrix} \Phi_1(\mathsf{z_{it}}) & \Phi_2(\mathsf{z_{it}}) & \cdots & \Phi_p(\mathsf{z_{it}}) \\ I_k & 0 & \cdots & 0 \\ \vdots & I_k & & \vdots \\ 0 & \cdots & \cdots & 0 \end{bmatrix} \times \begin{bmatrix} y_{it-1} \\ y_{it-2} \\ \vdots \\ y_{it-p} \end{bmatrix} + \begin{bmatrix} \beta_1 \\ \beta_2 \\ \vdots \\ \beta_q \end{bmatrix}' \times \begin{bmatrix} v_{t-1} \\ v_{t-2} \\ \vdots \\ v_{t-q} \end{bmatrix} + \begin{bmatrix} \varepsilon_{it} \\ 0 \\ \vdots \\ 0 \end{bmatrix}$$

$$Y_{it} = C_i + \Phi(\mathsf{z_{it}}) Y_{it-1} + BV_{t-1} + \Upsilon_{it}$$

through recursive substitution we obtain

$$\begin{aligned} Y_{it} &= C_i + \Phi(\mathsf{z_{it}}) Y_{it-1} + BV_{t-1} + \Upsilon_{it} \\ &= C_i + \Phi(\mathsf{z_{it}})\Phi(\mathsf{z_{it-1}}) Y_{it-2} + \Phi(\mathsf{z_{it}}) BV_{t-2} + \Phi(\mathsf{z_{it}})\Upsilon_{it-1} + \Upsilon_{it} \\ &= C_i + \left[\prod_{j=1}^{s} \Phi(\mathsf{z_{it-j}})\right] Y_{it-s} + \sum_{j=0}^{s} \left[\prod_{q=1}^{j} \Phi(\mathsf{z_{it-q}})\right] BV_{t-j} + \sum_{j=0}^{s} \left[\prod_{k=1}^{j} \Phi(\mathsf{z_{it-k}})\right] \Upsilon_{it-j} \end{aligned}$$

By premultiplying the above equation by the matrix J $= [I_k, 0, \ldots, 0]$ we get

$$JY_{it} = JC_i + J\left[\prod_{j=1}^{s}\Phi(\mathsf{z_{it-j}})\right]Y_{it-s} + J\sum_{j=0}^{s}\left[\prod_{q=1}^{j}\Phi(\mathsf{z_{it-q}})\right]BV_{t-j}$$

$$+ J\sum_{j=0}^{s}\left[\prod_{k=1}^{j}\Phi(\mathsf{z_{it-k}})\right]J'J\Upsilon_{it-j}$$

$$y_{it} = c_i + \eta_s y_{it-s} + \sum_{j=0}^{s}\alpha_j(\mathsf{z_{it-j}})\beta_j v_{t-j} + \sum_{j=0}^{s}\psi_j(\mathsf{z_{it-j}})\varepsilon_{it-j}$$

Finally, we obtain the impulse response coefficients from the matrices

$$\sum_{j=0}^{s}\psi_j(\mathsf{z_{it-j}}) \tag{1.6}$$

1.4 Econometric Results

1.4.1 Impulse Response Functions of the PCHVAR Model

Figure 1.2 displays the real GDP responses for different conditioning variables resulting from the PCHVAR estimation. The magnitude of the response is shown on the y-axis. The x-axis shows the impulse response horizon in quarters and the z-axis the level of the respective conditioning variable. The results reveal a positive relationship between the extent of the contraction in real GDP and the degree of financial openness, the level of bank leverage and the level of household leverage. Consequently, a higher degree of financial openness, a higher level of bank leverage and a higher level of household leverage seem to intensify the contraction in real GDP after a positive monetary policy shock.

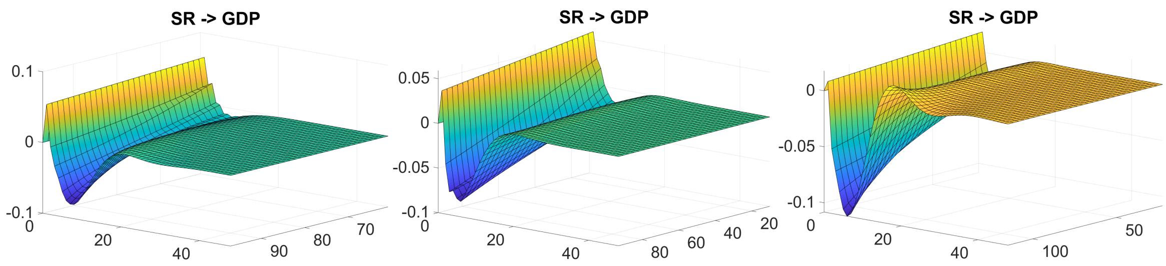

Figure 1.2: The figure shows the orthogonalized impulse response functions of real GDP to a shock in the short-term interest rate (SR) generated by the PCHVAR model. The left-hand panel plots the impulse responses for varying degrees of financial openness. The middle panel plots the impulse responses for varying levels of bank leverage. The right-hand panel plots the impulse responses for varying levels of household leverage.

The subfigure on the left hand side shows the response of real GDP to a positive one standard deviation monetary policy shock for varying degrees of financial openness. The trough increases from

-0.01% at the lowest degree of financial openness to -0.08% at the highest degree of financial openness. Overall, the degree of financial openness seems to have only a minor impact on the contraction in real GDP, as the percentage changes are relatively small.

The subfigure in the middle shows the response of real GDP to a one standard deviation monetary policy shock for varying levels of bank leverage. The trough increases from -0.02% at the lowest level of bank leverage to -0.08% at the highest level of bank leverage. Similar to our results regarding the degree of financial openness, the level of bank leverage has only a minor impact on the contraction in real GDP.

The subfigure on the right hand side displays the response of real GDP to a one standard deviation monetary policy shock for varying levels of household leverage. The trough increases from -0.03% at the lowest level of household leverage to -0.11% at the highest level of household leverage. Hence, the impact of a contractionary monetary policy shock seems to be stronger when households are relatively more indebted. This result is explainable by changes in household liquidity and the resulting consumption behavior of households with different marginal propensities to consume, as in Cloyne et al. (2019). Accordingly, the contraction in the monetary policy rate and the resulting decrease in aggregate income induces liquidity constrained mortgage holders to reduce consumption expenditures. In other words, mortgage holders are less able to substitute the reduction in income with liquidity leading to a reduction in consumption expenditures. The resulting decrease in aggregate expenditures contributes to the reduction in real GDP. Along similar lines, Flodén et al. (2021) point out that liquidity constrained households holding a relatively high amount of debt linked to short-term fluctuations in the interest-rate reduce their consumption expenditures more strongly in response to a rise in the short-term interest rate. The reduction in consumption expenditures is either proportional to the rise in the debt burden or, if the possibility of consumption smoothing exists, less pronounced due to the short-term nature of the monetary policy shock. A further explanation is based on the depression of inflation after a rise in the monetary policy rate which leads to a transfer of wealth from debtors to creditors. In other words, the debt burden increases leading to a reduction in expenditures. However, as the monetary policy shock is temporary, this effect might only have a minor impact (Cloyne et al. 2019). In general, as the percentage changes are relatively small, the level of household leverage seems to be of minor relevance for the contraction in real GDP, however.

Figure 1.3 shows the real housing price responses for different conditioning variables resulting from the PCHVAR estimation. The estimation reveals a positive relationship between the extent of the contraction in real housing prices and the degree of financial openness, the level of bank leverage and the level of household leverage after a positive one standard deviation monetary policy shock.

The subfigure on the left hand side shows the response of real housing prices to a one standard deviation monetary policy shock for varying degrees of financial openness. The trough increases from -0.06% at the lowest degree of financial openness to -0.28% at the highest degree of financial openness.

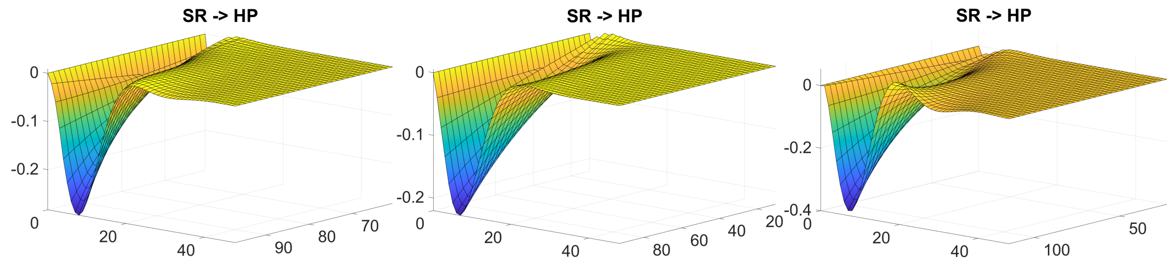

Figure 1.3: The figure displays the orthogonalized impulse response functions of real housing prices (HP) to a shock in the short-term interest rate generated by the PCHVAR model.

The percentage change at a low degree of financial openness is relatively small. However, at a high degree of financial openness, the results reveal a more pronounced impact of financial openness on the fall in real housing prices. These findings highlight the amplifying effects of international financial linkages on the fall in real housing prices and demonstrate the importance of cross-border capital flows for the transmission of monetary policy shocks to housing prices. The results can be explained by assuming that a rise in the monetary policy rate leads to a retrenchment of capital invested in the housing market. This process is amplified through the liquidation of foreign investment positions (Sá and Wieladek 2015). One channel through which the retrenchment of cross-border capital flows occurs are cross-border banking flows (Milesi-Ferretti and Tille 2011). As shown by Shin (2012), in the run-up to the financial crises starting in 2007, increasing cross-border banking flows channeled global liquidity to U.S. asset markets. Our estimation results offer insights into the intermediating role of global liquidity after a change in domestic financing conditions. The effects may be intensified through a rise in global risk aversion which leads to a retrenchment of capital flows on an aggregate level (Forbes and Warnock 2012). Overall, the findings suggest that highly volatile capital flows have the potential to affect the transmission of monetary policy with considerable consequences for asset price changes.

The subfigure in the middle shows the response of real housing prices to a one standard deviation monetary policy shock for varying levels of bank leverage. The trough increases from -0.03% at the lowest level of bank leverage to -0.22% at the highest level of bank leverage. Hence, we see a more pronounced impact of the level of bank leverage on the fall in real housing prices after a positive one standard deviation monetary policy shock at high levels of bank leverage. These findings lend support to the assumption that a trend towards more leveraged financial institutions seems to result in an amplification of monetary policy shocks through the banking sector. The change in banking practices is a more important determinant of the negative response of real housing prices. The impact on housing prices demonstrates the potential consequences of an increased importance of real estate lending for the business of financial intermediation. The effects may intensify under the assumption that banks are subject to similar exposures leading to heightened systemic risks (Greenwood et al.

2015).

The subfigure on the right hand side shows the response of real housing prices to a one standard deviation monetary policy shock for varying levels of household leverage. The trough reaches -0.03% at the lowest level of household leverage. It increases to -0.38% at the highest level of household leverage. If we compare the PCHVAR impulse response functions across the different conditioning variables, we notice that the level of household leverage has the highest impact on the fall in real housing prices. Thus, a positive trend in household leverage seems to serve as an important amplifier of monetary policy shocks to the housing market. The finding that the impact of monetary policy shocks is stronger for the response of housing prices suggests that an increasing share of mortgages in the composition of household debt has considerable consequences for the monetary policy transmission mechanism. The findings are in line with research conducted by Iacoviello and Minetti (2003) showing that the impact of monetary policy shocks on housing prices are stronger in financially more liberalized economies. Financial liberalization refers in this context to the relaxation of borrowing constraints such as down-payment requirements or the removal of ceilings on lending rates. In addition, compared to the PCHVAR model in which we restrict the transmission process on the level of bank leverage, the estimation results show that household leverage seems to be the more important determinant of the transmission of monetary policy shocks to housing prices. Hence, whereas the transmission of monetary policy shocks to the housing market is shaped by changes in the leverage positions of the banking and household sectors, a positive trend in household leverage seems to be a more important determinant of the transmission mechanism.

1.4.2 Comparison of Impulse Response Functions

In this section, we focus on the significance of financial openness, bank risk-taking and household indebtedness in shaping the transmission of monetary policy shocks to output and housing prices. As the variation in the PCHVAR models depends solely on the conditioning variables, we compare the impulse response functions of the country-specific SVAR models with the impulse response functions of the PCHVAR models in order to examine the extent to which the empirical variation in the country-specific SVAR models might be explainable by the variation in the PCHVAR models. Although the identification schemes of the country-specific SVAR models and the PCHVAR models differ, comparison is still possible as recursively identified shocks are basically equivalent to orthogonalized shocks obtained by applying a cholesky decomposition. The difference is that the recursive structure does not restrict the variance of the disturbances to unity (Lütkepohl 2005).

Graphical Comparison

Figure 1.4 shows the output responses to a positive one standard deviation monetary policy shock of the country-specific SVAR models together with the responses estimated by the PCHVAR models. The x-axis refers to the impulse response horizon in quarters whereas the y-axis shows the magnitude of the response in percent. The impulse responses of the PCHVAR models are fixed at the average of the respective conditioning variable. Hence, they represent the response of real GDP and real housing prices at the euro area average of the respective conditioning variable. If the impulse responses generated by the PCHVAR models coincide with the impulse responses of the country-specific SVAR models, we conclude that the empirical variation in the country-specific case can be explained by the euro area average of the respective conditioning variable. Hence, the variation in the PCHVAR model, which depends on the respective conditioning variable, has some explanatory power for the empirical variation in the country-specific SVAR models. However, differences between the country-specific impulse responses and the average PCHVAR impulse response functions point either to asymmetries in the transmission of monetary policy shocks across the euro area countries or to further empirical factors not included in the PCHVAR model but relevant for the transmission process.

The dynamics shown by the impulse response functions of the country-specific SVAR models are in line with standard macroeconomic theory. As expected, an increase in the monetary policy rate leads to a contraction in output. GDP reaches a trough after about ten quarters in almost all countries included in the panel. Exceptions are Greece, Spain and Ireland where output contracts immediately. In general, it takes about twenty to thirty quarters until the shock vanishes. Obviously, in most of the countries, output rises in the first quarter before it contracts showing a puzzling behavior (Uhlig 2005).

The country-specific impulse responses of Germany, France, Italy, Austria and the Netherlands show similarities with the PCHVAR impulse responses at the average of financial openness. Differences with respect to the timing and strength of the trough and the return to baseline are observable, though. Hence, the degree of financial openness has some explanatory power for the contraction in real GDP after a positive one standard deviation monetary policy shock in these euro area countries. By contrast, the degree of financial openness has only limited explanatory power for the contraction in real GDP in the remaining euro area economies.

Along similar lines, the country-specific real GDP impulse responses hardly coincide with the PCHVAR impulse responses at the average of household leverage. Obviously, there are considerable differences with respect to the strength and timing of the trough and the return to baseline pointing to asymmetries in the transmission of monetary policy across the euro area economies. These observations lead us to conclude that the average level of household leverage hardly offers explanatory power for the contraction in real GDP after a positive monetary policy shock. Moreover, as already noted in section 1.4.1, the percentage changes of real GDP are relatively small suggesting a minor impact of

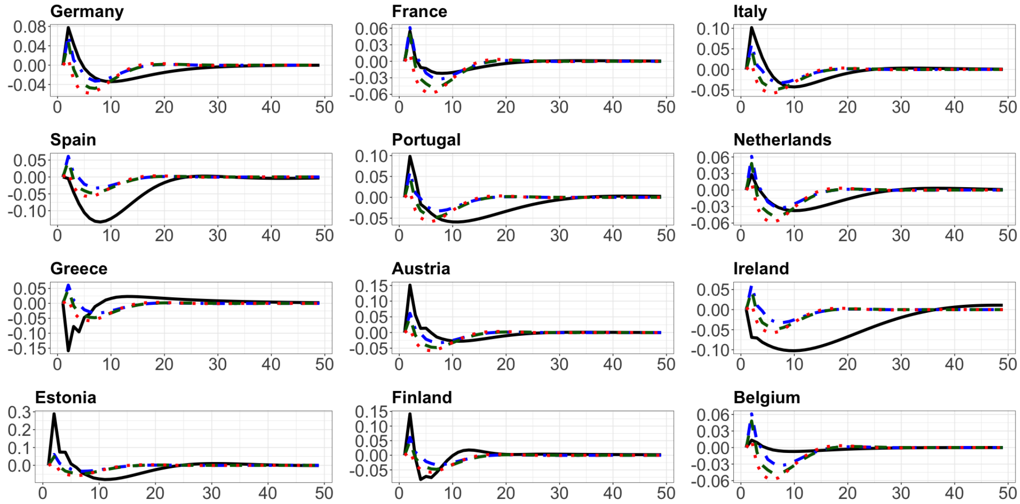

Figure 1.4: Impulse responses of real GDP to a one standard deviation monetary policy shock generated by the country-specific SVAR models and the PCHVAR model. The blue dash-dotted line refers to the impulse response of the PCHVAR model at the average of financial openness. The green dashed line shows the impulse response at the average of bank leverage and the red dotted line the impulse response at the average of household leverage.

the conditioning variable on the contraction in real GDP.

Similar to the PCHVAR impulse responses at the average of household leverage, the PCHVAR impulse response at the average of bank leverage hardly coincides with the country-specific real GDP responses. Again, differences with respect to the strength and timing of the trough and the return to baseline point to asymmetries in the transmission of monetary policy shocks across the euro area economies leading us to conclude that the average level of bank leverage hardly offers explanatory power for the contraction in real GDP after a positive monetary policy shock.

Figure 1.5 shows the housing price responses to a positive one standard deviation monetary policy shock of the country-specific SVAR models together with the responses estimated by the PCHVAR models. Regarding the impulse responses of the country-specific SVAR models, we see a contraction of housing prices in almost all countries. Differences with respect to the timing and strength of the trough and the return to baseline are observable, though. In some countries, the fall in housing prices occurs shortly after the shock has hit the economy indicating a higher sensitivity. In general, the trough is reached in the first fifteen quarters.

The impulse response functions for Austria and Belgium increase on impact showing signs of a puzzle similar to the "price puzzle" (Eichenbaum 1992, p. 1002). The price puzzle refers to increases in inflation after a positive monetary policy shock. Following Sim's (1992) explanation, it might be caused by anticipated inflationary pressures due to a rise in commodity prices. The monetary contraction then has a dampening effect on the rise in inflation. However, as we are dealing with real

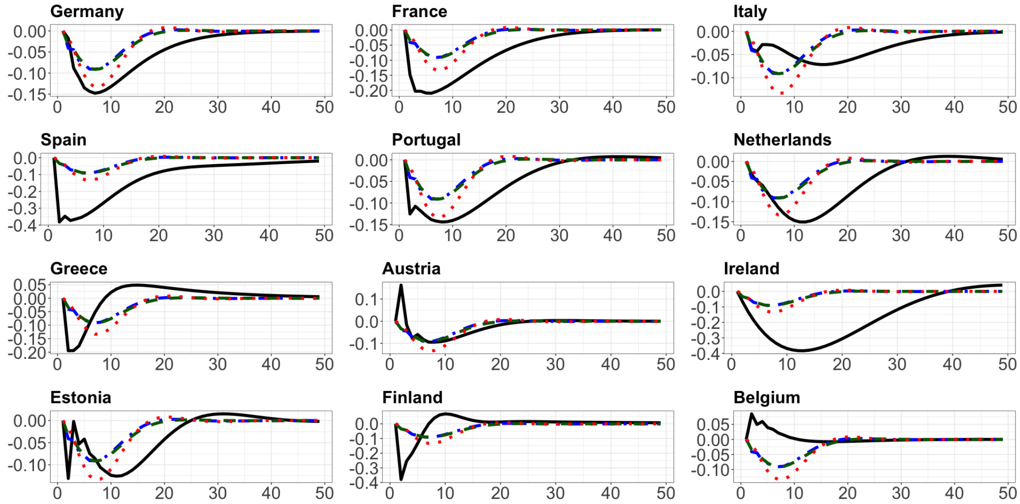

Figure 1.5: Impulse responses of real housing prices to a one standard deviation monetary policy shock generated by the country-specific SVAR models and the PCHVAR model. The blue dash-dotted line refers to the impulse response of the PCHVAR model at the average of financial openness. The green dashed line shows the response at the average of bank leverage and the red dotted line the response at the average of household leverage.

housing prices, the occurrence of the puzzle appears to be surprising as it implies that either nominal housing prices rise higher than goods prices do or that housing prices decrease less than goods prices do. Nevertheless, the rise in housing prices might be due to what is thought to be a positive innovation in monetary policy.[3] Indeed, Miranda-Agrippino and Ricco (2021) point to frictions due to asymmetric information between economic agents and the monetary authority that are likely responsible for the puzzling responses after a monetary policy shock. Accordingly, a rise in the policy rate is interpreted either as an unexpected monetary policy innovation or an endogenous response of the monetary authority to improved economic fundamentals. In the presence of informational frictions, agents confuse the monetary policy shock with an aggregate demand shock to which the monetary authority endogenously responds leading to the puzzling behavior of output and prices.

If we compare the country-specific impulse response functions with the impulse response functions generated by the PCHVAR model, we see that the country-specific response of Germany shows similarities with the PCHVAR impulse response at the average of household leverage. Again, differences with respect to the timing and strength of the trough and the return to baseline are observable. The deeper trough observable in Spain and Ireland points to further empirical factors not included in the PCHVAR models but relevant for the transmission of monetary policy shocks. Based on these

[3] We deal with this pattern in the section on robustness checks. Specifically, we estimate the country-specific SVAR models including the quarterly growth rate of the consumer price index as an endogenous variable. This specification is motivated by the assumption that the rise in housing prices might be caused by inflationary pressures associated with a rise in rent prices. Moreover, we estimate the SVAR impulse response functions with the sign-restriction approach.

observations, we notice that the level of household leverage has some explanatory power for the fall in real housing prices after a positive one standard deviation monetary policy shock in Germany. However, as the country-specific impulse responses of the other countries hardly coincide with the PCHVAR impulse responses at the average of household leverage, we notice asymmetries involved in the transmission process. Similar asymmetries are observable when we compare the country-specific impulse responses with the PCHVAR impulse responses at the average of financial openness and bank leverage, respectively.

The graphical comparison conducted in this subsection is more speculative in nature. In the following section, we use further econometric methods to sharpen our understanding of the relevance of financial openness, bank-risk taking and household indebtedness for the monetary policy transmission mechanism.

Polynomial Regression Analysis

After a graphical comparison of the impulse response functions, we proceed with a quantitative examination and regress the impulse responses of the country-specific SVAR models on the PCHVAR impulse responses at the average of the respective conditioning variables. Provided that the estimated coefficients are significant, we take this as evidence that the empirical variation in the country-specific SVAR models can be explained by the structural characteristics included in the PCHVAR models.

The polynomial regression equation for real GDP and real housing prices respectively, looks as follows

$$IR_i^{SVAR} = c_i + \beta_1 IR_j^{PCHVAR} + \beta_2 (IR_j^{PCHVAR})^2 + \varepsilon_i \tag{1.7}$$

where $i = (1, 2, \dots, N)$ indexes countries and $j = (1, 2, 3)$ indexes the average impulse response of the PCHVAR model for each conditioning variable.[4]

Table (2) shows the adjusted R^2 for each country-specific polynomial regression. Choosing France as an example, about 92% of the empirical variation in the GDP response can be explained by the degree of financial openness. Additionally, the level of bank leverage explains about 89% of the variation in the GDP response. However, taking Ireland as an example, the results show a weaker link between the responses of real GDP and real housing prices and the degree of financial openness and the level of bank leverage. Obviously, most of the empirical variation in the country-specific real GDP responses is attributable to the degree of financial openness. For the majority of countries, financial openness and bank leverage seem to be more important for variations in the GDP impulse responses. On the contrary, household leverage seems to be more important for variations in the housing price

[4]Note that in order to improve the significance of the estimated coefficients, we drop the quadratic term for some country-specific regression equations. Please refer to tables 1.5 and 1.6 in the appendix for detailed regression results.

impulse responses. Compared to the degree of financial openness and the level of household leverage, bank risk-taking seems to be the more important determinant for the transmission of monetary policy shocks to housing prices. This result is at odds with our PCHVAR estimation results, as they lead us to conclude that household leverage is a more important determinant of the transmission of monetary policy shocks to housing prices. However, the difference in the results may be due to the averaging of the PCHVAR impulse responses.

After calculation of the average adjusted R^2 over each column in Table (2), we claim that 66% of the decline in the growth rate of real GDP and 51% of the fall in real housing prices is attributable to the degree of financial openness. Bank risk-taking explains on average 60% of the decline in the growth rate of real GDP and 55% of the fall in real housing prices. Household indebtedness accounts for 33% of the decline in the growth rate of real GDP and 44% of the fall in real housing prices.

Table 1.2: Polynomial regressions adjusted R^2

	GDP Response			HP Response		
Country	FINOP	BLev	HLev	FINOP	BLev	HLev
DEU	0.6965	0.5259	0.1788	0,8309	0.8950	0.8382
FRA	0.9220	0.8932	0.5242	0.8813	0.9182	0.7904
ESP	0.7973	0.8016	0.7261	0.8959	0.8863	0.7669
ITA	0.7027	0.5126	0.2038	0.2014	0.3097	0.0913
AUT	0.8218	0.7267	0.2223	0.4166	0.4762	0.5350
BEL	0.6736	0.4835	0.1721	0.3180	0.2528	0.2057
FIN	0.5887	0.7171	0.5341	0.1164	0.1170	0.0711
GRC	0.5318	0.5351	0.2693	0.2627	0.2007	0.1415
IRL	0.3683	0.3595	0.3071	0.2832	0.3774	0.2557
NLD	0.5925	0.4955	0.3407	0.4823	0.5951	0.4335
PRT	0.6335	0.5211	0.2257	0.7938	0.8639	0.6893
EST	0.6309	0.6658	0.2832	0.6433	0.7223	0.5067

Note: The second column shows the adjusted R^2 obtained from regressing the country-specific SVAR real GDP response on the PCHVAR real GDP response at the average of financial openness. The third column refers to the PCHVAR GDP response at the mean of bank leverage. The fourth column to the PCHVAR GDP response at the mean of household leverage. The fifth column refers to the PCHVAR real housing price response at the average of financial openness. The sixth column shows the PCHVAR housing price response at the mean of bank leverage. Finally, column seven displays the PCHVAR housing price response at the average of household leverage.

1.4.3 Robustness Checks

As there might be exogenous factors not included in the analysis, such as global economic activity or the development of commodity prices, we check the robustness of the results generated by the PCH-VAR models by repeating the estimation choosing world GDP and oil prices as exogenous variables. The time series are taken from the World Bank World Development Indicators and FRED databases, seasonally adjusted and measured in logs and first differences to obtain percentage changes. The world GDP series is interpolated from yearly to quarterly frequency. The analysis shows that the results of the PCHVAR models are robust with respect to the change of the exogenous variables.

Changing the order of the endogenous variables is a standard way for checking the validity of the estimation results. We reorder the endogenous variables as follows: (1) Real GDP, (2) Short-term interest rate, (3) Real housing prices. The GDP responses of the PCHVAR models and the country-specific SVAR models are robust under this alternative order of the endogenous variables. The impulse responses of housing prices differ in their initial responses. This might be caused by the change in the contemporaneous relation between housing prices and the short-term interest rate. However, as we are foremost interested in the impact of a monetary policy shock, it is reasonable to order the short-term interest rate last and assume that initial changes in GDP and housing prices are included in the reaction function of the monetary authority.

As already mentioned, the dynamics of housing prices might also be driven by changes in consumer prices. To account for this, we include consumer price inflation (CPI) as additional endogenous variable in the country-specific SVAR models. The time series are taken from the OECD, seasonally adjusted and measured in logs and first differences. We order inflation at an anterior position in the model, as we assume that rent prices are sluggish, so that variations in inflation due to a change in rent prices occur slowly. The endogenous variables are ordered as follows: (1) Real GDP, (2) CPI, (3) Real housing prices, (4) Short-term interest rate. The resulting impulse response functions are similar to the responses generated by the SVAR models without inflation. The puzzling behavior of the initial housing price and GDP responses could not be eliminated, as the price puzzle is visible in Germany, Italy and the Netherlands. Additional output puzzles are visible in Spain and Ireland. However, the initial positive output response for the Netherlands is weaker.

Estimation in Levels

As mentioned in section three, the test results regarding the stationarity of the time series are mixed. Hence, the country-specific SVAR models estimated in first differences might be subject to mis-specification. In order to test this possibility, we estimate the country-specific SVAR models in levels and draw a comparison to the country-specific SVAR models in first differences (Georgiadis 2015). The real GDP and real housing price series are measured in logs. Considering the responses of real

GDP, the model in levels generates stationary impulse response functions for Italy. For the other countries, estimation in first differences eliminated the explosive behavior of the impulse response functions obtained from the model in levels. Although output puzzles are still visible, the initial positive responses are less pronounced. The responses of housing prices obtained from the model in levels are stationary for France, Spain, Italy and Belgium. Estimation in first differences eliminated the explosive behavior of the housing price impulse responses of the other countries in the panel.[5]

Estimation in Fourth Differences

The impulse response functions obtained from the country-specific SVAR models in fourth differences are stationary for all countries included in the panel. For some countries, the output and price puzzles could be eliminated. This indicates that the initial increase in output and prices is only of a temporary nature. For Spain, Austria, Belgium and the Netherlands it takes about twenty years till the response of housing prices to a monetary policy shock returns to baseline. The GDP response for Ireland hardly vanishes. Because of non-stationarity of the GDP response obtained from the model in levels, this result must be taken with caution.[6]

Identification with Sign Restrictions

To eliminate the immediate positive responses of output and housing prices, we estimate the country-specific SVAR models by imposing sign restrictions on the monetary policy shock as well as the housing price and GDP responses, respectively. Specifically, a positive innovation in the short-term interest rate

- Does not decrease for four quarters after the shock.
- Does not increase real housing prices for four quarters after the shock.
- Does not increase real GDP for four quarters after the shock.

We choose four quarters as the positive responses of output and housing prices occur immediately after the shock has hit the economy and vanish shortly thereafter. Estimation of impulse responses is based on the sign restriction approach by Uhlig (2005). This approach allows a parsimonious specification of prior theoretical assumptions regarding the direction of the responses.

Figure 1.10 in the appendix displays the impulse responses of real housing prices with the real GDP responses restricted. Real housing prices contract in the majority of countries. However, the initial increases of housing prices in Belgium and Austria are still visible. In general, with the exception of Finland and Greece, the housing price responses are less persistent.

[5] Figures 1.6 and 1.7 in the appendix show the estimated impulse response functions.

[6] Figures 1.8 and 1.9 in the appendix show the corresponding estimated impulse response functions.

Figure 1.11 in the appendix shows the resulting impulse responses for real GDP with the housing price responses restricted. Real GDP immediately increases in the majority of countries. Exceptions are Greece, Ireland, Italy and Estonia.

Long-term Interest Rate as Monetary Policy Proxy Variable

As the time period considered in our econometric analysis coincides to a substantial part with the period during which the short-term interest rate hit the zero lower bound and unconventional monetary policy measures were used instead, we estimate the PCHVAR model using the long-term interest rate as a monetary policy proxy variable. Figure 1.12 in the appendix shows the resulting impulse responses of real GDP to a positive one standard deviation shock in the long-term interest rate at varying degrees of financial openness (left panel), bank leverage (middle panel) and household leverage (right panel). As can be seen from the left panel, a rise in the long-term interest rate leads to a stronger reduction in GDP growth at low degrees of financial openness reaching a trough at -0.09% before returning to baseline. On the contrary, a higher level of bank leverage seems to intensify the decrease in GDP growth. The corresponding PCHVAR impulse response reaches a trough at -0.09% within the first period before increasing to -0.02% in the second period decreasing again and returning to baseline. Similar dynamics can be seen from the impulse response at varying levels of household leverage. The PCHVAR impulse response reaches a trough at -0.11% at the highest level of household leverage within the first quarter before increasing to -0.06% contracting again and returning to baseline.

Figure 1.13 in the appendix displays the PCHVAR impulse response functions of real housing prices to a positive one standard deviation monetary policy shock. The left panel reveals a positive relationship between the degree of financial openness and the decline in the growth rate of real housing prices. Real housing price growth reaches a trough at -0.24% at high degrees of financial openness before returning to baseline. However, at low degrees of financial openness, real housing price growth increases within the first 5 periods. Similar patterns can be seen from the real housing price response at varying levels of household leverage, although at different magnitudes. The real housing price response reaches a trough at -0.53% at high levels of household leverage. The middle panel shows a stronger decline in real housing price growth at higher levels of bank leverage. The trough reaches -0.35% at high levels of bank leverage compared to -0.04% at low levels of bank leverage.

To sum up, our conclusions regarding the amplifying effects of financial openness, bank leverage and household leverage are mainly confirmed when using the long-term interest rate as a monetary policy proxy. However, a notable exception is the response of real GDP growth which is negatively related to the degree of financial openness.

1.5 Concluding Remarks

The present study quantifies the impact of financial globalization, bank risk-taking and household indebtedness for the transmission of monetary policy shocks to output and housing prices. The econometric results of this article point to noticeable asymmetries in the monetary policy transmission mechanism across the euro area economies. These asymmetries are due to structural characteristics underlying the individual economies. Our PCHVAR analysis reveals a positive relationship between the degree of financial openness, the level of bank leverage and the level of household leverage and the extent of the contraction in real GDP and the fall in real housing prices after a contractionary monetary policy shock. Further, a polynomial regression analysis shows that an average of 66% of the decline in the growth rate of real GDP and 51% of the fall in real housing prices is attributable to the degree of financial openness. Bank risk-taking explains on average 60% of the decline in the growth rate of real GDP and 55% of the fall in real housing prices. Moreover, household indebtedness accounts for 33% of the decline in real GDP growth and 44% of the fall in real housing prices. Hence, the amplification of monetary policy shocks to real economic activity occurs foremost through international financial linkages. On the contrary, bank risk-taking is an important determinant of the transmission of monetary policy shocks to the housing market.

The asymmetries in the transmission process have important implications not only for the conduct of monetary policy but also for the process of economic integration in the euro area. If one considers the differences in the member countries' degree of financial openness and the heterogeneity in the banking and household sectors, it is clear that greater harmonization efforts are needed to reduce asymmetric reactions to monetary policy shocks. Thus, our results call for policies to monitor and reduce possible asymmetric reactions among currency union members after a common monetary policy shock.

Against the background of the impact of the structural characteristics considered in this article on the transmission of monetary policy, future research could gain deeper insights by focusing on the endogenous mechanisms underlying the interaction between monetary policy and the real and financial side of the economy.

1.6 Appendix to Chapter 1

Table 1.3: Countries included and respective time series range

Country	Time Series Range
Germany	1999Q2:2018Q4
France	1999Q2:2018Q4
Spain	1999Q2:2018Q4
Italy	1999Q2:2018Q4
Austria	2000Q2:2018Q4
Belgium	1999Q2:2018Q4
Finland	1999Q2:2018Q4
Greece	1999Q2:2018Q4
Ireland	2002Q2:2018Q4
Netherlands	1999Q2:2018Q4
Portugal	1999Q2:2018Q4
Estonia	2005Q2:2018Q4

Table 1.4: Time series

Variable	Unit	Source	Key	S.A.
Real GDP	Index value	OECD	VOBARSA	•
Real housing prices	Index value	OECD	RHP	•
Short-term interest rate	%	OECD	IR3TIB	
Long-term interest rate	%	OECD	IRLT	
Equity held by MFIs	Million Euro	ECB	QSA.Q.N.DE.W0.S12K.S1.N.A.LE.F51._Z._Z.XDC._T.S.V.N._T*	
Loans granted by MFIs	Million Euro	ECB	QSA.Q.N.DE.W0.S12K.S1.N.A.LE.F4.T._Z.XDC._T.S.V.N._T	
Currency and deposits of MFIs	Million Euro	ECB	QSA.Q.N.DE.W0.S12K.S1.N.A.LE.F2.T._Z.XDC._T.S.V.N._T	
Debt securities held by MFIs	Million Euro	ECB	QSA.Q.N.DE.W0.S12K.S1.N.A.LE.F3.T._Z.XDC._T.S.V.N._T	
KOF financial globalization index	Index value	KOF	KOFFiGIdf	
Household credit-to-GDP ratio	% of GDP	BIS	n.a.	
VIX	Index value	CBOE	VIX	
Real GDP World	Trillion USD	World Bank WDI	NY.GDP.MKTP.KD	•
Oil prices	Index value	FRED	POILAPSPINDEXQ	•
Consumer price index	Index value	OECD	IDX2015	•

Note: S.A. = Seasonally adjusted. *The fourth entry varies across the countries included in the analysis as it refers to the respective country code. DE corresponds to Germany.

Table 1.5: Polynomial regression results for GDP impulse responses

	GDP Response								
	FINOP			BLev			HLev		
Country	c	β_1	β_2	c	β_1	β_2	c	β_1	β_2
DEU	-0.0051***	1.0525***	5.9826**	-0.0056***	1.0048***	14.5044***	-0.0052*	1.6514***	28.7209***
	(0.0016)	(0.1123)	(2.6359)	(0.0021)	(0.1352)	(3.3324)	(0.0027)	(0.4957)	(9.9449)
FRA	-0.0014***	0.7637***	2.6776***	-0.0010*	0.7763***	8.0063***	-0.0003	1.3035***	19.0943***
	(0.0005)	(0.0348)	(0.8175)	(0.0006)	(0.0393)	(0.9676)	(0.0012)	(0.2309)	(4.6322)
ESP	-0.0136***	2.8728***	-43.7253***	-0.0129***	1.7917***	-23.4325***	-0.0145***	3.6198***	31.1673**
	(0.0033)	(0.2238)	(5.2540)	(0.0032)	(0.2133)	(5.2574)	(0.0038)	(0.6982)	(14.0095)
ITA	-0.0006	1.4079***	5.8131*	-0.0014	1.2874***	17.5983***	-0.0012	2.2725***	39.7839***
	(0.0021)	(0.1441)	(3.3818)	(0.0027)	(0.1777)	(4.3802)	(0.0034)	(0.6327)	(12.6938)
AUT	-0.0018	1.2200***	22.0645***	-0.0019	1.5385***	32.2711***	0.00004	2.6620***	51.3700
	(0.0017)	(0.1198)	(2.8116)	(0.0022)	(0.1429)	(3.5217)	(0.004)	(0.6710	(13.4700)
BEL	-0.0008**	0.2196***		-0.0011**	0.1882***	2.2703***	-0.0011**	0.3023***	5.0214**
	(0.0003)	(0.0220)		(0.0004)	(0.0276)	(0.6800)	(0.0005)	(0.0973)	(1.9522)
FIN	0.0025	1.5569***	10.3752**	0.0065**	1.8070***	13.8005***	0.0095***	1.2436***	
	(0.0031)	(0.2131)	(5.0012)	(0.0026)	(0.1703)	(4.1959)	(0.0033)	(0.1662)	
GRC	0.0046	-0.7017***	-33.4083***	0.0065*	-1.1515***	-42.8226***	0.0047	-2.3390***	-60.0085***
	(0.0035)	(0.2408)	(5.6519)	(0.0035)	(0.2312)	(5.6969)	(0.0043)	(0.8072)	(16.1952)
IRL	-0.0287***	1.6374***	-36.7050	-0.0286***	0.8182**	-23.7891***	-0.0306***	1.3317***	
	(0.0054)	(0.3677)	(8.6314)	(0.0054)	(0.3568)	(8.7915)	(0.0056)	(0.2822)	
NLD	-0.0050***	0.9161***	-5.4067	-0.0049***	0.6623***		-0.0055***	1.3640***	18.9939**
	(0.0016)	(0.1081)	(2.5384)	(0.0017)	(0.0955)		(0.0020)	(0.3691)	(7.4055)
PRT	-0.0103***	1.7101***		-0.0113***	1.5498***	16.6138***	-0.0108**	2.4858***	38.5973**
	(0.0026)	(0.1866)		(0.0032)	(0.2132)	(5.2533)	(0.0041)	(0.7549)	(15.1459)
EST	0.0041	3.2007***		-0.0050	3.2005***	59.9315***	-0.0017	6.1879***	116.4480***
	(0.0049)	(0.3474)		(-0.0050)	(0.3326)	(8.1970)	(0.0073)	(1.3567)	(27.2213)

*** significance at the 1% level, ** significance at the 5% level, * significance at the 10% level. Standard errors in parentheses. *Note*: Gaps indicate that the coefficients are estimated by dropping the quadratic term in the regression equation.

Table 1.6: Polynomial regression results for housing price impulse responses

	HP Response								
	FINOP			BLev			HLev		
Country	c	β_1	β_2	c	β_1	β_2	c	β_1	β_2
DEU	-0.0169***	1.5109***		-0.0131***	2.2630***	9.0630**	-0.0182***	1.6543***	5.2137**
	(0.0035)	(0.0982)		(0.0028)	(0.3088)	(3.8324)	(0.0033)	(0.2738)	(2.3359)
FRA	-0.0228***	4.2494***	25.6920***	-0.0193***	4.4620***	28.0651***	-0.0294***	3.0217***	13.4858***
	(0.0044)	(0.4981)	(6.1866)	(0.0037)	(0.4024)	(4.9940)	(0.0056)	(0.4602)	(3.9266)
ESP	-0.0480***	6.6165***	38.8526***	-0.0444***	6.6408***	39.6031***	-0.0596***	4.7683***	21.5786***
	(0.0065)	(0.7371)	(9.1547)	(0.0069)	(0.7500)	(9.3075)	(0.0094)	(0.7670)	(6.5449)
ITA	-0.0266***	1.4350***	15.4070***	-0.0246***	1.6802***	17.9564***	-0.0286***	0.6713**	4.6065*
	(0.0037)	(0.4162)	(5.1691)	(0.0035)	(0.3766)	(4.6741)	(0.0038)	(0.3087)	(2.6339)
AUT	-0.0022	0.9140		-0.0004	0.9730***		-0.0018	0.7271***	
	(0.0054)	(0.1539)		(0.0052)	(0.1456)		(0.0047)	(0.0970)	
BEL	-0.0022	-0.3480***		-0.0018	-0.3124***		-0.0010	-0.5480**	-3.1822*
	(0.0025)	(0.0720)		(0.0027)	(0.0752)		(0.0027)	(0.2215)	(1.8896)
FIN	0.0126	3.6569**	38.4053**	0.0124	3.8358***	42.5386**	0.0033	2.4150**	19.8392**
	(0.0125)	(1.4225)	(17.6675)	(0.0127)	(1.3842)	(17.1779)	(0.0124)	(1.0141)	(8.6533)
GRC	0.0200**	1.0165***		0.0186**	0.8975***		0.0143	0.5431***	
	(0.0084)	0.2389		(0.0088)	(0.2484)		(0.0089)	(0.1819)	
IRL	-0.1094***	6.7331***	53.2208*	-0.0981***	8.0234***	66.2268**	-0.1217***	1.8271***	
	(0.0219)	(2.4910)	(30.9383)	(0.0208)	(2.2597)	(28.0425)	(0.0213)	(0.4369)	
NLD	-0.0200***	3.4916***	28.5636***	-0.0154**	3.8818***	32.1427***	-0.0243***	1.9636***	9.4903*
	(0.0073)	(0.8281)	(10.2850)	(0.0066)	(0.7129)	(8.8473)	(0.0074)	(0.6023)	(5.1395)
PRT	-0.0158***	3.6577***	26.1925***	-0.0124***	3.8833***	28.4498***	-0.0215***	2.2795***	10.6146***
	(0.0045)	(0.5079)	(6.3075)	(0.0037)	(0.4015)	(4.9830)	(0.0053)	(0.4334)	(3.6982)
EST	-0.0060	3.7170***	32.7029***	-0.0027	3.8165***	33.1264***	-0.0114*	1.9909***	10.6611**
	(0.0051)	(0.5790)	(7.1908)	(0.0046)	(0.4973)	(6.1715)	(0.0058)	(0.4735)	(4.0399)

*** significance at the 1% level, ** significance at the 5% level, * significance at the 10% level. Standard errors in parentheses. *Note*: Gaps indicate that the coefficients are estimated by dropping the quadratic term in the regression equation.

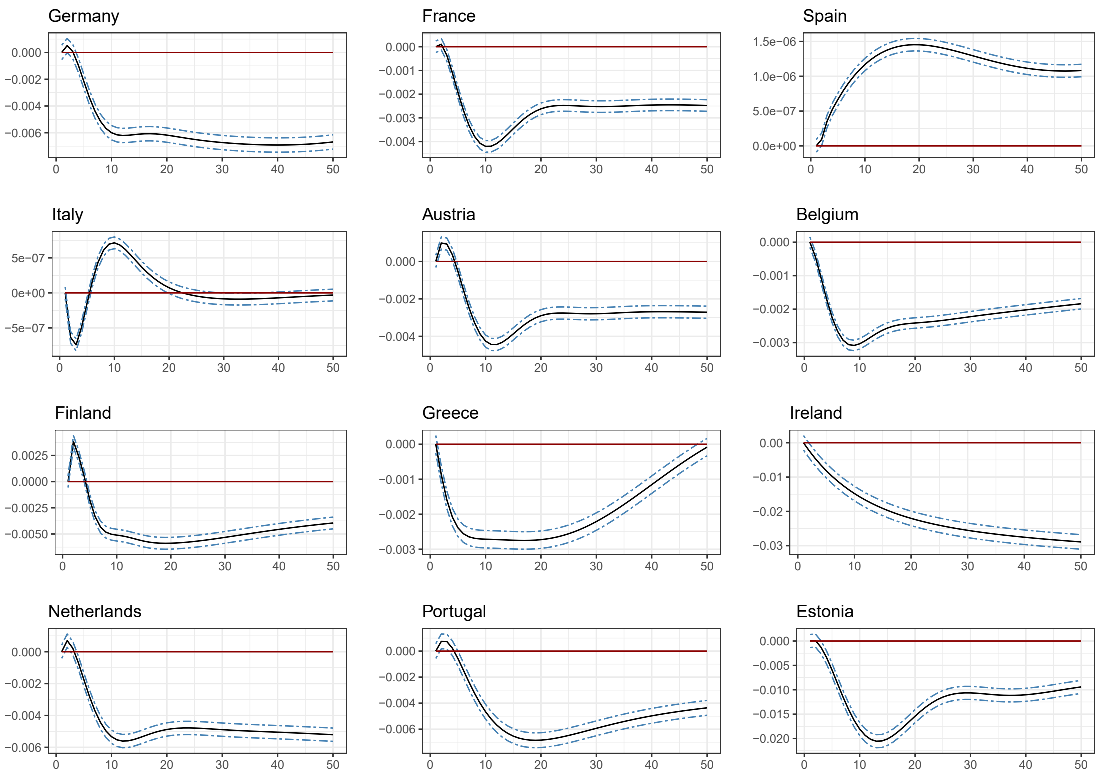

Figure 1.6: Real GDP responses in levels to a positive one standard deviation monetary policy shock. Dash-dotted lines indicate 95% confidence intervals.

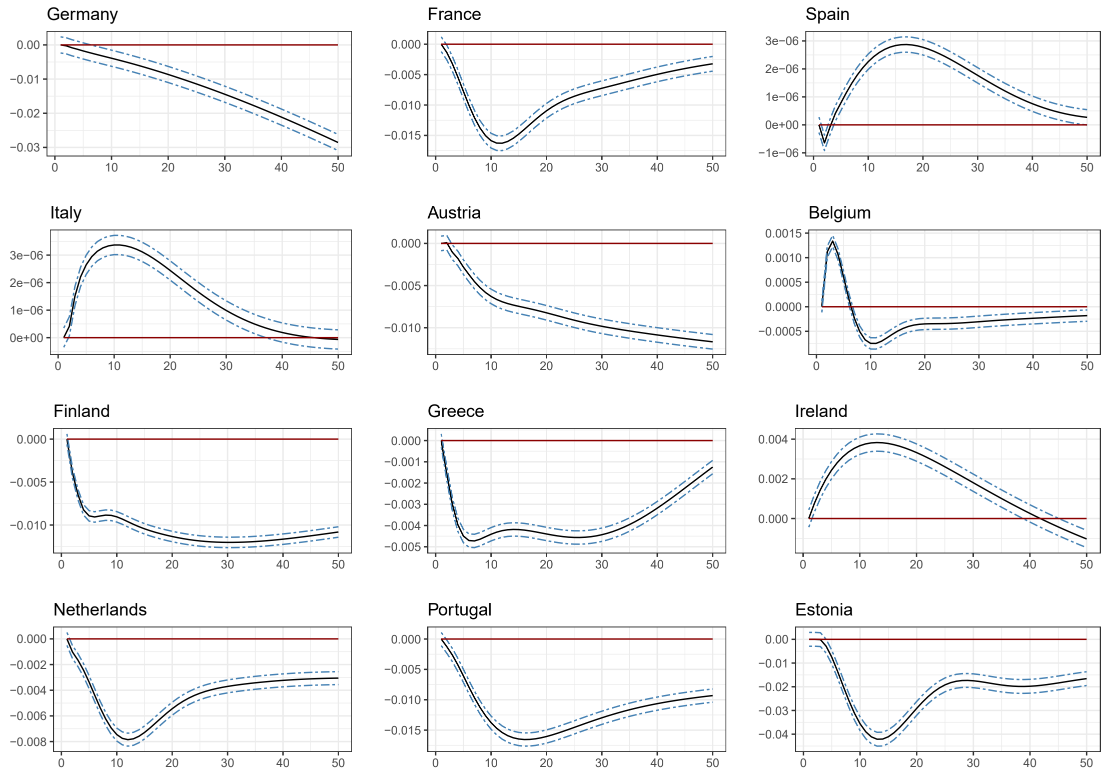

Figure 1.7: Real housing price responses in levels to a positive one standard deviation monetary policy shock.

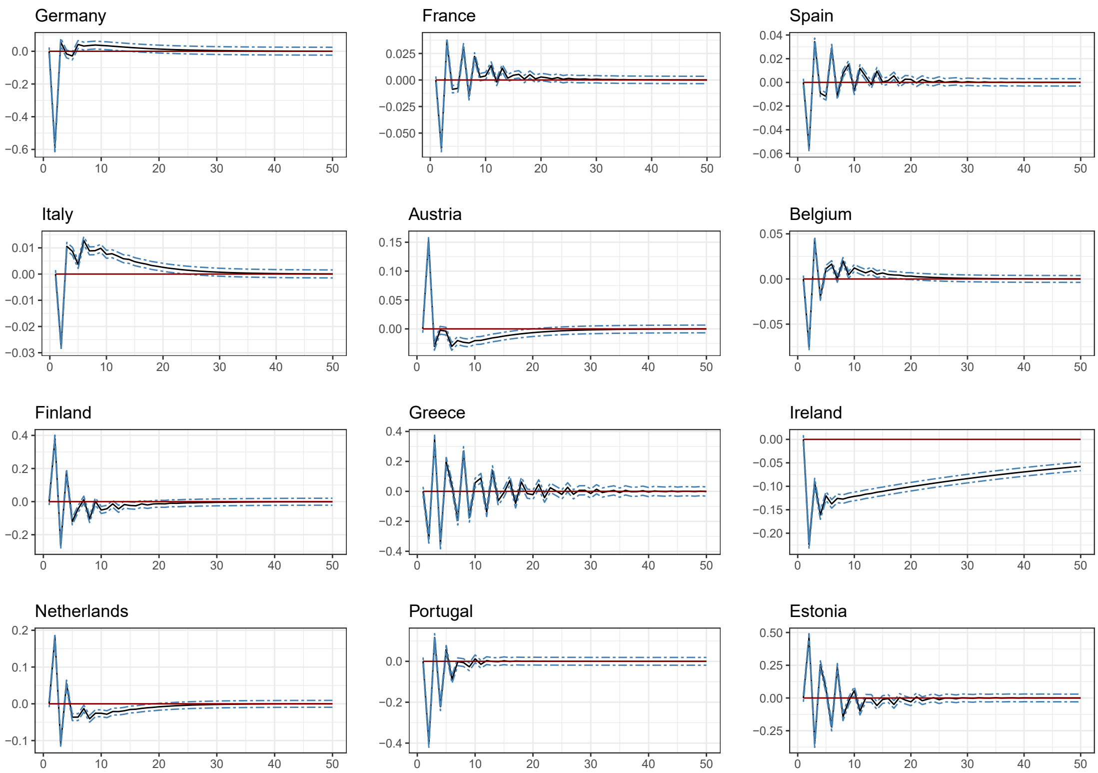

Figure 1.8: Real GDP responses in fourth differences to a positive one standard deviation monetary policy shock.

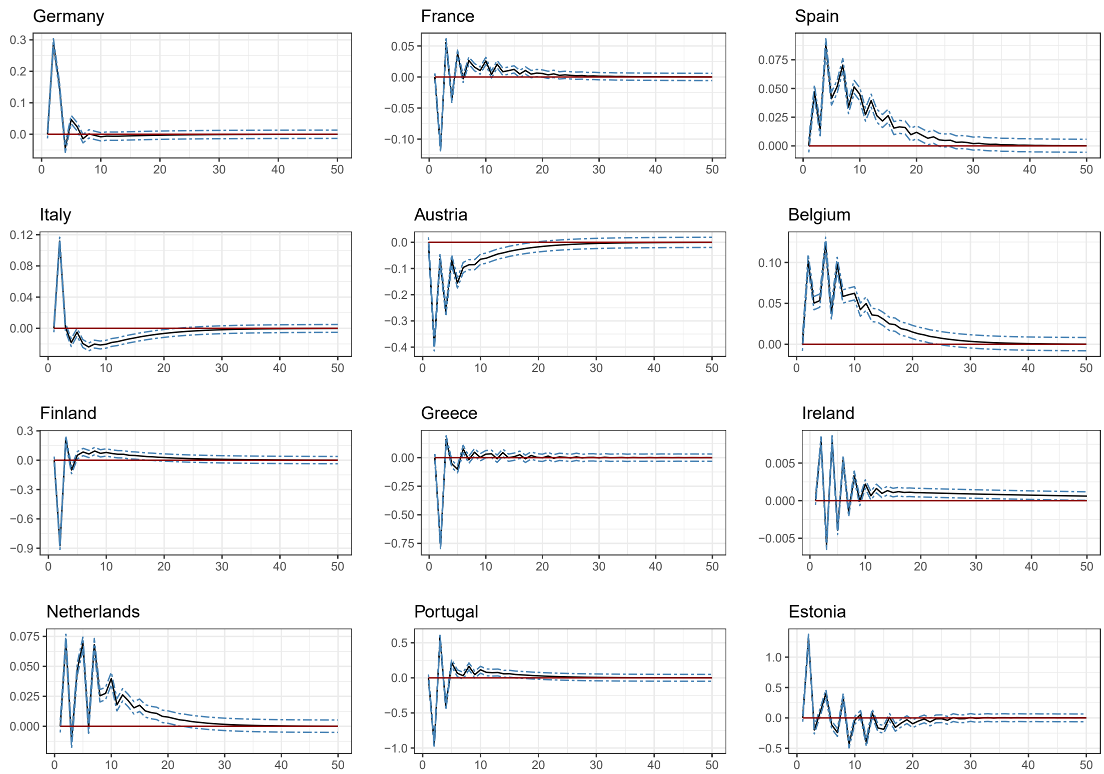

Figure 1.9: Real housing price responses in fourth differences to a positive one standard deviation monetary policy shock.

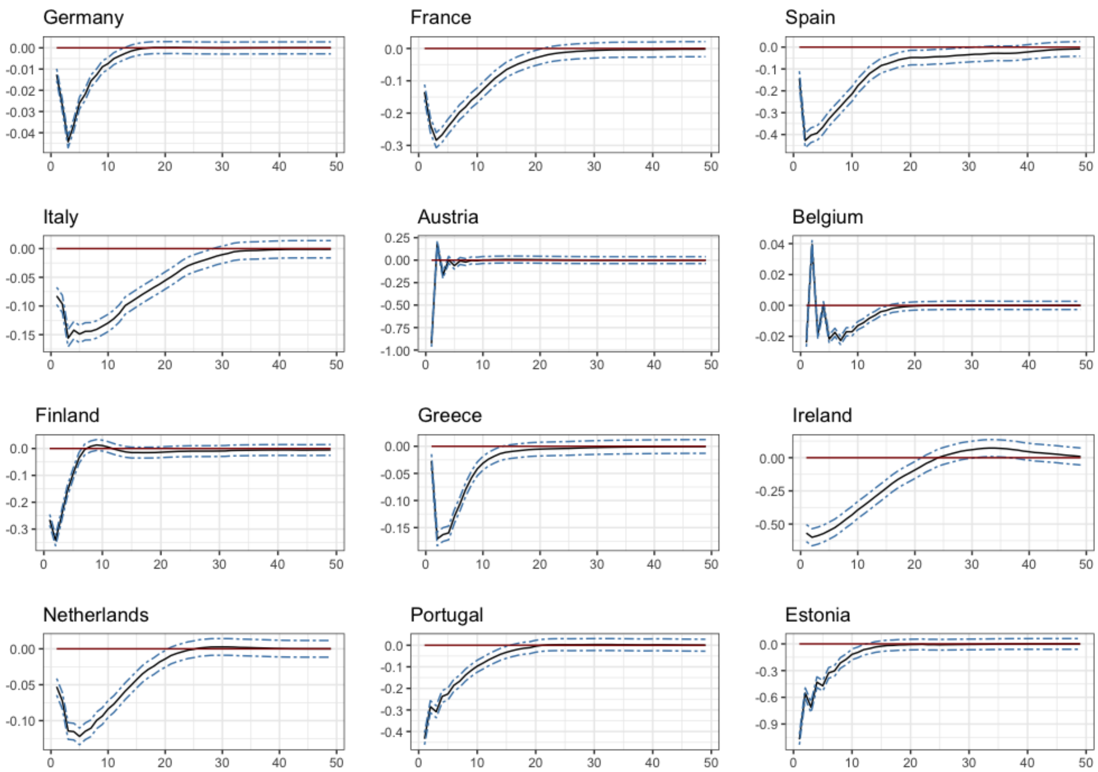

Figure 1.10: Real housing price responses to a positive one standard deviation monetary policy shock with real GDP restricted.

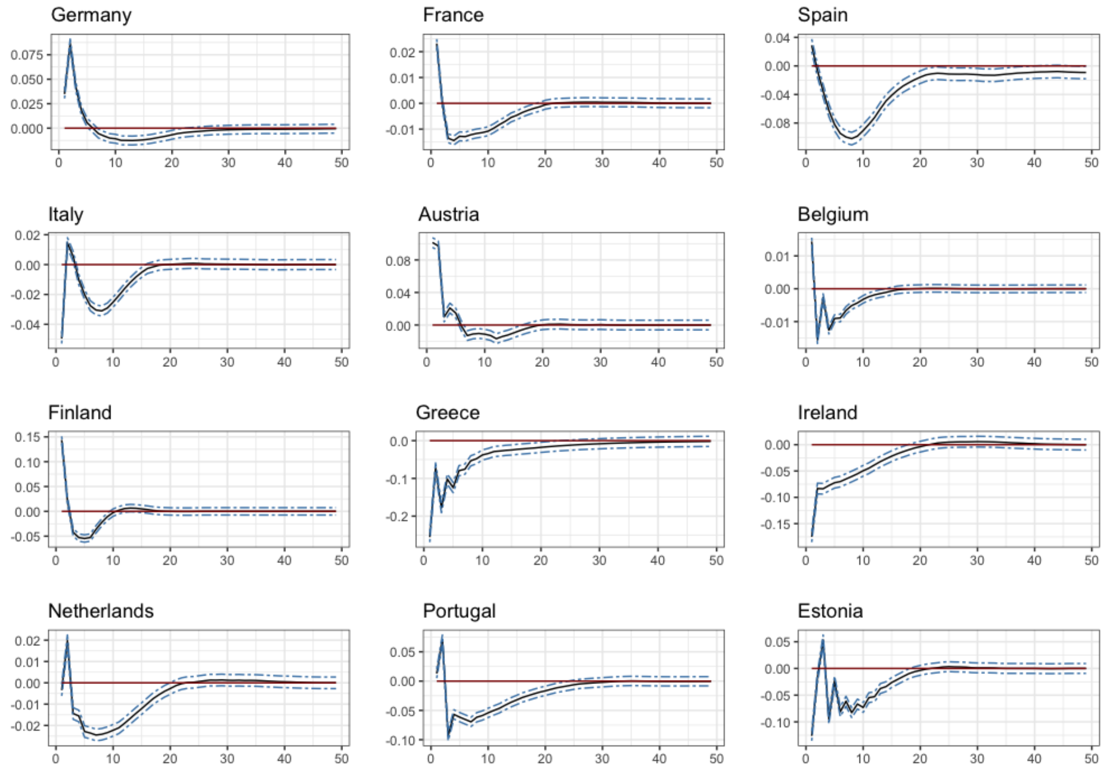

Figure 1.11: Real GDP responses to a positive one standard deviation monetary policy shock with real housing prices restricted.

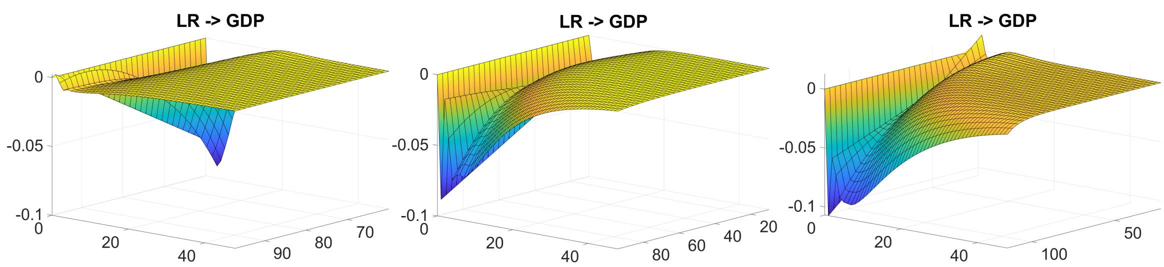

Figure 1.12: The figure shows the orthogonalized impulse response functions of real GDP to a shock in the long-term interest rate (LR) generated by the PCHVAR model. The left-hand panel plots the impulse responses for varying degrees of financial openness. The middle panel plots the impulse responses for varying levels of bank leverage. The right-hand panel plots the impulse responses for varying levels of household leverage.

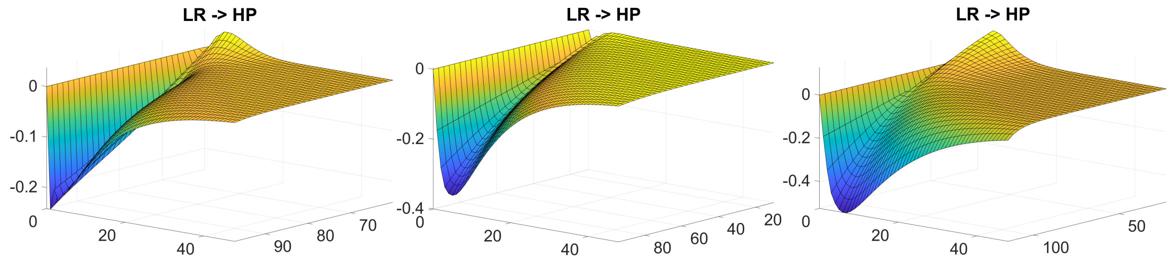

Figure 1.13: The figure shows the orthogonalized impulse response functions of real housing prices to a shock in the long-term interest rate generated by the PCHVAR model.

Chapter 2

Government Debt, Interest Rates, and Income Distribution in a Post-Keynesian Framework[1]

[1]This chapter is based on joint work with Prof. Dr. Hagen M. Krämer. I would like to thank Jochen Hartwig, Eckhard Hein, Christian R. Proaño and Johannes Schmidt for helpful comments and suggestions as well as participants at the 26th Forum for Macroeconomics and Macroeconomic Policies in Berlin and the 19th Annual Meeting of the Keynes Gesellschaft in Hannover. The chapter is in a submission process at the journal *Metroeconomica*. The current status is *revise and resubmit*.

2.1 Introduction

The development of advanced economies over the past four to five decades has been characterized by an increase in the ratio of public debt-to-GDP and by a rise in income inequality (Atkinson et al. 2011; Eichengreen et al. 2021; Saez and Zucman 2020). This article analyzes some important relationships between these trends. The main objective is to assess the claim that higher government debt generally increases income inequality. Although it is not unlikely that higher public debt causes greater income inequality the typical argument that follows a partial-analytical approach is flawed. It will be shown that the assertion that public debt typically leads to a redistribution from rich to poor is not correct, as distributional effects depend on specific macroeconomic circumstances.

The literature on the linkages between public debt and income distribution is far from conclusive. Early contributions such as Miller (1950) or Cohen (1951) based their reasoning on a partial-analytical mechanism Gandenberger (1970) referred to as the *transfer approach*. According to this approach, higher government debt leads to a redistribution of income from taxpayers to recipients of interest payments from government bonds. The rationale behind this claim is that since government securities are usually distributed more progressively than taxes, a rise in government debt is assumed to transfer income from the bottom and middle to the top of the income distribution (Samuelson 1967, p. 347). However, the transfer approach has been criticized for its simplistic link between public interest payments and tax rates, which is too narrow a view accounting for the complex nexus between public debt and income distribution (Anselmann and Krämer 2016). Recent contributions include empirical studies with econometric methods such as Autoregressive Distributed Lag (ARDL) based boundary tests (Obiero and Topuz 2022) and theoretical models in a DSGE framework (Sakkas and Varthalitis 2021).

Empirical studies on the impact of government debt on the distribution of income do not come to clear conclusions (Hager 2013; Obiero and Topuz 2022). In particular, empirical research on this issue is hampered by the difficulty of obtaining data on which income groups within the population hold government bonds. This kind of data problem is illustrated in Arbogast's (2020) study for Italy: An accurate allocation of government bond holdings to households is complicated by the fact that financial institutions hold most government bonds. However, even if the necessary data were available, studies based on a solely partial-analytical approach would be inappropriate. Because it is not the formal incidence that matters for the distributional effects but rather how recipients of interest payments and taxpayers react in their savings and consumption decisions, and how that affects macroeconomic variables such as investment and growth (Oberhauser 2008). Therefore, a macroeconomic approach is necessary to analyze public debt's influence on income distribution. Theoretical studies like Schlicht (2006) and, in the post-Keynesian tradition, Pasinetti (1989) and You and Dutt (1996) have analyzed the distributional effects of public debt by integrating growth and interest rate dynamics into an aggregate analytical framework.

In this article, we further extend the model originally developed by You and Dutt (1996). Our model also takes into account significant recent macroeconomic trends. These trends include a decline in advanced economies' growth rates over the past decades and the prolonged decline in long-term real interest rates. The model also sheds light on the resulting implications for economic policy as highlighted by the academic literature (Eggertsson et al. 2019; Rachel and Summers 2019; Summers 2014, 2015). To do so, we analyze the consequences of changes in government spending, investment and the real interest rate for the possible nexus between government debt and income inequality. We argue that investment and economic growth are major factors in analyzing the relationship between public debt and income distribution. Our model shows that two effects mainly determine the distribution of income. First, an increase in government spending and the resulting increase in government debt results in greater inequality in income distribution through changes in the interest income. Second, the expansionary effect of an increase in investment results in a reduction in income inequality. Variations in the real interest rate do not have a substantial impact on these effects. The model illustrates that the distributional effects depend on a complex interplay between government spending, tax rates, interest rates, debt-to-capital ratios, income, investment, consumption and growth.

The article is structured as follows: Section 2 gives an overview of the relevant literature. The theoretical model and the results of the comparative static analysis are introduced in section 3. Section 4 continues with the implications for economic policy and some concluding remarks.

2.2 The Impact of Government Debt on Income Distribution in the Post-Keynesian Literature

Post-Keynesian macroeconomic models that examine the relationship between public debt and income distribution typically incorporate factors such as economic growth, interest rates, and financial globalization into their analytical framework. There are some earlier examples of growth models in the post-Keynesian literature in which income distribution and government debt play essential roles. In the following, we briefly review this strand of the theoretical literature.

Pasinetti (1989) is an earlier example of a post-Keynesian dynamic model with public debt. His model includes workers and capitalists, both of whom receive profits and save a fraction of their disposable income. Pasinetti examined the effects of different propensities to consume out of wage and non-wage income. His model shows that when additional government spending is financed by an increase in public debt, every individual taxpayer serves as a debtor, but only the fraction of the population that owns government bonds receives the interest income. This contributes to growing income inequality. However, he was particularly interested in a situation in which Ricardian equivalence holds. Moreover, his analysis was conducted in a framework that assumed full employment and an economy growing at its natural rate.

In the post-Keynesian tradition, the model by You and Dutt (1996) represents an important contribution to the analysis of the relationship between public debt and income distribution. The model assumes that economic activity is determined by aggregate demand rather than by the supply of resources. In addition, investment activities in the corporate sector depend on expectations about the future of the economy, reflecting the animal spirits hypothesis. Further assumptions include that the money supply is determined by aggregate demand and that workers and capitalists differ in their propensities to save out of wage and non-wage income. They show that the distributional effects of changes in government debt are ambiguous and depend on the particular magnitudes and relationships of the relevant variables in their model.

In contrast to the model by You and Dutt (1996), Commendatore et al. (2004) present a post-Keynesian model consisting of two classes, both saving and receiving interest income. Their model shows that an increase in the government deficit increases government debt, which leads to greater income inequality. However, their model shows that this is not due to a higher share of government debt owned by the rentier class. The increase in income inequality comes about through a higher propensity to save of the rentier class compared to workers.

In the models by Pasinetti (1989) and You and Dutt (1996), only capitalists hold government bonds. In these models, a rise in government debt and the resulting increase in interest income leads to a change in the distribution of income. Another common feature is that these models analyze only the effects on the functional distribution of income since this plays an essential role in post-Keynesian growth models. However, in order to assess the social situation and the material conditions of individuals, households and social groups in a society, the distribution of personal income must also be examined (Atkinson 1997). The study by Commendatore et al. (2004) concentrates on the personal distribution of income. It demonstrates that the distributional consequences of increases in government debt depend on the saving rates of the individual households. In the present study, we attempt to bridge functional and personal income distribution by assuming that the importance of capital income as a source of income increases when one moves from the bottom to the top of the personal income distribution (Bengtsson and Waldenström 2018). By contrast, labor income is a more important source of income for lower-income classes. This implies that as the wage share decreases, personal income distribution becomes more unequal. Hence, increases in the capital share are associated with a stronger concentration of income at the top of the personal income distribution and, therefore, result in higher income inequality (Bengtsson and Waldenström 2018).

Besides post-Keynesian model-theoretic studies, several econometric studies on the relationship between government debt and income distribution exist.[2] Empirical evidence by Salti (2015), as

[2] A review of the empirical literature on government debt and income distribution can be found in Obiero and Topuz (2022).

well as Obiero and Topuz (2022) shows that an increase in public debt increases income inequality. By contrast, Akram (2016) and Tung (2020) find that an increase in public debt decreases income inequality. While the above-mentioned empirical studies point to a causal relationship running from public debt to income inequality, evidence also points to causality running from income inequality to public debt. For example, Jabłoński (2015) and Luo (2020) find that an increase in income inequality leads to an increase in public debt. The empirical evidence, thus, offers mixed conclusions regarding the nexus between government debt and income distribution.

2.3 A Theoretical Model on Government Debt and Income Distribution

Our analysis of the relationship between government debt and the distribution of income is based on the post-Keynesian model of You and Dutt (1996). Their model provides a broad macroeconomic framework by incorporating interest rate and growth dynamics. Our model differs from theirs first by assuming that not only capitalists but also workers save a fraction of their disposable income and hold government bonds. Second, we explicitly include the real rate of interest in our model. Third, we integrate the interest-growth differential into our analysis. Moreover, while You and Dutt limited their analysis to the impact on the functional distribution of income, we also consider the personal distribution of income.[3]

In the model by You and Dutt (1996), a distinction is made between the short-run and long-run dynamics of the model. This distinction is based on the view that the long-run is a succession of short-run periods (Kalecki 1971, p. 165). Therefore, the long-run dynamics of the model require an examination of the short-run dynamic behavior of the relevant variables (Lavoie 2009, p. 14). Similarly, we first introduce the behavioral equations determining the dynamic system and afterwards analyze its dynamic evolution. In this respect, our model is characterized by treating the debt-to-capital ratio and the share of government debt held by capitalists as exogenously given. However, the debt-to-capital ratio and the share of government debt held by capitalists are then endogenized and the dynamic evolution of the resulting system of differential equations is analyzed.

2.3.1 The Model in the Short-run

We assume a closed economy in which aggregate demand determines output and there are no supply constraints regarding labor and production capacity. As in Hein (2018), the model consists of a

[3] Although holding government bonds is an important feature of our model, for simplicity, we do not consider the distribution of wealth, but limit ourselves to analyzing changes in the distribution of income. For a model of government debt that includes wealth distribution, see Schlicht (2006).

government sector and a private sector in which a single good is produced. The following equation gives consumption demand

$$C = (1 - s_w)(1 - \tau_w)[(1 - \mu)Y + (1 - \phi)(rD/p)] + (1 - s_c)(1 - \tau_c)[\mu Y + \phi(rD/p)] \tag{2.1}$$

where s_w denotes the saving rate of workers, s_c the saving rate of capitalists and Y real national income. Thus, both capitalists and workers save a part of their disposable income. Following Kaldor (1955), we assume $s_w < s_c$ and, hence, that saving by capitalists exceeds saving by workers. τ_w is the income tax rate of workers and τ_c the income tax rate of capitalists. μ denotes the share of profits in net national income and $1 - \mu$ the share of wages in net national income. In the present model, we assume that financial saving by workers and capitalists takes place only in the form of government bonds and not through the purchase of shares issued by firms or corporate bonds (Hein 2018). The real rate of interest is defined as $r = i - \pi$, where i denotes the nominal rate of interest and π the inflation rate. D determines the nominal stock of government debt and p is the price level. Following You and Dutt (1996), the price level is assumed to be constant. Hence, $\pi = 0$ and the real interest rate $r = i$. The profit share, the saving rates, the share of government bonds held by capitalists and the nominal interest rate are all exogenously given.

The investment function is given by the following behavioral equation

$$I = [\alpha_o + \alpha_1 u + \alpha_2(1 - \tau_c)\mu]K \tag{2.2}$$

where the rate of capacity utilization is defined as $u = \frac{Y}{K}$, with K as the real stock of capital and α_0, α_1 and α_2 being positive and constant parameters. Investment demand is determined by animal spirits of firms, represented by the parameter α_0, as well as expectations of firms regarding the future profit share μ and capacity utilization u.[4] In other words, when firms are optimistic, i.e., they expect a higher rate of capacity utilization or a higher profit share, investment demand increases (Lavoie 2022, pp. 83, 372). The sensitivity of investment with respect to changes in animal spirits, the rate of capacity utilization and the rate of capital accumulation is measured by the parameters α_0, α_1, and α_2 respectively.

Real government expenditure G is given by

$$G = \beta K \tag{2.3}$$

where β is a constant parameter with $0 \leq \beta \leq 1$. Hence, government spending is modeled as a constant fraction of the capital stock (Chiarella et al. 2005; You and Dutt 1996).

[4]The investment function does not depend on the interest rate i. We follow Bhaduri and Marglin (1990) in this respect and consider an investment function that is dependent on the expected rate of capacity utilization and the expected profit share.

Using $Y = C + I + G$ and substituting equations (1) - (3), we obtain real national income (Y)

$$\begin{aligned} Y = &(1-s_w)(1-\tau_w)[(1-\mu)Y + (1-\phi)(rD/p)] + (1-s_c)(1-\tau_c)(\mu Y + \phi(rD/p)] \\ &+ [\alpha_0 + \alpha_1 u + \alpha_2(1-\tau_c)\mu]K + \beta K \end{aligned} \tag{2.4}$$

We proceed by dividing both sides of equation 2.4 by K and solve for u

$$u = \gamma(\mu)[(1-s_w)(1-\tau_w)(1-\phi)r\sigma + (1-s_c)(1-\tau_c)\phi r\sigma + \alpha_0 + \alpha_2(1-\tau_c)\mu + \beta] \tag{2.5}$$

where $\gamma(\mu) = (\tau_w + s_w - s_w\tau_w + \theta\mu - \alpha_1)^{-1}$, with $\theta = (1-s_w)(1-\tau_w) - (1-s_c)(1-\tau_c)$, is the output multiplier, $\sigma = \frac{D}{pK}$ is the debt-to-capital ratio and $\gamma, \theta > 0$.

The debt-to-capital ratio is a major determinant of changes in the rate of capacity utilization in our model. In order to determine the impact of the debt-to-capital ratio on the rate of capacity utilization, we take the partial derivative of u with respect to σ.

$$\frac{\partial u}{\partial \sigma} = \gamma(\mu)[(1-s_w)(1-\tau_w)(1-\phi)r + (1-s_c)(1-\tau_c)\phi r] > 0 \tag{2.6}$$

Equation 2.6 shows a positive impact of the debt-to-capital ratio σ on the rate of capacity utilization. Hence, an increase in the debt-to-capital ratio raises the interest income of workers and capitalists, which leads to an increase in consumption expenditures and a subsequent rise in the rate of capacity utilization.

The effect of changes in the saving rates on capacity utilization is obtained by taking the partial derivative with respect to s_w and s_c respectively.

$$\frac{\partial u}{\partial s_w} = \gamma(\mu)[-(1-\tau_w)((1-\mu)u + (1-\phi)(rD/p))] < 0 \tag{2.7}$$

$$\frac{\partial u}{\partial s_c} = \gamma(\mu)[-(1-\tau_c)(\mu u + \phi(rD/p)] < 0 \tag{2.8}$$

noticing that

$$\partial(C/K)/\partial s_w = -(1-\tau_w)[(1-\mu)u + (1-\phi)(rD/p)] \tag{2.9}$$

$$\partial(C/K)/\partial s_c = -(1-\tau_c)[\mu u + \phi(rD/p)] \tag{2.10}$$

Equations 2.7 and 2.8 show that a rise in the propensity to save of workers and capitalists reduces capacity utilization through a reduction in their respective disposable incomes, resulting in a decrease in consumption expenditures. This effect corresponds to the *paradox of thrift*, which states that increases in the propensity to save lead to a reduction in economic activity (Keynes 1936; Lavoie

2009, pp. 84, 94). As can be seen from equation 2.12 below, a reduction in capacity utilization negatively impacts the accumulation rate.

Additionally, from the definition of the profit rate $\nu = (1 - \tau_c)\mu u$, we recognize that a decrease in the rate of capacity utilization has a negative impact on the rate of profit. Therefore, the *paradox of saving*, according to which increases in saving propensities lead to a reduction in consumption demand with adverse effects on the rates of capacity utilization and capital accumulation (Hein 2014), holds in our model as well.

In order to evaluate the consequences of redistribution for the rate of capacity utilization, we take the partial derivative of u with respect to the profit share μ

$$\frac{\partial u}{\partial \mu} = [\alpha_2(1 - \tau_c) - \theta u]\gamma(\mu) \tag{2.11}$$

where $\partial(I/K)/\partial\mu = \alpha_2(1 - \tau_c)$ and $\partial(C/K)/\partial\mu = -\theta u$.

From equation 2.11, it is clear that a rise in the profit share μ has a positive effect on capacity utilization if its positive impact on investment exceeds its negative impact on consumption. In this case, demand is profit-led. The positive impact of the profit share increases with the weight it is given in the investment function by the parameter α_2. However, it decreases with τ_c as a rise in the income tax rate results in a reduction in the disposable income of capitalists, dampening the positive impact of increases in the profit share on capacity utilization. On the contrary, if the negative effect on consumption exceeds the positive impact on investment demand, a rise in the profit share negatively impacts the rate of capacity utilization and demand is wage-led. However, this effect is dampened by an increasing saving rate of workers s_w or an increasing income tax rate τ_w.

The behavioral equation for the real rate of capital accumulation is as follows

$$g = I/K = \alpha_0 + \alpha_1 u + \alpha_2(1 - \tau_c)\mu \tag{2.12}$$

We take the partial derivative of g in equation 2.12 with respect to σ

$$\frac{\partial g}{\partial \sigma} = \alpha_1 \frac{\partial u}{\partial \sigma} > 0 \tag{2.13}$$

This yields a positive relationship between the rate of capital accumulation and the debt-to-capital ratio. Thus, as shown in equation 2.6, a rise in the debt-to-capital ratio induces a rise in the rate of capacity utilization through an increase in the disposable income of workers and capitalists. This leads to a rise in investment demand and a resulting increase in the rate of accumulation g.

Taking the partial derivative of g with respect to the profit share μ, we obtain

$$\frac{\partial g}{\partial \mu} = \alpha_1 \frac{\partial u}{\partial \mu} + \alpha_2(1 - \tau_c) \tag{2.14}$$

Equation 2.14 shows that in the case of profit-led demand, a rise in the profit share has a positive effect on the rate of accumulation. Hence, growth is profit-led. By contrast, in the case of wage-led demand, a rise in the profit share has a negative impact on the rate of accumulation and growth is wage-led. Both effects are determined by the elasticity of accumulation with respect to changes in demand α_1. In case the second term of equation 2.14 is greater than the negative impact of μ on u, the higher elasticity of accumulation with respect to changes in the profit share α_2 results in profit-led growth.

We now consider the distribution of income. Following You and Dutt (1996), ϑ is the ratio between the income of workers and the income of capitalists, which is given as

$$\vartheta = \rho \frac{(\mu + \phi r\sigma/u)}{(1-\mu) + (1-\phi)r\sigma} \tag{2.15}$$

where $\rho = \frac{(1-\tau_c)}{(1-\tau_w)}$.

ϑ is, therefore, a measure of income distribution between workers and capitalists.[5] Equation 2.15 reveals a positive relationship between changes in the interest income of capitalists and changes in profits. Hence, higher interest income of capitalists increases income inequality. In contrast, the higher the rate of capacity utilization, the lower the inequality of income distribution. Equation 2.15 also shows that higher (lower) interest income of workers causes lower (higher) income inequality.

Taking the partial derivative of ϑ with respect to μ we obtain

$$\frac{\partial\vartheta}{\partial\mu} = \frac{\rho - \rho(\phi r\sigma/u^2)(\partial u/\partial\mu)}{(1-\mu) + (1-\phi)r\sigma} \tag{2.16}$$

This equation illustrates that in the case of profit-led demand, a rise in the profit share may lead to lower income inequality. However, this necessitates that the interest income of capitalists as a share of output is large. In the case of wage-led demand, a rise in the profit share exerts a negative impact on the rate of capacity utilization. This leads to higher income inequality.

Following You and Dutt (1996), we first assumed that the debt-to-capital ratio and the share of government debt held by capitalists are constant. In the next section, we relax this assumption and endogenize the debt-to-capital ratio as well as the share of government debt held by capitalists.

2.3.2 Laws of Motion

In this section, we focus our theoretical analysis on the dynamic evolution of the debt-to-capital ratio as well as the share of government debt held by capitalists. At first, we will endogenize the debt-to-capital ratio and the share of government debt held by capitalists. Afterwards, we discuss the analytical equilibrium solution of the dynamic system.

[5] If ϑ increases, we can not only say that income distribution has changed in favor of capitalists, but also that income inequality within the population has increased. This is so because we assume that the importance of capital income as a source of income increases when one moves from the bottom to the top of the personal income distribution. Hence, as already noted, increases in the capital share are associated with a stronger concentration of income at the top of the personal income distribution (Bengtsson and Waldenström 2018), and therefore, result in higher income inequality.

Following You and Dutt (1996), the time path of the stock of government debt is defined as

$$\frac{dD}{dt} = (G - T) + rD \tag{2.17}$$

where $T = \tau_w[(1-\mu)Y + (1-\phi)rD/p] + \tau_c(\mu Y + \phi rD/p)$ are real taxes based on worker's and capitalist's income. Differentiating the debt-to-capital ratio σ with respect to time and substituting equation 2.17 yields the time rate of change of σ.

$$\dot{\sigma} = \frac{d\sigma}{dt} = [\beta - \tau^* u(\sigma) - \tau_w(1-\phi)r\sigma - \tau_c\phi r\sigma] + [r - g(\sigma)]\sigma \tag{2.18}$$

where $\tau^* = \tau_w(1-\mu) + \tau_c\mu$ defines the average income tax rate. Equation (2.18) shows that the dynamics of the debt-to-capital ratio are determined by the primary deficit and the difference between the real interest rate on government debt and the growth rate of the economy, $r - g$. If we assume that Bowley's law holds, that is that the profit share is approximately constant in the long-run (Krämer 2011), μ is fixed and u and g are solely determined by the debt-to-capital ratio σ.

We follow You and Dutt (1996, p. 341) and define the rate of capacity utilization as well as the rate of capital accumulation as a function of σ only, reflecting the assumption that the profit share μ is constant in equilibrium.

$$u(\sigma) = \gamma[\alpha_0 + \alpha_2(1-\tau_c)\mu + \beta] + \sigma\frac{\partial u}{\partial\sigma} = u(0) + \sigma\frac{\partial u}{\partial\sigma} \tag{2.19}$$

$$g(\sigma) = [\alpha_0 + \alpha_1 u(0) + \alpha_2(1-\tau_c)\mu] + \alpha_1\sigma\frac{\partial u}{\partial\sigma} = g(0) + \alpha_1\sigma\frac{\partial u}{\partial\sigma} \tag{2.20}$$

The time rate of change of the share of government debt held by capitalists ϕ is given as

$$\dot{\phi} = \frac{d\phi}{dt} = s_c(1-\tau_c)(\mu + \frac{\phi r\sigma}{u}) \tag{2.21}$$

Equation 2.21 shows that the share of government debt held by capitalists changes with the saving rate and the tax rate of capitalists, the profit share, the interest income from holding government bonds, and the capacity utilization rate.

The equilibrium solution of the model is obtained from the dynamic system of nonlinear equations given by

$$[\beta - \tau^* u(\sigma) - \tau_w(1-\phi^*)r\sigma^* - \tau_c\phi^* r\sigma^*] + [r - g(\sigma)]\sigma^* - \sigma^* = 0 \tag{2.22}$$

$$s_c(1-\tau_c)(\mu + \frac{\phi^* r\sigma^*}{u}) - \phi^* = 0 \tag{2.23}$$

$$\gamma[\alpha_0 + \alpha_2(1-\tau_c)\mu + \beta] + \sigma^*\frac{\partial u}{\partial\sigma} - u^* = u(0) + \sigma^*\frac{\partial u}{\partial\sigma} - u^* = 0 \tag{2.24}$$

$$[\alpha_0 + \alpha_1 u(0) + \alpha_2(1-\tau_c)\mu] + \alpha_1\sigma^* \frac{\partial u}{\partial \sigma^*} - g^* = g(0) + \alpha_1 \sigma^* \frac{\partial u}{\partial \sigma} - g^* = 0 \quad (2.25)$$

$$\rho \frac{(\mu + \phi^* r\sigma^*/u^*)}{(1-\mu) + (1-\phi^*) r\sigma^*} - \vartheta^* = 0 \quad (2.26)$$

where σ^*, ϕ^*, u^*, g^* and ϑ^* are the equilibrium values of the debt-to-capital ratio, the share of government debt held by capitalists, the rate of capacity utilization, the rate of capital accumulation and the distribution of income, respectively.

2.3.3 Stability of the Model

In this section, we determine the stability of the model by means of the Jacobi matrix. Stability of the dynamic system consisting of the equilibrium values of the debt-to-capital ratio and the share of government debt held by capitalists requires a positive determinant and a negative trace of the Jacobian matrix J (Chiang 1984, pp. 641–643).

$$J = \begin{pmatrix} \frac{\partial \dot{\sigma}}{\partial \sigma} & \frac{\partial \dot{\sigma}}{\partial \phi} \\ \frac{\partial \dot{\phi}}{\partial \sigma} & \frac{\partial \dot{\phi}}{\partial \phi} \end{pmatrix} \quad (2.27)$$

where the determinant and trace are defined as:

$$det(J) = \frac{\partial \dot{\sigma}}{\partial \sigma} * \frac{\partial \dot{\phi}}{\partial \phi} - \frac{\partial \dot{\phi}}{\partial \sigma} * \frac{\partial \dot{\sigma}}{\partial \phi} \quad (2.28)$$

$$tr(J) = \frac{\partial \dot{\sigma}}{\partial \sigma} + \frac{\partial \dot{\phi}}{\partial \phi} \quad (2.29)$$

Derivation of $\dot{\sigma}$ and $\dot{\phi}$ yields the following values of the Jacobian matrix J:

$$\frac{\partial \dot{\sigma}}{\partial \sigma} = -\tau^* \frac{\partial u}{\partial \sigma} - \tau_w(1-\phi)r - \tau_c \phi r + r - 2\sigma\alpha_1 \frac{\partial u}{\partial \sigma} \quad (2.30)$$

$$\frac{\partial \dot{\sigma}}{\partial \phi} = \tau_w r\sigma - \tau_c r\sigma \quad (2.31)$$

$$\frac{\partial \dot{\phi}}{\partial \sigma} = \frac{s_c(1-\tau_c)\phi r(u - \sigma \frac{\partial u}{\partial \sigma})}{u^2} \quad (2.32)$$

$$\frac{\partial \dot{\phi}}{\partial \phi} = \frac{s_c(1-\tau_c) r\sigma(u - \phi \frac{\partial u}{\partial \phi})}{u^2} \quad (2.33)$$

Substituting equations 2.30 - 2.33 into equations 2.28 and 2.29, we obtain the following determinant and trace:

$$\begin{aligned} det(J) = {} & [-\tau^* \frac{\partial u}{\partial \sigma} - \tau_w(1-\phi)r - \tau_c\phi r + r - 2\sigma\alpha_1 \frac{\partial u}{\partial \sigma}] * [\frac{s_c(1-\tau_c)r\sigma(u - \phi\frac{\partial u}{\partial \phi})}{u^2}] \\ & - [\frac{s_c(1-\tau_c)\phi r(u - \sigma\frac{\partial u}{\partial \sigma})}{u^2}] * [\tau_w r\sigma - \tau_c r\sigma] \end{aligned} \tag{2.34}$$

$$tr(J) = -\tau^* \frac{\partial u}{\partial \sigma} - \tau_w(1-\phi)r - \tau_c\phi r + r - 2\sigma\alpha_1 \frac{\partial u}{\partial \sigma} + \frac{s_c(1-\tau_c)r\sigma(u - \phi\frac{\partial u}{\partial \phi})}{u^2} \tag{2.35}$$

Table 2.1: Local stability of the equilibrium

Case	$\frac{\partial u}{\partial \sigma}$	$\frac{\partial u}{\partial \phi}$	$u - \sigma\frac{\partial u}{\partial \sigma}$	$u - \phi\frac{\partial u}{\partial \phi}$	det(J)	tr(J)	Stability
1	+	+	-	-	+	-	stable focus
2	+	+	-	+	+	0	unstable
3	+	-	-	+	+	0	unstable
4	+	+	+	-	+	-	stable node
5	+	-	+	+	-	-/0/+	saddle point (unstable)
6	+	-	-	+	-	-/0/+	saddle point (unstable)

Classification of stability according to Chiang (1984, pp. 641–643).

Table 2.1 offers six cases that provide different terms determining the stability of the equilibrium. Cases 1 and 4 show parameter combinations leading to stable equilibrium values of the government debt-to-capital ratio and the share of government debt held by capitalists. Case 1 is classified as a *stable focus* which is characterized by cyclical fluctuations toward a stable equilibrium (Chiang 1984, p. 643). According to case 1 local stability requires that $\frac{\partial u}{\partial \sigma} > 0$, $\frac{\partial u}{\partial \phi} > 0$, $u - \sigma\frac{\partial u}{\partial \sigma} < 0$ and $u - \phi\frac{\partial u}{\partial \phi} < 0$. Equation 2.6 shows that the first condition holds. The second condition requires that $\frac{\partial u}{\partial \phi} > 0$. Taking the partial derivative of u with respect to ϕ yields

$$\frac{\partial u}{\partial \phi} = \gamma(\mu)[-(1-s_w)(1-\tau_w)r\sigma + (1-s_c)(1-\tau_c)r\sigma] \tag{2.36}$$

which is positive when

$$-(1-s_w)(1-\tau_w)r\sigma < (1-s_c)(1-\tau_c)r\sigma \tag{2.37}$$

holds. This implies that the disposable interest income of capitalists exceeds the disposable interest income of workers which causes an increase in the rate of capacity utilization. Condition three is fulfilled when the expansionary effect of an increase in the debt-to-capital ratio on the rate of capacity utilization is such that it exceeds the rate of capacity utilization. Condition four implies that an increase in the share of government debt held by capitalists has an expansionary effect on the rate of capacity utilization through an increase in the disposable interest income of capitalists. In order for condition four to be fulfilled, the expansionary effect of an increase in the share of government debt held by capitalists is such that it exceeds the rate of capacity utilization. This generates a path to a steady state which is characterized by cyclical movements.

Case 4 is classified as a *stable node* which is characterized by non-cyclical movement towards a stable equilibrium (Chiang 1984, p. 643). According to Case 4 local stability requires that $\frac{\partial u}{\partial \sigma} > 0$, $\frac{\partial u}{\partial \phi} > 0$, $u - \sigma \frac{\partial u}{\partial \sigma} > 0$ and $u - \phi \frac{\partial u}{\partial \phi} < 0$. In contrast to case 1, condition three shows that $u - \sigma \frac{\partial u}{\partial \sigma} > 0$. This condition implies that the expansionary effect of an increase in the debt-to-capital ratio on the rate of capacity utilization is smaller than the rate of capacity utilization. Hence, a careful increase in the debt-to-capital ratio generates a stable path to a steady state.

Cases 2 and 3 are unstable equilibria in which cyclical fluctuations do not lead to a steady state. Further, cases 5 and 6 are classified as a *saddle point* which is an unstable equilibrium (Chiang 1984, p. 633).

2.3.4 Effects of Parametric Changes

Now we analyze the effects of changes in exogenous parameters on the equilibrium values of the debt-to-capital ratio, the share of government debt held by capitalists, the rate of capacity utilization, the rate of capital accumulation as well as the distribution of income. The effects of parametric changes are obtained by partial derivation of the relevant model parameters. We focus our analysis on an increase in government spending represented by an increase in the parameter β. Further, we analyze the effects of an increase in autonomous investment α_0 and of an increase in the real interest rate r. In order to determine the effects of changes in exogenous parameters on the equilibrium debt-to-capital ratio σ^*, we set equation 2.18 equal to zero and solve for σ.

$$\sigma^* = \frac{-\tau^* u(0) + \beta - g(0)}{-\frac{\partial u}{\partial \sigma} + \tau_w(1-\phi)r + \tau_c \phi r - r - \alpha_1 \sigma \frac{\partial u}{\partial \sigma}} \tag{2.38}$$

From equation 2.38 we see that a rise in the parameter β directly increases the debt-to-capital ratio. Taking the partial derivative of σ^* with respect to β yields

$$\frac{\partial \sigma^*}{\partial \beta} = \frac{(1 - \tau^* \gamma)}{-\frac{\partial u}{\partial \sigma} + \tau_w(1-\phi)r + \tau_c \phi r - r - \alpha_1 \sigma \frac{\partial u}{\partial \sigma}} \tag{2.39}$$

which shows us, provided that $(1 - \tau^* \gamma) > 0$, that a rise in β increases the equilibrium debt-to-capital ratio. By contrast, when $(1 - \tau^* \gamma) < 0$, an increase in β has a negative impact on the equilibrium debt-to-capital ratio. Put differently, when the direct positive impact of β on σ^* is smaller than the negative impact through the expansionary multiplier effect, the equilibrium debt-to-capital ratio decreases.

Equations 2.19 and 2.20 show that an increase in the autonomous investment component α_0 increases the rate of capacity utilization as well as the rate of capital accumulation. From equation 2.38

we recognize that this decreases the equilibrium debt-to-capital ratio σ^*. Taking the partial derivative of equation 2.38 with respect to α_0, we obtain

$$\frac{\partial \sigma^*}{\partial \alpha_0} = \frac{-[1 + \gamma(\tau^* + \alpha_1)]}{-\frac{\partial u}{\partial \sigma} + \tau_w(1-\phi)r + \tau_c \phi r - r - \alpha_1 \sigma \frac{\partial u}{\partial \sigma}} \tag{2.40}$$

which shows a negative impact of an increase in autonomous investment on the equilibrium debt-to-capital ratio.

Derivation of σ^* with respect to r yields

$$\frac{\partial \sigma^*}{\partial r} = (1 - \tau_w(1-\phi) - \tau_c\phi)(\beta - \tau^* u(0) - g(0)) \tag{2.41}$$

Equation 2.41 shows that a rise in the real interest rate increases the equilibrium debt-to-capital ratio. However, when the negative impact of the income generated through the average income tax as well as the rate of capital accumulation exceed the direct positive impact of β, the equilibrium debt-to-capital ratio decreases.

In order to determine the effects of changes in exogenous parameters on the equilibrium share of government debt held by capitalists ϕ^*, we set equation 2.21 equal to zero, solve for ϕ and substitute σ^* as well as u^*.

$$\phi^* = \frac{s_c(1-\tau_c)\mu}{s_c(1-\tau_c)(\frac{r\sigma^*}{u^*})} = \frac{\mu}{\frac{r\sigma^*}{u^*}} \tag{2.42}$$

From equation 2.42, we see that an increase in the equilibrium debt-to-capital ratio σ^* decreases the equilibrium share of government debt held by capitalists ϕ^* and vice versa. The impact of an increase in government spending on the equilibrium share of government debt held by capitalists depends on the effect of β on σ^*. If an increase in government spending increases σ^*, the equilibrium share of government debt held by capitalists decreases. On the opposite, if an increase in government spending decreases σ^*, ϕ^* increases. As an increase in autonomous investment α_0 leads to a decrease in σ^*, the equilibrium share of government debt held by capitalists increases. Finally, an increase in the real interest rate decreases the equilibrium share of government debt held by capitalists.

To determine the equilibrium value of the rate of capacity utilization, we substitute σ^* into equation 2.19.

$$u^* = u(\sigma^*) = \gamma[\alpha_0 + \alpha_2(1-\tau_c)\mu + \beta] + \sigma^* \frac{\partial u}{\partial \sigma} = u(0) + \sigma^* \frac{\partial u}{\partial \sigma} \tag{2.43}$$

The fact that both an increase in β and an increase in α_0 lead to a rise in u^* follows from:

$$\frac{\partial u^*}{\partial \beta} = \gamma > 0 \tag{2.44}$$

$$\frac{\partial u^*}{\partial \alpha_0} = \gamma > 0 \tag{2.45}$$

An increase in the real interest rate increases the equilibrium rate of capacity utilization through its positive impact on σ^*.

Substituting σ^* into equation 2.20, we obtain the equilibrium value of the rate of capital accumulation g^*.

$$g^* = g(\sigma^*) = [\alpha_0 + \alpha_1 u(0) + \alpha_2(1-\tau_c)\mu] + \alpha_1\sigma^*\frac{\partial u}{\partial \sigma} = g(0) + \alpha_1\sigma^*\frac{\partial u}{\partial \sigma} \tag{2.46}$$

Derivation of g^* with respect to β and α_0 yields:

$$\frac{\partial g^*}{\partial \beta} = \alpha_1\gamma > 0 \tag{2.47}$$

$$\frac{\partial g^*}{\partial \alpha_0} = 1 + \alpha_1\gamma > 0 \tag{2.48}$$

Equations 2.47 and 2.48 reveal a positive impact of β and α_0 on the equilibrium rate of capital accumulation g^*. Likewise, a hike in the real interest rate increases the equilibrium rate of capital accumulation as it has a positive impact on the equilibrium debt-to-capital ratio.

The equilibrium distribution of income is obtained by substituting σ^*, ϕ^* and u^* into equation 2.15.

$$\vartheta^* = \rho\frac{(\mu + \phi^* r\sigma^*/u^*)}{(1-\mu) + (1-\phi^*)r\sigma^*} \tag{2.49}$$

Equation 2.49 reveals that an increase in β reduces income inequality through its positive impact on the equilibrium rate of capacity utilization u^*. However, depending on the effect of β on σ^* and ϕ^*, income inequality increases. An increase in autonomous investment leads to a decrease in income inequality as it increases the equilibrium rate of capacity utilization. On the contrary, an increase in the equilibrium share of government debt held by capitalists increases income inequality. Taking the partial derivative of ϑ^* with respect to σ^* yields

$$\frac{\partial \vartheta^*}{\partial \sigma^*} = \frac{\rho r\phi^*(u - \sigma^*\frac{\partial u}{\partial \sigma})}{((1-\mu) + (1-\phi^*)r)u^2} \tag{2.50}$$

Equation 2.50 reveals that the effect of an increase in the equilibrium debt-to-capital ratio σ^* on the equilibrium inequality ratio depends on the specific cases discussed earlier. Since case 1 implies that $(u - \sigma^*\frac{\partial u}{\partial \sigma}) < 0$, an increase in σ^* would decrease income inequality. By contrast, case 4 implies that $(u - \sigma^*\frac{\partial u}{\partial \sigma}) > 0$. Hence, an increase in σ^* would increase income inequality.

The differentiation between cases 1 and 4 is also relevant for the effect of an increase in the real interest rate on the distribution of income. Under case 1, an increase in the real interest rate reduces income inequality, despite its direct positive impact on the equilibrium debt-to-capital ratio. On the contrary, case 4 implies that income inequality would increase if the interest rate were to rise.

Table 2.2 summarizes the effects of changes in exogenous variables on the equilibrium values of the debt-to-capital ratio, the share of government bonds held by capitalists, the rate of capacity utilization, the rate of capital accumulation as well as the distribution of income.

Table 2.2: Effects of changes in exogenous variables on equilibrium values

Exogenous Variable	σ^*	ϕ^*	u^*	g^*	ϑ^*
β	-/+	-/+	+	+	-
α_0	-	+	+	+	-
r	+	-	+	+	-

Effects of an increase in exogenous variables on equilibrium values for case 1.

Summing up, as can be seen from table 2.2, an increase in government spending, autonomous investment and the real interest rate has a positive effect on the equilibrium rates of capacity utilization and capital accumulation. By contrast, the impact on income inequality in equilibrium is negative (reduction of income inequality). An increase in autonomous investment increases the debt-to-capital ratio and the share of government debt held by capitalists in equilibrium. A rise in the real interest rate has the opposite effects. However, the impact of a rise in government spending on the debt-to-capital ratio and the share of government debt held by capitalists in equilibrium is ambiguous. Our analysis revealed that the exact consequences of changes in the exogenous model parameters depend on the parameter constellations and the validity of the specific cases determining the stability of the model in equilibrium. In the next section, we carry out a comparative static analysis to get a clearer picture of the consequences of parametric changes.

2.3.5 Comparative Static Analysis

Next we proceed with a comparative static analysis in which we determine the steady state values of the endogenous model parameters after some change in the exogenous parameters of the model has occurred. The graphical analysis conducted in this section gives further insights into the effects of parametric changes in the model.

Table 2.3 shows the baseline values for the exogenous parameters of the model. The starting value for the real stock of capital (K) is taken from Prante et al. (2022). We assume that the sensitivity of firms' investment decisions with respect to changes in the after tax profit income is stronger than the sensitivity with respect to changes in the capacity utilization rate. This assumption implies that $\alpha_1 < \alpha_2$, as reflected in the respective starting values presented in table 2.3. The values for the saving rate of workers (s_w), the saving rate of capitalists (s_c) as well as the profit share (μ) correspond to the estimated values for France in Ederer and Rehm (2020). We choose France as it is one of the largest economies in the Eurozone accounting for approximately 20% of Eurozone GDP.[6] The values for the tax rate of workers (τ_w) and the tax rate of capitalists (τ_c) are taken from the OECD.Stat database and correspond to the marginal tax rates of the third and fourth income quartiles in France for the year 2022.[7] The price level (p) is set to 100 which corresponds to the value in the base year. We further assume an initial share of government debt held by capitalists (ϕ) of 6% and a real interest rate (r) of 2%. In addition, we assume that the debt-to-capital ratio (σ) corresponds to the Maastricht criterium implemented by a European Monetary Union (EMU) agreement which restricts the government debt-to-GDP ratio to 60%. In order to fulfill this criterium, the initial nominal stock of government debt approaches a value of 2,688 monetary units in our model.[8]

Table 2.3: Baseline setting of the exogenous model parameters

Exogenous Variable	Value	Unit of Measure	Source
K	40	Monetary units	Prante et al. (2022)
s_w	1	%	Ederer and Rehm (2020)
s_c	29	%	Ederer and Rehm (2020)
μ	37	%	Ederer and Rehm (2020)
τ_w	30	%	OECD.Stat
τ_c	41	%	OECD.Stat
		Further Values	
α_1	0.02	Parameter value	
α_2	0.03	Parameter value	
ϕ	6	%	
r	2	%	
p	100	Index value	
D	2,688	Monetary units	

OECD.Stat: https://stats.oecd.org/. Accessed: September 18, 2023.

Figure 2.1 shows the results of the comparative static analysis for the baseline parameter setting.

[6]Due to a lack of data availability regarding the saving rates and the profit share, we did not do the analysis for Germany. However, we conducted the comparative static analysis for the larger Eurozone country Spain and for the two smaller open economies Belgium and Austria. The results can be found in appendices 2.5.7, 2.5.8 and 2.5.9.

[7]In addition, we did the analysis using the effective tax rate of a single household without children (16.26%) and the effective corporate tax rate (25.9%) for France for the year 2021. The data is from the OECD.Stat database. The results can be found in appendix 2.5.5.

[8]We rearranged the equation $\sigma = \frac{D}{pK}$ to $D = \sigma * pK$ and substituted the given values for σ, p and K to calculate the nominal stock of government debt.

The left-hand panel in the first row of figure 2.1 shows the equilibrium values of the debt-to-capital ratio σ^* for different values of the parameters β and α_0. One can see that a higher value of the government spending parameter β results in a higher equilibrium debt-to-capital ratio. By contrast, increasing the autonomous investment parameter α_0 results in a lower equilibrium debt-to-capital ratio. For instance, when the government spends 50% of the capital stock, the debt-to-capital ratio amounts to 4.8% in equilibrium. Increasing the autonomous investment parameter to 0.05 reduces the equilibrium debt-to-capital ratio to 4.6%.

The right-hand panel in the first row of figure 2.1 shows the equilibrium share of government debt held by capitalists ϕ^* for different values of β and α_0. It reveals that increasing the parameter β leads to a higher share of government debt held by capitalists in equilibrium. However, it further reveals that the equilibrium share of government debt held by capitalists approaches a steady value of 6.3% irrespective of further increases in the government spending parameter β. Additionally, a higher autonomous investment parameter α_0 reduces the equilibrium share of government debt held by capitalists. This effect becomes less pronounced at higher values of the government spending parameter β.

The left-hand panel in the second row of figure 2.1 shows the equilibrium capacity utilization rate u^* for different values of β and α_0. One can see that increasing both the government spending parameter β and the autonomous investment parameter α_0 results in a higher capacity utilization rate in equilibrium. For example, at a government spending parameter β of 0.3, meaning that government spending approaches 30% of the capital stock, and an autonomous investment parameter α_0 of 0.05, capacity utilization reaches 91.7% in equilibrium.

Similarly, the right-hand panel in the second row of figure 2.1 reveals that a higher value of the government spending parameter β and the autonomous investment parameter α_0 leads to a higher equilibrium rate of capital accumulation g^*. For instance, at a government spending parameter β of 0.3 and an autonomous investment parameter α_0 of 0.05, the rate of capital accumulation amounts to 7.5% in equilibrium.

The panel in the third row of figure 2.1 shows the equilibrium distribution of income ϑ^* for different values of β and α_0. One can see that increasing the government spending parameter β leads to greater inequality in income distribution in equilibrium. By contrast, increasing the autonomous investment parameter α_0 reduces the inequality in income distribution in equilibrium. However, these effects are only of a marginal magnitude. For example, at a government spending parameter of 0.5 the inequality ratio reaches a value of 0.498. Increasing the autonomous investment parameter to 0.05 reduces the inequality ratio to 0.495. While the mentioned effects apply at higher levels of the government spending parameter β the opposite effect is observable when government spending approaches a value of zero. At a government spending parameter β of zero, an increase in autonomous investment increases income inequality.

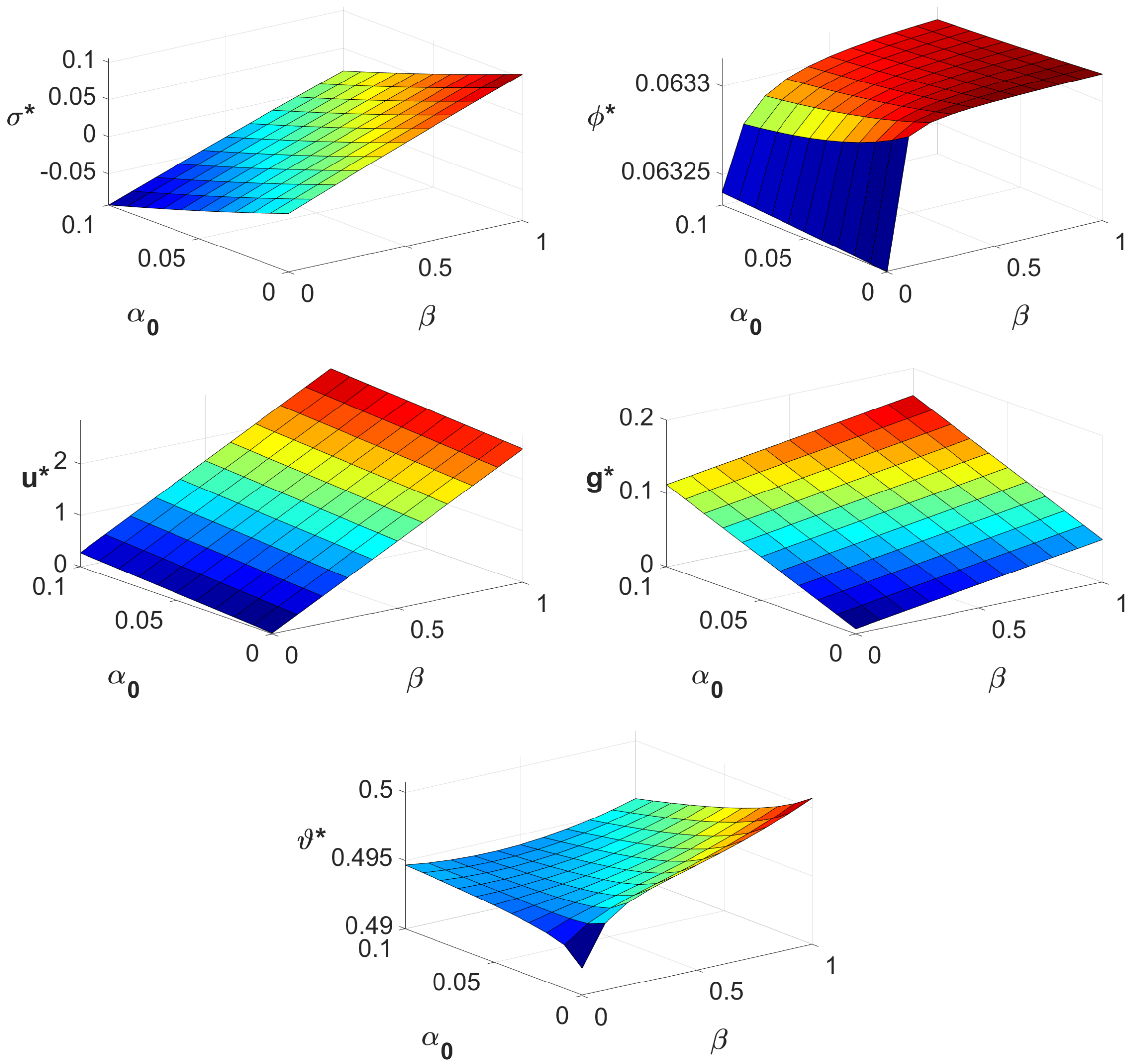

Figure 2.1: Effects of parametric changes in β and α_0 on the equilibrium values at a real interest rate of 2%.

In order to analyze how changes in the real interest rate influence the above mentioned effects, we simulate the model at a real interest rate of 6%. Figure 2.2 in appendix 2.5.2 shows the effects of parametric changes in β and α_0 on the equilibrium values at a real interest rate of 6%. The resulting effects of parametric changes are similar to the ones presented in figure 2.1.[9]

In addition, we vary the tax rate of workers τ_w and the tax rate of capitalists τ_c in order to see how changes in taxation affect the equilibrium parameters. The results can be found in appendices 2.5.3 and 2.5.4. Figure 2.3 in appendix 2.5.3 shows the effects of changes in the parameters τ_w and α_0 on the equilibrium values. The left-hand panel in the first row of figure 2.3 shows the equilibrium debt-to-capital ratio for different values of τ_w and α_0. The figure reveals that a higher tax rate of workers decreases the debt-to-capital ratio in equilibrium. Similarly, a higher autonomous investment parameter decreases the debt-to-capital ratio in equilibrium. Specifically, at an autonomous investment parameter of 0.01, increasing the tax rate of workers from 10% to 30% decreases the equilibrium debt-to-capital ratio from 3.2% to 1.41%.

The right-hand panel in the first row of figure 2.3 shows the effects of parametric changes of τ_w and α_0 on the equilibrium rate of capital accumulation. It reveals that an increase in the tax rate of workers τ_w reduces the equilibrium share of government debt held by capitalists, albeit marginally. By contrast, increasing the autonomous investment parameter α_0 reduces the share of government debt held by capitalists in equilibrium. For example, at a tax rate of workers of 20%, increasing autonomous investment reduces the share of government debt held by capitalists by up to 6.33%.

The left-hand panel in the second row of figure 2.3 shows the equilibrium capacity utilization rate for different values of the tax rate of workers τ_w and the autonomous investment parameter α_0. It points out that a higher tax rate of workers reduces the capacity utilization rate in equilibrium. By contrast, higher autonomous investment increases the capacity utilization rate in equilibrium. For instance, at an autonomous investment parameter of 0.01, increasing the tax rate of workers from 10% to 30% reduces the capacity utilization rate from 120.26% to 81.55%.

The right-hand panel in second row of figure 2.3 reveals that a higher tax rate of workers reduces the rate of capital accumulation in equilibrium. On the contrary, higher autonomous investment increases the rate of capital accumulation in equilibrium. At an autonomous investment parameter of 0.05, increasing the tax rate of workers from 10% to 30% reduces the equilibrium rate of capital accumulation from 8.36% to 7.49%.

The panel in the last row of figure 2.3 points out that an increase in the tax rate of workers results in higher income inequality in equilibrium. On the contrast, an increase in autonomous investment reduces income inequality in equilibrium but this effect is only of a marginal magnitude. At an autonomous investment parameter of 0.05, increasing the tax rate of workers from 10% to 30% increases

[9]We conducted the comparative static analysis at a real interest rate of 4% as well. The resulting effects of parametric changes are similar to the ones shown in figures 2.1 and 2.2. Hence, we do not report the results here.

the inequality ratio from 38.5% to 49.46% in equilibrium.

The effects of parametric changes in the tax rate of capitalists τ_c are displayed by figure 2.4 in appendix 2.5.4. The panel on the left-hand side in the first row of figure 2.4 shows the equilibrium debt-to-capital ratio for different values of the tax rate of capitalists τ_c and the autonomous investment parameter α_0. It reveals that a higher tax rate of capitalists reduces the debt-to-capital ratio in equilibrium. Similarly, a higher autonomous investment parameter reduces the equilibrium debt-to-capital ratio. At an autonomous investment parameter of 0.01, increasing the tax rate of capitalists from 40% to 60% reduces the equilibrium debt-to-capital ratio from 1.51% to -0.32%.

The right-hand panel in the first row of figure 2.4 reveals that increasing the tax rate of capitalists reduces the share of government debt held by capitalists in equilibrium. An increase in the autonomous investment parameter has only a marginal impact on this effect. For instance, at an autonomous investment parameter of 0.05, increasing the tax rate of capitalists from 40% to 60% reduces the equilibrium share of government debt held by capitalists from 6.44% to 4.29%.

The left-hand panel in the second row of figure 2.4 shows the equilibrium capacity utilization rate for different values of the tax rate of capitalists and autonomous investment. It points out that increasing the tax rate of capitalists results in a lower capacity utilization rate in equilibrium. By contrast, higher autonomous investment increases the equilibrium capacity utilization rate. As is shown, at an autonomous investment parameter of 0.01, increasing the tax rate of capitalists from 40% to 60% reduces the equilibrium capacity utilization rate from 82.13% to 71.73%.

The right-hand panel in the second row of figure 2.4 reveals that increases in the tax rate of capitalists reduce the rate of capital accumulation in equilibrium. On the contrary, higher autonomous investment increases the rate of capital accumulation in equilibrium. At an autonomous investment parameter of 0.05, increasing the tax rate of capitalists from 40% to 60% reduces the equilibrium rate of capital accumulation from 7.51% to 7.1%.

The panel in the third row of figure 2.4 points out that a higher tax rate of capitalists results in lower income inequality in equilibrium. Increasing the autonomous investment parameter has only a marginal impact on this effect. At a tax rate of capitalists of 40% and an autonomous investment parameter of 0.05, the inequality ratio amounts to 50.3% in equilibrium. Increasing the tax rate of capitalists to 60% reduces the inequality ratio to 33.53%.

Table 2.4 summarizes the effects of parametric changes obtained from our comparative static analysis.

As a robustness check, we did the comparative static analysis using effective tax rates. Figure 2.5 in appendix 2.5.5 shows the corresponding results. The results are similar to the ones presented in figure 2.1. However, the equilibrium value of the share of government debt held by capitalists reaches 8% and is, therefore, higher compared to our baseline setting. Also, the equilibrium debt-to-capital ratio

Table 2.4: Effects of parametric changes

Exogenous Variable	σ^*	ϕ^*	u^*	g^*	ϑ^*
β	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$
α_0	$\downarrow$	$\downarrow$	$\uparrow$	$\uparrow$	$\downarrow$
τ_w	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\uparrow$
τ_c	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$

Effects of an increase in exogenous variables on equilibrium values. $\uparrow$ denotes an increase, $\downarrow$ a decrease of the respective equilibrium variable.

and the equilibrium capacity utilization rate are higher at high values of the government spending parameter β and the autonomous investment parameter α_0. This applies also to the inequality ratio, although at a smaller magnitude.

As a further robustness check, we conducted the comparative static analysis for Spain, Belgium and Austria using the respective parameter setting shown in table 2.6 in appendix 2.5.6. The results for Belgium and Austria, shown in appendices 2.5.8 and 2.5.9, reveal effects similar to the ones we presented for France, albeit the equilibrium share of government debt held by capitalists amounts to approximately 5% in these economies. However, the results for Spain point out some notable differences. As the results in appendix 2.5.7 show, the sensitivity of the equilibrium debt-to-capital ratio with respect to changes in autonomous investment is much higher than with respect to changes in government spending. Similarly, the equilibrium distribution of income reacts stronger to changes in autonomous investment than to changes in government spending. Additionally, the equilibrium share of government debt held by capitalists amounts to 2.2% and is, therefore, lower compared to our baseline results. To conclude, the robustness checks confirm the effects of parametric changes obtained from our baseline model. Regarding Spain, the results show that the equilibrium debt-to-capital ratio and the equilibrium distribution of income react stronger to changes in autonomous investment.

In summary, our comparative static analysis reveals that increases in government spending and autonomous investment increase the capacity utilization rate and the capital accumulation rate in equilibrium and have, thus, expansionary effects. However, while an increase in government spending increases the equilibrium debt-to-capital ratio as well as income inequality, an increase in autonomous investment has the opposite effects. Moreover, the equilibrium share of government debt held by capitalists approaches a steady value irrespective of further increases in government spending and autonomous investment. These results apply also at different parameter settings, as our robustness checks pointed out. Moreover, variations in the real interest rate do not alter these results substantially. Additionally, we analyzed the implications of changes in the tax rates of workers and capitalists for the dynamic evolution of the equilibrium values in our model. The results reveal that an increase in the tax rate of workers increases income inequality in equilibrium and reduces the equilibrium rates of capacity utilization and capital accumulation. Further, an increase in the tax rate of capitalists decreases income inequality in equilibrium and the equilibrium rate of capacity utilization. However, the impact on the equilibrium rate of capital accumulation is only of a limited magnitude.

2.4 Economic Policy Implications and Conclusions

This article examined a possible nexus between the rise in government debt-to-GDP ratios and the resurgence of income inequality in major advanced economies. In addition, we shed light on the implications of changes in investment activity, real interest rates, government spending, and tax rates for the possible link between government debt-to-GDP ratios and income distribution.

The present analysis indicated that the question of the distributional effects of public debt requires a broad framework to consider factors such as investment and economic growth. Empirical studies based solely on comparing interest incomes from government bonds and tax payments by income group cannot provide a complete picture of the distributional effects of government debt. We have, therefore, further developed a model-based framework in the post-Keynesian tradition to analyze the complex relationships between public debt and income distribution.

Our analysis revealed that an increase in government spending has an elevating effect on the equilibrium debt-to-capital ratio. Further, the fiscal expansion increases the equilibrium rate of capacity utilization as well as the equilibrium rate of capital accumulation. In the event of a decline in autonomous investment, we note that this decline decreases the equilibrium rate of capacity utilization and the equilibrium rate of capital accumulation and increases the debt-to-capital ratio in equilibrium. However, the decline in autonomous investment can be offset by an increase in government spending, which would increase the capacity utilization rate and the capital accumulation rate in equilibrium at the cost of a higher debt-to-capital ratio, however. On the contrary, an increase in autonomous investment would not only increase the equilibrium rate of capacity utilization and the equilibrium rate of capital accumulation. However, it would also reduce the equilibrium debt-to-capital ratio through its positive impact on the equilibrium rate of capital accumulation. This result is in line with Parui (2023), who shows that a rise in autonomous investment increases the rate of capital accumulation and decreases the debt-to-capital ratio in equilibrium.

Regarding income distribution, the results show that an increase in government spending increases income inequality in equilibrium through its positive impact on the equilibrium debt-to-capital ratio and the resulting increase in interest income of capitalists. By contrast, an increase in autonomous investment has a counteracting effect as it reduces income inequality in equilibrium through its positive impact on the equilibrium rate of capacity utilization. Variations in the real interest rate have only a limited impact on these effects. Further, an increase in the tax rate of workers would increase income inequality in equilibrium and would decrease the rate of capacity utilization and the rate of capital accumulation in equilibrium as the decline in the disposable interest income of workers would depress consumption demand. However, increasing the tax rate of capitalists would reduce income inequality in equilibrium. This would also reduce the equilibrium rate of capacity utilization but would have only a marginal impact on the equilibrium rate of capital accumulation.

Against the background of the discussion about *secular stagnation* (Summers 2014, 2015; Weizsäcker and Krämer 2021), our analysis sheds light on the relevance of the interest-growth differential $r - g$ for the dynamics of government debt and income distribution. The model demonstrates that under the condition that $r < g$, both government debt and income inequality will decrease.

We do not claim the generality of our results. Beyond the present analysis, additional impact factors such as inflation dynamics have important implications for the nexus between government debt and income distribution. However, the analysis of these additional impact factors is left to future research.

2.5 Appendix to Chapter 2

2.5.1 List of Variables

Table 2.5: List of variables

C	Real consumption demand
D	Nominal stock of government debt
g	Real rate of capital accumulation
g^*	Real equilibrium rate of capital accumulation
G	Real government expenditure
i	Nominal interest rate
I	Real investment demand
K	Real stock of capital
p	Price level
r	Real interest rate
s_c	Saving rate of capitalists
s_w	Saving rate of workers
T	Real tax income of the government
u	Rate of capacity utilization
u^*	Equilibrium rate of capacity utilization
Y	Real national income
α_0, α_1, α_2	Sensitivity parameters
γ	Output multiplier
ϑ	Inequality ratio
ϑ^*	Equilibrium inequality ratio
μ	Share of profits in net national income
ν	Profit rate
π	Rate of inflation
ρ	Relative tax rate
σ	Real debt-to-capital ratio
σ^*	Real equilibrium debt-to-capital ratio
τ_c	Income tax rate of capitalists
τ_w	Income tax rate of workers
ϕ	Share of government debt held by capitalists
ϕ^*	Equilibrium share of government debt held by capitalists

2.5.2 Results of the Comparative Static Analysis at a Real Interest Rate of 6%

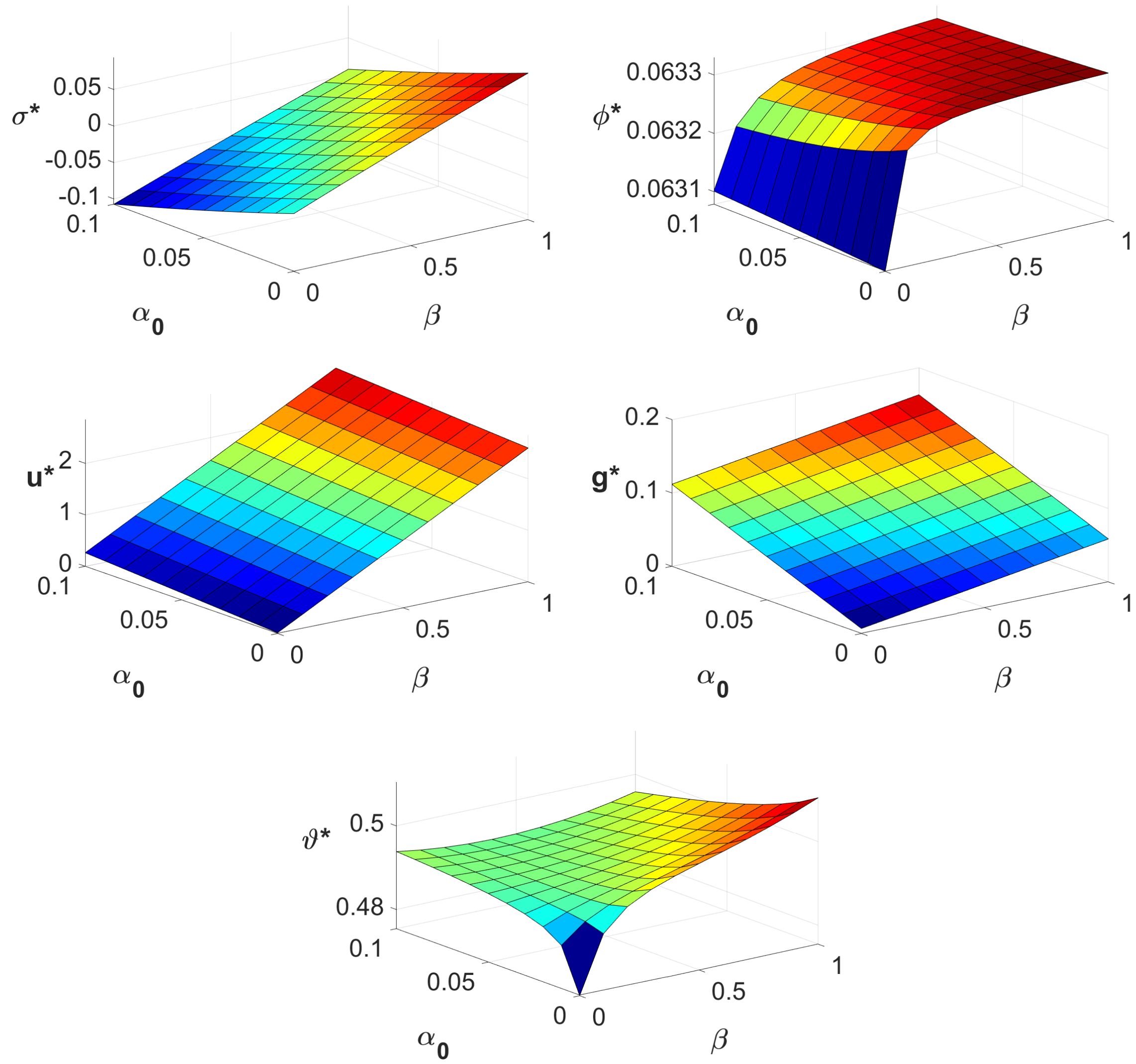

Figure 2.2: Effects of parametric changes in β and α_0 on the equilibrium values at a real interest rate of 6%.

2.5.3 Results of the Comparative Static Analysis with the Tax Rate of Workers and Autonomous Investment

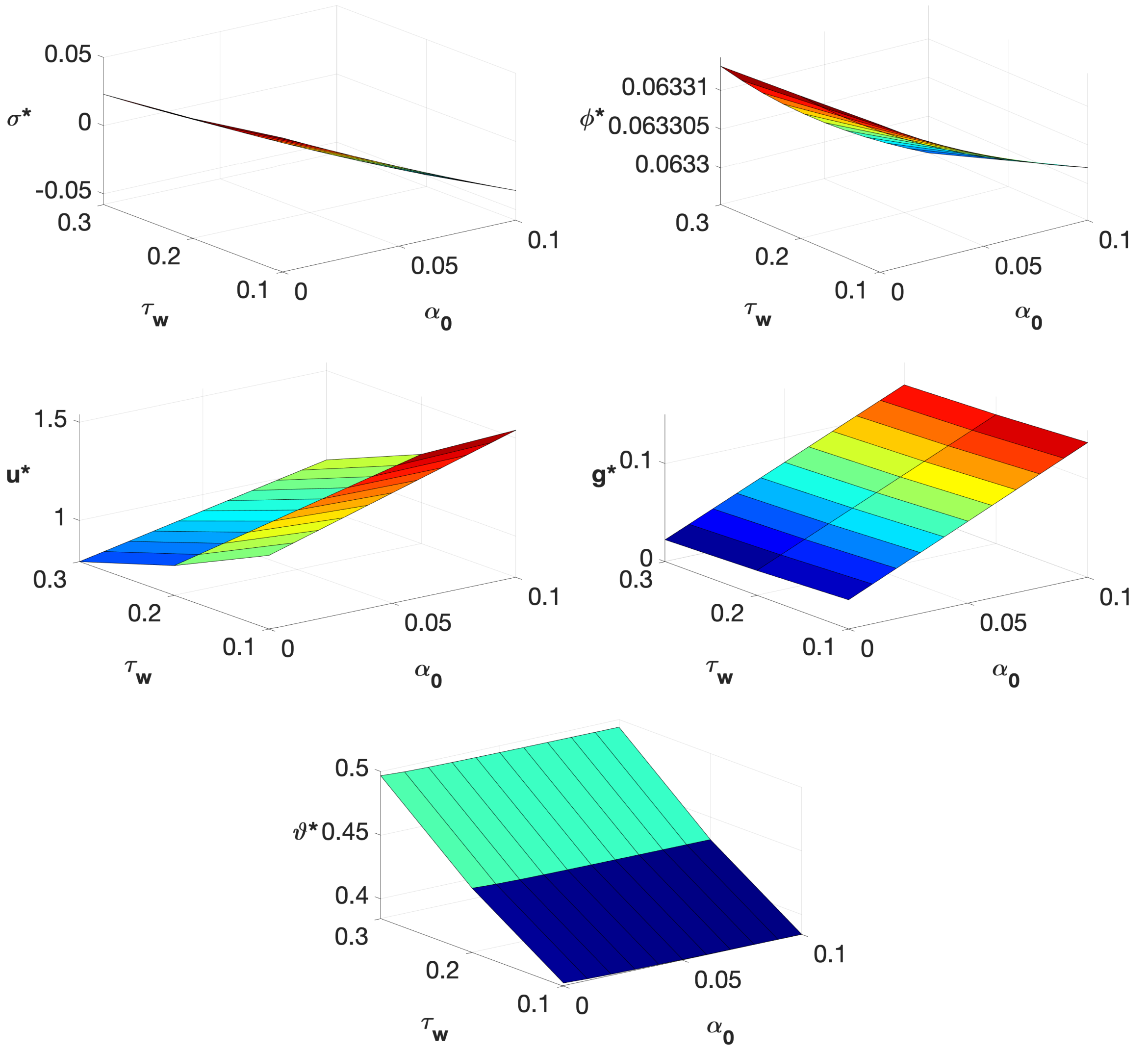

Figure 2.3: Effects of parametric changes in τ_w and α_0 on the equilibrium values.

2.5.4 Results of the Comparative Static Analysis with the Tax Rate of Capitalists and Autonomous Investment

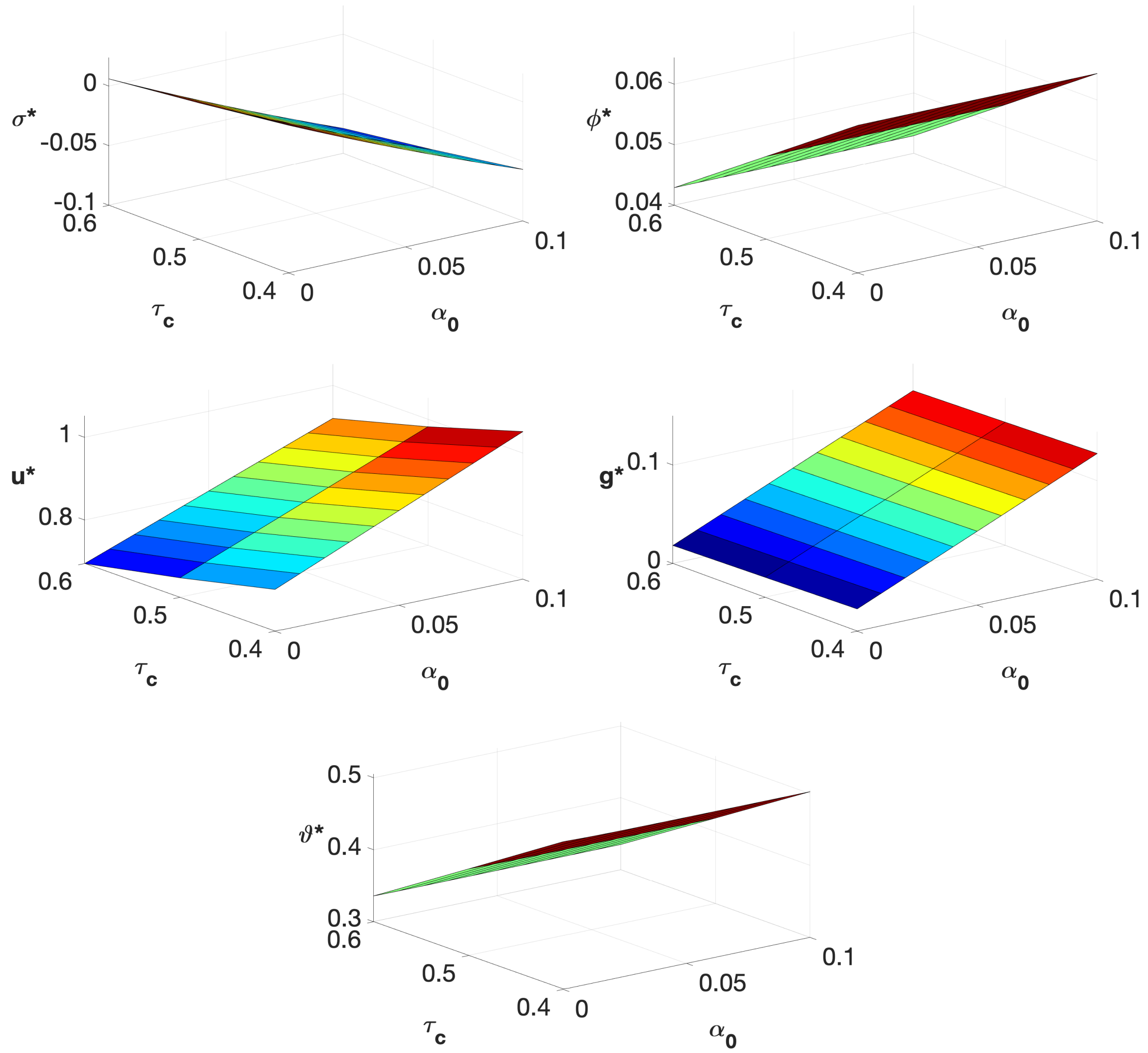

Figure 2.4: Effects of parametric changes in τ_c and α_0 on the equilibrium values.

2.5.5 Results of the Comparative Static Analysis with Effective Tax Rates

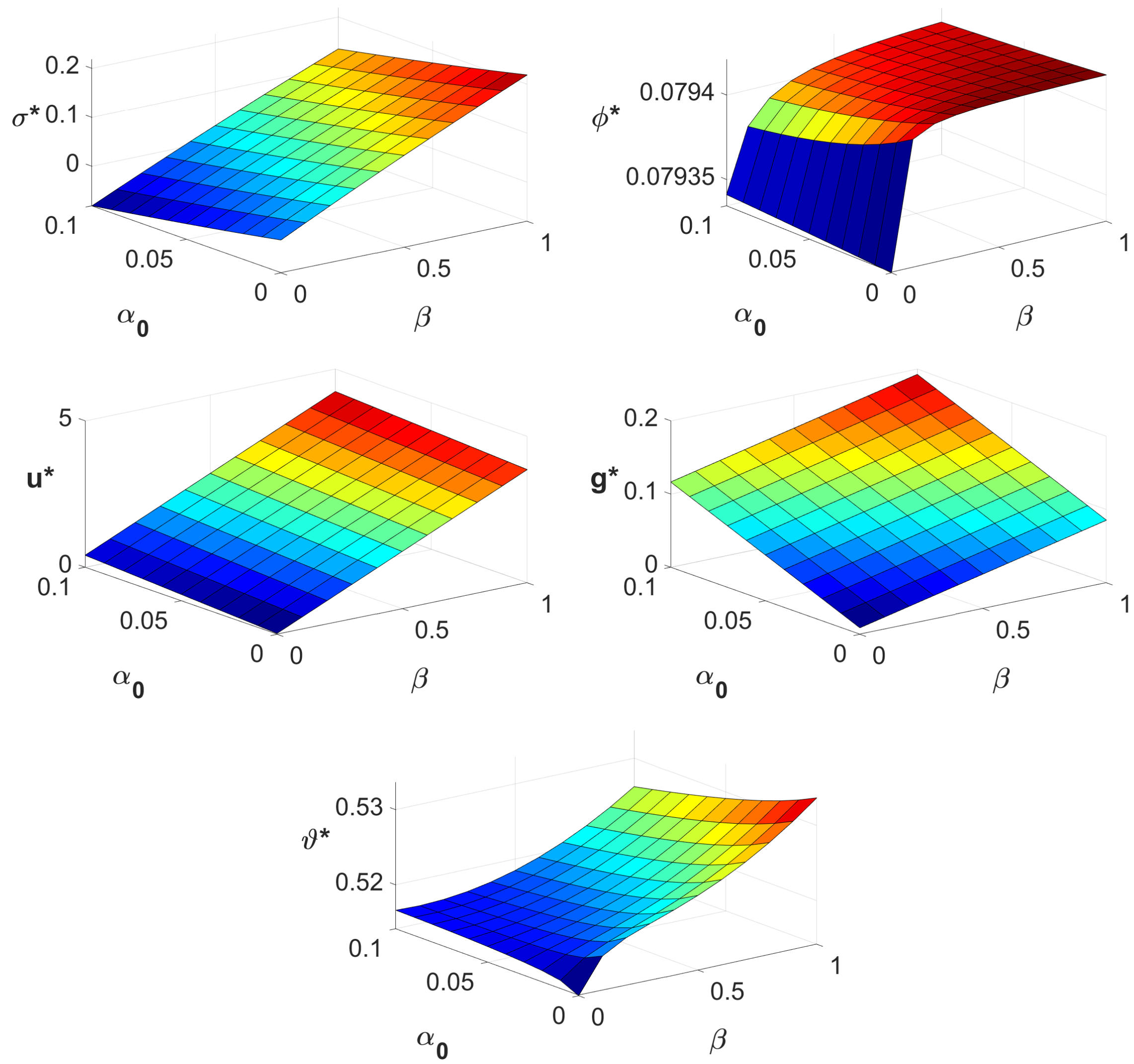

Figure 2.5: Effects of parametric changes in β and α_0 on the equilibrium values using the effective tax rate of a single household without children and the effective corporate tax rate.

2.5.6 Parameter Setting of Exogenous Model Parameters for Spain, Belgium and Austria

Table 2.6: Parameter setting of exogenous model parameters for Spain, Belgium and Austria

Exogenous Variable	Spain	Belgium	Austria	Unit of Measure	Source
K	40	40	40	Monetary units	Prante et al. (2022)
s_w	0	10	5	%	Ederer and Rehm (2020)
s_c	7	29	23	%	Ederer and Rehm (2020)
μ	41	34	38	%	Ederer and Rehm (2020)
τ_w	19	40	42	%	OECD.Stat
τ_c	23	45	48	%	OECD.Stat
Further Values					
α_1	0.02	0.02	0.02	Parameter value	
α_2	0.03	0.03	0.03	Parameter value	
ϕ	2	5	5	%	
r	2	2	2	%	
p	100	100	100	Index value	
D	2,784	2,928	2,904	Monetary units	

OECD.Stat: https://stats.oecd.org/. Accessed: September 18, 2023.

2.5.7 Results of the Comparative Static Analysis for Spain

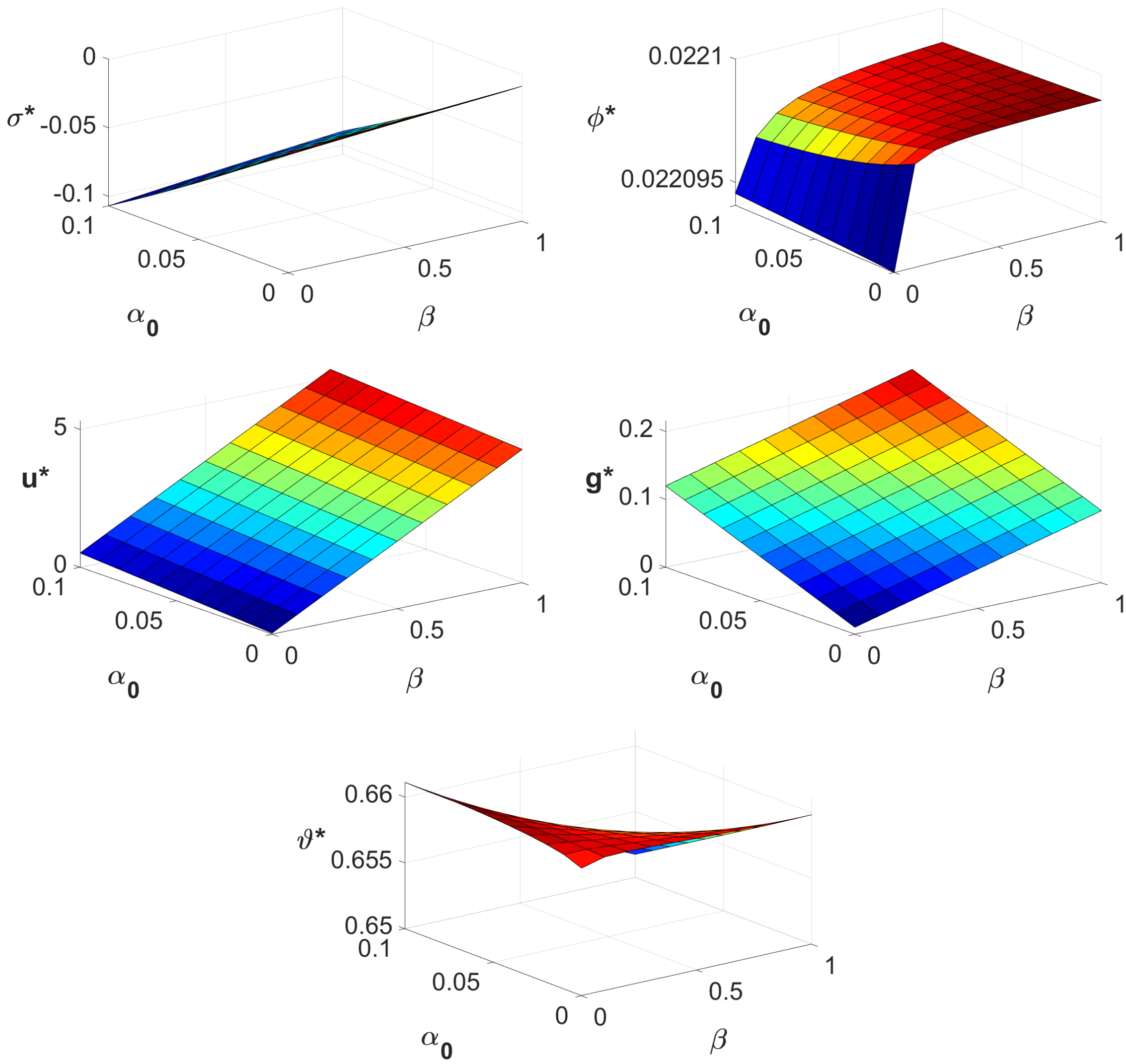

Figure 2.6: Effects of parametric changes in β and α_0 on the equilibrium values for Spain.

2.5.8 Results of the Comparative Static Analysis for Belgium

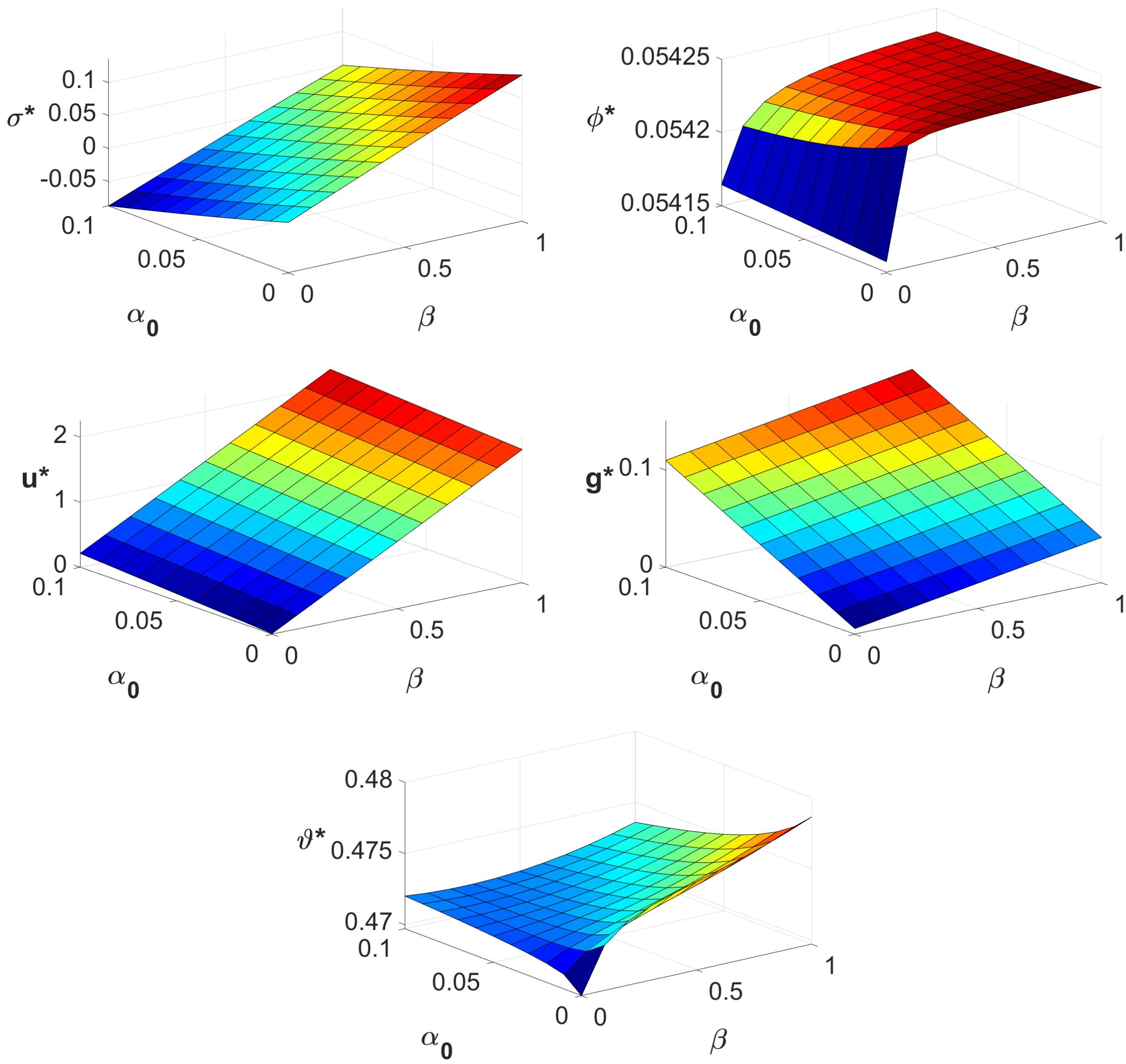

Figure 2.7: Effects of parametric changes in β and α_0 on the equilibrium values for Belgium.

2.5.9 Results of the Comparative Static Analysis for Austria

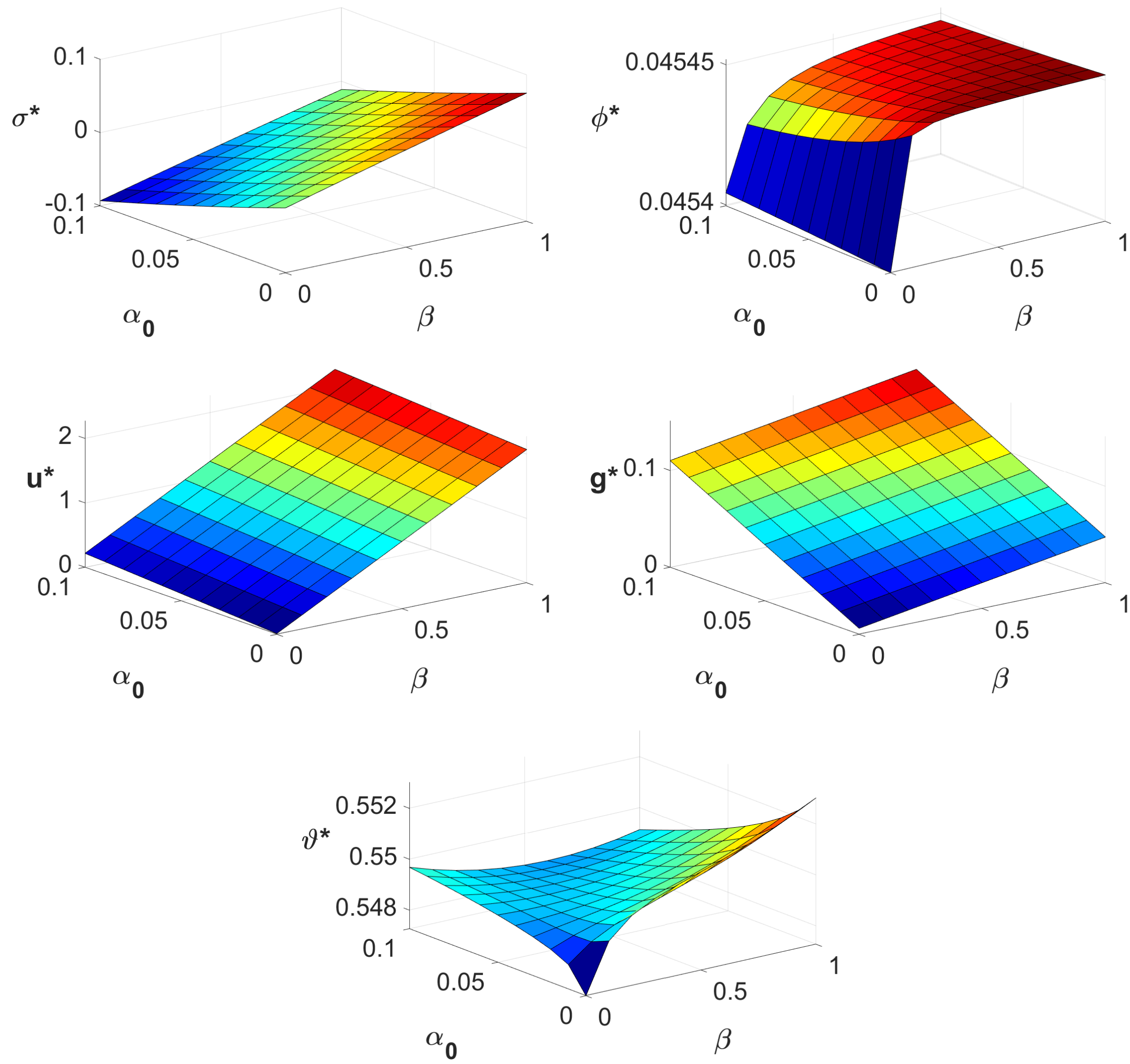

Figure 2.8: Effects of parametric changes in β and α_0 on the equilibrium values for Austria.

Chapter 3

How Does Financial Development Affect the Growth-Inequality Nexus? Evidence from a PCHVAR Analysis[1]

This chapter is published as a journal article in *Industrial and Corporate Change*:

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[1]This chapter is based on joint work with Prof. Dr. Christian R. Proaño and Dr. Juan Carlos Peña Méndez.

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