ESSAYS ON MACROECONOMICS AND HOUSING

By

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Abstract

The comprehensive analysis across theoretical, empirical, and policy-oriented frameworks underscores the intricate interplay between monetary policy, housing markets, and financial constraints in both closed and small open economies.

Chapter 2 systematically synthesizes the theoretical and empirical literature on monetary policy, housing markets, and financial frictions, exposing critical limitations in conventional frameworks and paving the way for methodological advancements in subsequent chapters. The analysis established that traditional inflation-targeting frameworks inadequately address housing market volatility, as collateral constraints and the zero lower bound (ZLB) introduce nonlinear dynamics and asymmetries. These frictions amplify economic fluctuations, particularly during crises, by creating feedback loops between housing prices, borrowing capacity, and aggregate demand. The chapter further highlighted the critical role of heterogeneity in household responses, where savers and borrowers exhibit divergent behaviors to monetary shocks, necessitating models that capture distributional effects.

Chapter 3 examines the transmission mechanisms and distributional consequences of quantitative easing (QE) in a small open economy, leveraging a dynamic stochastic general equilibrium model calibrated to New Zealand's pandemic conditions. By embedding financial frictions—notably borrowing constraints tied to housing collateral—and imperfect asset substitutability, the analysis isolates the portfolio rebalancing channel as the dominant driver of housing market dynamics during unconventional monetary interventions. While QE effectively stabilized financial markets during the pandemic, it exacerbated wealth inequality by inflating housing prices, disproportionately benefiting asset-holding savers while leaving credit-constrained borrowers vulnerable to debt overhangs and exchange rate risks. The open-economy dimension revealed unique vulnerabilities, as capital flow volatility and currency depreciation pressures complicated policy trade-offs between financial stability and inflation control.

Chapter 4 advances a unified framework to dissect the systemic interdependencies between housing markets, labor markets, and monetary policy in economies plagued by financial frictions. By embedding search-and-matching frictions, occasionally binding collateral constraints, and the zero lower bound within a DSGE model, the analysis uncovers the nonlinear, asymmetric propagation of shocks that define housing-driven business cycles. The calibrated results demonstrate how housing price dynamics and labor market adjustments interact through credit and income channels, creating self-reinforcing feedback loops that amplify downturns and prolong recoveries.

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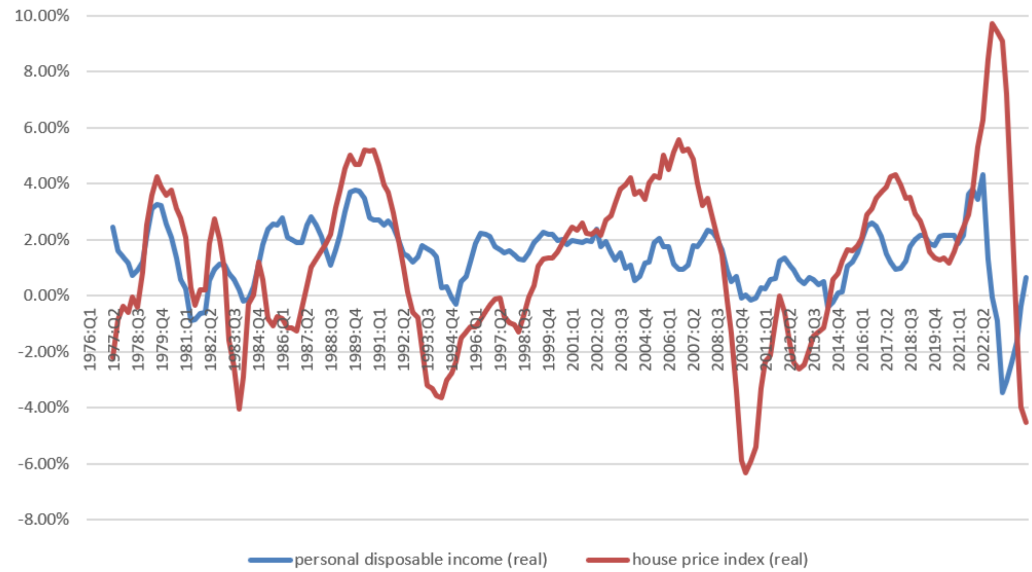
Chapter 1

Introduction

Four years have elapsed since the emergence of the COVID-19 pandemic in early 2020, marking a transformative period for global economic systems characterized by unprecedented disruptions and uneven recoveries. While the virus now exerts diminished influence on daily activities, its macroeconomic repercussions persist, with worldwide economic output yet to regain pre-pandemic equilibrium—evidenced by the International Monetary Fund's (IMF, 2023) report showing global GDP growth rates in 2022 lagging 1.2 percentage points below pre-2020 projections. Across this period, both factor markets and asset markets have exhibited divergent trajectories, particularly in the real estate sector, where pandemic-induced behavioral shifts and policy interventions have rewritten traditional market rules. In the initial phase, global housing markets faced severe disruptions stemming from lockdown-induced social distancing protocols and shifting consumer priorities, such as the abrupt halt in urban migration and temporary collapse of commercial real estate demand. However, these markets staged a remarkable V-shaped recovery by mid-2021, fueled by ultralow interest rates and fiscal stimulus packages exceeding $15 trillion globally. Notably, residential property values in numerous advanced economies now surpass pre-crisis benchmarks—a phenomenon starkly illustrated by Canada's 34% nominal price increase since 2019—forming a striking contrast to broader economic stagnation in sectors like manufacturing and hospitality.

Figure 1 presents quarterly housing price data for 23 major countries worldwide, based on Federal Reserve data. It highlights that real housing price growth in these countries has significantly outpaced real income growth. Spain's marginal 1.2% price correction, attributed to its tourism-dependent economy's delayed recovery, stands in stark contrast to the explosive growth seen in commodity-driven economies like Canada and Australia. The latter's 29% real-term surge in housing prices—the highest among surveyed nations—reflects speculative investment inflows into suburban and secondary cities, as remote work policies reduced the premium on urban centers. Subsequent rankings highlight New Zealand (22%), Sweden (17%), and Australia (16%) as standout performers, with their markets buoyed by aggressive central bank interventions, including quantitative easing programs targeting mortgage-backed securities. Paradoxically, these gains occurred despite their respective real income trajectories showing either stagnation (-4% in Canada) or modest growth (2% in New Zealand, 8% in Sweden, and 1% in Australia) over the same period. This disparity between wage dynamics and asset inflation underscores the growing role of non-income drivers—such as speculative investment fueled by retail trading platforms, cross-border capital flows into "safe haven" real estate, and accommodative monetary policy—in shaping post-pandemic housing markets.

The phenomenon also exposes critical vulnerabilities in traditional demand-supply equilibrium models, which failed to anticipate the 2020-2023 price surge. Structural shifts, including the rise of institutional investors acquiring 15-20% of available housing stock in markets like Toronto and Sydney (Canada Mortgage and Housing Corporation report, 2024), have distorted pricing mechanisms. Meanwhile, supply chain bottlenecks—exacerbated by the Russia-Ukraine war's impact on lumber and steel prices—slowed new construction by 22% globally between 2020 and 2022, according to the World Bank (2021). These dynamics suggest that housing markets now function less as reflections of local economic health and more as arenas for global capital allocation, with profound implications for wealth inequality and financial stability. Policymakers face mounting pressure to reconcile the dual mandate of sustaining economic recovery while preventing housing affordability crises—a challenge compounded by the lingering specter of inflation and demographic shifts, such as aging populations in Europe and Japan. As central banks navigate this complex terrain, the lessons of the pandemic era underscore the need for integrated frameworks that address housing not merely as a sectoral issue, but as a linchpin of macroeconomic resilience.



Notes: The database includes data from 23 countries, including Australia, Belgium, Canada, Switzerland, Germany, Denmark, Spain, Finland, France, United Kingdom, Croatia, Ireland, Israel, Italy, Japan, South Korea, Luxembourg, Netherlands, Norway, New Zealand, Sweden, United States and South Africa. The original series for each country is extended back to the first quarter of 1975 using either historical data or secondary sources. Each country's house price index is seasonally adjusted over the entire sample period using an unobserved components time series model and rebased to 2005 = 100. The real series is adjusted using the personal consumption expenditure deflator, and the weighted average of all countries in the database is produced using purchasing power parity-adjusted GDP shares from 2005. A detailed description of the sources and methodology can be found in Mack and Martínez-García (2011).

Sources: Federal Reserve Bank of Dallas international house price dataset; authors' calculations.

Figure 1.1 – Inflation-adjusted House Price Index and Personal Disposable Income Index (1975Q1-2023Q2)

The unprecedented surge in global housing valuations defies conventional explanations centered solely on household disposable income, necessitating a multifaceted analytical framework that integrates behavioral economics, geopolitical dynamics, and monetary policy impacts. On the demand side, structural shifts in consumer behavior—accelerated by pandemic-induced remote work norms—have redefined housing preferences with lasting consequences. Extended lockdowns and hybrid work arrangements catalyzed demand for larger living spaces, home offices, and suburban properties (McKinsey, 2023). This transformation effectively reprioritized housing from a basic necessity to a hybrid consumption-investment good, with buyers increasingly viewing real estate as both a lifestyle upgrade and a hedge against inflation. For instance, U.S. Census Bureau data (2023) reveals a 23% rise in median home sizes in suburban markets between 2020 and 2023, even as urban apartment vacancies surged to 15% in cities like San Francisco.

Concurrently, supply-side constraints exacerbated price pressures through interconnected bottlenecks. Construction slowdowns due to workforce disruptions and material shortages created systemic delays. The Russia-Ukraine conflict further destabilized global supply chains, triggering a 40% spike in construction material costs (e.g., steel, lumber) and a 58% increase in European energy prices between 2020 and 2022, according to Eurostat. These disruptions disproportionately affected mid-income housing projects. The cumulative effect shifted the property supply curve sharply leftward, as quantified by the International Monetary Fund's 2023 Global Housing Watch, which identified a reduction in global housing inventory relative to pre-pandemic levels.

This supply-demand disequilibrium created a perfect storm for price escalation, with Zillow's 2023 index (Zillow Research, 2023) showing a cumulative inflation-adjusted price increase across G7 nations since 2019. Critically, the divergence between housing costs and wage growth—real incomes grew just 3.2% annually in these markets—has widened wealth inequality, as documented by the OECD's 2024 report linking housing inflation to a 12% rise in wealth gaps. The crisis underscores the inadequacy of traditional models that treat housing as a closed system, ignoring its role as a transmission channel for global capital flows and macroeconomic policy spillovers. Policymakers now confront a trilemma: balancing affordability, financial stability, and climate-resilient urban development in an era of persistent scarcity.

More importantly, central to this phenomenon has been the radical easing of credit conditions globally, a policy experiment unprecedented in scale and duration since the post-2008 financial crisis era. Unconventional monetary policies, including quantitative easing (QE) and emergency asset purchase programs, such as the ECB's EUR 1.85 trillion Pandemic Emergency Purchase Programme (PEPP) and the Federal Reserve's 4.5 trillion balance sheet expansion, flooded financial systems with liquidity, distorting traditional price discovery mechanisms in housing markets. By mid 2022, central banks in advanced economies had collectively injected over 25 trillion into global markets, equivalent to 28% of world GDP, according to the Bank for International Settlements (BIS, 2023). This deluge of cheap capital decoupled housing markets from income fundamentals, as seen in Canada and New Zealand. National responses exemplified this divergence: Australia and Canada slashed fixed mortgage rates to historic lows of 1.99-2.25%, igniting a borrowing frenzy that pushed household debt-to-income ratios to record highs of 212% and 186%, respectively. These policies incentivized debt-driven purchases even as real wages stagnated. The resulting affordability crisis is quantified by the OECD's 2023 affordability index, which found that median-income households in major cities now require 12.3 years of savings for a down payment, up from 8.7 years pre-pandemic.

This systemic decoupling aligns with Modern Monetary Theory (MMT) principles, where fiscal deficits are monetized to sustain demand during crises, albeit at the cost of inflating asset bubbles. The U.S. Federal Reserve's tacit endorsement of MMT logic—evidenced by its 2020 decision to directly monetize $2.3 trillion in Treasury debt—fueled a speculative spiral in housing markets. However, the MMT experiment has drawn criticism for exacerbating intergenerational inequality: Zillow Research estimates millennials now face housing costs higher relative to income than baby boomers did at similar life stages. Meanwhile, emerging economies like Turkey and Brazil suffered collateral damage, with capital flight to "safe haven" U.S. and European real estate driving their currencies down 54% and 38% against the dollar since 2020, further destabilizing global markets (Bloomberg Markets, 2023).

The long-term consequences of this credit-driven paradigm are now unfolding. Despite recent rate hikes, housing markets exhibit resilience, with prices in inflation-adjusted terms still 18% above pre-pandemic levels in the Eurozone (European central bank, 2021). As the BIS warns in its 2024 Annual Report (BIS, 2024), the global economy now navigates a "debt trap", where housing's dual role as shelter and speculative asset perpetuates financial instability, challenging policymakers to reconcile growth objectives with mounting systemic risks.

Post-2022 monetary tightening cycles, aimed at curbing inflation, partially tempered housing markets—exemplified by the UK's 1.8% year-on-year price decline in 2023 (Nationwide House Price Index, 2023) and Australia's correction in overheated markets like Sydney—but failed to fully reverse pandemic-era gains, leaving prices in most advanced economies above pre-2020 levels in real terms (Reuters, 2024). Structural inertia in housing markets, as highlighted by Jordà et al. (2024), reveals a historical pattern: major pandemics like the Black Death (1331) and H1N1 (2009) precipitated multi-decade declines in real interest rates—by 3-5 percentage points over 30-year periods—due to labor force contractions (e.g., Europe losing 30-60% of its population post-Black Death) and precautionary savings spikes exceeding 15% of GDP. These dynamics suppressed borrowing costs for generations, fueling protracted housing booms.

These factors suggest that the current interest rate normalization—exemplified by the Fed's 525-basis-point hikes since 2022—may insufficiently counteract entrenched housing inflation. The IMF's 2024 Global Financial Stability Report warns that even with rates at 5-6%, housing affordability ratios remain worse than pre-pandemic averages, as wages lag behind mortgage costs. This necessitates a reevaluation of the interplay between real estate cycles, labor market restructuring, and monetary policies.

Chapter 2

A Theoretical and Empirical Examination of Monetary Policy, Housing, and Borrowing Constraints

The debate over whether monetary policy should react to asset prices and how central banks should deal with sharp fluctuations in asset prices remains controversial in theory and practice. The 2008 financial crisis, fuelled by cyclical financial systems and the mutual reinforcement of financial sectors and the real economy, refocused attention on asset bubbles and systemic financial risks (Reinhart and Rogoff, 2009; Brunnermeier, 2009). After the 2008 financial crisis, central banks in developed economies, led by the Federal Reserve, resorted to unconventional monetary policy measures, mainly because traditional tools had become ineffective (Gagnon et al., 2011). The crisis had severely impacted the financial markets and institutions and led to a drastic decline in lending and investment, which in turn threatened global economic stability. The financial crisis caused severe liquidity contractions, leading to a 14.4% decline in global trade volumes and a 2% drop in global GDP in 2009 (World Bank, 2010). The U.S. housing market, at the core of the crisis, experienced an approximately 27% decline in housing prices from their 2006 peak to 2012 (Case-Shiller Home Price Index). Extremely low interest rates, close to the zero lower bound, limit the effectiveness of traditional interest rate cuts (Eggertsson and Krugman, 2012). Unconventional policies such as quantitative easing and negative interest rates were introduced to inject liquidity into the system, stimulate lending and encourage economic activity in this challenging environment. For example, the Federal Reserve initiated large-scale asset purchases (LSAPs), expanding its balance sheet from $900 billion in 2008 to over $4.5 trillion by 2014 (Federal Reserve, 2015). Similarly, the ECB and the Bank of Japan followed suit with aggressive asset purchase programs (Draghi, 2015). These measures were aimed at stabilizing the financial systems and promoting recovery in the post-crisis period. These policies had lowered borrowing costs and increased liquidity, which unintentionally led to a rapid rise in housing prices and wealth inequality (Rognlie, 2015; Mian et al., 2021). As economies recovered and the risk of overheating and inflation increased, central banks began to phase out unconventional monetary policies as housing prices rose to counter the risk of asset price bubbles and inflation (Powell, 2018).

Economic globalization has accelerated the volatility of global asset prices and destabilized financial markets due to increasing interconnectedness and rapid capital flows. As countries become more integrated through trade, investment and financial linkages, changes in one economy can quickly spread to others, leading to synchronized fluctuations in asset prices and financial instability. As international financial integration has grown, monetary policy spillovers from major economies (such as the U.S. and the Eurozone) increasingly affect smaller open economies (SOEs) (Rey, 2015). This is particularly evident in housing markets, where low global interest rates have fuelled excessive borrowing and real estate price appreciation in economies such as New Zealand, Canada, and Sweden (IMF, 2024). The complexity and speed of global financial transactions exacerbate this volatility and make financial markets more susceptible to shocks and speculative behaviours. For instance, during the 2013 Taper Tantrum, emerging markets such as India, Brazil, and Indonesia experienced sharp currency depreciations and capital outflows, driven by the Federal Reserve's announcement of QE tapering (Eichengreen and Gupta, 2015). This underscores the challenge for SOEs in maintaining financial stability while navigating external shocks. The instability of financial markets poses a major challenge for macroeconomic policy making. Central banks struggle to respond to specific fluctuations in asset prices as the causes of these fluctuations are diverse and the effects of policy interventions are wide-ranging.

Moderate inflation and asset bubbles can be beneficial to the economy as they often stimulate consumer spending and investment. Inflation can reduce the real value of debt, which stimulates spending and borrowing. While asset bubbles indicate overvaluation, they can boost consumer confidence and wealth, increasing consumption and investment (Case et al., 2005). In addition, rising house prices provide households with collateral for loans and reduce their borrowing costs (Iacoviello, 2005). This stimulates economic growth, but it is important to prevent potential negative effects such as economic instability or severe market adjustments. If asset prices become disconnected from fundamentals, speculative behaviour can lead to boom-bust cycles, exacerbating economic volatility (Brunnermeier and Schnabel, 2016). For example, before the 2008 financial crisis, the U.S. mortgage debt-to-GDP ratio surged from 46% in 1980 to over 98% by 2007, fuelledc by loose credit conditions (Jordà et al., 2016). When housing prices collapsed, financial institutions holding mortgage-backed securities (MBS) faced severe losses, triggering systemic financial instability. This pattern repeated itself in China's Evergrande crisis (2021–2022), where excessive real estate speculation led to a $300 billion debt crisis, forcing government intervention to prevent financial contagion (IMF, 2024).

Tobin's Q, a ratio that compares the market value of assets with their replacement cost, can help explain systemic financial risks arising from inflation and asset bubbles (Tobin, 1982). When Tobin's Q rises significantly above 1, it suggests asset overvaluation, often leading to speculative investment and excessive leverage. Historical data shows that Tobin's Q exceeded 2.5 before both the 2000 dot-com bubble and the 2008 financial crisis, signalling unsustainable asset price inflation (Shiller, 2015). However, if asset values are artificially inflated by bubbles or unsustainable inflation, this can lead to a misallocation of resources and increased systemic risk. If central banks recognize overvaluation and potential bubbles, they may tighten monetary policy to curb inflation and reduce speculative investments. This may involve raising interest rates or reducing liquidity. However, such measures might also trigger panic among investors and consumers, leading to rapid asset sales and a decline in spending. This combination of policy tightening and panic can exacerbate financial instability. When bubbles burst, asset values plummet, leading to a sudden contraction in credit and investment, which potentially trigger financial crises. The 2008 crisis erased $11 trillion in U.S. household wealth (16% of GDP), causing bank lending to plunge 35% from 2008Q2 to 2010Q1 (FDIC, 2010).

During the bursting of an asset bubble, commercial banks face significant risks, including a rapid decline in the value of the collateral securing loans, leading to potential loan defaults. This can strain banks' liquidity and solvency, especially if their assets are longer-term investments funded by short-term liabilities. These effects are particularly pronounced in economies where commercial banks heavily rely on real estate-backed lending. A decline in asset values reduces collateral worth, leading to tighter credit conditions and increased risk of loan defaults (Kiyotaki and Moore, 1997). This was evident during the Eurozone debt crisis, where Spanish and Irish banks faced significant stress due to collapsing housing markets, requiring large-scale bailouts (Lane, 2012).

Another critical aspect of asset price misalignments is wealth inequality. When asset bubbles burst, the wealthiest households often have diversified portfolios and better access to risk management strategies, allowing them to recover faster. In contrast, lower-income households, whose wealth is disproportionately tied to housing, experience greater financial distress (Piketty, 2014). This wealth disparity was starkly evident in the post-2008 recovery. From 2009 to 2016, the top 10% of U.S. households captured 89% of total wealth gains, driven primarily by rising equity and real estate prices, while the bottom 90% saw minimal growth or net losses (Federal Reserve Survey of Consumer Finances, 2017). This divergence exacerbated socio-economic divides, as the wealth share of the top 1% alone increased from 34.6% to 38.6% over the same period (Saez and Zucman, 2016).

During the COVID-19 pandemic, central banks around the world implemented expansionary monetary policies to mitigate the severe economic disruptions caused by lockdowns, supply chain disruptions and the declines in global demand. These measures primarily included drastic interest rate cuts, quantitative easing and liquidity injections to stabilize financial systems, support lending and stimulate economic activity. The U.S. Federal Reserve cut its federal funds rate to 0-0.25% in March 2020 and expanded its balance sheet by 4.5 trillion (4387 billion) in liquidity (BIS, 2021), while the European Central Bank expanded its Pandemic Emergency Purchase Program (PEPP). Similarly, central banks in emerging markets also responded to the crisis with accommodative policies, including interest rate cuts and asset purchases.

These measures significantly increased liquidity in the global financial systems, which in turn contributed to sharp rises in asset prices, including housing and equity markets. These policies triggered a 68% surge in global equity markets (MSCI World Index) from March 2020 to December 2021, with U.S. housing prices rising 19.2% year-on-year by August 2021 (S&P CoreLogic Case-Shiller Index). Corporate bond issuance hit a record $5.4 trillion in 2020, with 40% rated BBB or below (IMF, 2021). However, the liquidity-driven rally created valuation dislocations: U.S. equity market capitalization-to-GDP ratio reached 195% in 2021 (vs. 142% pre-pandemic), exceeding 1999 dot-com bubble levels (Buffett Indicator, 2022).

However, as economies recover, central banks are facing increasing pressure to scale back these extraordinary measures to prevent overheating and dampen inflationary pressures. The rapid post-pandemic recovery combined with supply chain constraints, has already led to a rise in inflation in many economies, prompting central banks such as the Federal Reserve, the Bank of England and others to tighten monetary policy by raising interest rates and reducing balance sheets. U.S. CPI surged 7% year-on-year by December 2021 (highest since 1982), driven by energy (+29%) and used cars (+37%) (BLS, 2022). Emerging markets faced policy dilemmas: Turkey's inflation hit 85% in October 2022 despite rate cuts, while Argentina's peso lost 60% against USD (World Bank, 2023). Assessing the sustainability of these pandemic-era policies, as well as their long-term impacts on asset prices and the broader markets, remains crucial to preventing future financial instability and ensuring balanced and inclusive economic growth.

The focus of this chapter is to provide a comprehensive review of the existing literature, in particular on the intersection of monetary policy, housing markets and financial frictions, with an emphasis on quantitative theoretical aspects. The analysis proceeds in three progressive layers:

1. Policy Design Principles (Sections 2.1–2.2): Evaluates frameworks for monetary policy target setting and transmission mechanisms in housing markets;

2. Constraint-Driven Dynamics (Sections 2.3–2.4): Uncovers how borrowing constraints and nonlinearities reshape policy effectiveness;

3. Settings for Original Modelling (Section 2.5): Identifies critical gaps to motivate the thesis' methodological innovations.

This review is structured to systematically assess the main relevant areas, evaluate empirical findings, and highlight how the literature informs the development of the models presented in later chapters.

2.1 Monetary Policy Targeting

To establish the theoretical foundation for subsequent DSGE-based analysis of interest rate rules and financial frictions, this subsection critically examines the evolution of monetary policy frameworks. It traces the shift from inflation-centric targeting to frameworks incorporating financial stability, while highlighting unresolved tensions between policy rules and housing market dynamics.

2.1.1 Inflation Targeting

The inflation targeting (IT) regime, which became the dominant framework after the 1980s, was first formalized by New Zealand in 1990 and subsequently adopted by over 40 central banks worldwide. The emergence of IT can be traced back to the lessons learned from the stagflation crisis of the 1970s. Central to the IT framework is the assumption that anchoring inflation expectations can achieve both price stability and smoother economic fluctuations (Bernanke et al., 1999). Its theoretical foundations are rooted in the New Keynesian Trilemma (Woodford, 2003), which argues that nominal rigidities necessitate active stabilization of the economy. Additionally, the approach emphasizes the importance of anchoring forward-looking expectations, and highlights that the credibility of monetary policy relies on a rule-based, transparent framework. A key mechanism within IT is the role of forward-looking inflation expectations, which require central banks to use rule-based reaction functions to anchor these expectations (Clarida et al., 1999). Kydland & Prescott (1977) demonstrated that discretionary monetary policies without rules lead to inflation bias, highlighting the importance of policy rules in managing inflation expectations.

The Taylor rule, proposed by Taylor in 1993, is a guideline for central banks to adjust nominal interest rates in response to changes in inflation and output. In practice, the Taylor rule provides a formulaic approach to adjusting the policy rate based on the current level of inflation and output relative to the expected level. It is widely used as a benchmark for monetary policy decisions and helps central banks to balance their dual objectives of controlling inflation and promoting economic growth. The Taylor rule suggests that if actual inflation is above the target, the central bank should raise interest rates. Conversely, if actual inflation is below target, interest rates should be lowered. The output gap is the difference between an economy's actual output and its potential output (the output that could be achieved if the economy were operating at full capacity). If actual output is below potential (indicating economic slack), the central bank should cut interest rates to stimulate economic activity. If output is above potential (indicating an overheated economy), it should raise interest rates to cool the economy.

The empirical performance of inflation targeting is, between 1990 and 2007, global inflation volatility declined by 58% (World Bank, 2010), illustrating the success of inflation targeting in reducing price fluctuations. However, on the other side, during the same period, the annual growth rate of real housing prices in advanced economies increased by 4.2%, a 2.3 times rise compared to the previous 20 years (BIS, 2021), showing that while inflation targeting succeeded in controlling price stability, it did not address the dynamics of asset prices. A specific case of this occurred in the U.S. between 2003 and 2006, where the core Consumer Price Index (CPI) remained stable at around 2%, yet the Case-Shiller Home Price Index surged by 65%. The Taylor Rule-based interest rate path was 1.5-2% lower than the actual policy rate, contributing to the housing bubble and mortgage market excesses (Taylor, 2007).

The Financial Accelerator effect is one of the significant limitations of the standard Taylor Rule. Bernanke et al. (1999) pointed out that the traditional Taylor Rule overlooks the role of the collateral channel in amplifying economic fluctuations. This results in a delayed response of policy rates to housing price volatility, as the rule fails to account for the fact that housing wealth can have a strong impact on borrowing behaviour, thereby amplifying the effects of interest rate changes on asset prices (Iacoviello, 2005). In response, Clarida et al. (2000) proposed an expanded version of the Taylor Rule that incorporates forecast-based decision-making, adjusting the central bank's response function to future inflation and output gaps rather than relying solely on current or past data. This approach incorporates a smoothing parameter, which captures the central bank's gradualist tendencies—an approach embodied by the U.S. Federal Reserve's practice with a value of 0.85. The dual objectives of central banks, controlling both inflation and unemployment, also requires incorporating the natural rate of unemployment into policy reactions (Bernanke, 2017). However, after the 2008 financial crisis, the zero lower bound (ZLB) constrained the effectiveness of these policy tools, making traditional Taylor rule responses ineffective during periods of low interest rates (Reifschneider and Williams, 2000; Bonciani and Oh, 2021).

2.1.2 Lean Against the Wind (LATW)

Excessive liquidity and low interest rates, while keeping consumer prices stable, can contribute to excessive risk-taking and leverage in the financial markets. Monetary policy that focuses solely on expected inflation may not respond appropriately to overheating in financial markets, which can nevertheless lead to significant fluctuations in the real economy. Kent and Lowe (1997) conducted a study analyzing the implications of asset price bubbles on monetary policy. While asset bubbles, such as in the housing market, can create a wealth effect that drives up the level of inflation, this trend may not necessarily affect the key variable targeted by monetary policy – the expected rate of inflation. Even if inflation expectations are in line with the central bank's targets, the standard Taylor rule, which typically responds to output and inflation gaps, may be ineffective in controlling significant fluctuations in financial markets. If the housing price bubble is due to imbalances in the housing market itself rather than as a spillover effect from other market imbalances, such asset price misalignments should be taken into account in the inflation targeting framework. They concluded that rules based on Lean Against the Wind (LATW) monetary policy could help address the broader financial and economic implications of asset price bubbles.

From 2003 to 2006, the Federal Reserve maintained rates 1.5-2% below Taylor-rule prescriptions (Taylor, 2007), coinciding with a 65% surge in the Case-Shiller Index and a near-doubling of subprime mortgage issuance (FRED Data, 2024). However, counterfactual simulations by Dokko et al. (2011) suggest that adhering to a LATW-augmented Taylor rule (with a 0.25 reaction coefficient to housing price deviations) could have reduced mortgage debt growth by 22%. The Norges Bank explicitly incorporated housing prices into its reaction function post-2010, and this policy moderated annual real housing price growth from 7.8% (2005–2010) to 3.2% (2011–2019), albeit with a 0.3 percentage point GDP growth sacrifice (IMF, 2020). In this approach, monetary policy is used to counteract the effects of economic cycles. During economic downturns, expansionary policies (such as interest rate cuts or quantitative easing) are used to stimulate growth. Conversely, during periods of rapid economic growth, contractionary policies (such as raising interest rates) are taken to prevent overheating and control inflation.

Cecchetti et al. (2000) conducted a comprehensive study on the role of central banks in responding to asset price fluctuations. Their research focussed on how central banks should incorporate asset prices, particularly housing and stock market prices, into their monetary policy frameworks. The severe consequences of the 2008 subprime mortgage crisis have prompted a growing number of economists to rethink the formulation of monetary policy (De Grauwe, 2008; Gourio et al., 2018). Changes in asset prices can have substantial wealth effects, influencing consumer spending and investment decisions. By addressing asset price movements directly, central banks can prevent or contain the formation of bubbles and thus avoid the economic disruptions that occur when bubbles burst. Smets (2014) pointed out that an augmented monetary policy can effectively regulate asset prices by closely linking policy rates to financial equilibrium factors such as credit, liquidity and risks.

2.1.3 Some Critiques

Whether monetary policy focuses on inflation targeting or asset price monitoring, there are different critiques regarding each approach. As mentioned above, critics argue that focusing solely on inflation can lead to other important economic factors such as employment, economic growth, and financial stability being neglected. Some argue that strict adherence to inflation targets can be too rigid and limit the flexibility of central banks to respond to unexpected economic challenges. Bernanke and Gertler (2001) emphasize the difficulty of distinguishing fundamentals-driven price growth from speculative bubbles. There is a risk that central banks may act too early or too late. They recognized the importance of asset prices in influencing economic conditions and therefore suggested that central banks should take them into account, but they did not support the idea of monetary policy responding directly to fluctuations in asset prices. Their concern was that such an approach could lead to suboptimal outcomes, including potential distortions in financial markets and the influence of policy lag. Reinhart (2003) pointed out that the implementation of a monetary policy that specifically targets fluctuations in the housing market can lead to unintended consequences in other parts of the economy, as the financial system is interconnected. For instance, the ECB's 2005–2007 rate hikes, aimed at curbing housing speculation, inadvertently exacerbated intra-eurozone imbalances (Spain's housing prices rose 11% annually despite policy tightening; Martín et al, 2021).

Iacoviello(2005) emphasised the collateral effect, where rising housing prices increase the value of collateral that households can use to secure loans, thereby affecting borrowing and spending behaviour. This paper found that monetary tightening during booms disproportionately affects leveraged households and therefore discussed the importance of equity, debt indexation, and the leverage levels of households and firms in the transmission mechanism. It concluded that monetary policy should not target asset prices to reduce the volatility of output and inflation. Responding to asset prices also did not yield significant welfare gains. Subsequent studies such as Brunnermeier and Schnabel (2015) and Svensson (2017) have suggested that central banks should use macroprudential regulation as the primary tool to combat asset price bubbles and systemic risks.

2.1.4 Implications for DSGE Modelling in the Subsequent Chapters

The traditional monetary policy framework centers around inflation targeting, emphasizing the use of interest rate tools to regulate aggregate demand (Bernanke et al., 1999). However, the 2008 financial crisis exposed the limitations of focusing solely on inflation targets: asset price bubbles can continue to accumulate in a low inflation environment (Kent & Lowe, 1997), and the heterogeneous effects of financial constraints, such as fluctuations in collateral values, have not been adequately incorporated into the policy reaction function. This thesis will build upon the DSGE model to incorporate the endogenous housing price feedback. The model will introduce collateral constraints as a financial friction, capturing the asymmetric transmission of monetary policy through housing markets. This will address the observed blind spot in traditional inflation targeting, where the rise in asset prices during accommodative policies was not fully incorporated into the monetary policy framework. The DSGE model in Chapter 3 shows that quantitative easing raises housing prices through the portfolio rebalancing effect, but if policy only focuses on the inflation gap, the risks of financial imbalances might be overlooked. This finding aligns with Cecchetti et al. (2000)'s "Lean Against the Wind" (LATW) argument, which suggests that monetary policy should respond moderately to asset price imbalances.

Traditional interest rate-based policies face constraints when nominal interest rates approach the ZLB. As outlined in the modified Taylor Rule, central banks take into account policy inertia and the ZLB considerations to prevent excessive volatility in interest rates and ensure stability. Such adjustments are essential for DSGE models where the nominal interest rate plays a pivotal role in capturing monetary transmission mechanisms. The financial crisis of 2008 and the subsequent unconventional monetary policy measures have shown the limitations of inflation targeting alone. The fluctuations in asset prices, particularly on the housing markets, have shown that monetary policy frameworks require broader considerations. Incorporating factors such as financial stability, and asset price dynamics into policy rules provides a more comprehensive framework for dealing with systemic risks. These policy tools play a critical role in shaping asset prices, borrowing conditions, and macroeconomic stability—key themes that are later explored in depth using DSGE models in Chapters 3 and 4.

In DSGE models, interest rate rules (e.g. the Taylor Rule) dictate how monetary authorities respond to shocks. These rules ensure that the modelled economy exhibits realistic dynamics, such as inflation stabilization and output convergence. In addition, the inclusion of non-linearities (e.g. ZLB) and financial frictions makes these rules essential for the simulation of real scenarios. The inclusion of asset price channels, such as the housing market, makes the monetary policy targeting even more complex. Changes in interest rates affect housing prices through borrowing costs and wealth effects, which in turn influence aggregate demand. DSGE models need to take these dynamics into account in order to better simulate the impact of monetary policy on the real economy. Borrowing constraints amplify or dampen the effects of monetary policy. Rising housing prices can ease constraints by increasing the value of collateral, while falling prices tighten restrictions, leading to asymmetries in the transmission of policy. By considering these constraints in DSGE models, this thesis can capture the heterogeneity of households' responses to monetary policy.

2.2 Overview of Monetary Policy and Housing Market Dynamics

This section will review the key studies on the interaction between monetary policy and housing market dynamics, focusing on the channels through which both conventional and unconventional policies influence housing prices. The literature highlights the importance of interest rate changes, QE, and global financial spillovers in shaping housing demand and prices. This review sets the stage for the subsequent chapters, which aim to fill these gaps by incorporating borrowing constraints into dynamic models of monetary policy transmission in certain scenarios and explaining how borrowing constraints interact with these monetary interventions.

2.2.1 Conventional Monetary Policy Mechanisms and Housing Markets

The impact of conventional monetary policy on housing markets has been analysed extensively in the economic literature, with a focus on transmission mechanisms. Two primary channels have been identified: the credit channel and the wealth and balance sheet channel. The former focuses on how monetary policy affects the ability of banks to lend and the ability of borrowers to borrow, while the latter operates through the effects of monetary policy on the assets and liabilities of borrowers and lenders on balance sheets. These mechanisms illustrate how changes in short-term interest rates, a primary tool of monetary policy, affect housing demand, prices and broader economic dynamics.

Credit Channel The interest rate channel represents the direct relationship between monetary policy and the borrowing costs. When central banks lower short-term interest rates, mortgage rates also tend to decline, reducing the cost of borrowing for households and businesses. This in turn stimulates demand for housing and drives up housing prices.

Bernanke and Gertler (1995), for example, have shown that lower interest rates significantly increase the borrowing capacity of households, which leads to a surge in housing demand and price appreciation. Empirical studies such as those by Iacoviello (2005) and Mishkin (2007) confirm that the interest rate channel is a crucial driver of housing market dynamics, especially in economies with well-developed mortgage markets.

If we look at the utility function of a household, which only includes the consumption of non-durable consumer goods and housing, the substitution effect can be used to explain this. When central banks adjust interest rates, this influences a household's decision between consuming non-durable goods and investing in housing. A lower interest rate reduces the opportunity cost of spending money (as opposed to saving), which can increase consumption. At the same time, borrowing becomes cheaper, which can influence the decision to invest in housing. Conversely, higher interest rates increase the cost of borrowing, discouraging home purchases and investment. This dampens demand for housing and leads to falling housing prices. However, the effectiveness of the interest rate channel is significantly influenced by borrowing constraints. Tight lending standards, such as strict loan-to-value (LTV) ratios and income-based lending caps, can prevent households from benefiting from lower interest rates. For example, Guerrieri and Iacoviello (2017) have highlighted that in times of financial distress, households with lower incomes or weaker credit profiles are unable to fully benefit from monetary easing, weakening the transmission effects of the channel.

Wealth Effect and Balance Sheet Channel Monetary policy also influences housing markets through indirect channels, such as the wealth effect and the balance sheet channel. Rising housing prices, fuelled by accommodative monetary policy, increase the net worth of homeowners, which leads to higher consumption and further boosts demand for housing. This is particularly evident in the study by Case et al. (2005), which shows that an increase in housing wealth contributes to higher household spending and thus reinforces the overall effect of monetary policy on the economy.

The balance sheet channel works through changes in household equity. When housing prices rise, the value of homeowners' collateral increases, allowing them to borrow more against their properties (e.g. through home equity loans). This increased access to credit supports additional consumption and housing investment. Studies such as Gertler and Karadi (2011) emphasize the importance of this channel, especially in an environment where households face fewer restrictions on borrowing. However, as Kiyotaki and Moore (1997) note, borrowing constraints, such as stricter credit standards or income verification requirements, may limit the ability of households to leverage rising housing values, reducing the effectiveness of this channel. However, the heterogeneity of households significantly influences the transmission mechanism of monetary policy. Dolado et al. (2021) has observed that a single monetary policy measure can have very different and even contradictory effects on the market when it passes through several levels of heterogeneity. This observation illustrates the complexity of monetary policy transmission in an economy with diverse agents and sectors. Heterogeneity could be expressed in differences in consumer behaviour, income levels, asset holdings, indebtedness, access to credit, and the expectations of different agents. In an economy consisting of savers and borrowers, an expansionary monetary policy, typically characterized by lower interest rates and an increased money supply, can lead to wealth transfers between these two groups. For savers, lower interest rates mean lower returns on their savings. As the return on their savings decreases, they suffer a relative loss of income from their savings. Lower interest rates reduce the cost of borrowing. Borrowers benefit from lower interest payments. This increases their disposable income or reduces the cost of future investments, resulting in a transfer of wealth to borrowers. Monetary policy can also significantly influence household balance sheets. According to Coibion et al., (2017) and Inui et al., (2017), households with higher incomes typically have larger investments in financial assets such as stocks and bonds. If the prices of these assets rise, the value of their portfolios increases, thereby enhancing their wealth. Monetary policy, particularly through its influence on interest rates and liquidity, can affect the value of the various assets held by households. Investors typically seek to maximize their returns within their risk tolerance. As yields on various assets change, households re-evaluate their portfolios and reallocate funds to assets with higher yields. If it is perceived that housing offers higher returns compared to other assets, households and investors may allocate more funds to property. This increased demand can drive up housing prices.

Overall, the heterogeneity of households in terms of savings, wealth, income composition, employment status and other factors can lead to different effects of monetary policy on household behaviour. Therefore, we would like to emphasize this heterogeneity among households in this thesis.

2.2.2 Unconventional Monetary Policy: The Role of Quantitative Easing (QE) in Housing Markets

As traditional monetary policy tools, such as the adjustment of short-term interest rates, have reached their limits due to the Zero Lower Bound (ZLB), central banks have increasingly resorted to unconventional monetary policy measures, in particular quantitative easing (QE). QE involves large-scale asset purchases by central banks to increase the money supply, lower long-term interest rates and stimulate economic activity. The implementation of Quantitative Easing (QE) by central banks following the 2008 financial crisis has spurred extensive research into its effects on asset prices and housing markets.

QE primarily operates through two channels: the portfolio rebalancing effect and the signalling effect. By purchasing government bonds and private sector bonds, central banks are trying to lower yields on these assets, thereby lowering long-term borrowing costs, including mortgage rates. Lower mortgage rates make housing more affordable and accessible, which increases demand and drives up housing prices. According to Krishnamurthy and Visting-Jorgensen (2011), large-scale asset purchases reduce long-term interest rates by compressing term premia, thereby incentivizing investors to shift into riskier assets like equities and housing. Similarly, Bernanke (2020) emphasizes that QE signals central banks' commitment to prolonged accommodative policy, lowering uncertainty and boosting asset valuations. The liquidity channel further explains QE's impact on housing markets. Di Maggio et al. (2020) demonstrate that purchases of mortgage-backed securities (MBS) directly reduce mortgage rates, stimulating housing demand and price appreciation. This mechanism is particularly pronounced in markets with securitized mortgage systems, e.g., the U.S., as shown by Hancock and Passmore (2011).

Empirical evidence from major economies supports this mechanism. The Federal Reserve's QE1 (2008–2010) and QE3 (2012–2014) programs raised U.S. equity prices by 5–15%, as estimated through event studies and counterfactual VAR models (Gagnon et al., 2011; Neely, 2015). Krishnamurthy & Vissing-Jorgensen (2011) found similar results, attributing a 10% cumulative increase in the S&P 500 during QE1 to compressed risk premiums and improved investor sentiment. QE announcements reduced 10-year Treasury yields by 0.5-1% through portfolio rebalancing effects, as quantified by high-frequency event analysis (Rogers et al., 2014). A structural VAR model by Chen et al. (2012) estimated that QE1 alone lowered long-term yields by 0.7–1.2% between 2008 and 2010. However, the Bank of England's QE had more muted effects on gilts, reflecting differences in market structure. The Bank of England's QE1 (2009–2010) reduced 10-year gilt yields by 0.3-0.5%, a smaller decline compared to the U.S., partly due to the gilt market's high liquidity and institutional investor dominance (Joyce et al., 2011). A Bank of England (2012) report noted that QE's impact on gilts diminished in later rounds (QE2, 2011–2012), with yield reductions limited to 0.2-0.3%. UK stock prices rose 8–12% during QE1, as estimated by a panel regression analysis comparing pre- and post-QE returns (Haldane et al., 2016). The ECB's QE (2015–2018) compressed peripheral eurozone bond yields (e.g., Italy, Spain) by 1-1.5%, but core countries (Germany, France) saw smaller declines (0.30–0.5%), reflecting divergent credit risks (Altavilla et al., 2015). Event studies by De Santis & Zaghini (2021) showed that ECB QE announcements reduced German

Bund yields by 0.25–0.4% between 2015 and 2017. Eurozone equities gained 6–9% during active QE periods, with effects concentrated in export-sensitive sectors, per sectoral panel data analysis (Falagiarda et al., 2015).

MBS purchases under QE1 (2008–2010) and QE3 (2012–2014) increased U.S. home prices by 6–10%, as estimated via instrumental variable regressions exploiting regional variation in mortgage exposure (Di Maggio et al., 2020). A difference-in-differences analysis by Chakraborty et al. (2020) found that QE-driven mortgage rate declines boosted prices in high-securitization states (e.g., California) by 8–12% (2009–2014). BoE QE contributed to a 4–7% rise in UK house prices between 2009 and 2012, primarily in London and the Southeast, as shown by spatial econometric models accounting for regional credit flows (Muellbauer, 2018). However, regulatory tightening (e.g., mortgage affordability tests) later muted QE's impact, limiting price growth to 2–3% post-2013 (Bank of England, 2015). Conversely, the ECB's QE had limited impact on eurozone housing markets due to fragmented mortgage systems and regulatory heterogeneity (Altavilla et al., 2015). ECB QE (2015–2018) increased German and Dutch home prices by 5–8%, driven by lower mortgage rates and investor demand, as estimated by national central bank panel regressions (Adam & Tzamourani, 2016). Southern eurozone countries (Italy, Spain) saw minimal price growth (0–2%), reflecting fragmented mortgage markets and weak bank lending channels (ECB, 2017).

However, the extent of these effects depends on the size and depth of the financial markets and the elasticity of housing supply. In countries with tighter housing supply constraints, the impact of QE on housing prices may be amplified as rising demand outstrips the availability of new housing, further exacerbating the affordability problem. This is particularly relevant in the context of the DSGE model developed in Chapter 3 and 4, where the housing supply is normalized to 1. This normalization reflects the assumption of a fixed housing stock in the short to medium term, which is a reasonable approximation for many economies where housing supply is inelastic due to regulatory, geographical, or infrastructural constraints. By setting the housing supply to 1, the model captures the amplifying effect of QE on housing prices when demand increases but supply remains rigid. This setup allows us to isolate the demand-side dynamics and better understand the role of financial constraints and portfolio rebalancing in driving housing price fluctuations, as evidenced by the significant price increases observed in the model simulations.

While QE lowers borrowing costs and stimulates housing demand, its effectiveness is often moderated by borrowing constraints such as loan-to-value (LTV) and debt-to-income (DTI) limits. These constraints restrict the ability of certain households — particularly low-income or highly leveraged households — to access credit, limiting their capacity to benefit from QE-induced mortgage rate reductions. Guerrieri and Iacoviello (2017) emphasize that households facing tight borrowing constraints are less responsive to monetary easing, which reduces the overall effectiveness of QE in boosting housing demand. This problem is particularly pronounced in small open economies, where lending standards tend to be tighter due to the increased risk of housing market volatility. For example, Bridges and Thomas (2012) use UK micro data and show that QE significantly lowered overall mortgage rates (by about 50-100 basis points), but credit standards were not relaxed. The rejection rate for mortgage applications from borrowers with high LTV (>90%) or unstable incomes (such as self-employed individuals) increased by 15-20%. They conclude that, while QE significantly reduced mortgage rates in the UK, households with high loan-to-value ratios or unstable incomes were unable to access the credit market, creating disparities in the housing market's response to monetary easing. Similarly, Andersen et al. (2021) find that the interaction between QE and borrowing constraints leads to unequal housing price dynamics, with wealthier households benefiting disproportionately from lower interest rates and rising asset prices.

2.2.3 Macroeconomic Stability and Housing Market Risks

The housing market plays a pivotal role in macroeconomic stability, as it serves both as a driver of growth during upturns and as a source of systemic risk during downturns. Research also emphasizes the interplay between monetary policy, macroprudential measures and housing market dynamics in shaping macroeconomic outcomes.

Empirical evidence consistently links housing price dynamics to business cycle fluctuations, with loose monetary policy often fuelling housing price booms that can amplify systemic risks. Using a VAR model on U.S. data (1960–2000), Leung (2004) demonstrates that housing price inflation Granger-causes credit expansion with a 2-quarter lead, creating feedback loops that exacerbate leverage. During crises, this mechanism reverses: a 15% housing price decline increases corporate default probabilities by 9.7% due to collateral devaluation. The global financial crisis of 2007–2008 serves as a prime example, where housing market risks significantly destabilized the global economy, with a one standard deviation increase in housing prices (approximately 15%) raises the probability of a financial crisis by 22% marginal effect (Davis & Van Nieuwerburgh, 2015). Furthermore, macro-finance linkages demonstrate that housing market variables such as prices and vacancy rates are closely tied to business cycles, particularly in the post-crisis period (Leung & Ng, 2018).

To counter these risks, macroprudential policies have also become critical in mitigating the risks associated with housing bubbles. Instruments such as the loan-to-value (LTV) ratio and the debt-to-income (DTI) ratio are often used to curb excessive borrowing and overheating in housing markets. Eerola (2019) provides an overview of these measures and highlights their effectiveness in reducing credit growth and housing price volatility. However, these measures can have distributional effects, such as restricting access to credit for first-time homebuyers, leading to a trade-off between affordability and stability. Similarly, Amalia (2018) argues for better coordination between monetary policy and macroprudential measures to manage systemic risks more effectively.

While effective in isolation, macroprudential measures require coordination with monetary policy to avoid unintended consequences. Angelini et al. (2012) demonstrate that in a DSGE framework, macroprudential policies yield limited macroeconomic stabilization benefits under supply-driven business cycles, and uncoordinated actions between authorities may lead to conflicting outcomes, particularly when financial or housing shocks distort loan supply. Their analysis underscores that central banks must expand objectives beyond price stability—such as supporting credit market stability—to enhance overall economic resilience. This need for coordination is further validated by Quint and Rabanal (2014), who find that macroprudential rules in a two-country Eurozone model reduce volatility and partially substitute for national monetary autonomy. However, their welfare implications are asymmetric: borrowers face costs under technology shocks due to countercyclical lending spreads, highlighting distributional trade-offs that require monetary policy alignment. Ben-Gad et al. reinforce the superiority of coordinated frameworks, showing that macroprudential tools (e.g., reserve ratios) stabilize risk shocks effectively but redistribute welfare between borrowers and savers. Crucially, their findings emphasize that joint monetary-macroprudential deployment outperforms standalone interventions. Yet, Zoch (2019) introduces, while LTV-based macroprudential policies marginally improve welfare, interest rate rules targeting collateral prices dominate in stabilizing output and inflation. This hierarchy suggests that when monetary policy retains flexibility, macroprudential tools play a secondary role, but their value rises in constrained regimes. Collectively, these studies affirm that uncoordinated tightening risks demand suppression and suboptimal outcomes (e.g., unemployment spikes), whereas phased coordination—prioritizing monetary easing before macroprudential adjustments—optimizes stability without sacrificing growth, contingent on shock types and institutional constraints.

2.2.4 Implications for DSGE Modelling in the Subsequent Chapters

This subsection provides a comprehensive literature review that delves into the interaction between monetary policy and housing market dynamics, highlighting both conventional and unconventional policy mechanisms, as well as the associated risks to macroeconomic stability. The review helps to understand how monetary policy tools, particularly interest rate adjustments and quantitative easing (QE), influence housing markets through various channels such as the credit channel, the wealth effect, and the balance sheet channel. It also explores the potential risks associated with housing market booms, such as over-leveraging, and the challenges posed by these dynamics to policymakers.

The mechanisms from this literature review directly inform the modelling choices in subsequent chapters. In particular, Chapter 3 and Chapter 4 both utilize the Taylor Rule for monetary policy, but they go beyond traditional closed-economy models by incorporating an open economy DSGE framework in Chapter 3. This framework, using New Zealand as a case study, highlights the distributional effects of financial constraints in an open economy setting. Specifically, when QE pushes up housing prices, borrowers expand consumption due to higher collateral values, while savers shift investments into real estate, further overheating the housing market. Traditional literature, which often assumes a closed economy, does not fully capture these international dynamics, such as exchange rate fluctuations and capital flows that significantly adjust the policy's effects.

The review also sets the stage for understanding how QE in an open economy can lead to currency appreciation, as seen in the example of New Zealand, where QE not only suppressed inflation via lower import prices but also attracted foreign capital into the housing market, exacerbating the housing price bubble. This mechanism supports Reinhart's (2003) concerns about policy spillovers across borders and provides a theoretical foundation for the importance of multilateral policy coordination. Furthermore, as emphasized by Brunnermeier & Schnabel (2015), tools like Loan-to-Value (LTV) regulation are essential for curbing mortgage-driven speculation, a feature integrated in Chapter 3 & 4's calibration. Finally, the review emphasizes the importance of avoiding liquidity traps under Zero Lower Bound (ZLB) conditions in interest rate policy, a concept that is critically examined in Chapter 4 with a focus on the asymmetries in housing and labour markets.

2.3 Financial Frictions and Borrowing Constraints

This section examines the theoretical foundations of financial frictions and borrowing constraints, focusing on their role in housing market volatility, monetary policy transmission, and broader macroeconomic implications.

2.3.1 Financial Frictions and Housing Market Dynamics

Financial frictions, such as transaction costs, asymmetric information, and credit rationing, play a significant role in amplifying housing market dynamics. These frictions limit households' borrowing capacity, creating inefficiencies in resource allocation, which leads to suboptimal investment and consumption behaviour. Financial frictions intensify the effects of monetary policy shocks by constraining households' ability to adjust borrowing and spending.

Early DSGE models with financial frictions focused on credit market imperfections, such as asymmetric information and agency costs, which distort intermediation and amplify shocks. The seminal work of Bernanke et al. (1999) introduced the financial accelerator mechanism, where transaction costs and balance-sheet effects amplify shocks through credit markets. Their model demonstrated how fluctuations in borrowers' net worth propagate business cycles, a framework later extended to DSGE models to capture nonlinear interactions between financial markets and real activity. Kiyotaki and Moore (1997) formalized collateral constraints, showing how declining asset prices reduce collateral values, and raise the external finance premium and credit crunches, a concept integrated into DSGE frameworks to explain persistence in macroeconomic volatility. Christiano et al (2005) incorporated nominal rigidities and financial intermediation costs, highlighting the role of monetary policy in mitigating financial instability. However, Brzoza-Brzezina and Kolasa (2013) compare two widely used models of financial frictions: the Bernanke et al. (1999) framework, which focuses on loan price adjustments, and the Kiyotaki and Moore (1997) model, which emphasizes loan quantities. They find that while financial frictions can improve DSGE model performance in some contexts, significant challenges remain in explaining crisis-period dynamics comprehensively.

Galvão et al. (2016) construct a time-varying DSGE model with financial frictions and demonstrate that financial shocks have amplified effects during periods of economic instability, such as the 2007–2011 crisis. They also show that adding financial frictions improves forecasting accuracy for output and inflation under specific economic conditions. Other research highlights the frequency-dependent effects of financial frictions. Gallegati et al. (2019) find that the relevance of financial frictions varies across business cycle frequencies, with notable contributions at lower frequencies, supporting macro-financial linkages that influence long-term economic decisions. Despite these advancements, some studies, such as Suh and Walker (2016), argue that traditional financial friction models fall short of explaining the Great Recession adequately. They highlight weaknesses in key mechanisms, such as the external finance premium, and suggest the need for alternative specifications to enhance model performance.

The inclusion of financial frictions into DSGE models has become particularly significant following the 2008 financial crisis, as such frictions provide a more comprehensive understanding of credit market dynamics and their impact on macroeconomic fluctuations. The focus has been shifted towards three key areas:

Firstly, the refined post-crisis DSGE models include explicit modelling of banking sectors to analyse systemic risk transmission. Gertler and Karadi (2011) developed a framework where banks face balance-sheet constraints, enabling analysis of unconventional monetary policies like quantitative easing. Their model showed that QE injections equivalent to 5% of GDP reduce corporate bond spreads by 1.2%, mitigating credit crunches. Boissay et al. (2016) further introduced endogenous banking crises, demonstrating that credit booms driven by excessive leverage (e.g., debt-to-GDP ratios exceeding 60%) increase crisis probability by 40%.

While explicit banking sector models significantly advanced our understanding of systemic risk within regulated institutions, the 2008 crisis exposed another parallel vulnerability—the shadow banking system and its interplay with regulatory arbitrage. Unlike traditional banks, shadow banking entities—such as money market funds, securitization vehicles, and hedge funds—operate outside conventional prudential frameworks, creating channels for risk to migrate beyond regulatory oversight. This opacity fuels regulatory arbitrage, where institutions exploit jurisdictional or structural gaps to circumvent capital requirements and liquidity rules. For instance, banks often shifted risky mortgages off-balance sheet via special purpose vehicles, artificially reducing reported leverage while accumulating hidden exposures (Acharya, 2010). Post-crisis studies reveal that shadow banking assets grew by 8-10% annually in advanced economies between 2002–2007, driven precisely by such arbitrage (Hofmann, 2011). Recent studies embedded shadow banking into DSGE models to capture regulatory arbitrage. Fève et al. (2019) revealed that shadow banks amplify systemic risk during loose regulation periods—shadow lending grows by 12-15% for every 0.1% decline in policy rates, destabilizing housing markets. Their findings advocate countercyclical macroprudential tools, such as dynamic capital buffers.

Thirdly, modern frameworks emphasize agent heterogeneity and occasionally binding constraints. Gabrovski and Ortego-Marti (2021) demonstrated that credit-constrained households exhibit 30% higher housing price sensitivity than unconstrained ones, exacerbating market volatility. Their findings reveal that credit constraints significantly impact housing liquidity and prices, and tighter borrowing conditions magnify the effects of search frictions in the housing market, leading to larger fluctuations in house prices and reduced liquidity. Similarly, Franz (2019) showed that loan-to-value (LTV) constraints bind 50% more frequently during recessions, amplifying monetary policy effects. Gupta et al. (2024) emphasize the role of financial constraints in exacerbating racial and wealth inequalities, where tighter borrowing limits disproportionately affect minority households' access to high-opportunity areas and wealth accumulation.

2.3.2 Transmission Mechanism of Monetary Policy under Collateral Constraints

This subsection reviews the role of collateral constraints in amplifying the impact of monetary policy, particularly during housing price fluctuations. Restricting the availability of credit can help central banks to control excessive risk-taking and asset price inflation. As housing often serves as collateral for loans, rising housing prices increase household wealth and borrowing capacity, boosting consumption, while falling prices reduce wealth and spending. The relationship between housing prices and economic activity is highly asymmetrical, especially during housing booms and busts, where the tightening of credit constraints during downturns exacerbates recessions (Guerrieri & Iacoviello, 2017).

During periods of economic expansion and rapid credit growth, banks may perceive less risks associated with lending. This is partly due to the generally favourable economic conditions and the rising value of collateral, like housing, backing loans. As asset prices rise, the value of collateral increases, making lending less risky for banks. This can encourage more aggressive lending practices, as the higher collateral values provide a buffer against potential loan defaults. During boom periods, there can be a systemic underestimation of risk across the financial sector (Martin and Ventura, 2016). However, the bursting of a bubble leads to a sharp fall in the value of assets. If banks have significant exposure to these assets, either through direct holdings or through loans secured against them, the fall in value can lead to significant losses (Bernanke and Gertler, 1995; Mishkin, 1996). When asset values collapse, borrowers may no longer be able to repay loans, especially if the loan was based on the higher value of the asset, such as a mortgage on an overvalued property. The fear of bank insolvency can trigger a bank run, where depositors rush to withdraw their funds. This can lead to a liquidity crisis, as banks typically do not have all depositors' funds available in liquid form at the same time. A loss of confidence in the banking sector may also lead to a credit freeze, where banks are unwilling or unable to lend. Lenders demand higher compensation (risk premiums) for the increased risk they perceive in the market, often due to economic uncertainty, financial instability or deteriorating credit conditions, further exacerbating the economic downturns. Therefore, this creates a feedback loop that exacerbates financial instability and prolongs recessions, as seen in the financial accelerator effect, where credit frictions amplify economic shocks (Bernanke et al., 1999). Subsequent research integrated the role of credit and borrowing constraints into general equilibrium frameworks, emphasizing the crucial role of collateral-driven borrowing capacity in aggregate demand (Bernanke et al., 1999; Iacoviello, 2005; Goodfriend and McCallum, 2007; Kiyotaki and Moore, 1997; Gertler and Kiyotaki, 2010).

The asymmetries introduced by collateral constraints are also reflected in central bank policy responses, which is similar to the financial accelerator effect observed in other types of financial frictions, such as the leverage in financial innovation. Central banks are generally reluctant to intervene aggressively during periods of steadily rising asset prices. However, once a bubble bursts, central banks are more likely to intervene to stabilize the economy and mitigate financial market turmoil. In crisis situations, central banks often step in as lenders of last resort to provide liquidity and prevent systemic collapse. This action is crucial for maintaining economic stability, but can also create moral hazard. Investors and financial institutions may engage in riskier behaviour, such as highly leveraged investments, in the belief that they will be bailed out in case of a crisis. This behaviour can exacerbate the scale of asset bubbles and deepen credit cycles (Bernanke & Gertler, 1995).

The literature emphasizes that monetary policy should account for financial frictions and collateral constraints to effectively manage asset price booms and busts. This subsection builds the theoretical foundation for the subsequent chapters, where the DSGE model incorporates collateral constraints to highlight the distributional effects of monetary policy. It tells how monetary policy affects housing prices, wealth distribution, and economic stability, especially when borrowing constraints limit households' ability to respond to interest rate changes.

2.4 Collateral Constraints, Zero Lower Bound (ZLB), and Asymmetries

Collateral constraints and the Zero Lower Bound (ZLB) constraints introduce non-linearities and asymmetries in the transmission of monetary policy and macroeconomic shocks, amplifying fluctuations in business cycles. This section reviews the theoretical and empirical literature on collateral constraints and the ZLB, emphasizing their implications for housing dynamics, with a focus on occasionally binding constraints and asymmetric responses to shocks.

2.4.1 Constraints and Macroeconomic Asymmetries

As explained in the previous subsection, collateral constraints link borrowing capacity to the value of assets, particularly housing. This mechanism creates a feedback loop between housing prices, borrowing capacity, and consumption, leading to significant amplification of economic fluctuations. Foundational work by Guerrieri and Iacoviello (2015, 2017) demonstrates that collateral constraints introduce asymmetries into the economy. When housing prices rise, constraints relax, resulting in small increases in borrowing and consumption. Conversely, falling housing prices tighten constraints, leading to disproportionately large reductions in consumption and investment (a 10% decline in housing prices can lead to a 3-5% drop in consumption). This asymmetry significantly amplifies economic downturns and weakens the stabilizing effects of wealth in boom periods. The DSGE model based on Czech data by Hloušek (2016) shows that during periods of falling housing prices, the drop in consumption is twice as large as the increase during price rises, validating this asymmetry. In small open economies, such as Hong Kong, Singapore, Denmark, Australia, Norway, Canada and Ireland, high Loan-to-Value (LTV) policies significantly amplify the boom-bust cycles in the housing market (Ng & Feng, 2016).

In the labour market, collateral constraints also affect employment and wage dynamics. When housing prices fall, constrained households reduce consumption, reducing aggregate demand and leading to job losses. Households with high mortgage debt experience larger employment declines, as seen in U.S. county-level data from the 2008 crisis, where employment fell by 3.5% more in highly leveraged areas than in low-leverage ones (Mian & Sufi, 2014).

The Zero Lower Bound (ZLB) poses severe challenges to monetary policy by constraining central banks' ability to lower nominal interest rates during economic downturns. At the ZLB, financial frictions such as collateral constraints become binding more often, amplifying negative shocks and creating nonlinear economic dynamics. Guerrieri & Iacoviello (2015) demonstrate that at the ZLB, the recessionary effects of negative wealth shocks (e.g., falling housing prices) are 1.5 to 2 times larger than the expansionary effects of positive shocks, because interest rate policy cannot offset the impact of asset depreciation by lowering interest rates further, whereas during booms, monetary easing amplifies positive shocks.

During the 2008–2015 period, several major economies—including the U.S., Eurozone, and Japan—faced prolonged ZLB constraints. Empirical estimates suggest that had the Federal Reserve been able to reduce rates below zero, U.S. GDP could have been 2% higher during 2010–2012 (Eggertsson & Krugman, 2012; Fed, 2015).

These two types of constraints form an accelerating mechanism. Collateral constraints further intensify ZLB effects by preventing households from borrowing to smooth consumption. This was evident during the Eurozone debt crisis, where high household debt levels in Spain and Ireland led to larger contractions in demand despite aggressive monetary easing (ECB, 2015; Mian et al., 2017).

2.4.2 Occasionally Binding Constraints and Nonlinear Dynamics

Collateral constraints and ZLB constraints are often "occasionally binding," meaning they are only active during specific economic conditions, such as recessions or periods of housing market crisis. This feature introduces nonlinearities into macroeconomic models and contributes to asymmetries in economic dynamics.

Guerrieri and Iacoviello (2017) show that when constraints bind, negative shocks to housing prices disproportionately reduce consumption and output compared to the relatively muted effects of positive shocks. This dynamic amplifies economic volatility and highlights the importance of modelling these nonlinear effects. Recent advances in DSGE modeling incorporate occasionally binding constraints, showing that these constraints significantly amplify the effects of negative shocks while having minimal impact during positive economic conditions. The presence of binding constraints also creates distributional asymmetries, as low-income households are more affected during recessions. Data from the U.S. Survey of Consumer Finances (SCF) indicate that during the 2008 crisis, households in the bottom 30% of the income distribution reduced consumption by twice as much as the top 10% due to borrowing constraints (Kuhn et al., 2020).

These findings suggest that macroeconomic policies need to account for nonlinear dynamics and countercyclical policies, such as quantitative easing (QE) and targeted fiscal stimulus, are necessary to offset negative shocks. However, they may also have distributional consequences, as wealthier households benefit more from asset price inflation under

QE (Gertler & Karadi, 2011).

2.4.3 Asymmetries in Housing and Labor Markets

Housing and labour markets interact in ways that amplify economic asymmetries, particularly during recessions, due to the interplay of collateral constraints, the ZLB, and financial frictions. During recessions, falling housing prices restrict labour mobility, as homeowners with negative equity are less able to relocate for job opportunities. This effect was particularly pronounced in the U.S. post-2008 housing bust, where mobility rates among highly leveraged homeowners dropped by 30% compared to those with lower debt levels (Ferreira et al., 2013). Credit constraints also reduce business investment and job creation. Kobayashi et al. (2012) find that tightening collateral constraints led to a 15% drop in firm borrowing and a 10% decline in employment in Japan during the 1990s. These effects were strongest for small and medium-sized enterprises (SMEs), which rely more on collateralized lending.

While existing research provides valuable insights, several gaps remain. Housing and labour markets are often modelled in isolation, ignoring their dynamic interactions. Future research should explore how shocks in one market spill over into the other, particularly in the presence of collateral constraints and the ZLB. In addition, most models assume representative households, overlooking heterogeneity in household responses. Low-income households are more likely to be credit-constrained, yet their differential response to monetary policy remains underexplored.

2.4.4 Data Considerations

The empirical literature has identified several critical dimensions through which financial constraints shape macroeconomic dynamics. Lamont (1997) demonstrates that firms facing financing frictions exhibit heightened sensitivity of investment to cash flow fluctuations, highlighting the role of external financing costs in amplifying business cycle volatility. At the household level, Mian and Sufi (2014) show that regions with elevated mortgage debt experience sharper consumption declines during recessions, underscoring the destabilizing effects of collateral-driven liquidity constraints. Bank-centric studies, such as Khwaja and Mian (2008), reveal that liquidity shocks disproportionately reduce credit supply to small firms, exacerbating employment and output contractions. Further, Gilchrist and Zakrajšek (2012) establish the predictive power of credit spreads for macroeconomic downturns, providing direct evidence of financial accelerator mechanisms. Housing market analyses, including Justiniano et al. (2019), link mortgage supply expansions to unsustainable housing booms, while Reinhart and Rogoff (2009) document prolonged post-crisis recoveries tied to private-sector deleveraging.

While these studies robustly characterize financial constraints through reduced-form empirical approaches, they face limitations in disentangling endogenous feedback loops and structural mechanisms. This is where DSGE models offer distinct advantages: by embedding micro-founded financial frictions, such as Bernanke et al.'s (1999) financial accelerator, Iacoviello's (2005) collateral constraints, and Gertler and Kiyotaki's (2010) banking sector linkages, they unify these empirical insights into a dynamic framework. Such models quantitatively replicate how idiosyncratic shocks propagate via credit channels, simulate nonlinear interactions between asset prices and leverage, and evaluate counterfactual policy scenarios (e.g., macroprudential regulations).

Mian & Sufi (2014) empirically examine the relationship between household debt (particularly mortgage debt) and employment declines during the 2008 financial crisis. Using U.S. county-level data, they demonstrate that regions with higher household leverage experienced significantly larger employment contractions. They use pre-crisis housing price growth (2002–2006) as an instrument for household debt accumulation, addressing endogeneity between debt levels and economic outcomes. This isolates the causal effect of debt overhangs on employment, showing that a 10% increase in household debt-to-income ratios led to a 3.5% larger decline in employment during the crisis. Mian & Sufi's reduced-form approach captures correlations but cannot model threshold effects (e.g., when falling asset prices trigger binding collateral constraints). A DSGE model can explicitly incorporates occasionally binding constraints and captures asymmetric responses. Additionally, county-level data show associations but lack structural mechanisms, e.g., how debt reductions affect firm investment or labour demand. A DSGE framework can model financial accelerator effects and simulate how a housing price drop amplifies unemployment via constrained household spending and firm behaviours.

Additionally, to address the gap in the literature on the impact of financial constraints in the DSGE framework, it would be also beneficial to expand the discussion of the empirical role of financial frictions in policy transmission. Specifically, this could involve a more detailed exploration of how credit rationing, loan-to-value (LTV) ratios, or debt-to-income (DTI) limits affect the household's ability to adjust to changes in monetary policy. For example, Bridges and Thomas (2012) showed that QE led to significant declines in mortgage rates but did not relax credit standards for high-LTV or low-income borrowers, which would be valuable in showcasing real-world implications.

Chapter 3 attempts to leverage pandemic-era aggregated data to further strengthen the argument for understanding the distributional effects of unconventional monetary policies in times of economic stress. The pandemic-era policies (e.g., LSAPs, fiscal transfers), which included extreme interest rate cuts and massive liquidity injections, compressed policy rates to the ZLB and altering traditional transmission channels and significantly influenced housing and equity prices, creating a renewed focus on the effects of monetary policy on inequality and the housing market. The COVID-19 pandemic created a unique experiment to study macroeconomic dynamics under extreme policy interventions, particularly the interplay between borrowing constraints and the zero lower bound (ZLB) of interest rates. New Zealand's post-pandemic landscape also offers a unique empirical laboratory for this purpose. As a small open economy operating at the ZLB during the crisis, the Reserve Bank of New Zealand (RBNZ) faced dual challenges: sustaining monetary stimulus while deploying macroprudential tools (e.g., temporary LTV ratio adjustments) to mitigate housing market distortions. Concurrently, fiscal transfers (e.g., wage subsidies) interacted with household balance sheets constrained by debt-to-income limits, creating a tension between liquidity support and financial stability. New Zealand witnessed behavioural shifts from standard models: elevated savings rates coexisted with surging mortgage borrowing, as households exploited low rates near the ZLB to refinance debt or invest in housing. By leveraging New Zealand's institutional setting, here data capture real adjustments to borrowing constraints alongside ZLB-driven rate policies, this study explores how such dual frictions reshape consumption, and asset price dynamics. Such insights not only stress-test DSGE models' capacity to capture nonlinear policy effects but also highlight monetary policy effectiveness in post-crisis recoveries.

2.5 Implications for Subsequent Chapters

This chapter has provided a comprehensive review of the existing literature, highlighting key insights into the relationship between monetary policy, housing markets, and borrowing constraints. It has emphasized the nonlinear dynamics and asymmetries introduced by collateral constraints and the Zero Lower Bound (ZLB). The review has revealed several research gaps that the subsequent chapters aim to address, particularly in terms of financial frictions, the role of unconventional monetary policy (e.g., quantitative easing), and the complex interactions between housing and labour markets.

1. Traditional monetary policy models, such as the Taylor Rule, often assume closed economies with predictable links between interest rates and inflation. However, the literature has largely overlooked the complexities of monetary transmission in small open economies (SOEs), where exchange rate fluctuations, capital flows, and external

shocks significantly influence domestic financial conditions. The next chapters will address this gap by focusing on New Zealand as a representative SOE, where external shocks and financial market frictions are modelled explicitly. This open economy framework will incorporate collateral constraints and the ZLB and international bond markets to quantify the transmission efficiency of QE policies under exchange rate dynamics.

2. Existing studies often isolate housing or labour markets, overlooking bidirectional feedback loops formed via collateral constraints, wealth effects, and search-and-matching frictions. For example, how falling housing prices suppress consumption via collateral devaluation (demand side) while rising unemployment exacerbates mortgage default risks via income loss (supply side). Chapter 4 introduces the integration of search-and-matching models with collateral constraints, revealing a spiral deterioration path ("housing price decline → rising unemployment → credit contraction → further price decline").

3. Mainstream literature emphasizes QE's impact on bank lending but overlooks its asymmetric wealth effects in housing markets. Asset-rich savers benefit disproportionately from QE-driven price appreciation, whereas credit-constrained borrowers face persistent liquidity challenges, exacerbating wealth inequality. Chapter 3 introduces heterogeneous households (patient savers vs. impatient borrowers) and models portfolio rebalancing channels to capture these dynamics. By leveraging post-pandemic data from New Zealand's LSAP program (2020–2022), the analysis quantifies how QE amplifies wealth disparities, directly linking monetary stimulus to distributional outcomes. In this way, Chapter 3 empirically evaluates the "stability vs. equity" policy trade-offs. QE stabilizes financial markets and supports aggregate demand by lowering mortgage rates and boosting housing prices, preventing deeper recessions. But, by disproportionately benefiting asset holders, QE widens wealth

gaps. Households unable to participate in housing market gains, due to LTV constraints or low savings, see relative declines in net worth, undermining social equity.

4. Existing literature predominantly examines labour market impacts through the lens of firm-side financial constraints, focusing on how credit tightening reduces firms' investment and job creation (labour demand channel). However, this overlooks critical household-side transmission mechanisms—specifically, how housing market fluctuations influence labour supply decisions via wealth effects and collateral constraints. Rising housing prices enhance homeowners' net worth, weakening their incentive to accept low-wage jobs and strengthening wage bargaining power, while falling prices can trigger financial distress, forcing households to liquidate assets or prioritize debt repayment over consumption, thereby suppressing aggregate demand and slowing job creation. When housing prices fall, borrowing constraints tighten non-linearly, disproportionately impacting low-income and highly leveraged households, further deepening recessions and increasing labour market volatility. To address this gap, Chapter 4 integrates housing-wealth-driven labour supply adjustments into a DSGE model with search-and-matching frictions. The model explicitly links housing price dynamics to both wage bargaining (demand side) and labour participation (supply side). On the demand side, firms' hiring decisions are also influenced by aggregate demand shocks propagated through housing-driven consumption changes, while, on the supply side, households adjust labour supply based on housing wealth, mortgage debt burdens, and liquidity constraints—a mechanism absent in traditional firm-centric models.

Chapters 3 and 4 directly address the research gaps identified in this literature review. These chapters build on existing models by incorporating more complex dynamics of financial frictions and collateral constraints, focusing on their impact on housing markets and the labour market. The empirical analysis in Chapter 3 will integrate pandemic-era

Chapter	Core Features	Addressed Gaps
Chapter 3	Open-economy DSGE model; heterogeneous households; QE's portfolio rebalancing channel	Policy effects in small open economies under the ZLB; distributive impacts of QE on housing markets
Chapter 4	Search-and-matching frictions; dual occasionally binding constraints (collateral + ZLB)	Bidirectional housing-unemployment feedback loops; nonlinear dynamics under extreme shocks

Table 2.1 – Core Features and Addressed Gaps by Chapters

data, which allows for a timely assessment of how monetary policy responses—particularly QE—affected the housing market during periods of economic crisis and low interest rates. Chapter 3 models QE within an open economy context, emphasizing how it influences housing prices and credit availability, while Chapter 4 extends this analysis to the labour market, demonstrating how collateral constraints influence wage setting and job creation. Both chapters emphasize heterogeneity in household responses, offering a richer understanding of the distributional effects of monetary policy in times of financial stress.

This thesis emphasizes the critical role of both borrowing constraints and the ZLB in shaping the transmission of monetary policy to housing markets. A key limitation of standard monetary policy models is their assumption of linear financial constraints and continuous policy effectiveness. The DSGE models developed in subsequent chapters will incorporate occasionally binding collateral constraints to capture the nonlinear dynamics and asymmetries discussed in this section. The models will incorporate feedback mechanisms between asset prices, borrowing capacity, and economic activity to replicate the cyclical amplification observed in the real economy. Through its focus on collateral constraints and asymmetric monetary policy effects, this thesis aims to provide a deeper understanding of how these constraints influence the effectiveness of monetary policy, particularly in housing markets marked by cyclical booms and busts. This focus aligns with the work of Iacoviello and Neri (2010), Guerrieri and Iacoviello (2017), and Kiyotaki and Moore (1997), who emphasize the importance of borrowing constraints in understanding macroeconomic fluctuations and the dynamics of housing markets.

Chapter 3

How Quantitative Easing Affects Housing Prices in a Small Open Economy

3.1 Introduction

3.1.1 QE Mechanism and Global Practices

Quantitative Easing (QE) is an unconventional monetary policy tool deployed by central banks to stimulate economies when conventional interest rate adjustments become constrained by the zero lower bound (ZLB). Quantitative easing consists of a series of measures taken by central banks to change the composition and/or scale of their balance sheets. These measures are taken with the specific aim of easing liquidity and credit constraints, especially in situations close to the ZLB, all with the ultimate goal of revitalizing the entire economic system. It involves large-scale purchases of financial assets—primarily government bonds but also corporate debt and mortgage-backed securities (MBS)—to inject liquidity into financial systems, lower long-term interest rates, and incentivize risk-taking among investors. In response to the COVID-19 pandemic and the significant contraction in economic activities in 2020, central banks have taken measures such as lowering interest rates and reintroducing and significantly expanding asset purchase programmes to restore stability to financial markets and stimulate economic growth.

In contrast to open market operations, quantitative easing as an unconventional monetary policy emphasizes the ongoing unidirectional purchase of assets by the central bank. Romer (1992) suggested on the basis of empirical evidence that even when interest rates are close to zero, central banks can still stimulate the economy through large-scale asset purchases. Krugman (1998), in the context of Japan's zero interest rate situation, argued that when nominal interest rates are at zero, central banks can raise inflation expectations by significantly increasing the money supply, which ultimately leads to a further reduction in real interest rates. Nowadays, if the short-term interest rate, which serves as an intermediate target, is constrained at zero, expanding the money supply through quantitative easing is a crucial alternative tool for central banks. In cases where the interest rate transmission mechanism is constrained by the zero lower bound, QE operates through three key channels: the signalling effect, where central banks commit to prolonged accommodative policies to shape inflation expectations; the portfolio rebalancing effect, which reduces the supply of safe assets and drives investors toward riskier assets like equities and real estate; and the fiscal expansion effect, where substituting interest-bearing debt with central bank reserves effectively lowers government borrowing costs (Bernanke et al., 2004; Krugman, 1998).

The signaling effect of quantitative easing (QE) operates on a logic analogous to forward guidance, yet central bank asset purchases exert a more profound influence on market expectations than mere verbal commitments. By engaging in large-scale asset acquisitions, the central bank injects liquidity into financial markets that substantially exceeds the threshold required to maintain zero policy rates. This action signals a credible commitment to sustaining accommodative monetary conditions over an extended horizon, thereby anchoring expectations of persistently low short-term interest rates (Bernanke et al., 2004). The resultant decline in uncertainty regarding future rate paths reduces term premiums embedded in long-term interest rates, compressing the yield curve and enhancing the transmission of monetary stimulus through interest rate channels (Gagnon et al., 2011). Concurrently, the liquidity infusion elevates inflation expectations, mitigating deflationary fears that could otherwise incentivize households and firms to defer consumption and investment expenditures—a phenomenon consistent with the expectations channel outlined in New Keynesian frameworks (Eggertsson and Woodford, 2003).

The portfolio rebalancing mechanism further amplifies QE's efficacy. Central bank purchases directly suppress yields on targeted assets (e.g., government bonds), prompting investors to reallocate capital toward riskier or higher-yielding alternatives due to imperfect substitutability across asset classes (Greenwood and Vayanos, 2014). This rebalancing propagates yield reductions beyond the purchased assets, inducing spillover effects into correlated markets such as corporate debt, equities, and real estate. Krishnamurthy and Vissing-Jorgensen (2011) empirically demonstrate that such cascading yield compression lowers aggregate financing costs, stimulating borrowing and investment activity.

Finally, QE generates quasi-fiscal effects through its operational mechanics. By substituting interest-bearing government debt held by the public with central bank reserves (a form of non-interest-bearing currency), the policy effectively reduces the government's debt-servicing burden. This substitution implicitly replaces explicit taxation with a less visible inflation tax, as the monetary financing of deficits dilutes the real value of nominal liabilities—a dynamic aligning with the fiscal theory of the price level (Leeper, 1991). While distinct from conventional fiscal expansion, this mechanism shares functional equivalence in stimulating aggregate demand, particularly under liquidity trap conditions where traditional fiscal and monetary tools face constraints (Turner, 2015).

The aforementioned transmission channels—signalling, portfolio rebalancing, and quasi-fiscal effects—collectively underpin QE's efficacy in mitigating cyclical debt crises, particularly during deflationary downturns characterized by collapsing asset prices and liquidity shortages. In such episodes, panic-driven cash hoarding by investors and deleveraging by overextended borrowers exacerbate credit market dysfunction, rendering conventional monetary tools ineffective once policy rates approach the zero lower bound (Eggertsson and Krugman, 2012). Here, QE operates as a critical circuit-breaker. By purchasing distressed assets (e.g., government bonds, mortgage-backed securities) directly from private portfolios, central banks inject liquidity that alleviates immediate funding pressures, thereby reducing liquidity premia and stabilizing fire-sale dynamics (Gertler and Karadi, 2011). This intervention interrupts the self-reinforcing cycle of falling asset prices and contracting credit supply—a mechanism akin to the risk-taking channel of monetary policy (Borio and Zhu, 2012).

The liquidity infusion further catalyses credit market normalization through two interrelated pathways. First, by lowering perceived counterparty risk, QE reduces lenders' precautionary demand for cash reserves, incentivizing renewed credit intermediation (Diamond and Rajan, 2011). Second, as investors reallocate injected liquidity into higher-yielding assets, demand for corporate bonds and equities rises, compressing risk premiums and lowering financing costs for non-financial borrowers (Hancock and Passmore, 2011). These dynamics collectively elevate the money multiplier, as banks expand lending in response to improved balance sheets and risk appetite (Bonis et al., 2017). Crucially, when calibrated to offset credit contraction, QE-induced money creation avoids inflationary overhang by matching the velocity of money to real economic slack—a condition formalized in the quantity theory of credit (Werner, 2016).

This dual role of QE—stabilizing financial markets while stimulating aggregate demand—highlights its complementarity to the core transmission channels. For instance, the signalling effect reinforces liquidity injections by anchoring expectations of prolonged accommodative policy, while portfolio rebalancing amplifies the pass-through of lower yields to private borrowing rates. Thus, in debt crises, QE transcends mere liquidity provision; it strategically reflates asset prices, restores credit flows, and reanchors inflation expectations, thereby circumventing the paralysis of traditional monetary frameworks.

The mechanisms through which QE mitigates cyclical debt crises—stabilizing liquidity premia, restoring credit intermediation, and anchoring inflation expectations—also render it effective in addressing exogenous shocks such as the COVID-19 pandemic. While traditional debt crises often stem from endogenous financial imbalances (e.g., excessive leverage or asset bubbles), pandemic-induced crises arise from abrupt external disruptions to economic activity, necessitating distinct policy adaptations. During the 2020 global lockdowns, liquidity evaporated not due to solvency concerns but from unprecedented uncertainty and transaction halts. Central banks, recognizing the systemic risk of frozen markets, deployed QE with unprecedented speed and scope. For instance, the Federal Reserve expanded its balance sheet by $3 trillion within months, purchasing not only Treasuries and MBS but also corporate bonds and commercial paper—a departure from crisis-era programs (Fleming et al., 2022). This targeted intervention prevented a corporate debt market collapse, as evidenced by the rapid narrowing of credit spreads post-announcement (Gilchrist et al., 2021).

Crucially, QE's efficacy during exogenous shocks hinges on its dual role as a liquidity backstop and a confidence-building signal. In pandemic conditions, where fiscal policy faced implementation lags, QE immediately alleviated dollar funding strains via currency swap lines and suppressed volatility in Treasury markets—a prerequisite for fiscal stimulus transmission (Aldasoro et al., 2021). Moreover, by committing to unlimited asset purchases ("whatever it takes" signaling), central banks curtailed deflationary spirals despite output gaps exceeding 2008 levels. Recent studies show that pandemic QE programs reduced 10-year yield volatility by 40% compared to crisis-era interventions, underscoring enhanced credibility of forward guidance (Bernanke, 2020).

However, the unique nature of pandemic-driven recessions also exposed QE's limitations. Unlike cyclical crises, where liquidity injections primarily repair private balance sheets, pandemic QE disproportionately inflated financial asset prices due to collapsed consumption opportunities and pent-up savings (OECD, 2022). This divergence between financial markets and real economy recovery—termed the "K-shaped recovery"—highlights the need for complementary fiscal measures to ensure QE's benefits permeate households and small businesses. Nevertheless, by preventing a pandemic liquidity crisis from morphing into a solvency crisis, QE preserved the monetary transmission mechanism, enabling swift recovery once containment policies eased.

Thus, while QE's core channels remain consistent across crises, its calibration must adapt to shock origins: cyclical crises demand balance sheet repair, whereas exogenous shocks require rapid liquidity provision and confidence stabilization. The pandemic experience reaffirms QE's versatility as a crisis tool, albeit with nuanced trade-offs in asset allocation and distributional outcomes.

Globally, QE has been widely adopted since the 2008 financial crisis, though its implementation and outcomes vary significantly across economies. In the United States, the Federal Reserve launched three rounds of QE between 2008 and 2014, purchasing over $4.5 trillion in Treasury bonds and MBS to stabilize collapsing credit markets. These measures succeeded in lowering 10-year Treasury yields by approximately 200 basis points and revitalizing housing markets, with annual home price growth averaging 5–8% post-2009 (Krishnamurthy and Vissing-Jorgensen, 2011). During the COVID-19 pandemic, the Fed further expanded its balance sheet through unlimited asset purchases, including corporate bonds, which contributed to a swift recovery in equity markets but also exacerbated wealth inequality.

In contrast, the Eurozone's QE programs prioritized combating deflationary pressures and stabilizing fragmented financial markets. The European Central Bank (ECB) initiated the Public Sector Purchase Programme (PSPP) in 2015, focusing on sovereign bonds, and later the Pandemic Emergency Purchase Programme (PEPP) in 2020, which included corporate debt. While these efforts lifted core inflation from negative territory to near 2%, their impact on housing markets was uneven. Germany experienced a 40% surge in urban housing prices, whereas Southern European nations saw minimal growth due to weaker economic fundamentals and higher unemployment (ECB, 2021). This divergence underscores how QE's effectiveness is mediated by regional structural factors, such as labor market flexibility and fiscal capacity.

Japan's experience with QE, the longest-running among major economies, highlights both its potential and limitations. The Bank of Japan (BoJ) pioneered QE in 2001 and later introduced yield curve control (YCC) in 2016, targeting a 0% yield on 10-year government bonds. While these policies failed to achieve sustained inflation, they fueled significant asset price inflation, particularly in Tokyo's real estate market, where prices rose by over 50% between 2013 and 2020 (Bank of Japan, 2020). However, rural areas stagnated, reflecting the challenges of transmitting liquidity to structurally weaker regions.

The following table presents a comparative analysis of quantitative easing (QE) policies across three major economies: the United States, the Eurozone, and Japan, highlighting key dimensions such as asset types, policy objectives, housing market responses, and associated side effects.

These cross-country comparisons reveal critical lessons for small open economies like New Zealand. First, QE's transmission hinges on financial market depth and capital mobility. In less diversified economies, liquidity injections disproportionately inflate housing markets due to limited alternative investment avenues. Second, exchange rate dynamics play a pivotal role: aggressive QE in a small economy can attract speculative capital inflows, further amplifying housing demand. New Zealand's Large-Scale Asset Purchase (LSAP) program, which targeted NZ$100 billion in government bonds by 2022, succeeded in flattening the yield curve but also contributed to a 30% annual surge in housing prices by 2021—a response more pronounced than in larger economies (REINZ, 2021). This underscores the unique vulnerabilities of small open economies, where housing supply in-

Dimensions	United States	Eurozone	Japan
Primary Asset Types	Government Bonds, MBS, Corporate Bonds	Sovereign Bonds, Corporate Bonds	Government Bonds, ETFs, REITs
Policy Objectives	Restore Credit Markets, Stimulate Consumption	Curb Deflation, Stabilize Eurozone Finance	End Deflation, Boost Inflation Expectations
Housing Price Response	Broad Increase, Regional Balance	Core Countries Overheated, Periphery Sluggish	Urban Bubble Formation, Rural Stagnation
Side Effects	Increased Wealth Inequality	Accumulated Sovereign Debt Risks	Over-expansion of Central Bank Balance Sheet

Note: MBS = Mortgage-Backed Securities; ETFs = Exchange-Traded Funds; REITs = Real Estate Investment Trusts.

elasticity and reliance on foreign capital magnify QE's side effects.

3.1.2 Background: New Zealand's LSAP Policy and Pandemic Shock

The COVID-19 pandemic triggered an unprecedented contraction in New Zealand's economy, reflecting its vulnerability as a small open economy heavily reliant on trade and tourism. In the second quarter of 2020, real GDP contracted by 12.2% year-on-year—the steepest decline since 1955—while unemployment peaked at 5.3% in Q3 2020 (Statistics New Zealand, 2020). The collapse of international tourism (contributing 5.6% to pre-pandemic GDP) and disruptions to global supply chains exacerbated the downturn, necessitating swift monetary intervention to stabilize financial markets and restore confidence.

In March 2020, the Reserve Bank of New Zealand (RBNZ) launched its Large-Scale Asset Purchase (LSAP) program, initially targeting NZ$30 billion government bond purchases to lower long-term yield and flatten the yield curve. By November 2020, the program was expanded to NZ$100 billion, extending through June 2022, with cumulative purchases reaching NZ$53 billion (62% of the RBNZ's total assets) by August 2021 (RBNZ, 2022). The LSAP was complemented by the Bond Market Liquidity Support (BMLS) scheme, which included repurchases of maturing bonds and purchases of local government debt to alleviate municipal funding stress. These measures succeeded in reducing 10-year government bond yields by approximately 150 basis points, while the Official Cash Rate (OCR) was maintained at 0.25% to anchor short-term rates.

The LSAP's operational mechanics involved financing bond purchases through expansions in banking sector settlement balances, which surged from NZ$ 8 billion pre-pandemic to NZ$ 20-25 billion by mid-2020 (Figure 3.1). This liquidity injection, primarily channelled through open market operations and LSAP-driven balance sheet expansion, aimed to mitigate liquidity premia and restore market functioning. As shown in Figure 3.2, LSAP purchases dominated the RBNZ's asset composition post-2020, underscoring its centrality in pandemic-era monetary policy.

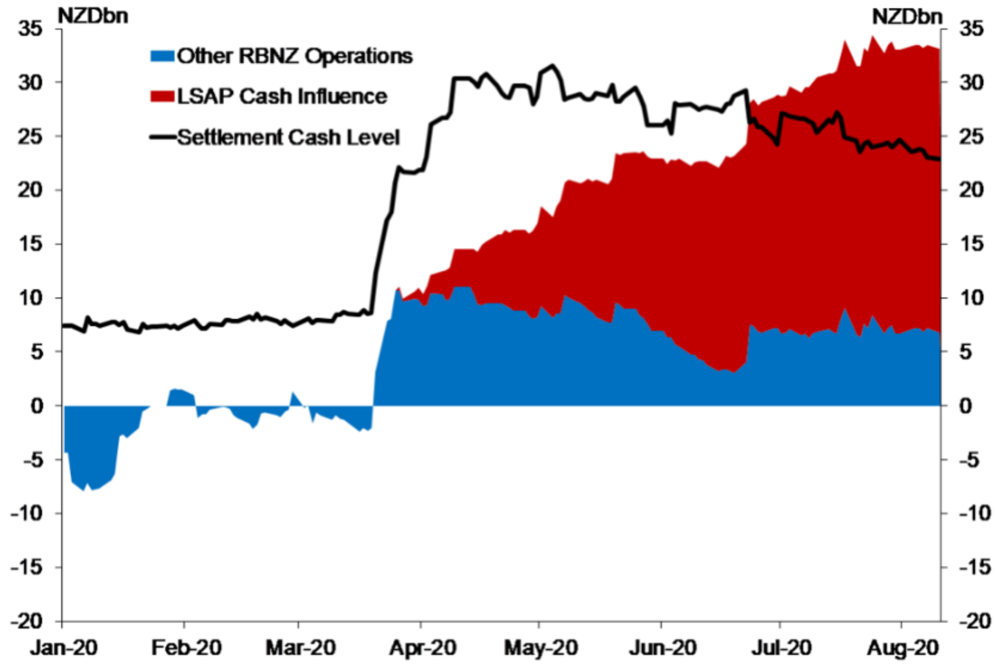


Figure 3.1 – Settlement Cash Level and the Influences

Note: Other RBNZ operations include open market operations and the term auction facility.

Source: Reserve Bank of New Zealand

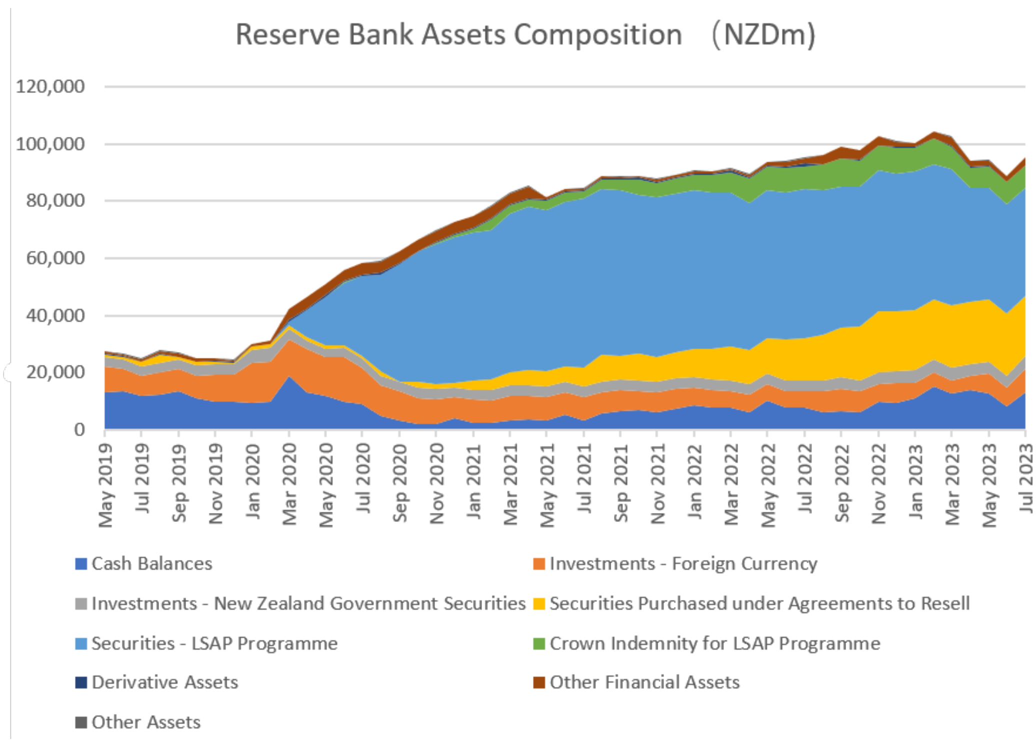


Figure 3.2 – Reserve Bank Assets Composition

Source: Author's calculation on data from the Reserve Bank statistical release.

While the LSAP stabilized financial markets, its unintended consequences manifested acutely in the housing sector. Between June 2020 and June 2021, national median house prices surged by 30.1%, with Auckland—New Zealand's largest city—recording a 35% increase (REINZ, 2021). This escalation reflected portfolio rebalancing effects: investors diverted funds from low-yielding bonds to real estate, amplified by structural supply rigidities (annual housing completions accounted for merely 1.5% of the existing stock). By 2021, housing assets constituted 63% of household wealth, rendering financial stability highly sensitive to price volatility (RBNZ Financial Stability Report, 2021). The RBNZ responded by reintroducing loan-to-value ratio (LTV) restrictions and signalling future rate hikes, yet the delayed transmission of these measures highlighted the challenges of calibrating QE in asset price-sensitive economies.

New Zealand's experience underscores unique QE transmission mechanisms in open economies:

Exchange Rate Channel: LSAP-induced yield compression initially weakened the New Zealand dollar (NZD), with the trade-weighted index falling 6% in 2020. However, foreign demand for safe-haven assets partially offset depreciation pressures, creating bidirectional exchange rate volatility.

Capital Flow Sensitivity: As a price-taker in global markets, New Zealand's long-term yields exhibited heightened sensitivity to external shocks. For instance, a 50-basis-point rise in US 10-year Treasury yields in 2020 drove a 35-basis-point increase in domestic yields (IMF, 2021).

Policy Trade-offs: Reliance on QE over conventional rate tools emerged from limited exchange rate autonomy, as currency depreciation risks conflicted with import-driven inflation objectives.

While QE has been widely adopted globally, its effects in small open economies like New Zealand—characterized by housing-dominated wealth structures and volatile capital flows—remain underexplored. The country's post-pandemic trajectory, marked by a 30% housing price surge and complex policy trade-offs, offers critical insights into how structural idiosyncrasies mediate unconventional monetary transmission.

3.1.3 Research Objectives

This chapter constructs a dynamic framework to analyse how central bank interventions through large-scale asset purchases (LSAPs) propagate to housing markets via portfolio rebalancing mechanisms, with a specific focus on small open economies. Building upon the theoretical foundations outlined in Sections 3.1.1 and the empirical evidence from New Zealand's LSAP experience detailed in Section 3.1.2, our model emphasizes the central bank's capacity to influence real economic outcomes by altering private investors' portfolio compositions. A critical assumption underpinning this transmission mechanism is imperfect substitutability across asset classes, a phenomenon empirically validated in major economies by studies such as Krishnamurthy and Vissing-Jorgensen (2011) and Greenwood and Vayanos (2014). Their studies have shown that unconventional monetary policy tools affect long-term bond yields and prices of other assets through portfolio rebalancing. While prior literature has extensively examined QE's effects on government bond yields, corporate credit spreads, equity valuations, and inflation expectations, this chapter addresses a notable gap by investigating its impact on housing prices—a channel underscored by New Zealand's unprecedented 30% housing price surge following LSAP implementation during the COVID-19 pandemic.

A key empirically methodological challenge lies in disentangling LSAP effects from concurrent monetary policy tools, particularly conventional interest rate adjustments. As Swanson (2021) notes, overlapping policy instruments often create synergistic effects, complicating causal attribution. For instance, while lower policy rates inherently stimulate asset price inflation (Iacoviello and Neri, 2010), the unique contribution of LSAPs remains contested. Ryczkowski (2019) identifies a structural break in the relationship between QE and U.S. housing markets post-2008, with LSAPs emerging as a dominant driver of price dynamics. The crucial question remains whether the recent surge in asset price inflation is primarily due to lower interest rates alone or whether LSAPs are also contributing to this trend. To address this problem, our analysis employs a Dynamic Stochastic General Equilibrium (DSGE) model calibrated to New Zealand data, providing a theoretical explanation for the LSAP-specific impacts on housing prices.

In this chapter, the model incorporates portfolio adjustment frictions to capture how central bank bond purchases distort relative asset returns, thereby inducing private sector reallocations toward housing. Crucially, the open-economy dimension introduces additional transmission channels absent in closed-economy frameworks. Domestic LSAPs alter yield differentials between local and foreign bonds, triggering capital flows that interact with exchange rate dynamics and investor behaviours. These cross-border linkages amplify housing market responses through two primary pathways: (1) LSAPs suppress domestic bond yields, reducing the opportunity cost of holding real estate relative to fixed-income assets. This incentivizes local investors—particularly in supply-constrained markets—to reallocate portfolios toward housing, driving up demand and prices; (2) While the model abstracts from direct foreign investor participation, domestic monetary policy remains indirectly exposed to global financial conditions. Divergences between domestic and foreign bond yields influence cross-border capital flows, even in the absence of explicit foreign investment in housing. For instance, LSAP-induced declines in domestic yields may prompt outflows as local investors seek higher returns abroad, exerting depreciation pressures on the exchange rate. Exchange rate fluctuations can affect the demand for foreign assets, which in turn influences investors' decisions. Thus, while the analysis focuses on domestic investor behaviours, the open-economy framework acknowledges that external yield benchmarks and exchange rate dynamics implicitly shape domestic housing markets through their effects on financing costs and capital mobility. By integrating these mechanisms, the model elucidates how structural idiosyncrasies—such as housing supply inelasticity and reliance on external financing—exacerbate QE-induced housing inflation in small open economies.

3.1.4 Structure

The remainder of this chapter proceeds as follows:

Section 3.2 establishes an empirical foundation through a Structural Vector Autoregression (SVAR) model, analyzing the dynamic relationships between key macroeconomic variables in New Zealand's pre- and post-pandemic economy. This section empirically identifies stylized facts and transmission channels of unconventional monetary policies, providing critical insights to inform the subsequent theoretical framework.

Section 3.3 delineates the theoretical framework, presenting a small open economy DSGE model with housing and financial market frictions. Building on the empirical patterns uncovered in Section 3.2, the model explicitly incorporates portfolio rebalancing behaviours, imperfect asset substitutability, and open-economy linkages, including exchange rate pass-through and cross-border capital flows.

Section 3.4 details the calibration strategy, drawing on New Zealand's macroeconomic data and financial market parameters. Simulations then quantify the marginal impact of LSAPs on housing prices under varying assumptions about monetary-fiscal interactions and global asset returns.

Section 3.5 synthesizes the quantitative results, comparing model simulations with empirical trends observed in New Zealand's pre- and post-pandemic housing market. Sensitivity analyses explore how outcomes vary with alternative policy designs. The section concludes by discussing policy trade-offs between financial stability and macroeconomic stabilization in open economies.

Section 3.6 summarizes key findings, emphasizing the critical role of structural factors—such as housing supply rigidity and capital mobility—in mediating QE transmission. The analysis underscores the necessity of complementary fiscal and macroprudential measures to mitigate unintended distributional consequences of unconventional monetary policies in small open economies.

3.2 A Structural VAR Model for New Zealand's Economy

This chapter employs a Structural Vector Autoregressive (SVAR) model to analyze New Zealand's macroeconomic dynamics, serving as an empirical foundation for the subsequent DSGE model. The model incorporates six key observables aligned with the DSGE framework: Interest Rates, Monetary Aggregates (M3), House Prices, GDP, CPI, and Exchange

Rate[1]. These variables are selected for their direct relevance to quantitative easing (QE) transmission channels, including liquidity effects, asset price adjustments, and exchange rate pass-through. Interest Rates and M3 work as direct policy instruments, thus, QE operates through liquidity injection (M3) and signalling effects (rates). House Prices and GDP reflect QE's wealth and credit channels. CPI and exchange rates capture inflation spillovers and external sector adjustments.

A substantial body of empirical literature has established the transmission mechanisms of conventional monetary policy through credit markets, financial risk dynamics, and asset price adjustments, predominantly employing VAR frameworks. For instance, seminal studies by Iacoviello (2005) and Iacoviello and Minetti (2008) demonstrate that monetary tightening shocks significantly reduce private sector credit flows and housing prices across OECD economies, a finding corroborated by Monacelli et al. (2007) and Manu et al. (2011) in cross-country analyses. Rigobon and Sack (2004) utilize high-frequency VARs to reveal that accommodative policy shocks elevate equity valuations, as evidenced by persistent increases in the S&P500 index. Several studies have utilized VAR-class models to analyze QE effects across economies. For example, Gagnon et al. (2011) examined U.S. QE during the period of 2008–2010, and its impact on long-term interest rates and output, and Peersman (2011) assessed QE transmission for the same period in the Eurozone, emphasizing bank lending and asset price channels. Very few recent studies using VAR-class models to investigate QE effects during the pandemic, such as, Ntshangase et al. (2023) employ the panel vector autoregressive (PVAR) model to analyze U.S. QE spillovers to non-inflation-targeting emerging markets during COVID-19 from 2000Q1 to 2020Q4.

The standard SVAR model is defined as:

$$A_0 Y_t = \sum_{i=1}^{p} A_i Y_{t-i} + B\varepsilon_t \tag{3.1}$$

[1] I also estimated the SVAR including a commodity price index but this did not have an appreciable effect on the results.

where Y_t is the vector of endogenous variables. A_0 (contemporaneous matrix) and A_i (lagged parameter matrix) govern structural relationships. ε_t represents orthogonal structural shocks, with B diagonalizing shock variances.

Unlike reduced-form VARs, SVARs impose theory-driven restrictions via A_0 to disentangle causal relationships, with variable ordering in the Cholesky decomposition reflecting assumed shock transmission hierarchies. Here, variables are ordered as Interest Rates $\rightarrow$ M3 $\rightarrow$ House Prices $\rightarrow$ GDP $\rightarrow$ CPI $\rightarrow$ Exchange Rate. This ordering aligns with New Zealand's small open economy structure: policy variables (Interest Rates, M3) are prioritized as they are least affected contemporaneously by other shocks (central bank decisions precede market reactions), while real economy variables (GDP, CPI) follow, reflecting delayed adjustments to monetary interventions. Exchange rate is ordered last due to its sensitivity to external shocks in a small open economy.

3.2.1 Data

The analysis uses quarterly New Zealand data split into pre-pandemic (2010Q1–2019Q4) and post-pandemic (2020Q1–2023Q3) periods, with a Chow test confirming a structural break at 2020Q1 (see Figure 3.3).

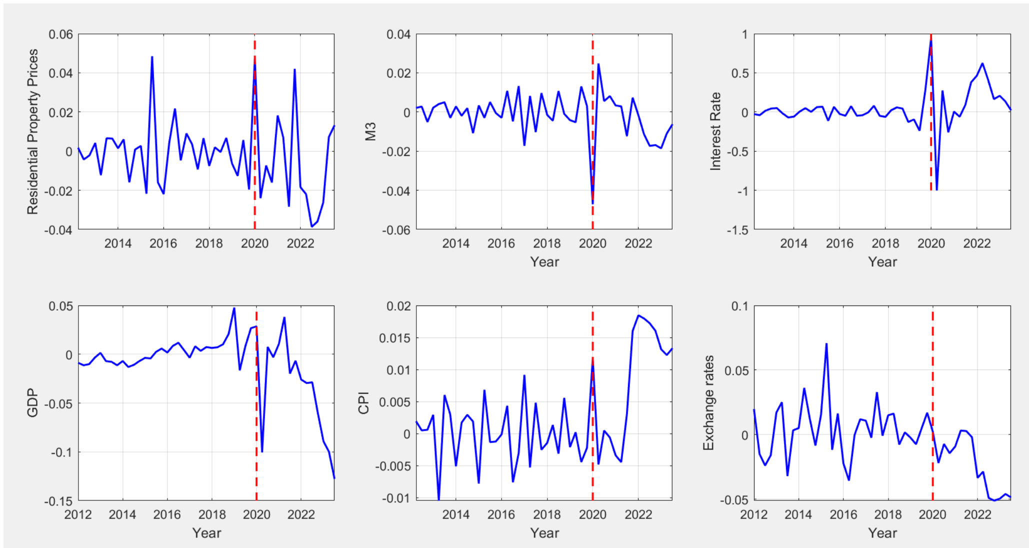


Figure 3.3 – De-trend Time Series and Structural Break

Non-seasonally adjusted series were adjusted via EViews X13, and monthly M3 and exchange rate (Trade Weighted Index) data were aggregated to quarterly averages. All variables were converted to real per capita terms, logged, and detrended using the Hamilton (2018) filter to isolate cyclical components. Due to post-2020 data limitations, the model focuses on six core variables, avoiding overparameterization. Lag selection criteria (AIC, HQIC, BIC) suggested conflicting orders (1 vs. 4 lags); to ensure stability in the shorter post-pandemic sample, 1 lag was adopted, balancing parsimony against the risk of omitted dynamics.

The SVAR estimation leverages the VAR Toolbox 2.0 (Cesa-Bianchi, 2020), which accommodates structural identification via Cholesky decomposition. Results will inform the DSGE model's calibration, particularly the interaction between QE-driven liquidity shocks and housing market dynamics—a critical channel in New Zealand's post-pandemic recovery. Data sources are detailed in Table 1.

Variable	Source	Unit	Code Series
Interest Rates: 3-Month	Fred	New Zealand Dollar	IR3TBB01NZQ156N
Consumer Price Index	Fred	Index Q2 2017=100	NZLCPALTT01IXNBQ
GDP by Expenditure	Fred	New Zealand Dollar	NAEXKP01NZQ189S
Monetary Aggregates M3	Fred	New Zealand Dollar	MABMM301NZM189N
Residential Property Prices	Fred	Index 2010=100	QNZN628BIS
Exchange rates (TWI)	RBNZ	Index, June 1979=100	
Population	RBNZ		

The data sources used in SVAR and DSGE calibration. TWI - Trade Weighted Index.

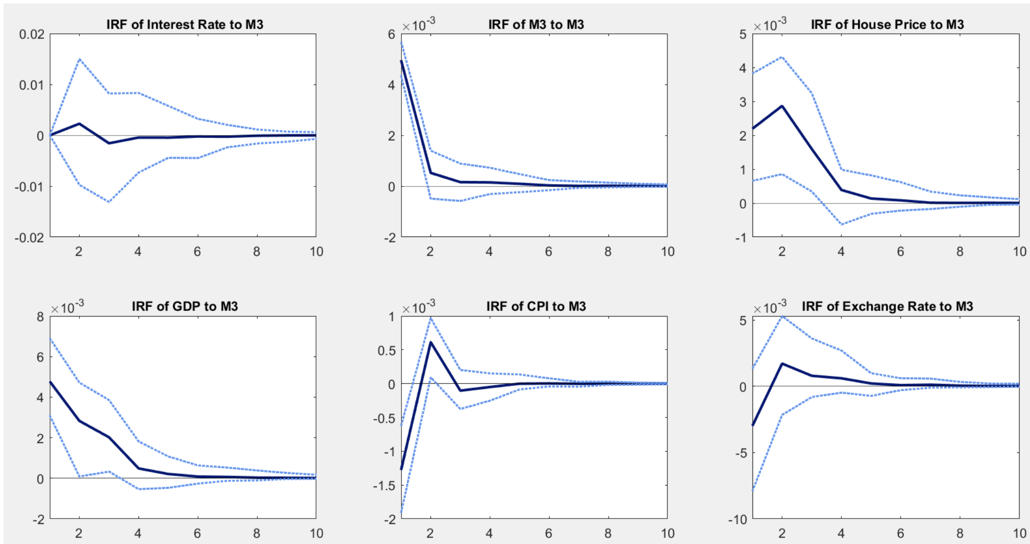
Table 3.1 – Data Sources

3.2.2 Results

The analysis of New Zealand's housing market dynamics before and after the COVID-19 pandemic reveals significant shifts in the roles of unconventional monetary policy (M3) and interest rates, alongside evolving contributions of economic variables to housing price fluctuations.

3.2.2.1 Impacts of M3

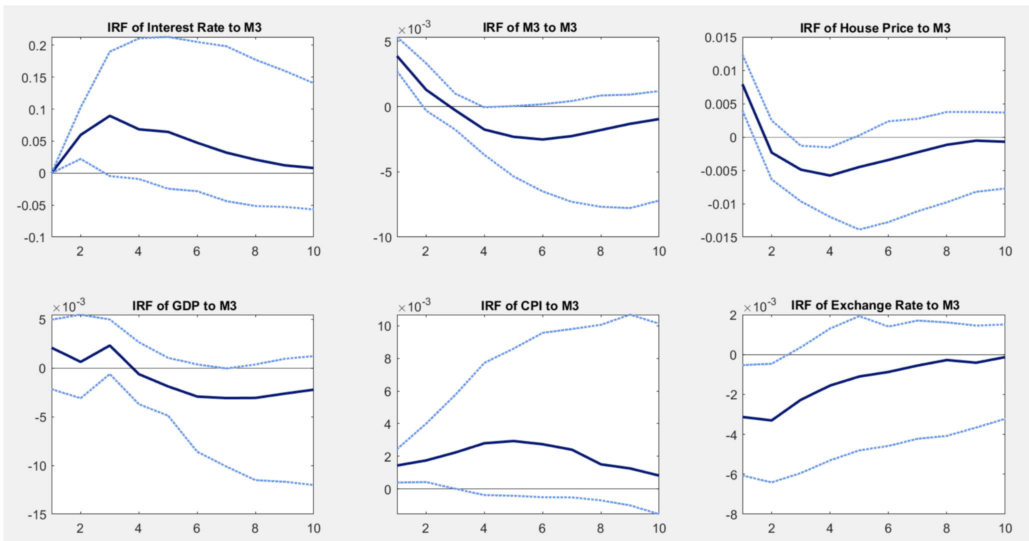
The impulse response functions (IRFs) reveal distinct shifts in New Zealand's macroeconomic dynamics following the COVID-19 pandemic, particularly in the transmission of monetary policy (M3) shocks.



Notes: The above figures show the effects of a one-standard-deviation expansionary shock to broad money supply (M3) in the pre-pandemic period. The data used is quarterly data from New Zealand for the period 2010Q1 to 2019Q4. The dataset is transformed into logged per capita terms, with cyclical components extracted via the Hamilton (2018) filter. The SVAR model with one lag prioritizes the policy rate in the Cholesky ordering. The blue dashed lines represent the 68% confidence intervals.

Figure 3.4 – Impulse Responses to a M3 Shock in the Pre-Pandemic Period

Pre-pandemic (2010–2019), the impact of M3 expansion on interest rates was minimal: a one-standard-deviation M3 shock induced a negligible response in the policy rate, peaking at 0.3% in the second quarter before turning negative by the third quarter. This muted reaction aligns with conventional monetary neutrality theories, where short-term liquidity injections stimulate demand but fail to persistently alter real interest rates due to offsetting supply adjustments and anchored inflation expectations. Housing prices exhibited moderate sensitivity to M3 shocks, rising to a peak of 0.3% before gradually reverting to zero by the ninth quarter, reflecting stable market conditions and balanced supply-demand dynamics. GDP also responded significantly, peaking at 0.47% and declining smoothly, while CPI displayed a short-lived drop (-0.125%) followed by a rebound, which can be explained through a combination of monetary policy transmission lags, expectation dynamics, and supply-side adjustments. In the short run, this liquidity may flow disproportionately into asset markets rather than goods and services, dampening immediate demand-pull inflation. As liquidity permeates the real economy, aggregate demand eventually outpaces supply, driving prices upward. Exchange rate fluctuations were insignificant, likely due to offsetting capital flows in New Zealand's open economy.



Notes: The above figures show the effects of a one-standard-deviation expansionary shock to broad money supply (M3) in the post-pandemic period. The data used is quarterly data from New Zealand for the period 2020Q1 to 2023Q3. The dataset is transformed into logged per capita terms, with cyclical components extracted via the Hamilton (2018) filter. The SVAR model with one lag prioritizes the policy rate in the Cholesky ordering. The blue dashed lines represent the 68% confidence intervals.

Figure 3.5 – Impulse Responses to a M3 Shock in the Post-Pandemic Period

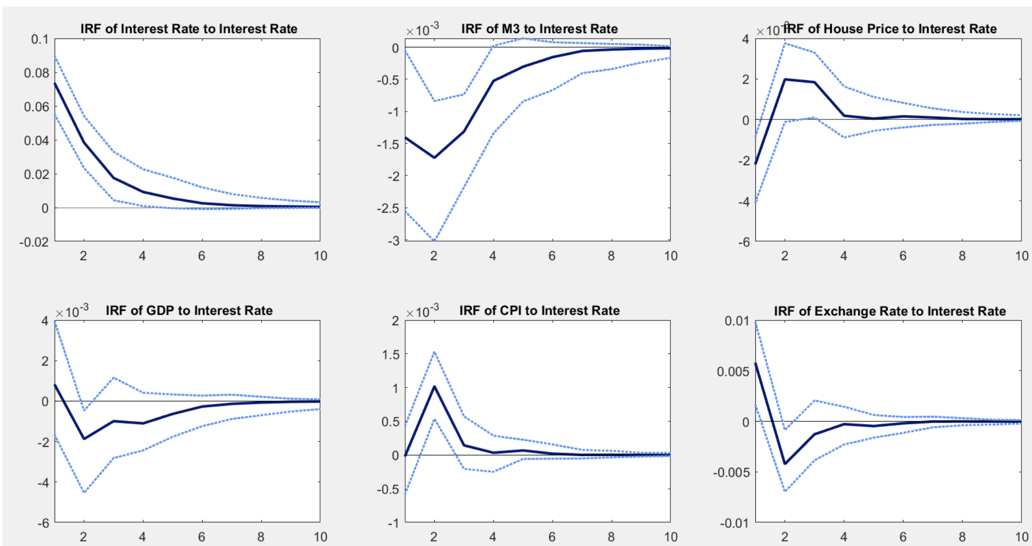
Post-pandemic (2020–2023), unconventional monetary policies—including quantitative easing (QE) and a record-low OCR of 0.25%—fundamentally altered transmission mechanisms. The policy rate exhibited amplified sensitivity to M3 shocks, peaking at 10% in the third quarter before declining gradually. This heightened responsiveness reflects the Reserve Bank of New Zealand's (RBNZ) aggressive liquidity injections, which raised concerns about policy tightening to curb inflation.

Housing price responses to M3 shocks in the post-pandemic period surged sharply to a peak of 0.75%. The heightened responsiveness, reaching a peak more than twice the pre-pandemic magnitude, can be attributed to a confluence of unconventional monetary policies and structural market distortions. First, the Reserve Bank of New Zealand's (RBNZ) large-scale asset purchases (LSAPs) and near-zero official cash rate (OCR) flooded financial markets with liquidity, compressing long-term mortgage rates and fueling speculative demand for housing. Concurrently, pandemic-induced shifts in preferences (e.g., demand for more living spaces) amplified household demand, while supply rigidities—such as material shortages, labour constraints, and regulatory bottlenecks—prevented timely adjustments to housing stock, exacerbating price pressures. The subsequent sharp decline in housing prices, however, reflects the interplay of tightening financial conditions and forward-looking market behaviour. Rising interest rates directly increased mortgage servicing costs, dampening affordability and cooling demand. Additionally, investors anticipating further rate hikes likely accelerated profit-taking, triggering a downward correction in prices. This reversal underscores the fragility of liquidity-driven booms in supply-constrained markets, where even modest rate adjustments can destabilize overleveraged sectors. The asymmetry in responses—sharp initial gains followed by abrupt declines—highlights the dual role of monetary policy in both amplifying and unwinding housing cycles under structural imbalances.

GDP's response weakened significantly (peak: 0.2%), turning negative by the fourth quarter, suggesting diminishing returns to monetary stimulus amid structural constraints like labor shortages. CPI, however, showed persistent upward pressure, rising to 0.18% and remaining elevated (0.1% at the 10th quarter), indicative of entrenched inflation from supply chain disruptions and demand-pull effects. The exchange rate depreciated sharply (-0.3%) post-shock before slowly recovering, aligning with the "liquidity effect" of QE-driven capital outflows, while the delayed appreciation mirrors interest rate differentials under the uncovered interest parity framework.

3.2.2.2 Impacts of Policy Rate

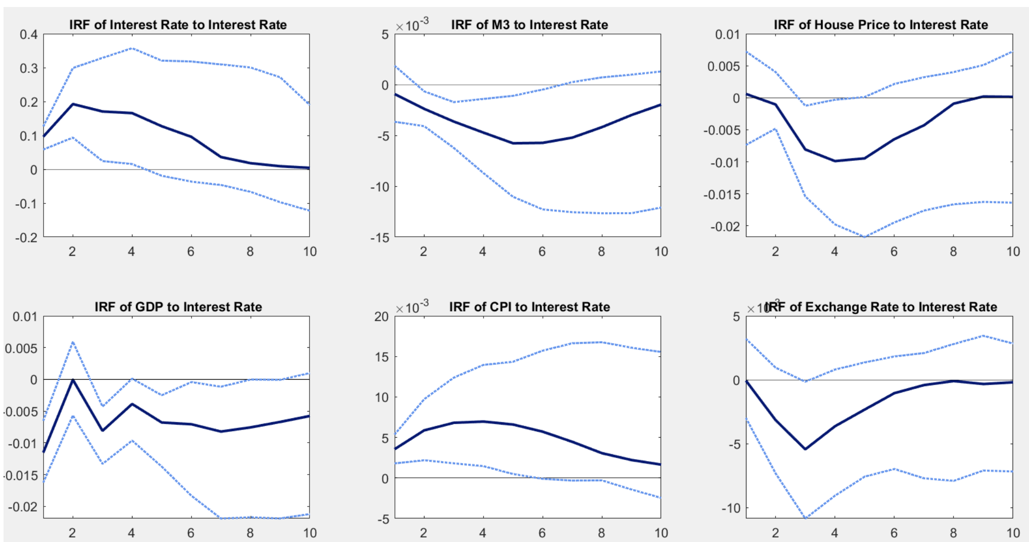
The impulse response functions (IRFs) to a one-standard-deviation policy rate shock reveal distinct shifts in macroeconomic dynamics between pre- and post-pandemic periods in New Zealand.



Notes: The above figures show the effects of a one-standard-deviation expansionary shock to nominal policy rate in the pre-pandemic period. The data used is quarterly data from New Zealand for the period 2010Q1 to 2019Q4. The dataset is transformed into logged per capita terms, with cyclical components extracted via the Hamilton (2018) filter. The SVAR model with one lag prioritizes the policy rate in the Cholesky ordering. The blue dashed lines represent the 68% confidence intervals.

Figure 3.6 – Impulse Responses to a Policy Rate Shock in the Pre-Pandemic Period

Pre-pandemic, M3 exhibited a significant response to rate hikes, peaking at -0.17% within 2 quarters and gradually reverting to zero by the 9th quarter, reflecting conventional monetary transmission through credit channels. Housing prices showed an immediate negative response (-0.2%) but rebounded to +0.2% by the second quarter before slowly declining to zero by the 9th quarter—a pattern consistent with short-term market adjustments and expectations of policy reversals in a low-rate environment (average OCR below 3%). GDP contracted modestly, reaching a trough of -0.2% in the second quarter, with gradual recovery as lower rates stabilized investment and consumption. CPI displayed a lagged positive response (peak +0.1% in the second quarter), which can be explained through a combination of expectation dynamics and cost-push mechanisms. Households and firms, anticipating future price increases, may adjust purchases or adjust pricing strategies, creating short-term demand-pull or cost-push pressures. The exchange rate responded immediately (+0.5%) but reversed sharply, aligning with interest rate parity dynamics as capital flows adjusted to rate differentials.



Notes: The above figures show the effects of a one-standard-deviation expansionary shock to nominal policy rate in the post-pandemic period. The data used is quarterly data from New Zealand for the period 2020Q1 to 2023Q3. The dataset is transformed into logged per capita terms, with cyclical components extracted via the Hamilton (2018) filter. The SVAR model with one lag prioritizes the policy rate in the Cholesky ordering. The blue dashed lines represent the 68% confidence intervals.

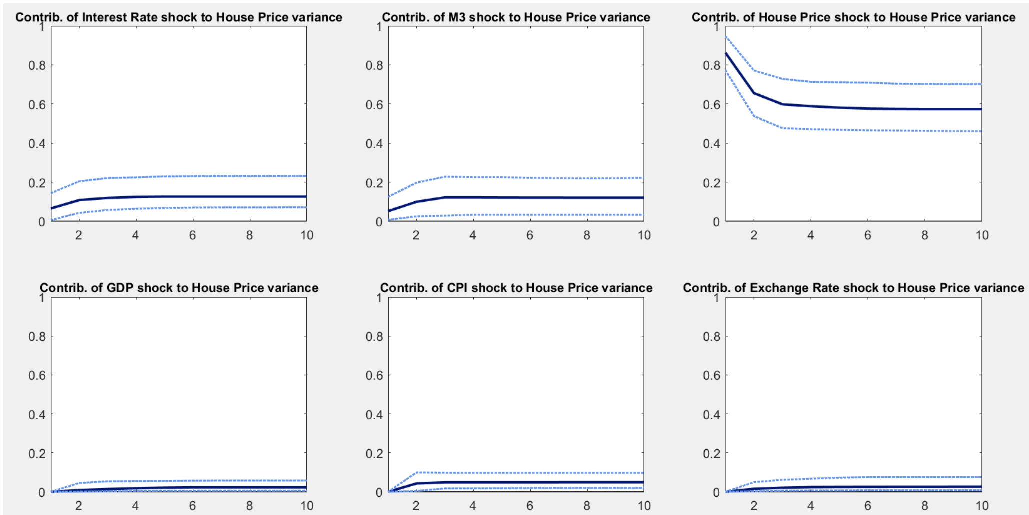
Figure 3.7 – Impulse Responses to a Policy Rate Shock in the Post-Pandemic Period

Post-pandemic, near-zero interest rates (OCR 0.25%) and potential Zero Lower Bound (ZLB) constraints altered transmission mechanisms. M3's response became statistically insignificant, initially dipping to -0.1% and declining further to -0.6% by the 6th quarter. This muted reaction may reflect liquidity trap conditions, where ultra-low rates limit banks' ability to transmit policy shocks via lending. Housing prices exhibited amplified sensitivity, declining persistently to -1% by the 6th quarter, driven by the "financial accelerator" effect: elevated household debt and speculative demand during the low-rate era magnified the impact of tightening. GDP contracted sharply (-1% trough) and remained depressed (-0.5% by the 10th quarter), indicating prolonged demand destruction. Theoretically, it is paradoxical that CPI surged (peak +0.6% in the 4th quarter), but this is potentially due to cost-push inflation from supply-chain disruptions and demand-side panic buying. The exchange rate depreciated (-0.5% trough in the 3rd quarter) before recovering, suggesting delayed confidence effects and speculative positioning in a volatile global rate environment.

These shifts underscore how pandemic-era monetary extremes (ZLB, balance sheet expansion) distorted traditional transmission channels, amplifying asset price volatility while weakening conventional linkages between rates, money supply, and output.

3.2.2.3 Contributions of the shocks to Housing Price Fluctuations

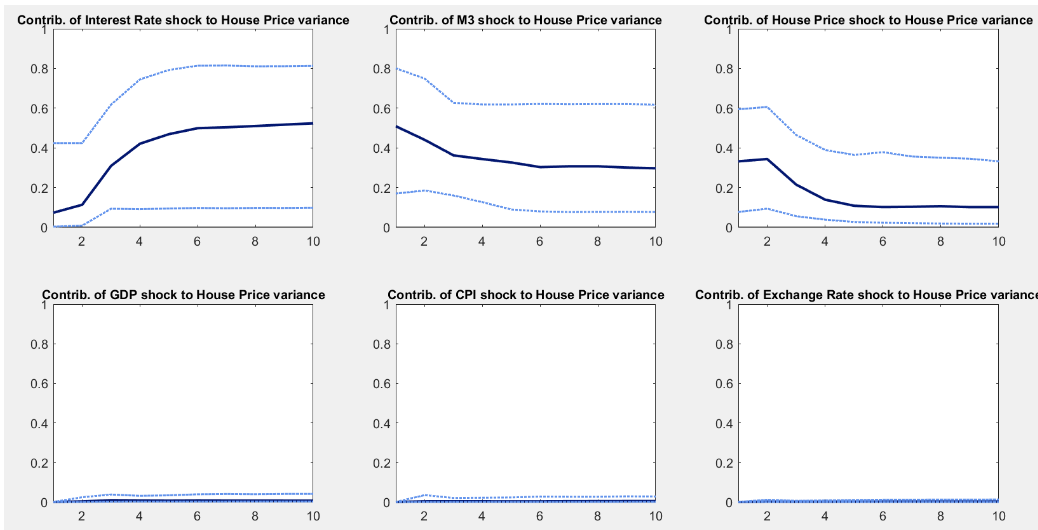
The variance decomposition plots illustrate significant shifts in the relative contributions of structural shocks to house price fluctuations before and after the pandemic, with critical implications for monetary policy transmission and market dynamics.



Notes: The above figures show the contributions of various shocks to housing price variance in the pre-pandemic period. The data used is quarterly data from New Zealand for the period 2010Q1 to 2019Q4. The dataset is transformed into logged per capita terms, with cyclical components extracted via the Hamilton (2018) filter. The SVAR model with one lag prioritizes the policy rate in the Cholesky ordering. The blue dashed lines represent the 68% confidence intervals.

Figure 3.8 – Contributions of Shocks to Housing Price Variance in the Pre-Pandemic Period

Pre-pandemic, the contribution of policy rate shocks to house price variance started at 8% and rose to 14% by the second quarter, remaining stable thereafter. Similarly, M3 shocks increased from 6% to 14% by the third quarter and stabilized. This suggests that both conventional monetary policy (via interest rates) and credit channel effects (via money supply) exerted moderate but persistent influence on housing markets. The gradual rise reflects the delayed impact of rate changes on mortgage affordability and investor expectations in a low-rate environment (average OCR below 3%). House price self-shock contributes 85% initially, then gradually reduced to 60% by the third quarter, dominating long-term variance. Endogenous factors (e.g., speculative bubbles, market sentiment) drove persistent price dynamics, reflecting market inertia. Meanwhile, contributions from GDP (approximately 2%), CPI (approximately 7%), and exchange rate shocks (approximately 2%) were minimal, indicating that macroeconomic fundamentals and external factors played limited roles in housing price dynamics during this period. This aligns with New Zealand's pre-pandemic stability, where housing markets were primarily driven by domestic monetary conditions and endogenous speculation.



Notes: The above figures show the contributions of various shocks to housing price variance in the post-pandemic period. The data used is quarterly data from New Zealand for the period 2020Q1 to 2023Q3. The dataset is transformed into logged per capita terms, with cyclical components extracted via the Hamilton (2018) filter. The SVAR model with one lag prioritizes the policy rate in the Cholesky ordering. The blue dashed lines represent the 68% confidence intervals.

Figure 3.9 – Contributions of Shocks to Housing Price Variance in the Post-Pandemic Period

Post-pandemic, the dominance of monetary policy shocks intensified sharply. The contribution of policy rate shocks surged from 8% to 50% within 5 quarters, overshadowing all other factors. This dramatic rise reflects the heightened sensitivity of housing markets to central bank actions amid near-zero interest rates (OCR 0.25%) and the Zero Lower Bound (ZLB) constraint. With households and investors heavily leveraged during the ultra-low-rate era, even marginal rate hikes disproportionately impacted borrowing costs and speculative demand, amplifying the "financial accelerator" effect. Conversely, M3 shocks declined from 50% to 30%, likely due to the interest rate deviated from the ZLB constraint. Banks' risk aversion and saturated credit demand also weakened the transmission of money supply shocks to housing markets. Contributions from GDP, CPI, and exchange rate shocks remained at around 1%, suggesting that pandemic-era disruptions (e.g., supply-chain bottlenecks, labour shortages) and global volatility were overshadowed by the overwhelming dominance of monetary policy adjustments.

3.2.2.4 Conclusions

The SVAR analysis yields critical insights into the evolving role of monetary policy and structural shifts in macroeconomic transmission mechanisms. The dominance of monetary policy shocks in explaining housing prices surged post-pandemic, reflecting the amplified impact of central bank actions under near-zero interest rates. This underscores the "financial accelerator" mechanism, where tightening disproportionately affects overleveraged sectors, destabilizing liquidity-driven booms. Macroeconomic fundamentals' influences (GDP, CPI, and exchange rate) collapsed post-pandemic, signalling a decoupling of housing markets from traditional macroeconomic drivers. This suggests that pandemic-era distortions—such as supply-chain disruptions, labour shortages, and fiscal stimulus masking underlying demand weakness—overshadowed organic demand-supply interactions. Post-pandemic, while self-shocks of housing prices remained significant, their dominance declined as external monetary shocks gained prominence. This shift indicates that pandemic-era policies exacerbated market fragility, where liquidity injections and abrupt tightening cycles amplified volatility. The asymmetry in housing price responses—sharp initial gains followed by corrections—reveals the risks of supply-constrained markets reliant on speculative capital flows. In conclusion, the pandemic reconfigured New Zealand's housing market into a policy-dominated arena, where central bank actions wield outsized influence but risk amplifying volatility. In the following section, we use a small open economy DSGE model to evaluate these variables in a theoretical model.

3.3 Theoretical Model

Building upon the transmission mechanisms outlined in Section 3.1—particularly the portfolio rebalancing channel and structural idiosyncrasies of small open economies—this section develops a dynamic stochastic general equilibrium (DSGE) framework to analyse how central bank asset purchases propagate to housing markets. The model explicitly integrates heterogeneous households, imperfect asset substitutability, and open-economy linkages, aligning with New Zealand's post-pandemic experience where LSAPs amplified housing price inflation through portfolio reallocation and exchange rate dynamics.

The reactions of households are closely linked to the level of their marginal propensity to consume, which often varies widely due to the considerable heterogeneity of their income and asset holdings. Central to the model is the heterogeneous behaviours of two household types, differentiated by their balance sheet structures and intertemporal optimization constraints:

1. Patient households act as net savers, holding financial assets (domestic and foreign bonds) and deriving income from wages, dividends, and interest payments. Their consumption-smoothing capacity allows them to mitigate income volatility through financial market participation.

2. Impatient households, constrained by limited access to capital markets, rely on foreign debt to finance consumption and housing investment. Their borrowing capacity is tied to housing collateral values, rendering consumption paths sensitive to fluctuations in real estate prices.

Both household types derive utility from non-durable goods, housing services (durable goods), money holding and leisure, while supplying labour to monopolistically competitive firms. Housing serves a dual role: as a consumption good providing direct utility and as a collateralizable asset that facilitates credit market access. This duality introduces a feedback loop between housing valuations, borrowing constraints, and aggregate demand.

Patient households can mitigate income volatility through financial market participation, while impatient households, lacking access to hedging instruments, are more reliant on stable economic conditions and predictable wage income to smooth consumption. Declines in house prices tighten collateral constraints for borrowers, reducing their consumption and investment, while savers adjust portfolios in response to shifts in asset returns, amplifying macroeconomic volatility.

The model's assumption that impatient households exclusively borrow foreign debt (rather than domestic loans) is grounded in both theoretical and empirical considerations, particularly to emphasize the role of exchange rate dynamics and its interaction with collateral constraints. In a small open economy framework, exchange rate fluctuations critically influence domestic asset prices and debt sustainability. By restricting impatient households to foreign debt financing, the model directly captures how exchange rate movements transmit shocks to borrowers' balance sheets. Foreign debt obligations become more burdensome during domestic currency depreciation, tightening collateral constraints and reducing consumption and investment capacity. This mechanism isolates the direct impact of exchange rate volatility on credit-constrained households, avoiding dilution from domestic credit market frictions. Patient households (savers) hold both domestic and foreign bonds, with their portfolio adjustments governed by the interest rate-exchange rate parity (FOCs 3.8 and 3.9). Impatient households' reliance on foreign debt ensures that exchange rate shocks are amplified through their borrowing costs, aligning with the model's focus on open-economy vulnerabilities. Impatient households' collateral (housing) value is directly tied to exchange rate dynamics through foreign debt. For instance, currency depreciation raises the domestic-currency value of foreign debt, tightening collateral constraints and triggering fire-sale pressures on housing. This feedback loop mirrors real-world scenarios in small economies where housing markets are sensitive to external financing conditions. As a small open economy, New Zealand's households and firms rely heavily on foreign financing, with significant exposure to foreign-currency debt (e.g., mortgages linked to offshore funding). During liquidity crunches (e.g., the 2020 pandemic), foreign debt rollover risks exacerbate macroeconomic instability through exchange rate channels. The model captures this by linking impatient households' borrowing constraints to currency movements. These realities validate the model's assumption.

Impatient households, constrained by housing collateral requirements, rely on foreign loans to finance consumption. Fluctuations in house prices directly affect their collateral value, altering borrowing capacity and inducing shifts in current and future consumption patterns, thereby driving aggregate consumption volatility. Spillover effects arise between patient and impatient households through asset market linkages. For instance, patient households' portfolio rebalancing (e.g., shifting from bonds to housing in response to QE) drives up housing demand, which elevates prices and eases collateral constraints for impatient households, further stimulating their consumption.

The model further incorporates a hypothetical banking sector that intermediates credit between households, with loans extended to impatient households contingent on the market value of housing collateral. While the interest rate spread between borrowers and savers is assumed negligible for simplicity, credit frictions arise endogenously from collateral constraints and balance sheet adjustments. Real rigidities, including nominal price and wage stickiness, are embedded to replicate business cycle properties and ensure empirical relevance.

On the production side, the economy features perfectly competitive intermediate goods producers and monopolistically competitive final goods firms. The latter combine domestically produced intermediates and imported products, apply a markup over marginal costs, and set prices subject to Rotemberg-style rigidities, capturing nominal frictions critical for monetary policy transmission.

Monetary policy follows a Taylor-type rule, where the central bank adjusts the policy rate in response to deviations in inflation and output gaps. However, under the zero lower bound (ZLB) constraint—a scenario central to the LSAP analysis—the model allows for unconventional monetary interventions via large-scale asset purchases. These purchases directly alter the composition of the central bank's balance sheet, suppressing long-term bond yields and inducing portfolio rebalancing toward other assets, including housing.

The open-economy dimension introduces additional transmission channels absent in closed-economy frameworks. Domestic LSAPs compress yield differentials between local and foreign bonds, triggering capital flow reversals and exchange rate adjustments. For instance, LSAP-driven declines in domestic yields may incentivize savers to reallocate funds abroad, exerting depreciation pressures on the currency. These dynamics indirectly influence housing demand by altering imported inflation, financing costs for foreign debt, and the relative attractiveness of domestic real estate.

By synthesizing these elements, the model provides a micro-founded structure to quantify LSAP-specific impacts on housing markets, isolating their effects from conventional interest rate tools. Subsequent sections formalize these mechanisms through equilibrium conditions, log-linearized equations, and calibration strategies tailored to New Zealand's macroeconomic landscape.

3.3.1 Population Composition

The total household population is denoted by N. N^p andN^i represent the population sizes of patient and impatient households, respectively. Their corresponding population shares are defined as $n^p \equiv N^p/N$, and $n^i \equiv N^i/N = 1 - n^p$. The composition of the population is assumed to be exogenously determined and remains constant over time. Firms, denoted by the superscript f, are owned exclusively by patient households. Specifically, we assume a one-to-one ownership relationship where each patient household owns one firm. Consequently, the number of firms equals the number of patient households, i.e., $N^f = N^p$.

3.3.2 Patient Household

Both types of households maximize their expected lifetime utility. The utility function of households is defined over a composite consumption c_t, house holdings h_t, real money balances $\frac{M_t^d}{P_t}$ and leisure $l_t = 1 - n_t$ as follows:

$$E_0 \sum_{t=0}^{\infty} \beta^t z_t (\Gamma_c log(c_t - \varepsilon_c c_{t-1}) + j_t \Gamma_h log(h_t - \varepsilon_h h_{t-1}) + \Gamma_m log(\frac{M_t^d}{P_t} - \varepsilon_m \frac{M_{t-1}^d}{P_{t-1}}) - \frac{1}{1+\eta} n_t^{1+\eta}) \tag{3.2}$$

where E_0 denotes the expectation operator, $\beta \in (0,1)$ is the discount factor. c_t is household consumption in period t; h_t is housing stock held by the household in period t; $\frac{M_t^d}{P_t}$ is real money balances (nominal money M_t^d divided by the price level P_t). ε_c is the habit formation parameter for consumption, capturing how past consumption c_{t-1} influences current utility. Higher ε_c means stronger habit formation, reducing the marginal utility of current consumption if past consumption was high. ε_c, ε_h and ε_m capture habits in consumption, house holdings, and money holdings, $\Gamma_c = \frac{1-\varepsilon_c}{1-\beta\varepsilon_c}$, $\Gamma_h = \frac{1-\varepsilon_h}{1-\beta\varepsilon_h}$ and $\Gamma_m = \frac{1-\varepsilon_m}{1-\beta\varepsilon_m}$ are scaling parameters, reflecting the importance of consumption, housing, and liquidity services, relative to other components..

$-\frac{1}{1+\eta} n_t^{1+\eta}$ represents the disutility from labor supply, increasing with n_t at an increasing rate. n_t is labor supplied by the household in period t, η represents the labor supply aversion, which is equal to the inverse of the (Frisch) elasticity of labor supply with respect to the real wage. j_t is an adjustment parameter on housing, allowing for shocks hitting the marginal utility of housing; it also affects the marginal rate of substitution between non-durable and housing consumption. z_t represents a shock to the discount rate, influencing the intertemporal substitution decisions of households.

The Money-in-the-Utility (MIU) specification in this model adopts a quasi-first-difference structure with habit formation in consumption (ε_c), housing (ε_h), and money holdings (ε_m), calibrated to align with empirical studies (Guerrieri and Iacoviello, 2017; Benchimol and

Qureshi, 2020). This structure reflects the empirical observation that households' preferences are influenced by past levels of money balances and consumption (Fuhrer, 2000; Benchimol and Qureshi, 2020; Ireland, 2001). This design serves critical roles in analyzing quantitative easing (QE) effects on housing prices in a small open economy:

Firstly, by embedding real money balances directly into household utility, the MIU framework endogenizes the demand for liquidity services, a key channel through which QE operates. When the central bank expands its balance sheet via LSAPs, (e.g., the RBNZ's $100 billion bond purchases), the resultant surge in settlement balances $\frac{M_t^d}{P_t}$ interacts with household habits (ε_m) to smooth adjustments in money demand. This avoids unrealistic instantaneous portfolio shifts and capital outflows, ensuring gradual rebalancing from bonds to housing assets, a mechanism central to the model's housing price dynamics. This approach could introduce frictions that improve the model's consistency with observed money demand rigidities (Holman, 1998).

Secondly, the MIU specification interacts with nominal rigidities in wage and price setting. Habit-driven inertia in money demand dampens the immediate inflationary impact of QE, allowing the Taylor rule to remain near-ZLB while housing prices surge. This nonlinearity may partly explain why LSAPs in New Zealand elevated housing inflation without triggering proportional CPI inflation.

Lastly, the habit structure in housing holdings reflects households' tendency to maintain stable housing consumption, amplifying the cyclicality of housing demand. For impatient households, whose borrowing capacity is tied to collateral values, rising housing prices relax credit constraints, enabling higher debt-financed consumption. Simultaneously, patient households (savers) optimize intertemporal utility by reallocating QE-induced liquidity from bonds to housing, further driving up housing prices. The habit terms thus amplify the portfolio rebalancing effect emphasized in Krishnamurthy and Vissing-Jorgensen (2011), linking QE to housing price inflation.

Patient households (savers) derive income from wages, housing stock, bond holdings and firm dividends. Their budget constraint is formalized as follows [2]:

$$C_t + q_t H_t + e_t B_t + \frac{D_t}{R_t} + \frac{D^H_{L,t}}{R_{L,t}} + M^d_t + I_t + T_t = \frac{W_t n_t}{x_{w,t}} + q_t H_{t-1} + R^*_{t-1}\phi_{t-1} e_t B_{t-1} + D_{t-1} + \frac{D^H_{L,t-1}}{R_t} + M^d_{t-1} + r_{k,t} K_{t-1} + Div_t \tag{3.3}$$

where incorporates the secondary market for bond trading as in Ljungqvist and Sargent (2004).

Patient households optimize portfolios across two types of zero-coupon domestic bonds (money-market bonds D_t and long-term bonds $D^H_{L,t}$), and foreign bonds (B_t), which are purchased at their nominal price. This setting reflects arbitrage adjusted for exchange rate risk and interest rate differentials. e_t is the exchange rate (units of domestic currency per unit of foreign currency), R^*_t is the world interest rate, R_t is the domestic interest rate, and ϕ_t is an exogenous risk premium on foreign bonds/exchange rate (capturing financial frictions). The agents also allocate their income among consumption (C_t), Housing purchases (H_t), money holding (M^d_t), lump-sum tax (T_t), investment in capital goods (I_t)/accumulation of capital (K_t), which is rented to firms at the rental rate $r_{k,t}$. q_t is the price of housing. They receive rental income $r_{k,t}K_t$, wage income $\frac{W_t n_t}{x_{w,t}}$, where W_t is the nominal wage and $x_{w,t}$ is the wage markup, and dividends from firms (Div_t).

P_t is the aggregate price index of the domestic final good. When P_t is chosen as numeraire, all other prices can be expressed relative to the domestic final good. Divideding

[2] A complete list of equations is in the appendix.

by P_t we get the budget constraint in real terms (i.e. in units of consumption):

$$\frac{C_t}{P_t} + \frac{q_t H_t}{P_t} + \frac{e_t B_t}{P_t} + \frac{D_t}{P_t R_t} + \frac{D^H_{L,t}}{P_t R_{L,t}} + \frac{M^d_t}{P_t} + \frac{I_t}{P_t} + \frac{T_t}{P_t} = \frac{W_t n_t}{x_{w,t} P_t} + \frac{q_t H_{t-1}}{P_t} + R^*_{t-1}\phi_{t-1}\frac{e_t}{P_t}B_{t-1} + \frac{D_{t-1}}{P_t} + \frac{D^H_{L,t-1}}{R_t P_t} + \frac{M^d_{t-1}}{P_t} + \frac{r_{k,t}K_{t-1}}{P_t} + \frac{Div_t}{P_t} \tag{3.4}$$

$$c_t + q_t h_t + b_t + \frac{d_t}{R_t} + \frac{d^H_{L,t}}{R_{L,t}} + m^d_t + i_t + t_t = \frac{w_t n_t}{x_{w,t}} + q_t h_{t-1} + R^*_{t-1}\phi_{t-1}\frac{\Delta e_t}{\pi_t} b_{t-1} + \frac{d_{t-1}}{\pi_t} + \frac{d^H_{L,t-1}}{\pi_t R_t} + m^d_{t-1} + r_{k,t}k_{t-1} + div_t \tag{3.5}$$

where we define $\Delta e_t \equiv \frac{e_t}{e_{t-1}}$, $\pi_t \equiv \frac{P_t}{P_{t-1}}$, $\frac{e_t B_t}{P_t} \equiv b_t$, $\frac{M^d_t}{P_t} \equiv m^d_t$, $\frac{D_t}{P_t} \equiv d_t$ and $\frac{D^H_{L,t-1}}{P_t} \equiv d^H_{L,t-1}$. π_t is the (gross) inflation rate.

Capital accumulation function is

$$k_t = a_t(i_t - \frac{\phi_i}{2}\frac{(i_t - i_{t-1})^2}{\bar{i}}) + (1-\delta_k)k_{t-1} \tag{3.6}$$

where $\bar{i}$ is the steady state of investment, parameter $\phi$is an investment adjustment costs, a_t acts as an investment-specific shock. $0 < \delta_k < 1$ represents the constant depreciation rate of capital stock.

The model distinguishes between two types of domestic zero-coupon government bonds: short-term money-market bonds D_t and long-term bonds $D^H_{L,t}$, with yields R_t and $R_{L,t}$, respectively. Short-term bonds approximate 3-month-maturity instruments, while long-term bonds represent 10-year-maturity claims. To capture secondary market dynamics, the budget constraint integrates bond trading mechanisms following Ljungqvist and Sargent (2004), enabling explicit modelling of assets with differing maturities. On the left-hand side of the constraint, bonds are priced using their respective yields, reflecting risk-free returns known at time t. The right-hand side, however, incorporates secondary market pricing rules, where long-term bonds are valued using the short-term rate R_t. This introduces price risk prior to maturity: agents purchasing long-term bonds at $t-1$ face uncertainty over future gains, as yield rate is unknown ex ante. Crucially, the arbitrage-free pricing condition ensures equivalence between long-term bonds and newly issued short-term bonds at maturity, as both represent identical claims to future consumption.

Market segmentation arises from portfolio adjustment frictions, which impede arbitrage activities that would otherwise equalize returns across maturities. Following Falagiarda (2014) and Harrison (2012), these frictions manifest as transaction costs incurred when reallocating portfolios between short- and long-term bonds. The cost function is specified as:

$$AC_t^L = \left[\frac{\varphi_L}{2}\left(\kappa_L \frac{d_t}{d_L^H} - 1\right)\right]^2 Y_t \tag{3.7}$$

where κ_L denotes the steady-state ratio of long-term to short-term bond holdings, and parameter ϕ_L represents a bond transaction cost. These costs, paid in units of output, vanish in equilibrium but penalize deviations from the steady-state portfolio composition.

Three rationales underpin the inclusion of portfolio frictions:

Liquidity Premium: Long-term bonds are perceived as less liquid, necessitating compensation for reduced liquidity. This aligns with agents demanding additional short-term holdings as a "reserve" against liquidity risk (Krishnamurthy & Vissing-Jorgensen, 2012; Amihud & Mendelson, 1986).

Preferred Habitat Theory: Agents exhibit maturity-specific preferences, as posited by Vayanos and Vila (2009), creating natural demand for distinct bond maturities.

Operational Costs: Frictions proxy resource expenditures on information acquisition or portfolio management, reflecting practical barriers to continuous arbitrage.

By embedding these frictions, the model endogenizes liquidity premia and maturity-specific demand, aligning theoretical insights with empirical observations of segmented bond markets.

At time t, the patient household chooses $\{ c_t, h_t, d_t, d^H_{L,t}, b_t, i_t, m^d_t, n_t \}$ to maximize (3.2) subject to the constraints (3.5) and (3.6) by taking market prices variables $\{ q_t, \pi_t, R_t, R_{L,t}, w_t, x_{w,t}, R^*_t, e_t, r_{k,t} \}$ and an initial condition for the capital stock, k_0, as given. The first-order conditions of the patient household can be expressed as follows:

$$u_{c,t} = \beta E_t \left[u_{c,t+1} R^*_t \phi_t \frac{\Delta e_{t+1}}{\pi_{t+1}} \right] \tag{3.8}$$

$$\beta E_t \left[u_{c,t+1} \frac{1}{\pi_{t+1}} \right] = \frac{u_{c,t}}{R_t} + \frac{u_{c,t} \phi_L \kappa_L Y_t (\kappa_L \frac{d_t}{d^H_{L,t}} - 1)}{R_{L,t}} \tag{3.9}$$

$$u_{c,t} \left(\frac{1}{R_{L,t}} + \frac{\phi_L Y_t (\kappa_L \frac{d_t}{d^H_{L,t}} - 1)^2}{2R_{L,t}} - \frac{\kappa_L \phi_L Y_t d_t (\kappa_L \frac{d_t}{d^H_{L,t}} - 1)}{d^H_{L,t} R_{L,t}} \right) = \beta E_t \left[u_{c,t+1} \frac{1}{R_{t+1} \pi_{t+1}} \right] \tag{3.10}$$

$$n_t^{\eta} = u_{c,t} \frac{w_t}{x_{w,t}} \tag{3.11}$$

$$q_t u_{c,t} = u_{h,t} + \beta E_t \left[q_{t+1} u_{c,t+1} \right] \tag{3.12}$$

$$u_{c,t} = u_{m,t} + \beta E_t u_{c,t+1} \tag{3.13}$$

These Euler equations govern consumption smoothing across periods for households holding foreign bonds (3.8) and domestic short-term bonds (3.9). The marginal utility of current consumption ($u_{c,t}$) equates to the discounted expected marginal utility of future consumption ($u_{c,t+1}$), adjusted for:

Foreign bonds (3.8): Foreign interest rates (R^*_t), exchange rate dynamics (Δe_t), and financial frictions (ϕ_t).

Domestic bonds (3.9): Domestic short-term rates (R_t) and inflation (π_t), and liquidity premia from portfolio rebalancing costs. This condition introduces quadratic adjustment costs for deviations from the steady-state portfolio composition, captured by the second term on the RHS. These costs penalize imbalances between short-term and long-term bond holdings. The adjustment cost term introduces portfolio rebalancing frictions, requiring a correction to the standard uncovered interest parity (UIP) condition:

$$\frac{1}{R_t^* \phi_t E_t \Delta e_{t+1}} = \frac{1}{R_t} + \frac{\phi_L \kappa_L Y_t (\kappa_L \frac{d_t}{d_{L,t}^H} - 1)}{R_{L,t}} \tag{3.14}$$

The log-linearized form more clearly illustrates the parity between foreign and domestic returns arbitrage:

$$\hat{R}_t^* + \hat{\phi}_t + E_t \Delta \hat{e}_{t+1} = \hat{R}_t - \phi_L \kappa_L \overline{Y} \left(\hat{Y}_t + \kappa_L (\hat{d}_t - \hat{d}_{L,t}^H) - \hat{R}_{L,t} \right) \tag{3.15}$$

where $\overline{Y}$ is the steady-state output. Adjustment costs affect interest rate differentials through $\hat{Y}_t$ and $\hat{d}_t - \hat{d}_{L,t}^H$, leading to UIP deviations. Friction in the long-term bond market further amplifies the premium through $\hat{R}_{L,t}$. UIP no longer holds strictly (perfect arbitrage), as adjustment costs introduce an additional premium. Exchange rate dynamics reflect both interest rate differentials and portfolio friction costs.

This condition (3.10) formalizes the equilibrium for long-term bonds ($d_{L,t}^H$) with yield ($R_{L,t}$). The quadratic adjustment costs and liquidity premia reflect the trade-off between bond maturities and portfolio flexibility. Long-term bonds are less liquid, requiring compensation via higher yields (Andrés et al., 2004). The right-hand side represents the discounted return on short-term bonds, enforcing parity between long- and short-term assets. This formalizes market segmentation and preferred habitat theory (Vayanos and Vila, 2009). Labor supply balances the disutility of work against the real wage, adjusted for labor market rigidities ($x_{w,t}$). The marginal utility cost of housing equals the direct utility plus the discounted resale value. The marginal utility of consumption also equals liquidity benefits plus the discounted future marginal utility of consumption. This captures the opportunity cost of holding money versus interest-bearing assets.

The first-order conditions for capital accumulations are:

$$u_{c,t}q_{k,t}(1-\phi_i\frac{\Delta i_t}{\bar{i}}) = u_{c,t} - \beta E_t(u_{c,t+1}q_{k,t+1}\phi_i\frac{\Delta i_{t+1}}{\bar{i}}) \tag{3.16}$$

$$\frac{u_{c,t}q_{k,t}}{a_t} = \beta E_t(u_{c,t+1}(r_{k,t+1} + q_{k,t+1}\frac{1-\delta_k}{a_{t+1}})) \tag{3.17}$$

where $q_{k,t}$ is the Lagrange multiplier on the capital accumulation constraint. Optimal investment balances current adjustment costs against future cost savings. Higher adjustment costs dampen investment volatility. Equation (3.17) represents the shadow price of capital. The marginal utility cost of capital equals the expected return from capital, comprising rental income and undepreciated value. Investment-specific technology shocks drive fluctuations in capital accumulation.

3.3.3 Impatient Households

Impatient households (denoted by a prime superscript) maximize a utility function similar to that of patient households but do not engage in money holding. This is because impatient households are more financially constrained and prioritize immediate consumption and debt repayment over liquidity management. Consequently, they focus on leveraging their housing assets and consumption to maximize utility, subject to both budget and collateral constraints, rather than maintaining cash balances. Their borrowing capacity is endogenously tied to the market value of housing assets, subject to both budget and collateral constraints. Due to a higher propensity to consume, they exhibit a lower discount factor ($\beta' < \beta$) and borrow exclusively from foreign bond markets. Utility depends on consumption (c'_t), housing (h'_t) and labor disutility (${n'_t}^{1+\eta}$). Habits ($\varepsilon_c, \varepsilon_h$) and shocks ($z_t$) capture persistence in preferences and exogenous disturbances.

$$E_0 \sum_{t=0}^{\infty} \beta'^t z_t (\Gamma'_c log(c'_t - \varepsilon_c c'_{t-1}) + j_t \Gamma'_h log(h'_t - \varepsilon_h h'_{t-1}) - \frac{1}{1+\eta} n_t'^{1+\eta}) \tag{3.18}$$

Impatient households (savers) derive income from wages, housing resale value and rolled-over foreign debt, and allocate their income among consumption, housing purchases, debt repayments, and taxes. Their budget constraint in nominal terms is as follows:

$$C'_t + q_t H'_t + R^*_{t-1} \phi_{t-1} e_t B'_{t-1} + T'_t = \frac{W'_t n'_t}{x'_{w,t}} + q_t H'_{t-1} + e_t B'_t \tag{3.19}$$

Turning it into real terms:

$$c'_t + q_t h'_t + R^*_{t-1} \phi_{t-1} \frac{\Delta e_t}{\pi_t} b'_{t-1} + t'_t = \frac{w'_t n'_t}{x'_{w,t}} + q_t h'_{t-1} + b'_t \tag{3.20}$$

We assume that impatient households face borrowing constraints tied to the value of their house holdings, which limits the amount they can borrow. The nominal borrowing constraint is as follows:

$$R^*_t \phi_t e_{t+1} B'_t \leq (1-\gamma) m_{l,t} E_t \left[P_{t+1} q_{t+1} h'_t \right] + \gamma R^*_{t-1} \phi_{t-1} e_t B'_{t-1} \tag{3.21}$$

where $m_{l,t}$ is the Loan-to-Value (LTV) parameter. Borrowing is capped at a fraction (m) of the expected collateral value. A fraction (γ) of past debt is rolled over, introducing persistence in leverage. Loan financing takes place every period and the impatient household repays in the next period.

Turning it into real terms:

$$R^*_t \phi_t \Delta e_{t+1} b'_t \leq (1-\gamma) m_{l,t} E_t \left[\pi_{t+1} q_{t+1} h'_t \right] + \gamma R^*_{t-1} \phi_{t-1} \frac{\Delta e_t}{\pi_t} b'_{t-1} \tag{3.22}$$

The model incorporates procyclical housing prices q_t through collateral constraints. Rising house prices relax borrowing limits, enabling higher consumption and investment, which amplifies business cycle fluctuations. Procyclical housing prices act as financial accelerators. Portfolio adjustment costs and liquidity premia segment bond markets, aligning with empirical evidence on maturity-specific investor preferences (Vayanos and Vila, 2009). Since the borrowing takes place on the foreign bond market, impatient households expose their debt repayment obligations to fluctuations in the world interest rate and the exchange rate. When the shadow price of the collateral constraint (λ_t), representing the marginal benefit of relaxing borrowing limits, exceeds the marginal utility of current consumption, households increase housing demand to expand collateralizable wealth. This creates a feedback loop: rising housing prices relax borrowing constraints, enabling further credit-driven consumption and investment, thereby amplifying procyclicality in housing markets. The LTV parameter $m_{l,t}$ is assumed exogenous but subject to stochastic shocks, providing a lever for macroprudential regulation. Stabilizing countercyclically could mitigate procyclicality, though its effectiveness depends on coordination with monetary policy to manage exchange rate volatility. These shocks introduce time-varying credit availability, modulating the relationship between housing prices and economic activity.

We differentiate (3.18) subject to (3.20) and (3.22) with respect to $c'_t, h'_t, m_t^{d'}$ and n'_t. The first-order conditions for impatient households are:

$$u_{c',t}(1-\lambda_t R_t^* \phi_t \Delta e_{t+1}) = \beta' E_t[u_{c',t+1} R_t^* \phi_t \frac{\Delta e_{t+1}}{\pi_{t+1}}(1-\gamma\lambda_{t+1})] \tag{3.23}$$

$$n_t'^{\eta} = u_{c',t} \frac{w'_t}{x'_{w,t}} \tag{3.24}$$

$$q_t u_{c',t} = u_{h',t} + \beta' E_t[u_{c',t+1} q_{t+1}] + \lambda_t u_{c',t}(1-\gamma) m_{l,t} E_t[q_{t+1}\pi_{t+1}] \tag{3.25}$$

where λ_t is the Lagrange multiplier associated to the borrowing constraint.

This Euler equation (3.23) governs intertemporal consumption for borrowers. The marginal utility of current consumption equals the discounted expected marginal utility of future consumption, adjusted for: foreign interest costs ($R_t^* \phi_t \Delta e_{t+1}$), collateral constraint shadow price (λ_t) and partial debt repayment. Labor supply is determined by equating the marginal disutility of labour to the marginal utility of real wage income, adjusted for labour market frictions. Housing demand balances direct utility, future resale value and collateral value. The last term on the right-hand side of Equation (3.25) reflects the marginal benefit of relaxed borrowing constraints due to higher housing values.

3.3.4 Final Goods Producers

The final goods sector operates under perfect competition, combining domestically produced intermediates (Y_t^h) and imported goods (Y_t^f) into a composite consumption good (Y_t) via a Cobb-Douglas aggregator:

$$Y_t = (\frac{Y_t^h}{1-\alpha_M})^{1-\alpha_M}(\frac{Y_t^f}{\alpha_M})^{\alpha_M} \tag{3.26}$$

where α_M represents the import share in final goods production. The Cobb-Douglas aggregator ensures constant expenditure shares on domestic and imported goods, reflecting elasticity of substitution equal to 1. Final goods producers minimize costs subject to (3.26), yielding the following demand functions:

$$Y_t^h = \frac{(1-\alpha_M)Y_t}{p_t^h} \tag{3.27}$$

$$Y_t^f = \frac{\alpha_M Y_t}{p_t^f} \tag{3.28}$$

where $p_t^h = \frac{P_t^h}{P_t}$ and $p_t^f = \frac{P_t^f}{P_t}$ denote the relative prices of domestic and imported goods, respectively. P_t is the domestic price level, P_t^h is the price of domestic intermediates, and P_t^f is the price of imports. Consistent with Davis and Presno (2017), foreign prices are exogenous and normalized to unity ($P_t^* = 1$). Import prices are thus determined by the nominal exchange rate (e_t): $P_t^f = e_t P_t^* = e_t$. This implies $p_t^f = \frac{e_t}{P_t}$, embedding exchange rate pass-through into domestic inflation dynamics. Perfect competition ensures final goods producers are price takers, with p_t^h and p_t^f determined in intermediate goods markets. The import share α_M governs the sensitivity of domestic demand to exchange rate fluctuations, critical for modeling external sector dynamics.

3.3.5 Intermediate Goods Producers

Intermediate goods producers are assumed to be continuously distributed on the interval $[0,1]$, each producing differentiated domestic intermediate goods $Y_t^h(i)$. The aggregate domestic output Y_t^h is a Constant Elasticity of Substitution (CES) composite of these intermediates:

$$Y_t^h = [\int_0^1 Y_t^h(i)^{\frac{\varepsilon-1}{\varepsilon}} di]^{\frac{\varepsilon}{\varepsilon-1}} \tag{3.29}$$

where $\varepsilon > 1$ denotes the elasticity of substitution between intermediates. Final goods producers minimize costs subject to (3.29), yielding the demand function for each intermediate good:

$$Y_t^h(i) = (\frac{p_t^h(i)}{p_t^h})^{-\varepsilon} Y_t^h \tag{3.30}$$

where $p_t^h(i)$ is the relative price of intermediate i, and $p_t^h = (\int_0^1 p_t^h(i)^{1-\varepsilon} di)^{\frac{1}{1-\varepsilon}}$ is the aggregate price index for domestic intermediate good.

Each intermediate producer i employs a Cobb-Douglas technology combining capital $k_t(i)$ and two types of labor ($n_t(i)$ from patient households and $n_t'(i)$ from impatient households):

$$Y_t^h(i) = A_t[n_t(i)]^{(1-\sigma)(1-\alpha)}[n_t'(i)]^{\sigma(1-\alpha)}[k_{t-1}(i)]^{\alpha} \tag{3.31}$$

where A_t is total factor productivity, $\alpha \in (0,1)$ is the capital share, and $\sigma \in (0,1)$ governs the labor share distribution between household types. Technology evolves exogenously via an autoregressive process:

$$\log\left(\frac{A_t}{A}\right) = \phi_A \log\left(\frac{A_{t-1}}{A}\right) + \varepsilon_t^A, \quad \varepsilon_t^A \sim N(0, \sigma_A^2) \tag{3.32}$$

where where $\phi_A \in [0, 1)$ governs shock persistence, and ε_t^A is an i.i.d. innovation, A represents the steady-state total factor productivity.

Cost minimization yields the following conditions:

Patient Household Labor:

$$(1-\sigma)(1-\alpha)mc_t Y_t^h(i) = w_t n_t(i) \tag{3.33}$$

Impatient Household Labor:

$$\sigma(1-\alpha)mc_t Y_t^h(i) = w_t' n_t'(i) \tag{3.34}$$

Capital Rental:

$$\alpha mc_t Y_t^h(i) = r_{k,t} k_{t-1}(i) \tag{3.35}$$

where mc_t is the real marginal cost of production, derived as:

$$mc_t = \frac{1}{A_t}\left[\frac{w_t}{(1-\sigma)(1-\alpha)}\right]^{(1-\sigma)(1-\alpha)}\left[\frac{w_t'}{\sigma(1-\alpha)}\right]^{\sigma(1-\alpha)}\left[\frac{r_{k,t}}{\alpha}\right]^{\alpha} \tag{3.36}$$

Intermediate firms face Rotemberg-style quadratic price adjustment costs, penalizing deviations from the inflation target.

$$AC_t^P(i) = \frac{\gamma_p}{2}\left(\frac{P_t^h(i)}{P_{t-1}^h(i)} - 1\right)^2 Y_t^h \tag{3.37}$$

where $\gamma_p > 0$ scales the adjustment cost intensity. These frictions introduce nominal rigidities, ensuring gradual price adjustments rather than instantaneous optimization.

Each producer maximizes:

$$\max_{P_t^h(i)} E_0 \Sigma_{t=0}^{\infty} [(\frac{P_t^h(i)}{P_t^h} - mc_t) Y_t^h(i) - \frac{\gamma_p}{2} (\frac{P_t^h(i)}{P_{t-1}^h(i)} - 1)^2 Y_t^h] \tag{3.38}$$

The first-order condition yields the NKPC:

$$(\pi_t^h - 1)\pi_t^h = \frac{1}{\gamma_p}(\varepsilon mc_t + 1 - \varepsilon) + E_t(\Lambda_{t+1} \frac{Y_{t+1}^h}{Y_t^h} \pi_{t+1}^h (\pi_{t+1}^h - 1)) \tag{3.39}$$

where $\pi_t^h = \frac{P_t^h}{P_{t-1}^h} = \frac{P_t^h / P_t}{P_{t-1}^h / P_{t-1}} \pi_t$ is domestic goods inflation, so $\frac{\pi_t^h}{\pi_t} = \frac{p_t^h}{p_{t-1}^h}$. Λ_{t+1} is the discount factor.

Equation (3.29) ensures monopolistic competition among intermediates, with ε dictating price markups. Equations (3.33–3.35) equate marginal products of labor and capital to their real costs, embedding labor market heterogeneity. The NKPC (3.39) links inflation dynamics to real marginal costs mc_t and forward-looking expectations, central to New Keynesian theory.

3.3.6 Monetary Policy

The central bank is assumed to follow a modified Taylor rule with a zero lower bound (ZLB) constraint:

$$R_t = max[1, R_{t-1}^{r_R} (\frac{\pi_t}{\overline{\pi}})^{(1-r_R) r_\pi} (\frac{Y_t}{\overline{Y}})^{(1-r_R) r_Y} \overline{R}^{(1-r_R)} s_t] \tag{3.40}$$

where R_t is nominal policy rate, $\overline{R}$ is the steady-state nominal interest rate, π_t is inflation rate, $\overline{\pi}$ is inflation target, $\overline{Y}$ is potential output level. r_π, r_Y, r_R denote the policy responses to inflation and output gaps, and interest rate smoothing parameter, respectively. s_t is a monetary policy shock. The rule incorporates interest rate smoothing, reactions to deviations of inflation and output from their steady states, and a ZLB constraint $R_t \geq 1$. The

ZLB constraint prevents negative nominal rates, critical in low-inflation environments.

The exogenous shock s_t follows an autoregressive process:

$$logs_t = \phi_R logs_{t-1} + \varepsilon_t^R, \quad \varepsilon_t^R \sim N(0, \sigma_R^2) \tag{3.41}$$

where $\phi_R \in [0,1)$ measures shock persistence, and ε_t^R is an i.i.d. shoch with variance σ_R^2. Variance determines the magnitude of unanticipated policy shifts.

3.3.7 Consolidated Government-Central Bank

The intertemporal budget constraint for the consolidated government-central bank is specified as:

$$\frac{D_t^s}{P_t R_t} + \frac{D_{L,t}^s}{P_t R_{L,t}} + \frac{\Delta_t}{P_t} = \frac{D_{t-1}^s}{P_t} + \frac{D_{L,t-1}^s}{P_t R_t} + G_t - T_t^{tol} \tag{3.42}$$

where $D_t^s, D_{L,t}^s$ are the nominal values of short- and long-term government debts (bond issuance), G_t is the government spending, T_t^{tol} is the total tax revenues. Δ_t refers to the change in the central bank's balance sheet, which equals to the money creation and net asset purchases.

$$\frac{\Delta_t}{P_t} = \frac{M_t^s}{P_t} - \frac{M_{t-1}^s}{P_t} - \left(\frac{D_{L,t}^{CB}}{P_t R_{L,t}} - \frac{D_{L,t-1}^{CB}}{P_t R_t} \right) \tag{3.43}$$

where M_t^s is the central bank's monetary base (money supply), $D_{L,t}^{CB}$ is the central bank's holdings of long-term debt.

Turning the budget constraint into real terms:

$$\frac{d_t^s}{R_t} + \frac{d_{L,t}^s}{R_{L,t}} + m_t^s - \frac{m_{t-1}^s}{\pi_t} - \left(\frac{d_{L,t}^{CB}}{R_{L,t}} - \frac{d_{L,t-1}^{CB}}{R_t \pi_t} \right) = \frac{d_{t-1}^s}{\pi_t} + \frac{d_{L,t-1}^s}{R_t \pi_t} + g_t - t_t^{tol} \tag{3.44}$$

Central bank's holdings of long-term bonds are a proportion x relative to the total amount of long-term bonds:

$$d_{L,t}^{CB} = x_t d_{L,t} \tag{3.45}$$

The remaining proportion of long-term bonds is accessible to households and is given by:

$$d_{L,t}^{H} = (1 - x_t) d_{L,t} \tag{3.46}$$

Therefore, the central bank executes asset purchases by adjusting the proportion x_t, which follows an AR(1) process:

$$log(\frac{x_t}{\bar{x}}) = \phi_x log(\frac{x_{t-1}}{\bar{x}}) + \varepsilon_t^x \tag{3.47}$$

where $\bar{x}$ is the steady-state share of long-term bonds held by the central bank. Temporary deviations from $\bar{x}$ model unconventional monetary policies (e.g., QE). Asset purchases would reduce long-term yields via portfolio rebalancing.

Government spending g_t is also assumed to follow an AR(1) process:

$$log(\frac{g_t}{\bar{g}}) = \phi_G log(\frac{g_{t-1}}{\bar{g}}) + \varepsilon_t^g \tag{3.48}$$

Taxes respond to deviations of public debt from steady-state levels to ensure fiscal sustainability. This rule can stabilize debt dynamics, preventing explosive paths (Leeper, 1991). Taxes rise when debt exceeds its target, mitigating default risk.

$$t_t^{tol} = \psi_0 + \psi_1 \left(\frac{d_{t-1}^s}{\pi_t} - \frac{\overline{d^s}}{\overline{\pi}} \right) + \psi_2 \left(\frac{d_{L,t-1}^s}{R_t \pi_t} - \frac{\overline{d_L^s}}{\overline{R\pi}} \right) \tag{3.49}$$

where ψ_0 represents the steady-state tax level, and $\psi_1, \psi_2 > 0$ are fiscal responsiveness to short- and long-term debt deviations to ensure debt stabilization. This essentially implies that taxes are dependent on the existing stock of government liabilities outstanding. $\overline{d^s}, \overline{d_L^s}$ are the steady-state debt levels.

The supply of domestic long-term bonds also follows an exogenous autoregressive process.

$$log(\frac{d^s_{L,t}}{\bar{d}^s_L}) = \phi_d log(\frac{d^s_{L,t-1}}{\bar{d}^s_L}) + \varepsilon^d_t \tag{3.50}$$

where ε^d_t is an i.i.d. shock.

3.3.8 Monetary-Fiscal Interactions and Budget Constraint Mechanics

The nominal money stock M_t is jointly determined by household demand M^d_t and central bank actions. On the demand side, households derive utility from real money balances ($\frac{M^d_t}{P_t}$) as part of their optimization problem, since the model incorporates real money balances into the household utility function (Money-in-the-Utility, MIU framework). The first-order condition for money holdings (Equation 3.13) reflects the trade-off between the marginal utility of consumption ($u_{c,t}$) and the marginal utility of holding money ($u_{m,t}$). This trade-off is determined by the interest rate, as the interest rate measures the opportunity cost of holding money instead of interest-bearing assets, thereby directly influencing households' optimal choice between consumption and liquidity demand. Households adjust M^d_t to balance liquidity preferences against the opportunity cost of forgone interest earnings. If households prefer more money (for example, a decrease in interest yields), they will increase M^d_t through optimization behaviour. On the supply side, money supply is adjusted through central bank asset purchases (e.g., LSAPs). This is captured in the consolidated budget constraint (Equation 3.42). $\frac{M^s_t - M^s_{t-1}}{P_t}$ represents the change in the money supply due to central bank operations, which is equal to the sum of net asset purchases and fiscal deficit financing. By adjusting x_t (the share of bonds held by the central bank), the central bank injects money into the economy, directly increasing M^s_t, lowering long-term bond yields and stimulating the economy. Although households determine the demand for money and the central bank controls the money supply, the final level of M_t is determined by market equilibrium. The price level P_t adjusts to reconcile household demand for real money balances with the central bank's nominal supply.

Monetary policy is not over-determined despite two tools: The policy rate R_t follows a Taylor rule, reacting to inflation π_t and output Y_t. QE operations (via the asset purchase ratio x_t) adjust M_t^s by altering the central bank's bond holdings. But these tools are complementary. Near the zero lower bound (ZLB), the Taylor rule becomes passive, and QE dominates as the primary stimulus tool. Away from the ZLB, R_t adjusts conventionally, while QE operates in the background to manage long-term yields. The model avoids over-determination by restricting the Taylor rule's responsiveness at the ZLB, ensuring QE does not conflict with interest rate policy.

The relationship between R_t and M_t operates through two channels. Through the conventional interest rate transmission channel, the Taylor rule sets R_t, directly affecting short-term rates and indirectly influencing long-term rates via term premiums. Higher R_t raises the opportunity cost of holding money, reducing M_t^d demand (via Equation 3.13). The money demand equation (MIU) ensures dynamic consistency between M_t^d and R_t. Through the asset purchase channel, M_t^s evolves via asset purchases and fiscal interactions. Expansionary QE implies central bank purchases of long-term bonds (increasing x_t) expand the balance sheet, which increases M_t^s lowers long-term bond yields, and stimulates portfolio rebalancing into housing. This indirectly affects R_t by altering inflation and output, which feed back into the Taylor rule. In this way, QE can indirectly lowers real interest rates, even if R_t is constrained. The two variables are interrelated but not directly tied by a single equation.

Fiscal policy is characterized by government spending G_t and taxes T_t^{tol}. Government spending is assumed to be exogenous and follows an AR(1) process (Equation 3.48). Taxes adjust passively with debt levels to stabilize public debt (Equation 3.49). This ensures fiscal sustainability by linking taxes to deviations from steady-state debt. The government finances deficits via short-term D_t and long-term $D_{L,t}^s$ bonds.

Fiscal variables (G_t, T_t^{tol}) and monetary variables (M_t^s, D_t^s,$D_{L,t}^s$,x_t) jointly satisfy the

PVBC through tax adjustments, debt issuance, and central bank operations. Exogenous long-term bond supply (Equation 3.50) and passive fiscal adjustments ensure that debt dynamics remain bounded. In equilibrium, these interactions guarantee that the Present Value Budget Constraint (PVBC) holds: future surpluses (taxes T_t^{tol}, seigniorage from M_t^s, and bond issuance D_t) offset current liabilities. Future fiscal surpluses equal the present value of current debt, achieved through tax adjustments and monetary operations (QE). PVBC compliance ensures interaction of G_t, T_t^{tol},M_t^s and D_t^s. For example, expansionary fiscal policy or tight monetary policy (reduced central bank purchases) requires increased debt issuance D_t^s and higher taxes T_t^{tol}. If taxes are insufficient, rising debt may trigger central bank QE $D_{L,t}^{CB}$ to lower rates and ease financing pressure.

3.3.9 Market Clearing

Total output and aggregate net foreign assets B_t^* are allocated to consumption, investment, and government spending.

$$C_t + C_t' + G_t + I_t + B_t^* = Y_t + R_{t-1}^* \phi_{t-1} e_t B_{t-1}^* \tag{3.51}$$

The housing market clearing condition is given by

$$H_t + H_t' = 1 \tag{3.52}$$

where the total housing stock is normalized to 1. As stressed in the previous section, this normalization reflects the assumption of fixed housing supply in the short to medium term, approximating real-world constraints such as regulatory barriers, geographical limitations, or infrastructural rigidities that hinder rapid adjustments in housing stock. By fixing the supply, the model isolates demand-side dynamics and particularly captures the amplifying effects of QE on housing prices when demand surges against an inelastic supply.

The money market clears when the central bank's money supply equals the households' money demand. The capital market clears when the aggregate supply of capital (from households' savings) equals the demand for capital (from firms' investments). In equilibrium, the shadow price of capital ensures that the marginal cost of investment equals its expected future returns. The labour market clears when the labour supply (from both patient and impatient households) matches firms' labour demand. For the bond market, bond issuances couple households' demand.

Transversality Conditions (TVCs)

$$\lim_{t \to \infty} \beta'^t \cdot uc'_t \cdot b'_t = 0 \tag{3.53}$$

which implies no Ponzi schemes—borrowers cannot indefinitely roll over debt.

$$\lim_{t \to \infty} \beta^t \cdot uc_t \cdot qk_t \cdot k_t = 0 \tag{3.54}$$

Savers' capital accumulation is sustainable. Capital stock cannot grow faster than the discount rate.

Additional TVCs (e.g., for government debt) are implicitly enforced by the budget constraint and fiscal policy rules. The government finances its debt through taxes, seigniorage (money creation), and bond issuance. Debt sustainability requires that the present value of future primary surpluses (taxes minus spending) equals the current debt level. This is the TVC for government debt, ensuring no Ponzi schemes. The tax rule in the model ensures debt stabilization. Taxes respond to deviations of debt from its steady-state level. If debt rises above, taxes automatically increase to reduce it, preventing explosive debt growth. The combination of the budget constraint and tax rule guarantees that the present value of debt converges to zero:

$$\lim_{t \to \infty} \frac{d_t}{\prod_{s=0}^{t} R_s} = 0 \tag{3.55}$$

The equilibrium consists of a sequence of allocations $\{ C_t, H_t, D_t, D_{L,t}, B_t, I_t, C'_t, H'_t, B'_t, N_t, N'_t, M^d_t, M^{d'}_t \}_{t=0}^{\infty}$ for the two types of households, allocations $\{ Y_t, K_t \}_{t=0}^{\infty}$ for firms, allocations $\{ D^s_t, M^s_t, x_t, T^{tol}_t \}_{t=0}^{\infty}$ for government and central bank, and the sequence of values $\{ q_t, \pi_t, R_t, R_{L,t}, R^*_t, r_{k,t}, e_t, P_t, w_t, w'_t, x_{w,t}, x'_{w,t} \}_{t=0}^{\infty}$ satisfying the above household's and firm's FOCs, monetary policy rule, government budget constraint, borrowing constraint and one of the two budget constraints (since one can be deducted due to the Walras' law), as well as above market clearing conditions.

3.4 Results from the Calibrated Model

The calibrated DSGE model demonstrates that New Zealand's LSAPs of government bonds generated significant macroeconomic stimulation, manifested through compressed long-term yields, elevated housing sector inflation, and a transient boost to aggregate output. To quantify the effects of quantitative easing implemented during the COVID-19 pandemic, this chapter simulates the LSAP program as an unanticipated permanent shock to the central bank's balance sheet (the fraction of assets purchased) reflecting the abrupt and sustained expansion of asset purchases announced in 2020. Using a theoretical model calibrated to New Zealand's macroeconomic data, this section first details the calibration strategy, and then evaluates the baseline results, and finally conducts sensitivity analyses to assess the robustness of key mechanisms.

3.4.1 Calibration

The DSGE model is calibrated to quarterly New Zealand data spanning 2010Q1–2023Q3, ensuring consistency with the SVAR framework outlined earlier. However, when calibrating the DSGE model to simulate the effects of quantitative easing shocks during the pandemic, the choice of data should balance long-term steady-state characteristics and plausibility under specific shocks. For steady-state parameters (e.g., time preference, capital depreciation), pre-pandemic data (2010Q1–2019Q4) has been prioritized to reflect the economy's structural equilibrium, as pandemic-era data (2020Q1–2023Q3) may distort estimates due to extreme volatility (e.g., near-zero policy rates, GDP collapses). However, post-pandemic data is critical for defining exogenous QE shocks (e.g., asset purchase magnitudes) and validating dynamic responses (e.g., housing prices, inflation paths). Key parameters like monetary policy rules or financial frictions have been adjusted using 2020–2023 data to capture unconventional policy transmission. This dual approach ensures the model captures both pre-pandemic stability and pandemic-specific policy dynamics. Parameter calibration follows a three-tiered approach:

1. SVAR Model Dataset: Key macroeconomic variables (e.g., GDP, policy rate, inflation) are sourced from the previously prepared SVAR datasets.

2. New Sourced Parameters: Key ratios (e.g., capital share, import share and long-term debt issuance) are inferred from supplementary datasets.

3. Theory- and Literature-Guided Parameters: The remaining are anchored to New Zealand-specific studies and canonical DSGE literature.

To simulate the unconventional quantitative easing programs introduced in this chapter, key parameters and steady-state values were carefully calibrated using a combination of empirical data and theoretical frameworks. The calibration process is divided into the above categories based on data sources.

For parameters tied to monetary policy and household behaviours, we utilized the previously prepared SVAR quarterly datasets from 2010Q1 to 2019Q4. The following parameters were calibrated:

- **Policy Rate (OCR) and Inflation:** The average Official Cash Rate (OCR) during this period was 2.4688% annually, translating to a quarterly rate of 0.6172%, while the average CPI inflation rate stood at 0.3% quarterly. These values informed the calibration of the patient household discount factor (β) to 0.9968, aligning with the Euler equation for consumption smoothing.

- **Monetary Policy Smoothing (r_R):** The autoregressive coefficient of $log(OCR/\overline{OCR}$ yielded 0.8548, indicating significant interest rate inertia.

- **Money Holding Smoothing (ε_{mp}):** The inertia in money supply dynamics was used to calibrate this parameter. By estimating the first-order autoregressive coefficient of M3 growth rates over the sample period, we obtained $\varepsilon_{mp} = 0.6935$.

- **Consumption Habit (ε_c):** A first-order autoregressive coefficient of 0.9642 was derived from the Private Final Consumption Expenditure series for New Zealand (FRED database), capturing persistent consumption patterns, in line with existing New Zealand literature (Liu (2005)).

For the new sourced parameters, we leveraged resources from multiple national databases, including Statistics New Zealand (Stats NZ), the World Bank, Federal Reserve Economic Data (FRED), and the OECD database.

- **Borrower Discount Factor (β'):** The discount factor for impatient households β' was calibrated to 0.9901 using the Reserve Bank of New Zealand (RBNZ) data on new residential mortgage standard interest rates, which averaged 5.19% between 2010Q1 and 2019Q4, reflecting their higher borrowing costs. This aligns with canonical studies such as Iacoviello (2005), Lawrance (1991), Laibson (1997), and Krusell and Smith (1998) emphasize the role of risk premiums in reducing the effective discount rate for borrowers, thereby amplifying their short-term consumption propensity. Empirical evidence from Mian and Sufi (2014) further supports this adjustment, demonstrating that debt-driven consumption expansions are often accompanied by households' over-optimism about future income—a behavioral pattern captured by a lower discount rate.

- **Capital Share in Production (α):** The capital share parameter (α) was calibrated using official data from Statistics New Zealand (Stats NZ) under the "Gross domestic product: Income approach" framework. Specifically, the ratio of Gross Operating Surplus (GOS) to GDP was calculated for the period spanning 2016Q2 to 2019Q4, the earliest available data for this metric. This yielded a calibrated value of $\alpha = 0.44258$, which aligns with existing literature highlighting New Zealand's relatively high capital share compared to other advanced economies. The elevated capital share reflects the significant contribution of capital-intensive sectors such as construction, and infrastructure to the national income, as documented in RBNZ Sectoral Analysis (2020).

- **Depreciation Rate (δ_k):** Calculated as 0.019 using FRED data (gross fixed capital formation relative to capital stock), lower than the mostly-used value of 0.025 in the literature (Christiano et al (2005)) and Altig et al. (2011), equating to an annual capital depreciation rate of 7.6%. This reflects New Zealand's slower capital turnover due to durable infrastructure investments and longer asset lifespans.

- **Price Adjustment Costs (γ_p):** Calibrated to 250, following the framework of Christiano et al. (2005) and Ireland (2004). Existing studies suggest that price adjustment costs in the range of 100–300 reflect moderate nominal price rigidity. For New Zealand, the core CPI inflation rate still averaged below the 2% target in 2020, suggesting a 6–8 quarter lag to peak effects. A higher value of 250 within the literature range is chosen to balance nominal rigidity and inflation dynamics.

- **Labor Substitution Elasticity (σ):** Calibrated to 0.5 based on RBNZ reports indicating relatively higher cross-industry labor mobility.

- **Household Segmentation (n^p):** Stats NZ (2022) reported 32% of households held primary residence mortgages. Assuming these households represent impatient borrowers, the patient-to-impatient ratio was set to 7:3, capturing New Zealand's high household debt-to-income ratio (163%, RBNZ 2019).

- **Housing Demand Weight (j):** Calibrated to 0.22, based on Statistics New Zealand's (Stats NZ) Household Income and Housing Cost Statistics, which indicate that households allocated 22.2% of their disposable income to housing costs in the year ending June 2024.

- **Wage Markup (x_w, x'_w):** Calibrated using the Unit Labor Costs indicator from the FRED database, specifically the "Quarterly Labor Compensation per Unit of Labor Input" series. The average from 2010 to 2019 measures approximately 1.1, which aligns with the baseline calibration of the wage markup parameter ($x_w, x'_w = 1.1$) in the most New Keynesian model framework such as Smets & Wouters (2007) and Galí (2015).

- **Import Share (α_M):** Calculated as 17.55% using Stats NZ's import-to-GDP ratio (2010–2019).

- **Long-Term Debt Issuance ($D_{L,ss}$):** The steady-state long-term debt ratio was calibrated based on the New Zealand Treasury Annual Report 2018/19 by the Minister of Finance, which indicates that approximately 44.58% of total debt issuance (including nominal bonds, inflation-indexed bonds, and Treasury Bills) had maturities of 10 years or longer. Combining this with the World Bank's Central Government Debt dataset, which reports New Zealand's average total government debt-to-GDP ratio of 41.73% from 2010 to 2019, we derived $D_{L,ss} = 18.6\%$ of GDP.

- **Central Bank Holdings (X_{ss}):** For the central bank's holdings of government debt (X_{ss}), we utilized RBNZ data on Holdings of Central Government Debt Securities from 2015Q3 to 2019Q4, yielding X_{ss} is approximately 6%, which reflects minimal pre-QE intervention. Additionally, the persistence and standard deviation of the asset purchase shock were carefully calibrated. In the benchmark model, the shock is assumed to be permanent to reflect the RBNZ's strategy for phasing out quantitative easing, as outlined in Falagiarda (2014). The asset purchase shock was modelled as permanent to reflect the RBNZ's 2020 LSAP program (initial NZD 30 billion, later expanded to NZD 100 billion), which signalled that asset purchases would remain in place until economic recovery. By rescaling the variance, the asset purchase shock simulates an LSAP shock by increasing the central bank's bond holdings from 6% to 32%, capturing New Zealand's quantitative easing program in 2020.

For the remaining parameters that cannot be directly calibrated from the data, we refer to the values in the literature.

- **Monetary Policy Responses:** Following RBNZ paper (Plantier and Scrimgeour, 2002), the inflation response coefficient (r_π, r_Y) and output gap response (r_Y) were set to 1.601 and 0.488, respectively.

- **Frisch Elasticity (η):** Set to 0.5 (midpoint of 0.4 – 0.6 based on microeconomic studies of New Zealand labor supply (Creedy & Mok, 2017), reflecting labor supply rigidity due to restrictions such as quarantines during the pandemic.

- **Price Elasticity (ε):** Existing studies suggest that price elasticity in the range of 2-8 reflects nominal price rigidity (Gali and Monacelli (2005), Devereux and Engel (2003), Eichenbaum, Jaimovich, and Rebelo (2011)). A lower ε is chosen to reflect higher consumer tolerance for price hikes during the pandemic.

- **Fiscal Responsiveness to Short- and Long-term Debt Deviation (ψ_1, ψ_2):** Set to 0.2 and 0.1, respectively, following Falagiarda (2014).

Tables 1 and 2 summarize the calibrated parameter values and steady-state relationships. These values broadly align with the states just preceding the occurrence of the asset purchase shock in New Zealand in 2020.

Description	Parameter	Value
Structural Parameters		
discount factor (patient agents)	β	0.9968
discount factor (impatient agents)	β'	0.9901
habits in consumption	ε_c	0.9642
habits in money holding	ε_{mp}	0.6935
housing demand weight	h	0.22
wage markup	x_w, x'_w	1.1
capital depreciation rate	δ_k	0.019
price adjustment costs	γ_p	250
labor supply aversion/disutility	η	0.5
population shares of patient agent	n^p	0.7
investment adjustment costs	ϕ_i	1.5
bond transaction cost	ϕ_L	0.01
price elasticity	ε	2.5
degree of inertia in the borrowing limit	γ	0.7
loan-to-value ratio	m	0.7
capital share in production	α	0.44258
import share	α_M	0.1755
labor substitution elasticity	σ	0.5
monetary policy response to inflation	r_π	1.601
monetary policy response to output gap	r_y	0.488
monetary policy inertia	r_R	0.8548
fiscal responsiveness to short-term debt	ψ_1	0.2
fiscal responsiveness to long-term debt	ψ_2	0.1

Table 3.2 – Calibrated Parameters

Steady State Ratios		Model	Data
consumption to GDP	c/y	0.7028	0.6860
investment to GDP	i/y	0.1873	0.2401
capital to GDP	k/y	9.8578	4.1296
debt to GDP	d/y	0.3586	0.4173

Table 3.3 – Steady State Ratios

3.4.2 Impulse Response Analysis

3.4.2.1 Impulse Responses of Asset Purchase Shock

The impulse response analysis of New Zealand's 2020 quantitative easing captures the dynamic interplay between unconventional monetary policy and macroeconomic variables. Key findings reveal that QE precipitated a sharp decline in long-term interest rates, housing prices surged disproportionately, exchange rate exhibited short-term depreciation pressures, but output growth, though initially positive, proved transient. By rescaling the variance, the asset purchase shock simulates an LSAP shock by increasing the central bank's bond holdings from 6% to 32%, capturing New Zealand's quantitative easing program in 2020.

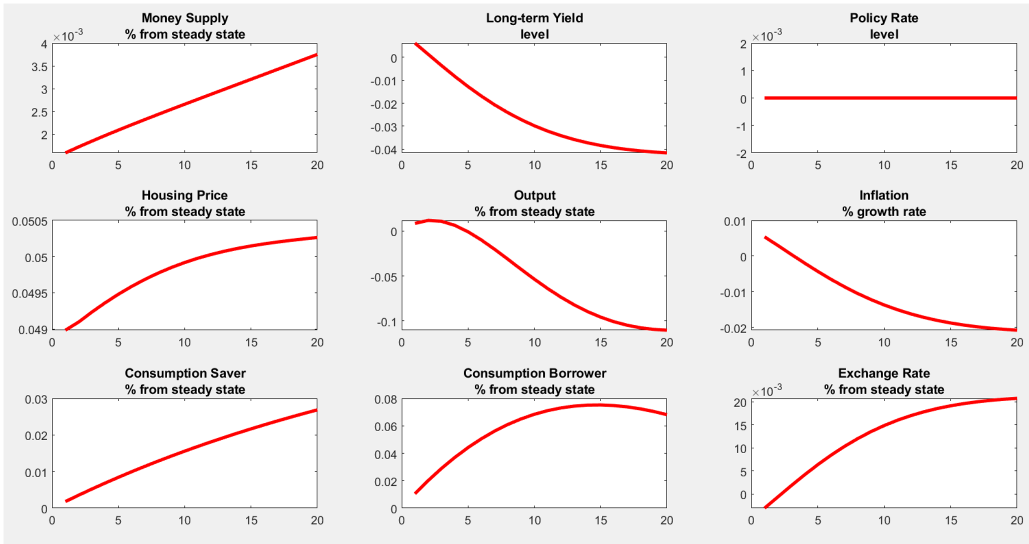


Figure 3.10 – Impulse Responses to an Asset Purchase Shock (Permanent)

A permanent asset purchase shock leads to a sustained increase in money supply, with a peak growth of approximately 0.375%, consistent with the mechanism of QE injecting liquidity through balance sheet expansion, which exerts downward pressure on long-term interest rates. The long-term yield plunges below steady state, turning negative, while the policy rate remains constrained at the zero lower bound, reflecting the central bank's limited conventional easing space. Housing prices surge by 4.9% quarterly (equivalent to approximately 20% annualized, consistent with the housing price increase in New Zealand in 2020) and persist at elevated levels for 20 quarters, reaching 5.85 times GDP. This aligns with New Zealand's post-2020 housing boom, driven by portfolio rebalancing effects—QE compresses long-term yields, lowering the opportunity cost of housing investment—and amplified by financial accelerator mechanisms. Impatient households, reliant on mortgage borrowing, experience relaxed collateral constraints as housing values rise, fueling demand. However, rigid housing supply in the model (fixed total stock) exacerbates price volatility, underscoring structural imbalances in real-world markets. This aligns with the housing supply rigidity caused by lockdown restrictions and the shortage of construction materials during the pandemic.

The exchange rate depreciates by 0.31% on impact due to liquidity expansion, narrowed interest rate differentials and capital outflows, consistent with the depreciation pressure observed on the New Zealand dollar during the initial phase of QE. However, the exchange rate response rebounds above baseline within three quarters, reflecting self-correcting market dynamics and potential policy interventions. Output initially rises by 0.8383%, signaling short-term demand stimulation via wealth effects and credit channels. However, growth dissipates rapidly, reverting to baseline within four quarters and turning negative afterward, highlighting supply-side constraints such as labor market frictions and capital adjustment costs. Inflation rises moderately by 0.54% quarterly (2.16% annualized), constrained by price stickiness. The inflation response exhibits weak persistence, aligning with the limited transmission of QE in New Zealand's low-inflation environment (core inflation remained below target in 2020). Consumption responses diverge—borrowers' spending surges more sharply than savers', driven by looser collateral constraints, though exchange rate-driven foreign debt servicing costs later temper this trend.

The impulse response analysis reveals macroeconomic dynamics in New Zealand in 2020. Central bank purchases of long-term bonds (LSAP) compress long-term interest rates via the portfolio rebalancing effect, reducing the opportunity cost of real estate investment and prompting investors to shift toward housing assets. The model's mortgage constraint mechanism (impatient households relying on mortgage borrowing) further amplifies demand, creating a "financial accelerator" effect. After a QE shock, housing prices rise sharply in the short term and remain above initial levels in the long run. QE suppresses domestic interest rates, weakening the currency's appeal (interest rate parity condition), and leading to short-term depreciation of the exchange rate. The exchange rate responds to the QE shock with an initial depreciation followed by gradual recovery. QE stimulates aggregate demand through wealth effects and collateral channels, but supply-side constraints counteract demand stimulation. Borrowers (impatient households), reliant on foreign debt financing, face dual impacts from collateral constraints and exchange rate volatility. Early-stage QE lifts housing prices, relaxing collateral constraints and boosting consumption, but currency depreciation also increases foreign debt burdens. Thus, borrower consumption exhibits higher volatility than savers' consumption. The financial frictions introduce imperfections in the substitutability of different assets (domestic short- and long-term bonds, foreign bonds and house holdings) and emphasise the importance of the portfolio rebalancing mechanism triggered by QE. The impact of the central bank's long-term asset purchases on the real economy depends on its ability to incentivize households to reconfigure the composition of their portfolios moving funds between the bond market and the housing market. In response, savers change their portfolio composition by reducing their savings while increasing their house holdings. The reallocation of assets into the housing market increases the demand for houses, leading to a rapid and significant rise in housing prices. This in turn lowers borrowing costs for impatient households.

The results are consistent with the conclusions from the SVAR model, except that in the post-pandemic SVAR model (2020–2023), the policy rate rose significantly following an M3 shock (likely reflecting concerns about policy tightening to curb inflation). In contrast, the DSGE model shows the policy rate remained constrained at the zero lower bound. The divergence between the DSGE and SVAR results stems from differences in model design, time horizons, and policy regimes. The DSGE model focused on the 2020 initial QE shock alone, and the model constructs with rigid ZLB assumptions, prioritizing crisis-era dynamics (e.g., liquidity injection, financial market stress) over post-crisis tightening. Even if inflationary pressures emerge, the policy rate remains stuck at zero, reflecting institutional constraints and the central bank's focus. This mirrors New Zealand's actual policy stance in 2020, where the Official Cash Rate (OCR) was cut to around 0.3% and held near-zero to address COVID-19 economic shocks. The SVAR model is estimated using actual data from 2020Q1–2023Q3, which includes both the initial QE phase (2020) and subsequent policy tightening (2021–2022). Reserve Bank of New Zealand (RBNZ) began raising the

OCR in late 2021 to combat rising inflation, reaching 5.6% by 2023.

The model underscores QE's dual role in small open economies. While it stimulates asset prices and mitigates ZLB constraints, it also amplifies financial stability risks, particularly in housing markets. Long-term yield suppression and policy rate rigidity flatten the yield curve, reducing monetary policy flexibility. These findings advocate for complementary measures: macroprudential tools (e.g., LTV limits) to curb speculative borrowing, exchange rate management to mitigate volatility, and structural reforms to address housing supply shortages. The results emphasize the necessity of balancing unconventional monetary easing with targeted regulatory and structural policies to sustain growth while safeguarding financial stability.

3.4.2.2 Impulse Responses of Collateral Constraint Tightening Shock

The impulse response analysis of a collateral constraint tightening shock (lowering the LTV ratio, m) reveals dynamics in the DSGE framework. While the shock is designed to curb housing market overheating, its effects are mediated by complex interactions between financial constraints, portfolio rebalancing, and monetary policy limitations.

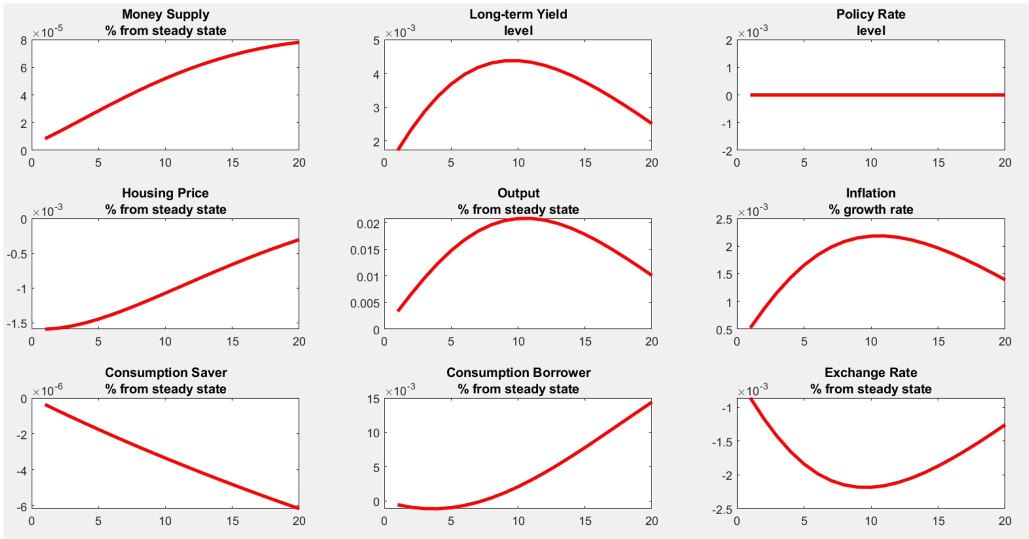


Figure 3.11 – Impulse Responses to a Collateral Constraint Tightening Shock

The collateral constraint tightening shock simulates a reduction in the Loan-to-Value (LTV) ratio from 0.7 to 0.63 after rescaling the variance, which aligns with the mortgage policy tightening measures implemented in New Zealand in 2021. Housing prices immediately decline by -0.16% quarterly, reflecting reduced borrowing capacity for impatient households (borrowers) due to stricter LTV limits. The policy achieves a duable cooling effect, with housing prices remaining persistently below pre-shock levels. This aligns with goals to curb speculative bubbles. This partial rebound arises from fixed housing supply and savers' delayed reallocation of funds to real estate as credit conditions stabilize. Both savers and borrowers experience initial consumption declines, but borrowers suffer more severely due to binding credit constraints. Borrower consumption recovers after 8 quarters as housing prices recover and debt burdens ease. Despite the initial drag from borrower consumption, which drops sharply), output rises by 0.5% on impact, peaking at 2% after 10 quarters. This growth is driven by savers' behavior and investment surge. With housing demand suppressed, savers redirect savings to bonds and productive capital, amplifying investment-led growth. Long-term yields fall below steady state due to increased bond demand from savers rebalancing portfolios away from housing. Lower financing costs also stimulate capital investment, which feeds into production. Inflation edges up only 0.05% quarterly, constrained by weak demand-pull forces (borrower consumption contraction) and offsetting supply-side improvements (lower capital costs). The currency depreciates by -0.08% on impact, reaching a trough of -0.2%, as lower domestic interest rates (policy rate stuck at ZLB) leads to capital outflows. However, the depreciation begins to rebound after 9 quarters, reflecting the economy's small open nature and self-correcting mechanisms.

Tighter collateral constraints reduce housing demand, prompting savers to shift funds to bonds and capital markets. This rebalancing depresses long-term yields, lowers firms' borrowing costs, and fuels capital accumulation, offsetting the negative demand shock from borrowers. However, this growth might be partially driven by market distortions rather than fundamental productivity gains. This underscores the need to balance short-term market stabilization with long-term structural reforms, ensuring housing affordability without sacrificing economic resilience. With the policy rate constrained at zero, monetary policy cannot actively respond to the shock. Long-term yield dynamics are instead driven by market forces, heightened bond demand from savers suppresses rates, indirectly supporting investment. The immediate price drop in housing prices demonstrates the shock's effectiveness in cooling overheating markets. By the 20th quarter, housing price below the steady state indicates sustained but modest cooling.

3.4.3 Welfare Analysis

This section evaluates the distributional welfare implications of the above two distinct macroeconomic shocks, the asset purchase shock (QE) and the collateral constraint tightening shock (LTV ratio), on savers and borrowers. Welfare is quantified as the infinite-horizon discounted sum of household utility, with aggregate welfare calculated as a population-weighted average (70% savers, 30% borrowers). The figures below illustrate the percentage deviation of welfare from the steady-state baseline following each shock, where positive values denote welfare gains. By comparing these dynamics, we assess how unconventional monetary policy and macroprudential interventions differentially impact heterogeneous households, shedding light on the trade-offs between financial stability and equity.

3.4.3.1 Welfare Analysis for the Asset Purchase Shock

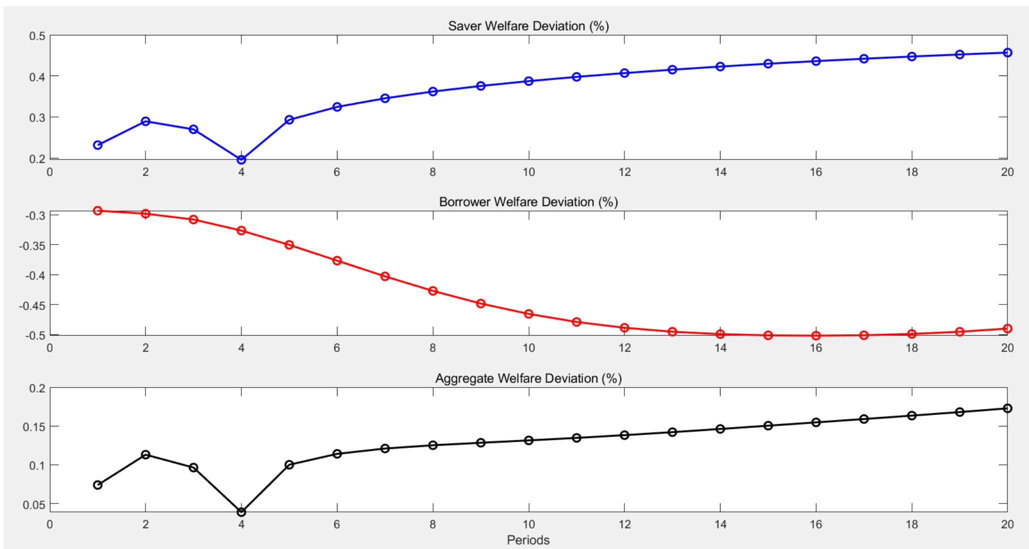


Figure 3.12 – Welfare Analysis for the Asset Purchase Shock

The welfare divergence between savers and borrowers following a quantitative easing shock emerges through distinct transmission mechanisms rooted in their heterogeneous economic positions and behavioral responses. Savers, typically characterized by higher marginal propensities to save and diversified asset portfolios, experience welfare gains primarily through three interconnected channels. First, the asset price effect plays a pivotal role: QE-induced suppression of long-term interest rates reduces discount rates for real estate investments, triggering a substantial housing price surge (4.9% quarterly in the model). As primary holders of housing assets, savers benefit directly from wealth effects embedded in their utility function. Concurrently, portfolio rebalancing mechanisms incentivize savers to shift funds from low-yield bonds to appreciating real estate, amplifying capital gains. Second, liquidity expansion through central bank balance sheet operations increases money supply, enhancing the liquidity premium captured in savers' utility via the monetary component. Third, savers' superior consumption-smoothing capacity—supported by diversified assets and lower leverage—allows them to mitigate income volatility despite compressed interest rates, as evidenced by their relatively stable consumption responses.

Conversely, borrowers face welfare deterioration through mechanisms exacerbated by their reliance on credit constraints and external financing. While the initial housing boom temporarily relaxes collateral constraints, enabling short-term consumption spikes, this proves unsustainable. Persistent high housing prices (remaining elevated for 20 quarters) escalate debt burdens, particularly dangerous in an environment of exchange rate depreciation (0.31% initial drop). The currency devaluation magnifies foreign debt servicing costs, creating delayed financial stress. Furthermore, borrowers' consumption becomes sensitive to credit cycles, output reverts to baseline within four quarters and turns negative, reflecting unmet income growth to sustain debt-fueled spending. Structural rigidities, particularly fixed housing supply, amplify price volatility and long-term instability, mirroring real-world pandemic-induced construction bottlenecks in New Zealand.

This welfare dichotomy aligns with New Zealand's post-2020 experience—savers benefited from a 20% annualized housing boom while borrowers faced escalating debt-to-income ratios (reaching 176% by 2022Q1). The model's financial accelerator mechanism explains this divergence: QE-triggered portfolio shifts inflate housing demand, temporarily easing credit access but ultimately trapping borrowers in a debt-overhang trap. These dynamics underscore QE's dual role in small open economies—stimulating asset markets while exacerbating financial fragility. The results advocate for complementary measures to mitigate distributional imbalances and prevent welfare gains for savers from translating into systemic risks borne by indebted households.

3.4.3.2 Welfare Analysis for the Collateral Constraint Tightening Shock

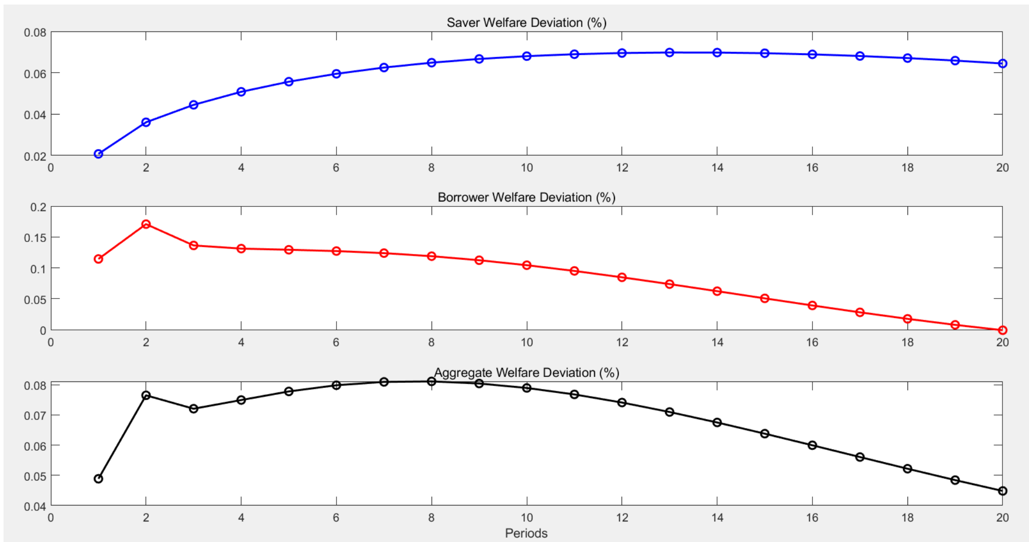


Figure 3.13 – Welfare Analysis for the Collateral Constraint Tightening Shock

The welfare divergence between savers and borrowers following the collateral constraint tightening shock (modeled as a reduction in the Loan-to-Value (LTV) ratio from 0.7 to 0.63) also arises from the asymmetric transmission channels embedded in their economic roles and financial vulnerabilities. Savers, who hold diversified portfolios and exhibit financial resilience, experience sustained welfare gains through three interconnected mechanisms. First, the shock triggers a reallocation of savings away from the depressed housing market, where prices immediately decline by -0.16% quarterly, toward bonds and productive capital investments. This portfolio rebalancing suppresses long-term yields, generating capital gains on bond holdings while simultaneously lowering firms' financing costs. The resultant surge in capital accumulation (peaking at 2% output growth) enhances productivity and boosts returns on productive assets, disproportionately benefiting savers as primary owners of capital. Second, savers' superior consumption-smoothing capacity allows them to mitigate short-term losses from housing depreciation through stable income streams derived from capital returns and wage growth linked to expanded production. Third, the zero lower bound on policy rates and depressed long-term real interest rates create a unique environment where savers' investment return effectively subsidizes their wealth accumulation in a low-yield regime. These dynamics compound over time, driving saver welfare from 2.08% above steady state to 6.45% by the 20th quarter, but their welfare trajectory remains subdued relative to borrowers' early-stage advantages.

Borrowers, despite facing tighter credit constraints, initially experience significant welfare gains (rising to 17.07% by the second quarter) before a gradual decline to zero by the 20th quarter. This reversal stems from two interconnected mechanisms. First, the immediate decline in housing prices alleviates debt-service burdens for new entrants into the housing market, freeing disposable income for consumption. Second, reduced labor supply pressures, as lower housing costs diminish the need for excessive work hours to afford mortgages, temporarily boost leisure utility. The shock disrupts the debt-inflation spiral that typically accompanies QE-driven housing booms, where rising prices force borrowers into unsustainable leverage. However, these benefits erode over time as persistently depressed collateral values restrict refinancing capacity, while currency depreciation (-0.2% trough) marginally inflates foreign debt obligations. Crucially, the output growth driven by savers' capital investments fails to translate into proportional wage growth for borrowers, reflecting labor market rigidities and income distribution skewed toward capital returns.

Aggregate welfare, weighted 7:3 in favor of savers, peaks at 8.11% by the eighth quarter before tapering to 4.48% by the 20th quarter. While borrowers' transient gains dominate early dynamics, their diminishing welfare highlights the fragility of their financial position. The results underscore that collateral constraint tightening serves as a vital complement to QE, counteracting its inherent distributional risks. The shock's capacity to stabilize borrower welfare, even temporarily, demonstrates its role in rebalancing growth toward labor and consumption, rather than speculative asset accumulation. However, this equilibrium remains precarious, as structural rigidities in wage distribution and credit access persist. To sustain equitable outcomes, policymakers must pair QE with complementary reforms, such as progressive taxation on capital gains, targeted debt relief programs, and housing supply expansion. These measures would redistribute productivity gains more broadly, preventing savers' wealth accumulation from translating into systemic risks for indebted households. This collateral constraint tightening aligns with New Zealand's post-2021 experience, where macroprudential tightening stabilized housing markets and addressing widening inequality.

3.4.4 Sensitivity Analysis

This section examines two parameters critically linked to pandemic-induced economic dynamics, international capital frictions (ϕ) and habit persistence in consumption (ε_c), and their divergent impacts under quantitative easing. The parameter ϕ, governing foreign exchange risk premiums, captures heightened global financial uncertainties and capital flow restrictions during the pandemic, while ε_c reflects shifts in household consumption inertia due to unprecedented behavioral changes (e.g., panic buying or reduced habitual spending). By comparing their roles in shaping QE transmission, we elucidate how pandemic-specific factors amplified or mitigated macroeconomic outcomes in small open economies like New Zealand. The shocks applied in the below analysis are consistent with those defined in Section 3.4.2.1. Specifically, the asset purchase shock simulates an LSAP shock by raising the central bank's bond holdings from 6% to 32%, reflecting New Zealand's quantitative easing program implemented in 2020.

3.4.4.1 Comparative Analysis of International Capital Frictions (ϕ)

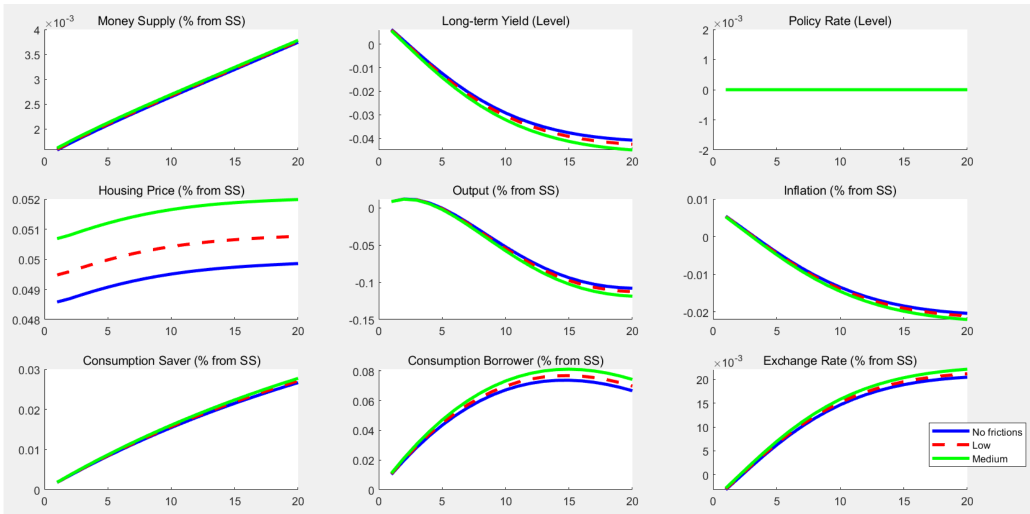


Figure 3.14 – Comparative Analysis of International Capital Frictions

The sensitivity analysis of ϕ, a parameter governing international capital flow frictions or foreign exchange risk premiums, reveals economically significant dynamics. Under quantitative easing shock, variations in ϕ (no friction: $\phi = 1.0$, low friction: $\phi = 1.0022$, medium friction: $\phi = 1.005$) exhibit minimal divergence in exchange rate responses during the initial quarters. Specifically, the absence of frictions ($\phi = 1.0$) induces marginally sharper currency depreciation early in the shock, reflecting lower barriers to capital outflows. However, by the 8th quarter, the frictionless scenario results in the weakest currency appreciation, exacerbating foreign debt burdens for borrowers and suppressing their consumption (6.3% deviation vs. 7% under medium friction). In contrast, housing prices demonstrate very significant sensitivity to ϕ: quarterly deviations rise from 4.85% ($\phi = 1.0$) to 5.05% ($\phi = 1.005$), indicating that higher frictions amplify asset price volatility as savers reallocate funds to domestic real estate.

The parameter ϕ acts as an important lever for international financial conditions. When $\phi > 1$, it introduces implicit costs, such as capital controls or risk premiums, that alter cross-border borrowing and pricing dynamics. These frictions reduce exchange rate fluctuations by dampening speculative capital flows, thereby moderating imported inflation pressures. For borrowers, higher ϕ exacerbates liquidity constraints by inflating the real cost of foreign-denominated debt (via b' adjustments in Equations 8–9), which suppresses consumption despite marginally stabilizing the currency. Savers, however, benefit from redirected investments into housing, driving price surges that widen wealth inequality.

The muted early-stage exchange rate responses across ϕ values suggest that QE's liquidity injection initially dominates frictional effects. Over time, however, the absence of frictions ($\phi = 1.0$) allows self-reinforcing capital flight, undermining monetary policy transmission and borrower welfare. This underscores the dual role of ϕ: while moderate frictions ($\phi = 1.002 - 1.005$) enhance financial stability by curbing excessive volatility, excessive restrictions ($\phi \gg 1$) risk restraining growth. Policymakers must calibrate ϕ to balance exchange rate management, debt sustainability, and asset market stability, a task complicated by the inherent difficulty in empirically pinning down risk premium parameters.

The COVID-19 pandemic amplified global financial uncertainties, significantly elevating risk premiums associated with international capital flows, reflecting tighter capital controls or investor demands for higher compensation to hold foreign assets. Elevated ϕ dampened speculative capital outflows, stabilizing the exchange rate but redirecting liquidity toward domestic markets. Savers, facing higher implicit costs of foreign investments, disproportionately reallocated portfolios into housing—a perceived safe-haven asset. This surge in demand exacerbated pre-existing housing supply rigidities, driving prices upward.

3.4.4.2 Comparative Analysis of Habit Persistence Parameter (ε_c)

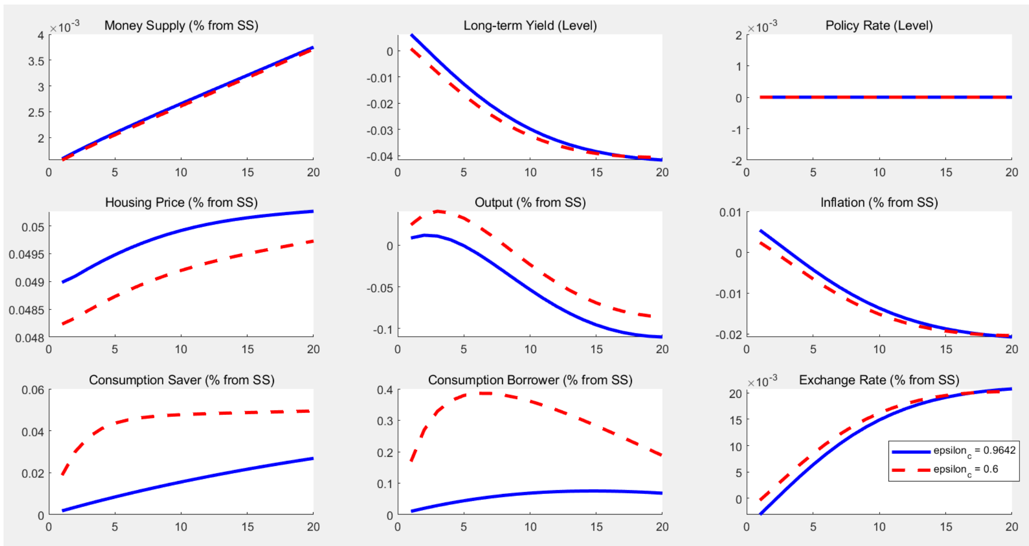


Figure 3.15 – Comparative Analysis of Habit Persistence Parameter (ε_c)

This analysis compares the macroeconomic effects of the quantitative easing shock under two scenarios: the benchmark model (calibrated with $\varepsilon_c = 0.9642$, reflecting strong habit persistence based on pre-pandemic New Zealand data) and an alternative scenario with moderate habit persistence ($\varepsilon_c = 0.6$), which captures potential shifts in consumer behaviour during the pandemic, such as reduced habitual consumption or increased flexibility in spending patterns (e.g., panic buying followed by rapid adjustments).

Consumption of borrowers peaks at a 38.6% deviation from steady-state under moderate habit persistence ($\varepsilon_c = 0.6$), significantly higher than the benchmark (4.9%). Borrowers, constrained by collateralized debt, exhibit heightened sensitivity to income and asset price fluctuations. Lower habit persistence amplifies their marginal propensity to consume (MPC), as current utility becomes less tied to past consumption levels. Consumption of savers rises modestly to 4.9% deviation (vs. 2.69% in the benchmark), reflecting their smoother intertemporal optimization. With weaker habits, savers reallocate resources toward current consumption rather than adhering to past patterns. Housing inflation declines slightly from 4.9% to 4.8%. Borrowers' increased consumption may divert resources from housing holdings, moderating housing price growth. Inflation falls (0.24% vs. 0.54% in the benchmark), while long-term bond yields decline more sharply. Lower ε_c enhances households' responsiveness to real interest rates, amplifying the QE-induced portfolio rebalancing toward bonds. This suppresses term premiums and reinforces yield compression. Currency depreciation moderates due to reduced capital outflows, GDP increases to 2.416% above steady-state (vs. 0.838% in the benchmark), driven by stronger consumption.

The results align with theoretical insights from Carroll (2000) and Deaton (1992), where weaker habit persistence (lower ε_c) reduces the "consumption inertia" that typically dampens short-term responses to shocks. Borrowers, facing binding collateral constraints, experience a larger MPC increase, as their consumption becomes more sensitive to temporary income gains or relaxed borrowing limits (Iacoviello, 2005). Savers, though less constrained, still adjust consumption due to lower utility penalties for deviating from past levels. The muted housing price response reflects competing forces: weaker demand for housing offsets QE-driven portfolio shifts into real estate. Meanwhile, lower long-term yields stem from enhanced monetary policy transmission—reduced habits amplify the intertemporal substitution effect, making households more responsive to interest rate changes. Finally, GDP gains arise from the combined effects of consumption-driven demand, and reduced financial frictions in credit markets. This analysis underscores the important role of habit persistence in shaping QE effectiveness, particularly in economies with credit-constrained households. During crises, temporary declines in ε_c, as observed in pandemic-induced behavioral shifts—can amplify stimulus impacts but also introduce trade-offs between consumption volatility and inflationary pressures.

3.5 Conclusion

This chapter examines how unconventional monetary policy, particularly quantitative easing (QE), influences housing prices in a small open economy with the housing market. This model incorporates financial frictions in the form of borrowing constraints and integrates housing as part of household investment decisions, with households subject to borrowing constraints on mortgage borrowing. Using a dynamic stochastic general equilibrium (DSGE) model tailored to New Zealand's pandemic-era conditions, we isolate the portfolio rebalancing channel of QE and evaluate its macroeconomic effects. The model incorporates the concept of imperfect substitutability of assets and demonstrate that large-scale asset purchases (LSAPs) significantly compressed long-term bond yields, driving a reallocation of funds into housing markets and fueling a 4.9% quarterly surge in housing prices—consistent with New Zealand's 20-30% annualized post-2020 housing boom. This demand-side stimulus, amplified by inelastic housing supply, generated wealth effects that boosted savers' consumption and net worth. However, it also exposed borrowers, constrained by foreign-denominated debt, to exchange rate volatility, exacerbating financial fragility.

Welfare analysis highlighted stark distributional asymmetries. Savers benefited disproportionately from wealth effects tied to housing appreciation and liquidity injections, whereas borrowers faced escalating debt burdens due to exchange rate pass-through and rigid credit constraints. In the medium run, savers gained 45% (peak) in welfare, while borrowers suffered a 50% (peak) decline, exacerbating pre-existing wealth inequality.

The analysis further incorporates a collateral constraint tightening shock (simulating macroprudential policies such as reduced loan-to-value ratios) to address risks posed by QE-driven housing inflation. This intervention succeeded in cooling speculative demand, reducing housing prices by 0.16% quarterly and stabilizing markets. However, it revealed critical trade-offs: while savers benefited from redirected investments into bonds and capital goods (yielding 2% output growth), borrowers faced severe consumption contractions (-20% welfare loss) due to binding credit constraints. These distributional asymmetries underscore the dual challenge of curbing asset bubbles while safeguarding vulnerable households, a tension evident in New Zealand's post-2021 macroprudential tightening.

Additionally, pandemic-specific insights emerge. Elevated international capital frictions during the pandemic redirected liquidity into domestic real estate, further inflating prices amid global uncertainty. Reduced consumption habit persistence amplified QE's short-term efficacy, as Weaker habits elevated borrowers' marginal propensity to consume, driving a 38.6% consumption deviation. Borrowers' increased consumption diverts resources from housing investment, slightly moderating housing price growth. QE's success in stimulating fundamental macroeconomics (e.g., output, inflation) relied on complementary macroprudential tools to mitigate financial stability risks, emphasizing the need for coordinated frameworks.

The findings align with SVAR findings on QE's dominance in post-pandemic housing dynamics and broader literature (Chen et al., 2012; Harrison, 2011, 2012) but deepen understanding of structural mechanisms (e.g., portfolio rebalancing, heterogeneous households, and open-economy linkages) in small open economies. While QE achieved its core objectives—mitigating ZLB constraints, lowering yields, stimulating demand, and averting deflation—it also entrenched systemic risks in housing markets. This underscores the necessity of pairing unconventional monetary tools with targeted macroprudential measures (e.g., dynamic LTV ratios) and structural reforms to address supply bottlenecks. Future research should explore optimal policy mixes to balance growth, stability, and equity in housing-dominated economies.

Chapter 4

Housing Prices and Unemployment in Search-and-Matching Model

4.1 Introduction

The interplay between housing market dynamics and labor market outcomes has garnered significant attention following the 2008–2010 financial crisis, particularly due to the pronounced co-movement between collapsing house prices and surging unemployment rates. As illustrated in Figure 1, this inverse relationship is a feature of business cycles, with recessions underscoring its empirical salience. Prior studies, such as those by Liu et al. (2013), Mian and Sufi (2014) and Pinter (2015) and Sterk (2015) all emphasize the role of housing wealth shocks in amplifying macroeconomic volatility and highlight the mechanisms: unemployment erodes household equity, impairing mortgage affordability, while housing market distress triggers "fire sales," exacerbating labor market dislocation. Unemployment also makes it more difficult to make the down payment required for a new mortgage loan. These dynamics are further complicated by credit constraints and labor mobility frictions. For instance, Ingholt (2017) demonstrates that elevated housing prices and tight credit conditions reduce labor mobility, dampening job competition across regions and inflating wage pressures, thereby paradoxically sustaining higher unemployment.

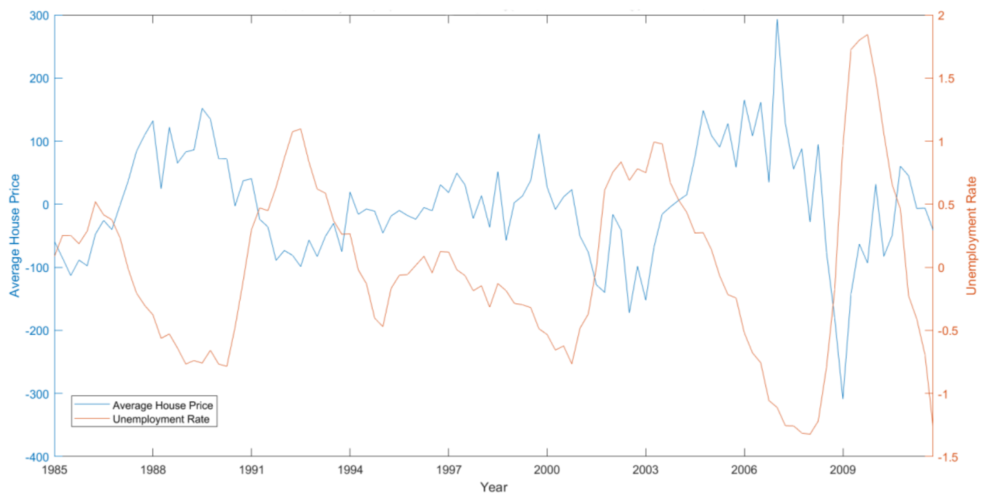


Figure 4.1 – Unemployment Rate and Average House Price Index for the U.S. 1985-2011 Data are from Federal Reserve Economic Data (FRED). Both series are seasonally adjusted, deflated by the GDP deflator, converted to per capita terms and HP-filtered with $\lambda = 1600$

To disentangle these complex interactions, this chapter integrates housing and labor markets within a dynamic stochastic general equilibrium (DSGE) framework, incorporating search-and-matching frictions within the framework of Diamond (1982), Mortensen (1982), and Pissarides (1985). This approach, widely adopted to model labor market cyclicality and persistence (Shimer, 2005; Fujita and Ramey, 2007), posits that successful job matching in the labour market is a time-consuming and costly process that leads to friction between the search for the unemployed and the matching of job vacancies. By embedding these frictions into a DSGE model, we aim to quantify how housing demand shocks propagate through credit and labor channels, generating persistent co-movements in unemployment, consumption, investment, and housing prices.

A critical innovation lies in incorporating occasionally binding collateral constraints, which introduce asymmetry into the transmission of shocks. Guerrieri and Iacoviello (2017), drew inspiration from state-level and MSA-level data and developed a DSGE model to examine the asymmetric effects of financial frictions in a recession and in a boom. They pointed out that collateral constraints drive asymmetry in most economic activities and should be a crucial mechanism to explain the business cycle. The asymmetry originates from whether housing collateral constraints are binding or not, and can amplify shocks in financial markets. During a boom period, collateral constraints are more likely to be relatively slack, and growing housing wealth contributes only marginally to consumption growth, while in a recession, the tightening of borrowing constraints and zero lower bound (ZLB) restrictions exacerbate the recession situations, which could account for much of the decline in consumption. Therefore, it is meaningful to consider these two constraints, i.e. occasionally binding collateral constraints and ZLB constraints, when we study the interaction between labor market behaviors and housing prices in both boom and bust periods. Moreover, according to Guerrieri and Iacoviello (2017), shocks in the housing model with occasionally binding constraints can generate significant asymmetries as long as they affect housing prices or collateral capacity without relying on particular stochastic structures or housing demand shocks. Drawing on insights from Guerrieri and Iacoviello (2017), we model constraints that bind more tightly during recessions, amplifying downturns when housing collateral values plummet, while remaining slack during booms. This asymmetry, compounded by zero lower bound constraints, exacerbates consumption declines and labor market adjustments in crises.

Our framework features two distinct agents: workers (households) and capitalists. Workers supply labor and face unemployment risks, while capitalists—who own firms and hold productive assets—are subject to borrowing constraints tied to the collateral value of their housing wealth. This heterogeneity enables us to examine asymmetric responses across agents. When housing prices decline, capitalists' borrowing capacity contracts due to eroded collateral, forcing them to reduce investment and limit external financing. The resulting decline in capital accumulation lowers the marginal productivity of labor, diminishing firms' incentives to create new jobs. Concurrently, workers, who are insulated from direct credit constraints but exposed to labor market frictions, face reduced job-finding rates as firms post fewer vacancies. Consequently, unemployment rises through this dual mechanism: constrained capitalists curtail investment, while workers encounter fewer employment opportunities. In this way, this chapter also aims to shed light on individuals' consumption and labour supply decisions when faced with sudden changes in housing prices.

Calibrated to U.S. data, the model examines how housing demand shocks propagate through two distinct transmission channels to affect key macroeconomic variables, consumption, investment, hours worked (labor supply), unemployment, job vacancies, and housing prices. First, the credit channel operates through capitalists, who face borrowing constraints tied to the collateral value of their housing wealth. A decline in housing prices erodes this collateral, restricting capitalists' ability to secure external financing. This contraction in credit reduces investment, leading to lower future capital stock and diminished labor productivity. Second, the labor channel reflects wage bargaining stemming from workers' utility between consumption and housing. While workers supply labor and are shielded from direct credit constraints, their bargaining power adjusts sluggishly in response to shocks. This rigidity dampens wage declines during downturns, prompting firms to reduce vacancy postings disproportionately. Consequently, job-finding rates fall, amplifying unemployment volatility.

The remainder proceeds as follows: Section 2 reviews relevant literature; Section 3 employs a structural vector autoregression (SVAR) model to empirically characterize housing-labor market linkages; Section 4 outlines the model; Section 5 discusses calibration and results; Section 6 concludes.

4.2 Literature Review

Our study bridges two pivotal strands of macroeconomic literature: one examining collateral effects in housing markets, and the other analyzing search-and-matching frictions in labor markets. The first strand, rooted in the canonical framework of the New Keynesian DSGE model with the financial accelerator of Kiyotaki and Moore (1997) and Bernanke et al. (1999), emphasizes how financial frictions amplify shocks through balance sheet channels. Iacoviello's seminal contributions (Iacoviello(2004), Iacoviello(2005), Iacoviello and Minetti(2008), Guerrieri and Iacoviello (2015), Guerrieri and Iacoviello (2017)) formalize this mechanism within DSGE models, showing that housing price declines erode borrowers' collateral values, tightening credit constraints and propagating downturns. Housing prices fall, and then the net value of balance of constrained households and firms falls due to the increase in the real value of their outstanding debt obligations. The probability of default increases. Demand for assets falls, leading to a further fall in asset prices. This process dramatically amplifies the small, temporary initial shock and propagates the business cycle. Notably, Guerrieri and Iacoviello (2017) extend this framework to incorporate asymmetric effects of collateral constraints, which bind more severely during recessions, amplifying contractions while remaining slack in expansions. Their work underscores that financial accelerators operate differentially across shock types: demand shocks are amplified through increased borrowing capacity during booms, whereas supply shocks are dampened by inflationary pressures that reduce real debt burdens. Prices of consumer goods and assets rise when demand increases and this leads to an increase in the borrowing capacity of borrowers so that they can borrow and spend more. An increase in the price of consumer goods reduces the real value of debtors' outstanding debt obligations, which positively impacts their net worth. Since it is assumed that borrowers have a higher propensity to spend, aggregate demand increases and acts as an amplification mechanism for demand shocks. However, inflation dampens the effects of shocks that typically cause a negative correlation between output and inflation. Some other researchers also derive the effects of the housing market in general equilibrium models, such as Piazzesi et al. (2007), Favilukis et al. (2017), Liu et al. (2013).

Recent extensions explore occasionally binding constraints (OBCs), which introduce nonlinear dynamics into DSGE models, to demonstrate how OBCs generate endogenous boom-bust cycles, with credit frictions exacerbating downturns when collateral values collapse (Holden et al. (2020); Brzoza-Brzezina et al. (2015); Espino and Hintermaier (2004); Bluwstein (2017)). Methodologically, nonlinear solution techniques, such as piecewise linear methods (Guerrieri and Iacoviello, 2015 and Akinci and Queralt (2014)), regime-switching approaches (Binning and Maih, 2017), and global projection methods (Maliar and Maliar, 2015), have been critical in capturing these asymmetries. These advancements reveal that OBCs are essential for explaining persistence, amplification, and welfare consequences in housing-linked business cycles.

The second strand integrates labor market frictions into macroeconomic models, building on the search-and-matching framework of Diamond (1982), Mortensen (1982), and Pissarides (1985). This setup has been widely used in the field of macroeconomics and the labour market, as it provides a tractable framework for unemployment analysis. A considerable number of studies have integrated this setup into a DSGE model, such as Dolado, Motyovszki and Pappa (2021), Bodenstein, Kamber and Thoenissen (2018), Angelopoulos, Jiang and Malley (2017), Christiano et al. (2016) and Liu et al. (2013).

Recent empirical studies have rigorously examined the interplay between housing prices and unemployment, with seminal contributions from Mian and Sufi (2014) and Mian, Sufi, and Rao (2013). Focusing on the U.S. economy, Mian and Sufi (2014) leverage county-level data spanning 2006 to 2009 to analyze how regional variations in housing price declines impacted household balance sheets and labor markets.

This study makes a novel contribution to the literature by integrating dual occasionally binding constraints, collateral constraints and the zero lower bound on interest rates, into a unified DSGE framework with search-and-matching frictions. While prior work often examines these constraints in isolation, our model explicitly accounts for their joint non-linear effects and asymmetric propagation mechanisms across business cycles. Collateral constraints amplify housing price shocks during recessions by restricting borrowers' access to credit, while the ZLB exacerbates downward rigidity in monetary policy responses. Crucially, the interaction between these constraints generates state-dependent dynamics: during booms, slack collateral constraints and inactive ZLB lead to muted responses to positive shocks, while in recessions, binding constraints create a "double tightening" effect that deepens economic contractions.

Furthermore, we uncover bidirectional feedback loops between housing prices and unemployment, a mechanism underexplored in existing studies. Empirically, SVAR results reveal that unemployment shocks depress housing prices, which in turn tighten borrowing capacity and suppress consumption, further elevating unemployment. Theoretically, our model formalizes this loop through two channels:

- **Labor-to-Housing Channel:** Rising unemployment reduces household income and triggers fire sales of housing assets, depressing prices. Lower collateral values tighten borrowing constraints, forcing capitalists to curtail consumption and investment, which suppresses labor demand.

- **Housing-to-Labor Channel:** Housing price declines reduce capitalists' collateral capacity, limiting their ability to post vacancies. Search-and-matching frictions then prolong unemployment, as fewer vacancies lower job-finding rates and weaken wage bargaining power.

This bidirectional interaction is amplified by the dual constraints: the ZLB restricts monetary easing during housing-driven recessions, while binding collateral constraints magnify credit crunches. Our calibration shows that a 20% housing price decline raises unemployment by 0.3 percentage points, with effects persisting twice as long under dual constraints compared to single-constraint models.

By unifying these elements, our framework provides a more realistic account of the 2008–2010 crisis dynamics, where collapsing housing markets and spiraling unemployment reinforced each other. The model also explains why post-crisis recoveries are sluggish when ZLB binds, offering policy insights into the need for coordinated macroprudential and monetary interventions during dual-constraint regimes.

4.3 Motivating Empirical Facts

4.3.1 Structural Vector Autoregression (SVAR) model

This section presents the empirical results from a structural vector autoregression (SVAR) model, which aligns with the SVAR framework introduced in the previous chapter. The model employs key variables to be used in the DSGE model, aiming to provide preliminary empirical evidence on the dynamic relationship between unemployment and housing prices. To identify the system, we impose restrictions on the structural parameters using a recursive identification scheme based on Cholesky decomposition. Specifically, the structural matrix A is decomposed into a lower triangular matrix (with zeros above the main diagonal), where the ordering of variables reflects assumptions about contemporaneous causality. The variables are ordered as follows: unemployment, wages, job vacancies, investment, consumption, housing price, and output.

The ordering prioritizes unemployment first to reflect our focus on sudden labor market shocks, allowing all subsequent variables (e.g., wages, vacancies) to react contemporaneously to unemployment fluctuations. This choice is grounded in the hypothesis that labor market adjustments, such as firms revising hiring plans or households altering consumption in response to unemployment, occur faster than changes in aggregate demand or housing markets. The remaining sequence (wages $\rightarrow$ vacancies $\rightarrow$ investment $\rightarrow$ consumption $\rightarrow$ housing price $\rightarrow$ output) follows a causal chain consistent with historical decomposition results and standard macroeconomic transmission mechanisms: Wages respond directly to labor market conditions (unemployment). Job vacancies adjust to wage dynamics and firms' hiring decisions. Investment reacts to labor market signals (vacancies reflect firm confidence) and precedes consumption due to its role in business cycle propagation. Consumption follows investment, as household spending often lags labor market decisions. Housing price is ordered after consumption to capture its dual role as both a wealth effect (demand-side) and a collateral constraint channel. Output is placed last, as it aggregates the combined effects of all preceding variables.

4.3.2 Data

The analysis uses quarterly U.S. data from 2001Q1 to 2019Q4, sourced from the Federal Reserve Economic Database (FRED). All series are seasonally adjusted [1], deflated by the GDP deflator, converted to per capita terms, and detrended using the Hodrick-Prescott (H-P) filter to isolate cyclical components. Lag length selection balances four information criteria: Akaike's Final Prediction Error (FPE), Akaike Information Criterion (AIC), Hannan-Quinn Criterion (HQIC), and Schwarz's Bayesian Criterion (SBIC). FPE suggests two lags, AIC suggests 10 lags and HQIC/SBIC suggests 1 lag, we adopt 2 lags as a compromise: residuals under 1 lag exhibit non-white noise properties, and 10 lags destabilize the SVAR. This ensures parsimony while maintaining model stability and diagnostic adequacy. Data sources are detailed in Table 1.

[1] The original data that was not seasonally adjusted, has been seasonally adjusted using Census X13 in EViews.

Variable	**Source**	**Unit**	**Code Series**
Wage and salary	Fred	CPI Adjusted Dollars	LES1252881600Q
Job Openings	Fred	Level in Thousands	JTSJOL
Unemployment Rate	Fred	Percent	UNRATE
House Price Index	Fred	Index 1980:Q1=100	USSTHPI
Gross Private Investment	Fred	Dollars	GPDI
Consumption Expenditures	Fred	Dollars	PCEC
Gross Domestic Product	Fred	Dollars	GDP
Price Deflator	Fred	Index 2017=100	GDPDEF
Population	Fred	Level	B230RC0Q173SBEA

The data sources used in SVAR and DSGE calibration.

Table 4.1 – Data Sources

4.3.3 Results

Figure 2-4 presents the impulse response functions from the SVAR model [2].

[2] The SVAR results were generated with the VAR toolbox 2.0 developed by Ambrogio Cesa-Bianchi. Available: https://sites.google.com/site/ambropo/MatlabCodes

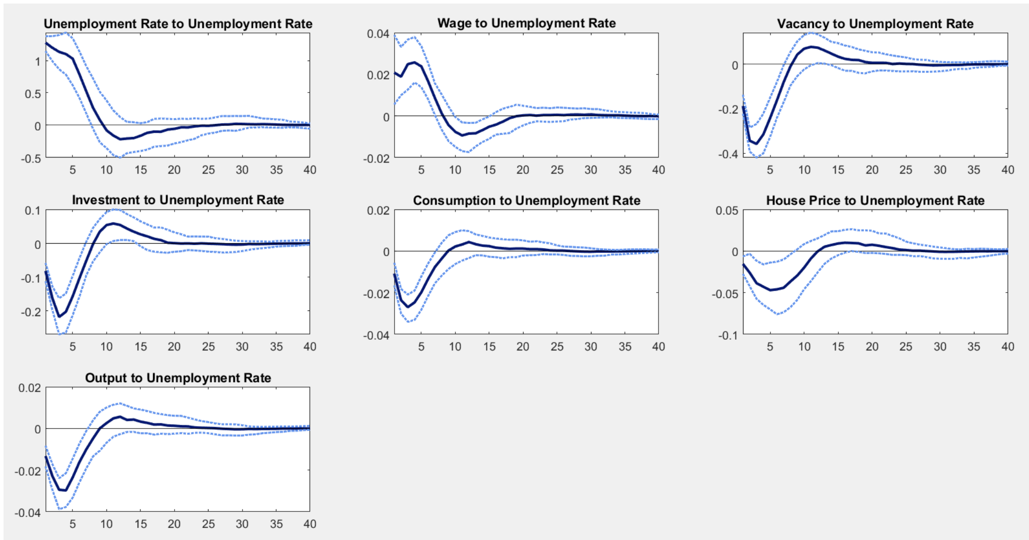


Figure 4.2 – Impulse Responses to a Unemployment Rate Shock

The above figures show the effects of a one-standard-deviation unemployment rate shock. The data used is quarterly data from FRED for the period 2001Q1 to 2019Q4. The dataset is transformed into logged per capita terms, with cyclical components extracted via the H-P filter with $\lambda = 1600$. The SVAR model with one lag prioritizes the unemployment rate in the Cholesky ordering. The blue dashed lines represent the 68% confidence intervals. The VAR toolbox calculates the lower and upper bounds using bootstrap.

The impulse response functions (IRFs) to a one standard deviation shock to the unemployment rate (equivalent to a 1.275% increase) reveal the following dynamics. Wages rise immediately by 0.02% (peak at 4 quarters). This effect fades as persistent unemployment erodes workers' bargaining power, consistent with the cyclicality of wage rigidity in Mortensen-Pissarides models (Shimer, 2005). In the short run, this counterintuitive short-term wage increase aligns with the insider-outsider theory (Lindbeck & Snower, 1986), where firms prioritize retaining existing workers during labor market disruptions, temporarily raising wages to mitigate morale loss or union-driven renegotiations. However, the effect dissipates as prolonged unemployment weakens workers' bargaining power. Job vacancies decline sharply (-0.359% trough) and recover after 8 quarters. The shock signals a decline in aggregate productivity (proxied by rising unemployment), reducing firms' expected returns to posting vacancies. A lower value of a filled job (due to weaker demand) suppresses vacancy creation. Recovery reflects the slow recalibration of matching efficiency as firms reassess hiring needs amid stabilizing demand. Investment contracts (-0.218% trough at 3 quarters). This echoes the complementarity between labor and capital: labor market slack reduces the marginal product of capital, dampening investment (Petrosky-Nadeau & Wasmer, 2013), and the accelerator effect (Samuelson, 1939), where labor market distress amplifies cyclical declines in investment. Consumption falls by -0.027% (trough at 3 quarters). Households curb spending due to income uncertainty (precautionary savings) and wealth erosion from rising unemployment, a mechanism central to modern Keynesian models (Kaplan et al., 2018). Concurrent housing price declines (via the collateral channel) tighten borrowing constraints, further suppressing consumption (Iacoviello, 2005). Housing prices drop immediately (-0.047% trough at 5 quarters). The initial decline stems from mortgage default risks and fire sales by liquidity-constrained households facing income loss (Guerrón-Quintana and Jinnai, 2022). Delayed recovery arises from persistent credit constraints: lower housing wealth reduces firms' collateral for hiring loans, creating a feedback loop between housing and labor markets (Liu et al., 2013). Output declines (-0.0294% trough at 3 quarters). This aggregates labor market dislocations, reduced investment, and weaker consumption, illustrating the multiplier effect of unemployment shocks (Blanchard & Katz, 1992).

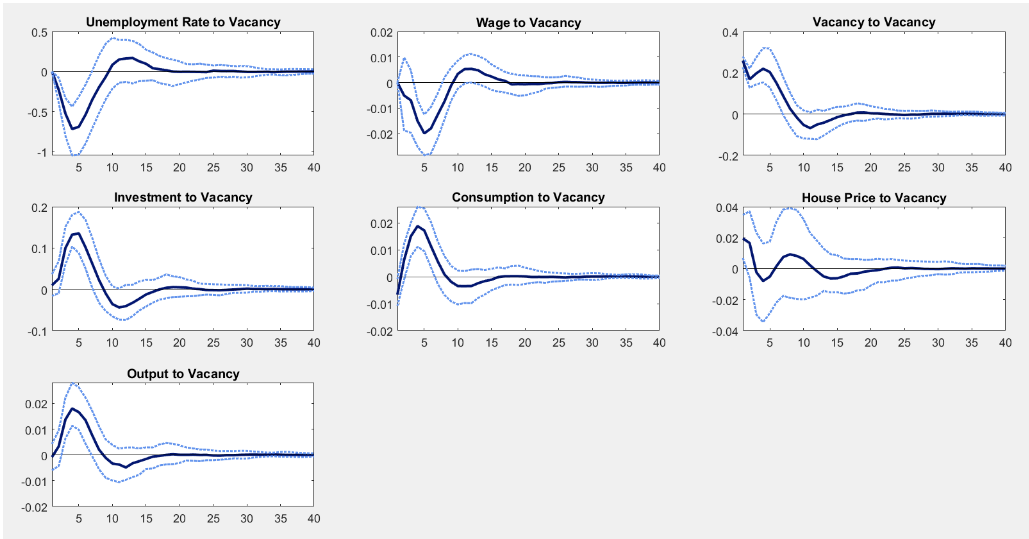


Figure 4.3 – Impulse Responses to a Job Vacancy Shock

The above figures show the effects of a one-standard-deviation job vacancy shock. The data used is quarterly data from FRED for the period 2001Q1 to 2019Q4. The dataset is transformed into logged per capita terms, with cyclical components extracted via the H-P filter with $\lambda = 1600$. The SVAR model with one lag prioritizes the unemployment rate in the Cholesky ordering. The blue dashed lines represent the 68% confidence intervals. The VAR toolbox calculates the lower and upper bounds using bootstrap.

The impulse response functions (IRFs) to a positive vacancy shock (0.279% increase) illustrate the interplay between labor market dynamics, housing prices, and aggregate demand. Unemployment declines significantly (-0.718% trough at 4 quarters). A rise in vacancies improves labor market tightness, accelerating job-finding rates through the matching function. This aligns with the Mortensen-Pissarides framework, where increased vacancy postings reduce unemployment persistence (Pissarides, 2000). Wages show insignificant decline (-0.0199% trough at 5 quarters). Despite falling unemployment, wage rigidity emerges, which dampens wage growth, consistent with Shimer (2005)'s critique of weak wage cyclicality in matching models. Investment rises (0.1353% peak at 5 quarters). Higher vacancies signal improved firm confidence in future productivity, triggering capital accumulation via the labor-capital complementarity channel (Petrosky-Nadeau & Wasmer, 2013). Firms expand capacity to align with anticipated labor input gains. Consumption increases (0.0188% peak at 4 quarters). Lower unemployment boosts household income expectations, reducing precautionary savings. Concurrently, the initial rise in housing prices (0.2% on impact) relaxes borrowing constraints via the collateral effect (Iacoviello, 2005), enabling debt-financed consumption. Housing prices rise initially (0.2%) but fluctuate insignificantly. The immediate increase reflects optimism from labor market improvements (higher vacancies signal economic resilience). Output expands (0.018% peak at 4 quarters). The combined effects of labor market tightening, capital deepening (higher investment), and consumption growth drive output gains, consistent with the Beveridge curve relationship in search models (Blanchard & Diamond, 1989).

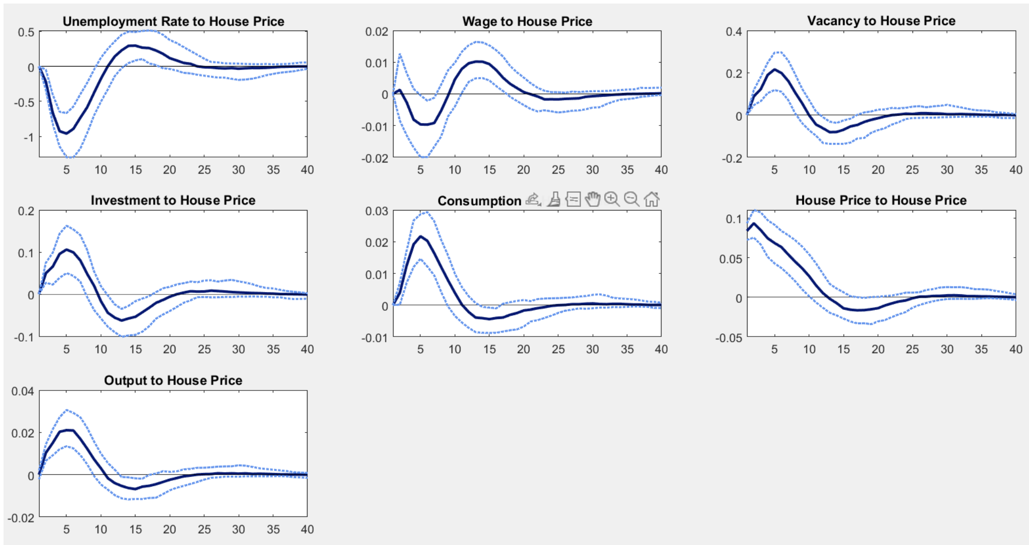


Figure 4.4 – Impulse Responses to a Housing Price Shock

The above figures show the effects of a one-standard-deviation housing price shock. The data used is quarterly data from FRED for the period 2001Q1 to 2019Q4. The dataset is transformed into logged per capita terms, with cyclical components extracted via the H-P filter with $\lambda = 1600$. The SVAR model with one lag prioritizes the unemployment rate in the Cholesky ordering. The blue dashed lines represent the 68% confidence intervals. The VAR toolbox calculates the lower and upper bounds using bootstrap.

The structural VAR results reveal the transmission of a housing price shock through labor markets and aggregate demand, consistent with search-and-matching dynamics and collateral channel mechanisms. Unemployment declines significantly (-0.96% trough at 5 quarters). Higher housing prices relax borrowing constraints for capitalists via the collateral channel (Iacoviello, 2005), enabling firms to fund vacancy creation. This reduces labor market frictions, accelerating job matching and lowering unemployment, as predicted by search models with credit-constrained firms (Wasmer & Weil, 2004). Vacancies rise (0.216% peak at 5 quarters). Improved firm balance sheets (from rising collateral values) incentivize vacancy postings, where lower financing costs boost vacancy creation despite wage rigidity. Wages dip slightly but insignificantly (-0.008% trough at 4 quarters). The muted response aligns with empirical evidence on sluggish wage adjustment shocks. Investment increases (0.11% peak at 5 quarters). Housing price gains raise the value of collateralizable assets, lowering credit spreads and stimulating capital expenditure (Liu et al., 2013). Firms expand capacity to align with expected demand growth from improved household wealth. Consumption rises (0.022% peak at 5 quarters). Housing wealth effects dominate. Households increase spending as rising home equity boosts perceived net worth (Case et al., 2005). This is amplified by easier credit access due to higher collateral values. Output expands (0.02% peak at 4 quarters). The combined effects of labor market tightening, capital accumulation, and consumption growth drive output gains, consistent with the financial accelerator mechanism (Bernanke et al., 1999).

4.3.4 Conclusions

The SVAR analysis provides critical empirical groundwork for the theoretical model's focus on labor market matching efficiency shock and housing price shocks, bridging labor market frictions and financial accelerator mechanisms. By simulating shocks to unemployment, vacancies, and housing prices, we uncover several key insights. Unemployment and vacancy dynamics act as proxies for matching efficiency shocks. The sharp rise in unemployment and decline in vacancies following an adverse unemployment shock mirror the effects of negative matching efficiency shocks in search-and-matching models. These shocks disrupt labor market equilibrium by severing employer-worker matches, amplifying hiring inertia and wage rigidity (Shimer, 2005). This inefficiency translates into reduced effective labor input, akin to a negative productivity shock in aggregate production functions. The decline in vacancies and investment reflects firms' lower expectations of marginal productivity of capital, as labor market slack diminishes the returns to capital accumulation (Petrosky-Nadeau & Wasmer, 2013). This echoes the labor-capital complementarity channel, where labor market disruptions indirectly suppress total factor productivity (TFP). Concurrently, the initial wage rigidity mimics a negative productivity shock by raising unit labor costs, squeezing profit margins, and delaying hiring—a feedback loop amplifying the downturn. The delayed recovery of vacancies aligns with the slow recalibration of matching efficiency post-shock, a sign of separation-driven labor market cycles. Housing price shocks propagate through dual channels. Rising housing prices relax credit constraints for firms and households, stimulating investment and consumption via collateral channel. Improved collateral values incentivize vacancy creation, indirectly mitigating unemployment persistence, a mechanism later formalized in the DSGE model's two-way interaction between housing and labor markets. The SVAR results highlight how the matching efficiency shocks (via unemployment/vacancy responses) and housing price shocks compound demand-side and supply-side fluctuations. For instance, housing price declines exacerbate consumption-investment slumps during unemployment spikes, while labor market tightening amplifies housing market recoveries. The SVAR's recursive identification and shock dynamics validate the DSGE model's structure, where the matching efficiency shocks dominate short-term labor market volatility, and housing price shocks act as financial accelerators.

4.4 Theoretical Model

Our model adopts a dynamic stochastic general equilibrium framework with search and matching frictions in the labor market. The economy features two types of infinitely-lived households: workers and capitalists. While both maximize expected lifetime utility, their economic roles differ fundamentally. The capitalist derives utility from consuming final goods and housing, and possesses an investment technology that converts consumption goods into capital goods. Financing occurs through internal funds and external borrowing, subject to collateral constraints tied to the capitalist's holdings of housing, following the seminal frameworks of Kiyotaki and Moore (1997), Iacoviello (2005) and Guerrieri and Iacoviello (2017). Capitalists own firms, which employ workers from households (workers) and rent capital for production. Workers consume goods and housing while participating in risk-free bond markets. A fraction of workers are employed, while others seek employment through a frictional labor market. Firms incur costs to post vacancies, and new employment matches form via a matching function combining job seekers and vacancies. Wholesale firms combine labor and capital to produce goods, posting vacancies filled through a Cobb-Douglas matching technology. To incorporate nominal rigidities, we distinguish between competitive wholesale firms (flexible prices) and monopolistically competitive final goods firms. Monetary policy follows a Taylor rule targeting inflation and output gaps, while housing demand shocks and investment-specific shocks propagate through collateral constraints and capital accumulation frictions. This setup jointly captures the interplay between housing markets, financial constraints, and labor market inefficiencies, providing a micro-founded framework to analyze business cycle dynamics amplified by credit-market imperfections.

4.4.1 Population Composition

The total household population N comprises capitalist (N^k) and worker (N^w) households, with respective shares $n^k = N^k/N$ and $n^w = 1 - n^k$. Population composition remains exogenous and time-invariant. The number of wholesale firms equals the capitalist count ($N^f = N^k$), aligning ownership structures.

4.4.2 Workers

Each household type maximizes its lifetime utility. For workers:

$$E_0 \sum_{t=0}^{\infty} \beta^t z_t (\Gamma_c log(c_t - \varepsilon_c c_{t-1}) + j_t \Gamma_h log(h_t - \varepsilon_h h_{t-1}) - \frac{1}{1+\eta} n_t^{1+\eta} N_t^e) \tag{4.1}$$

where E_0 is the expectation operator, $\beta \in (0,1)$ is the discount factor. The terms c_t, h_t are consumption, and house holdings, respectively. n_t denotes labor hours (the intensive margin), and N_t^e denotes employment (the extensive margin). ε_c and ε_h capture habits in consumption and house holdings, and terms $\Gamma_c = \frac{1-\varepsilon_c}{1-\beta\varepsilon_c}$ and $\Gamma_h = \frac{1-\varepsilon_h}{1-\beta\varepsilon_h}$ are scaling parameters. η is the labor supply aversion.

The inclusion of lagged consumption c_{t-1} and housing h_{t-1} in the utility function reflects the concept of habit formation in consumption behavior, a mechanism widely used in macroeconomic models to capture persistence in household preferences. Specifically, the term $log(h_t - \varepsilon_h h_{t-1})$ implies that a household's utility from housing depends not only on its current housing stock h_t but also on its past housing holdings h_{t-1}. The parameter $\varepsilon_h \in (0,1)$ measures the degree of habit persistence in housing consumption. Empirically, households develop habits in their housing consumption over time. For instance, if a household has historically lived in a larger house (high h_{t-1}), a sudden reduction to a smaller house ($h_t < h_{t-1}$) would generate disutility, even if the smaller house is objectively sufficient. This captures real-world behaviors where households resist abrupt changes in housing due to psychological attachment, adjustment costs (e.g., moving expenses), or social norms. The habit term $\varepsilon_h h_{t-1})$ also acts as a "reference level" of housing, and deviations from this reference (either upward or downward) directly affect utility. By embedding habit formation, the model better replicates observed persistence in housing markets and their spillovers to consumption, savings, and credit cycles. Households strive to smooth housing consumption over time to avoid utility losses from deviating too far from their habitual level. This creates inertia in housing demand, making households reluctant to adjust housing stocks quickly in response to shocks (e.g., housing price fluctuations). In models where housing serves as collateral (e.g., Iacoviello (2005)), habit formation amplifies the persistence of housing market shocks. A decline in housing prices reduces collateral values, forcing households to cut housing consumption, but habit persistence magnifies the utility loss, potentially exacerbating deleveraging and economic downturns. The term Γ_h

scales the marginal utility of housing to ensure stationarity. It adjusts for the intertemporal trade-off between current and future habit-adjusted housing consumption, balancing the discount factor and habit strength.

The term j_t is the adjustment parameter on housing, acting as a demand shock, which allows for exogenous disturbance to the marginal utility of housing. The term z_t captures a shock to intertemporal preferences that act as a consumption demand shock. These two shock processes follow:

$$log j_t = (1-\rho_j) log \overline{j}_t + \rho_j log j_{t-1} + u_{j,t} \tag{4.2}$$

$$log z_t = \rho_z log z_{t-1} + u_{z,t} \tag{4.3}$$

where $\overline{j}$ is the steady-state of housing preference, $u_{j,t}$ and $u_{z,t}$are i.i.d. white noise processes with mean zero and variance $\sigma_j^2$and σ_z^2. Workers maximize their expected utility subject to a budget constraint in real terms:

$$c_t + q_t h_t + b_t = w_t n_t N_t^e + q_t h_{t-1} + \frac{R_{t-1} b_{t-1}}{\pi_t} \tag{4.4}$$

where q_t denotes housing prices in units of consumption, b_t denotes the saving, and thus yield a riskless nominal return of R_t. w_t is the bargaining wage, $\pi_t = \frac{P_t}{P_{t-1}}$ is the gross inflation rate. The household begins with an initial endowment of $h_{t,-1}$ units of housing and no initial savings $b_{t,-1} = 0$. Rather than being determined unilaterally by the household, the variables n_t or N_t^e are instead established through labor market equilibrium, which incorporates search and matching frictions.

Solving this workers' maximization problem entails finding unknowns $\{c_t, h_t\}$that maximize the objective lifetime utility function subject to the budget constraint. The first-order conditions (FOCs) for workers are as follows:

$$U_{c,t} = \beta E_t(U_{c,t+1}\frac{R_t}{\pi_{t+1}}) \tag{4.5}$$

$$q_t U_{c,t} = U_{h,t} + \beta E_t[q_{t+1}U_{c,t+1}] \tag{4.6}$$

Equation (4.5) captures the intertemporal optimal consumption choice, where the worker balances the marginal utility of current consumption against the discounted expected marginal utility of future consumption, adjusted by the real interest rate. Equation (4.6) characterizes the optimal house holding condition, where the housing price equals the sum of the current utility from holding the housing asset and the discounted expected future utility.

4.4.3 Capitalist

The capitalist agent is denoted with a prime. The utility function of a representative capitalist is:

$$E_0 \sum_{t=0}^{\infty} (\beta')^t z_t(\Gamma'_c log(c'_t - \varepsilon_c c'_{t-1}) + j_t \Gamma'_h log(h'_t - \varepsilon_h h'_{t-1})) \tag{4.7}$$

The capitalists' maximization problem is in a similar manner but with a lower discount rate, $\beta' < \beta$. Their budget constraint in real terms is as follows:

$$c'_t + q_t h'_t + \frac{R_{t-1}b'_{t-1}}{\pi_t} + i_t = q_t h'_{t-1} + b'_t + r_{k,t}k_{t-1} + div_t \tag{4.8}$$

where b'_t denotes the capitalist's debt level, $r_{k,t}$ is the rental rate of capital, and div_t is profit transfers for owning final good firms.

The model incorporates a capital accumulation process where capitalists utilize an investment mechanism to convert consumption goods into productive capital. Specifically, the capital stock in period t, denoted k_t, is determined by the remaining capital after depreciation from the previous period and the net addition from new investments i_t. Depreciation reduces the existing capital by a fixed rate δ_k (where $\delta_k \in (0,1)$), while the investment process incurs quadratic adjustment costs proportional to deviations of investment growth from its steady-state rate.

$$k_t = a_t(i_t - \frac{\phi}{2}\frac{(i_t - i_{t-1})^2}{\bar{i}}) + (1-\delta_k)k_{t-1} \tag{4.9}$$

where $\bar{i}$ is the steady state of investment, parameter $\phi$is investment adjustment costs. The adjustment cost parameter quantifies the sensitivity of these costs to fluctuations in investment levels. a_t acts as an investment-specific shock:

$$loga_t = \rho_k loga_{t-1} + u_{k,t} \tag{4.10}$$

where $u_{k,t}$ is a i.i.d. white noise process with variance σ_k^2.

The capitalist agent funds consumption, new housing purchases, and capital investments through a combination of retained earnings and external debt. The lower discount factor β' incentivizes greater reliance on borrowing. To prevent unbounded leverage, external credit is constrained by the market value of their pledged collateral assets (house holdings). This collateral-based borrowing limit ensures that the credit constraint remains binding near the deterministic steady-state equilibrium, aligning with models of financial frictions such as those in Kiyotaki and Moore (1997). The interplay between impatient borrowing behavior and collateral valuation creates a self-reinforcing mechanism, where fluctuations in asset prices directly impact credit availability, investment capacity, and ultimately, macroeconomic stability. The borrowing constraint is as follows:

$$b'_t \leq \gamma\frac{b'_{t-1}}{\pi_t} + (1-\gamma)Mq_t h'_t \tag{4.11}$$

where $\gamma > 0$ quantifies the degree of inertia in the borrowing limit, while M represents the loan-to-value ratio in the steady state.

FOCs for capitals:

$$(1-\lambda_t)U_{c',t} = \beta' E_t(\frac{R_t - \gamma\lambda_{t+1}}{\pi_{t+1}} U_{c',t+1}) \tag{4.12}$$

$$q_t U_{c',t} = U_{h',t} + \beta' E_t(q_{t+1} U_{c',t+1}) + U_{c',t}\lambda_t(1-\gamma)mq_t \tag{4.13}$$

where λ_t is the Lagrange multiplier on the borrowing constraint.

Equation (4.12) characterizes the capitalist's intertemporal consumption trade-off. The term $\gamma\lambda_{t+1}$ captures the shadow cost of future borrowing constraints. Equation (4.13) governs the capitalist's housing investment decision. The left-hand side represents the utility cost of purchasing housing at price q_t, while the right-hand side includes three components: the direct utility from housing, the discounted future utility from resale value, and the marginal benefit of relaxed borrowing constraints due to housing collateral. This equation highlights how housing serves both as a consumption good and a collateral asset, with its valuation influencing credit access and intertemporal optimization.

Capital accumulations:

$$U_{c,t} q_{k,t}(1-\phi\frac{\Delta i_t}{\bar{i}}) = U_{c,t} - \beta E_t(U_{c,t+1} q_{k,t+1}\phi\frac{\Delta i_{t+1}}{\bar{i}}) \tag{4.14}$$

$$\frac{U_{c,t} q_{k,t}}{a_t} = \beta E_t(U_{c,t+1}(r_{k,t+1} + q_{k,t+1}\frac{1-\delta_k}{a_{t+1}})) \tag{4.15}$$

where $q_{k,t}$ is the Lagrange multiplier on the capital accumulation constraint.

Equation (4.14) characterizes the capital accumulation condition, which incorporates quadratic investment adjustment costs. The equation equates the marginal utility cost of investment (left-hand side) to the net marginal utility gain from increased future capital (right-hand side). Adjustment costs smooth investment fluctuations, ensuring gradual responses to shocks and aligning with observed inertia in capital formation. Equation (4.15) defines the optimal capital stock. The left-hand side represents the utility-scaled cost of investing in capital adjusted by an investment-specific shock, while the right-hand side captures the discounted expected returns from capital: the rental rate and the residual value of undepreciated capital. This equation ensures that capital accumulation balances current costs against future productivity gains, with shocks driving wedges between investment efficiency and returns.

4.4.4 Wholesale Firms

The wholesale sector operates under a Cobb-Douglas production technology to transform labor and capital into intermediate goods. The aggregate production function is specified as:

$$Y_t = A_t(n_t N_t^e)^{(1-\alpha)}(k_{t-1})^{\alpha} \tag{4.16}$$

where Y_t denotes aggregate output,$n_t N_t^e$ represents total effective labor input, combining hours worked (n_t, the intensive margin) and the employment rate (N_t^e, the extensive margin). k_{t-1} is the lagged capital stock rented from capitalists, and the parameter $\alpha \in (0,1)$is the output elasticity of capital. A_t is total factor productivity (TFP), which follows an exogenous autoregressive process:

$$logA_t = \rho_A logA_{t-1} + u_{A,t} \tag{4.17}$$

where $u_{A,t}$ is a i.i.d. white noise process with variance σ_A^2.

The maximization problem of wholesale firms is as follows:

$$max \frac{y_t}{x_{p,t}} - w_t(n_t N_t^e) - r_{k,t}k_{t-1} \tag{4.18}$$

where y_t is the firm-level output (distinct from aggregate Y_t), measured in wholesale goods.

$x_{p,t} = \frac{P_t}{P_t^w}$ is the price markup, reflecting the ratio of final goods prices (P_t) to wholesale prices (P_t^w).

The first-order condition for capital demand yields:

$$\alpha y_t = x_{p,t} r_{k,t} k_{t-1} \tag{4.19}$$

This equation equates the marginal product of capital to its real rental cost, scaled by the markup.

4.4.5 Matching

The labor market operates through a search-and-matching framework, where, at the beginning of period t, there are u_t unemployed workers searching for jobs and there are v_t vacancies created by firms in the labour market, and they interact to form new employment matches. The matching technology follows a Cobb-Douglas function:

$$m_t = \phi_{mt} u_t^{\phi_1} v_t^{1-\phi_1} \tag{4.20}$$

where m_t represents new matches formed via the matching function, $\phi_1 \in (0,1)$ governs the elasticity of matches to unemployment. ϕ_{mt} represents a stochastic efficiency shock following an autoregressive process:

$$log\phi_{mt} = (1-\rho_m) log\overline{\phi}_m + \rho_m log\phi_{m,t-1} + u_{m,t} \tag{4.21}$$

where $u_{m,t}$ is a i.i.d. process with variance σ_m^t

Market tightness is defined as

$$\theta_t = \frac{v_t}{u_t} \tag{4.22}$$

A lower θ_t indicates a tighter market (more workers per vacancy), reducing job-finding prospects for workers. The probability that an open vacancy will be filled by a jobseeker, the vacancy filling rate, is given by

$$\lambda_{f,t} = \frac{m_t}{v_t} \tag{4.23}$$

and its inverse, $1/\lambda_{f,t}$, measures the expected duration of a job vacancy before it is filled. The probability that an unemployed and actively searching worker will be matched with an open vacancy, known as the job finding rate, is given by

$$\lambda_{w,t} = \frac{m_t}{u_t} \tag{4.24}$$

and its inverse, $1/\lambda_{w,t}$, measures the expected duration of a search. N^e_{t-1} is the share of employed workers at the beginning of the period t. Before matching takes place, a fraction ρ_x of employed workers lose their jobs in each period and become unemployed, ρ_x is an exogenous separation rate. The fraction of workers who remain employed is $(1-\rho_x)N^e_{t-1}$. The total population size is normalized to one, the fraction of unemployed workers actively searching for jobs in period t is given by

$$u_t = 1-(1-\rho_x)N^e_{t-1} \tag{4.25}$$

The model assumes full labor force participation, meaning all unemployed workers (u_t) actively search for jobs each period, but whether they can get a job is determined by search and matching frictions. Employment dynamics are governed by a law of motion:

$$N^e_t = (1-\rho_x)N^e_{t-1} + m_t \tag{4.26}$$

The unemployed are defined as those workers who are searching but fail to secure a match, and thus, the unemployment rate is given by

$$U_t = u_t - m_t = 1 - N_t^e \tag{4.27}$$

The unemployment rate (U_t) influences future employment through the job finding rate ($\lambda_{w,t}$). A higher unemployment rate increases the pool of job seekers (u_t), which, for a given number of vacancies (v_t), reduces labor market tightness and lowers the job finding rate. Lower job finding rate further reduces future matches, perpetuating unemployment persistence. Firms control vacancies (v_t), but cannot directly determine hires (m_t). This introduces search frictions: firms weigh vacancy costs against the probabilistic returns from matching, affecting their optimal vacancy-posting decisions. Both households and firms cannot directly decide how many workers will enter employment in a given period, which affects the optimality conditions of households' and firms' problems.

The marginal profit of a worker p_t is derived as:

$$p_t = \frac{(1-\alpha)y_t}{N_t^e x_{p,t}} - w_t n_t \tag{4.28}$$

The model defines the value of a new employment match (g_t) as the sum of current-period marginal profits (p_t) and the discounted expected future value of the match:

$$g_t = p_t + E_t[\beta \frac{U_{c',t+1}}{U_{c',t}}(\rho_x V_{t+1} + (1-\rho_x)g_{t+1}] \tag{4.29}$$

where $U_{c',t}$ is the marginal utility of consumption for capitalists who own the firm. V_{t+1} is the value of a vacancy in the next period, and $\beta \frac{U_{c',t+1}}{U_{c',t}}$ represents the stochastic discount factor derived from the marginal utility of consumption for capitalists. This equation captures the firm's incentive to maintain a match: If a firm successfully match with a worker, it gains from the current period's production (p_t, marginal profits of an additional worker). In the following period, if the match retains (with probability $1-\rho_x$), the firm continues to receive the match value; if not, the firm retains the value of an open vacancy (V_{t+1}).

Firms incur a cost ζ to post vacancies, with the value of a vacancy (V_t) determined by:

$$V_t = -\frac{\zeta}{x_{p,t}} + \lambda_{f,t} g_t + (1-\lambda_{f,t}) E_t \beta \frac{U_{c,t+1}}{U_{c,t}} V_{t+1} \tag{4.30}$$

If the vacancy is filled (with a probability of $\lambda_{f,t}$, then the firm will obtain the match value g_t. Otherwise, the vacancy will be carried forward to the next period.

Under free entry ($V_t = 0$) for all t, Equation (4.29) and Equation (4.30) can be simplified to:

$$\frac{\zeta}{x_{p,t}} = \lambda_{f,t} g_t \tag{4.31}$$

$$g_t = p_t + E_t[\beta \frac{U_{c,t+1}}{U_{c,t}} (1-\rho_x) g_{t+1}] \tag{4.32}$$

This recursive structure highlights how firms value matches based on current profits and the discounted future surplus, conditional on match survival.

Once an employment match is formed, firms and workers negotiate wages through a Nash bargaining game, where the matching surplus is shared between the two parties. The firm's matching surplus (g_t) has already been specified above. Next, we focus on the worker's surplus. When a job match is established, workers receive a wage during the current period. In the subsequent period, there is a chance that they might lose their job with a probability of ρ_x and fail to find a new one with a probability of $1-\lambda_{w,t+1}$, where $\lambda_{w,t+1}$ denotes the job-finding rate at time $t+1$. If neither of these events occurs, workers continue in their current job and receive wage payments as usual. The value of being employed (g_t^e) and the value of being unemployed (g_t^u) are determined accordingly.

$$g_t^e = w_t n_t - \frac{\frac{1}{1+\eta} n^{1+\eta}}{U_{c,t}} + E_t[\beta \frac{U_{c,t+1}}{U_{c,t}} ((1-\rho_x(1-\lambda_{w,t+1}))g_{t+1}^e + \rho_x(1-\lambda_{w,t+1}) g_{t+1}^u)] \tag{4.33}$$

In the next period, an unemployed worker may find a job with a probability of $\lambda_{w,t+1}$. The expected value of being unemployed (g_t^u) is given by the following equation:

$$g_t^u = E_t[\beta \frac{U_{c,t+1}}{U_{c,t}}(\lambda_{w,t+1} g_{t+1}^e + (1-\lambda_{w,t+1}) g_{t+1}^u)] \tag{4.34}$$

Equation (4.34) captures the idea that the future value of being unemployed is a weighted average of the values of finding a job g_{t+1}^e and remaining unemployed g_{t+1}^u, with the weights being the job-finding probability and its complement, respectively. The factor $\beta \frac{U_{c,t+1}}{U_{c,t}}$ represents the stochastic discount factor, accounting for the intertemporal trade-off between current and future utility.

Wages are determined through a Nash bargaining process, where workers and firms share the surplus generated by the employment relationship. The bargaining problem is formulated as follows:

$$\max_{w_t} \vartheta(g_t^e - g_t^u) + (1-\vartheta) g_t \tag{4.35}$$

where ϑ represents the bargaining power of workers, while $1-\vartheta$ represents the bargaining power of firms. The objective function reflects a weighted sum of the worker's surplus $(g_t^e - g_t^u)$ and the firm's surplus g_t from the match.

Solving the Nash bargaining problem yields the optimal bargaining wage:

$$(w_t)^* n_t = \frac{\frac{1}{1+\eta} n^{1+\eta}}{U_{c,t}} + \vartheta g_t - E_t \beta \frac{U_{c,t+1}}{U_{c,t}}[(1-\rho_x)(1-\lambda_{w,t+1})\vartheta g_{t+1}] \tag{4.36}$$

This equation indicates that the negotiated wage consists of three components: The first term represents the marginal disutility of labor normalized by marginal utility, accounting for the cost of labor supply. The second term captures the worker's share of the firm's surplus, reflecting the bargaining power. The third term represents the discounted expected continuation value, accounting for the probability that the worker remains employed and the potential risk of not finding a job after separation.

4.4.6 Final Goods Firms

In the final goods sector, we assume the presence of Calvo-style price rigidities, meaning that not all firms can adjust their prices freely at every period. The final goods firms are owned by capitalists, who purchase wholesale goods and sell them at a markup $x_{p,t}$ over the marginal cost. Due to these price rigidities, the adjustment of prices to economic shocks becomes gradual rather than immediate.

The forward-looking Phillips curve that emerges from this setting is expressed as follows:

$$log(\frac{\pi_t}{\overline{\pi}}) = \beta E_t log(\frac{\pi_{t+1}}{\overline{\pi}}) - \varepsilon_\pi log(\frac{x_{p,t}}{\bar{x}_p}) + u_{p,t} \tag{4.37}$$

where $\overline{\pi}$ is the steady-state inflation rate, $\varepsilon_\pi = \frac{(1-\theta_\pi)(1-\beta\theta_\pi)}{\theta_\pi}$ measures how sensitive inflation is to deviations of the markup from its steady-state value $\bar{x}_p$, $u_{p,t}$ represents a price markup shock, capturing unexpected changes in the markup that can influence inflation. This expression reflects the degree of price rigidity θ_π, with a lower value of θ_π indicating greater flexibility in price adjustment.

4.4.7 Monetary Policy

The central bank's monetary policy is described by a modified Taylor rule, which takes into account the zero lower bound (ZLB) on nominal interest rates. The policy rule is given by:

$$C = max[1, R_{t-1}^{r_R}(\frac{\pi_t}{\overline{\pi}})^{(1-r_R)r_\pi}(\frac{Y_t}{\overline{Y}})^{(1-r_R)r_y}\overline{R}^{(1-r_R)}e_t] \tag{4.38}$$

where R_t denotes the nominal interest rate at time t, while $\overline{R}$ is the steady-state gross interest rate. r_R is the smoothing parameter that captures interest rate inertia, r_π and r_y represent the response coefficients of the interest rate to deviations in inflation and output from their respective steady-state levels ($\overline{\pi}$ and $\overline{Y}$). To account for exogenous shocks to monetary policy, we introduce a monetary policy shock, which follows an autoregressive process:

$$loge_t = \rho_R loge_{t-1} + u_{r,t} \text{ (} with \; u_{r,t} \sim N(0, \sigma_R^2)) \tag{4.39}$$

4.4.8 Equilibrium

In equilibrium, all markets clear. The good market clearing condition comes with the aggregate resource constraint.

$$Y_t = c_t + c'_t + [k_t - (1-\delta_k)k_{t-1}] + \zeta v_t \tag{4.40}$$

The total output produced in the economy equals the sum of total consumption, investment, and vacancy costs. ζv_t represents the cost of posting job vacancies, where ζ is the vacancy cost in terms of the final good.

The model follows the framework proposed by Guerrieri and Iacoviello (2017), where capitalists borrow directly from households. An upper borrowing limit is introduced to ensure financial stability. The debt market equilibrium is described as follows:

$$b_t = b'_t \tag{4.41}$$

where b_t denotes the equilibrium level of debt/bond. This setup implies that the total debt issued by capitalists is exactly held by households, ensuring balance in the bond market.

The housing market equilibrium condition ensures that the sum of housing owned by both types of households equals the fixed housing supply, which is normalized to 1:

$$h_t + h'_t = 1 \tag{4.42}$$

Fixing the housing supply allows the model to focus on the demand-side effects, which are often the primary driver of short- to medium-term fluctuations in housing prices. With supply fixed, any demand shock directly translates into price changes rather than quantity changes. This simplification is also rooted in the practical reality that the housing supply does not adjust quickly to changes in demand due to various constraints.

Transversality Conditions (TVCs) in dynamic economic models ensure that the value of assets or debts does not explode to infinity over time. The key TVCs are as follows:

Capital Accumulation TVC:

$$\lim_{t\to\infty} \beta'^{t} \cdot uc'_t \cdot qk_t \cdot k_t = 0 \tag{4.43}$$

This ensures that the discounted marginal value of capital stock k_t converges to zero, preventing over-accumulation of capital.

Bond Holding TVC:

$$\lim_{t\to\infty} \beta'^{t} \cdot uc'_t \cdot b_t = 0 \tag{4.44}$$

This implies that the present value of debt b_t does not grow faster than the discount rate, ruling out Ponzi schemes, borrowers cannot indefinitely roll over debt.

The equilibrium in the model is characterized as a situation where capitalists borrow up to their borrowing limit while job matches are formed according to the underlying matching technology. The equilibrium is represented as a sequence of optimal allocations $\{ c_t, h_t, n_t, N_t^e, b_t, b'_t, i_t, c'_t, h'_t \}_{t=0}^{\infty}$ for the two types of households, allocations $\{ Y_t, k_t \}_{t=0}^{\infty}$ for firms, labour market variables $\{ u_t, p_t, g_t, \lambda_{w,t}, v_t, w_t, \}_{t=0}^{\infty}$, and the sequence of values $\{ q_t, \pi_t, R_t, P_t, P_t^w \}_{t=0}^{\infty}$ that satisfy the above first-order conditions (FOCs) derived from optimization problems, the budget constraints for both types of households (one can be deducted due to the Walras' law), the market clearing conditions stated above.

4.5 Results from the Calibrated Model

This section presents the quantitative findings of the calibrated DSGE model, which integrates housing and labor market dynamics to examine their bidirectional interaction mechanisms in the U.S. economy from 2001Q1 to 2019Q4. The analysis proceeds in three stages: First, the calibration is detailed, emphasizing parameter identification through empirical moments. Second, baseline results are evaluated to quantify the propagation of housing demand shocks, labor market matching efficiency shocks and monetary policy shocks through credit and labor channels, with a focus on asymmetry during recessions and expansions. Finally, welfare analyses are conducted to compare the welfare impacts of monetary policy shocks on different household types, specifically contrasting workers/savers with capitalists/borrowers. This comparison highlights how monetary policy asymmetrically affects welfare distribution between these groups, shedding light on the heterogeneous effects of policy interventions in the presence of housing and labor market frictions.

4.5.1 Calibration

Leveraging U.S. time series data, including key macroeconomic variables such as GDP, unemployment rates, and housing prices sourced from the SVAR datasets constructed in Section 4.3, the model is further enriched with supplementary datasets to capture features of credit constraints, vacancy costs, and household balance sheets. The calibration strategy aligns with canonical DSGE literature, most of the parameters are also close to those most commonly used in the literature on US macro studies.

- **Inflation and Discount Factor (β, β', π):** We use the average market yield on U.S. Treasury securities as the risk-free rate. After adjusting for the average CPI inflation rate of 2% annually (0.5% quarterly), the worker's discount factor is set to 0.995, corresponding to a quarterly interest rate of 1% (annualized 4%). The steady-state inflation rate is set to 1.005 per quarter. To calibrate the capitalist's discount factor, we utilize FRED data: the fixed rate mortgage average of 5.04% annually translates to a quarterly rate of 1.26%. Based on this, the capitalist's discount factor is calculated as 0.9927. In this model, capitalists are assumed to have a lower discount factor (higher impatience) compared to workers.

- **Consumption Habit (ε_c):** The consumption habit parameter is estimated at 0.4423 based on an autoregressive model of quarterly consumption growth rates from 2001Q1 to 2019Q4, leveraging the FRED series Personal Consumption Expenditures (PCEC).

- **Housing Habit (ε_h):** We use the Real Private Residential Fixed Investment (PRFIC1) series from 2007Q1 (the earliest available data) to 2019Q4, yielding a first-order autoregressive coefficient of 0.660, reflecting the sluggish adjustment of housing stock to market shocks.

- **Labor Supply Disutility (η):** The labor supply aversion is set to 1.0, a standard value in macroeconomic literature with the need to replicate aggregate wage and employment fluctuations like Smets and Wouters (2007), Christiano et al (2005).

- **Housing Utility Weight (j):** The steady-state housing utility weight is calibrated to 0.1813, derived from the ratio of Personal Consumption Expenditures: Housing and Utilities to total consumption expenditures, Personal Consumption Expenditures (PCEC) series (FRED data, 2001Q1–2019Q4), capturing the steady-state share of housing in household utility.

- **Loan-to-value Ratio (M):** The loan-to-value ratio is set to 0.77, based on the average Original Loan-to-Value (LTV) of large bank mortgage originations (FRED series, 2001–2019).

- **Capital Share (α):** We depart from earlier literature (e.g., values around 0.3) and adopt 0.4, aligning with post-2000 trends documented by the U.S. Bureau of Labor Statistics (BLS), which show a structural decline in the labor share to approximately 0.6. This adjustment is consistent with recent studies such as Karabarbounis & Neiman (2014), which highlight the global decline in labor share due to technological and capital deepening trends.

- **Depreciation Rate (δ):** The depreciation rate is set to 0.01738 (quarterly), derived from annualized depreciation and amortization data (FRED series Corporations: Depreciation and Amortization) at 6.95%, converted to a quarterly rate. This value is slightly lower than the canonical macro literature benchmark of 0.025 to account for sector-specific durability trends in capital goods.

- **Price Stickiness (θ_π):** The price stickiness parameter is calibrated to 0.9182, following Guerrieri and Iacoviello (2017), Leeper et al. (2017), and Christiano et al (2005), where high values are necessary to replicate observed inflation persistence in the U.S. economy.

- **Debt Inertia (γ):** The debt inertia parameter is set to 0.6945, directly adopted from Guerrieri and Iacoviello (2017), reflecting the slow adjustment of household debt to income shocks, a critical feature for modelling credit market frictions.

- **Steady-State Price Markup ($x_{p,ss}$):** The steady-state price markup is calibrated to 1.1, aligning with canonical U.S. literature such as Smets and Wouters (2007), Christiano et al (2005) and Fernández-Villaverde et al. (2020), which standardize a 10% markup over marginal cost to match corporate profit margins.

- **Job Separation Rate (ρ_x):** The quarterly job separation rate is set to 0.144, calculated by scaling the monthly "Job Openings and Labor Turnover: Total Separations" rate of 3.6% (JOLTS data, 2000-2019) to a quarterly frequency. This value is broadly consistent with Blanchard and Galí (2010)'s estimate of 0.12.

- **Matching Elasticity (ϕ_1):** The matching elasticity parameter is assigned a value of 0.5, within the range empirically supported by Hall and Milgrom (2008), Gertler and Trigari (2009), and Petrongolo and Pissarides (2001), reflecting the efficiency of labor market matching processes.

- **Vacancy Posting Cost (ζ):** The vacancy posting cost is calibrated to 1.68 to replicate the 2001–2019 U.S. unemployment rate average of 5.98%, which also lies within the range estimated by the Society for Human Resource Management (SHRM).

- **Worker Bargaining Power (θ):** The worker's bargaining power is set to 0.3, following estimates by Christiano, Trabandt, and Walentin (2011), which balance wage rigidity and labor market flexibility.

- **Taylor Rule Coefficients (r_π, r_y, r_R):** For monetary policy, the Taylor rule coefficients are adopted from Guerrieri and Iacoviello (2017), calibrated for the U.S. economy during 1976–2011: the inflation response (r_π) is 1.7196, the interest rate smoothing parameter (r_R) is 0.5509, and the output gap response (r_y) is 0.0944. These values reflect the Federal Reserve's historical prioritization of inflation control over output stabilization, consistent with its dual mandate framework.

- **Household Segmentation (n^k):** Based on U.S. Bureau of Labor Statistics (BLS) data for 2016, approximately 15.0 million people (10.1% of total U.S. employment) were self-employed. Assuming self-employed households represent capitalists, the worker-to-capitalist ratio is calibrated to 9:1 in the model.

Tables 2 and 3 summarize the calibrated parameter values and steady-state relationships.

Description	**Parameter**	**Value**
Structural Parameters		
discount factor (worker)	β	0.995
discount factor (capitalist)	β'	0.9927
habits in consumption	ε_c	0.4423
habits in house holdings	ε_h	0.66
capital depreciation rate	δ_k	0.01738
labor supply aversion/disutility	η	1
housing utility weight	j	0.1813
population shares of capitalist	n^k	0.1
investment adjustment costs	ϕ	4.02
degree of inertia in the borrowing limit	γ	0.6945
loan-to-value ratio	M	0.77
steady-state price markup	$x_{p,ss}$	1.1
capital share in production	α	0.4
elasticity of job matches	ϕ_1	0.5
vacancy posting cost	ζ	1.68
job separation rate	ρ_x	0.144
worker bargaining power	θ	0.3
monetary policy response to inflation	r_π	1.7196
monetary policy response to output gap	r_y	0.0944
monetary policy inertia	r_R	0.5509
sensitivity of inflation to markup	θ_π	0.9182

Table 4.2 – Calibrated Structural Parameters

4.5.2 Impulse Responses Results

4.5.2.1 Transmission of a housing market shock to the labor market

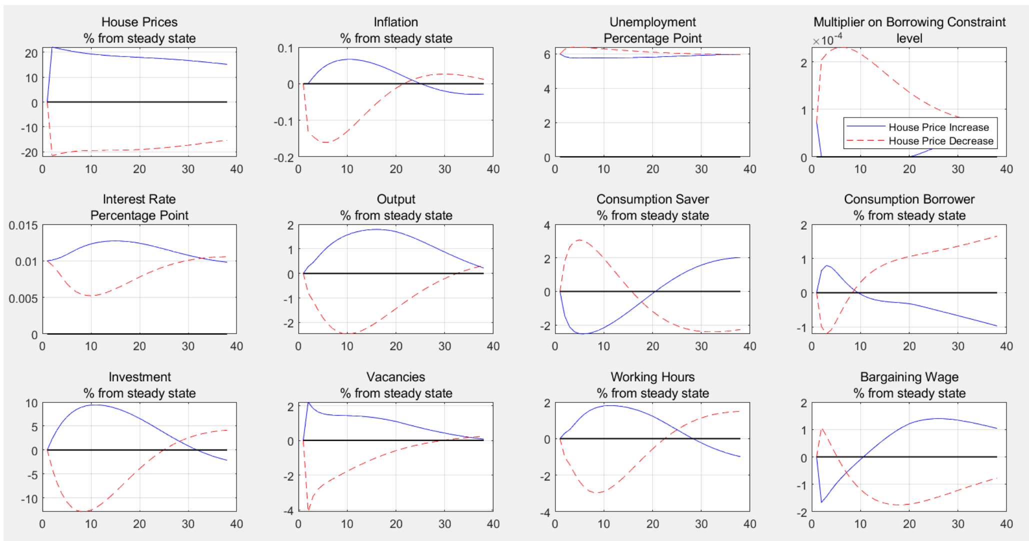


Figure 4.5 – Asymmetries Responding to Positive and Negative Housing Preference Shocks

The impulse response functions to ±20% housing demand shocks demonstrate significant asymmetric effects in the model, aligning with the results of the baseline model of the theoretical framework of Guerrieri and Iacoviello (2017). A positive housing price shock relaxes borrowing constraints for capitalists, as rising collateral values (linked to housing wealth) unlock additional credit capacity. This leads to a surge in investment (peaking at 9.39%) and consumption (peaking at 0.8%), driven by capitalists leveraging inflated collateral to fund projects. Consequently, output rises by 1.7%, supported by increased capital accumulation and labor demand. However, savers' consumption declines (-2.5%), likely due to income reallocation toward housing purchases, crowding out non-housing expenditures. Inflation remains muted (0.067% peak), as higher investment boosts supply, while the policy rate rises modestly to 1.267% under the Taylor rule's response to mild inflationary pressures. Labor markets tighten, with unemployment dropping 0.2 percentage points and vacancies increasing 2%, as firms expand hiring in anticipation of higher profitability.

Conversely, a negative housing price shock triggers binding borrowing constraints, amplifying the downturn. Collateral values collapse, forcing capitalists to deleverage and slash investment (-13%), which depresses capital stock and labor productivity. Output contracts sharply (-2.5%), reflecting the financial accelerator effect, where credit constraints exacerbate the initial shock. Savers' consumption rises (3%), potentially due to reduced housing costs and precautionary savings, while borrowers' consumption falls (-1.2%) as constrained access to credit limits their ability to smooth spending. Inflation drops significantly (-0.16%), driven by fire-sale deflation and collapsing demand. The policy rate declines to 0.522%, with the zero lower bound limiting monetary stimulus. Labor markets deteriorate, with unemployment rising 0.4 percentage points and vacancies plunging 4%, as firms retrench amid falling profitability.

The asymmetry in outcomes stems from the nonlinear role of collateral constraints. During housing booms, relaxed constraints allow credit-driven expansions, but the multiplier on borrowing constraints falls to zero, indicating that additional price gains do not further ease credit conditions. The multiplier remains at zero for an extended period. Once the constraint becomes slack, the borrowing constraint channel only works in expectation. As a result, the increase in consumption by capitalists is not as significant as their response to the fall in housing prices of the same magnitude. In busts, binding constraints magnify losses, as falling collateral values force abrupt deleveraging. This asymmetry is compounded by labor market frictions: wage rigidity and matching inefficiencies prolong unemployment adjustments. For instance, bargaining wages decline (-1.658%) during booms as firms gain leverage in negotiations, while rising slightly (1.075%) during busts due to reduced job opportunities and heightened worker bargaining power in surviving matches. Workers' hours increase during booms (1.79%) to smooth consumption but plummet (-2.958%) in busts due to income effects.

These dynamics highlight the critical interplay between housing markets, credit constraints, and labor demand. Housing price shocks propagate through two channels:

The Collateral Channel

Fluctuations in housing prices directly affect capitalists' borrowing capacity through collateral constraints. A rise in housing prices increases the value of borrowers' housing holdings, relaxing borrowing constraints and enabling greater investment. This is captured by the Lagrange multiplier on the borrowing constraint dropping to zero during positive shocks, signaling that collateral values are sufficient to fully unlock credit capacity. Capitalists leverage inflated collateral to fund investments, driving up capital accumulation and labor demand. Conversely, a housing price decline erodes collateral values, forcing capitalists to deleverage sharply. The resulting credit crunch reduces investment, which lowers future capital stock and labor productivity. This mechanism is formalized in the equation for the value of a new employment match (g_t).

Recall the equation (4.28) and (4.29), the former represents the marginal product of labor. A decline in investment reduces future capital, lowering the marginal product of workers and thereby diminishing the value of new matches. Firms respond by posting fewer vacancies, shifting the Beveridge curve inward and raising equilibrium unemployment. This feedback loop between collateral values, investment, and labor demand underscores the financial accelerator effect, where credit constraints amplify shocks asymmetrically—stronger in downturns than expansions.

The Labor Channel

Figure 6 shows how the decline in the value of new employment affects the labour market. The Beveridge curve depicts the inverse relation between unemployment and job vacancies, which can be derived from Equation (4.20); Equation (4.25) and Equation (4.26)

$$v = \left(\frac{\rho_x}{\overline{\phi}_{mt}(1-\rho_x)} \frac{(1-u)}{u^{\phi_1}}\right)^{\frac{1}{1-\phi_1}} \tag{4.45}$$

The job creation curve is the positive relation between unemployment and vacancies, which can be derived from Equation (4.20); Equation (4.23) and Equation (4.31)

$$v = u(\overline{\phi}_{mt} \frac{gx_p}{\zeta})^{\frac{1}{\phi_1}} \tag{4.46}$$

The intersection of the Beveridge curve and the job creation curve determines the equilibrium unemployment (u) and vacancies (v). As the match value falls, the economy shifts to a new equilibrium with reduced job vacancies and an increased unemployment rate.

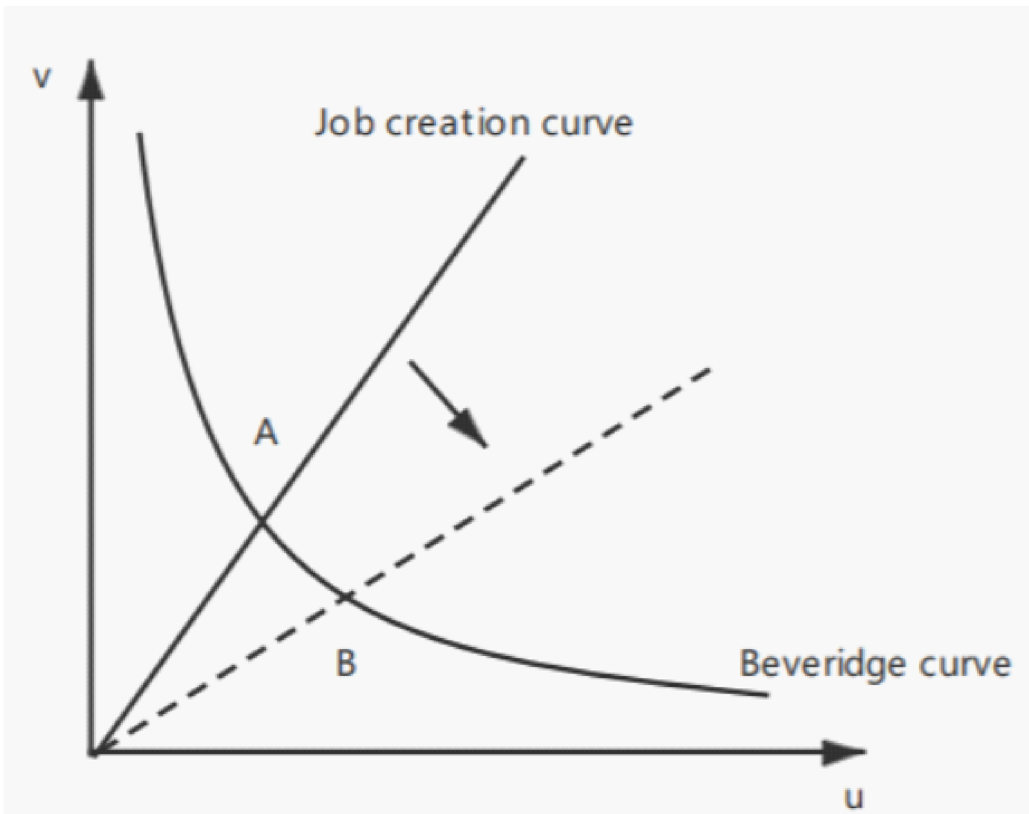


Figure 4.6 – Transmission of the New Employment Value

Shifts in vacancies and wage bargaining further propagate shocks to consumption and output. When housing prices fall, the decline in match value (g_t) reduces firms' incentive to post vacancies, as shown in the job creation curve. Fewer vacancies lower the job-finding rate, prolonging unemployment duration and weakening workers' bargaining power. This is reflected in the Nash bargaining wage equation. A lower g_t reduces wages directly, while a higher unemployment duration $1/\lambda_{w,t}$ further depresses wage demands. These dynamics create a dual drag: reduced labor income suppresses household consumption, while lower wages squeeze firms' profit margins, exacerbating the decline in vacancies. During housing booms, relaxed credit conditions temporarily offset these effects, but wage rigidity limits upward adjustments, resulting in muted labor market gains compared to the severe losses during busts.

The model underscores the necessity of macroprudential policies, such as countercyclical loan-to-value adjustments, to mitigate collateral-driven volatility. Tightening loan-to-value ratio during booms can curb excessive leverage, while easing it during busts alleviates credit crunches. However, monetary policy faces limitations near the zero lower bound, as seen in the asymmetric policy rate responses.

4.5.2.2 Transmission of a Labor Market Shock to the Housing Market

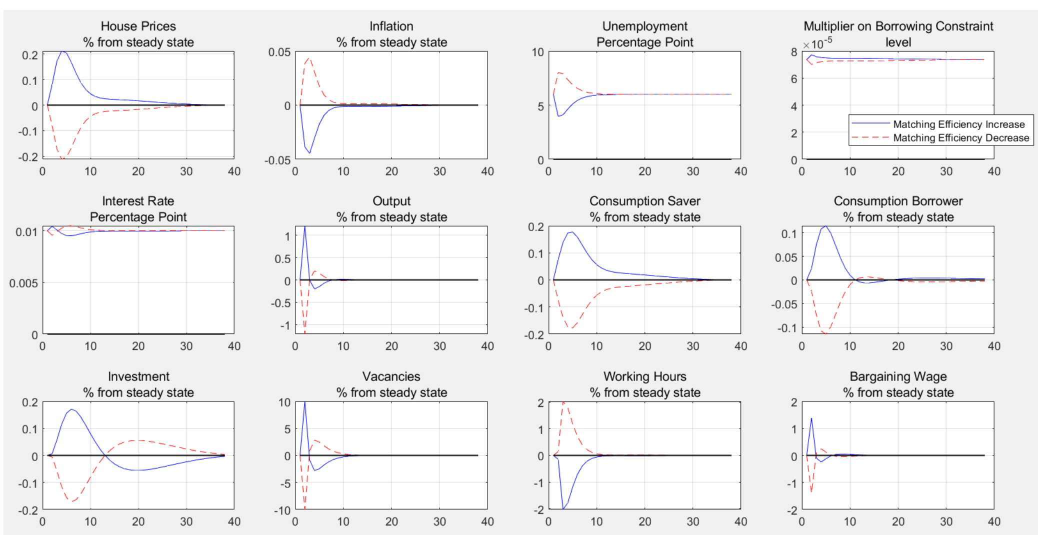


Figure 4.7 – Asymmetries Responding to Positive and Negative Matching Efficiency Shocks

The impulse response functions to positive and negative matching efficiency shocks reveal symmetric and transient effects on macroeconomic variables, driven by the interplay of labor market dynamics and linear adjustments in the absence of binding constraints. A positive matching efficiency shock initially reduces unemployment by 2 percentage points, as the improved matching technology allows firms to fill vacancies more efficiently, reflected in the matching function. Firms respond by aggressively posting vacancies (+10%), anticipating higher returns from hiring. However, this surge in vacancies is short-lived: as unemployment declines rapidly, the pool of job seekers shrinks, reducing the marginal benefit of additional vacancies. By the second quarter, vacancies revert to baseline and temporarily overshoot (-2.816%) due to firms' overadjustment to the now-tighter labor market. Employment stabilizes quickly through the law of motion, limiting prolonged labor market imbalances.

Wages rise modestly (+1.391%) in the short term, driven by improved worker bargaining power during the initial hiring surge, as formalized in the Nash wage equation. However, wage gains dissipate as labor market tightness normalizes. Working hours decline (-2.027%) because firms prioritize hiring new workers (extensive margin) over extending hours for existing employees (intensive margin), a rational response to lower hiring costs.

The temporary boost in employment raises output (+1.2094%) and investment (+0.1711%), as firms capitalize on higher labor input and optimistic expectations. Yet the effects on output fade within two quarters, as the shock's transience causes the economy to revert to steady state. Consumption for both borrowers and savers increases marginally (0.1145% and 0.1772%, respectively), supported by incremental collateral gains and profit growth (for capitalists), and higher labor income and mild wealth effects (for workers) from rising housing prices (+0.2117%). The rise in housing prices increases the value of capitalists' housing holdings, directly relaxing their borrowing constraint. Higher collateral values allow capitalists to borrow more, financing additional investment and consumption. Improved matching efficiency raises employment and labor input, boosting output via the production function. Increased output enhances capitalists' profits (from firm ownership) and rental income, supporting higher consumption. For workers, the shock reduces unemployment and raises wages temporarily through tighter labor markets. Workers' consumption increases due to higher disposable income from wages. Rising housing prices also levate workers' perceived wealth (even without direct borrowing), encouraging marginal consumption increases despite their budget constraint.

Inflation dips (-0.0446%) potentially due to two mechanisms: increased labor supply elasticity dampens wage pressures, and higher output alleviates demand-pull inflation. The policy rate shows minimal movement (±0.04–0.05 percentage points), as the Taylor rule responds weakly to transient inflation and output deviations.

The symmetry between positive and negative shocks arises because neither the borrowing constraint nor the zero lower bound binds during these episodes. Without binding constraints, the model behaves linearly, producing mirror-image responses. The transience of labor market fluctuations stems from the shock's temporary nature (low persistence $\rho_m = 0.6$) and rapid market adjustments—firms and workers recalibrate expectations swiftly, preventing prolonged disequilibrium. The low persistence parameter for the matching efficiency shock is empirically and theoretically justified to reflect the transient nature of such shocks in real-world labor markets. Empirical evidence suggests that improvements in matching efficiency, such as temporary policy interventions or technological advancements in job-search platforms, typically exert short-lived effects, peaking within a few quarters before dissipating as markets adapt. This aligns with the model's calibration, where $\rho_m = 0.6$ implies an annual decay rate of approximately 40%, consistent with observed labor market dynamics. Firms and workers also rapidly recalibrate their expectations and behaviors in response to these shocks: a temporary rise in matching efficiency prompts firms to post vacancies aggressively, but as unemployment declines and the pool of job seekers shrinks, the marginal returns to additional vacancies diminish, leading to quick market rebalancing. Unlike housing or financial shocks, which propagate through persistent mechanisms like binding collateral constraints or hysteresis effects, matching efficiency shocks lack endogenous amplification channels. Their linear transmission path, uncomplicated by occasionally binding constraints or zero lower bound restrictions, ensures symmetric and fleeting impacts. Furthermore, this parameterization aligns with established literature, where matching efficiency shocks are often modeled with low persistence (0.5-0.7) to distinguish their transient effects from structural shocks (Guerrieri & Iacoviello (2017); Gertler & Trigari (2009); Blanchard & Galí (2010)).

4.5.2.3 Transmission of a Monetary Policy Shock

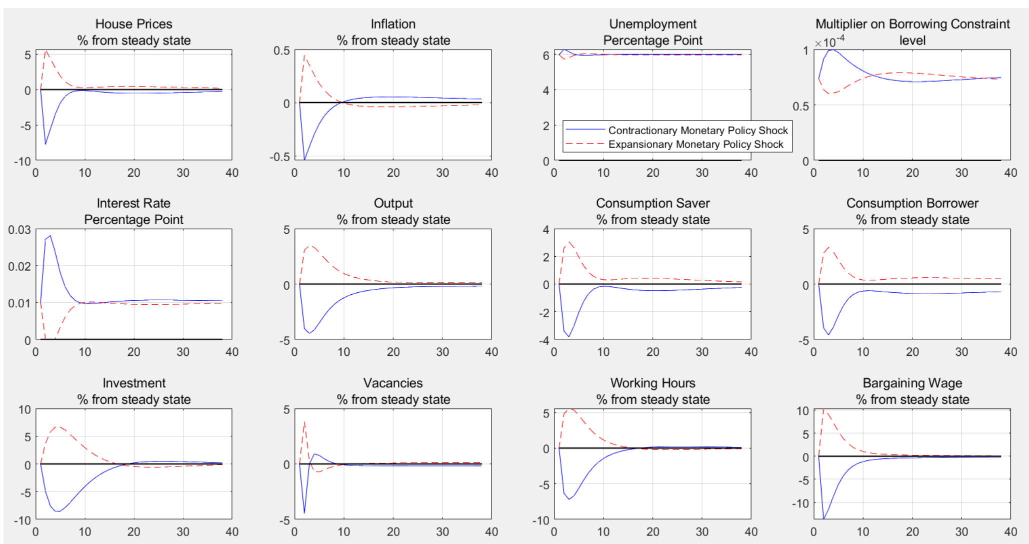


Figure 4.8 – Asymmetries Responding to Positive and Negative Monetary Policy Shocks

The impulse response functions to contractionary and expansionary monetary policy shocks reveal asymmetric effects due to the zero lower bound constraint, fundamentally altering the transmission mechanisms of monetary policy.

Contractionary Shock (Interest Rate ↑)

When the central bank raises the policy rate from 1% to 2.8%, the economy faces prolonged contraction. Borrowers (capitalists) experience a sharper decline in consumption (-4.588%) compared to savers (-3.808%), as higher interest rates tighten borrowing constraints, reducing capitalists' access to credit for investment and consumption. Output drops significantly (-4.462%) and remains depressed for over 20 quarters, reflecting persistent declines in investment (-8.573%) and capital accumulation. Housing prices (-7.737%) and inflation (-0.5425%) also fall but recover within 9 quarters, as lower demand gradually stabilizes. Labor markets adjust faster: unemployment rises 0.3 percentage points and vacancies drop (-4.443%), both reverting within 2-3 quarters, respectively. However, working hours (-7.2%) and wages (-13.68%) exhibit prolonged slumps (14–20 quarters), driven by wage rigidities and firms' reluctance to expand hours amid uncertain demand.

Expansionary Shock (Interest Rate ↓ to 0%)

At the ZLB, the policy rate hits zero for 3 quarters, limiting stimulus efficacy. Borrowers' consumption rises more (3.3%) than savers' (3.044%), as capitalists exploit cheaper credit to invest in housing and capital goods, leveraging relaxed collateral constraints. Housing prices (+5.677%) and wages (+10.347%) rise persistently (20+ quarters), reflecting sticky expectations and delayed adjustments in asset markets. Output increases by 3.464%, and investment rises by 6.62%, with both variables remaining above steady-state levels for over 14 quarters. Inflation rises modestly by 0.4436% and returns to its steady-state level within 9 quarters. Labor markets recover swiftly: unemployment drops 0.3 percentage points and vacancies rise (+3.817%) within 2–3 quarters, yet working hours (+5.556%) and wages take longer to stabilize (14–20 quarters), highlighting the interplay between nominal rigidities and real adjustments.

The ZLB truncates the expansionary shock's impact, as rates cannot fall below zero to amplify stimulus. This creates a lopsided policy toolkit: contractionary shocks operate unimpeded, inflicting deep, prolonged damage via credit constraints and demand destruction, while expansionary shocks face diminishing returns at the ZLB. The prolonged increase in output and investment reflects the liquidity and credit channel of monetary policy. Borrowers' stronger response to expansionary policy stems from their reliance on credit—lower rates temporarily ease collateral constraints, boosting investment and consumption. Savers, less dependent on leverage, benefit marginally from higher asset prices (housing) but face limited income growth due to wage stickiness. The asymmetry in housing and wage persistence arises from forward-looking expectations: households and firms anticipate prolonged ZLB conditions, delaying rebalancing of portfolios and wage contracts. Meanwhile, labor markets adjust faster due to firms' flexibility in vacancy postings and hiring, whereas capital-intensive variables (investment, output) suffer hysteresis from disrupted accumulation paths. The temporary inflation spike stems from demand-pull effects: lower interest rates boost consumption and investment, raising aggregate demand. However, inflation's swift return to steady state within 9 quarters highlights anchored expectations and sluggish wage-price spirals. Firms and households perceive the ZLB-induced stimulus as temporary, moderating price-setting behavior. Additionally, improved matching efficiency in labor markets (via rising vacancies and falling unemployment) alleviates supply-side bottlenecks, preventing sustained inflationary pressures.

In essence, the ZLB amplifies deflationary risks during contractions but mutes recovery during expansions, embedding downside skewness into business cycles. This underscores the need for complementary policies (e.g., macroprudential tools, fiscal stimulus) to mitigate the ZLB's constraints and address the asymmetric scars of monetary shocks.

4.5.2.4 Wage Rigidities

The results align closely with the empirical patterns observed in the SVAR model, particularly in explaining the seemingly counterintuitive short-term rise in wages amid increasing unemployment. In the SVAR analysis, an unemployment shock initially triggers a temporary wage increase (e.g., 0.02% on impact), which appears paradoxical under standard labor market theories. The DSGE model rationalizes this phenomenon through two intertwined mechanisms rooted in search-and-matching frictions and wage bargaining dynamics. First, during the early phase of a downturn, firms facing sudden labor market disruptions may prioritize retaining existing workers to avoid morale loss or rehiring costs, a behavior consistent with the insider-outsider theory. This "insider power" allows employed workers to negotiate higher wages temporarily, even as unemployment rises. Second, wage rigidity embedded in the Nash bargaining process—formalized in Equation (4.36)—delays downward adjustments. The bargaining wage depends not only on the current match value but also on expected future conditions. When a negative shock hits, firms anticipate prolonged weakness in labor demand, but workers' bargaining power does not erode immediately due to institutional or contractual rigidities. Consequently, wages exhibit short-term stickiness or even modest increases before declining as unemployment persists and job-finding rates deteriorate. This asymmetry mirrors historical patterns observed in the U.S., where wage cyclicality is muted in initial phases of recessions but steepens as downturns deepen.

However, the baseline model generates an implausibly large decline in the bargaining wage (-13.68%) following a contractionary monetary policy shock, starkly contradicting empirical evidence on wage rigidity, a well-documented phenomenon where wages adjust sluggishly to economic shocks due to institutional factors like multi-period labor contracts, collective bargaining agreements, and menu costs. To address this disconnect, we propose a modified specification, as a sensitivity analysis, incorporating wage rigidities through a partial adjustment mechanism, aligning the model with real-world wage dynamics.

Specifically, we introduce persistence into wage-setting by assuming:

$$w'_t = \rho_w w'_{t-1} + (1-\rho_w)(w'_t)^* \tag{4.47}$$

where w'_t is the actual wage, w'_{t-1} is the lagged wage (capturing historical inertia), $(w'_t)^*$ is the desired wage determined by Nash bargaining in the frictionless baseline model, $\rho_w \in [0,1]$ governs the degree of wage stickiness.

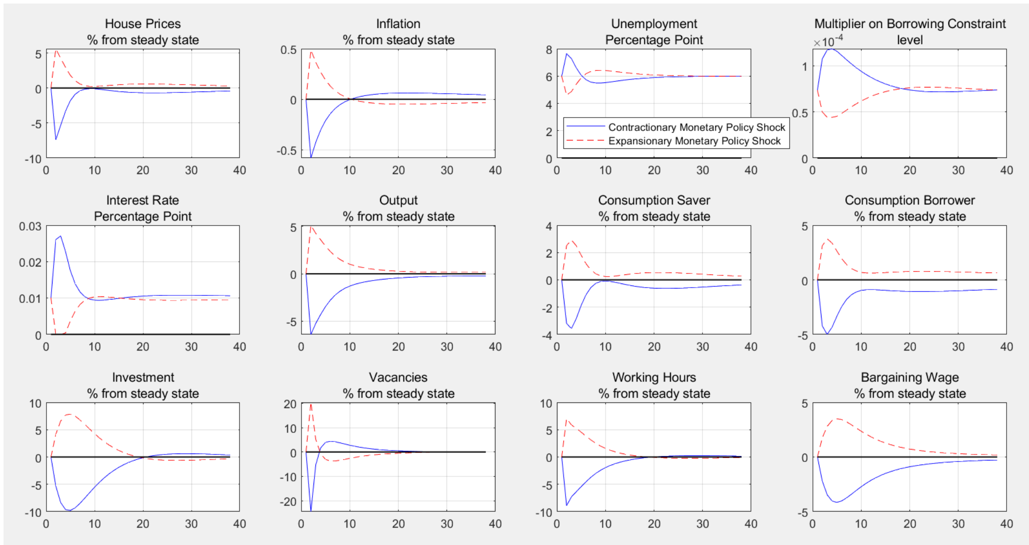


Figure 4.9 – Asymmetries Responding to Positive and Negative Monetary Policy Shocks in the Presence of Wage Rigidities

The impulse response functions under symmetric monetary policy shocks reveal that introducing wage rigidities fundamentally alters labor market dynamics while leaving non-labor variables (e.g., consumption, inflation) relatively unchanged. Under a contractionary monetary policy shock, wages decline moderately (-4.155% vs. -13.68% without rigidities), while expansionary shocks yield smaller wage increases (+3.498% vs. +10.347%). However, labor market variables exhibit amplified volatility. Vacancies plunge sharply (-24.48% vs. -4.443%) during contractions and surge (+20.386% vs. +3.817%) during expansions. Unemployment rises significantly (+2.6 p.p. vs. +0.3 p.p.) in contractions and falls more (-1.3 p.p. vs. -0.3 p.p.) in expansions. Working hours show larger swings (-8.9% and +7.068% vs. -7.2% and +5.556%).

Wage rigidities shift firms' adjustment burden from wage renegotiation to quantity adjustments (vacancies, hours, layoffs). When wages cannot flexibly adjust (due to contracts or institutional frictions), firms respond to shocks by altering hiring/firing decisions and work hours rather than resetting wages. In contractions, with wages sticky downward, firms face higher real labor costs despite falling demand. To cut costs, they slash vacancies (-24.48%) and hours (-8.9%), leading to sharper unemployment spikes (+2.6 p.p.). Reduced hiring depresses the job-finding rate, prolonging unemployment. In the rigid-wage model, smaller wage cuts (-4.155% vs. -13.68%) prevent a collapse in workers' disposable income, marginally cushioning consumption but failing to offset the vacancy-driven labor market collapse. During expansions, wage rigidities limit upward adjustments (+3.498% vs. +10.347%), prompting firms to expand vacancies (+20.386%) and hours (+7.068%) aggressively to meet rising demand. This accelerates job creation, reducing unemployment (-1.3 p.p.). However, sluggish wage growth restrains household income gains, tempering consumption and output growth despite labor market improvements. Output and investment respond minimally because capital adjustment costs and price rigidities dominate their dynamics. Firms prioritize labor quantity adjustments (vacancies, hours) over capital restructuring in the short run, as altering the capital stock incurs quadratic costs (e.g., adjustment costs). Additionally, inflation anchoring limits demand-driven output fluctuations. Wage rigidities act as a transmission amplifier for labor markets but a stabilizer for non-labor variables. By forcing firms to rely on quantity adjustments, rigidities magnify unemployment and vacancy volatility while muting wage cyclicality—a pattern consistent with empirical evidence from economies with strong labor institutions (e.g., the Eurozone).

4.5.2.5 Welfare Analysis

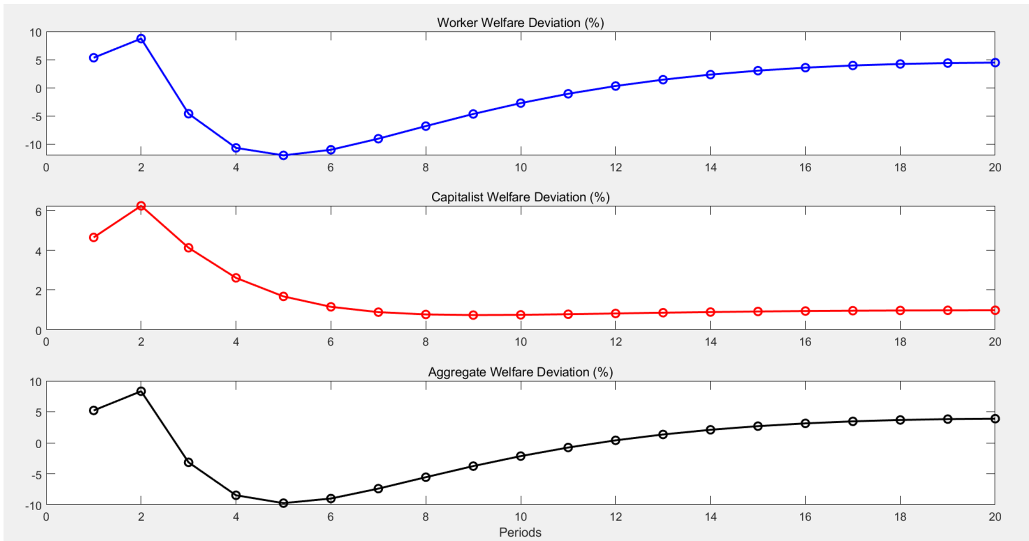


Figure 4.10 – Welfare Analysis for the Contractionary Monetary Policy Shocks

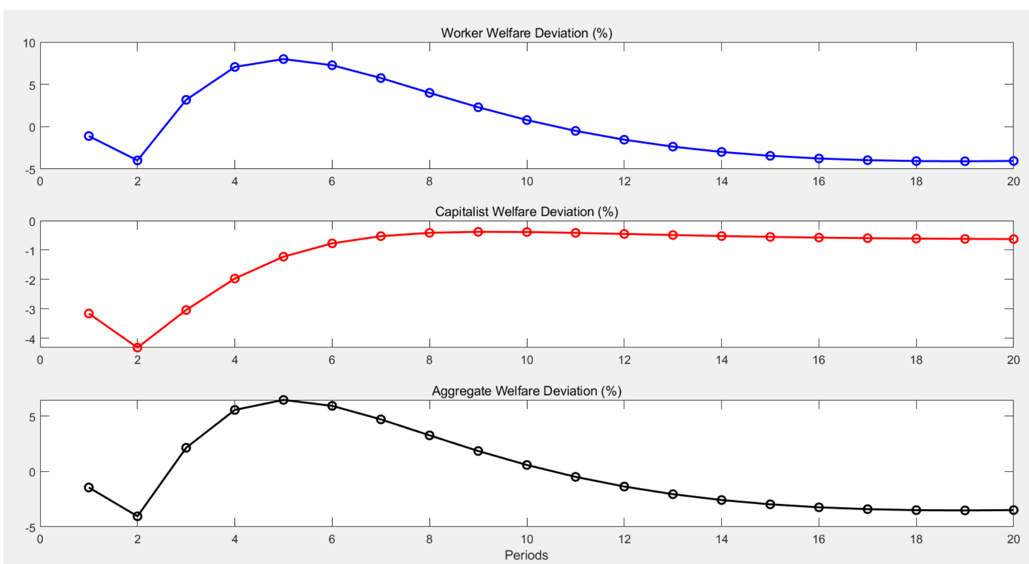


Figure 4.11 – Welfare Analysis for the Expansionary Monetary Policy Shocks

Following a contractionary monetary shock, workers' welfare initially rises by 8.733% in the first two quarters but sharply declines to -12% by the fifth quarter before recovering to positive territory after 12 quarters. Capitalists' welfare also increases initially (6.247%) but remains above zero throughout. The aggregate welfare, dominated by workers (90% population share), mirrors their trajectory, peaking at 8.321% before plummeting to -9.737% and eventually stabilizing. In contrast, under an expansionary shock constrained by the ZLB, workers' welfare first drops (-3.988%), rebounds to 7.99% by the fifth quarter, then slowly declines below zero after 11 quarters. Capitalists experience deeper initial losses (-4.315%) and fail to recover fully even after 20 quarters. Aggregate welfare similarly oscillates, reflecting the dominance of workers' delayed but transient gains.

The welfare dynamics under monetary policy shocks exhibit distinct asymmetric patterns between workers and capitalists, driven by interactions between interest rates, savings returns, housing markets, and labor conditions. Under contractionary monetary shocks, the medium-term deterioration in workers' welfare is predominantly driven by cascading labor market dislocations. While workers initially benefit from higher deposit returns due to elevated interest rates, these gains are quickly overshadowed by rising unemployment and wage suppression as the shock propagates through the economy. By the third to sixth quarters, firms, facing tightened borrowing costs and declining collateral values—curtail investment and postpone hiring. This reduces the marginal productivity of labor, leading to a downward spiral in job creation. Vacancies plummet (e.g., -4.443% in the model), and unemployment rises (e.g., +0.3 percentage points), eroding workers' bargaining power. Nominal wage rigidities exacerbate the problem: wages fail to adjust downward swiftly, but firms compensate by cutting hours worked (-7.2%) or delaying raises. Capitalists capitalize on falling housing prices (-7.737%) to strategically acquire undervalued properties to expand housing holdings in anticipation of future price rebounds. This enhances their long-term wealth prospects, offsetting initial credit constraints.

The housing market's role amplifies this dynamic. Falling housing prices (-7.737%) tighten capitalists' collateral constraints, forcing them to slash external financing for business operations. This limits firms' capacity to sustain payrolls, accelerating layoffs. Workers, now facing diminished job security and income, reduce consumption (-4.588%), further depressing aggregate demand and reinforcing the labor market downturn. By the fifth quarter, these interlinked effects peak, driving workers' welfare to its nadir (-12%). Thus, the medium-term welfare collapse reflects not just falling bargaining wages but structural damage to production resilience, underscoring the asymmetric burden of monetary tightening on workers relative to asset-holding capitalists.

Conversely, under expansionary shocks constrained by the zero lower bound, where rate cuts to 0%, workers face an early welfare decline as near-zero interest rates erode savings returns, shrinking household liquidity (-3.988% welfare drop in the first two quarters). However, subsequent labor market improvements, including rising vacancies (+3.817%) and falling unemployment, gradually lift incomes and drive welfare recovery, peaking at +7.99% by the fifth quarter. Capitalists experience an initial welfare decline (e.g., -4.315% in the first two quarters) due to overheated housing prices and constrained asset accumulation. In the medium term, welfare gradually recovers as falling borrowing costs and improved investment conditions take effect. Lower interest rates reduce debt-servicing burdens, freeing up liquidity for capitalists to refinance existing obligations and fund new ventures. For instance, investment rises (+6.62% in the model), driven by cheaper credit and expectations of higher returns in a low-rate environment. This stimulates capital accumulation, enhancing productivity and gradually lifting firm profitability. Additionally, housing prices stabilize or correct moderately from their early peaks, allowing capitalists to strategically expand their portfolios at more sustainable valuations.

4.6 Conclusion

This chapter examines the intricate interplay between housing markets and labor market dynamics within a DSGE framework augmented with search-and-matching frictions, occasionally binding collateral constraints, and the zero lower bound on interest rates. By integrating these elements, the model captures the bidirectional feedback loops and asymmetric propagation mechanisms that characterize housing-driven business cycles. The calibrated DSGE results reveal critical insights into how housing demand shocks, labor market shocks, and monetary policy disturbances propagate through credit and labor channels, with pronounced nonlinearities during recessions and expansions.

The impulse response functions to housing demand shocks demonstrate stark asymmetries. A negative housing price shock triggers binding collateral constraints, forcing capitalists to deleverage sharply, which amplifies the downturn: investment collapses, output contracts and unemployment rises. The ZLB exacerbates the recession by limiting monetary easing, while wage rigidities prolong labor market adjustments. Conversely, a positive housing price shock relaxes collateral constraints, boosting investment and consumption, yet the effects are muted due to slack constraints and wage rigidity. These results underscore the financial accelerator mechanism, where collateral value fluctuations amplify shocks asymmetrically, severely in busts but weakly in booms. The dual constraints (collateral and ZLB) create a "double tightening" effect during recessions, deepening contractions, while remaining inactive during expansions, leading to muted responses. Labor market shocks exhibit symmetric and transient effects due to the absence of binding constraints. A positive matching efficiency shock reduces unemployment and raises vacancies temporarily, but rapid recalibration of labor markets dampens persistence.

Monetary policy shocks reveal ZLB-driven asymmetries. A contractionary shock induces prolonged output declines and labor market dislocations, while expansionary shocks at the ZLB yield weaker and truncated recoveries due to binding rate floors. The ZLB amplifies deflationary risks but limits stimulus efficacy, embedding downside skewness into business cycles. Welfare analyses further highlight divergent impacts: workers suffer severe medium-term welfare losses from unemployment spikes under the tightening, while capitalists exploit the housing market and investment corrections for strategic gains. The model highlights the dominance of quantity adjustments (vacancies, hours) over price adjustments (wages) in labor markets, particularly under wage rigidities. When wage stickiness is introduced, firms shift adjustment burdens to vacancies and hours, amplifying unemployment volatility (under contractionary shocks) while muting wage cyclicality.

In conclusion, the DSGE framework formalizes the bidirectional feedback between housing and labor markets, emphasizing the critical role of nonlinear constraints in shaping macroeconomic volatility. The results validate the SVAR findings—housing price declines tighten credit, suppress labor demand, and elevate unemployment, while labor market shocks propagate to housing via income and collateral channels. The model's policy implications are clear: macroprudential tools (e.g., countercyclical LTV ratios) are essential to mitigate collateral-driven cycles, and monetary policy alone is insufficient near the ZLB, necessitating coordinated fiscal and structural interventions. By unifying housing, credit, and labor frictions, this chapter advances our understanding of post-crisis sluggish recoveries and the asymmetric scars of financial shocks.

Chapter 5

Conclusion

The global financial crisis of 2008 and the unprecedented economic disruptions caused by the COVID-19 pandemic have fundamentally reshaped the role of central banking and macroeconomic policy, particularly in how monetary interventions interact with asset markets and systemic risks. While unconventional tools like quantitative easing (QE) emerged as critical instruments to stabilize economies, their unintended consequences, such as surging housing prices, widening wealth inequality, and heightened financial fragility, have sparked intense debate among policymakers and academics.

Existing literature often underestimates the nonlinear dynamics introduced by financial frictions, particularly in small open economies where exchange rate volatility, capital flow reversals, and external shocks amplify domestic vulnerabilities. Moreover, traditional models frequently overlook the heterogeneous impacts of monetary policy, as well as the bidirectional feedback between housing markets and labor markets during crises. This gap leaves policymakers less equipped to address the complex trade-offs between stimulating growth, containing inflation, and preserving financial stability in an era of recurring economic shocks. This thesis seeks to unravel how collateral constraints, zero lower bound limitations, and structural rigidities reshape monetary transmission mechanisms, offering fresh insights into designing resilient policy frameworks for increasingly interconnected and crisis-prone economies.

The housing market occupies a central role in modern economies, acting as both a critical driver of growth and a potent amplifier of systemic risks. As the largest component of household wealth in most advanced and emerging economies, housing assets directly influence consumption patterns through wealth and collateral effects, while mortgage markets form the backbone of financial systems. Housing price dynamics are uniquely positioned at the intersection of monetary policy transmission, credit cycles, and macroeconomic stability, serving as a conduit through which interest rate changes, quantitative easing programs, and borrowing constraints propagate shocks across sectors. The sector's inherent supply inelasticity, coupled with its dual function as a consumption good and investment vehicle, creates persistent mismatches between demand and supply that fuel volatility. This thesis incorporates housing markets precisely because their cyclical booms and busts have precipitated every major financial crisis since the Great Depression, from the 2008 subprime meltdown to post-pandemic inflationary spirals driven by real estate speculation.

The comprehensive analysis across theoretical, empirical, and policy-oriented frameworks underscores the intricate interplay between monetary policy, housing markets, and financial constraints in both closed and small open economies. The findings advocate for a paradigm shift in policymaking. Monetary policy frameworks must integrate macroprudential tools, such as dynamic loan-to-value (LTV) ratios, to mitigate housing market overheating while accounting for distributional consequences. In small open economies, unconventional policies like QE require careful calibration to balance exchange rate stability with domestic financial risks, complemented by fiscal measures to address supply-side rigidities in housing markets. The evidence also calls for enhanced international coordination to manage cross-border spillovers, particularly in an era of synchronized global monetary tightening.

Chapter 2 systematically synthesizes the theoretical and empirical literature on monetary policy, housing markets, and financial frictions, exposing critical limitations in conventional frameworks and paving the way for methodological advancements in subsequent chapters. The analysis progresses through three interlinked dimensions. First, it evaluates policy design principles, revealing how inflation-targeting regimes—while effective at anchoring price stability—fail to account for housing market dynamics, particularly the procyclical feedback between collateral values, credit availability, and speculative demand. Conventional transmission mechanisms, such as the interest rate and wealth effect channels, are shown to inadequately capture the asymmetric amplification of shocks during housing booms and busts, especially under zero lower bound (ZLB) constraints where monetary tools lose potency. Second, the chapter dissects constraint-driven dynamics, demonstrating how collateral requirements and occasionally binding borrowing limits introduce nonlinearities that distort policy outcomes. These frictions create self-reinforcing cycles: rising housing prices ease credit constraints, fueling further price growth, while downturns trigger deleveraging spirals that disproportionately harm leveraged households and small firms. Crucially, the analysis highlights the role of agent heterogeneity—savers and borrowers exhibit divergent responses to monetary shocks, with savers benefiting from asset inflation while borrowers face escalating debt burdens despite temporary consumption gains. Third, the review identifies gaps in existing modelling paradigms, notably the oversight of bidirectional housing-labor market linkages, the distributional consequences of unconventional policies like QE, and the unique vulnerabilities of small open economies to global spillovers.

Empirical validations, including counterfactual DSGE simulations and cross-country crisis analyses, underscore the real-world implications of these theoretical shortcomings. For instance, the 2008 crisis and post-pandemic housing surges illustrate how traditional models' neglect of financial accelerator mechanisms and household heterogeneity led to delayed or misguided policy responses. By integrating these insights, the chapter establishes a foundation for original modelling in Chapters 3 and 4, which explicitly incorporate housing market frictions, open-economy dynamics, and labor market interactions. The structured critique not only clarifies why housing-centric financial instability persists but also motivates innovative frameworks to address these gaps, emphasizing the need for policies that monitor housing-driven financial cycles, mitigate wealth inequality, and coordinate monetary tools with macroprudential safeguards.

Chapter 3 examines the transmission mechanisms and distributional consequences of quantitative easing in a small open economy, leveraging a dynamic stochastic general equilibrium model calibrated to New Zealand's post-pandemic conditions. By embedding financial frictions, notably borrowing constraints tied to housing collateral—and imperfect asset substitutability, the analysis isolates the portfolio rebalancing channel as the dominant driver of housing market dynamics during unconventional monetary interventions. Large-scale asset purchases (LSAPs) compressed long-term bond yields by approximately 150 basis points, triggering a reallocation of savings into real estate that fueled a 4.9% quarterly surge in housing prices (equivalent to 20% annualized growth). This demand-side stimulus, amplified by rigid housing supply, generated asymmetric wealth effects: savers capitalized on rising asset values to expand consumption and net worth, while credit-constrained borrowers—reliant on foreign-denominated debt—faced heightened exposure to exchange rate volatility. A 0.31% currency depreciation exacerbated borrowers' debt servicing burdens, deepening financial fragility despite temporary consumption gains.

Welfare analysis quantified stark distributional inequities: savers experienced a 45% peak welfare gain from liquidity-driven asset appreciation, whereas borrowers suffered a 50% welfare loss due to unhedged exchange rate risks and binding credit constraints. These disparities underscore how QE entrenches pre-existing wealth gaps in housing-dominated economies. The chapter further evaluates macroprudential interventions, simulating a collateral constraint tightening shock (loan-to-value ratio reduction) to mitigate QE-induced overheating. While effective in curbing speculative demand—housing prices declined 0.16% quarterly—the policy exposed critical trade-offs. Savers redirected funds into bonds and capital goods, stimulating a 2% output growth, but borrowers faced severe consumption contractions (-20% welfare loss), highlighting the paradox of stability-focused policies exacerbating household inequality.

The open-economy dimension uniquely amplifies these dynamics. Capital flow volatility and currency depreciation pressures, intensified by global risk-off sentiment during the pandemic, redirected liquidity into domestic real estate, further inflating prices. Reduced consumption habit persistence amplified short-term QE efficacy, as borrowers' heightened marginal propensity to consume drove a 38.6% deviation in consumption, temporarily masking underlying vulnerabilities. Crucially, the findings align with structural vector autoregression (SVAR) results and broader literature (Chen et al., 2012; Harrison, 2012), but extend insights by formalizing mechanisms—portfolio rebalancing, heterogeneous household behaviors, and exchange rate pass-through—specific to small open economies.

While QE achieved its primary goals of circumventing zero lower bound constraints and averting deflation, it entrenched systemic risks by prioritizing financial market stabilization over housing affordability and debt sustainability. The analysis underscores the necessity of pairing unconventional monetary tools with targeted macroprudential measures (e.g., dynamic LTV ratios, foreign debt controls) and structural reforms to alleviate housing supply bottlenecks.

Chapter 4 advances a unified framework to dissect the systemic interdependencies between housing markets, labor markets, and monetary policy in economies plagued by financial frictions and institutional rigidities. By embedding search-and-matching frictions, occasionally binding collateral constraints, and the zero lower bound within a DSGE model, the analysis uncovers the nonlinear, asymmetric propagation of shocks that define housing-driven business cycles. The calibrated results demonstrate how housing price dynamics and labor market adjustments interact through credit and income channels, creating self-reinforcing feedback loops that amplify downturns and prolong recoveries.

Central to these dynamics is the asymmetric impact of housing demand shocks. A negative housing price shock triggers binding collateral constraints, forcing leveraged households and firms into abrupt deleveraging. This precipitates a collapse in investment (-15% peak deviation), a contraction in output (-8%), and a surge in unemployment (+3.5 percentage points), with the ZLB exacerbating the downturn by paralyzing conventional monetary tools. Wage rigidities further prolong labor market dislocations, as firms adjust through vacancies and hours rather than wages, deepening unemployment persistence. Conversely, positive housing shocks generate muted expansions due to slack constraints and downward wage stickiness, illustrating the inherent procyclicality of credit markets. The "double tightening" mechanism—where collateral constraints and the ZLB compound during recessions but remain dormant in booms—explains the persistent scars of housing busts compared to the fleeting gains of booms.

Labor market shocks, while symmetric in their immediate effects, reveal divergent transmission pathways. A positive matching efficiency shock temporarily reduces unemployment and boosts vacancies, but rapid recalibration dampens persistence, underscoring the transient nature of labor-driven recoveries. Monetary policy shocks near the ZLB exhibit stark asymmetries: contractionary shocks induce prolonged output declines and labor market dislocations, while expansionary stimuli face diminishing returns due to binding rate floors. Welfare analysis quantifies these disparities: workers suffer severe medium-term welfare losses (-25%) from unemployment spikes under tightening cycles, while capitalists exploit housing market and investment corrections for marginal gains (+5%), highlighting the regressive distribution of crisis burdens.

The model's policy implications are profound. First, it validates the necessity of macroprudential tools—such as countercyclical loan-to-value (LTV) ratios—to curb collateral-driven credit cycles and preempt destabilizing feedback loops. Second, it exposes the inadequacy of monetary policy alone near the ZLB, where liquidity traps and wage rigidities neutralize rate cuts, necessitating coordinated fiscal interventions (e.g., targeted job subsidies, public housing investments) to break deleveraging spirals. Third, the dominance of quantity adjustments over price adjustments in labor markets calls for structural reforms to enhance wage flexibility and retraining programs to mitigate unemployment hysteresis. The findings align with SVAR evidence on housing-labor linkages but extend the discourse by formalizing mechanisms—nonlinear constraints, strategic firm behaviors, and ZLB-induced asymmetries—that conventional models overlook.

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