Essays on Markets with Frictions: Applications to the Housing, Labour and Financial Markets

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Declaration

I certify that the thesis I have presented for examination for the MPhil/PhD degree of the London School of Economics and Political Science is solely my own work other than where I have clearly indicated that it is the work of others (in which case the extent of any work carried out jointly by me and any other person is clearly identified in it).

I declare that my thesis consists of 49446 words.

Abstract

The classical treatment of market transactions in Economics presumes that buyers and sellers engage in transactions instantly and at no cost. In a series of applications in the housing market, the labour market and the market for corporate bonds, this thesis shows that relaxing this assumption has important implications for Macroeconomics and Finance. The first chapter combines theory and empirical evidence to show that search frictions in the housing market imply a housing liquidity channel of monetary policy transmission. Expansionary monetary policy attracts buyers to the housing market, raising housing liquidity. Higher housing sale rates in turn allow lenders to threaten foreclosure more effectively, because the expected carrying costs on foreclosure inventory are lower. Ex-ante, this makes banks willing to offer larger loans, stimulating aggregate demand. The second chapter uses a heterogeneous firm industry model to explore how the macroeconomic response to a temporary employer payroll tax cut depends on the hiring and firing costs faced by firms. Controversially, the presence of non-convex labour adjustment costs suggests that tax cuts create fewer jobs in recessions. When firms hoard labour during downturns, they do not respond to marginal tax cuts by hiring additional workers. The third chapter develops a theory in which trader career concerns generate an endogenous transaction friction. Traders are reluctant to sell assets below historical purchase price, since realizing a loss signals to the employer that the trader is incompetent. The chapter documents empirically several properties of corporate bond transaction data consistent with this theory of career-concerned traders.

Acknowledgements

> Writing a book is an adventure. To begin with, it is a toy and an amusement; then it becomes a mistress, and then it becomes a master, and then a tyrant. The last phase is that just as you are reconciled to your servitude, you kill the monster, and fling him out onto the public.
> (Winston Churchill, Grosvenor House, London, November 2, 1949)

I am deeply indebted to my PhD supervisor Christopher Pissarides whose work on labour market search frictions inspired me to think about the role of transaction frictions in economics and whose trust allowed me to explore my wide interests in economics over the course of this thesis. I am also deeply indebted to Francesco Caselli who took me under his wing as research assistant when I started the PhD and who taught me his philosophy on how to do research. I also owe deep gratitude to Ethan Ilzetzki for his patience in listening to my many research ideas, for his critical questions that often helped me to rethink my positions and for his detailed comments on earlier drafts of this thesis. I thank Wouter Den Haan whose enthusiasm for research has been contagious, who introduced me to numerical methods in Economics and who has always had an open door for me. I owe deep gratitude to Andrei Shleifer who invited me to spend the Fall of 2010 at the Havard Economics Department as Visiting Scholar and who sparked my interest in Behavioural Economics and Finance. Finally, Dimitri Vayanos played a key role in opening my eyes to the role of institutional frictions (especially agency frictions) in financial markets.

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Finally, I would like to dedicate this thesis to my parents, Annelie and Herbert Ungerer, and my brother, Matthias Ungerer.

Contents

List of Figures

List of Tables

Chapter 1

Introduction

1.1 Research Question

The classical treatment of market transactions in Economics presumes the existence of a centralized market for each good. All potential buyers and sellers come together in the market place, prices adjust to ensure that demand equals supply and transactions take place - instantaneously and at no cost. This Walrasian markets approach has proven extremely influential and offers a reasonable approximation to many market situations. However, in reality it takes time for a housing seller to search for an appropriate new buyer, firms face substantial costs when hiring (or firing) a worker and institutional constraints may prevent traders from selling corporate bonds at current market prices.

This thesis aims to demonstrate, though a series of applications in the housing market, the labour market and the market for corporate bonds, that allowing explicitly for transaction frictions can yield important insights into phenomena in Macroeconomics and Finance.

The first chapter explores how search frictions in the housing market impact the monetary policy transmission channel. The standard housing channel of monetary policy ignores housing transaction frictions. A fall in the policy rate raises house prices. Consumer credit constraints relax because their property offers lenders better collateral protection against default. Does this basic story have to be augmented once one accounts explicitly for the fact that housing sellers have to search for an appropriate housing buyer before they can sell? Does the response of housing liquidity to the policy rate play a quantitatively important part in the monetary policy transmission process? The answer to these questions has broader implications for how policy interventions in the housing market should be evaluated.

The second chapter studies the interaction between non-convex labour adjustment costs faced by firms and the macroeconomic employment response to a temporary employer payroll tax cut. Standard theory neglects that firms face substantial costs in hiring and firing a worker. Once these costs are taken into account, should we still expect temporary tax cuts to effectively stimulate firm employment? What factors drive the answer to this question? If payroll tax cuts are still effective, do labour adjustment costs influence when tax cut stimulus will be cost-efficient? The study draws out implications of this analysis for macroeconomic theory, empirical studies of fiscal multipliers as well as for policy makers.

The third chapter is motivated by empirical evidence showing that traders are less likely to sell assets at loss than at gain. Since standard asset pricing theory suggests that traders should evaluate positions only considering future asset returns (irrespective of historical purchase price), the standard explanation for these findings has been a behavioural bias: traders suffer from loss averse preferences. The problem with this explanation is that professional traders make decisions with high stakes, the high decision-making frequency offers them plenty of opportunity to learn and they are under constant pressure to be replaced if they underperform. If there is a setting in which decisions should not suffer from behavioural biases, then it is the financial market. This paper therefore asks: can career concerns explain why profit-maximizing traders may make trading decisions as if they were loss averse? Are there distinct predictions of this career-concerns theory that can be tested in the data?

1.2 Methodology

The three chapters of this thesis share a common broad methodological approach. In each application, I use a theoretical model to show that explicitly allowing for plausible transaction frictions yields novel insights into how markets function. Based on realistic assumptions, the augmented models presented put into question common wisdom on how markets operate. Wherever possible, theoretical predictions are linked to empirical data.

However, the modelling approach in each chapter is tailored for its specific purpose and, jointly, the methods used in this thesis therefore span a range of approaches on how to do applied theory research in economics.

To formalize the housing liquidity channel of monetary policy proposed in the thesis, the first chapter builds on a New Keynesian Dynamic Stochastic General Equilibrium (NK DSGE) Model. This framework has been labelled the workhorse of modern macroeconomics. In contrast to Keynesian models of previous generations, DSGE models are based on an internally consistent structural model of consumption, labour and production sectors. The framework is New Keynesian in the sense that product prices are assumed not to be fully flexible, allowing for monetary policy to have temporary real effects on the macroeconomy. Since this class of models is often characterized by a large state space, log-linearization is generally used to solve for impulse response functions of the framework around the steady state. The first chapter of this thesis contributes to this methodological approach by showing how housing market search frictions and credit frictions can be jointly embedded in the DSGE framework and by exploring how this change impacts the simulated response of the economy to monetary policy shocks.

The second chapter studies the interaction between non-convex labour adjustment costs, the employment decisions of firms and fiscal policy. Since the impact of non-convexities can generally not be explored in log-linearized versions of the model, this analysis requires using global solution methods (this study uses value function iteration). Since employment at the firm level differs substantially from macroeconomic dynamics, the setup explicitly computes statistics by aggregating across a simulated population of heterogeneous firms.

The third chapter makes a qualitative point: rational traders may choose to behave loss averse in their trading decisions when they are career-concerned. To preserve transparency, the argument is therefore developed in a two period model. As a dynamic game of incomplete information, the concept of a (weak) Perfect Bayesian Equilibrium (PBE) is used to derive equilibrium predictions on trader behaviour.

The theoretical predictions of these three chapters are linked to empirical analysis wherever possible. In the first chapter, dynamic regressions using US Macroeconomic data explore in how far changes in the policy rate impact housing market liquidity empirically. These estimates are combined with data on US property tax rates and housing maintenance cost to gauge whether a housing liquidity channel of monetary policy can be quantitatively significant. In the second chapter, the jobs created by a temporary employer payroll tax cut are computed based on a heterogeneous firm simulation with micro-founded parameter values. In the third chapter, the predictions of the trading model are shown to be born out in US corporate bond transactions data made available by the Trade Reporting and Compliance Engine (TRACE) set up by the Financial Industry Regulation Authority (FINRA).

1.3 Results and Contribution to the Literature

Most of the existing literature on the housing channel of monetary policy puts focus on house prices. The first chapter of this thesis uses dynamic regressions to document that empirically the housing market responds much more through sales volume than through house prices. Does this housing liquidity response matter? This chapter presents a macroeconomic general equilibrium model with credit constrained consumers and housing market search frictions which suggests that the answer is yes. Higher housing sale rates allow lenders to threaten foreclosure more effectively, because the expected carrying costs on foreclosure inventory are lower. Ex-ante, this makes lenders feel comfortable offering larger loans and consumer credit constraints relax. Using property tax and housing maintenance cost estimates to calibrate the carrying costs of foreclosure inventory, simulations show that this housing liquidity effect can play a quantitatively important role for monetary policy transmission. This link between housing market liquidity and functioning mortgage markets implies that monetary policy alternatives, such as home buyer tax credits, should also be evaluated on basis of their impact on both house prices and housing sale rates.

The second chapter of this thesis uses heterogeneous firm industry simulations to show that employer payroll tax cuts can continue to stimulate employment even if firms face large hiring and firing costs. The two empirical factors that drive this result are (i) the high rate at which workers quit employment and (ii) the high firm-specific volatility in business conditions. Together, they imply that many firms are actively hiring in the simulation steady state. These marginal firms remain responsive to tax cuts even given substantial hiring and firing costs. Does this mean we can ignore labour adjustment costs? On the contrary, the presence of labour adjustment costs implies that tax multipliers are contingent on policy design. Because firm employment decisions are forward-looking, the multiplier strengthens with length of announcement period and length of tax cut implementation. Because the hiring decision of firms hoarding labour is insensitive to stimulus measures, a force towards procyclical fiscal multipliers emerges. For empirical researchers, these results imply that no single payroll tax multiplier exists. The multiplier depends on the specifics of the implementation plan. For policy makers, the results suggest that a cost-effective payroll tax cut stimulus is pre-announced, prolonged and takes place after the worst of the recession is over (as firms start to switch back into hiring).

The third chapter of this thesis develops a model in which career concerns make rational traders behave loss averse. The trader is employed by a financial institution and the financial institution decides whether to retain the trader. If the trader realizes a trading loss, he reveals that he is incompetent. The trader responds by only entering trades on which he is very unlikely to make a loss and, once a trade is entered, by "fishing" until an opportunity to resell at gain emerges. Consistent with loss averse trading behaviour, this study empirically documents that the distribution of prices at which corporate bond dealers sell is truncated sharply at the last observed buy price. Furthermore, the data supports a key prediction of the career-concerns hypothesis (not shared with baseline theories of underlying loss-averse preferences): traders appear to place special weight on avoiding multiple trade losses in a row.

Chapter 2

Monetary Policy, Hot Housing Markets and Household Debt

The conventional story of the housing channel of monetary policy transmission puts focus on housing transaction prices. Lower short-term policy rates feed through to mortgage rates, raising house prices to equilibrate demand and supply. As the transaction price of housing collateral rises, lenders allow credit-constrained consumers to borrow more. This stimulates aggregate demand and the macroeconomy. But this story neglects the substantial rise in the volume of housing sales following monetary policy easing. This study finds that a temporary 1% fall in the federal funds rate raises transaction prices by 3% on impact, while the monthly rate at which housing is sold rises by 20%.

Does this housing sales rate response matter for macroeconomic monetary policy transmission? This paper explores one channel that suggests the answer is yes. Intuitively, lenders value property collateral primarily for its resale value in case of default. This liquidation value depends on both (i) costs associated with carrying the property from moment of foreclosure until a buyer is found and (ii) the eventual transaction price at which the house is resold to a new household. The response of the housing sales rate to expansionary monetary policy therefore matters, because it implies that housing liquidation values rise by more than recorded housing transaction prices when policy rates are lowered. This offers a theory for how loose monetary policy can cause a rise in the leverage ratios that lenders are willing to accept.

In a first step towards assessing the quantitative importance of this housing liquidity effect, this study backs out the monetary policy response of lender liquidation values from the empirical impulse responses of housing sales rate and transaction prices. Key to implementation of this exercise, net carrying costs on foreclosure inventory are approximated using estimates of property tax and maintenance costs. The housing liquidity effect more than doubles the impact response of lender liquidation values relative to housing transaction prices.

In a second step, this study evaluates the general equilibrium role of this housing liquidity effect for monetary policy transmission to the macroeconomy. Incorporating housing market search frictions into a Iacoviello (2005) New Keynesian macroeconomic model with credit-constrained entrepreneur-households, a framework emerges that formalizes the housing liquidity transmission channel in general equilibrium. Temporarily low interest rates make home purchase relatively attractive. As more home buyers scout the market of for-sale property, housing sellers can find counterparties more quickly. A temporary increase in the housing sales rate therefore arises as an endogenous response to expansionary monetary policy. In turn, higher housing sale rates increase housing liquidation values and allow lenders to threaten foreclosure more effectively. Ex-ante, this raises the willingness of lenders to provide credit. Borrowing margins relax, credit flows more easily and this stimulates aggregate activity. In a calibrated model, this housing liquidity effect contributes substantially to monetary policy transmission.

The importance of this housing liquidity transmission mechanism is not limited to monetary policy. It has also, for example, direct implications for our evaluation of the US home-buyer tax credit of 2009-2010. Consider a temporary subsidy to house purchases of 3% relative to trend house prices. Conventional macroeconomic analysis emphasizes that sellers may be able to exploit resulting greater housing demand by raising transaction prices. But this effect is bounded from above by a 3% house price rise (in which case the benefits of the subsidy are fully passed on to the seller). Taking search frictions into account, the overall impact on housing debt capacity may however be much larger. Because the subsidy encourages buyers to enter the market, it raises housing liquidity. Lender liquidation valuations of collateral may rise by more than transaction prices. Direct cyclical subsidization of home purchases may be a more effective substitute for monetary policy than conventional analysis suggests.

In establishing these results, this paper develops a new explanation for why expansionary monetary policy causes looser borrowing margins: lenders feel more comfortable lending because seized property collateral can be resold more easily in hot markets. Furthermore, the paper develops a tractable Dynamic Stochastic General Equilibrium model with both search frictions in the housing market as well as credit-constrained agents. This allows examination of the interaction between asset market search frictions and credit frictions in a medium-scale macroeconomic framework. Finally, this analysis offers a novel approach towards calibrating the housing market search frictions technology. In the labour markets literature, search friction technology parameters can be estimated directly, since both the number of workers searching for work (the unemployed) as well as job vacancies are recorded. In the housing market however, while measures of for-sale housing are available, the mass of searching house buyers is not. Instead this study proposes an indirect calibration approach using perturbations from monetary policy shocks.

This paper expands on the growing literature that explores the macroeconomic implications of credit frictions. In the spirit of Shleifer and Vishny (1992) and Kiyotaki and Moore (1997), agents have to offer collateral in order to access loans. Specifically, this paper builds on work by Iacoviello (2005) and Iacoviello and Neri (2010) in which consumers borrow against housing. However, while existing work puts emphasis on the feedback from asset prices to credit access (keeping borrowing margins fixed), this paper focusses on the amplifying role of time-varying borrowing margins. Emphasizing the substantial time-variation in housing transaction volumes and loan-to-value ratios, this study suggests that an exclusive focus on asset prices may substantially underestimate the response of overall asset debt capacity to monetary policy.

In this sense, this study complements other current work studying procyclical borrowing margins.[1] Eisfeldt (2004) and Kurlat (2009) develop a theory of borrowing margins based on the greater severity of asymmetric information problems during downturns. Geanakoplos (2009) shows that disagreement between optimists and pessimists can cause

[1] The Costly-State-Verification models of Bernanke and Gertler (1989) and Bernanke, Gertler and Gilchrist (1999) also introduce time-varying leverage in a macroeconomic general equilibrium model, though this is not their focus. Because the setup implies a positive relation between credit spreads and leverage, their finding that spreads fall after expansionary monetary policy implies that leverage should fall. Linking their setup with the search frictions theory of asset liquidation values developed in this study appears a fruitful area for further research.

leverage to rise during asset booms.[2] Relative to this literature, this paper identifies the collateral sales rate as key contributing factor to borrowing margins in the housing market. Furthermore, this paper speaks directly to the popular notion that loose monetary policy causes loose credit conditions.

Finally, this paper is heavily indebted to the literature on markets with search frictions. Specifically, in terms of formalization and notation, this study borrows from the labour markets search frictions survey in Pissarides (2000). The idea that housing market search frictions are important for the evolution of house prices and transaction volume has been explored, among other contributions, in Wheaton (1990), Williams (1995), Krainer (2001), Albrecht et al. (2007), Novy-Marx (2009), Piazzesi and Schneider (2009) and Ngai and Tenreyro (2009). This paper applies these insights to study the interaction between search frictions in the housing market and access to mortgage finance.[3,4]

Section 2.1 documents the response of the macroeconomy and the housing market to monetary policy shocks. Section 2.2 uses these impulse response functions in a simple accounting exercise to propose that housing liquidation values plausibly respond much more strongly than regular house transaction prices alone would suggest. To explore the macroeconomic significance of this housing liquidity effect, section 2.3 develops a New Keynesian general equilibrium model with borrowing-constrained households and search frictions in the housing market. Section 2.4 shows that this liquidity effect also magnifies the predicted potency of a more targeted stimulus to housing demand, such as a home-buyer tax credit. Section 2.5 offers concluding comments.

[2] Simsek (2012) refines this work further, distinguishing between belief disagreement on the upside or downside of risk. In a related line of research, Brunnermeier and Pedersen (2009) and Adrian and Shin (2010) link borrowing margins to collateral asset return volatility.

[3] Parallel to the writing of this paper, Hedlund (2011) also proposes analysing the interaction between credit frictions and housing market search frictions. His paper puts focus on matching unconditional business cycle moments of the data, while this paper analyses how the interaction impacts the monetary policy response. This paper shows how to introduce this interaction in a New Keynesian general equilibrium model. Furthermore, this study disciplines the argument that search frictions matter using direct estimates of inventory holding costs: values for property tax and maintenance costs from the housing literature. This methodological insight is key to the quantitative exercises in this study. Also related, Milbradt and He (2012) study the interaction between liquidity and credit premium on corporate bonds in a search and matching market environment.

[4] Wasmer and Weil (2004) explore the interaction between labour search frictions and credit search frictions. A financial accelerator emerges because fewer entrepreneurs lower the number of financiers searching for counterparties and vice versa. In contrast, this paper explores the effect of search frictions in the collateral asset market. This allows the paper to offer a theory explaining cyclicality of borrowing margins.

2.1 Dynamic Regressions: The Effect of Monetary Policy on the Housing Market

Documenting the reduced form dynamic response of the macroeconomy and the housing market to monetary policy shocks, this section establishes the key facts that frame and discipline the argument developed in this paper. To overcome endogeneity of monetary policy stance, this study adopts the methodology of Romer and Romer (2004).[5]

Naive causal interpretation of the correlation between monetary policy stance and state of the real economy would conclude that expansionary monetary policy causes economic contractions. However, this neglects that the central bank policy rate responds endogenously to economic conditions, lowering rates in times of crisis precisely in order to counteract shocks from other sectors of the economy. To identify exogenous shocks to monetary policy, Romer and Romer (2004) therefore regress the historical intended federal fund rate on contemporaneous forecasts of the future macroeconomic state. They interpret the resulting estimated functional relationship as an estimate of the central bank policy response function. The historical deviation of actual federal funds rate from the policy rule (labelled f_t) therefore identifies movements in monetary policy that are not a response to macroeconomic fundamentals. Figure 2.1 plots the resulting monthly time series of exogenous US monetary policy shocks for the period 1969-1996.[6,7]

To analyse the dynamic impact of monetary policy shock f_t on an economic variable of interest x_t, Romer and Romer (2004) propose the single-equation regression model

[5] Appendix A.2 lists data sources used in this empirical study. Appendix A.1 explores robustness of the results developed. Crucially, it shows the key results developed in this section are qualitatively robust to using a recursive Vector-Autoregressions identification scheme along the lines of Christiano, Eichenbaum and Evans (2005) given the set of endogenous variables considered. The key benefit of using the Romer and Romer (2004) method in the main text is that the impulse response functions developed do not depend on the exact set of endogenous variables considered in the analysis.

[6] Romer and Romer (2004) have generously made this data series available on their website http://elsa.berkeley.edu/users/cromer/Shocks/RomerandRomerDataAppendix.xls at time of writing.

[7] What interpretation can we give to the monetary policy innovation f_t? Romer and Romer (2004) discuss six sources for the shock series: i. changes in central bank operating procedures (i.e. switch from focus on quantity measures to setting interest rates), ii. changes in the economic model used to reach policy decisions (i.e. speed of transmission from economic slack to inflation), iii. changes in tastes and goals of the monetary policy committee (i.e. periods of particular distaste for inflation), iv. political considerations (ie pursue expansionary monetary policy to secure renewed nomination of chair), v. special emphasis on non-standard targets during particular episodes (i.e. exchange rates in the mid-80s) and vi. idiosyncratic random elements in central bank decision making (i.e. mood swings).

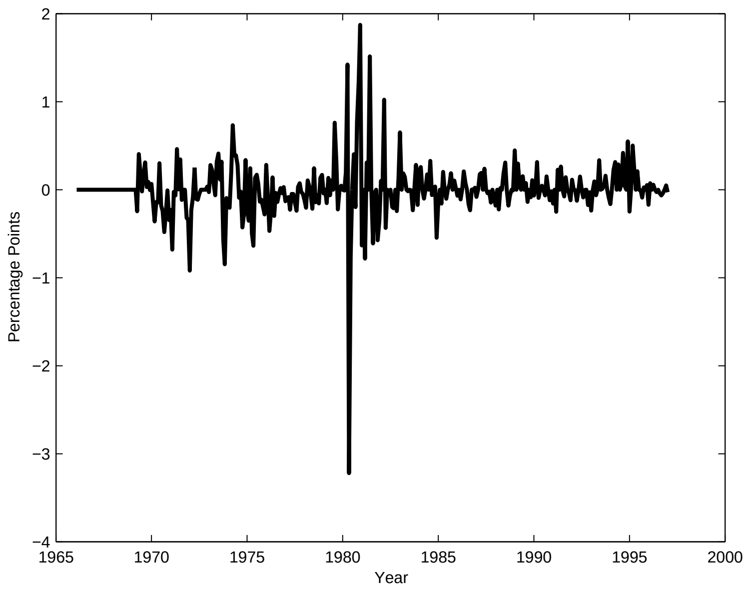

Figure 2.1: The Romer and Romer (2004) monetary policy shock series

2.1.1. Monthly dummies ($D_t(k)$ for dummy month k) are used as seasonal controls. Wherever not otherwise stated, the availability of the Romer and Romer (2004) shock series constrains the sample period considered in the regression.[8]

$$\Delta log(x_t) = a_0 + \sum_{k=1}^{11} a_k D_t(k) + \sum_{l=1}^{L_x} b_l \Delta log(x_{t-l}) + \sum_{l=1}^{L_f} c_l \Delta f_{t-l} + \epsilon_t \tag{2.1.1}$$

Figure 2.2 plots the six monthly time series considered in this analysis: the federal funds rate, real output, the price level, real house prices, housing rents and the monthly housing sales rate (the monthly ratio of new houses sold to new houses for-sale).[9,10] As crucial variable in the analysis of this study, note that the housing sales rate is highly cyclical (and seasonal). Furthermore, in any given month, the number of for-sale properties far exceeds the number of houses actually sold. Given an average sales rate of 17.7% (implying an average time-to-sale of 5.7 months), the time series reaches a minimum value

[8]Note specifically this means the results in this study, for better or for worse, do not cover the housing bubble of 2003-2007 and the subsequent credit crunch of 2006-2009.

[9]Note that the housing price series used (the Freddie Mac House Price Index) starts in 1975.

[10]Assuming (i) that for (most) households new and existing housing are broadly substitutable and (ii) that households prefer to search in less crowded markets, the new housing sales rate serves as useful proxy for the overall housing sales rate.

of 7% and a maximum value of 33%.[11,12,13]

What is the dynamic response of these macroeconomic and housing market aggregates to a one standard deviation Romer and Romer (2004) monetary policy shock?[14] Figure 2.3 shows that the effective federal funds rate falls by 100 basis points within two months, recovers and then overshoots after two years (presumably reflecting the systematic response of the Federal Reserve to rising inflation). The macroeconomic response to monetary policy is substantial. Output rises to peak at 3% (relative to its trend value) after two years. The aggregate price level responds sluggishly at first, but inflation decidedly gains momentum as the economy reaches the two year mark.[15] Turning to the housing market, as documented in for example Iacoviello (2005), house prices rise substantially after a fall in the federal funds rate (reaching a peak at 3% relative to steady state after 2 years). Rents, responding sluggishly to economic conditions, only decline in real terms as CPI inflation picks up.[16]

The crucial point of this section however is that the price response of housing pales in

[11] The inverse of this sales rate is often used in the real estate industry as measure of months of supply available (the months it would take to sell current for-sale inventory given stable monthly sales and no new housing coming on the market). As in this paper, the measure reflects how many sellers are on the market relative to buyers (how crowded the market is). This measure is computed as part of the US Housing Census output for example.

[12] The procyclicality of housing transaction volumes has been previously documented in Stein (1995) for US data and Andrew and Meen (2003) for the UK economy. Stein (1995) proposes that downpayment effects can explain this pattern. In recessions, house prices fall and household equity shrinks. Consequently, the sale of the current house would not cover downpayment for a mortgage on a new property and households cannot move. Genesove and Mayer (2001) propose that volume may dry up in times of falling house prices because households are averse to realizing losses on their housing investment. In contrast, this paper explains time-variation in housing transaction volumes based on the idea that the real estate market is characterized by search frictions (following Wheaton (1990), Williams (1995), Krainer (2001), Albrecht et al. (2007), Novy-Marx (2009), Piazzesi and Schneider (2009) and Ngai and Tenreyro (2009)). The aim of this study is to explore the consequences of this housing liquidity response for household access to mortgages.

[13] Note also that this paper does not speak to housing market fluctuations at seasonal frequency. For work exploring this dimensionality of the data, see for example Ngai and Tenreyro (2009) and references therein.

[14] Following Romer and Romer (2004), confidence intervals are computed through Monte-Carlo simulations. 10000 regression coefficients and associated impulse responses are drawn from a multivariate normal distribution with mean at the point estimates and estimated variance-covariance matrix. The month k standard error is then computed as the standard deviation across impulse response function values at month k.

[15] These impulse responses for the macroeconomic aggregates follow closely the results in Romer and Romer (2004). Specifically, relative to traditional recursive identification schemes, the real effect of monetary policy is stronger and the price level effect is more delayed.

[16] Note that a rental sector is not explicitly modelled in section 2.3 and it is not central to the mechanism of this study. Impulse response functions for rents are nonetheless included in this section to provide a more holistic picture of the housing market response to monetary policy.

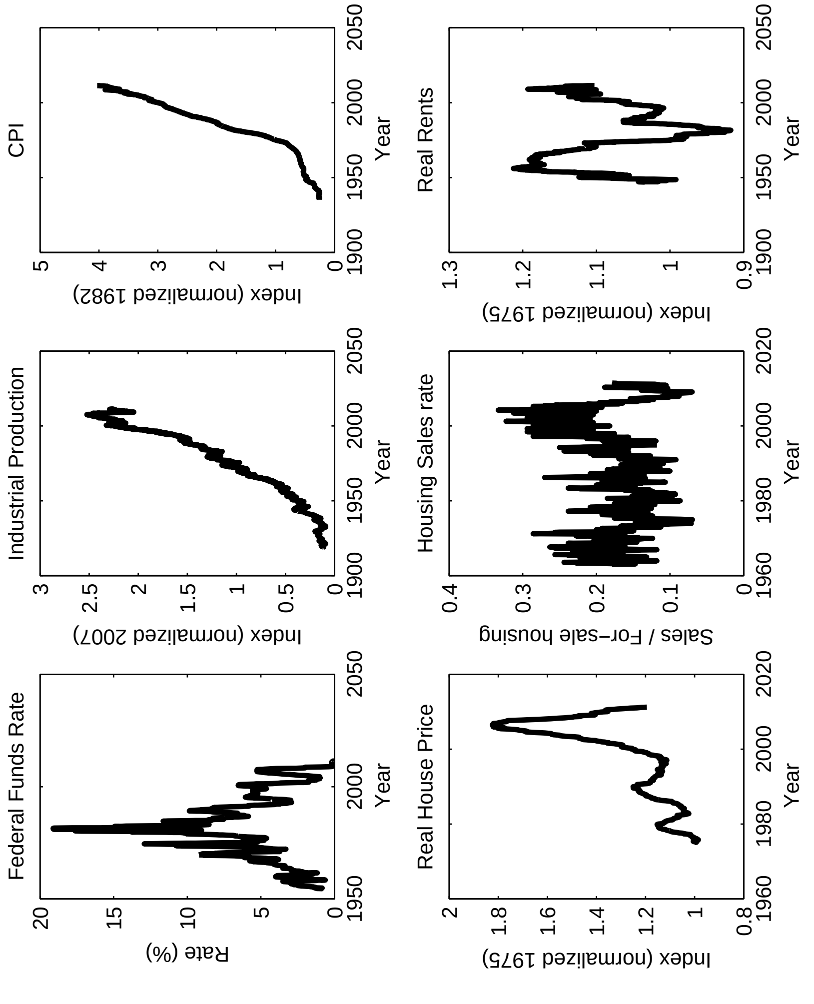

Figure 2.2: Raw time series

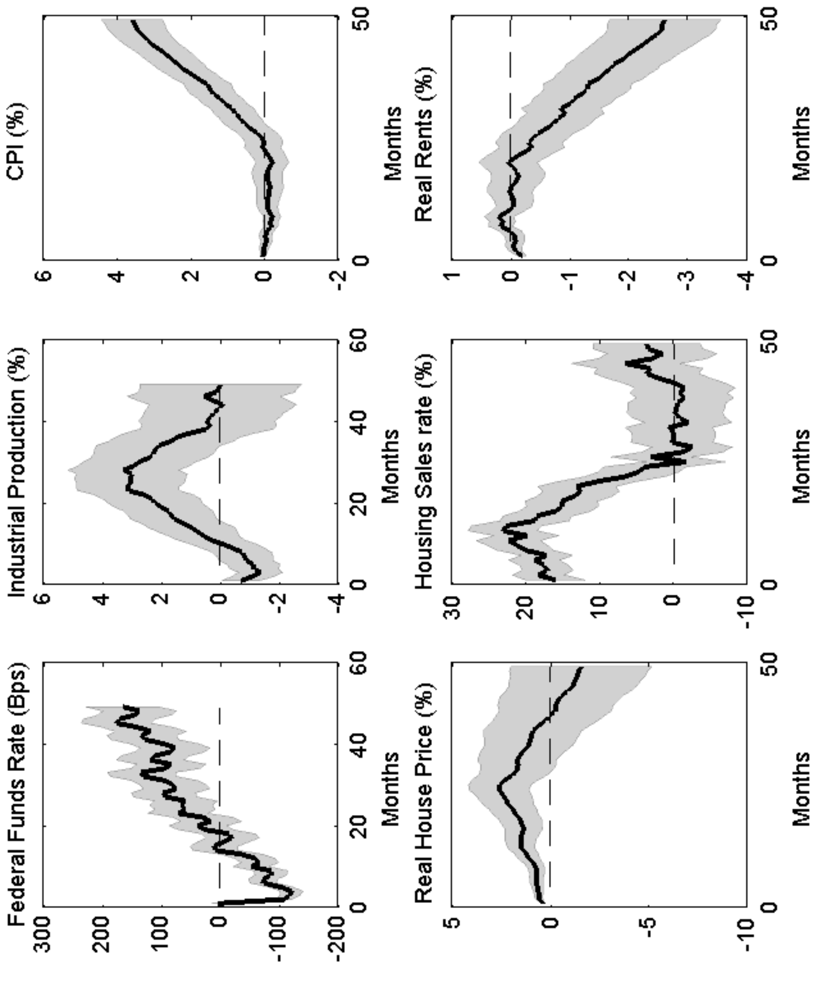

Figure 2.3: Response of the housing market (Romer and Romer (2004) shocks; in log dev. from trend; 95% confidence intervals)

comparison with the response of the housing sales rate: the latter jumps by 20 percent immediately following the policy shock (from a long term average of 17.7% to 21.2%). Only over time, as house prices pick up, does this increase in transaction volumes recede.[17]

This finding motivates the key questions pursued in this paper: Why do housing transaction volumes pick up after monetary policy easing? Does the housing liquidity response contribute to macroeconomic transmission of monetary policy? Or is it simply a symptom that plays no active role in transmission? Is there a housing liquidity channel of monetary policy?

2.2 A First Look at the Housing Liquidity Channel of Monetary Policy

This section proposes one channel through which housing liquidity can play an active role in the overall monetary policy transmission process. Subsection 2.2.1 introduces the intuition behind this channel. Subsection 2.2.2 proposes a partial equilibrium accounting exercise to explore whether this mechanism can be quantitatively important. This paves the way for subsequent general equilibrium analysis.

2.2.1 Intuition for the Channel

At the heart of the traditional housing channel of monetary policy transmission lies the idea that central bank interest rates impact on the liquidation value lenders assign to housing collateral. With higher liquidation values, lenders support larger mortgages. High recovery rates make default less risky. Equally, higher liquidation values allow lenders to effectively threaten borrowers with seizure of collateral should households demand renegotiation of the mortgage. Either way, the resulting relaxation of borrowing constraints allows households to expand consumption and to fuel aggregate demand.

The housing liquidity channel developed in this paper shares with this traditional account its focus on housing liquidation values. Where the two stories differ however is on how liquidation values depend on current housing market conditions. In the baseline

[17] Previous studies that look at the response of housing market variables to monetary policy on the price and volume dimension confirm these empirical results (see Hort (2000) for Swedish data).

credit frictions literature centred on Shleifer and Vishny (1992), Kiyotaki and Moore (1997) and Iacoviello (2005), the assumption of Walrasian asset markets implies that banks can instantly resell foreclosed housing at current market price (allowing for one-off costs associated with the transaction). By implication, the monetary policy response of housing liquidation values is directly tied to the extent to which central banks move current real estate transaction prices. In contrast, this paper captures the fact that banks take time to resell foreclosed property on the market. Given regular house transaction prices, housing liquidation values are higher in a hot housing market in which houses can be sold quickly, since the seller faces lower expected holding costs (such as maintenance and tax on the vacant property). In this setup, the response of vacant housing liquidation values to monetary policy depends both on the monetary policy response of house prices and the housing sales rate.[18]

Taking into account this link between liquidation values and housing time-to-sale, a natural mechanism emerges through which the housing market liquidity response from section 2.1 may play an active role in monetary policy transmission. As expansionary monetary policy lowers mortgage rates and attracts more buyers into the housing market, time-to-sale for foreclosed properties falls. This means that the liquidation value banks assign to housing collateral rises by more than transaction prices. The resulting excess sensitivity of housing credit access (relative to housing transaction price) gives rise to a housing liquidity channel of monetary policy.

2.2.2 An Initial Quantitative Exploration

This subsection uses a simple accounting exercise to offer an initial quantitative exploration of this housing liquity channel. Denote the liquidation value banks assign to a vacant house in their foreclosure inventory by $q_{v,t}$. Denote the per-period net holding costs the bank pays on vacant property, such as maintenance costs and property tax, by c_h. Given a new occupier for the property is found, the house is sold at market price

[18] On foreclosure, properties are generally subject to an auction. Only if the auction fails, does the property become part of the lender foreclosure inventory. Because in the foreclosure dataset of Campbell, Giglio and Pathak (2009) only 18% of foreclosures are sold at that stage, this paper abstracts from the auction procedure and assumes housing directly enters the lender housing inventory to be sold on the regular housing market.

$q_{m,t}$ and the seller pays a one-off proportional fixed sales cost F_s (reflecting for example real estate agent fees). Denoting the probability that a seller finds a willing buyer in period t with $P_{s,t}$ and denoting the seller stochastic discount factor with Q_t, the housing liquidation value is given by present value equation 2.2.1.

$$q_{v,t} = E_t(Q_{t+1}(-c_h + P_{s,t+1}q_{m,t+1}(1 - F_s) + (1 - P_{s,t+1})q_{v,t+1}) \tag{2.2.1}$$

To make equation 2.2.1 operational, this section requires an expression that identifies the seller discount factor Q_{t+1} empirically. The study therefore makes the assumption that banks price the risk-free asset with return $R_{f,t}$, yielding equilibrium expression 2.2.2.

$$1 = R_{f,t}E_t(Q_{t+1}) \tag{2.2.2}$$

Equations 2.2.1 and 2.2.2 represent basic accounting equations that will hold in a large class of general equilibrium settings. For example, they will be derived as outcomes of optimizing behaviour in the macroeconomic model of section 2.3. Key however is that these two expressions in themselves impose sufficient structure to infer from the impulse responses in section 2.1 how housing liquidation values respond to monetary policy.

Using first order approximations around the non-stochastic steady state, iterating 2.2.1 forward, imposing a no-bubble condition and using 2.2.2 to substitute out the discount factor, yields expression 2.2.3.[19] This equation is key to the quantitative exercise in this section. Given a calibration for ρ_1, ρ_2 and ρ_3, it backs out the liquidation value banks assign to housing collateral given the expected path of the risk-free rate, the housing sales rate and housing transaction prices (computed in section 2.1).

At this point, it is useful to note two features of this setup. First, note that the liquidation value can be interpreted as the price at which housing can be sold instantly on the market (to any speculator). Any intermediary will be willing to buy the house at liquidation value, since the implied fire-sale discount relative to regular transaction price compensates for expected holding costs until the house can be resold to a buyer household.[20] Second, the sensitivity of housing liquidation values to the housing sales rate

[19] Terms with star superscript denote steady state values and terms with hat accent denote (log) deviations from steady state. Appendix A.5 derives expression 2.2.3 formally.

[20] In other words, the fire-sale discount reflects compensation for delegation of the search task to

depends on the difference between this steady state fire-sale discount $1-(q_v^*/q_m^*)$ and the one-off cost of making the sale F_s (see ρ_1). Approximately, this difference represents how much of the steady state fire-sale discount is explained by expected holding costs. If expected holding costs are important, then the fire-sale discount also becomes more sensitive to fluctuations in the sales rate around steady state.

$$\hat{q}_{v,t} = \underbrace{-\sum_{j=0}^{\infty}\rho_3^j E_t(\hat{r}_{f,t+1+j})}_{\text{Discount factor component}} + \underbrace{\rho_1\sum_{j=0}^{\infty}\rho_3^j E_t(\hat{p}_{s,t+1+j})}_{\text{Sales rate component}} + \underbrace{\rho_2\sum_{j=0}^{\infty}\rho_3^j E_t(\hat{q}_{m,t+1+j})}_{\text{Price component}} \tag{2.2.3}$$

$$\text{where } \rho_1 = \frac{Q^*((1-F_s)-(q_v^*/q_m^*))P_s^*}{(q_v^*/q_m^*)} \tag{2.2.4}$$

$$\rho_2 = \frac{Q^* P_s^*(1-F_s)}{(q_v^*/q_m^*)} \tag{2.2.5}$$

$$\rho_3 = Q^*(1-P_s^*) \tag{2.2.6}$$

To calibrate expression 2.2.3 at monthly frequency, set the yearly steady state risk-free rate to 4%. To gauge the size of the steady state fire-sale discount in the housing market, this study uses evidence from existing empirical studies. Mayer (1998) finds that housing sales at auctions in the 1980s (generally associated with foreclosure events) sell at discounts of up to 9% in Los Angeles (boom market) and 9-21% in Dallas (oil bust). In a study of the Massachusetts housing market, Campbell, Giglio and Pathak (2009) estimate foreclosure-related price discounts of 27% of house value.[21] Taking orientation around these numbers, this paper assumes an average fire-sale discount of 15% as baseline scenario.[22]

It is generally difficult to pin down what fraction of the fire-sale discount on housing is explained by expected holding costs during time-to-sale and what fraction is explained

another agent.

[21] The Campbell, Giglio and Pathak (2009) foreclosure discount is an imperfect proxy for the fire-sale discount discussed in this paper, since they consider all sales of foreclosed housing (irrespective of whether they are instant) relative to regular transaction prices.

[22] This calibration has a second convenient interpretation. In the general equilibrium model of section 2.3, it will also represent the loan-to-value ratio on mortgages of credit-constrained households. A loan-to-value ratio of 85% for credit constrained households conforms with the prior set in Iacoviello and Neri (2010) for example.

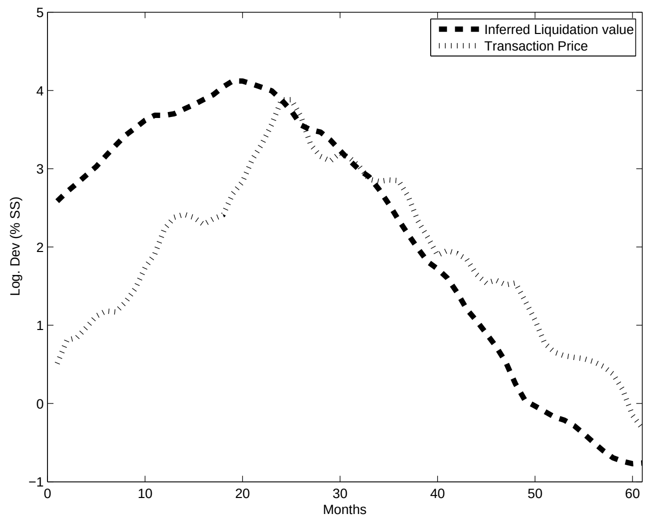

Figure 2.4: Response of liquidation value to temporary 1% exogenous fall in federal funds rate

by the one-off seller transaction costs once a buyer household is found.[23,24] At the same time, as the expression for ρ_1 demonstrates, exactly this calibration decision is crucial in determining how sensitive housing liquidation values are to the housing sales rate. This study therefore takes a conservative baseline approach in the main text. It formulates a lower bound on the size of expected holding costs and shows that, even given this conservative choice, the housing liquidity channel is a potent factor in the valuation of vacant for-sale housing. Specifically, as in Poterba (1991), this study assumes yearly holding costs of a vacant property equal yearly property tax and maintenance costs at 2% and 3.9% of house price respectively ($c_h = m + \tau$). Through expression 2.2.1, this implies one-off seller transaction costs of around 10% of steady state regular house price.

Under this conservative baseline parameterization, the impulse response function for the housing liquidation value can be backed out by feeding the section 2.1 reduced-form responses of the sales rate, transaction prices and the risk-free rate into expression 2.2.3. This results in figure 2.4 and illustrates the main point of the paper: housing liquidation values plausibly respond much more strongly to monetary policy than regular

[23]This problem is made even more difficult in that, strictly speaking, the one-off transaction costs in this accounting framework represent only those transaction costs that are incurred if the house is sold to a new household in a regular sale - over and on top one-off transaction costs that would be incurred irrespective of whether the house is sold to a household or to a speculator.

[24]This problem is at the heart of the empirical study by Campbell, Giglio and Pathak (2009) for example.

transaction prices alone would suggest.[25] Figure 2.5 shows that this overshooting can be traced back in large part to the strong sales rate response of the housing market.[26] Only after transaction volumes return to steady state in year 3 (post policy shock) does the response of liquidation values reflect more closely the behaviour of contemporaneous transaction prices.

Three arguments suggest that, in practice, figure 2.5 likely represents a lower bound on the true sensitivity of liquidation values to fluctuations in the housing sales rate. First, the 10% one-off seller transactions cost implied by the calibration appear high. Suppose, as is standard in the US, that housing sellers pay real estate agents a fee of 3% of the house price.[27] Assume an additional 1% in additional legal fees associated with the sales procedure. This leaves another 6% of the estimated one-off seller transaction cost unexplained. These additional costs could be rationalized by the cost of housing repairs and a general pre-sale face-lift, but more likely they suggest that the calibration underestimates expected holding costs during time-to-sale. Second, note that, in fact, Poterba (1991) suggests that ownership risk substantially drives up the holding costs of property. Effectively, owning a vacant house creates exposure to future house price fluctuations. Adding a yearly 4% risk premium to property holding costs, Poterba (1991) therefore estimates that overall yearly holding costs for housing are about 10% (relative to the 6% parameterization used in the conservative baseline scenario of this paper).[28]

[25] To make equation 2.2.3 operational, the summation is truncated at 60 months. Results are insensitive to raising the number of months considered.

[26] The discount factor and future transaction price components reinforce this effect. First, temporarily lower interest rates lower the opportunity cost of funds tied up in foreclosure inventory. Second, on impact, expansionary monetary policy feeds expectations of future house price appreciation (see the impulse response of house prices in section 2.1). Both these additional components raise housing liquidation values relative to current housing transaction prices (reinforcing the effect of a temporarily high sales rate).

[27] See Hsieh and Moretti (2003) and Levitt and Syverson (2008) that document this pricing practice and discuss its implications.

[28] Though adding a risk premium to the baseline property holding cost used in this study would strengthen the estimated magnitude of the housing liquidity channel (and therefore the case of this paper), this study refrains from its inclusion in the conservative baseline calibration for two reasons. First, the size of this risk premium is highly uncertain. By showing that the housing liquidity effect is important even if one believes that the risk premium is negligible, this paper highlights that whatever one assumes about the risk premium is not crucial to the quantitative argument in this paper. Second, note that this paper develops solutions using first-order approximation methods (as is common in the macroeconomic business cycle literature). In these approximations, risk considerations generally do not enter (they start to matter moving to second order approximations and higher). Ignoring the risk premium therefore ensures consistency of the calibration with the solution method used.

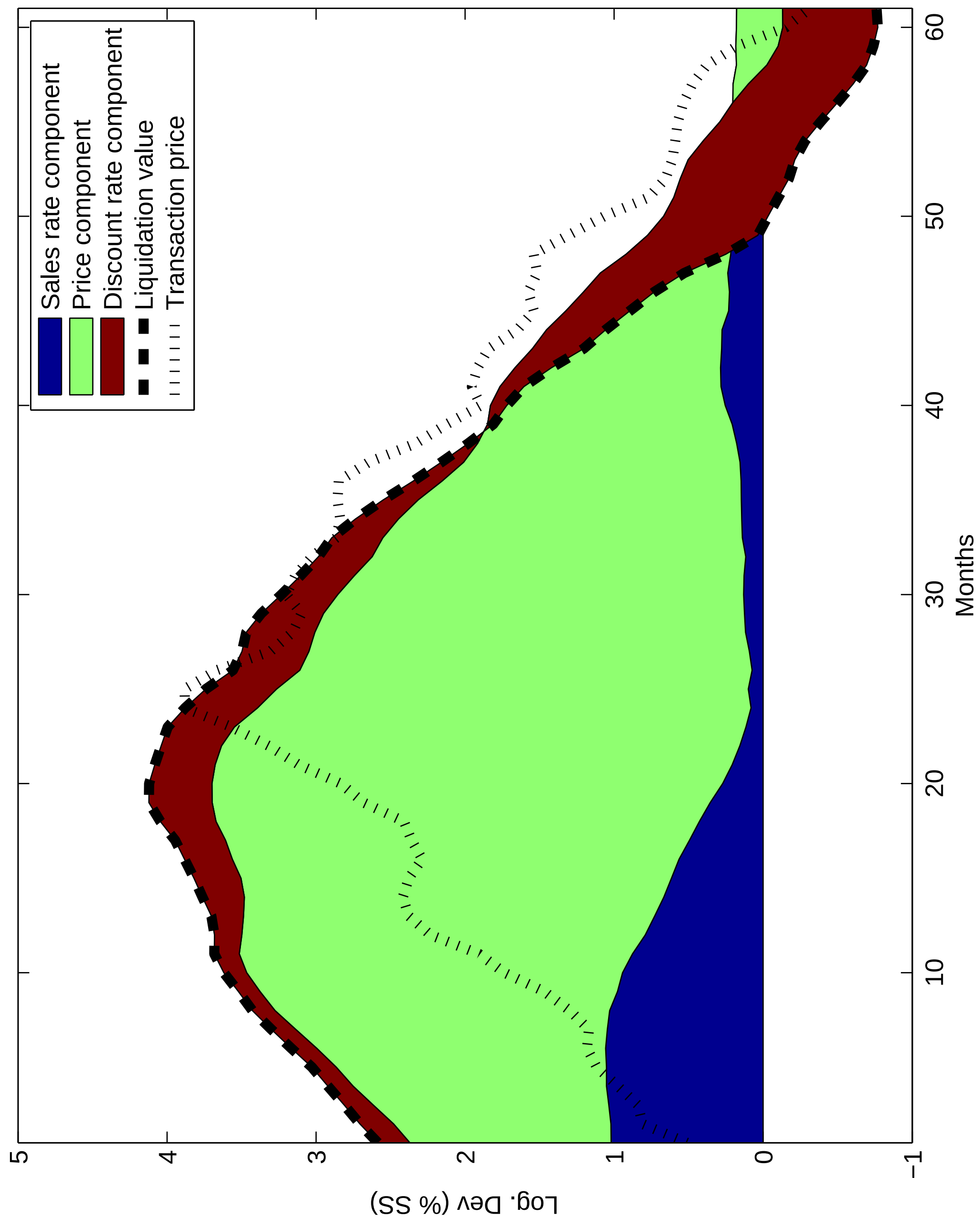

Figure 2.5: Response of liquidation value to temporary 1% exogenous fall in federal funds rate

Finally, notice that some empirical studies offer (rough) points of orientation regarding the trade-off between time-to-sale and sales price in the housing market. Genesove and Mayer (2001) suggest that homeowners with larger mortgages relative to housing value prefer to sell housing at a higher price. Specifically, 100% loan-to-value sellers keep houses 15 percent longer on the market and sell at 4% higher price (relative to an 80% loan-to-value seller). Levitt and Syverson (2008) find that realtors keep their own houses 10 percent longer on the market and end up selling at a 4% higher price than when they sell someone else's house. To explain this, Levitt and Syverson (2008) point to fixed real estate agent fees (proportional to sales price). This pricing structure means that agents have an incentive to sell other people's houses quickly (they bear all the search costs associated with keeping the property on the market for longer, while reaping only a fraction of the eventual gain in sales price). Either of these studies suggests that house prices are significantly more sensitive to time-to-sale than the model in this paper suggests.

Overall, this quantitative exercise shows that the empirical housing liquidity response to monetary policy is indeed strong enough to substantially raise housing liquidation values relative to observed transaction prices. However, it does not offer a story for why the housing market responds to central bank action through both house price and sales rate margin. It does not explicitly spell out how this collateral liquidity effect translates into expanding consumer credit and output growth. It does not estimate the contribution of the housing liquidity channel of monetary policy to the overall macroeconomic effect of central bank action. Section 2.3 develops a structural macroeconomic model that attempts to address these issues.

2.3 A Macroeconomic General Equilibrium Model

This section introduces housing market search frictions into the Dynamic Stochastic General Equilibrium model with credit-constrained consumers developed in Iacoviello (2005) and Iacoviello and Neri (2010). In this setup, the housing sales rate naturally manifests itself as a determinant of housing fire-sale discounts and of household borrowing margins, yielding a housing liquidity channel of monetary policy transmission to the real economy.

The model is calibrated to match the monetary policy impulse response functions of section 2.1. A counterfactual simulation then allows to gauge the quantitative significance of the liquidity effect for monetary policy transmission to mortgage lending and the real economy. If lenders were forced to maintain steady-state loan-to-value ratios on new mortgages (in effect re-establishing the traditional link between housing debt capacity and house price of the Walrasian setup), the simulations predict that the cumulative impact of a 1% temporary fall in the policy rate on output would fall from 5 % to 3%.

2.3.1 Model Structure

The economy consists of four agent types. Patient (p) consumer households consume, work, occupy housing and trade in a range of financial assets. Impatient (ip) entrepreneur households also consume, work, occupy housing and trade in a range of financial assets. However, in addition, they operate wholesale firms on their properties to produce intermediate goods. In equilibrium, impatient households will demand to borrow from the patient, creating a role for credit markets. Retail firms transform intermediates production into final goods that are sold to consumers under monopolistic competition with Calvo-style price adjustment rigidities. Finally, a central bank regulates nominal interest rates according to a Taylor-type monetary policy rule.

As shown in figure 2.6, each period t consists of four phases. In the first phase, aggregate shock innovations to the economy are observed. In the second phase, a fraction of occupied housing becomes unsuitable for the current occupiers (it becomes effectively vacant). The household may have to move town because of a new job opportunity. A growing family may require a house with more room for their children. A retired couple may wish to trade down into a smaller housing unit with wheelchair access. In the third phase, the housing, goods, labour, equity and debt markets open. Key is that households engage in a costly and time intensive search process to find a suitable new home. In the fourth phase, debtor households can make an offer to renegotiate debt (in the spirit of Hart and Moore (1994) and Kiyotaki and Moore (1997)). The creditor has the choice of accepting or rejecting the proposal. This renegotiation threat makes the collateral constraint of debt contracts relevant in equilibrium.

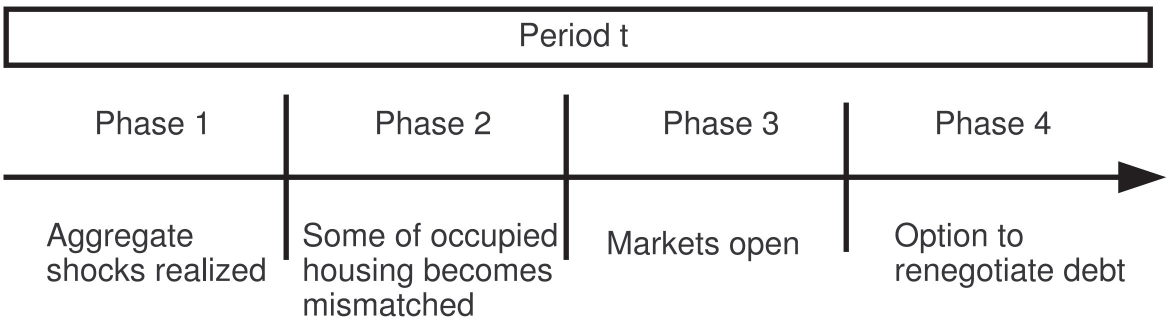

Figure 2.6: Period t consists of four distinct phases

Households

Type i households value consumption c_t^i and fit-for-occupation (matched) housing h_t^i. They experience disutility from providing labour effort l_t^i. Assuming that within-type households insure each other against idiosyncratic shocks through informal and formal financial contracts, all within-type households face identical decision problems. For analytical tractability, the setup can therefore be thought of as consisting of one patient and one impatient representative household.[29] As in Iacoviello (2005) and Iacoviello and Neri (2010), this paper assumes an expected utility objective function 2.3.1 for type i households with log utility in consumption and housing as well as general CRRA utility in leisure.[30] As key distinguishing feature between the two consumer types, patient households put greater weight on future felicity ($\beta^p > \beta^{ip}$). In equilibrium, this will generate existence of a debt market in which patient households lend their savings to impatient households.

[29]The big family assumption is clearly a convenient stylized modelling device (see its explicit use in Merz (1995) and Andolfatto (1996)). However, the notion has roots in reality. Assume a grandfather is bound to a wheelchair and can therefore not climb the stairs of his home. The daughter may have to drive to the grandfather's house after work every day to help him with the household. An office worker may find a new job in a distant city. To avoid the long commute, he may ask friends to stay in their guest room weekdays until his old house can be sold and he can himself settle closer to work. In utility terms, the cost of mismatched housing may well be spread across the extended network of a household.

[30]The log functional restrictions for consumption and housing ensure a stable relation between housing expenditures and consumption even in periods of prolonged house price deviations from steady state (see Davis and Heathcote (2005) and Fisher (2007)).

$$\sum_{s=0}(\beta^i)^{t+s}E_t(ln(c^i_{t+s}) + jln(h^i_{t+s}) - \chi\frac{(l^i_{t+s})^{1+\eta}}{1+\eta}) \tag{2.3.1}$$

$$\tag{2.3.2}$$

A fraction z of occupied housing becomes unfit for its current residents in phase 2 of period t. For simplicity, assume that owning housing that is unfit yields no utility benefits to its current owner. In this sense, unfit housing becomes effectively vacant. Given new acquisitions of matched housing $a^i_{m,t}$, equation 2.3.3 denotes the evolution of occupied housing for households of type i.

$$h^i_t = (1-z)h^i_{t-1} + a^i_{m,t} \tag{2.3.3}$$

To acquire new occupied housing, households search with effort $e^i_t \geq 0$. Denoting by $P_{b,t}$ the probability of finding appropriate housing (per unit of search effort), new acquisitions of matched housing are described by equation 2.3.4.

$$a^i_{m,t} = P_{b,t}e^i_t \tag{2.3.4}$$

Housing that becomes vacant is offered for sale to households searching for new homes (with per-period probability of sale $P_{s,t}$). If an appropriate buyer household is found, the transaction takes place at regular market price $q_{m,t}$. Once the search market closes, a vacant housing spot market opens in which vacant lots can be sold instantly to speculators at fire-sale price $q_{v,t}$ (denote by $a^i_{v,t}$ net acquisitions of vacant housing in the spot market). These instant sales effectively delegate search for new housing end-users to other households acting as intermediary. Equation 2.3.5 denotes the evolution of vacant housing held by type i households at the end of period t.[31]

[31] The existence of a spot market for vacant housing has two aims. First, conceptually, it offers households the option to sell quickly to a speculator (at a liquidation discount) or to engage in lengthy and costly search for a regular house buyer (and then sell at a higher regular price). In a stylized way, the framework therefore features a trade-off between speed of sale and sale price. In this sense, monetary policy affects the steepness of this trade-off. Second, technically, the vacant housing spot market ensures that vacant housing is priced by those households that put highest value on holding it (the patient households in equilibrium). This will simplify the bargaining game, since all sellers put the same value on owning vacant housing at the end of every period.

$$v_t^i = (1 - P_{s,t})(v_{t-1}^i + zh_{t-1}^i) + a_{v,t}^i \tag{2.3.5}$$

Transactions on the housing market are costly. In search market transactions that lead to occupation, buyers and sellers incur proportional one-off transaction costs F_b and F_s. Buyers pay consumption cost κ_b per unit of search effort devoted to finding new housing fit for occupation.[32] At the start of period t, households pay maintenance m and property tax τ on all housing held (vacant as well as occupied).

Equity in retail firms held o_t^i (normalized to net supply measure 1) trades on a spot market at price $q_{o,t}$. Given retail firm dividends $\Pi_{r,t}$, equity holdings yield $\Pi_{r,t}o_{t-1}^i$ in period t. Denote by $\Pi_{w,t}^i$ profits from wholesale production activity by consumer type ($\Pi_{w,t}^p = 0$ trivially, since only the impatient consumer is assumed to act as entrepreneur) taxed at rate τ_w. Denote government transfers to households by T_t^i. Denoting the nominal return on debt by R_{t-1} and denoting inflation by $\pi_t = p_t/p_{t-1}$, the real debt yield is R_{t-1}/π_t. Given wage w_t^i, equation 2.3.6 denotes the consumer budget constraint.

$$c_t^i + \frac{R_{t-1}b_{t-1}^i}{\pi_t} + q_{o,t}\Delta o_t^i - (w_t^i l_t^i + b_t^i + o_{t-1}^i\Pi_{r,t} + (1-\tau_w)\Pi_{w,t}^i + T_t^i) \tag{2.3.6}$$
$$= \underbrace{q_{m,t}(1-F_s)P_{s,t}(v_{t-1}^i + zh_{t-1}^i)}_{\text{Revenue from housing sales to new occupiers}} - \underbrace{(q_{v,t}a_{v,t}^i + q_{m,t}(1+F_b)a_{m,t}^i)}_{\text{Cost of property purchases}}$$
$$- \underbrace{\kappa_b e_t^i}_{\text{Cost of search effort}} - \underbrace{((m+\tau)(h_{t-1}^i + v_{t-1}^i))}_{\text{Cost of tax and maintenance on housing}}$$

Finally and crucially, the threat of debt renegotiation in phase four of period t imposes a borrowing constraint (as in Kiyotaki and Moore (1997) and Iacoviello (2005)). Effectively, borrowers have the option to repudiate the debt contract (in the spirit of Hart and Moore (1994)) in phase four of period t. In that case the lender takes control of the housing collateral underlying the contract. The borrower makes a take-it-or-leave-it alternative loan repayment offer to keep the house. The lender can either accept this

[32] As in section 2.2, assume sellers face no per-period direct intermediation costs (intermediation costs instead are paid one-off as part of F_s). Notice this assumption is not crucial for results. In fact, raising the cost of holding vacant housing inventory would increase the relevance of the housing liquidity channel further.

alternative offer or he can move the house into his foreclosure inventory.

To prevent renegotiation, lenders ex-ante must keep the loan small enough relative to the liquidation value they assign to collateral. They can then credibly commit to not accepting renegotiation offers. Equation 2.3.7 denotes the relevant condition.

$$E_t(Q^{i'}_{t+1}\frac{R_t}{\pi_{t+1}})b^i_t \leq q_{v,t}h^i_t \tag{2.3.7}$$

Search And Matching In The Housing Market

The search market for fit-for-occupation housing uses the labour market formalization summarized in Pissarides (2000). Assume a Cobb-Douglas matching function M_t that determines the mass of matches between buyers and sellers as function of aggregate buyer search effort e_t and vacant housing (the old stock v_{t-1} carried over from last period and newly vacated housing $z\sum_i h^i_{t-1}$).

$$M_t = e_t^{1-\gamma}(v_{t-1} + z\sum_i h^i_{t-1})^\gamma \tag{2.3.8}$$

Here aggregate search effort and vacant properties are straightforwardly defined from their type-specific equivalents:

$$e_t = e^p_t + e^{ip}_t \tag{2.3.9}$$

$$v_{t-1} = v^p_{t-1} + v^{ip}_{t-1} \tag{2.3.10}$$

Defining market tightness θ_t as the ratio of search effort over vacant housing, this yields closed-form solutions for the matching probabilities of buyers and sellers.

$$P_{b,t} = \frac{M_t}{e_t} = \theta_t^{-\gamma}$$
$$P_{s,t} = \frac{M_t}{v_{t-1} + z\sum_i h^i_{t-1}} = \theta_t^{1-\gamma}$$

How is the average transaction price $q_{m,t}$ determined once a household finds a vacant house it is willing to occupy? From section 2.1, it appears that house prices are sluggish. The model therefore assumes that house prices have a backward-looking component (encompassing flexible price Nash-bargaining as a special case). Specifically, assume that the average house transaction price in period t is determined as weighted average of the average transaction price in the preceding period and the current price outcome from Nash bargaining ($q^N_{m,t}$). In calibration of the model, the sluggishness parameters s of this pricing equation is set to match the impulse response function of the housing market to monetary policy (with $s = 1$ yielding fully flexible Nash-bargained house prices).[33]

$$q_{m,t} = sq^N_{m,t} + (1 - s)q_{m,t-1} \tag{2.3.11}$$

In the Nash bargaining solution to the search market house price $q^N_{m,t}$, denote the buyer and seller surplus from a transaction as the gain from making the transaction happen against the outside option of breaking off negotiations (without a new counterparty search being possible in period t). Since sellers can sell on the vacant housing spot market if they cannot sell on the search market, the outside option of sellers (of either consumer type) equals the vacant housing liquidation price $q_{v,t}$ in equilibrium. Denoting by ω the share of the total transaction surplus accruing to the seller (the bargaining weight) and by V^f_t the fundamental valuation that households assign to fit-for-occupation housing, this implies a unique per-period Nash bargained price determined by equation 2.3.12 (irrespective of which consumer type is buyer or seller in a specific negotiation).[34]

$$q^N_{m,t}(1 - F_s) - q_{v,t} = \omega(V^f_t - q_{v,t} - (F_s + F_b)q^N_{m,t}) \tag{2.3.12}$$

[33] A simple story justifying pricing rule 2.3.11 goes as follows. Assume that the economy consists of a large number of regions (and, implicitly, that search effort cannot be directed at specific regions). In a given region, the transaction price is determined with reference to the previous period transaction price with probability $1 - s$. With probability s, the transaction price is determined by the outcome $q^N_{m,t}$ of Nash bargaining between buyer and seller (defined further below). It follows that a region features the Nash bargaining price of k periods ago with probability $(1 - s)^k s$. If transactions occur whenever buyers find an appropriate vacant property, it follows that the average transaction price is given as weighted average of past Nash bargaining prices: $q_{m,t} = sq^N_{m,t} + (1-s)sq^N_{m,t-1} + s(1-s)^2 q^N_{m,t-2} + ...$ Writing this expression recursively yields equation 2.3.11 (as a natural analogue to Calvo pricing in firm price-setting).

[34] In the neighbourhood of the steady state, fundamental valuation of a matched property will be equalized across household types (see below). In introducing notation in this section, I anticipate this result.

Firms, Policy & The Shock Process

Impatient households use their occupied property, together with hired labour, to produce intermediate inputs. Output is sold to retailers in a perfectly competitive market at price p_t. Denoting by x_t the retailer mark-up on prices, equation 2.3.13 denotes the problem of the wholesale firm. The parameter α sets the equilibrium fraction of income going to labour. Equally, μ determines the fraction of labour income going to patient workers.[35]

$$Max \frac{1}{x_t} A(h_t^{ip})^{\alpha}((l_t^p)^{\mu}(l_t^{ip})^{1-\mu})^{1-\alpha} - \sum_i w_t^i l_t^i \tag{2.3.13}$$

Following the New Keynesian literature, retail firms differentiate output by type j and set prices $p_t(j)$ in a monopolistically competitive environment subject to Calvo-pricing (a fraction ϑ of firms can adjust prices in period t). Consumers aggregate output subject to a Dixit-Stiglitz technology. The optimisation problem for those retail firms that can adjust prices is therefore given by expression 2.3.14.[36] Profits from market power are rebated to the consumer through lump-sum per period dividends $\Pi_{r,t}$.

$$Max_{p_t(j)} \sum_{s=0} (\vartheta_f \beta^p)^s \frac{c_t^p}{c_{t+s}^p} \frac{p_t}{p_{t+s}} (p_t(j) - p_{t+s}) y_{t+s}(j) \tag{2.3.14}$$

$$\text{s.t.} y_{t+s}(j) = (\frac{p_{t+s}}{p_t(j)})^{\frac{\lambda_f}{\lambda_f - 1}} y_{t+s} \tag{2.3.15}$$

Following standard derivation (see Gali (2008)), this setup yields a forward-looking Phillips curve. Current inflation depends on expectations of future inflation and current mark-up of retailers over wholesale producers ($\hat{X}_t$ in deviation from steady state). Here we define $\nu = (1 - \vartheta)(1 - \beta^p \vartheta)/\vartheta)$.

$$\pi_t = \beta^p E_t(\pi_{t+1}) - \nu \hat{X}_t \tag{2.3.16}$$

[35] In equilibrium, competitive input markets imply wholesale profits $\Pi_{w,t}^{ip} = (\alpha/x_t)(A(h_t^{ip})^{\alpha}(l_t^p)^{(1-\alpha)\mu}(l_t^{np})^{(1-\alpha)(1-\mu)}/h_t^{ip})$. By assumption, $\Pi_{w,t}^p = 0$ since patient households are assumed not to be entrepreneurs. Notice, as special case of this framework, $\alpha = 0$ is observationally equivalent to a model in which patient and impatient are only households, wholesale firms make no profits and use only labour in production.

[36] The assumption that firms use the discounting factor of the patient consumer to evaluate future profits is subsequently validated, as in the neighbourhood of the steady state only patient households will hold firm equity.

The central bank sets interest rates according to a Taylor-type interest rate rule for monetary policy. Effectively, the central bank lowers the interest rate in response to widening of the output gap as well as rising inflation. Implicitly, the model assumes zero steady state inflation.

$$R_t = R^* \pi_t^{1+r_\pi} (\frac{Y_t}{Y^*})^{r_Y} m_{r,t} \tag{2.3.17}$$

The baseline setup explores AR(1) monetary policy shocks to this Taylor rule of form:

$$log(m_{r,t}) = \rho_{mr} log(m_{r,t-1}) + \epsilon_{mr,t} \tag{2.3.18}$$

Finally, assume that government redistributes tax on wholesale firm profits to patient consumer households. This is a technical assumption to ensure that patient households remain economically significant in steady state debt markets (despite the asymmetric assumption that only impatient households derive income from entrepreneurial activity).[37]

$$T_t^p = \tau(\Pi_t^w) \tag{2.3.19}$$

Equilibrium

To recapitulate, it is useful to define formally an equilibrium in this environment. An equilibrium is an allocation of prices (R_t, r_t, w_t^i, $q_{m,t}$, $q_{v,t}$, p_t, $q_{o,t}$) and quantities ($a_{m,t}^i$, $a_{v,t}^i$, c_t^i, h_t^i, v_t^i, e_t^i, l_t^i, o_t^i, b_t^i, $y_t(j)$) such that households maximimize utility, firms maximize profits, the search and matching market for foreclosed housing follow the dynamics set out in subsection 2.3.1, monetary policy follows the prescribed Taylor rule and all remaining markets clear given any history of shock realizations. Figure 2.7 presents a graphical overview of the markets in this economy. Appendix A.3 derives the first order conditions associated with the equilibrium.

[37]This transfer policy implies trivially $T_t^{ip} = 0$.

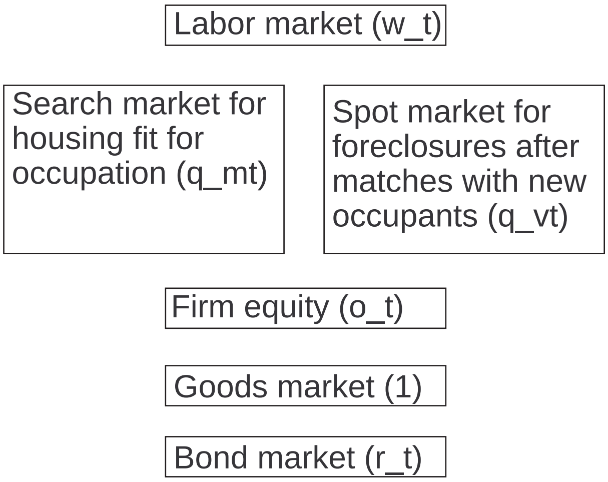

Figure 2.7: Schematic for markets in the model economy

2.3.2 Analytical Implications

The main features of this general equilibrium model can be represented analytically. First, the assumed joint existence of a search market in which housing can be sold to new occupants as well as a spot market in which vacant housing can be sold to speculators (effectively delegating search for new occupants) ensures that the steady state (and dynamics around the steady state) can be characterized transparently. Second, because low interest rates make home ownership more attractive, expansionary monetary policy raises the number of buyers searching for housing and therefore the rate at which vacant houses are sold. Third, higher housing sale rates raise the liquidation value of a foreclosed house (relative to regular house price), making the foreclosure threat of lenders more effective and therefore making banks ex-ante more willing to offer households larger loans. This suggests the existence of a housing liquidity channel of monetary policy transmission to the real economy. Fourth, under a flexible Nash-bargaining of house prices, a low housing sales rate allows buyers to drive down house prices, making buyer entry into the housing market more attractive and raising the housing sales rate. To get quantitatively large movements in housing liquidity in response to external shocks, some sluggishness in house prices is needed.[38] This subsection discusses each of these four model implications

[38] Alternatively, one could limit free buyer entry into the housing market or modify the assumption of a Cobb Douglas matching function. However, given the empirical dynamic response of house prices in section 2.1 suggests sluggishness in price setting, breaking the Nash bargaining assumption appears a

in turn.

Steady State

Since the remainder of the paper will be concerned with local perturbations around the steady state, it is useful to start by specifying the salient properties of this steady state through a series of statements (appendix A.4 develops analytical proofs).

Implication 2.3.1. *In any non-stochastic steady state, the impatient consumer is borrowing-constrained and the patient consumer is not*

A simple contradiction argument offers an intuitive interpretation. Conjecture a steady state in which the impatient consumer is not borrowing-constrained. For the bonds market to clear, steady state bond interest rates must be such that the impatient consumer is indifferent between borrowing and saving. But then the patient consumer must have unbounded demand for saving. The bond market cannot be in equilibrium.

This explains why the assumed heterogeneity in consumer discount rates ensures an operational (non-trivial) steady state credit market in the model. Moreover, for small perturbations of the model economy, it follows that the response of impatient households is limited by a binding credit constraint (while the patient consumer is unconstrained).

Implication 2.3.2. *In any non-stochastic steady state:*

- *Patient and impatient households are committing search effort to finding new housing for occupation* ($e_t^i > 0 \; \forall \; i = p, ip$)
- *Patient and impatient households assign the same fundamental value to occupied housing* ($V_{f,t}^{p} = V_{f,t}^{ip}$)

Again a contradiction argument is enlightening. Suppose consumer type i did not search for newly occupied housing in steady state. Remember now that a fraction of existing matched housing becomes vacant in every period, cost of searching and purchasing new housing for occupation is finite and marginal utility of occupied housing nears infinity as the occupied housing stock approaches 0. The supposition therefore implies

natural starting point.

that the consumer's marginal valuation of housing exceeds the cost of purchasing new housing for occupation in finite time. At that point, not searching for housing cannot be optimal for the consumer. Both consumer types searching must be part of any steady state solution.

Suppose now that both consumer types search for appropriate housing in steady state, but fundamental valuation of housing differs by type. Since both types must then (weakly) prefer searching to not searching, the type with higher fundamental valuation must strictly prefer searching. Optimally, the high fundamental valuation type should therefore raise search effort, increasing housing market tightness and search costs for both types until the lower valuation type is persuaded to quit searching. This contradicts a steady state in which both consumer types search actively for housing fit for occupation.

Implication 2.3.3. *In any non-stochastic steady state:*

- *the patient consumer holds all equity and vacant housing*
- *the patient consumer (the marginal buyer), prices equity and after-search vacant housing*

Intuitively, the patient consumer requires a lower rate of return to hold assets until the next period. The patient therefore price equity and vacant housing down to the level at which the impatient consumer leaves these markets. It follows that patient households hold all assets in steady state (as well as for small deviations around the steady state).[39]

Jointly, statements 2.3.2 and 2.3.3 lead to a key representational simplification of the model: in every period there exists a unique Nash bargained transaction price for housing. To understand why this is surprising, note that the Nash-bargained price depends on the payoffs and outside options of buyer and seller involved in a transaction. It follows that a model with two consumer types generally exhibits four different Nash bargained house prices (a price when the buyer is patient and the seller is patient, a price when the buyer is patient and the seller is impatient and so on).

In this specific modelling setup however, a unique Nash bargained transaction price emerges. Why? Notice implication 2.3.3 implies that the seller outside option does

[39]Appendix A.4, besides formally verifying these statements, also proves existence of a unique well-defined steady state.

not depend on seller type. Because of the spot market in vacant housing, the outside option of both types equals the liquidation value of housing for a patient consumer. Because implication 2.3.2 shows that the buyer pay-off is independent of type, it therefore follows that, in this framework, the Nash-bargained price of all four buyer-seller type encounters is identical. While this setup is presumably not crucial (in a qualitative sense) for the main conclusions developed in this paper, it substantially increases transparency of model output (as well as the calibration procedure). Implication 2.3.4 summarizes this argument.

Implication 2.3.4. *In any non-stochastic steady state:*

- *patient and impatient households face the same outside option during negotiations to sell a vacant house to a new occupant (the vacant house price)*
- *patient and impatient households face the same gain from successfully concluding negotiations to buy a vacant house for occupation (see fundamental value result for implication 2.3.2)*
- *by implication, all period t matches lead to a transaction at the same price $q_{m,t}$ (irrespective of buyer and seller types involved)*

Why Does Expansionary Monetary Policy Raise The Housing Sales Rate?

The interaction between housing market search frictions and house price Nash-bargaining offers a natural explanation for the section 2.1 finding that monetary policy stimulates housing liquidity. The argument relies on two steps. First, notice that the consumer optimality condition for buyer search effort e_t implies free entry condition 2.3.20:[40] In equilibrium, the net gain from purchasing a unit of housing equals expected search costs for buying that unit. Second, (and abstracting from house price rigidities) Nash bargaining in prices implies that the buyer surplus from moving into a vacant house is proportional to the economic surplus accruing from the household-property match.

[40] The free entry condition is already simplified taking into account local properties around the steady state summarized in implication 2.3.2.

$$\underbrace{\frac{\kappa_b}{\theta_t^{1-\gamma}}}_{\text{Expected cost of buyer search}} = \underbrace{V_t^f - q_{m,t}(1+F_b)}_{\text{Buyer surplus}} \tag{2.3.20}$$

$$= (1-\omega)\underbrace{(V_t^f - q_{v,t} - (F_s+F_b)q_{m,t})}_{\text{Total match surplus}}$$

In combination, these two steps offer a story for the link between monetary policy and housing market liquidity. Temporary low interest rates raise the present value (in consumption terms) of the current and future flow of housing services to an occcupier household. This drives up the economic surplus from a match between household and property and, through Nash bargaining, the buyer payoff from purchasing a home. In equilibrium, more buyers enter the housing market, driving up search costs to the point that search costs equalize expected benefits from locating a house. From a seller perspective, in a market crowded with potential buyers, the rate at which vacant housing can be resold to new occupiers rises.[41]

Why Does A Higher Housing Sales Rate Raise Consumer Credit Access?

In any period, a vacant house can be sold in two ways. First, a seller can offer the vacant property for sale on the search market for new occupants. If new occupants are found, then the vacant house can be sold at regular market price $q_{m,t}$. Second, if the search is unsuccessful, the seller can instantly sell the house on the period t spot market to a speculator at price $q_{v,t}$. This speculator then effectively takes over the task of searching for a new occupier household in subsequent periods. The ratio between $q_{v,t}$ and $q_{m,t}$ therefore represents a fire sale discount reflecting costs for searching for a new end-user of the asset.

This fire sale discount plays a central role in the housing liquidity channel of monetary

[41]Two additional comments are useful at this point. First, key to this result is that buyers have bargaining power. This ensures that house prices rise by less than the change in fundamental housing value following a fall in interest rates. It follows that the sensitivity of housing liquidity to monetary policy rises in buyer bargaining power. Second, notice house price rigidities mean that house prices respond even more sluggishly to monetary policy than under Nash bargaining. Following the intuition in the main text, this makes buyer surplus and housing liquidity even more sensitive to changes in the policy rate.

policy developed in this study. Notice first that a pricing equation for vacant property of the form studied in section 2.2 emerges naturally from the first order conditions of the patient consumer in this general equilibrium model. Rescaling equation 2.2.1 by current regular transaction price of housing yields an expression for the determinants of the fire sale discount (equation 2.3.21). Crucially, it depends on current and future measures of housing market tightness. When current and/or future housing sale rates are low, then searching for a new occupier of a vacant property is costly. It follows that speculators are only going to accept taking over the search process if the fire sale discount is large enough to compensate for high expected time-to-sale.

$$\underbrace{\frac{q_{v,t}}{q_{m,t}}}_{\text{Fire-sale discount}} = E_t(Q^p_{t+1}\frac{q_{m,t+1}}{q_{m,t}}(-\frac{m+\tau}{q_{m,t+1}} + \underbrace{P_{s,t}}_{\text{Sales rate}} (1+F_s-\frac{q_{v,t+1}}{q_{m,t+1}}) + \frac{q_{v,t+1}}{q_{m,t+1}})) \tag{2.3.21}$$

In turn, rewriting the impatient consumer credit constraint (that binds around steady state according to implication 2.3.1), the fire sale discount emerges as crucial determinant in household access to credit. The security offered to lenders by housing collateral depends inherently on the costs associated with liquidating that collateral in case of default.[42] When liquidation costs are high because fire-sale discounts are large, then banks tighten credit access.

$$\underbrace{b^{ip}_t}_{\text{Debt capacity}} = \underbrace{\frac{1}{E_t(Q^p_{t+1}\frac{R_t(1-z)}{\pi_{t+1}})}}_{\text{Inverse bond return}} \underbrace{\frac{q_{v,t}}{q_{m,t}}}_{\text{Fire-sale discount}} \underbrace{q_{m,t}h^{ip}_t}_{\text{Value of housing}} \tag{2.3.22}$$

Equations 2.3.21 and 2.3.22 therefore offer a natural argument suggesting that the housing sales rate response to monetary policy matters for the overall transmission process. By raising housing liquidity, monetary policy relaxes consumer credit constraints

[42] Assuming that households can use equity and vacant housing to secure credit has no impact on the model solution. Around the steady state, borrowers will not choose to hold such asset types in equilibrium. Therefore, in either case occupied housing is the only collateral used by borrowers. Ruling these other asset classes out ex-ante has the advantage of reducing clutter in an already complex modelling setup.

over and above the rise in regular book value of the housing stock.

Why are backward-looking house prices needed to generate large housing liquidity responses to monetary policy?

Notice that the Nash bargaining price implies that buyer and seller suplus from matching a vacant house to a new household are positively related (see equation 2.3.23). Combined with buyer free entry and a Cobb-Douglas matching technology, this generates a mechanism significantly dampening housing liquidity fluctuations.

Intuitively, buyers take advantage of low housing sale rates to drive down Nash-bargained prices in negotiations (since the seller surplus from a transaction rises). In turn, this raises the ex-ante incentive to search for housing. The number of buyers in the housing market rises, housing liquidity rises and the original fall in house prices is dampened.

$$\omega \underbrace{(V_t^f - (1+F_b)q_{m,t}^N)}_{\text{Buyer surplus from match}} = (1-\omega) \underbrace{(q_{m,t}^N(1-F_s) - q_{l,t})}_{\text{Seller surplus from match}} \tag{2.3.23}$$

As will be seen in the calibration of the subsequent section, the model therefore strongly suggests that house prices do not follow Nash-bargaining. Instead, house prices have a backward looking component. Buyers cannot instantly take advantage of the bad bargaining position of house sellers in illiquid property markets. In equilibrium, this amplifies the role of housing liquidity fluctuations.

2.3.3 Calibration

The quarterly calibration of the model follows a two-step procedure. Wherever possible, this study uses reference parameters from the literature. The housing search friction parameter γ, the house seller bargaining weight ω, the size of the underlying monetary policy shock $\epsilon_{m,1}$, the house price persistence parameter s as well as the housing shock persistence parameter ρ_m are set to match the empirical response of housing market and aggregate output to the Romer and Romer (2004) monetary policy shock.

As in Iacoviello (2005), set the yearly discount factors of patient and impatient households to 0.99 and 0.97. This reflects estimates on the range of discount factors across the US population.[43] Set labour market parameter $\chi_l = 1$ and housing preference parameter $\chi_h = 2.5$ (to ensure a steady state housing-GDP ratio of 6). Set a 75% Calvo price adjustment parameter ϑ. Normalize productivity factor $A = 1$ and the total housing supply $\bar{H}$ to 1. Set the monetary policy response to output gap and inflation as in Iacoviello (2005) ($r_y = 0.21$ and $r_\pi = 0.16$). Following convention, set labour wage elasticity to $\varphi = 1$ and steady state mark-up $X^* = 0.15$.

As in Ngai and Tenreyro (2009), set the rate at which housing is unmatched z to 2.78% for consistency with an average stay in a house of 9 years.[44] Matching a steady state time-on-market for vacant housing of 5.7 months and a fire-sale discount of 15%, set m, τ and F_s following the calibration approach in section 2.2. Given lack of other information, assume buyer fixed costs are equal to the seller's ($F_b = F_s$).[45] Set κ_b to ensure a steady state monthly sales rate of 20%.

As in Monacelli (2009) and Sterk (2010), set the fraction of labour income going to patient households μ to 0.5. This is close to the calibration used in Iacoviello (2005) and Iacoviello and Neri (2010).[46] Considering the empirical literature, note that this number reflects Campbell and Mankiw (1989) who find that about 50% of US households appear to behave as if they were rule-of-thumb households (or credit-constrained).[47] To ensure the assumption that the credit unconstrained own the wholesale firms does not affect relative economic weight of the two population groups, assume government lump-

[43] Iacoviello (2005) cites the micro studies of Lawrance (1991), Carroll and Samwick (1997) and Samwick (1998) as sources of these ballpark estimates.

[44] Ngai and Tenreyro (2009) in turn base their figures on median duration of stay in a house according to the American Housing Survey 1993-2005.

[45] Some evidene in favour of such equal sharing of costs comes from Levitt and Syverson (2008). They report that real estate agents on buyer and seller side generally charge each about 3% of house price for their services.

[46] This number is slightly greater than the DSGE estimates in Iacoviello (2005) (64%) and Iacoviello and Neri (2010) (using a Bayesian approach, they use a prior of 65% and find a mean posterior of 79%). Attempting direct calibration of this parameter in this framework, results turned out to be very sensitive to other parameter choices. This study therefore chooses to postulate a reasonable value for this parameter exogenously.

[47] The Jappelli (1990) study might suggest that a baseline number $\mu = 0.5$ is too low. He uses micro evidence from the 1983 Survey of Consumer Finances to identify that 20% of households either applied for a loan and were rejected or were deterred from applying because they expected rejection. However, this definition of the credit constrained may be more restrictive than that relevant for this study. For the purpose of this paper, the credit-constrained are those households whose terms of credit are sensitive to the debt capacity of their housing. This plausibly includes a much larger fraction of the population than those that are fully excluded from the credit market.

sum transfers T_t^i to move 50% of wholesale firm revenues from the unconstrained to the constrained.

The housing search friction parameter γ, the house seller bargaining weight ω, the size of the underlying monetary policy shock $\epsilon_{m,1}$, the house price persistence parameters s as well as the housing shock persistence parameter ρ_m are set to minimize the squared distance between model and empirical impulse responses to monetary policy. Specifically, set target moments as first quarter and fourth quarter response of house price and housing sales rate. Additionally, set parameters to ensure that peak model and empirical response of output coincide.[48] Formally, denoting by u and u^{emp} respectively the model and empirical peak response of variable x (in log-dev. from steady state), model parameters are chosen according to optimality criterion 2.3.25.

$$u = \begin{bmatrix} \hat{P}_{s,1} \\ \hat{P}_{s,4} \\ \hat{q}_{m,1} \\ \hat{q}_{m,4} \\ \hat{y}_1 \end{bmatrix} \tag{2.3.24}$$

$$Min_{\omega,\gamma,s,\rho_m}(\frac{u - u^{emp}}{u^{emp}})'(\frac{u - u^{emp}}{u^{emp}}) \tag{2.3.25}$$

The resulting calibration suggests setting $\gamma = 0.1$, $\omega = 0.19$, $\rho_m = 0.8$, $s = 0.33$ and $\epsilon_{m,1} = 0.007$. Intuitively, a low seller bargaining weight ω makes the buyer surplus especially sensitive to changes in the overall match surplus from occupying a house. A low γ in turn ensures that changes in the buyer surplus lead to large equilibrium buyer entry into the housing market. These two parameter choices therefore contribute to making the housing sales rate sensitive to monetary policy. Equally, a low value for parameter s ensures that house prices respond sluggishly to monetary policy, generating a hump-shaped response in prices that further raises the responsiveness of housing liquidity to

[48] Note that, in the model developed, output peaks on impact, while the Romer and Romer (2004) estimation results suggest a delayed output response. This weakness of the model is shared with many others. Christiano, Eichenbaum and Evans (2005) propose several bells and whistles to the baseline model that generate additional persistence in output and inflation impulse response functions. This paper refrains from introducing these additions in order to focus attention on the core features driving the housing liquidity channel of monetary policy.

policy intervention. Table 3.1 summarizes the baseline calibration.

2.3.4 Counterfactual: Monetary Policy without Liquidity Effect

To evaluate the contribution of the liquidity effect to macroeconomic transmission of monetary policy, consider a counterfactual scenario in which lenders are only allowed to raise loan amounts in line with house transaction price q_m: modified borrowing constraint 2.3.26 holds. Effectively, this rule blends out the liquidity effect, since a direct link between transaction prices and borrowing limit is artificially imposed. Figures 2.8, 2.9, 2.10 and 2.11 consider the impact of a 1% monetary policy shock under the baseline model (solid line) and the counterfactual no-liquidity effect scenario (dashed line).

$$E_t(Q^i_{t+1}\frac{R_t}{\pi_{t+1}})b^i_t \leq \frac{q^*_v}{q^*_m} q_{m,t} h^i_t \tag{2.3.26}$$

Consider first a monetary policy shock in the counterfactual no-liquidity effect model (dashed line). As in a standard New Keynesian model with perfect credit markets, the expansionary monetary policy shock lowers the returns on savings and encourages households to move consumption to the present. Because goods prices are sluggish, demand stimulates output, raises firm demand for labour inputs and starts a protracted period of inflation. Following the imposed Taylor rule, the nominal interest rate rises on impact to counteract the surge in output and inflation.[49] Additionally, in this setup with credit-constrained households, lower interest rates raise the attractiveness of home ownership, driving up house prices. The borrowing-constrained can access more credit. They therefore buy more housing, they raise consumption disproportionally and they raise work effort by less than patient households (since current income is more valuable when credit constraints bind tightly).[50]

Consider now the response of the economy to monetary policy shocks in the full model

[49] Notice this positive interest rate response to the expansionary monetary policy shock is counterfactual (compared to the empirical results in section 2.1). However, it is shared with other papers in this modelling class (see for example Sterk (2010)). Furthermore, note that the real interest rate in fact does fall in response to the policy shock since the rise in inflation is large and protracted.

[50] In this setting, housing search frictions play a secondary role. Effectively, as more buyers enter the housing market after expansionary monetary policy, the search cost of looking for housing rises. However, search frictions only really start to matter for the rest of the economy once interaction between credit and search friction is introduced.

Parameter	Value	Target
Consumer preferences		
β_p	$0.99^{\frac{1}{4}}$	Iacoviello & Neri (10)
β_{ip}	$0.97^{\frac{1}{4}}$	Iacoviello & Neri (10)
χ_h	0.25	$\frac{q_m^* h^*}{y^*} = 6$ (Iacoviello (05))
χ_l	1	Iacoviello (05)
φ	1	elastic labour demand
Production technology		
α	0.3	Labour income share of 70%
ϑ_f	0.75	av. 1 yr price reset (Iacoviello (05))
λ_f	1.15	Iacoviello (05)
μ	0.5	Sterk (2010)
Housing search market		
z	0.0278	av. ownership 9 yrs (Ngai & Tenreyro (09))
κ_b	1.57	satisfy buyer free entry
F_s	0.1	$\frac{V_s^*}{q_m^*} = 0.85$ (emp. fire-sale discount)
F_b	0.1	$F_b = F_s$
$\frac{m}{q_m^*}$	0.04/4	Poterba (91)
$\frac{\tau}{q_m^*}$	0.02/4	Poterba (91)
ω	0.19	match housing market impulse response
γ	0.1	match housing market impulse response
s	0.33	match housing market impulse response
Policy		
r_y	0.21	Iacoviello (05)
r_π	0.16	Iacoviello (05)
r_r	0.72	Iacoviello (05)
τ_h	0.5	split housing return evenly across types
ρ_m	0.8	match housing market impulse response
$\epsilon_{1,m}$	0.007	match housing market impulse response

Table 2.1: Calibration for baseline DSGE

(the solid line) that allows for interaction between housing search market and the credit market. Because the lower policy rate encourages buyers to enter the housing market, the housing sales rate rises. This boosts liquidation prices of housing by more than actual transaction prices.[51] The fire-sale discount on property narrows and, following equation 2.3.22, loan-to-value ratios offered by lenders rise. The housing liquidity effect roughly doubles the impact effect of monetary policy on debt expansion and output. Overall, these general equilibrium simulations suggest that the liquidity effect contributes substantially to the macroeconomic housing channel of monetary policy transmission.

2.4 Liquidity Effect & Home-Buyer Tax Credits

If housing liquidity plays an important role in the housing channel of monetary policy transmission, then a natural question must be whether the liquidity effect also raises the macroeconomic impact of other policy levers that operate through the housing market. In other words, does ignoring the liquidity effect lead us to underestimate the impact of housing market interventions in general? The macroeconomic model developed in section 2.3, calibrated using evidence on the housing and macroeconomic impact of monetary shocks, provides a natural environment in which to tackle this question.

A housing market intervention that received widespread coverage during the financial crisis of 2007-2009 will serve as inspiration for this exercise: the 8000 USD first time home-buyer tax credit towards purchase of new primary residences enacted by Congress on February 29 2009 as part of the American Recovery and Reinvestment Act (ARRA) (ultimately extended until summer 2010).[52,53] Given an average transaction price of 292,600 USD for new homes sold in the United States in 2008 (according to Census Bureau statistics on new housing sales), this policy measure amounts to an effective subsidy of slightly less than 3% on average new US home purchases.

In the model of section 2.3, such a temporary tax credit is proxied as a mean-reverting

[51] Following the analysis in section 2.1, liquidation values also rise because monetary expansion implies house price growth and liquidation values are forward-looking once an explicit time-to-sale assumption is introduced.

[52] The Act was preceded by another home buyer tax credit in 2008 in the form of an interest-free loan.

[53] The tax credit is limited to 10% of the house purchase price or 8000 USD. Recipients can add the tax credit to their tax refund (distinguishing the tax credit from a tax exemption).

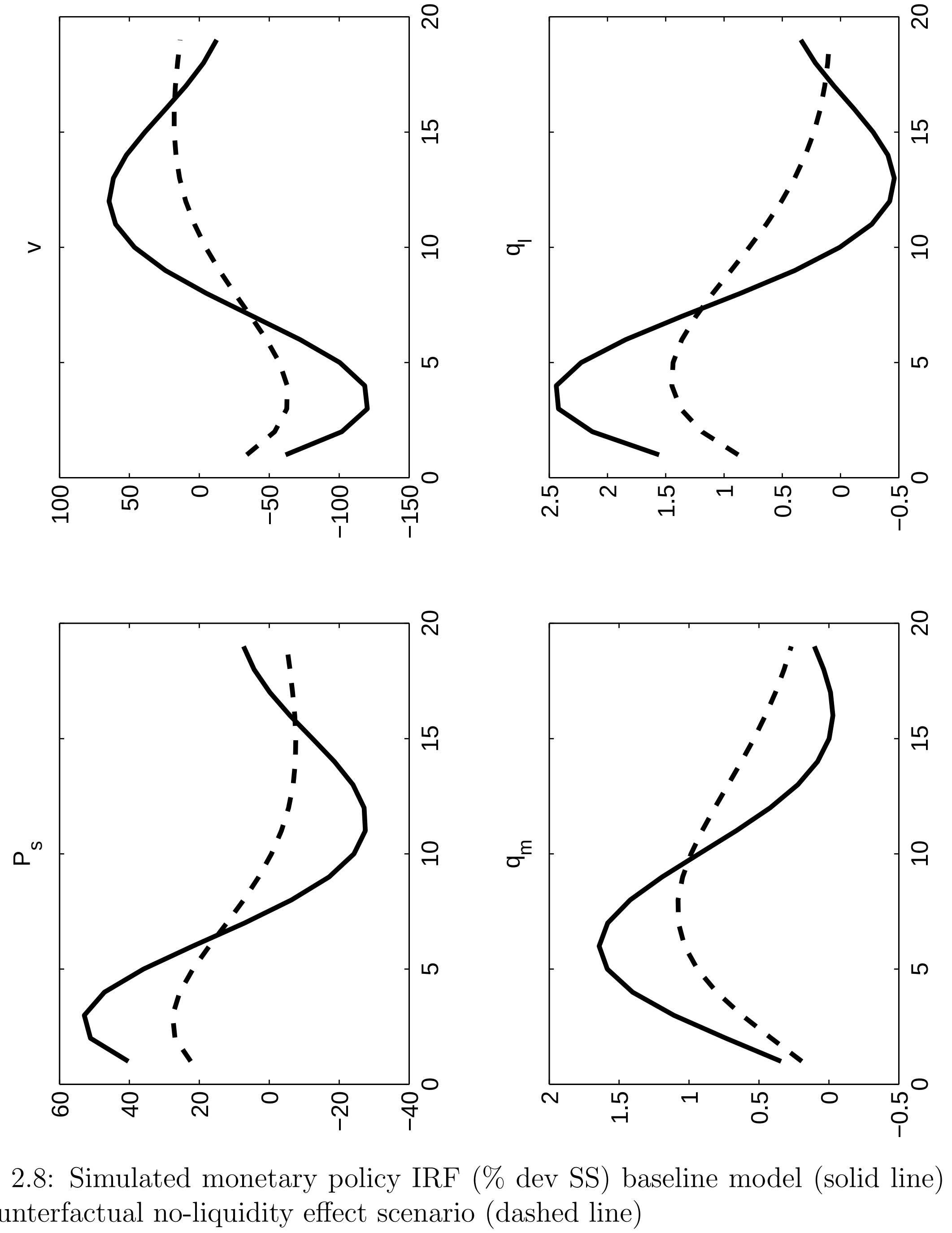

Figure 2.8: Simulated monetary policy IRF (% dev SS) baseline model (solid line) and the counterfactual no-liquidity effect scenario (dashed line)

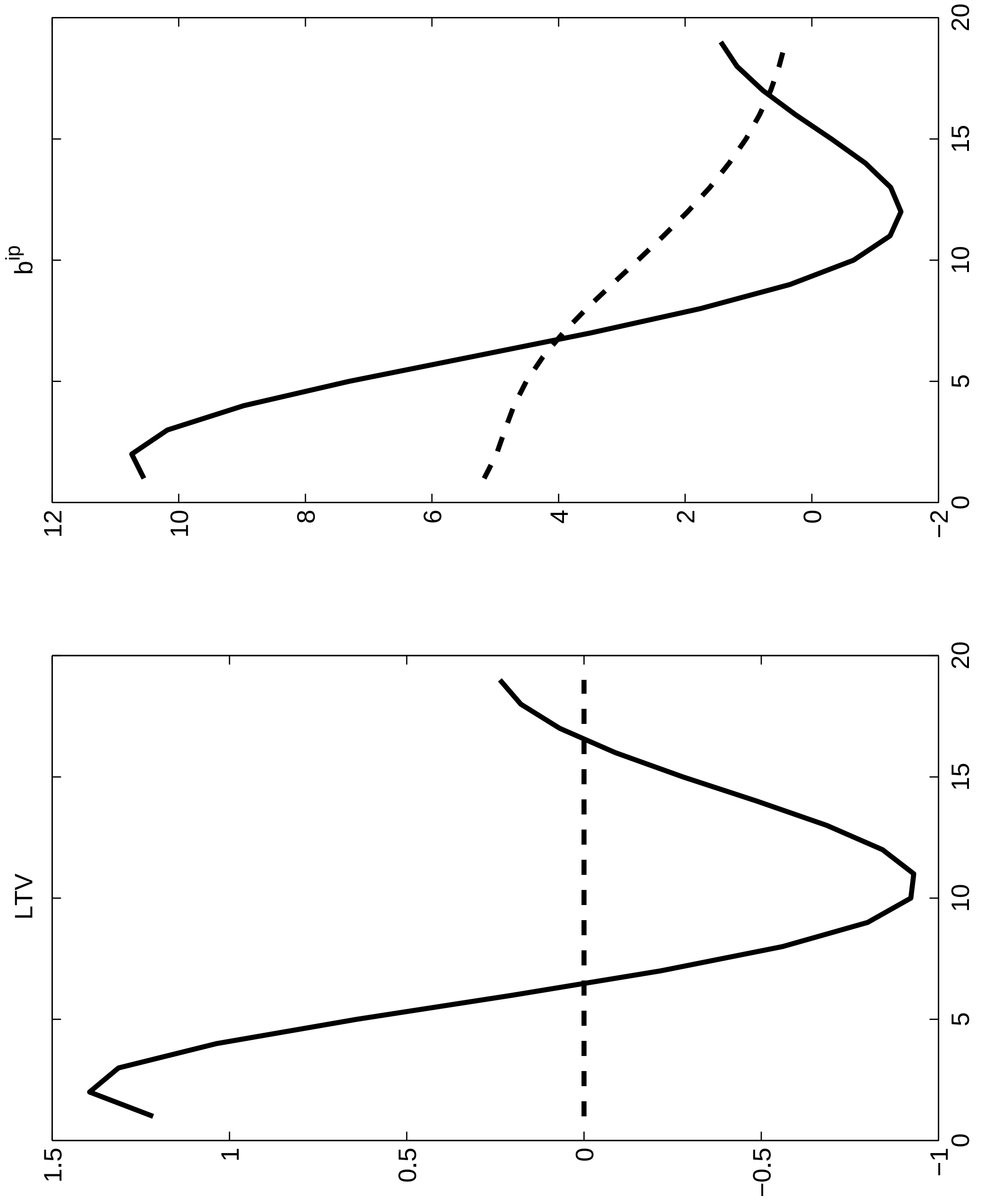

Figure 2.9: Simulated monetary policy IRF (% dev SS) baseline model (solid line) and the counterfactual no-liquidity effect scenario (dashed line)

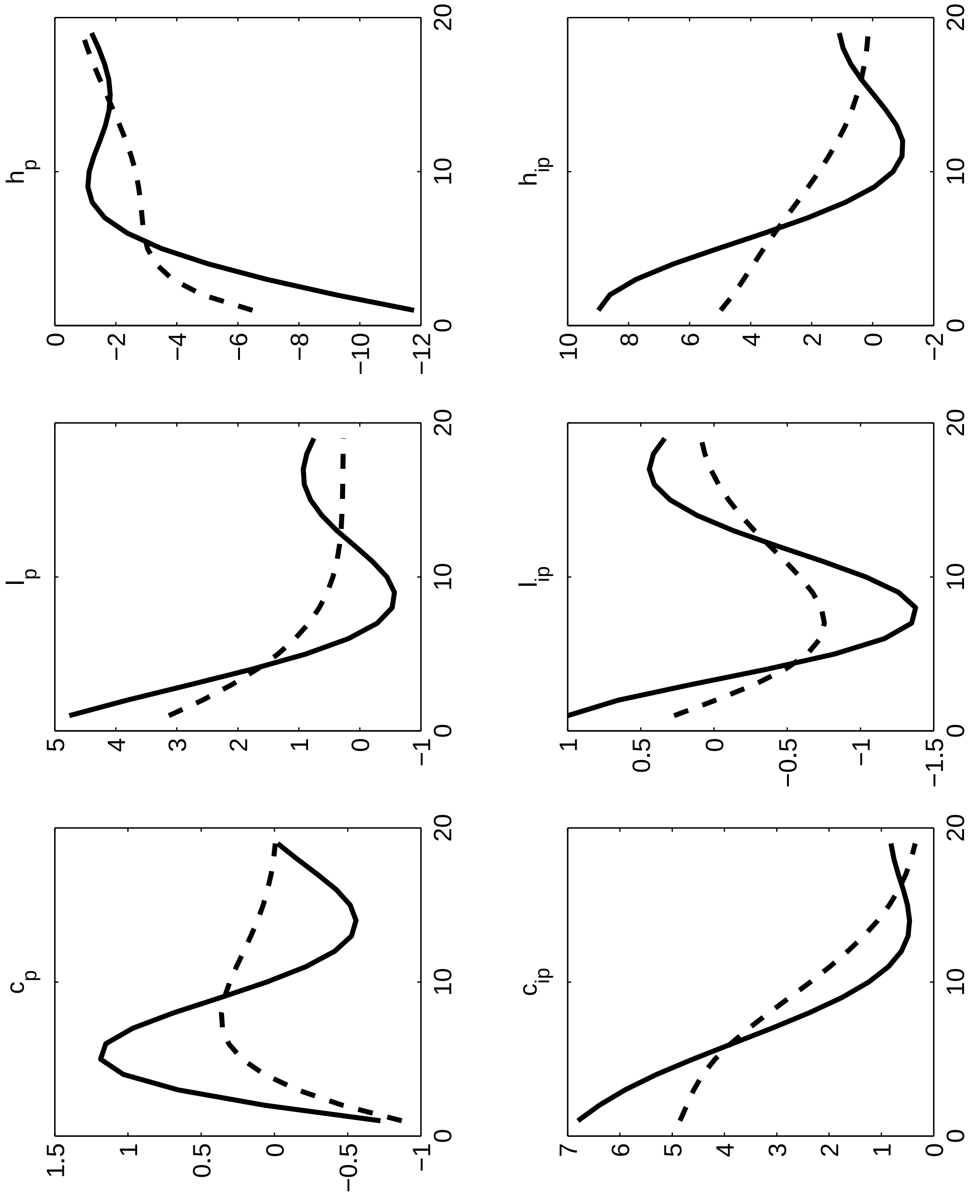

Figure 2.10: Simulated monetary policy IRF (% dev SS) baseline model (solid line) and the counterfactual no-liquidity effect scenario (dashed line)

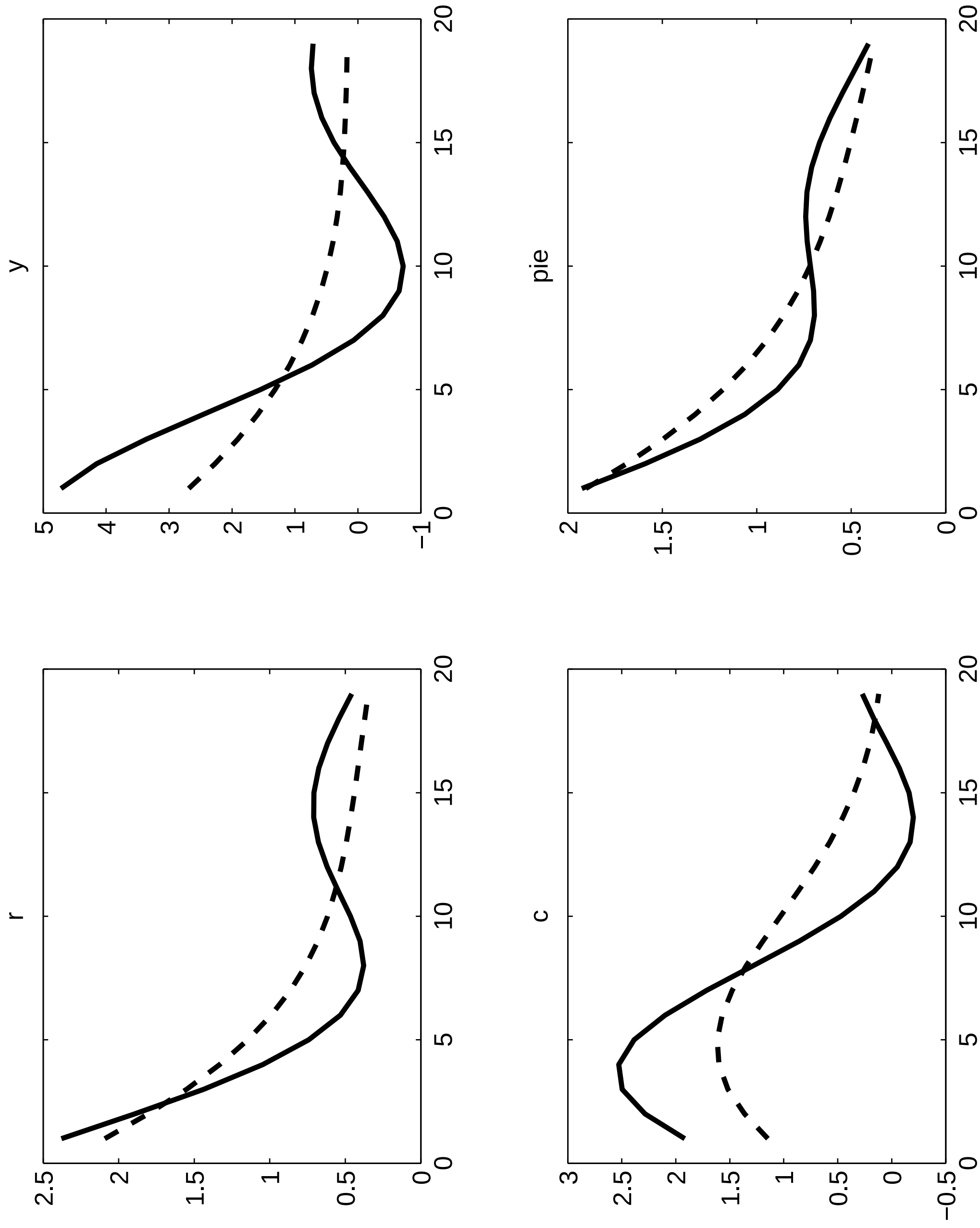

Figure 2.11: Simulated monetary policy IRF (% dev SS) baseline model (solid line) and the counterfactual no-liquidity effect scenario (dashed line)

process that provides housing buyers with partial compensation for the fixed costs associated with housing purchase.

$$s_t = \phi_s s_{t-1} + \epsilon_{s,t} \tag{2.4.1}$$

The key equations of the baseline model affected by the subsidy are the Nash bargaining equation and the consumer budget constraint. The study assumes the subsidy is financed with equivalent lump-sum taxes for the two consumer types $T^i_{s,t}$.

$$q_{m,t}(1 - F_s) - q_{v,t} = \omega(V^f_t - q_{v,t} - (F_s + F_b - s_t)q_{m,t}) \tag{2.4.2}$$

Figures 2.12, 2.13, 2.14 and 2.15 depict the response of the economy to a 3% shock to housing subsidy with persistence parameter $\phi_s = 0.8$. Consider first the solid line impulse response functions of the full framework. In the first instance, the subsidy raises house prices, as sellers capture some of the greater value that buyers put on closing the property transaction. At the same time, lower ultimate transaction costs attract more buyers into the housing market, raising housing market liquidity. Both the fall in time-to-sale and higher transaction prices raise the liquidation value that lenders associate with property collateral. Credit-constrained households respond by increasing consumption and by purchasing more housing. This allows them to expand their entrepreneurial activity and to raise aggregate output.

Consider now again the artificial no-liquidity effect exercise from section 2.3 for the subsidy shock. The stimulus to aggregate consumption and output is substantially weakened. The peak output response to the tax credit is 1/3 less. The housing liquidity effect introduced through housing search frictions plays a substantial role in the policy transmission process.[54]

Overall, the simulations in this section suggest that the macroeconomic stimulus provided by the housing tax credit of 2009-2010 may be much larger than an evaluation according to price impact alone would imply. As the subsidy encourages home buyers to

[54]Overall, it should be noted that the impact of the housing subsidy on the macroeconomy appears generally very high in this calibrated DSGE model. Nonetheless, the simulations are instructive in illustrating that the housing liquidity channel of monetary policy plausibly plays an important role in determining the relative magnitude of credit frictions over the business cycle.

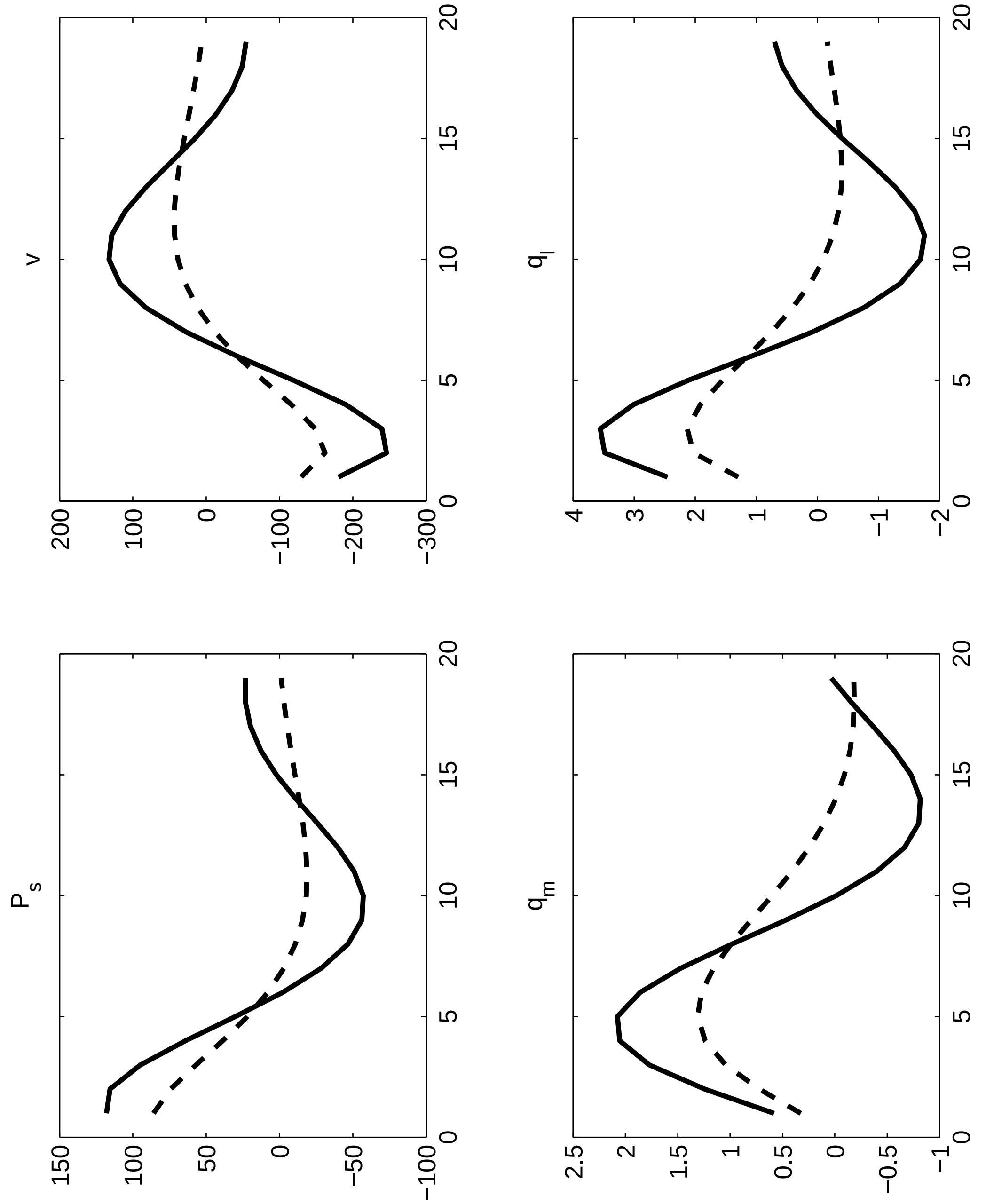

Figure 2.12: Simulated housing subsidy policy IRF (% dev SS) baseline model (solid line) and the counterfactual no-liquidity effect scenario (dashed line)

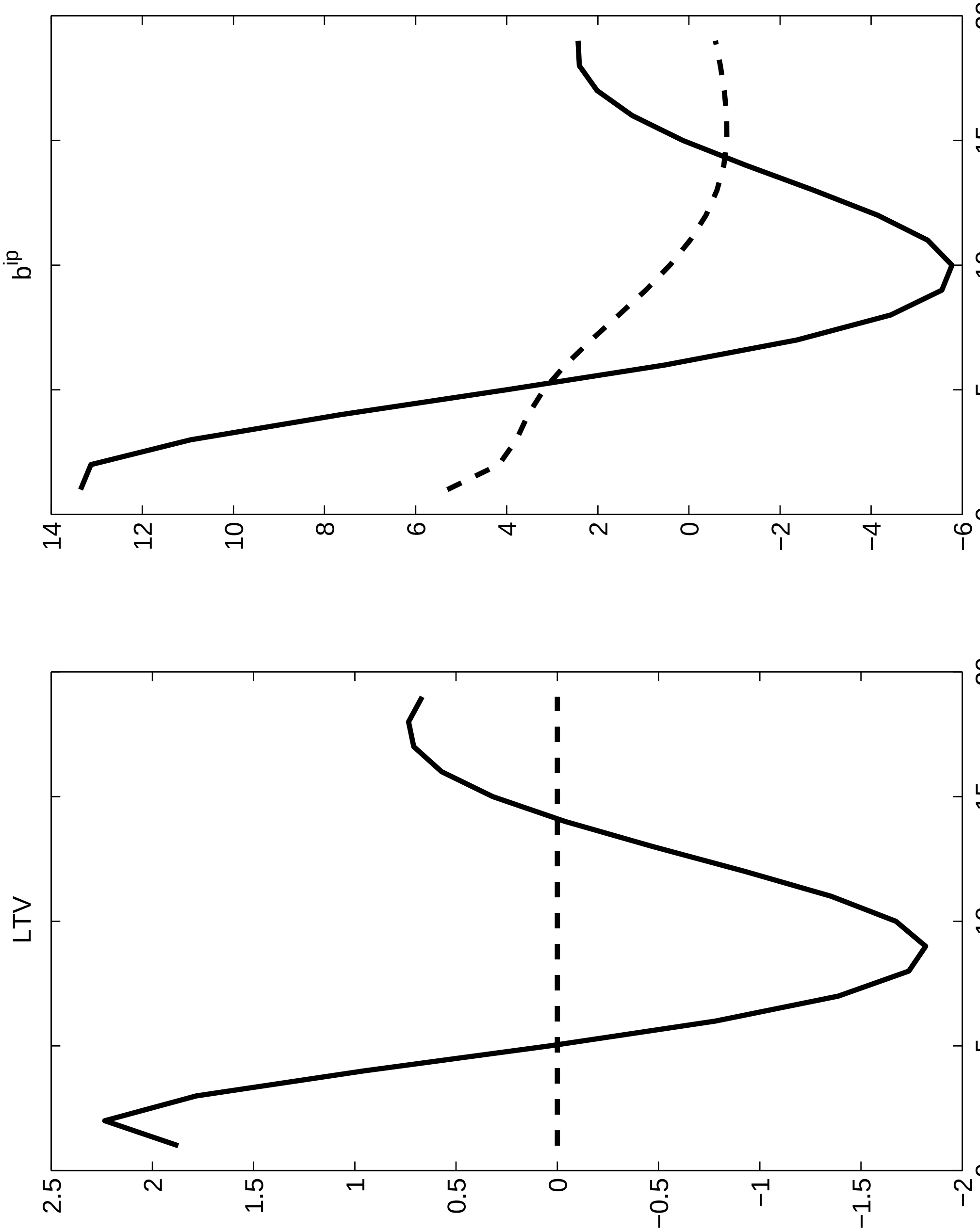

Figure 2.13: Simulated housing subsidy policy IRF (% dev SS) baseline model (solid line) and the counterfactual no-liquidity effect scenario (dashed line)

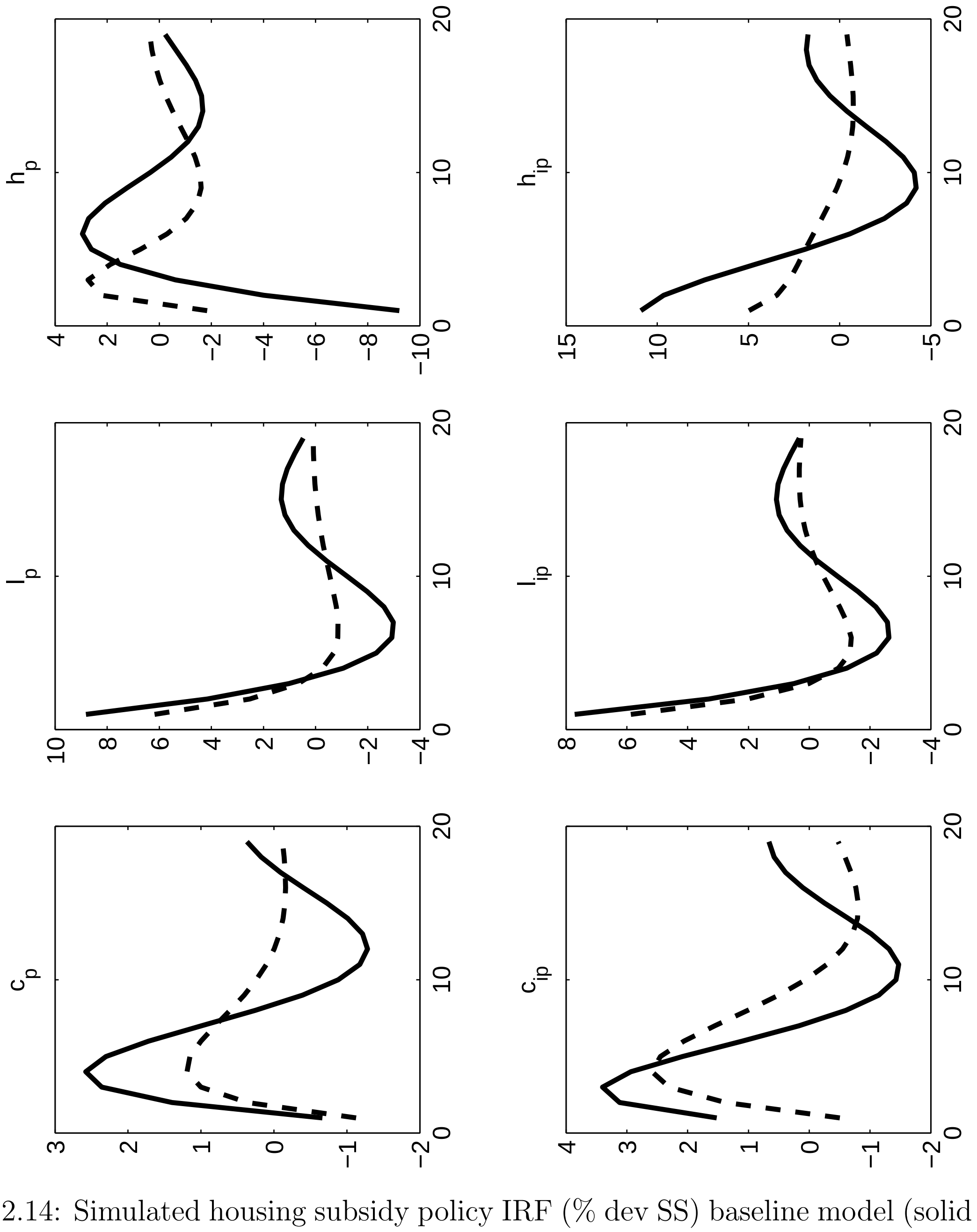

Figure 2.14: Simulated housing subsidy policy IRF (% dev SS) baseline model (solid line) and the counterfactual no-liquidity effect scenario (dashed line)

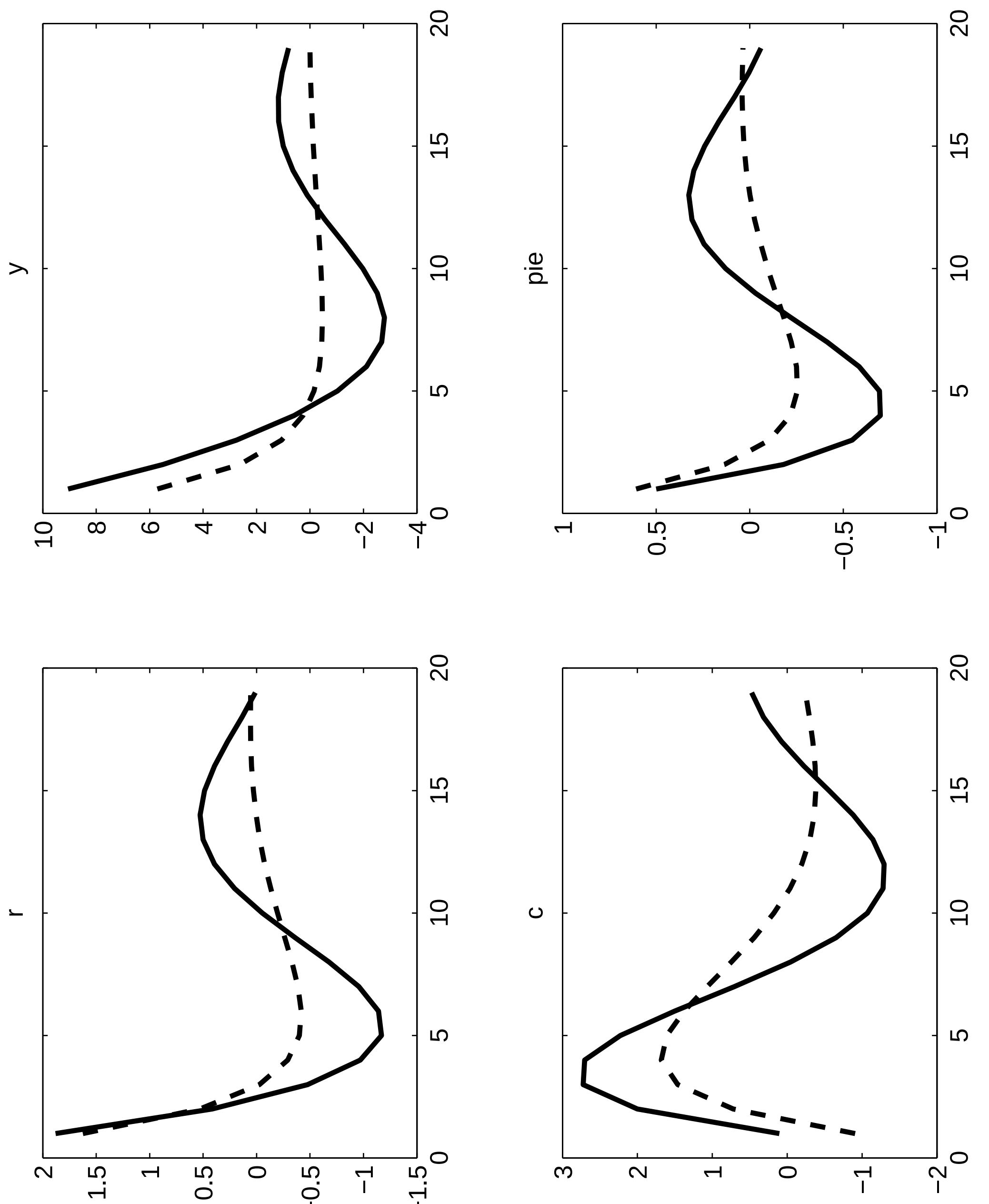

Figure 2.15: Simulated housing subsidy policy IRF (% dev SS) baseline model (solid line) and the counterfactual no-liquidity effect scenario (dashed line)

enter the housing market, it may have preserved housing collateral liquidity and stimulated a limited willingness of banks to provide households with mortgage finance in the crisis. The macroeconomic stimulus provided by housing market interventions should be judged based on their impact on both price and volume.

2.5 Concluding Discussion

This paper shows that the impact of monetary policy on housing debt capacity is plausibly much greater than the response of property transaction prices alone suggests. When lenders evaluate the security provided by property collateral, they should not only take into account the eventual resale price of the house in case of default, but also the substantial carrying costs they face until an appropriate counterparty is found. Based on the empirical finding that a fall in interest rates substantially lowers the time-to-sale of housing, simulations show that this housing liquidity effect can play an important quantitative role (distinct from the standard house price effect) in the transmission of monetary policy to household credit access and the macroeconomy.

Calibrating the model to fit monetary policy impulse response functions, the simulated impact of a temporary home buyer tax credit on the macroeconomy also rises substantially once its combined impact on time-to-sale and housing transaction prices is taken into account. Direct intervention in the housing market may constitute a more powerful substitute for conventional monetary policy than standard analysis would suggest.

For policy makers, the crucial message of the paper is therefore that housing market policies need to be evaluated not only by their impact on prices, but also by their impact on housing sales volume. Both price and volume plausibly matter for consumer access to mortgage credit. Having calibrated a macroeconomic model with borrowing-constrained households and housing market search frictions using empirical monetary policy impulse response functions, this study has developed a macroeconomic policy laboratory that takes into account both of these response dimensions.

This study naturally suggests several further avenues for research. First, to maintain links with the existing literature, this study has considered the impact of monetary policy in a macroeconomic model with one period risk-free mortgages. In light of the financial crisis of 2008-2009, introducing more realistic debt contracts constitutes an important step towards quantitatively meaningful macroeconomic models.[55] While the overall importance of the mechanism studied in this paper is conjectured to be robust to these extensions, exploring the exact quantitative implications of interaction between these refinements in the debt contracts and the liquidity effect is an important agenda item for further research.

Second, integrating housing market search frictions into a general equilibrium model of the US economy with credit-constrained households, this study proposes a theory for time-varying borrowing margins. In the face of a demand-slump, central banks face a trade-off between boosting demand through expansionary monetary policy and sowing the seeds of the next financial crisis by encouraging private sector leveraging. Analysing optimal monetary policy facing this trade-off requires at least a second-order approximation solution to the macroeconomic model developed and constitutes a potentially fruitful area for further research.

Third, the notion that asset debt capacity depends on the severity of resale market search frictions and fire-sale discounts offers a promising and tractable approach towards understanding fluctuations in credit access more generally. For example, the ability of the banking sector to sustain high leverage ratios may depend on the liquidity of the secondary market for the mortgage-backed securities (MBS) held by these institutions. Applying this search-theoretic approach to procyclical borrowing margins in over-the-counter financial asset markets is a fascinating topic for further research.

[55] Current research makes first steps in this direction. Forlati and Lambertini (2011) introduce risky mortgages in the DSGE framework. Calza, Monacelli and Stracca (2007) explore the impact of introducing long-term mortgages into macroeconomic general equilibrium setups.

Chapter 3

When Do Temporary Payroll Tax Cuts Work? Taking Hiring and Firing Costs Seriously

Can a temporary employer payroll tax cut stimulate job creation? Given a regular US employer payroll tax contribution of 6.2% of yearly wage, even a complete full-year payroll tax holiday may reasonably not pay for the costs of hiring (and eventual firing) of an additional worker. This implies that the tax cut will only sway firms with employment levels at which hiring new workers is close to profitable ex-ante. But how many firms have employment levels close to this hiring threshold?

Using simulations in a dynamic heterogeneous firm model with non-convex labour adjustment costs, this paper finds that the job creation multipliers associated with employer payroll tax cuts can be substantial. In the baseline framework, a one year payroll tax cut to 3% leads to a peak employment response of 2% relative to steady state. The source for this result lies in the high empirical rate at which workers quit employment and the importance of idiosyncratic shocks to firm-level business conditions. These two factors imply that, in normal times, many firms have employment levels close to the hiring threshold. These marginal firms remain responsive to tax cuts even given substantial labour adjustment costs.

Does this mean that hiring and firing costs can be ignored for the analysis of aggregate tax multipliers? On the contrary, when firms face labour adjustment costs the cost-effectiveness of tax stimulus depends crucially on exact tax design. First, tax cuts should be pre-announced. Announced future tax cuts persuade firms to retain employment today without lowering current tax intake. Second, tax cuts should be bold. If firms know that tax cuts are sustained, they respond more strongly to current tax incentives, making the stimulus more cost-efficient. Third, labour adjustment costs weaken multipliers in recessions. When business cycle conditions suddenly deteriorate, hiring thresholds move far below current employment levels. Many firms are hoarding labour and, at the margin, aggregate employment becomes less sensitive to tax incentives. This formalizes the notion that tax cuts persuade few firms to raise hiring when demand conditions are weak.

The study highlights three implications from these results. First, this work offers an important caveat for empirical work on fiscal multipliers. One cannot use the employment effect of a prolonged backloaded increase in employer payroll tax in normal times (such as a permanent rise in employer payroll tax in the 1950s to finance expansion of social security) to directly infer the impact of a present-value adjusted temporary frontloaded payroll tax cut in bad times (such as a temporary tax cut to boost employment during a recession). This suggests an important role for structural macroeconomic estimation (that can take into account the specific implementation of a given present value tax cut) in stimulus policy evaluation.

Second, for policy makers, the mechanism studied in this paper offers several take-away messages on when and how to use employer payroll tax stimulus. While policy implementation lags are generally seen as an argument against the use of fiscal stimulus, allowing firms to foresee a future tax cut may maximize the total number of jobs created per tax dollar foregone. Current practice to propose stimulus measures for one or two years at a time may limit the effectiveness of policy, since tax cut persistence matters for the strength of the multiplier. By the same logic, tax cuts in election years may be particularly ineffective if elections are contested and firms are not certain that the stimulus will be implemented at full length (in case of a change in ruling party).

Third, and maybe most controversially, these findings put into question a commonly held belief that fiscal policy is always more effective in recessions. In an economy with a high labour adjustment cost sector and a sector with low labour adjustment costs, the recessionary labour hoarding effect that makes fiscal stimulus less effective in downturns may operate only in the high labour adjustment cost sector. Countercyclical fiscal multipliers for stimulus targeted towards low-labour-adjustment-cost sectors (such as the countercyclical government spending shock multipliers recently found in Almunia et al. (2010), Auerbach and Gorodnichenko (2010) and Ilzetzki, Mendoza and Vegh (2010)) may be consistent with procyclical multipliers for broad-based employer payroll tax cuts.[1] A broad brush statement, based on empirical government spending multipliers, that all fiscal multipliers are countercyclical may miss on this important distinction.

The analysis in this paper links with a large empirical and theoretical body of work on the impact of fiscal policy. Empirically, Blanchard and Perotti (2002) introduce recursive identification of tax liability shocks using Vector-Autoregressions. Romer and Romer (2010) propose a narrative approach to identify exogenous tax liability changes. Neither approach however distinguishes between the source of tax cuts considered. Ilzetzki (2011) uses a novel international panel dataset on income, VAT and corporate tax rates in a first attempt to disentangle the effect of various tax cuts. Reflecting limited historical experience, none of these studies consider explicitly the impact of payroll tax cuts (on employer or employee side).

On the theoretical front, starting with Baxter and King (1993), the workhorse model for analysis of fiscal policy has been the Dynamic Stochastic General Equilibrium (DSGE) model. Using log-linearizations, the strength of this line of research has been full general equilibrium analysis of fiscal policy outcomes. Contributions following this approach touch on various issues discussed in this paper, though the conclusions reached are quite different. Concerning tax cut anticipation effects, Susan Yang (2005), House and Shapiro (2006) and Mertens and Ravn (2011) suggest that anticipated labour tax cuts are recessionary in the pre-implementation phase due to intertemporal labour substitution by workers.[2] In contrast, this paper highlights a force that makes anticipated labour tax cuts

[1] Note that Ramey (2011) points out that Pereira and Lopes (2010) and Pereira and Lopes (2010) do not find that fiscal mutlitpliers depend on the business cycle. She suggests a key distinction may be whether estimation treats the business cycle state as exogenous or endogenous.

[2] Mertens and Ravn (2011) also provide some empirical evidence that anticipated tax liability changes, using the identification scheme, are recessionary before implementation. They however concede in their conclusions that the impact of specific tax policy changes may be quite heterogeneous. Unfortunately, limited historical variation in employer payroll tax does not allow repetition of their exercise for the specific tax measure analysed in this paper only.

expansionary today. Firms may hire today because they expect that the present value of payroll taxes paid on the position will fall due to a future tax cut stimulus. Concerning the length of the tax cut, papers starting with Baxter and King (1993) have highlighted the crucial role intertemporal utility maximization by consumers plays in translating expectations of tax cut length into current response of the economy. This paper argues that, even if consumers respond mostly to current business conditions and are therefore less forward-looking than classical models predict, labour adjustment costs create a strong incentive for forward-looking firms to adjust their labour market response to stimulus length. Concerning business-cycle-dependent fiscal multipliers, Christiano, Eichenbaum and Rebelo (2011) show fiscal multipliers may be much larger when the economy is at the zero lower bound on nominal interest rates (implying countercyclical fiscal multipliers). Michaillat (2011) suggests that employer payroll tax multipliers may be countercyclical, because labour markets are "slack" in downturns. This paper shows that non-convex labour adjustment costs imply a force towards procyclical fiscal multipliers. Slackness inside the firm creates a force towards tax stimulus multipliers, just as slackness outside the firm (in the labour market) creates a force towards countercyclical policy multipliers.[3]

The importance of non-convex adjustment costs for macroeconomic dynamics has been highlighted in a growing literature starting with Oi (1962). The framework applies the modelling approach used in papers such as Bertola and Caballero (1994), Abel and Eberly (1994), Caballero and Engel (1999) and Bloom (2009) towards analysis of payroll tax multipliers.

This paper proceeds by developing the model policy laboratory used for analysis in section 3.1. Section 3.2 analyses the response of this economy to a baseline temporary employer payroll tax cut. Section 3.3 shows that hiring and firing costs make tax multipliers contingent on exact policy design. Section 3.4 discusses two implications that follow from these results. Section 3.5 offers concluding comments.

[3]Bloom, Floetotto and Jaimovich (2010) use a model with non-convex input adjustment costs to show that wage subsidies are less effective when economic uncertainty is high. Vavra (2012) shows that recessionary uncertainty leads firms to readjust prices more frequently, meaning that monetary policy is a less effective stimulus tool in high uncertainty periods. In contrast to this work, my study shows that policy will be less effective in downturns without having recourse to simultaneous second moment shocks.

3.1 The Policy Laboratory

The main goal of the paper is to highlight the economic forces that non-convex labour adjustment costs introduce into a simulated dynamic heterogeneous firm economy subject to a temporary employer payroll tax cut. The model used therefore aims to be rich enough to encompass the major channels through which labour adjustment costs matter, while preserving expositional transparency.

Subsection 3.1.1 describes the theoretical model used as policy laboratory. Subsection 3.1.2 proposes a baseline calibration. Subsection 3.1.3 discusses the steady state properties of the model. This sets the stage for the policy experiments conducted in this paper.

3.1.1 Setup

In every period t, the problem of monopolistically competitive firm i consists of choosing output price $p_t^i \geq 0$, hours per worker $h_t^i \geq 0$, the mass of workers to hire $e_t^i \geq 0$ and the mass of workers to fire $f_t^i \geq 0$ to maximize expected present discounted profits 3.1.1 subject to output demand 3.1.2, the evolution of employed workers $l_t^i \geq 0$ described in equation 3.1.3 and the production function 3.1.4. Firms are risk-neutral and use discount factor r to evaluate future profits. They are subject to an employer payroll tax contribution defined as a fraction τ_t of their payroll expenditure.[4]

$$\underset{h_{t+s}^i, l_{t+s}^i, e_{t+s}^i, f_{t+s}^i}{Max} \sum_s E_t((\frac{1}{1+r})^s(p_{t+s}^i y_{t+s}^i(h_{t+s}^i, l_{t+s}^i) - (1+\tau_{t+s})w(h_{t+s}^i)l_{t+s}^i - c(e_{t+s}^i, f_{t+s}^i))) \tag{3.1.1}$$

Output demand is negatively related to output price set by the firm (with price elasticity ϵ) and positively related to a random demand shifter b_t^i.

[4]Notice this rule amplifies how the employer payroll tax operates in practice. Specifically, it ignores that earnings above a maximum threshold are not subject to payroll tax ("Maximum taxable earning"). There is also a policy debate whether to introduce a payroll tax cut that applies only to new hires by the firm (by limiting the tax cut to payroll expenditure in year t beyond expenditure in year t-1). For more information on this, please see a short history of the US employer payroll tax in appendix B.2.

$$y_t^i(h_t^i, l_t^i) = b_t^i (p_t^i)^{-\epsilon} \tag{3.1.2}$$

Labour hired today becomes operative in the following period.[5] Given a fraction λ of the existing workforce quits (employee-initiated job separations) in every period, equation 3.1.3 describes the dynamic path of employment at firm i.

$$l_{t+1}^i = l_t^i(1-\lambda) + e_t^i - f_t^i \tag{3.1.3}$$

The production function 3.1.4 allows for diminishing returns to labour $\tilde{\alpha}$ in employed workers and hours. Technology is subject to random productivity shifter $\tilde{a}_t^i$.

$$y_t^i(h_t^i, l_t^i) = \tilde{a}_t^i (h_t^i l_t^i)^{\tilde{\alpha}} \tag{3.1.4}$$

Combining expressions 3.1.1, 3.1.2 and 3.1.4 yields the optimization problem 3.1.5. This takes the form of an "as-if" competitive firm maximisation problem subject to "productivity shocks" only (where $\alpha = \frac{\epsilon}{\epsilon-1}\tilde{\alpha}$ and $a_t^i = (\tilde{a}_t^i)^{\frac{\epsilon-1}{\epsilon}} (b_t^i)^{\frac{1}{\epsilon}}$). To link with previous literature, this paper from hereon refers to a_t^i as a productivity shock, though the implicit understanding is that the shock reflects wider business conditions (such as weaker demand for the product).

$$\underset{h_{t+s}^i, l_{t+s}^i, e_{t+s}^i, f_{t+s}^i}{Max} \sum_s E_t((\frac{1}{1+r})^s (a_t^i (h_t^i l_t^i)^{\alpha} - (1+\tau_t) w(h_{t+s}^i) l_{t+s}^i - c(e_{t+s}^i, f_{t+s}^i))) \tag{3.1.5}$$

Following Bloom (2009), wages per worker $w(h_t)$ depend on hours per worker h_t through flexible form 3.1.6. Effectively, the model therefore assumes that firms can ask workers to shift to a part-time work arrangement, take on an extra shift or work overtime in return for wage compensation. This reflects that firms can, to some extent, circumvent hiring and firing costs by adjusting labour input along the intensive labour utilization margin.

[5]This realistic assumption (used also in Bloom (2009)) allows pre-optimization of hours in a given period, substantially speeding up computation of the model solution. Effectively, one can solve analytically for optimal labour hours given period t employment and productivity shock. The numerical procedure then only has to determine the optimal employment policy response.

$$w(h_t^i) = \omega_1(1 + \omega_2(h_t^i)^\gamma) \tag{3.1.6}$$

The baseline setup assumes that hiring and firing workers entails a proportional component (that rises linearly with the number of hires and fires). This is formalized in equation 3.1.7.[6]

$$c(e_t^i, f_t^i)) = c_{p,e}e_t^i + c_{p,f}f_t^i \tag{3.1.7}$$

The stochastic processes for demand shifter b_t^i and productivity shifter $\tilde{a}_t^i$ are expressed directly in terms of a combined stochastic process for the reduced-form shock a_t^i. Specifically, assume that the reduced-form shock can be represented as the product of a firm-specific component $a_t^{f,i}$ and a macroeconomic component a_t^m shared by all firms.

$$a_t^i = a_t^{f,i} a_t^m \tag{3.1.8}$$

Both the firm-specific and macroeconomic component can be expressed as log-AR(1) processes with persistence parameter ϕ.[7] Since the simulations consider the impact of payroll tax cuts given a certain state of the business cycle, only idiosyncratic firm productivity is subject to stochastic shocks (independently distributed across firms).

$$log(a_t^{f,i}) = \phi log(a_{t-1}^{f,i}) + \epsilon_t^{f,i};\ \epsilon_t^{f,i} \sim N(0, (\sigma^f)^2) \tag{3.1.9}$$

$$log(a_t^m) = \phi log(a_{t-1}^m) \tag{3.1.10}$$

Of course, the partial equilibrium nature of this framework ignores a range of factors that potentially interact with the effect of employer payroll tax cuts. At this point, it is useful to discuss some of these more prominent factors. First, the tax cut could improve demand conditions. Higher employment (and maybe some pass-through of the tax cut

[6]Bloom (2009) also considers quadratic adjustment costs (that raise the cost of hiring in the number of hires) and fixed adjustment costs (that are incurred for hiring and firing activity irrespective of the number of hires and fires). Key for the results in this paper is the existence of non-convex labour adjustment costs.

[7]Assuming that firm-specific and macroeconomic component shocks both share the same persistence parameter improves computational tractability. Under this assumption, firms do not keep track of the contribution of idiosyncratic and macroeconomic shocks to their current business environment (instead using as state variables overall business environment and current firm-specific employment stock only.

to higher worker wages) could stimulate consumption and raise the overall stimulus from the policy. Equally, if central banks respond to inflationary pressure created by the stimulus by raising interest rates, demand may decline. Second, the rise in labour demand may put upward pressure on real wages. This would dampen hiring. Third, payroll tax multipliers may be stronger if firms could respond by also expanding physical capital (weakening diminishing returns to employment). In contrast, the policy laboratory proposed keeps market conditions, wages and physical capital effectively exogenous to the policy intervention.[8]

To take the simulation multipliers presented in this paper at face value, one would therefore need to assume these other channels of secondary importance for the stimulus response. And indeed, since the intervention considered is inherently short-run, this interpretation has some appeal. There may be significant frictions that prevent these other forces to play out at this high frequency. Consumers may be reluctant to raise consumption in response to the tax cut, if uncertainty over the future path of the economy remains significant (as is plausibly the case in crisis when stimulus is introduced). Wages may be rigid in the short run (for example Olivei and Tenreyro (2007) show wages are often negotiated yearly). Physical capital investments may be subject to substantial time-to-build.

This paper however pushes a more conservative interpretation. The results presented provide a first stab at the impact of non-convex adjustment costs on fiscal multipliers in dynamic heterogeneous firm economies. As such, emphasis lies on transparency and tractability. The paper highlights several fundamental forces and shows that they can be quantitatively significant in the partial equilibrium setting considered (implicitly conjecturing that results will be robust to future general equilibrium analysis).[9]

[8]The model also abstracts from the fact that worker quits respond endogenously to labour market conditions (see for example http://www.bls.gov/opub/mlr/2011/08/art2full.pdf on worker quits during the Great Recession of 2008-2009) and that firms can smooth production by accumulating inventories during recessions.

[9]The solution procedure proposed in Krusell, Smith and Jr. (1998) appears applicable for a general equilibrium extension. Thomas (2002) suggests that these general equilibrium considerations can partially undo the effect of non-convex adjustment costs. I conjecture however that the results in this paper will be robust to this extension assuming realistic adjustment frictions in prices.

3.1.2 Calibration

The baseline calibration considers an economy with 1000 homogeneous firms. The quarterly calibration of the model follows standard values wherever possible.[10] The standard deviation of idiosyncratic productivity shocks is set to match the empirical standard deviation in firm-level sales growth.

Following King and Rebelo (1999), the annual firm discount factor r is set to 6.5% and the labour elasticity of production $\tilde{\alpha}$ is set to 0.6. Setting the shock persistence parameter ρ to 0.96 reflects slow-changing business conditions. As in Bloom (2009), the demand elasticity ϵ is set to 4, the quit rate λ is set to a yearly rate of 10% and γ is set to 2. ω_1 is set to normalize quarterly wage to 1, while ω_2 ensures that hourly wage is maximized at 40 hours per week. The employer payroll tax is initialized at 6.2% of yearly wage bill, reflecting 2010 employer payroll tax contribution to social security ("http://www.ssa.gov/pressoffice/factsheets/HowAreSocialSecurity.htm").

Considerable uncertainty over labour adjustment cost parameters remains. Empirical work offers some anecdotal industry/occupation level direct estimates of hiring and firing costs. However, given substantial heterogeneity in these costs across industries, it is not clear which number should be used as empirical counterpart to the hiring and firing costs in the model. The theoretical literature on labour adjustment costs has therefore turned to indirect calibration of these parameters to match firm-level or macroeconomic data. Results based on this approach have turned out to be sensitive to exact specification considered. Table 3.1 offers an eclectic survey of non-convex labour adjustment costs used in the literature.

Given this disparity in results (and the sensitivity of indirect calibration to model assumptions), this paper chooses as baseline a conservative proportional hiring and firing cost of a monthly wage (8.3% of yearly worker wage or 33% of quarterly worker wage). Bentolila and Bertola (1990) use the same specification and these numbers are generally in the range of reported estimates in table 3.1. This baseline implies that labour adjustment costs are substantial (a premise for the relevance of this paper). Notably, the cost of

[10]The simulation results are substantially unchanged if the number of firms is increased. A quarterly calibration reflects standard practice in business cycle modelling as well as the frequency at which many macroeconomic aggregates are reported.

Costs	Prop. (%)
Baseline in this paper	8.3
Bloom (2009)	1.8
Nickell (1987)	8-25
Oi (1962)	5.4
Bentolila and Bertola (1990)	8.3
Blatter, Muehlemann and Schenker (2008)	32

Table 3.1: Labour adjustment cost parameters used in literature; proportional hiring costs are reported as percent of yearly worker wage

hiring a worker is not covered even by a full one year payroll tax holiday. Acknowledging uncertainty on this labour adjustment cost parameter choice, the results in the main text consider sensitivity of results to this parameter.

Statistics and graphs are represented as average results from 1000 macroeconomic simulation runs over 100 quarters (25 years). The tax cut is announced in quarter 49 (though graphs will label the tax announcement quarter as period 1 for reference). The exact computational strategy is presented in appendix B.1.

To calibrate standard deviation for idiosyncratic business cycle conditions, the simulations aim to match idiosyncratic yearly firm sales growth standard deviation from Compustat.[11] The model can match yearly empirical sales growth volatility for an idiosyncratic productivity shock standard deviation of 0.06. Table 3.1 then summarizes the baseline calibration used in the simulation.

3.1.3 Characterizing the Steady State

To gain a sense of the properties of this modelling setup, this subsection reviews behaviour of the heterogeneous firm framework in steady state. Notice steady state in this class of models does not imply the absence of uncertainty. Firms are subject throughout to idiosyncratic business condition shocks. Instead, steady state refers to the distribution the economy converges to after a prolonged period with payroll tax at 6.2%. Several

[11]Following Bloom (2009), the following filters were applied to yearly Compustat North America entries to compute empirical sales growth standard deviation. To deal with mergers and acquisitions, observations with sales or employment growth in the top or bottom 1% were excluded. To ensure a minimum level of homogeneity of firms, data for firms with less than 500 employees were excluded.

Parameter	Value	Target
r	0.0053	6.5% US yearly firm discount rate (King and Rebelo (1999))
ϵ	4	33% markup (Bloom (2009))
λ	0.019	JOLTS average monthly quit rate (2001-2010)
$\tilde{\alpha}$	0.6	60% labour income share
γ	2	Bloom (2009)
ω_1	0.47	normalize monthly wage to 1
ω_2	$3.1 * (10^{-5})$	hourly wage minimized at 40 hour week
τ^*	0.062	US employer payroll tax 2011
ϕ	0.95	persistent productivity shocks
$c_{p,e}$	0.33	proportional hiring costs (% quarterly wage)
$c_{p,f}$	0.33	proportional firing costs (% quarterly wage)
σ^f	0.06	monthly firm productivity shock (match firm sales volatility)

Figure 3.1: Calibration for accounting exercise (quarterly frequency)

crucial features stand out.

First, non-convex labour adjustment costs introduce a zone of inaction in the firm employment decision. Firms will only hire if the marginal value product of taking on an extra worker exceeds significantly the marginal wage cost of employing that worker - such that expected profits from the employment relationship cover the costs of hiring (and possible eventual firing). Firms will only fire if the marginal value product of that worker significantly falls short of the marginal wage cost of employing that worker - such that expected losses from continuing employment exceed the cost of firing the worker.

Figure 3.2 plots the steady state distribution of firms in firm-specific employment-productivity space (each cross represents a firm in the simulation). All firms below the solid line optimally hire new workers in that quarter. This line is referred to as the hiring threshold from here on. All firms above the dashed line fire workers in that quarter. This line is referred to as the firing threshold. All firms in between these two thresholds are inactive (in the sense that they neither hire nor fire - though of course they still use their existing workforce to produce).

Second, the firm distribution in the model reflects several important empirical stylized facts. Empirically, the inactivity zone of the model fits evidence of lumpy firm labour adjustment first documented by Hamermesh (1989).[12] Equally, in the theoretical framework, hiring and firing employment thresholds rise with productivity. Firms facing more favourable business conditions optimally produce on a bigger scale, since they run into diminishing marginal returns at a higher level of employment. Empirically, this pattern between productivity and firm size is documented for example in van Ark and Monnikhof (1996) for OECD countries. Finally, the log-normal distribution of productivity shocks translates into a firm productivity distribution skewed towards lower productivities. This implies that, as in the data, the majority of firms operate on a small scale (with a few exceptionally large firms). In broad brushes, this mirrors the pattern documented empirically (see Axtell (2001) for example).

Third, figure 3.2 reveals that, despite a relatively large inaction zone, a substantial fraction of firms do hire and fire every period. In the model, two factors move firms out of the inaction zone. First, and trivially, firms are subject to stochastic changes in business conditions that can lead them to re-evaluate target employment levels. Second, firms suffer labour attrition due to worker quits. This moves firms into the hiring range to replenish employment. Overall, this skews the firm distribution towards the hiring threshold. As we will see below, the interaction between idiosyncratic business condition shocks and labour attrition will act as crucial driver of the aggregate employment response to tax cuts.

3.2 Exploring a Baseline Payroll Tax Cut

This section considers the impact of a baseline employer payroll tax cut on the economy of section 3.1. Specifically, consider an employer payroll tax cut from 6.2% to 3% given the economy is in initial steady state. The tax cut is announced at the start of quarter 1 and then implemented for quarters 2 to 5. In effect, this reflects a legislative proposal adopted in Q4 of year x for the payroll tax applicable in fiscal year $x + 1$. Figure 3.3 illustrates the timing of the tax cut.

Subsection 3.2.1 characterizes the baseline macroeconomic response and subsection

[12] Indeed the response to Hamermesh (1989) has been a large literature arguing that non-convex labour adjustment costs are important for firm and macroeconomic dynamics.

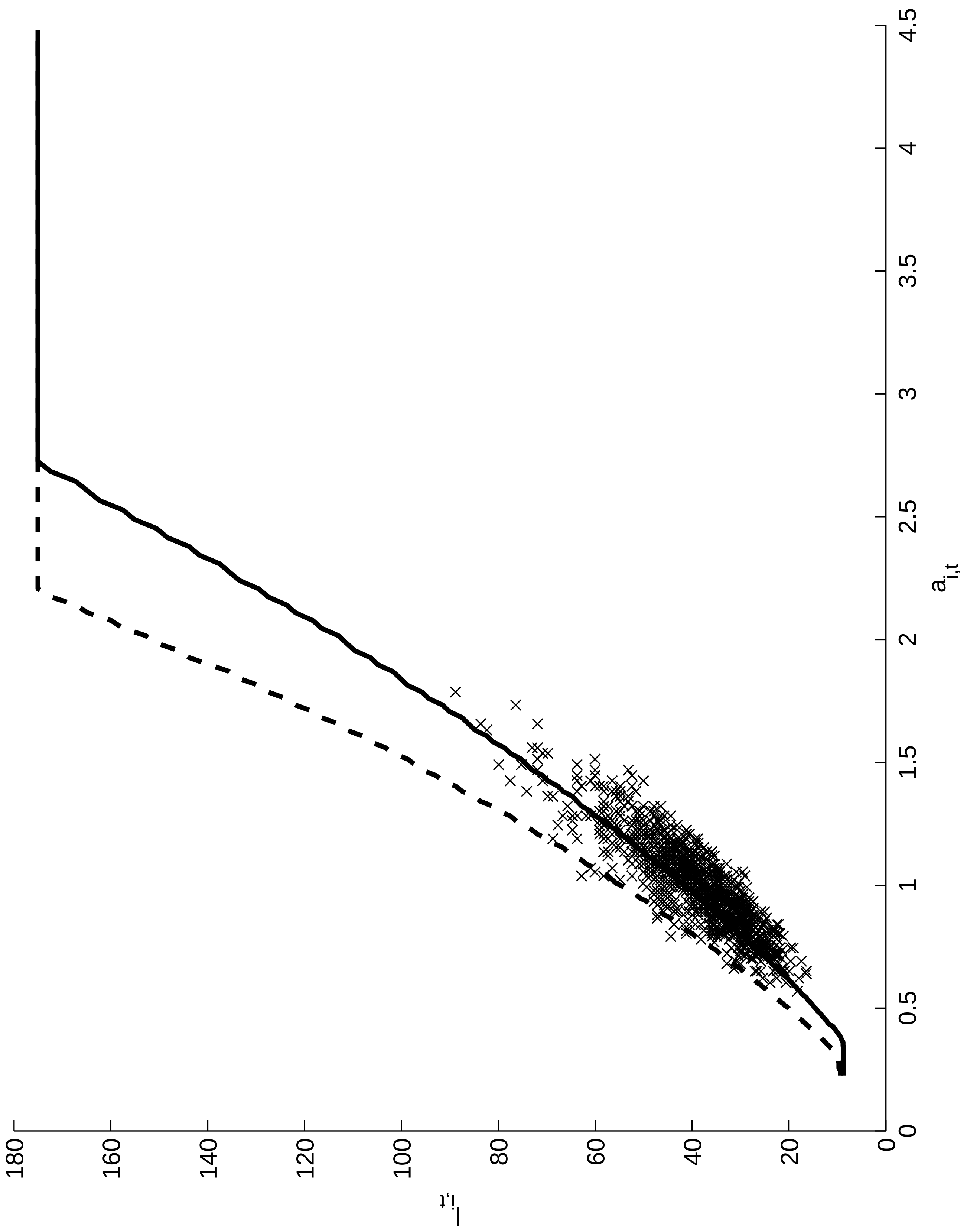

Figure 3.2: Steady state firm distribution; with hiring threshold (solid line) and firing threshold (dashed line); cross represents firm in employment-productivity state space

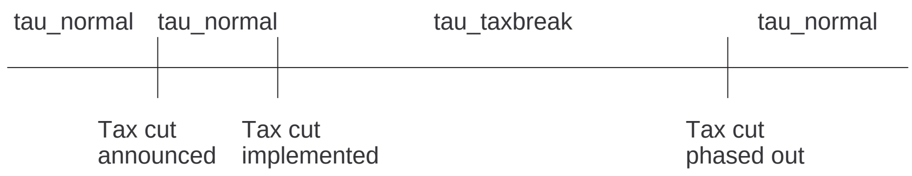

Figure 3.3: Timing of tax cut experiment

3.2.2 explores why the tax cut remains effective in an environment with high hiring and firing costs.

3.2.1 The Macroeconomic Effect of the Tax Cut

Figure 3.4 shows impulse response functions for the macroeconomy under the baseline parameterization of section 3.1 (solid line) as well as a counterfactual economy without labour adjustment costs (dashed line).

Consider first the model without labour adjustment costs. On impact, employment jumps by 6% as firms face lower marginal wage costs per employee. Hours per worker are unresponsive, since firms set hours to minimize wage cost per worker. It follows that total hours (defined as persons employed times work hours per employee) also rise by 6%. Overall, this jump in employment raises output by more than 2.5%.

Taking account of labour adjustment costs, this macroeconomic response is predictably dampened. Firms in the inactivity region do not respond to marginal changes in employer payroll tax cuts. However, the extensive employment decision of firms remains significant (the peak response is still 2% relative to steady state). Furthermore, firms adapt by exploiting the intensive labour utilization margin (the hours choice) to expand payroll and take advantage of low taxes, while circumventing the costs of hiring and (eventual) firing of workers. Total labour hours rise to a peak response of 3% relative to steady state . Overall, the stimulus therefore remains surprisingly effective even given significant labour adjustment costs. The peak response of output to the tax stimulus is 1.5%.

Following the methodology of the US Congressional Budget Office (CBO), this paper considers two measures for evaluation of program cost-effectiveness. First, the cumulative output multiplier reports the ratio of total output produced over tax revenues foregone

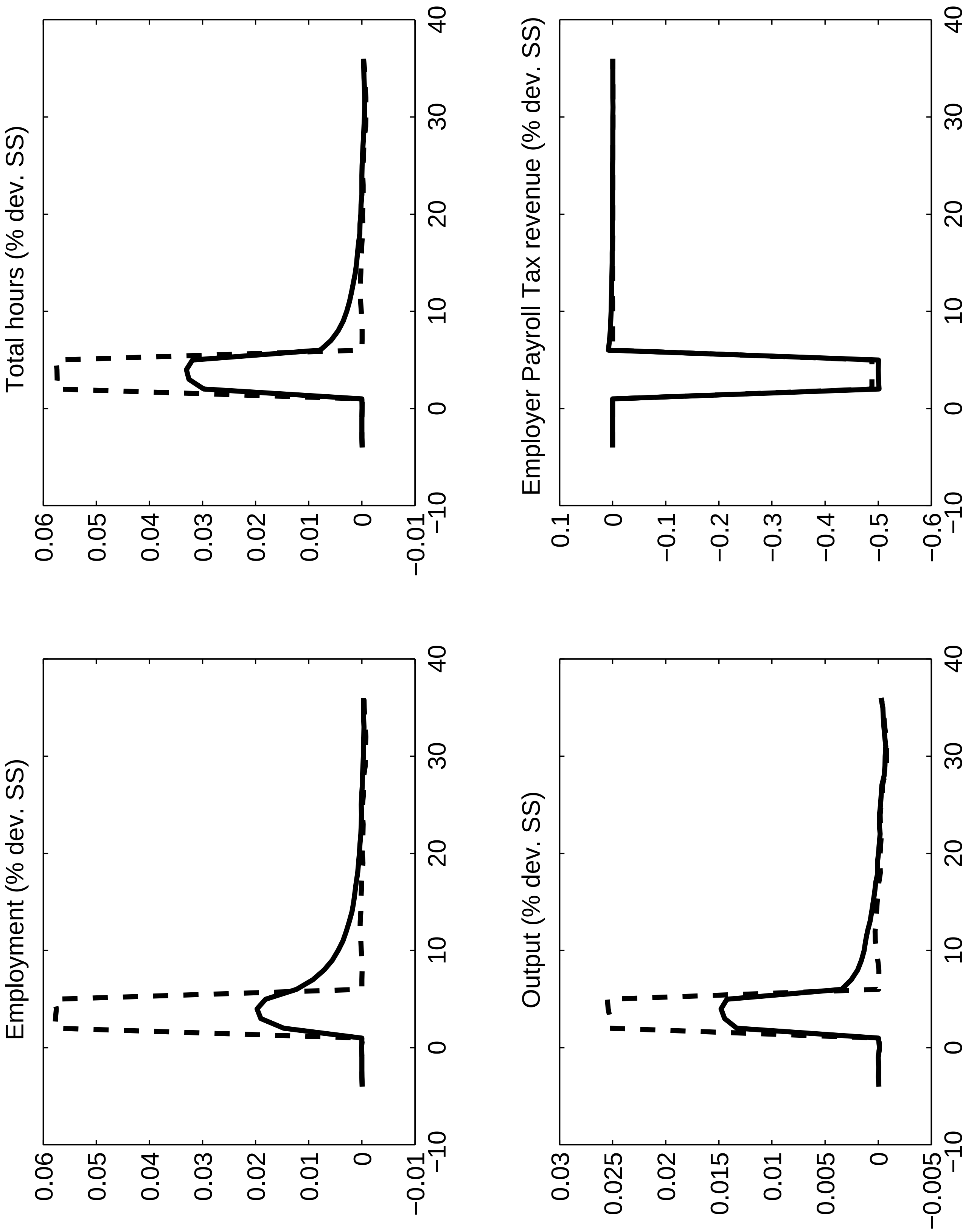

Figure 3.4: Macroeconomic response for baseline tax cut in economy with labour adjustment costs (solid line) and without (dashed line)

(relative to steady state without tax policy intervention). Second, this paper reports the tax revenue foregone relative to full-time equivalent (FTE from hereon) job-years created by the stimulus. [13,14]

$$M_Y = \frac{\Delta \sum_t Y_t}{\Delta \sum_t T_t} \tag{3.2.1}$$

$$M_L = \frac{\Delta \sum_t T_t}{\Delta \sum_t L_t} \tag{3.2.2}$$

The value of these multipliers depends on the interval over which numbers are cumulated. Table 3.2 shows multipliers for the baseline tax cut from 1 year to 5 years. As expected, multipliers are very large in a counterfactual world without labour adjustment costs. With labour adjustment costs, fiscal multipliers strengthen considerably when longer time intervals are evaluated. This reflects the fact that labour adjustment costs introduce a certain sluggishness in the employment response.[15]

To establish a sense of magnitudes involved, consider the CBO testimony before the Committee on the Budget of the United States Senate (entitled Policies for Increasing Economic Growth and Employment in 2012 and 2013 (http://www.cbo.gov/doc.cfm?index=12437). This offers CBO estimated output and employment multipliers for an employer payroll tax cut implemented over fiscal year 2012, considering the cumulative effect of the policy over the period 2012 to 2013.[16] At the two year interval, table 3.2 reports an output

[13]Note the simulation results in fact allow us to track the simulated response of hours per worker as well. It is therefore possible to compute employment multipliers taking into account the overall labour hours response (persons and hours per person). The study focusses on multipliers based on fixed work hours for two reasons. First, this ensures comparability with CBO methodology. Second, while outside of the model, to the extent that policy makers attempt to alleviate unemployment (and associated skills deterioration, crime, health costs) arguably the extensive employment margin should be the focus of policy evaluation.

[14]To operationalize these measures, the study uses (2010) US GDP of 14.6 trillion USD and employer payroll tax revenue of 318 billion USD in steady state. FTE job-years assume a 40 hour work week for every week of the year.

[15]To explain this sluggishness, consider the firm response to a tax cut in quarter t. In quarter t, those firms ex-ante in the hiring range will decide to hire more workers. Some firms ex-ante in the inactivity range will decide to start hiring. Overall, period t employment rises. In period $t+1$, a new set of firms experience an improvement in business conditions that shift them out of inactivity into the hiring zone. Again, the tax cut will lead these firms to raise hiring by more than they would in steady state. Meanwhile, most firms that have hired in period t will retain their workforce since firm business conditions are persistent. Overall, period t+1 employment (relative to steady state) will exceed the period t labour market response. It is this effect that translates into sluggish employment response to policy given labour adjustment costs.

[16]Notice also that the 2011 tax stimulus proposal on which the CBO bases its estimates only roughly

		1 Year	2 Years	3 Years	4 Years	5 Years
Employment Mult.	Adj. costs	45.57	38.52	36.24	35.36	35.10
(1000 USD)	No adj. costs	24.61	24.62	24.51	24.47	24.55
Output Mult.	Adj. costs	1.29	1.52	1.63	1.67	1.67
	No adj. costs	2.36	2.36	2.38	2.39	2.37

Table 3.2: Baseline employer payroll tax cut multipliers evaluated over different horizons

multiplier of 1.52 (meaning that every dollar in tax revenue foregone generates an increase in industry output of 1.52 dollars) and an employment multiplier of 38,520 dollars (meaning 38,520 dollars in tax revenue are foregone per job created). In comparison, the CBO reports output multipliers in the (admittedly wide) range of 0.2 to 1.3. Every one million dollar in tax revenue foregone would create 3 to 13 FTE job-years in the period 2012-2013 (for a tax cut in fiscal year 2012). This compares with an estimate of 26 jobs created based on the simulations in this study.[17,18]

Overall, the baseline model multipliers therefore exceed current CBO estimates for the impact of policy in fiscal year 2012. This result is not surprising, since the partial equilibrium analysis in this paper makes a range of assumptions (such as wage rigidity and no policy uncertainty) that create "ideal" conditions for fiscal policy to be effective. This reflects the aim of the study to provide a transparent analysis of the interaction between labour adjustment costs and the cost-effectiveness of temporary tax cuts to kick start the economy.

corresponds to the 50% reduction of the employer payroll tax considered in the model. For a more detailed discussion of the 'American Jobs Act", see appendix B.2.

[17]Note here the study simply uses the inverse of the cost per job measure from the simulation to compute jobs per dollar. Strictly speaking, since the numbers reported are expected multipliers, simply taking the inverse is incorrect. However, for the purposes of this study, it offers a rough sense of magnitudes.

[18]While a message of this paper is that fiscal policy interventions cannot all be lumped together, it is nonetheless informative to briefly compare how these estimates compare with other fiscal multipliers found in the literature. Hall (2009) reviews existing research. Empirically, he suggests government spending multipliers in the range of 0.7 to 1. However he acknowledges substantial uncertainty given currently available estimation strategies. Romer and Romer (2010) for example examine exogenous changes in tax liability and find a tax multiplier of 3. On the theory front, Real Business Cycle models typically yield multipliers smaller than 1. But New Keynesian models (especially when monetary policy does not actively move against the fiscal stimulus such as when nominal interest rates are at the zero nominal lower bound) can yield multipliers up to 1.7.

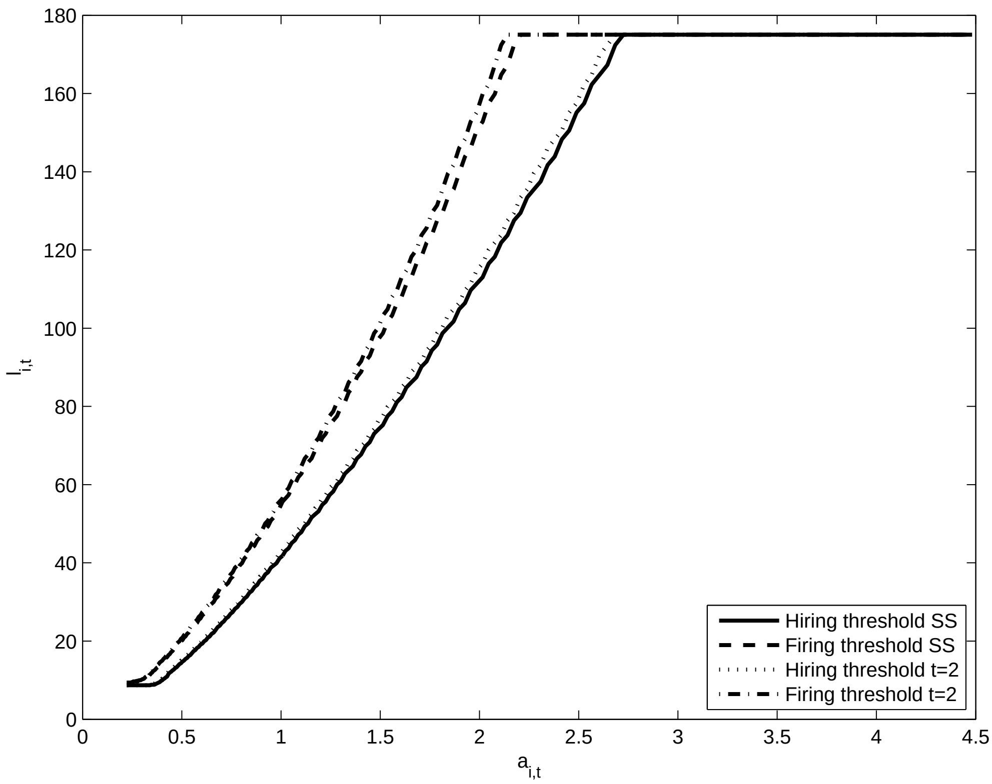

Figure 3.5: Tax cut shifts hiring and firing thresholds

3.2.2 Why Does the Tax Cut Stimulate?

The fact that tax stimulus policy remains effective even in a model in which firms face substantial hiring and firing costs is striking. Figure 3.5 illustrates this. Effectively, tax cuts do not move hiring and firing thresholds by much relative to the size of the inactivity region. The tax stimulus persuades few firms to hire that were not hiring in the first place. Instead, the tax stimulus raises employment in the model because, at any given time, many firms are hiring- and marginal tax stimulus will persuade these active firms to hire more.[19]

But this shifts the question to the next level. Why are so many firms hiring workers in steady state? Figure 3.6 helps to illustrate the role of two factors by comparing the baseline employment response to a hypothetical scenario without labour attrition, a scenario without business condition shocks and a scenario with neither worker quits nor business condition shocks. Without labour attrition, figure 3.6 shows that the em-

[19]Technically, the tax cut also persuades firms that are originally firing to fire less (or not at all) by moving the firing threshold upwards. Since the firm distribution is tilted towards the hiring margin, firing plays little quantitative role for the simulation results.

ployment response dampens substantially relative to the baseline. Worker quits skew the distribution of firms toward the hiring threshold, contributing to a large number of firms being active in recruiting in steady state. In the absence of worker quits, the tax stimulus remains effective because idiosyncratic market conditions still shift enough to force firms to hire and fire workers.

This argument would suggest that idiosyncratic business condition shocks unambiguously contribute to making labour markets responsive to tax stimulus when hiring and firing costs are large. However, this is not the case as figure 3.6 illustrates. In a hypothetical world in which firms experience worker quits but no idiosyncratic business condition shocks, employment would be even more responsive to the tax cut than in the baseline simulation.[20] In this case all firms cluster exactly on the hiring threshold in steady state. In this sense, there are no inactive firms and employment at all firms responds to a marginal cut in payroll taxes. Only in a hypothetical scenario without idiosyncratic business condition shocks and without worker quits, is the tax stimulus ineffective. In steady state, all firms are inside the inactivity region in graph 3.5 and no firms respond to marginal hiring incentives. The source of the result that payroll tax stimulus remains effective even in the face of significant labour adjustment costs lies in the interaction between labour attrition and idiosyncratic business condition shocks.

3.3 Contingent Tax Multipliers

At first sight, the results in section 3.2 suggest that hiring and firing costs, making room for some quantitative adjustments (perhaps by making labour supply inelastic enough in a Real Business Cycle setup), can be abstracted from in the study of fiscal policy. This section shows that this conclusion is not warranted. Introducing labour adjustment costs yields qualitative insights. The broad thrust of this argument lies in the idea that, within the class of heterogeneous firm labour demand models considered in this paper, introducing labour adjustment costs makes the cost-effectiveness of the stimulus program sensitive to exact tax design. This point is made considering three dimensions of policy

[20] In fact, responsiveness is very similar to the employment response in figure 3.4 when there are no labour adjustment costs.

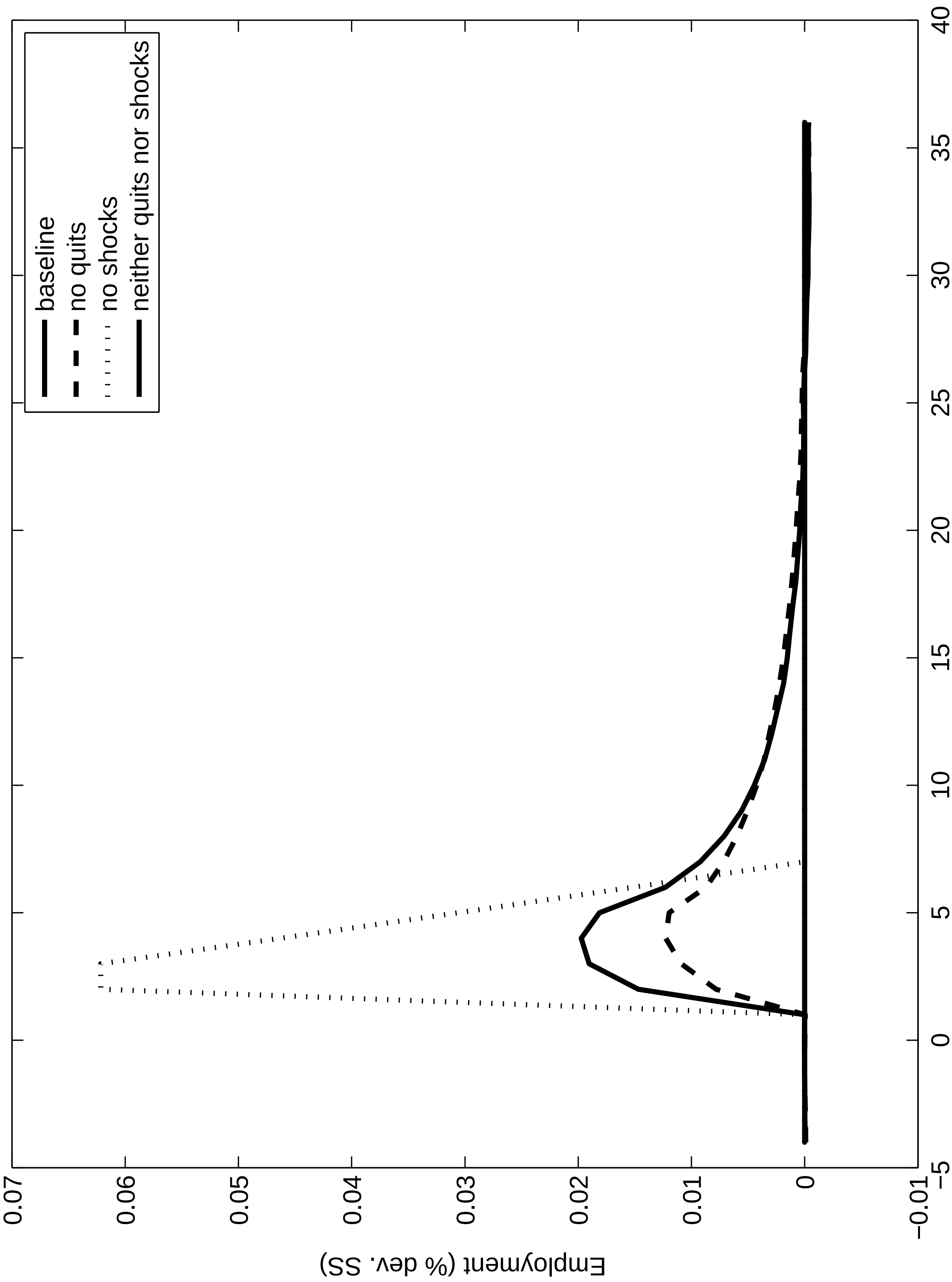

Figure 3.6: Comparison baseline employer payroll tax cut employment response with hypothetical scenarios (i) without labour attrition, (ii) without business condition shocks and (iii) without either labour attrition or business condition shocks

layout: length of anticipation period, length of the tax cut and macro business cycle conditions. This offers new insights both for policy makers designing effective stimulus measures as well as for empirical research on fiscal multipliers.[21]

This section is subdivided into three parts. Subsections 3.3.1, 3.3.2 and 3.3.3 develop respectively results for tax multiplier contingency on announcement period, length of the actual tax cut and state of the business cycle.[22]

3.3.1 The Benefit of Announcements

Figures 3.7 and 3.8 show that tax multipliers increase in the announcement period before the stimulus is implemented. All other parameters of the tax cut follow section 3.2. Reflecting uncertainty about the actual size of hiring and firing costs, multipliers are computed for a range of parameter values (including the case of no labour adjustment costs). In this setting, allowing for a four quarter announcement of the policy change reduces the baseline cost of creating a full-time job for a year by more than 5.000 USD (or 18%). Highlighting the role of labour adjustment costs in this anticipation effect, note that the relation breaks down in the frictionless special case of the model.

To explain this anticipation effect, note that labour adjustment costs make the hiring and firing decision of firms forward-looking. In effect, the labour force becomes a form of capital that the firm invests in.[23] To illustrate this more clearly, turn to the first order conditions of the firm problem in section 3.1. The shadow value of employing a worker in firm i, denoted μ_t^i, is given by the present discounted value of profits from the employment relationship.

$$\mu_t^i = E_t(\frac{1-\lambda}{1+r}(\alpha\frac{a_{t+1}^i(h_{t+1}^i l_{t+1}^i)^\alpha}{l_{t+1}^i} - (1+\tau_{t+1})w(h_{t+1}^i) + \mu_{t+1}^i)) \tag{3.3.1}$$

Firms do not hire if the shadow value is below the proportional cost of hire. They do

[21]In the wider class of general equilibrium models with fiscal policy, other mechanisms have been highlighted to generate a link between tax design and fiscal multipliers. However, as will be seen, labour adjustment costs can yield forces going in directions opposite to some popular stories in this literature.

[22]Simulations in this section are run over 9 years to fully capture the overall impact of all payroll tax cuts considered.

[23]Notice that these two properties would also emerge in a log-linearized model with quadratic input adjustment costs for the firm. In the context of fiscal policy however, existing general equilibrium models tend to focus on forward-looking behaviour of consumers (and not firms).

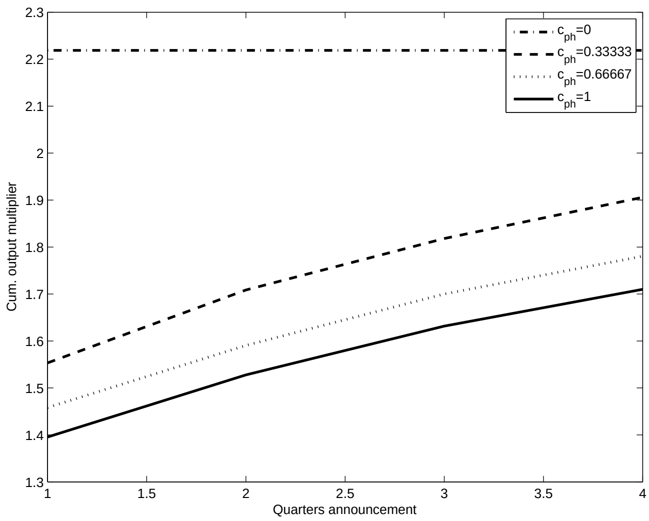

Figure 3.7: Output multipliers for employer payroll tax cut depending on announcement periods

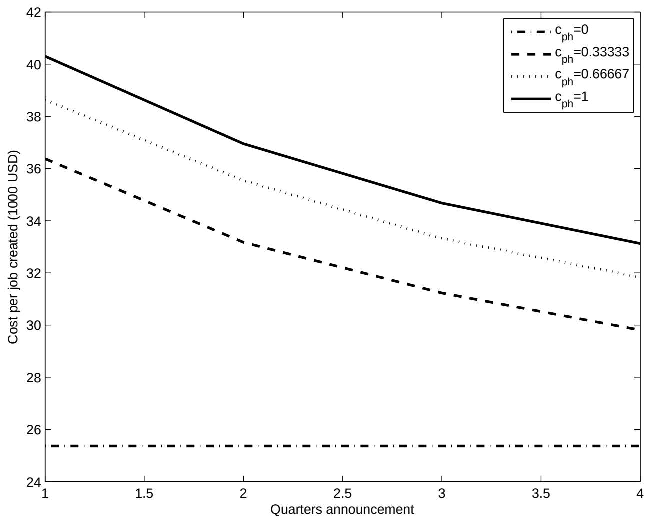

Figure 3.8: Employment multipliers for employer payroll tax cut depending on announcement periods

not fire if the shadow value is above the proportional cost of firing. This logic is formally reflected in the complementary slackness conditions associated with the firm optimization solution.[24]

$$c_{p,e} \geq \mu_t^i;\ e_t^i \geq 0;\ (c_{p,e} - \mu_t^i)e_t^i = 0 \tag{3.3.2}$$

$$\mu_t^i \geq -c_{p,f};\ f_t^i \geq 0;\ (c_{p,f} - \mu_t^i)f_t^i = 0 \tag{3.3.3}$$

It follows that a promise of a future tax cut raises the shadow value of employment today and encourages more hiring for given firm business conditions. Effectively, the firm hires today "for free" in the sense that taxpayers are not currently foregoing tax dollars. This logic also explains why the anticipation effect in figure 3.8 runs into diminishing returns. As firms plan with a high worker quit rate, tax reductions are discounted in current decision-making if they occur far into the future. Effectively, this reflects the substantial likelihood that the newly hired worker will have left the company by the time the stimulus kicks in.

[24]In the special frictionless case, note the equilibrium must involve $\mu_t^i = 0$. Firms hire and fire up to the point that marginal productivity equals wage in that period. Only in this special case is the firm (optimally) myopic in its employment policy.

3.3.2 Bold Tax Cuts

Figures 3.9 and 3.10 show that persistence of the tax cut also raises policy cost-effectiveness. As in the previous exercise, all other parameters are kept as in section 3.2. The simulations are repeated for a range of labour adjustment costs parameters. For the baseline parameterisation, the cost of creating an FTE job falls from 42.000 USD to 32.000 USD (or roughly 24%) as the tax cut period is extended from half a year to two years.

The intuition for this implementation effect follows directly that in the previous subsection. Hiring a worker today is an investment - and the associated stream of profits depends on current as well as future tax costs associated with payroll expenditure. If payroll tax cuts are extended for longer, hiring becomes more attractive for firms today.

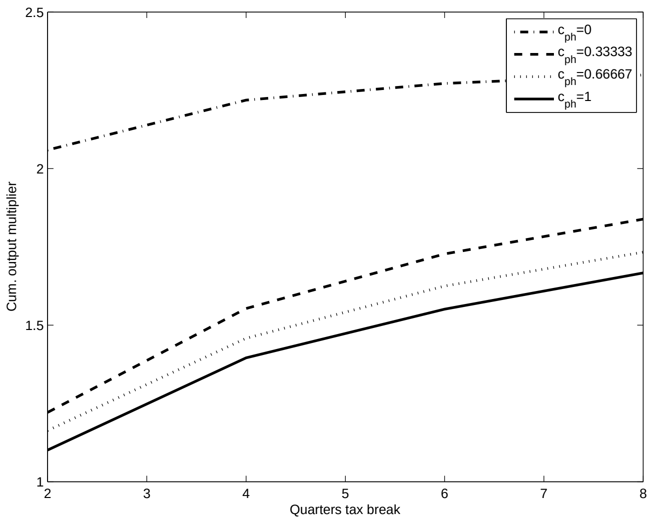

Figure 3.9: Output multipliers for employer payroll tax cut depending on implementation periods

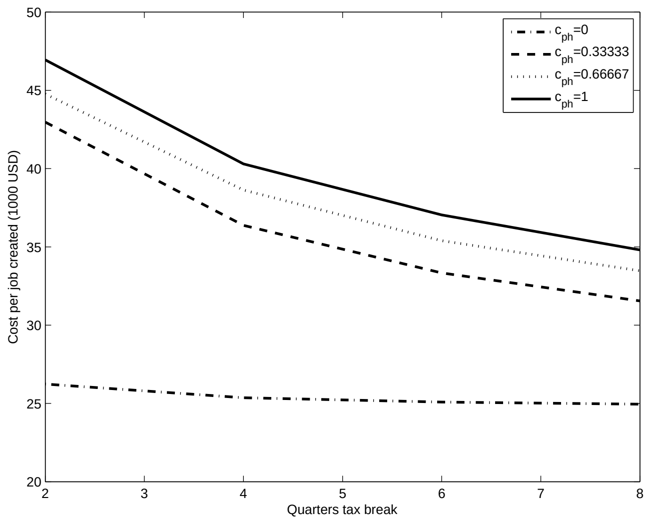

Figure 3.10: Employment multipliers for employer payroll tax cut depending on implementation period

3.3.3 Procyclical Employment Multipliers

Figures 3.11 and 3.12 consider how tax multipliers depend on the state of the business cycle. Starting from steady state, the model economy is shocked with a simultaneous x% fall in macro business conditions shock as well as the temporary tax cut of section 3.2. Multipliers are computed relative to a recession economy without the tax stimulus.

Surprisingly, the tax multiplier is stronger in booms than in recessions. The reason for this lies in the fact that adverse market conditions imply that many firms move from active hiring into inactivity. Since the number of ex-ante active firms is key for the effectiveness of the stimulus (see discussion in subsection 3.2.2), fewer jobs are created in response to the payroll tax cut in recessions.[25]

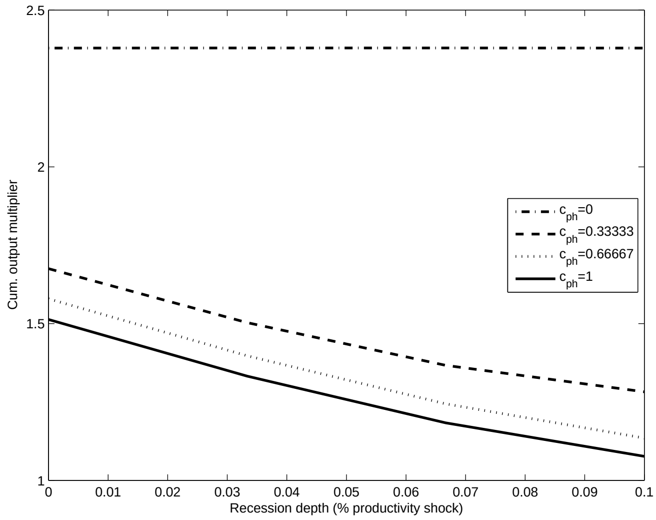

Figure 3.11: Output multipliers for employer payroll tax cut depending on depth of recession

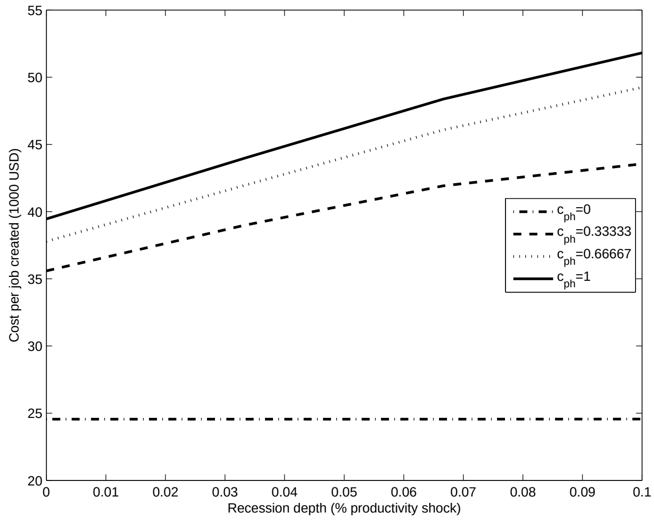

Figure 3.12: Employment multipliers for employer payroll tax cut depending on depth of recession

3.4 Extensions

The finding that labour adjustment costs make tax multipliers contingent on specific tax design has implications for policy makers as well as researchers. This section aims to discuss two issues raised by these results. First, subsection 3.4.1 offers an important caveat for researchers that estimate multipliers for a temporary payroll tax cut stimulus using historical permanent increases in payroll tax associated with social insurance expansion. Second, subsection 3.4.2 offers a more nuanced perspective on the subsection 3.3.3 result that payroll tax multipliers can be procyclical.

[25] Of course, one could imagine a disastrous recession in which demand conditions are so weak that most firms are actively firing. In this case, tax multipliers would be large, since marginal payroll tax cuts would persuade firms to fire less. The procyclical tax multiplier must therefore be qualified as a local result. It applies for reasonably small shocks to market conditions.

3.4.1 Tax Multipliers from Structural Adjustments and Stimulus

Section 3.3 implies an important caveat for empirical work on employer payroll tax cuts. Using the tax multiplier estimated using historical payroll tax changes to directly infer by how much a future payroll tax cut stimulus would help the economy may be seriously misleading.

Key is that historical tax changes have not been stimulus measures. In the period 1953 to 1990, payroll taxes were increased in a series of steps from 2% to 12.4% in the early 1990s (split in equal measure between employer and employee contributions) to finance the growing US social security system.[26] Legislation concerning payroll tax increases in this period tended to specify a schedule of future tax increases (as noted in Romer and Romer (2010): "The 1950 amendments, for example, called for a change in the tax base in 1952 and for changes in the tax rate in 1954, 1960, 1965, and 1970"). A substantial fraction of payroll tax changes was therefore announced. Since the tax increases reflected structural change in the social security system, we can safely assume that they were largely expected to be permanent. None of the tax increases of 1952-1990 occurred in a period of recession as deep as the current crisis.

In the language of section 3.3, the historical structural changes in employer payroll tax cut were thus (largely) announced, bold and occurring in normal business conditions. In contrast, a stimulus employer payroll tax cut, in all likelihood, would be largely unannounced (in response to a crisis), short term (limited to the next fiscal year) and in recession. Taking the policy laboratory results in section 3.3 at face value, multipliers from structural tax changes would be much larger than those associated with stimulus payroll tax cuts.

To illustrate this point, consider a stylized comparison between (i) a one year unannounced 3% employer payroll tax reduction when the economy is hit by a 3% productivity shock ("stimulus") and (ii) a two year 3% payroll tax in normal times that is announced one year in advance ("structural adjustment"). Figure 3.13 illustrates just how much stronger the structural adjustment policy impacts employment. Furthermore, 3.14 illus-

[26] Appendix B.2 proposes a historical summary of the US payroll tax introduction.

		"Stimulus"	"Structural Adjustment"	Difference
Employment Mult.	Adj. costs	38.21	29.39	30.00 %
	No adj. costs	24.86	25.81	-3.68%
Output Mult.	Adj. costs	1.54	1.94	-20.73%
	No adj. costs	2.35	2.19	7.31%

Table 3.3: Multipliers for alternative payroll tax cuts

trates that this result depends almost entirely on the presence of hiring and firing costs. Table 3.3 reports output and employment multipliers for the interventions confirming this visual impression. Moreover, the table makes clear that the two policies evaluated would yield largely similar multipliers in a framework without labour adjustment costs.[27]

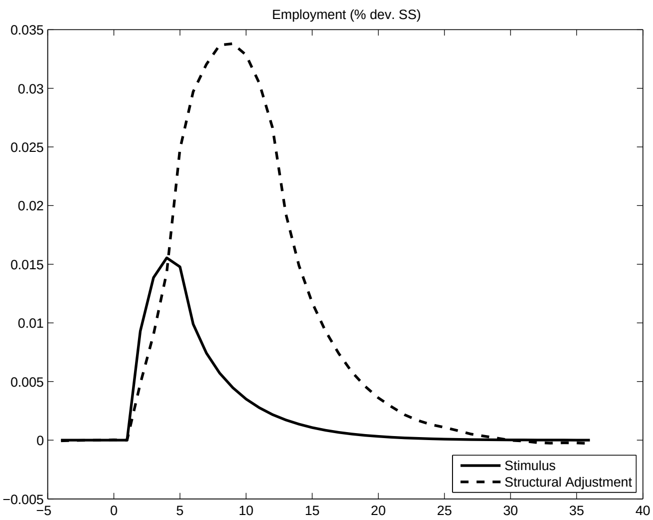

Figure 3.13: Employment response to employer payroll tax cut given labour adjustment costs

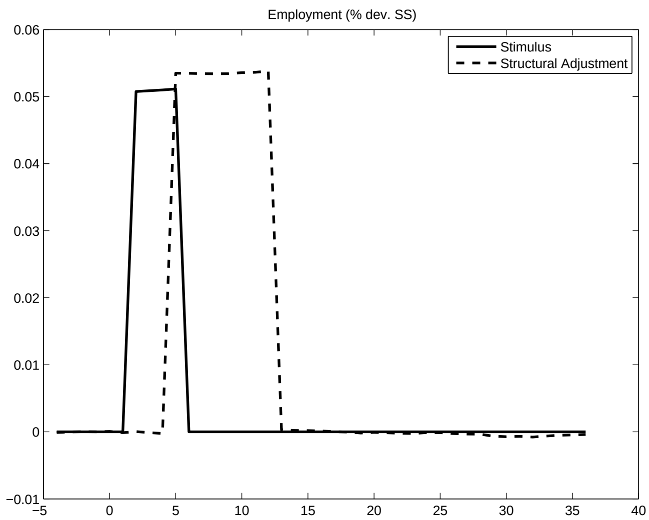

Figure 3.14: Employment response to employer payroll tax cut without labour adjustment costs

Overall, the results in this paper suggest that using multipliers associated with historical employer payroll tax changes to directly infer the impact of a future payroll tax cut stimulus may lead to over-optimistic predictions. Key to this result are the presence of non-convex labour adjustment costs. Instead, a more promising approach may be to

[27]Notice that, even in the frictionless comparison simulations, multipliers differ across policy scenarios. This difference goes in the opposite direction of the overestimation effect due to labour adjustment frictions. This study attributes this discrepancy to sample uncertainty remaining even though statistics are averaged over a large number of simulation runs.

calibrate a structural macroeconomic model (as developed in this paper), to validate it against its ability to match historical structural payroll tax change multipliers and then to analyse the impact of a payroll tax cut stimulus within the model framework.

3.4.2 Tax Multipliers in a Heterogeneous Sector Economy

A widely held view is that fiscal policy is countercyclical. On the theoretical front, Michaillat (2011) uses a search frictions framework to formalize the idea that fiscal multipliers may be stronger in downturns because labour markets are "slack". Christiano, Eichenbaum and Rebelo (2011) show fiscal multipliers may be much larger when the economy is at the zero lower bound on nominal interest rates (implying countercyclical fiscal multipliers). Empirically, Almunia et al. (2010), Auerbach and Gorodnichenko (2010) and Ilzetzki, Mendoza and Vegh (2010) find evidence that government spending multipliers may be larger during recessions. However, Auerbach and Gorodnichenko (2010) also acknowledge that evidence on tax multipliers is less clear cut.

In contrast, one of the results highlighted in section 3.3 has been that labour adjustment costs yield a force towards procyclical multipliers. Intuitively, when firms face weak demand and are running below capacity (hoarding labour), then tax cuts of reasonable size cannot persuade them to hire more workers. This result sits uncomfortably with the current empirical studies - cited above - that find countercyclical government spending multipliers. Does this mean that the force towards procyclical multipliers highlighted in this paper is outweighed by other factors that have not been considered explicitly in the model of section 3.1?

This section proposes a more nuanced perspective. Even if government spending multipliers are countercyclical, employer payroll tax multipliers may well be procyclical. The crux of this argument lies in the proposition that government spending stimulus is directed in large parts towards sectors with low labour adjustment costs (such as education, transport and infrastructure). In these sectors, labour hoarding in downturns is less likely to matter. The force towards procyclical multipliers from hiring and firing costs emerges only for broad-based stimulus measures that encompass sectors with high labour adjustment costs - such as an employer payroll tax cut. This means that, even if government spending multipliers are procyclical, employer payroll tax multipliers may plausibly turn out to be procyclical.

Allowing for two modifications, the model from section 3.1 can analyse this argument quantitatively. First, up to this point, the paper has assumed that firms are homogeneous in labour adjustment costs. In reality, hiring a waiter may be significantly less costly than training a nuclear scientist. To study the impact of sectoral heterogeneity in labour adjustment costs, this section therefore introduces two firm-types into the framework. Firm type 1 faces no labour adjustment costs. Firm type 2 faces hiring and firing costs equal to a quarterly wage. For scaling, the no friction sector represents ω of the total workforce in steady state. All other parameter choices reflect calibration in section 3.1.

Second, the model so far has assumed that wage rates do not respond to the stimulus. In reality, one would expect that an increase in labour demand would put upward pressure on wages. Furthermore, this demand pressure effect may plausibly be larger in booms than during downturns (say because workers have more bargaining power in the tight labour market associated with the boom). Full modelling of equilibrium wage dynamics is beyond the scope of this paper. Instead, this study adopts a quasi-GE approach as suggested in Bloom (2009). In effect, this paper introduces a wage shifter c_t into the wage equation (yielding modified wage equation 3.4.1) that temporarily "shocks" wages for the length of the stimulus (announcement and implementation period). To reflect the difference between normal times and a downturn, the wage shifter raises wages by 1% in response to the stimulus in normal times and leaves wages unaffected during downturns. In reduced form, this modification introduces a powerful force towards procyclical fiscal multipliers.

$$w(h_t) = c_t\omega_1(1 + \omega_2 h_t^{\gamma}) \tag{3.4.1}$$

The experiment considers, as in section 3.2, a temporary employer payroll tax cut to 3% announced in quarter 1 and implemented for quarters 2 to 5. In scenario 1, the tax cut occurs in normal times and is broad-based. In scenario 2, the tax cut occurs in normal times and is narrow (restricted to the low labour adjustment cost sector). In effect, scenario 2 offers an ad-hoc way of introducing a stimulus policy focussed on sectors with low labour adjustment costs (like a government spending stimulus). Scenarios 3 and 4 consider multipliers if the tax cut coincides with a disastrous 10% fall in the business conditions variable. Figure 3.15 explore how tax multipliers for these four scenarios evolve as a function of employment share in the high labour adjustment cost sector (ω) and idiosyncratic business condition volatility.

The graphs show that the wage response to the tax cut in booms makes narrow tax cuts strongly countercyclical. Broad tax cuts can be procyclical however, if idiosyncratic business condition volatility is low enough and the employment share of the high labour adjustment cost sector is large enough. Why? With low idiosyncratic business condition volatility the distribution of firms in employment space "does not forget quickly." After the downturn, many high labour adjustment cost firms move into the labour market inactivity region and become insensitive to taxes.

3.5 Concluding Discussion

Can a temporary employer payroll tax cut stimulate employment? This paper has shown that substantial hiring and firing costs in themselves do not imply that such a stimulus measure is ineffective. Business condition shocks and labour attrition move many firms close to the hiring threshold. In turn, these firms that are marginal to hiring do respond strongly to tax cut incentives even if labour adjustment costs are substantial.

The presence of non-convex labour adjustment does however make the labour market response sensitive to the exact design of the tax cut. For policy makers, this paper suggests that a cost-effective implementation would include a) pre-announcement of the policy, b) pledging to keep the tax cut in place for a prolonged period of time and c) waiting until the economy has left the deepest trough of the recession. Recognizing that labour adjustment costs differ across sectors, cost-efficiency would also suggest targeting the tax cut on sectors with low adjustment costs that are relatively more responsive (especially during downturns).

Of course, in practical policy making, stimulus cost-effectiveness would be only one criterion used to judge the optimal course of action for government. If the duration of the recession is uncertain, allowing for an announcement phase of policy may imply

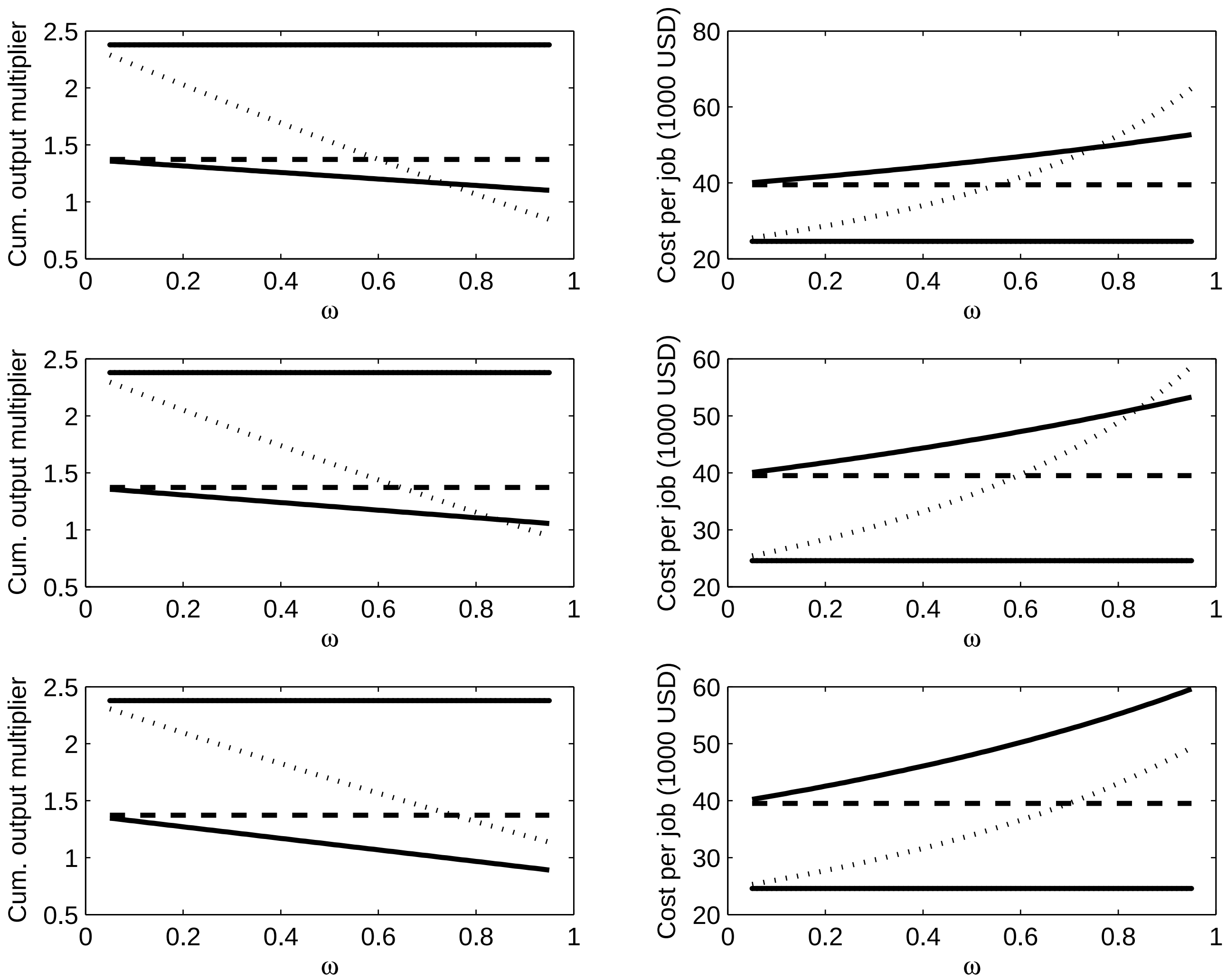

Figure 3.15: Tax cut multiplier graphs; top to bottom graphs vary firm-level idiosyncratic productivity volatility ($\sigma_f = 0.01$, $\sigma_f = 0.03$, $\sigma_f = 0.06$); right to left graphs show output multipliers and employment multipliers; ω denotes share of high labour adjustment cost sector in economy; scenario 1 is tax cut with focus on low labour adjustment cost sector in recession (solid line); scenario 2 is tax cut with focus on low labour adjustment cost sector in normal times (dashed line); scenario 3 is broad tax cut in recession (dotted line); scenario 4 is broad tax cut in normal times (dash-dot line)

that stimulus kicks in when the downturn is already over. Bold tax cuts may worsen fiscal deficits and cause funding problems on the sovereign debt market. Realizing that legislation on tax cuts is the result of compromise across the political spectrum, bold measures may simply not be feasible. A case can be made arguing government should help the people most when the recession is at its worse, even if firms require strong tax incentives to start hiring then. Targeting stimulus to low-labour adjustment cost sectors may be more cost-effective in recessions, but this inherently throws up the question whether such a policy would be fair.

For the empirical study of fiscal multipliers, contingency of tax multipliers offers an important caveat. The presence of labour adjustment costs means that no unique tax multiplier exists. The macroeconomic response to stimulus depends on exact tax design. Estimates of historical tax change multipliers cannot be used to directly infer the effectiveness of current stimulus proposals.[28]

This paper is part of a first generation of studies that analyse fiscal multipliers in heterogeneous firm economies with non-convex labour adjustment costs. For tractability and transparency, the analysis has therefore considered a baseline with rigid wages and interest rates. It has abstracted from physical capital accumulation. One the one hand, these simplifications do reflect presumed short-run rigidities in price and factor adjustment. On the other hand, these modelling assumptions allow this study to highlight the interaction between non-convex labour adjustment costs and payroll tax stimulus at the heart of this analysis. The findings in this paper suggest that future work, moving this framework closer to general equilibrium, could yield further important insights in our quest for the size of fiscal multipliers.

[28]One way forward would be to use the empirical historical response to tax changes to calibrate a structural model of the labour market. One could then use the structural model to infer the stimulus impact of tax changes with alternative design properties. Such a quantitative approach would require a more refined modelling environment than the one used in this study (which instead emphasizes transparency and simplicity).

Chapter 4

Trader Loss Aversion and Career Concerns

It is generally difficult to believe that sophisticated financial traders suffer from a behavioural bias such as loss aversion. The Kahneman and Tversky (1979) proposition that people have reference-dependent preferences has proven extremely insightful in understanding people's every-day decisions. Specifically, it offers an explanation for why people appear to place special value on avoiding outcomes perceived as loss (relative to a status quo).[1] However, in financial markets, List (2003) argues that learning and selection effects should ensure that (approximately) standard profit-maximizing preferences prevail.[2] Since sophisticated traders face investment decisions at great frequency and with high stakes, they have opportunity and incentive to overcome innate behavioural biases such as aversion to losses. If they do not, then they will be driven out of the market by others that do focus on profit maximization.[3] In sum, sophisticated financial traders

[1]Key subsequent theoretical contributions to reference-dependent preferences are Tversky and Kahneman (1991), Tversky and Kahneman (1992) and Koszegi and Rabin (2005). Various empirical tests of loss aversion in the laboratory and in the field have been conducted since Kahneman and Tversky (1979). In the laboratory, examples include Thaler et al. (1997) and Gneezy and Potters (1997). In the field, Camerer et al. (1997) for example find evidence that New York Taxi drivers adjust labor supply to reach daily income targets. Pope and Schweitzer (2011) suggest that professional golf players are loss averse. Linked to the notion that reference points matter for behaviour, Mas (2006) shows that policing performance falls if pay negotiations fail to meet a certain threshold expected by the police force.

[2]List (2003), List (2004) and List (2011) find evidence for this. Dhar and Zhu (2002) and Calvet, Campbell and Sodini (2009) show that wealthier households are less likely to display loss aversion in their portfolio trading decisions.

[3]The market selection theory in favour of rational agents can be traced back to Alchian (1950). Recent work (such as Long, Shleifer and Waldmann (1991)) shows conditions under which agents deviating from

should make trading decisions to maximize expected future (risk-adjusted) profits- and put no inherent value on whether a sale takes place above the price at which the position was historically purchased.

However, these theoretical arguments for profit-maximizing trader preferences clash with empirical evidence suggesting traders do in fact avoid closing trades at a loss.[4] Traders are more likely to sell stocks that have appreciated in value since purchase ("winners") than stocks that have lost in value ("losers").[5] This "disposition effect" has been documented for professional investors in Israel (Shapira and Venezia (2001)), Finland (Grinblatt (2001)) and Taiwan (Barber et al. (2007)).[6] This paper provides additional evidence in support of loss averse trading behaviour: the price at which US corporate bond dealers sell is truncated sharply at purchase price.

The main contribution of this paper is to propose a possible resolution of this clash between theory and empirics. It develops a theory in which traders are profit-maximizing and yet traders behave as if they were loss averse. No loss averse preferences need to be postulated to explain why traders that are employed by financial institutions tend to hold on to losers.

The argument is based on trader career-concerns (in the spirit of Fama (1980) and Holmstrom (1999)).[7] Profit-maximizing financial institutions delegate market-making to profit-maximizing traders. Traders vary in skill and financial institutions attempt to infer trader skill from trading history. Key is that skilled traders have superior information about the evolution of asset prices. When evaluating a trading opportunity, skilled traders will sometimes foresee a loss, sometimes a small gain and sometimes a large gain. They will choose to enter the trade if they foresee a gain. This implies that financial institutions extract relatively little information about trader skill whether they observe

full rational expectations can in fact survive in the market.

[4]This evidence has prompted a theoretical literature that explores the consequences of loss aversion for asset pricing (such as Benartzi and Thaler (1995), Barberis, Huang and Santos (2001), Barberis, Huang and Thaler (2006), Yogo (2008), Barberis and Huang (2009)).

[5]This tendency is especially surprising since tax considerations and momentum in returns create incentives to sell losers.

[6]Odean (1998) uses trading accounts at a large discount brokerage house to document the "disposition effect" for individual investors in the US.

[7]Important contributions in the career-concerns literature include Scharfstein and Stein (1990), Zwiebel (1995), Prendergast and Stole (1996). This study differentiates from these papers by showing that career concerns can make closing trades at gain/loss a key endogenous threshold in the trader retention decision of financial institutions.

that trades are closed at a small gain or a large gain. Both skilled and unskilled traders would have entered such a trade. In contrast, a trade closed at loss strongly revises the financial institution's prior on trader skill. A skilled trader is unlikely to have entered such a trade in the first place, making it likely that the employed trader is unskilled. Endogenously, the number of loss-making trades therefore becomes a key criterion in the financial institutions' trader retention strategy (potentially trumping average historical profits of the trader). Traders (skilled and unskilled) know this and therefore aim to avoid closing trades at a loss.

To explore this argument formally, this study develops two models that explore two notions of what it means "to avoid closing trades at a loss". The first model (model A) emphasizes that, once a trading position is opened, career concerns make traders reluctant to resell the position at loss. Instead, they will lean towards holding out until an opportunity to resell at gain emerges. Career concerns generate a "disposition effect". The second model (model B) shows that, even if financial institutions and traders are risk-neutral, traders worried about their reputation will not open a trading opportunity that is on expectation profitable if the possibility of incurring a loss is large. Trading opportunities will be entered only if they are sufficiently attractive to make a loss very unlikely.

To test a core prediction of this career-concerns hypothesis, this paper turns to TRACE corporate bond transactions data. This dataset offers some new evidence that corporate bond dealers are loss averse: the distribution of prices at which dealers resell assets is truncated sharply at the last observed purchase price. More importantly, it allows to estimate the probability of a trade loss conditional on whether a gain or loss was realized on the previous trade in that asset. Baseline loss-averse preference models assume trades are evaluated on a transaction-by-transaction basis (the so-called assumption of narrow framing), implying that current loss probability is uncorrelated with whether the previous trade was a gain/loss. In contrast, the career-concerns hypothesis predicts that the probability of a trade loss is lower if the previous trade was realized as a loss. Intuitively, one loss may be due to low skill or pure bad luck. Two losses in a row, however, substantially move the institution's prior towards a view that the trader has low skill. This makes traders especially intent on avoiding multiple trades closed at loss within a short period of time. The data appears in line with this prediction of the career-concerns hypothesis.

This paper contributes to an emerging body of theoretical and empirical work emphasizing that delegated trading by institutional investors can have important implications for asset pricing and corporate finance. For example, Vayanos and Woolley (2011) develop a theory in which asymmetric information between investors and mutual fund managers generates momentum and eventual reversal in asset prices. Dasgupta, Prat and Verardo (2011) show that career-concerns create incentives for mutual fund managers to herd, generating return persistence. Basak and Pavlova (2011) propose a theory in which career-concerned mutual fund managers tilt their portfolio towards stocks included in the benchmark index against which they are assessed.[8]

Section 4.1 shows that career concerns make traders reluctant to close positions that are trading at a loss. Reputational concerns can explain a disposition effect for professional investors. Section 4.2 develops a model in which career concerns make traders reluctant to enter trading positions that are on expectation profitable for fear of taking a loss. This effect is magnified if previous trades were closed at loss. Section 4.3 documents some new empirical evidence that US corporate bond dealers are loss averse. As predicted by the career concerns mechanism, loss aversion becomes stronger if the trader has recently realized a trade loss. Section 4.4 offers concluding discussion.

4.1 Exiting Trading Positions and Career Concerns

This section develops a model to show that career concerns can induce a disposition effect: traders are reluctant to resell a position that they hold at loss. This model is from hereon referred to as model A. Subsection 4.1.1 presents the setup and equilibrium concept used. Subsection 4.1.2 shows that with high enough trader firing cost (c_f) a simple equilibrium emerges that can be transparently specified. Specifically, the solution exhibits an endogenous disposition effect due to career concerns. Subsection 4.1.3 shows

[8] Other contributions that highlight the implications of delegated portfolio management for trading behaviour and asset pricing results include Shleifer and Vishny (1997), Vayanos (2004), Berk and Green (2004), Dasgupta and Prat (2008), Petajisto (2009), Kaniel and Kondor (2011), He and Krishnamurthy (2011), Cuoco and Kaniel (2011), Guerrieri and Kondor (2011) and Malliaris and Yan (2012).

that this endogenous disposition effect generalizes to any model A equilibrium. Subsection 4.1.4 shows that results are robust to an extension of the model in which the financial institution observes how long traders take before closing asset positions.

4.1.1 Model A Setup

Theoretical analysis in this paper is based on a common general framework. Consider a two period model ($t = \{1, 2\}$) in which a profit-maximizing financial institution delegates trading in an asset to a profit-maximizing trader. A fraction γ of a unit measure of candidate traders are skilled (the others are referred to as unskilled), but the financial institution cannot directly observe trader type. Denote $i_t = 1$ if the trader employed at the start of period t is skilled (and $i_t = 0$ otherwise). At the start of period $t = 1$, nature assigns a random trader for employment at the financial institution. Each of periods $t = 1, 2$ is characterized by two phases: a trading phase and an evaluation phase. In the trading phase, the trader receives the option of purchasing one unit of the asset at price p_b (he is confronted with a trading opportunity). Before deciding whether to enter the trade, the skilled trader observes a signal s_t on resale market conditions. For notation, denote $e_t = 1$ if the trader enters the period t trade ($e_t = 0$ otherwise). The trading phase ends when the asset is resold back on the market at price $p_{s,t}$. In the evaluation phase of period t, the financial institution observes period t trading outcomes and updates its belief on trader skill type. Trader reputation matters for trader remuneration.

Model A completes this general specification along three dimensions. It specifies how trading positions are closed, the nature of the signal skilled traders receive on the trading opportunity and how trader remuneration depends on trader reputation. First, model A assumes that, once a trading position is opened, the trader draws a series of resale price offers $p_{s,t,j}$ from distribution $F(p_{s,t,j}|m_t)$ at cost c_s until he accepts to close the position (where j denotes the jth price offer). Define indicator function $x_{t,j} = 1$ if the trade is closed (and $x_{t,j} = 0$ otherwise) and $j_t = j$ if the period t position is closed at the jth draw.[9] Asset market conditions random parameter m_t (with associated cumulative density function $G(m_t)$) is revealed to all trader types once the trade is entered. Second,

[9]For notational consistency, denote $p_{s,t} = j_t = 0$ if the trade is not entered in period t in the first place.

to make the skills gap between trader types especially stark, assume that the signal received by skilled traders perfectly reveals asset market resale conditions ($s_t = m_t$). Third, model A assumes that the financial institution has the option to replace a trader at cost c_f at the end of the period t evaluation phase. Denote $r_1 = 1$ if the trader is retained in period $t = 1$ ($r_1 = 0$ otherwise). The fired trader receives outside option o_1^i and does not re-enter the candidate pool. Whenever the employment relationship ends, financial institution and employed trader split net trading revenue proportionally (with fraction ω of trading revenue going to the trader). If the trader is fired after period 1 trading, a new trader is hired from the candidate pool at the start of period 2.[10]

Figure 4.1 summarizes graphically the sequence of decisions in model A.[11] Notice that, since the game ends after two periods, it is never optimal for the financial institution to incur the cost of firing the trader in the evaluation phase of period 2. This (trivial) decision option is therefore suppressed from hereon.[12] For the baseline result, assume that the financial institution observes whether the period t trade is entered and at what price the trade is eventually closed.[13] An extension in subsection 4.1.4 shows that the results are substantively unaltered once one allows the financial institution to gain information on how long the trader keeps the trading position open.

Before defining equilibrium, note that the game has five potential player types: skilled and unskilled traders hired at the start of period 1, skilled and unskilled trader hired at the start of period 2 as well as the financial institution. To define equilibrium strategies,

[10]Notice the paper does not solve for the optimal financial contract. Instead, it aims to offer a simple setting that retains the flavour of real-world employment contracts in the financial industry: remuneration is largely driven by performance-dependent bonus payments and the firing threat looms large in the background.

[11]This decision tree clarifies that the model makes particular timing assumptions that ensure tractability. For example, the setup assumes that a trading position has to be closed before an alternative trading position is opened. This abstracts away from strategic interaction between different open trading positions. In practice, this assumption may reflect risk limits on trading positions or trader limited attention. Equally, the model assumes that traders are evaluated by the financial institution only after a trade is closed. This appears a natural assumption, since it is difficult for an outsider to evaluate whether an open position trading at loss reflects a good trading idea waiting for prices to realign or a bad trading idea that a loss-averse trader is reluctant to close. If the trader closes a position at loss, then he reveals that he also believes the trading idea is bad.

[12]Alternatively, the results would be unchanged if firms were forced to fire their traders at the end of period 2.

[13]Assume that trading profits are only shared between trader and financial institution when the trader is replaced or the game ends. This ensures that the financial institution cannot infer the number of resale draws taken by the trader (j_t) from period profits received.

it is useful to introduce additional notation. Specifically, denote strategy functions of a trader with first superscript i (for type i trader where $i = 1$ indicates the trader is skilled and $i = 0$ otherwise) and second superscript h (where h indicates the period the trader first has a trading opportunity). Under this notation for example, $x_{t,j}^{i,h}$ denotes an indicator function that equals 1 if the trader of skill type i with first trading opportunity in period h accepts to exit a given trading position at the draw j resale price offer in period t (0 otherwise). After period t trading, denote with μ_t the updated probability that the financial institution assigns to the employed trader being skilled.

This is a dynamic game of incomplete information. The study therefore appeals to the notion of a (weak) Perfect Bayesian Equilibrium to study equilibrium play. The strategies of all players must be optimal given actions of other players and beliefs. Beliefs must be consistent with Bayes law for any set of actions played with positive probability in equilibrium. Definition 4.1.1 operationalizes this concept for model A.

Definition 4.1.1. *A perfect Bayesian Nash equilibrium in pure strategies specifies trader entry strategy functions $e_t^{i,h}$, trader exit stratgies $x_{t,j}^{i,h}$, financial institution trader retention strategies r_t and financial institution beliefs μ_t such that:*

1. *The skilled trader hired in period 1 ($i = 1, h = 1$) makes trade entry decisions $e_1^{1,1}(s_1)$ and $e_2^{1,1}(s_2, e_1, p_{s,1}, j_1)$ as well as trade exit decisions $x_{1,j}^{1,1}(p_{s,1,j}, m_1)$ and $x_{2,j}^{1,1}(p_{s,2,j}, m_2, e_1, p_{s,1}, j_1)$ to maximize profits given retention strategy of the financial institution:*

$$\begin{aligned} \underset{e_1^{1,1},e_2^{1,1},x_{1,j}^{1,1},x_{2,j}^{1,1}}{Max} & E_0(\omega(p_{s,1} - p_b - j_1 c_s)1(e_1 = 1) \\ & +\omega(p_{s,2} - p_b - j_2 c_s)1(e_2 = 1, r_1 = 1) \\ & +o_1^1 1(r_1 = 0)) \end{aligned} \tag{4.1.1}$$

2. *The unskilled trader hired in period 1 ($i = 0, h = 1$) makes trade entry decisions $e_1^{0,1}$ and $e_2^{0,1}(e_1, p_{s,1}, j_1)$ as well as trade exit decisions $x_{1,j}^{0,1}(p_{s,1,j}, m_1)$ and $x_{2,j}^{0,1}(p_{s,2,j}, m_2, e_1, p_{s,1}, j_1)$ to maximize profits given retention strategy of the financial*

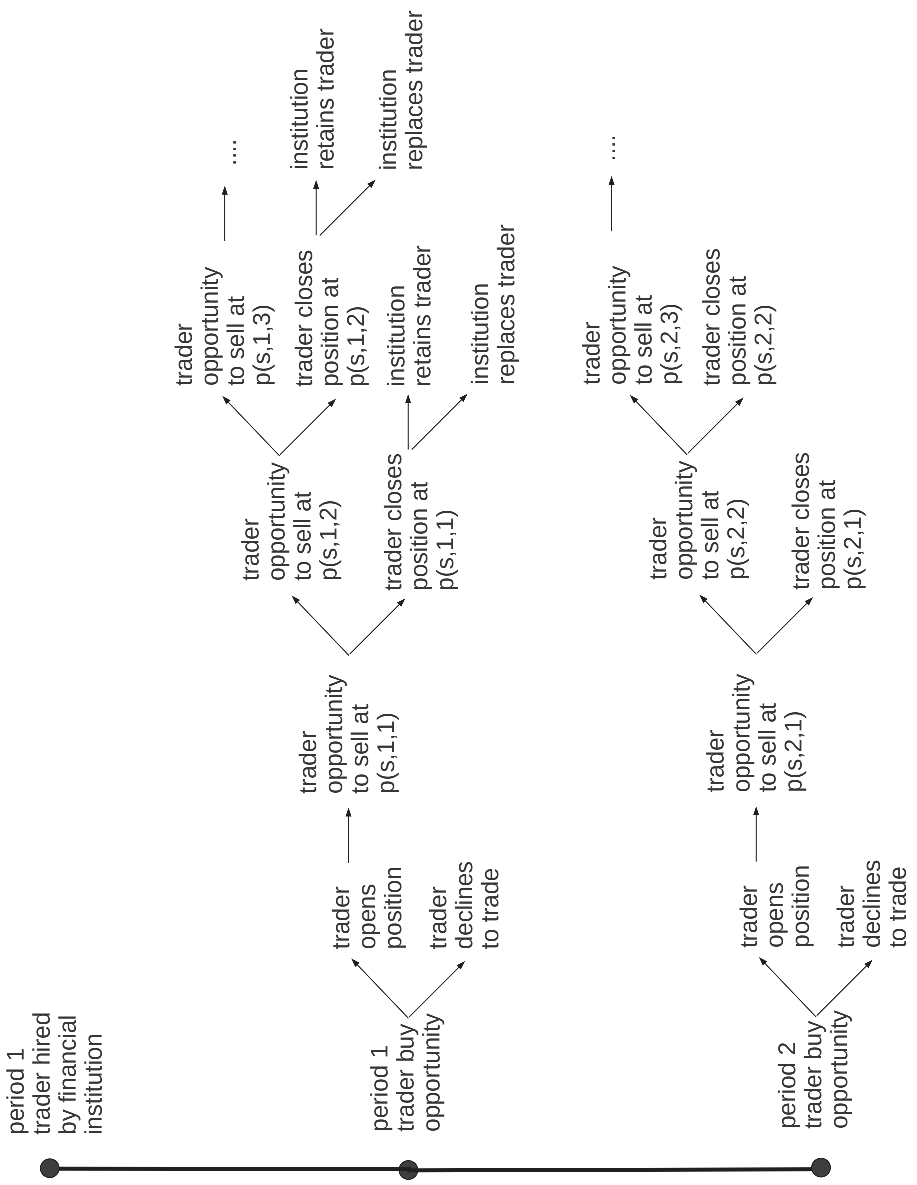

Figure 4.1: Model A decision tree

institution:

$$\underset{e_1^{0,1},e_2^{0,1},x_{1,j}^{0,1},x_{2,j}^{0,1}}{Max} E_0(\omega(p_{s,1} - p_b - j_1 c_s)1(e_1 = 1) \tag{4.1.2}$$

$$+\omega(p_{s,2} - p_b - j_2 c_s)1(e_2 = 1, r_1 = 1)$$

$$+o_1^0 1(r_1 = 0))$$

3. *The skilled trader hired in period 2 ($i = 1, h = 2$) makes trade entry decision $e_2^{1,2}(s_2)$ as well as trade exit decision $x_{2,j}^{1,2}(p_{s,2,j}, m_2)$ to maximize profits given retention strategy of the financial institution:*

$$\underset{e_2^{1,2},x_{2,j}^{1,2}}{Max} E_0(\omega(p_{s,2} - p_b - j_2 c_s)1(e_2 = 1)) \tag{4.1.3}$$

4. *The unskilled trader hired in period 2 ($i = 0, h = 2$) makes trade entry decision $e_2^{0,2}$ as well as trade exit decision $x_{2,j}^{0,2}(p_{s,2,j}, m_2)$ to maximize profits given retention strategy of the financial institution:*

$$\underset{e_2^{0,2},x_{2,j}^{0,2}}{Max} E_0(\omega(p_{s,2} - p_b - j_2 c_s)1(e_2 = 1)) \tag{4.1.4}$$

5. *The financial institution chooses whether to retain the trader $r_1(e_1, p_{s,1})$ to maximize expected trading profits subject to beliefs on trader type employed:*

$$\underset{r_1}{Max} \hat{E}_0((1 - \omega)(p_{s,1} - p_b - j_1 c_s)1(e_1 = 1) \tag{4.1.5}$$

$$+(1 - \omega)(p_{s,2} - p_b - j_2 c_s)1(e_2 = 1)$$

$$-c_f 1(r_1 = 1))$$

6. *Financial institution equilibrium beliefs on trader type employed are consistent with Bayes Law given any observed trading history $\{e_1, p_{s,1}\}$ played with positive proba-*

bility in equilibrium:

$$\mu_1 = \frac{Pr(e_1, p_{s,1}|i_1 = 1)\gamma}{Pr(e_1, p_{s,1}|i_1 = 1)\gamma + Pr(e_1, p_{s,1}|i_1 = 0)(1-\gamma)} \textit{ if } e_1, p_{s,1} \textit{ equilibrium play} \tag{4.1.6}$$

Notice model A can be interpreted as reflecting either centralized spot market trading or over-the-counter search market trading. Under the spot market interpretation, trading opportunities reflect trading ideas that come to the trader. Once the trader opens a position, he observes the evolution of spot prices and decides when to close the trade.[14] The cost of drawing another sales price c_s then reflects the time (risk) cost associated with exposure to the open position. Under the search market interpretation, a trading opportunity reflects meeting a counterparty willing to sell the asset. If the trade is entered, repeated draws from the resale price distribution reflect meeting different potential buyers with different private asset valuations. The cost of drawing another sales price c_s can then also be interpreted as an effort cost of contacting another counterparty.[15]

4.1.2 Baseline Equilibrium

This subsection presents a baseline model A equilibrium in which career concerns generate an endogenous disposition effect. To develop this result, it is natural to proceed by backward induction and to first solve for period 2 equilibrium. Since the game ends after period 2, traders face no career concerns. Final period trading behaviour therefore offers a benchmark against which to subsequently compare the effect of trader career concerns in period 1.

Period 2 equilibrium: No career concerns

Key to structuring this problem is to realize that an open trading position effectively represents an infinitely lived option to resell. For the lifetime of the option, traders pay

[14] Given idiosyncratic draws from the resale price distribution $F(.)$, notice that the model does not allow for serial correlation in price offers. This assumptions is without loss of generality and the intuition behind all results would go through qualitatively in more general cases. Effectively, serial correlation would simply introduce an additional state variable in the decision of the trader at what price to close an open trading position.

[15] Of course the (risk) cost story of c_s in the spot market interpretation also remains valid once one views the market through a search market lens.

a per-period fee c_s. The value of the open position ($V(m_2)$) therefore reflects the cost c_s of taking another draw from the resale price distribution as well as the subsequent choice of whether to exercise the resell option.[16,17]

$$V_2(m_2) = -c_s + \int_0^{\bar{p_s}} max(V_2(m_2), p_s) dF(p_s|m_2) \tag{4.1.7}$$

Once this option value formulation is adopted, optimal period 2 trade exit and entry decisions follow naturally. The trader (whether skilled or unskilled) resells whenever the offered resale price exceeds the value of the resell option, yielding optimal resale condition 4.1.8.

$$x_{2,j}^{i,h} = 1 \text{ iff. } p_{s,2,j} > V_2^1(m_2) \tag{4.1.8}$$

A skilled trader enters the trading opportunity whenever purchasing the position (p_b) is cheaper than the option value of the open position given the received signal on the resale market ($V_2(m_2)$). Unskilled traders go through the same thought process. However, since they do not observe asset resale market conditions, they base their decision on the unconditional expected option value of the open position. Since results will extend to period 1, these equilibrium properties are stated in general period t terms in expressions 4.1.9 and 4.1.10.[18]

$$e_t^{1,h} = 1 \text{ iff. } V_t^1(m_t) \geq p_b \tag{4.1.9}$$

$$e_t^{0,h} = 1 \text{ iff. } \int_0^{\bar{m}} V_t^0(m_t) dG(m_t) \geq p_b \tag{4.1.10}$$

In combination, the arguments 4.1.8 and 4.1.9 imply that skilled traders do not realize a trading loss in period 2 equilibrium play. Figure 4.2 illustrates this graphically. The

[16]Notice, as alternative to imposing a fixed cost c_s on keeping a position open, one could introduce traders with a proportional discount factor. All results would go through under this alternative specification.

[17]Technically, the option value of the open position for the trader is $\omega V(m_2)$. This reflects that the trader receives only a fraction of trading profits (the rest going to the financial institution that employs him). The main text considers a rescaled option value expression to simplify notation.

[18]Notice that this characterization implies that the period 2 trading sub-equilibrium is unique. Moreover, optimal play is independent of the trading and retention outcomes in period 1.

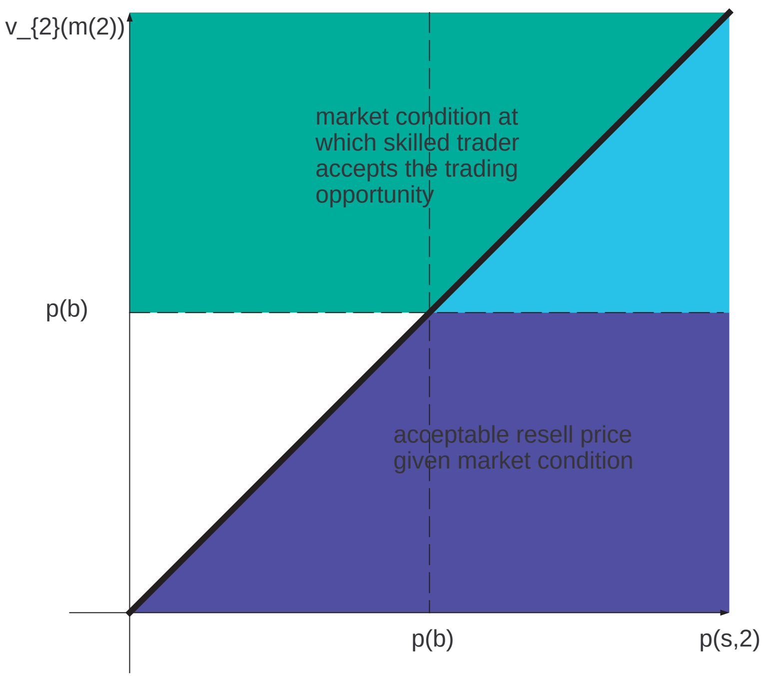

Figure 4.2: A skilled trader does not make a trading loss in period 2

horizontal axis denotes resale price $p_{s,2}$ and the vertical axis reflects the option value of an open position given resale market condition m_2 is known $(V_2(m_2))$. The region below the thick black line denotes combinations of open position option value and resale price offers at which a trader accepts to close the position (expression 4.1.8). The region above the horizontal dashed line denotes market conditions at which the option value of an open position exceeds its purchase price and skilled traders enter the trade (expression 4.1.9). Trading outcomes, given a skilled trader enters the trade, are therefore always in the triangle above the horizontal dashed line and below the diagonal thick solid line. By implication, a skilled trader never records a trading loss in period 2 equilibrium. Proposition 1 states this result formally.[19]

Proposition 1. *In period 2 of any perfect Bayesian equilibrium of model A, the skilled trader closes the position at gain if he enters the trade, since:*

[19]A natural first reaction to this threshold result is to ask how the resale threshold occurs at purchase price p_b given that traders expect to incur transaction costs c_s. To cover transaction costs, should the threshold point not be greater than p_b? The answer to this question lies in the fact that the trade entry decision is based on expected value. The trader enters whenever the expected net trade gain exceeds expected transaction costs. The expected trade gain threshold for skilled trader entry is therefore indeed positive. However, this concept does not extend to limit the set of realized resale price offers at which the trader decides to close an open trading position.

1. *any trader closes the trade only if the resale price offer exceeds the option value* ($p_{s,2,j} \geq V(m_2)$)

2. *the skilled trader enters the trade only if the option value exceeds purchase price* ($V(m_2) \geq p_b$)

Interestingly, proportional profit sharing ensures that the period 2 privately optimal equilibrium solution coincides with the socially optimal solution to the trading problem (in the sense that the financial institution would choose the same trading strategy itself if it did not have to employ a trader agent to do its bidding). In period 1, private career concerns of the trader will distort trading decisions away from the profit-maximizing outcome for the bank.

Proposition 2. *Trader equilibrium strategies in period 2 of model A coincide with optimal per-period trader equilibrium strategies in an alternative game in which traders face no career concerns (cannot be fired)*

Full Equilibrium With Career Concerns

In period 1, the employed trader makes trade entry and exit decisions taking into account not only within-period trading profits, but also reputational consequences. In order to be retained for period 2 trading, the trader aims to convince the financial institution that he is skilled. Denote by $\omega\pi_2^i$ expected payoff of trader i for period 2 trading. Then $V_1^i(m_1)$ denotes the period 1 option value of an open position.

$$V_1^i(m_1) = -c_s + \int_0^{\bar{p_s}} max(V_1(m_1), p_s + (\frac{o_1^i}{\omega} - \pi_2^i)(1 - r_1(e_1, p_s)))dF(p_s|m_1) \quad (4.1.11)$$

Notice, in contrast to period 2, this option value is contingent on the trader retention decision of the financial institution. The employed trader takes into account whether he will be fired if he closes the trading position at the current resale price offer. Furthermore, the option value of an open position is type-specific, reflecting that skilled and unskilled traders may have different outside options and skilled traders have more to gain by staying employed.

As in period 2, the traders optimally enter the trading opportunity subject to conditions 4.1.9 and 4.1.10. However, in contrast to period 2, the trade exit decision is modified. In effect, the trader will reject to exit some resale opportunities where the offered resale price exceeds the option value of the open position. Reputational concerns about the future lead the agent to forego some within-period gains. Expression 4.1.12 expresses this mathematically. The wedge $(o_1^i/\omega) - \pi_2^i$ represents the reputational concerns key to the endogenous disposition effect described in this section.

$$x_{1,j}^{i,h} = 1 \text{ iff. } p_{s,1,j} + ((o_1^i/\omega) - \pi_2^i)(1 - r_1(e_1, p_s)) \geq V_1(m_1) \tag{4.1.12}$$

Conjecture now a simple equilibrium in which the financial institution retains the trader whenever either the trade is not entered ($e_1 = 0$) or the trade is entered and closed at a gain ($e_1 = 1$ and $p_{s,1} \geq p_b$). If the trader closes a trade at loss, he is replaced by a new candidate for period 2 trading. In this case, figure 4.3 illustrates the effect of career concerns in period 1. As in figure 4.2, the area under the thick black line identifies resale price offers at which the trader closes the open position given resale market conditions. Key is that career concerns generate a kink. Effectively, the trader is reluctant to close the position at loss because he will then not be retained for period 2 trading. Waiting longer to sell at gain becomes relatively more attractive. For moderate resale market conditions, the trader will not accept selling at loss even though he would do so in the absence of career concerns. There is an endogenous disposition effect.

This reputational effect does not impact trading decisions of a skilled trader. Since he enters trades only if the option value of the open position (given resale market conditions) exceeds the price of purchase, his trade exit decision is unaffected by the reputational threat. The threat of being fired only affects the trade exit decision of unskilled traders that are considering selling positions at loss.

To support the conjectured retention strategy of the financial institution in equilibrium, assume (for a non-trivial) equilibrium that the unskilled trader optimally enters the trade in period 1. Furthermore, the conditional distribution of resale price offers and the distribution of market resale conditions has full and finite support. In this case, Bayes law postulates that the financial institution assigns positive probability to the employed

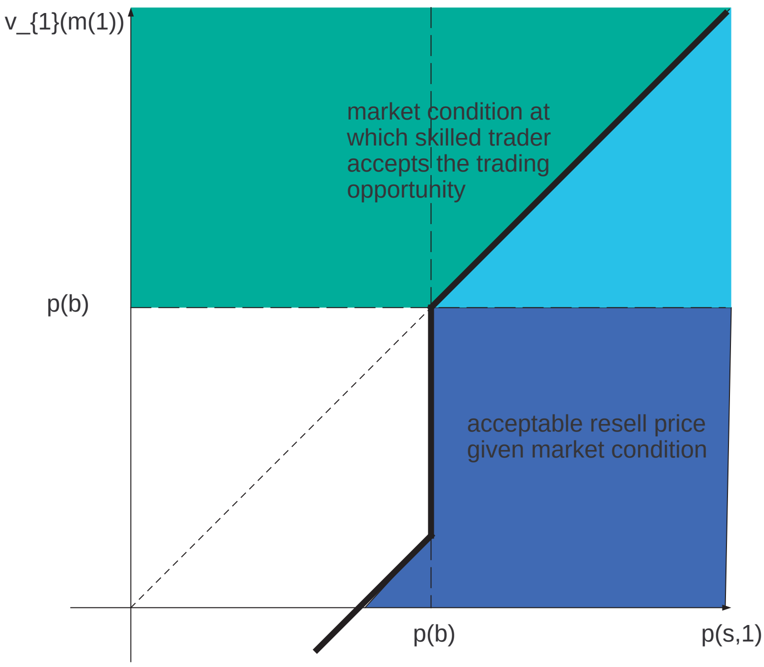

Figure 4.3: Unskilled traders are reluctant to realize losses in period 1

trader being skilled whenever the trade is not entered or the trade is entered and closed at gain. Financial institutions put a zero probability on the period 1 trader being skilled if they observe that the trade was entered and closed at loss. With high enough firing costs c_f, given trader strategies, the financial institution optimally replaces the trader after period 1 if and only if the period 1 trade is entered and closed at loss. Proposition 3 summarizes this equilibrium.

Proposition 3. *In the baseline version of model A, define*

$$V_1^i(m_1) = -c_s + \int_0^{\bar{p_s}} max(V_1(m_1), p_s + (\frac{o_1^i}{\omega} - \pi_2^i)1(p_s < p_b))dF(p_s|m_1) \tag{4.1.13}$$
$$V_2^i(m_2) = -c_s + \int_0^{\bar{p_s}} max(V_2(m_2), p_s)dF(p_s|m_2)$$

$$\pi_2^1 = \int_0^{\bar{m}} max(V_2^1(m_2) - p_b, 0)dG(m_2) \tag{4.1.14}$$
$$\pi_2^0 = \int_0^{\bar{m}} (V_2^0(m_2) - p_b)dG(m_2)$$

$$q^1(m_1) = 1(p_{s,1} \geq V_1^1(m_1) \geq p_b)(\sum_{j=1}^{\infty}(1 - \int_0^{\bar{p_s}} 1(p_s < V_1^1(m_1))dH(p_s|m_1))^{j-1}) \quad (4.1.15)$$

$$q^0(m_1) = 1(p_{s,1} \geq V_1^0(m_1))(\sum_{j=1}^{\infty}(1 - \int_0^{\bar{p_s}} 1(p_s < V_1^0(m_1))dH(p_s|m_1))^{j-1})$$

$$\hat{\mu}_1(e_1, p_{s,1}) = \begin{cases} 0 & \textit{if } e_1 = 1, p_{s,1} < p_b \\ 1 & \textit{if } e_1 = 0 \\ \frac{\int_0^{\bar{m}} q^1(m_1)\gamma dG(m_1)}{\int_0^{\bar{m}}(q^1(m_1)\gamma + q^0(m_1)(1-\gamma))dG(m_1)} > 0 & \textit{if } e_1 = 1, p_{s,1} \geq p_b \end{cases} \quad (4.1.16)$$

$$\bar{\mu} = \min_{p_{s,1} \geq p_b,} (\hat{\mu}_1(e_1 = 1, p_{s,1})) \quad (4.1.17)$$

assume that,

1. *the set of trade outcomes observed by the financial institutions is bounded*
    - $p_{s,t}|m_t$ *and* m_t *has support on* $[0, \bar{p_s}]$ *and* $[0, \bar{m}]$ *where* $\bar{p_s} \in \Re^+$ *and* $\bar{m} \in \Re^+$
2. *the outside options of both trader types are not better than staying in the game*

$$\frac{o_1^i}{\omega} \leq \pi_2^i \quad (4.1.18)$$

3. *entry incentive for unskilled traders is high enough*

$$\int_0^{\bar{m}} (V_1^0(m_1) - p_b)dG(m_1) \geq 0 \quad (4.1.19)$$

4. *the costs that financial institutions face in firing a worker are large*

$$\bar{\mu}\pi_2^1 + (1 - \bar{\mu})\pi_2^0 \geq \gamma\pi_2^1 + (1 - \gamma)\pi_2^0 - \frac{c_f}{1 - \omega} > \pi_2^0 \quad (4.1.20)$$

then there exists a (weak) perfect Bayesian equilibrium in which:

1. *the strategy of the skilled trader hired in period 1 ($i = 1$, $h = 1$) is:*

$$e_t^{1,1} = \begin{cases} 1 & \textit{if } V_t^1(m_t) \geq p_b \\ 0 & \textit{if } V_t^1(m_t) < p_b \end{cases} \quad \forall t = 1, 2 \quad (4.1.21)$$

$$x_{1,j}^{1,1} = \begin{cases} 1 & \text{\textit{if} } p_{s,1,j} + (\frac{o_1^1}{\omega} - \pi_2^1)1(p_{s,1,j} < p_b) \geq V_1^1(m_1) \\ 0 & \text{\textit{if} } p_{s,1,j} + (\frac{o_1^1}{\omega} - \pi_2^1)1(p_{s,1,j} < p_b) < V_1^1(m_1) \end{cases} \tag{4.1.22}$$

$$x_{2,j}^{1,1} = \begin{cases} 1 & \text{\textit{if} } p_{s,2,j} \geq V_2^1(m_2) \\ 0 & \text{\textit{if} } p_{s,2,j} < V_2^1(m_2) \end{cases} \quad \forall t = 1, 2 \tag{4.1.23}$$

2. *the strategy of the unskilled trader hired in period 1 ($i = 0$, $h = 1$) is:*

$$e_t^{0,1} = 1 \forall t = 1, 2 \tag{4.1.24}$$

$$x_{1,j}^{0,1} = \begin{cases} 1 & \text{\textit{if} } p_{s,1,j} + (\frac{o_1^0}{\omega} - \pi_2^0)1(p_{s,1,j} < p_b) \geq V_1^0(m_1) \\ 0 & \text{\textit{if} } p_{s,1,j} + (\frac{o_1^0}{\omega} - \pi_2^0)1(p_{s,1,j} < p_b) < V_1^0(m_1) \end{cases} \tag{4.1.25}$$

$$x_{2,j}^{0,1} = \begin{cases} 1 & \text{\textit{if} } p_{s,2,j} \geq V_2^0(m_t) \\ 0 & \text{\textit{if} } p_{s,2,j} < V_2^0(m_t) \end{cases} \tag{4.1.26}$$

3. *the strategy of the skilled trader hired in period 2 ($i = 1$,$h = 2$) is:*

$$e_2^{1,2} = \begin{cases} 1 & \text{\textit{if} } V_2^1(m_2) \geq p_b \\ 0 & \text{\textit{if} } V_2^1(m_2) < p_b \end{cases} \tag{4.1.27}$$

$$x_{2,j}^{1,2} = \begin{cases} 1 & \text{\textit{if} } p_{s,2,j} \geq V_2^1(m_2) \\ 0 & \text{\textit{if} } p_{s,2,j} < V_2^1(m_2) \end{cases} \quad \forall t = 1, 2 \tag{4.1.28}$$

4. *the strategy of the unskilled trader hired in period 2 ($i = 0$, $h = 2$) is:*

$$e_2^{0,2} = 1 \tag{4.1.29}$$

$$x_{2,j}^{0,2} = \begin{cases} 1 & \text{\textit{if} } p_{s,2,j} \geq V_2^0(m_t) \\ 0 & \text{\textit{if} } p_{s,2,j} < V_2^0(m_t) \end{cases} \tag{4.1.30}$$

5. *the financial institution retention rule for the trader is:*

$$r_1 = \begin{cases} 0 & \text{if } e_1 = 1, p_{s,1} < p_b \\ 1 & \text{if otherwise} \end{cases} \tag{4.1.31}$$

6. *financial institution belief whether the trader is skilled is given by* $\hat{\mu}_1(e_1, p_{s,1})$

4.1.3 Equilibrium Property: Endogenous Disposition Effect

There may exist alternative equilibria in which the trader is fired even if the period 1 trade is realized as gain. In these cases, the threat of firing can lead the skilled trader to avoid closing trades at such prices, sustaining equilibrium beliefs and financial institution retention strategy. However, it is possible to characterize some general properties of any model A solution. Specifically, any model A equilibrium exhibits an endogenous disposition effect. Proposition 4 summarizes these results.

Proposition 4. *In the baseline version of model A, assume that,*

1. *the outside options of both trader types are not better than staying in the game*

$$\frac{o_1^i}{\omega} \leq \pi_2^i \tag{4.1.32}$$

2. *the costs that financial institutions face in firing are not too large*

$$\gamma\pi_2^1 + (1-\gamma)\pi_2^0 - \frac{c_f}{1-\omega} > \pi_2^0 \tag{4.1.33}$$

3. *there exist bad enough market conditions*

- $p_{s,t}|m_t$ *and* m_t *has support on* $[0, \bar{p_s}]$ *and* $[0, \bar{m}]$ *where* $\bar{p_s} \in \Re^+$, $\bar{p_s} > p_b$ *and* $\bar{m} \in \Re^+$
- $f(p_{s,t} = 0|m_t = 0) = 1$

then any (weak) Perfect Bayesian Equilibrium of model A satisfies,

1. *the skilled trader never resells at a loss*

$$x_{t,j}^{1,1} = 1 \text{ only if } p_{s,t,j} \geq p_b \tag{4.1.34}$$

2. *in period 1, the financial institution fires the trader if a loss is realized*

$$r_1 = 0 \text{ if } e_1 = 1, p_{s,1} < p_b \tag{4.1.35}$$

3. *in period 1, the unskilled trader behaves loss averse*

$$\exists \{m^*, p_s^*\} \in \{m, p_s | p_s < p_b; x_{1,j}^0(m, p_{s,}) = 0; x_{2,j}^0(m, p_{s,}) = 1\} \tag{4.1.36}$$

$$\{m, p_s | p_s < p_b; x_{1,j}^0(m, p_{s,}) = 1; x_{2,j}^0(m, p_{s,}) = 0\} = \emptyset \tag{4.1.37}$$

Intuitively, the skilled trader never enters trades if the purchase price exceeds the value of an open position. No trader closes a position if the value of the open position exceeds the resale price offer. It follows that a skilled trader does not close a position at loss. If firing costs are not too large, the financial institution therefore fires the trader if a loss is realized in period 1. This makes unskilled trader reluctant to realize loss-making trades. Appendix C.1 provides a formal proof for proposition 4.

It should be noted that the baseline equilibrium discussed in the previous section relied on the notion that firing costs are "large enough". This ensured the existence of an especially clean and simple solution to the model that is useful for initial discussion. In contrast, the equilibrium properties discussed in this subsection do not rely on this assumption. Specifically, this implies that the endogenous loss aversion result does not require "high enough" firing costs.

4.1.4 Extension: Signal on Trader Holding Period

The baseline version of model A assumes that the financial institution does not observe how long the trader waits before closing an open position. In practice, this assumption appears unrealistic. Employers can learn about trader type if they observe that a trading position is not closed for a long time, suggesting that a bad trader is stuck with a bad trading decision and is "fishing" to resell at a gain. Key is however that revelation is not perfect. A good trader that enters a fundamentally attractive trading opportunity may also take considerable time selling the position if he is unlucky and he receives a series of bad resale price offers.

To show that the baseline equilibrium in proposition 3 is robust to relaxing this assumption, assume that the financial institution observes signal $\hat{j}_t$ on the number of resale draws j_t taken by the period t trader. In this case, appendix C.2 shows that an equilibrium of the same form as proposition 3 emerges.

Proposition 5. *In a version of model A in which the financial institution observes a finite partition signal on the number of resale draws taken by the trader in period t ($\hat{j}_t = k(j) : j \mapsto \{1, 2, ..., N\}$), there exists an equilibrium of the same form as proposition 3.*

4.2 Opening Trading Positions and Career Concerns

Section 4.1 developed one manifestation of career concerned trader loss aversion: employees are reluctant to resell open asset position at a loss. In practice however, traders may also pursue a complementary strategy. Traders may choose to be selective in entering trades in the first place, only accepting trading opportunities that look attractive enough to make an eventual loss very unlikely. This section explores this alternative manifestation of trader loss aversion.

In model A, reluctance to enter profitable trades is not present by construction. Skilled traders can perfectly discriminate between trading opportunities and they can therefore avoid entering loss-making trades with certainty. Unskilled traders cannot discriminate between trading opportunities, implying they cannot choose to enter only attractive trades. To introduce reluctance to enter profitable trades, this section therefore develops model B. Effectively, this setup builds on the general framework underlying model A, but it assumes that skilled traders receive an imperfect signal about asset market resale conditions.

Once this (realistic) assumption is introduced, a core prediction of the career concerns mechanism for loss aversion emerges: loss aversion increases in the number of previous trade losses. Intuitively, one loss might be interpreted as a skilled trader having a bad day. Two losses in a row substantially move the institution's posterior towards the belief that the employed trader is unskilled. Because traders know this, they particularly avoid taking a loss after a recent string of losses.

Subsection 4.2.1 presents the setup and equilibrium concept used. Subsection 4.2.2 develops the equilibrium. It shows that traders pass out on profitable trading opportunities because they are worried about taking a loss. This trading reluctance effect becomes more severe if the previous trade is closed at loss.

4.2.1 Model B Setup

Model B builds on the same general framework as model A. The model consists of two periods. Each period has a trading phase and an evaluation phase. In the trading phase, the employed trader receives a trading opportunity that he can decide to enter. In the evaluation phase, the reputation of the trader is linked to remuneration.

However, model B differs on how this general framework is closed. First, model B focusses on the trade entry decision of traders (and not on the trade exit decision that is vital to model A). It therefore assumes that, once a trade is entered, the trader receives a resale price $p_{s,t}$ drawn from the distribution with cumulative density function $F(p_{s,t})$. The trader is forced to close the position at this resale price. Second, model B makes the (realistic) assumption that skilled traders receive only an imperfect signal about the attractiveness of the period t trading opportunity. Particularly, assume the signal s_t equals the actual resale price in period t plus noise ($s_t = p_{s,t} + \epsilon_t$ where ϵ_t has associated cdf $H(.)$). Third, following Prendergast and Stole (1996), model B assumes that trader per-period wage is directly linked to trader reputation at the end of that period. In reduced form, this arrangement reflects the idea that traders with a good reputation face high outside options. They can therefore leverage their bargaining position during wage negotiations with their employer. To be able to solve the model transparently, assume (as in Prendergast and Stole (1996)) that the trader maximizes current period payoff in every period.[20] Figure 4.4 summarizes the decision tree in model B.

[20]This eliminates one layer of strategic thinking in the model. Effectively, the trader does not take into account that his trading decisions in period 1 affects his reputation not only during the evaluation

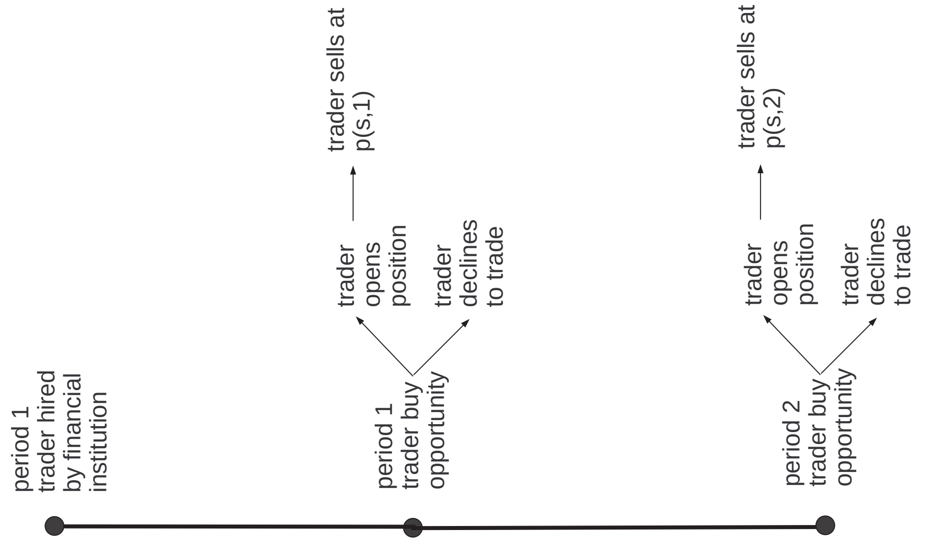

Figure 4.4: Snapshot of general framework game from the perspective of the financial institution

As in model A, this game is solved using the concept of a (weak) Perfect Bayesian Equilibrium. Definition 4.2.1 operationalizes this for model B. Since traders are not replaced after period 1, model B has only three player types: a skilled trader, an unskilled trader and the financial institution. Since there is no exit decision, optimal trader strategy reduces to specifying under what conditions the period t trading opportunity is entered. Assume trader reputation enters linearly (with parameter coefficient a) into per-period remuneration.

Definition 4.2.1. *A perfect Bayesian Nash equilibrium in pure strategies specifies trader entry strategy functions e_t^i and financial institution beliefs μ_t such that:*

1. *The skilled trader ($i = 1$) makes trade entry decisions $e_1^1(s_1)$ and $e_2^1(s_2, e_1, p_{s,1})$ to maximize per-period profits given financial institution belief on trader type:*

$$\underset{e_1^1}{Max} E^1(\omega(p_{s,1} - p_b)1(e_1 = 1) + a\mu_1) \tag{4.2.1}$$

phase of period 1 but also during the evaluation phase of period 2. The cost of this approach is that the model is not fully rational in the conventional sense of the word used in the context of expected utility maximization. The trader is rational in the sense that he acts to maximize the posited objective function faced in the given period. The benefit of this assumption is simplicity and transparency.

$$\underset{e_2^1}{Max}E^1(\omega(p_{s,2}-p_b)1(e_2=1)+a\mu_2) \tag{4.2.2}$$

2. *The unskilled trader ($i=0$) makes trade entry decisions e_1^0 and $e_2^0(e_1,p_{s,1})$ to maximize per-period profits given financial institution belief on trader type:*

$$\underset{e_1^0}{Max}E^0(\omega(p_{s,1}-p_b)1(e_1=1)+a\mu_1) \tag{4.2.3}$$

$$\underset{e_2^0}{Max}E^0(\omega(p_{s,2}-p_b)1(e_2=1)+a\mu_2) \tag{4.2.4}$$

3. *Financial institution equilibrium beliefs on trader type employed are consistent with Bayes Law given any observed trading history played with positive probability in equilibrium:*

$$\mu_1=\frac{Pr(e_1,p_{s,1}|i_1=1)\gamma}{Pr(e_1,p_{s,1}|i_1=1)\gamma+Pr(e_1,p_{s,1}|i_1=0)(1-\gamma)} \tag{4.2.5}$$
$$\text{if } e_1,p_{s,1} \text{ equilibrium play}$$

$$\mu_2=\frac{Pr(e_1,e_2,p_{s,1},p_{s,2}|i_1=1)\gamma}{Pr(e_1,e_2,p_{s,1},p_{s,2}|i_1=1)\gamma+Pr(e_1,e_2,p_{s,1},p_{s,2}|i_1=0)(1-\gamma)} \tag{4.2.6}$$
$$\text{if } e_1,e_2,p_{s,1},p_{s,2} \text{ equilibrium play}$$

4.2.2 Model B Solution: Reluctance to Enter Profitable Trades

The study takes advantage of the per-period profit maximization simplification and solves for period 1 and 2 equilibrium sequentially. The key link between action in the two periods is trader reputation. The trading outcome in period 1 affects the reputation that the trader has at the start of period 2. In turn, traders take account of their starting reputation when formulating period 2 trading decisions.

Period 1 Equilibrium: Reluctance To Enter Profitable Trades

Notice that the model B signal s_t on trading opportunity has a natural interpretation: the higher the value of the signal, the more attractive is the trade. Based on this intuition, posit therefore a period 1 equilibrium in which the skilled trader follows a threshold strategy. He enters the trade whenever the signal exceeds a threshold κ_1.

$$e_1^1 = \begin{cases} 1 & \text{if } s_1 \geq \kappa_1 \\ 0 & \text{otherwise} \end{cases} \quad \forall t = 1, 2 \tag{4.2.7}$$

Conditional on the period 1 trader being skilled, the joint probability of observing a period 1 trade closed at $p_{s,1}$ depends on the likelihood that that resale price is drawn from the resale distribution as well as the likelihood that the skilled trader enters the trade. Given the posited threshold strategy for skilled trader entry, this joint probability can be re-expressed as:

$$Pr(p_{s,1}, s_1 \geq \kappa_1 | i_1 = 1) = Pr(\epsilon_1 \geq \kappa_1 - p_{s,1} | p_{s,1}, i_1 = 1) Pr(p_{s,1}) \tag{4.2.8}$$

$$= (1 - H(\kappa_1 - p_{s,1})) f(p_{s,1}) \tag{4.2.9}$$

Posit now that the unskilled trader enters the period 1 trading opportunity. Using Bayes law, posterior belief about trader type consistent with these equilibrium strategies is given by equation 4.2.10. If the period 1 trade is not entered, then the institution knows the trader is skilled. If the trade is entered, then it becomes more likely that the trader is unskilled the lower the resale price $p_{s,1}$. Effectively, for low $p_{s,1}$ it is unlikely that a skilled trader would receive a signal above the κ_1 threshold. Therefore, it is unlikely that the skilled trader would have entered such a trade in the first place.

$$\mu_1 = \begin{cases} \frac{\gamma(1-H(\kappa_1 - p_{s,1}))}{\gamma(1-H(\kappa_1-p_{s,1}))+1-\gamma} & \text{if } e_1 = 1, p_{s,1} \\ 1 & \text{if otherwise} \end{cases} \tag{4.2.10}$$

Assume that the noise term ϵ_t in the signal received by the skilled trader is normally distributed. Then figure 4.5 shows how posterior belief μ_1 responds to realized period 1 sales price. This makes two points. First, the higher the sales price, the higher the

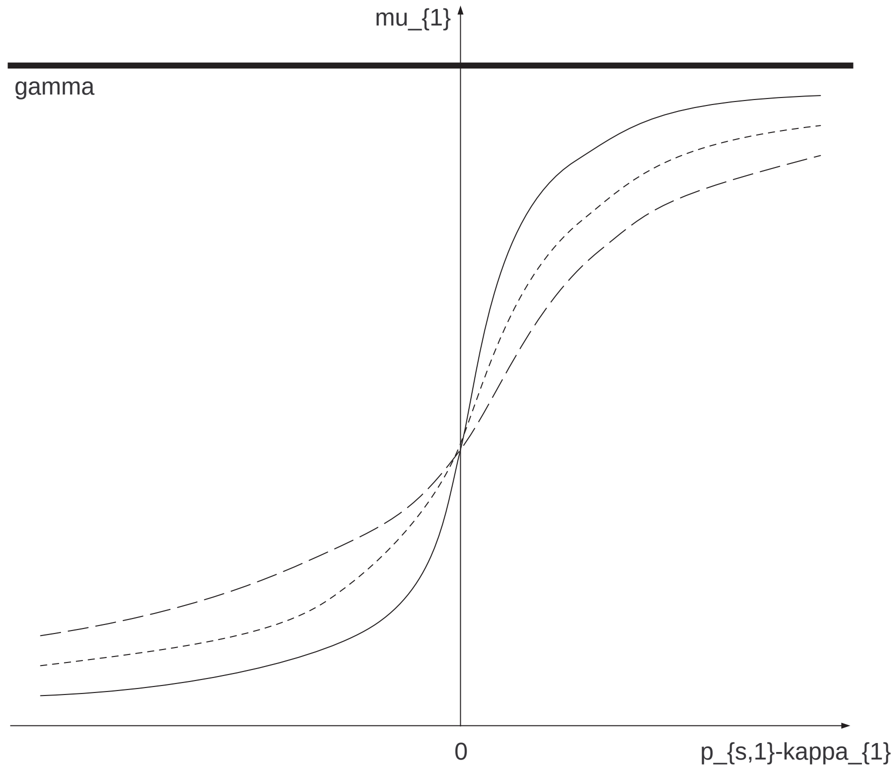

Figure 4.5: Period 1 posterior belief as function of realized sales price; imprecise signal (dashed line), medium signal (dotted line), precise signal (solid line)

posterior belief that the employed trader is skilled. Intuitively, it is very unlikely that a skilled trader would have received a signal above the threshold κ_1 if the realized sales price is low. Since the trade was entered, the employed trader is very likely to be an unskilled one. Second, the lower the variance of the noise in the signal received by skilled traders, the more the posterior belief becomes a step function around κ_1. If κ_1 is close to p_b (and we show below this is the case when the noise variance is low), then posterior beliefs effectively conclude the trader is unskilled if the trade is closed at loss. Their prior is not moved if the trade is closed at gain. In this sense, the reputational concerns of the trader in this conjectured equilibrium approximate concerns about whether the trade will be closed at loss if entered.

Using posterior beliefs 4.2.10, one can re-express the expected payoff of a skilled trader from entering the period 1 trade. The higher the signal on resale price, the greater the expected trading profit from entering (differentiation shows $\partial \pi^1_{e,1} / \partial s_1 > 0$).

$$\pi^1_{1,e=1}(s_1) = E_1(p_{s,1} - p_b + a(\frac{\gamma(1 - H(\kappa_1 - p_{s,1}))}{\gamma(1 - H(\kappa_1 - p_{s,1})) + 1 - \gamma})|s_1) \tag{4.2.11}$$

$$= s_1 - p_b + aE_1(\frac{\gamma}{\gamma + \frac{1-\gamma}{1-H(\kappa_1 - s_1 - \epsilon_1)}}) \tag{4.2.12}$$

In contrast, not entering the trading opportunity implies foregoing the possibility of a trading gain. The reputation of the trader improves however, since he reveals himself as skilled (given posited equilibrium strategies). Expression 4.2.13 denotes the period payoff from not entering the trade.

$$\pi^1_{1,e=0} = a \tag{4.2.13}$$

Comparing expressions 4.2.11 and 4.2.13, it follows naturally that the skilled trader entry strategy is indeed a cut-off function. The skilled trader enters if the signal s_1 is large enough. The cutoff κ_1 denotes the signal s_1 for which the skilled trader is indifferent between entering or not entering the period 1 trade ($\pi_{1,e=1}(\kappa_1) = \pi_{1,e=0}$). This yields closed form expression 4.2.14 for the threshold κ_1.

$$\kappa_1 = p_b + a(1 - \int (\frac{\gamma}{\gamma + \frac{1-\gamma}{1-H(-\epsilon_1)}})dH(\epsilon_1)) \tag{4.2.14}$$

To ensure that the posited entry strategy of the unskilled trader is optimal, notice that expected payoff from entering and not entering are identical to the skilled trader except for the fact that skilled traders condition expectations on the signal s_1. Assuming that the unconditional expected profit from entering the trade is large enough ($a < E_1(p_{s,1} - p_b)$) is sufficient to ensure that the unskilled trader optimally enters in period 1. Then the conjectured strategies for skilled and unskilled traders are indeed a period 1 equilibrium of model B.

Expression 4.2.14 is key to understanding in what sense traders in model B are reluctant to enter profitable trades. A period 1 trade is profitable on expectation for the skilled trader whenever $s_1 > p_b$. Hence the trader will decline profitable trades (those linked with signals $\kappa_1 > s_1 > p_b$). To understand the source of this result, it is useful to break up the κ_1 expression in two components (expression 4.2.15). The first component is an entry effect. By entering, the trader foregoes not entering and revealing himself to be a skilled trader. The second component is a trade loss effect. By entering, the trader exposes himself to closing the trade at loss and making the institution believe that he is in fact unskilled. Both factors mean that equilibrium trade entry by the skilled trader occurs only if the resale market conditions signal s_t is sufficiently attractive.

$$\kappa_1 = p_b + \underbrace{a(1-\gamma)}_{\text{Entry effect}} + \underbrace{a(\gamma - \int (\frac{\gamma}{\gamma + \frac{1-\gamma}{1-H(-\epsilon_1)}})dH(\epsilon_1))}_{\text{Trade loss effect}} \tag{4.2.15}$$

Loss Averse Behaviour Increasing In Recent History Of Losses

In period 2, the model can be solved for equilibrium along the same lines as the approach used in period 1. The trade entry decision of the skilled trader is again governed by a cut-off decision. Crucially, however, period 2 beliefs about trader type depend on equilibrium play observed in both periods 1 and periods 2. The cut-off κ_2 becomes a function of trading outcomes in period 1:

$$\kappa_2 = \begin{cases} p_b + a(1 - \int (\frac{\gamma(1-H(\epsilon_2))(1-H(\kappa_1 - p_{s,1}))}{\gamma(1-H(\epsilon_2))(1-H(\kappa_1-p_{s,1}))+(1-\gamma)})dH(\epsilon_2)) & \text{if } e_1 = 1, p_{s,1} \\ p_b & \text{if otherwise} \end{cases} \tag{4.2.16}$$

Notice now κ_2 falls in the period 1 profitability of the trade (if the trade is opened). Why? Effectively, a less profitable period 1 trade moves the institution's prior towards the fact that it is employing an unskilled trader. This makes period 2 beliefs more sensitive to additional information that points towards the trader being unskilled. Traders know this and an unprofitable trade in period 1 makes them especially averse to taking an unprofitable trade in period 2.

Proposition 6 summarizes the equilibrium:

Proposition 6. *In model B, define:*

$$\kappa_1 = p_b + a(1 - \int (\frac{\gamma(1-H(-\epsilon_1))}{\gamma(1-H(-\epsilon_1)) + 1 - \gamma})dH(\epsilon_1)) \tag{4.2.17}$$

$$\kappa_2 = \begin{cases} p_b + a(1 - \int(\frac{\gamma(1-H(-\epsilon_1))(1-H(\kappa_1-p_{s,1}))}{\gamma(1-H(-\epsilon_1))(1-H(\kappa_1-p_{s,1}))+(1-\gamma)})dH(\epsilon_2)) & \text{if } e_1 = 1, p_{s,1} \\ p_b & \text{if otherwise} \end{cases} \tag{4.2.18}$$

assume that trading opportunities are on average attractive enough:

$$E_t(p_{s,t} - p_b) > a \tag{4.2.19}$$

then there exists a (weak) perfect Bayesian equilibrium in which:

1. *the entry strategy of the skilled trader is:*

$$e_t^1 = \begin{cases} 1 & \text{if } s_t \geq \kappa_t \\ 0 & \text{otherwise} \end{cases} \quad \forall t = 1, 2 \tag{4.2.20}$$

2. *the entry strategy of the unskilled trader is:*

$$e_t^0 = 1 \forall t = 1, 2 \tag{4.2.21}$$

3. *financial institution belief whether the trader is skilled is given by:*

$$\hat{\mu}_1 = \begin{cases} \frac{\gamma(1-H(\kappa_1-p_{s,1}))}{\gamma(1-H(\kappa_1-p_{s,1}))+1-\gamma} & \text{if } e_1 = 1, p_{s,1} \\ 1 & \text{if otherwise} \end{cases} \tag{4.2.22}$$

$$\hat{\mu}_2 = \begin{cases} \frac{\gamma(1-H(\kappa_2-p_{s,2}))(1-H(\kappa_1-p_{s,1}))}{\gamma(1-H(\kappa_2-p_{s,2}))(1-H(\kappa_1-p_{s,1}))+(1-\gamma)} & \text{if } e_1 = 1, e_1 = 2, p_{s,1}, p_{s,2} \\ 1 & \text{if otherwise} \end{cases} \tag{4.2.23}$$

4.3 Empirical Evidence from Corporate Bond Dealers

The corporate bond market offers empirical support for the trading theory developed in this paper. Given the over-the-counter structure of this market, the typical trade involves an investor (say Fidelity) trying to sell a bond position. He contacts a dealer (say Goldman Sachs). The dealer purchases the position and subsequently contacts other investors in the market until another investor buyer for the position is found (say Allianz Group) and the asset is resold. The dealer thus effectively takes the position of a trader in the theory developed in this paper. He is an agent employed by a financial institution to trade. He receives trading opportunities and decides whether to take a position given the purchase price. Having opened a position, he samples resale prices offered by different counterparties in the market until he chooses to close the trade.[21]

Traditionally, transactions in this market have been shrouded in secrecy. However, since 2002, the National Association of Security Dealers (NASD) requires its members to report transactions using the Trade Reporting And Compliance Engine (TRACE).[22] Since October 2008, the reporting system also identifies publicly whether the reporting dealer acts as buyer or seller on a given transaction (or whether the transaction is inter-dealer). The corporate bond market therefore offers a natural opportunity to analyse the properties of trader gains and losses.

In practice, to develop a dataset of dealer trade outcomes, this study takes two steps. First, the raw transactions data is cleaned following the procedure in Dick-Nielsen (2009) (also used in Feldhuetter (2012)). This involves deleting duplicates, applying trade submission corrections and cancellations. Outlier buy and sell transactions at extreme prices (relative to other reported transaction prices) are eliminated. In a second step, the TRACE dataset based on reported individual transactions has to be transformed into a set of round-trip trade observations (linking trade entry and exit price). A given dealer sale is therefore linked to the previous observed dealer purchase for that asset. Trade gain/loss is computed as the percentage difference between dealer sell price and purchase price. To raise the likelihood that the two linked transactions in fact constitute a round-trip trade, observations are limited to cases in which the two transactions occur on the same trading day.

The key issue with this approach to linking transactions is that TRACE does not allow

[21]For a good institutional overview of the corporate bond market, see Bessembinder and Maxwell (2008).

[22]In February 2005, NASD announced 99% coverage of corporate bond transactions in TRACE. See the following news announcement: http://www.finra.org/Newsroom/NewsReleases/2005/P013274.

to verify whether the morning purchase transaction is executed by the same dealer as the afternoon sell decision. Bessembinder and Maxwell (2008) provides some justification for this approach by observing that "except for the largest and most actively traded bonds, only a few dealers (including the investment bank or the syndicate that originally underwrote the bond issue) typically "make a market"- that is actively buy and sell a particular bond issue." Coupled with the fact that bond trading is infrequent, it follows that a dealer buy report in the morning and a dealer sell report in the afternoon are likely to be originated by the same dealer as part of a round-trip trade.[23,24] The ultimate test for the linking procedure however are the empirical results below. If the linking procedure ends up merging unrelated transactions, then no patterns should emerge in the resulting trade gains/losses dataset. As seen below, in fact the trade dataset yields strong patterns consistent with career-concern induced loss aversion in traders.[25]

The constructed trade dataset spans trading years 2009 and 2010, containing 364.274 trades for 16.402 bonds. The average transaction gain is 1.69% (with one standard deviation of 2.48).[26] On average, it takes 72 minutes to do a trade.

[23]Concerning low deal trading frequency, Bessembinder and Maxwell (2008) report the following statistics from Edwards, Harris and Piwowar (2007): "individual bond trades did not trade in 48 percent of days in their 2003 sample, and ... the average number of daily trades in an issue, conditional on trading, is just 2.4."

[24]In practice, one often observes in TRACE that a dealer buys an asset position in the morning. In the afternoon of the same day, TRACE then records an inter-dealer transaction for the same asset volume, followed within a few minutes by a dealer selling the same asset to a customer. The algorithm used in this dataset to compute a trade would compare the dealer purchase price in the morning with the dealer sale price in the afternoon. A natural interpretation of this type of pattern is that dealer A purchases the asset from a seller in the morning. Dealer B then identifies a potential buyer, purchases the asset from dealer A and immediately resells the asset to the buyer. In this case, the morning buy and afternoon sell do not originate from the same dealer. Nonetheless, it appears natural to use the price information from these two transactions to learn about trade gains/losses. If dealer A trades subject to career concern induced loss aversion and dealer B charges a (small) mark-up on his intermediation service, then the difference between morning buy price and afternoon sell price is a good proxy for the trade gain/loss of dealer A.

[25]One approach to tightening the link between purchase and sell transactions further would be to only consider trades in which purchase and sale volume coincide. However, in practice, limiting attention to this subset of trades severely reduces sample size. Studying TRACE transaction patterns offers a potential explanation for this. It appears that dealers often purchase large lots and then resell them by parcelling them up into several smaller resale transactions.

[26]In line with findings in the previous empirical literature (Edwards, Harris and Piwowar (2007)), the average transaction gain falls dramatically with volume of assets sold. A natural explanation for this finding is the notion that retail investors have less bargaining power than institutional investors. Duffie, Garleanu and Pedersen (2005) develop a search and matching model that formalizes this notion (see also Duffie, Garleanu and Pedersen (2007)).

4.3.1 Truncation of Trading Profits Distribution

Two features stand out in the resulting histogram of trade gains/losses (figure 4.6). There is a spike of trades for which buy and sell prices nearly coincide as well as a truncation of trade gain/losses at the break-even mark.

The spike of trades at the break-even mark reflects so-called agency trades. In these trades, a customer that wants to sell calls the dealer. The dealer then contacts other customers until a buyer is found. Once counterparties are established, the dealer executes the transaction (first purchasing the asset from the customer that wants to sell and then immediately selling the asset to the customer that wants to buy). Since the terms of the purchase and sale are pre-agreed, in such trades the dealer takes no balance sheet risk and collects only a small price mark-up fee. Reflecting that principal trades (in which dealers do take on balance sheet risk) make up 92% (FINRA report: "http://www.finra.org/Industry/Compliance/MarketTransparency/TRACE/p011447") of transactions in the corporate bond market, the theory in this paper does not speak to these agency trades.

Support for a core prediction of the theory developed in this paper comes from the truncation of the trade gain/loss distribution at the break-even point. Compared to standard asset pricing theory, it appears that traders make purchase and sale decisions by putting special weight on avoiding losses.[27] This is consistent with the career concerns theory developed in this paper. Traders aim to avoid closing trades at loss by only entering trades that are very unlikely to end in a loss or by "fishing"- holding on to open positions until the opportunity to resell at gain emerges.

Figure 4.7 shows that this truncation result persists if one considers only trades that are closed after several hours. This speaks against two alternative stories. First, the dataset may reflect more agency trades than the 8% reported in the 2004 "http://www.finra.org/Industry report". Second, dealers may have a very good notion of eventual resale price when entering the trade (effectively, most traders are of the skilled type in model A). Either of these stories would predict that dealers only enter trades that they eventually close at gain. Both theories would however also predict that the truncation result should disap-

[27]A natural baseline model of dealer trade gains/losses without career concerns is represented by the period 2 model A equilibrium outcome.

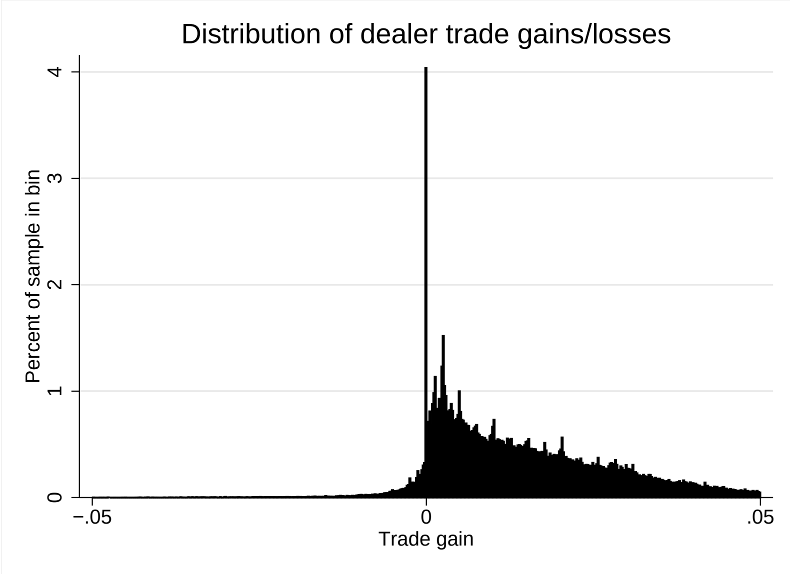

Figure 4.6: Distribution of dealer trade gains/losses

pear for that subset of trades that are closed after a prolonged period of time (several hours). Presumably, such long-horizon trades are unlikely to be pre-arranged and, if they are not pre-arranged, it would be difficult for the dealer to forecast resale prices at time of position purchase.[28]

Figure 4.8 provides suggestive evidence that this truncation in resale prices is at least in part due to a disposition effect. The time-to-sale increases substantially for trades that sell at loss (especially for the upper quantiles). This is consistent with traders 'fishing' for a counterparty until they can resell at gain. Regression 4.1 confirms that this result is statistically significant.

4.3.2 Dynamic Effect of Trading Loss

The truncation result in subsection 4.3.1 is consistent with the career concerns story developed in this paper. However, it could also reflect two natural alternative factors. First, Green, Hollifield and Schuerhoff (March 2007) report similar trade gain/loss distributions for dealers in the municipal bond market (high expected return, low frequency of

[28]Another objection to these two alternative stories are the large expected trade gains reported in this section. It is hard to believe that such high expected returns (for an average holding period of little more than an hour) from market-making can persist if dealers do not take on substantial balance sheet risk in the process.

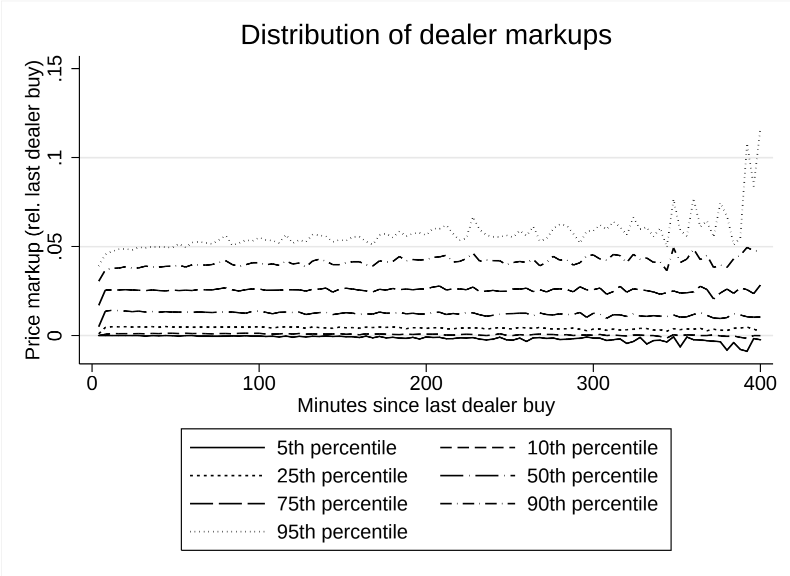

Figure 4.7: Distribution of dealer trade gains/losses as function of time that position is open

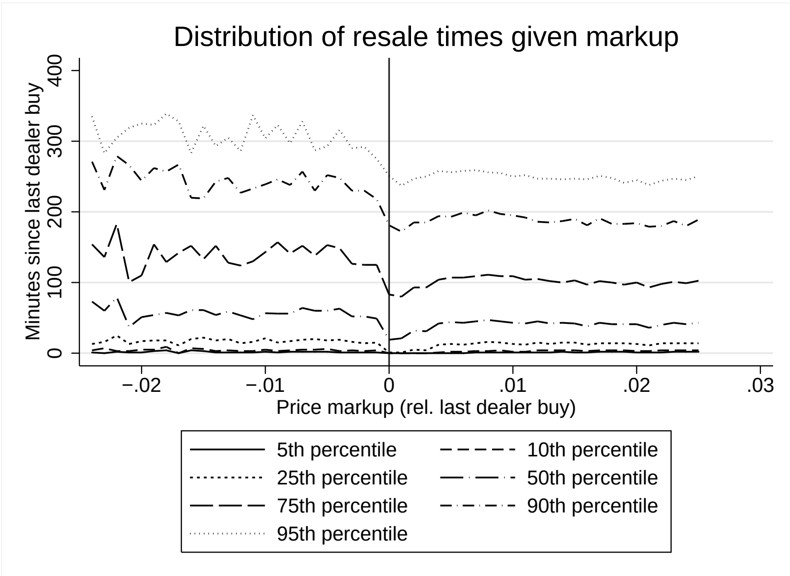

Figure 4.8: Conditional distribution graph: 'losers' take longer to sell

VARIABLES	(1) time	(2) time	(3) time	(4) time
loss	8.519***	4.166***	3.832***	3.575***
	(0.648)	(0.651)	(0.649)	(0.649)
liqu_month				-0.352***
				(0.0165)
Constant	70.90***	71.15***	63.19***	68.64***
	(0.155)	(0.148)	(0.845)	(0.883)
Observations	290,274	290,274	290,274	290,274
R-squared	0.001	0.000	0.007	0.008
Number of id		8,419	8,419	8,419

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4.1: Regression: 'losers' take longer to sell

loss-making trades, a distribution skewed towards gains). Their explanation for this phenomenon relies on dealer bargaining power. Dealers lower purchase prices below average market price when facing customers especially eager to sell. This skews the distribution of trade gains/losses towards gains.[29] Second, the truncation result may simply reflect the behavioural hypothesis that traders have loss averse preferences.

This section therefore tests for an implication of the career concerns theory not directly shared with these other alternatives. Specifically, note that the career concerns mechanism suggests that loss aversion becomes stronger after a recent string of losses. Why? The trader can blame one loss on bad luck. However, a string of losses is likely to lead the financial institution to exclude bad luck and instead believe that the trader is unskilled. Section 4.2 illustrates this effect explicitly in the trade entry decision of the trader. In contrast, theories of loss averse preferences or dealer bargaining power do not naturally predict a dynamic relationship between trading outcomes.[30]

[29] Consistent with the notion that dealers have much less bargaining power when facing large institutional traders, they report that mean, variance and loss frequency of dealer trade gains fall when the par value of trades increases. However, they also report that a "high level of skewness in the mark-ups persists for all trade sizes." These results are broadly replicated in the corporate bond dataset of this study. Moreover, the truncation of trade gain/loss at the break-even mark remains a salient visual feature when restricting attention to large trades.

[30] Coval and Shumway (2005) find that Chicago Board of Trade (CBOT) proprietary traders take more risk in the afternoons if they have taken trading losses in the morning session. To explain this finding, they suggest that traders have loss averse preferences defined over end-of-day trading profits. This would also introduce a dynamic element into trade-by-trade loss probabilities - however it would

VARIABLES	(1) loss	(2) loss	(3) loss	(4) loss	(5) loss
L.loss_1_4	-0.00382***	-0.00450***	-0.00491***	-0.00504***	-0.00539***
	(0.00123)	(0.00125)	(0.00125)	(0.00125)	(0.00125)
L.loss_2_4		-0.00808***	-0.00904***	-0.00940***	-0.0100***
		(0.00252)	(0.00253)	(0.00254)	(0.00254)
L.loss_3_4			-0.0204***	-0.0216***	-0.0223***
			(0.00550)	(0.00551)	(0.00551)
L.loss_4_4				-0.0396***	-0.0408***
				(0.0130)	(0.0130)
liqu_month					-0.000475***
					(4.79e-05)
Constant	0.0497***	0.0499***	0.0500***	0.0500***	0.0577***
	(0.00269)	(0.00269)	(0.00269)	(0.00269)	(0.00280)
Observations	281,855	281,855	281,855	281,855	281,855
R-squared	0.001	0.001	0.001	0.001	0.001
Number of id	6,798	6,798	6,798	6,798	6,798

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4.2: Regression of dynamic loss aversion

To construct a measure of recent trading history, the study constructs a variable that counts the number of losses among the previous four trades. It then creates four dummy variables depending on whether there was one loss, two losses, three losses or four losses. The baseline specification then analyses how a recent history of losses affects the probability of observing a loss in the subsequent trade (regression results in table 4.2). As seen, the probability of observing a loss falls from about 5% to less than 1% if the previous four trades were losses (regression four). These regressions are consistent with the view that traders behave more loss averse if they have recently experienced a string of losses.

A simple regression of a loss dummy on the history of recent losses could reflect learning in liquidity clusters. After a long period without trades, the first trade of the dealer is likely to end up as a loss because the dealer cannot assess the current resale

not explain the regression results in this paper. A daily loss aversion target would suggest that morning losses are more likely to result in afternoon losses (traders gamble for resurrection and increase risk in the afternoon). Such a theory would also not explain the truncation of trade-by-trade resale prices at last observed purchase price.

market price distribution. Because trading opportunities are clustered, the dealer learns from the first trade about market conditions and becomes much more adept at avoiding trading losses in subsequent trades of the same liquidity cluster.

To provide some evidence against this learning story alternative, the final regression in 4.2 adds a proxy for recent liquidity (the number of trades observed in the previous month). As predicted, greater liquidity lowers the probability of observing a loss-making trade. It presumably reflects that traders are better able to ex-ante evaluate the trading opportunity if they have recently been in touch with buyers and sellers. Once inside the trade, a counterparty for the position can be found quickly since many traders are active. However, even controlling for intensity of recent trading activity, the main result remains: recent trading losses substantially lower the probability of observing trading losses in the near future.

4.4 Concluding Discussion

This paper shows that career concerns can lead rational profit-maximizing traders to exhibit loss aversion. Fear of realizing a loss makes them reluctant to enter trades that are profitable on expectation. Once they hold a position that is trading at a loss, they are reluctant to close the trade. Key is that loss realizations send especially powerful signals about trader skill to employers. Corporate bond dealer transactions data offers some empirical evidence consistent with this story.

To conclude, this section discusses three natural questions that arise from this career concerns theory of loss aversion: in what situations is it most likely to apply? What does it imply for the literature on loss averse preferences? And finally, how should trading floors be organized to avoid the decision-distorting effects of trader career concerns?

4.4.1 Where Does this Career Concerns Theory Bite?

Three ingredients are central to the career-concerns mechanism developed in this paper. First, traders must have some discretion over when to enter and when to exit trading positions. Second, some traders must have an edge over others in evaluating trading opportunities. Third, traders must care about how trading losses impact on their reputation.

At first sight, this suggests that the theory does not bite in explaining the trading patterns of at least three empirically prominent trader types: high frequency traders, traders with a long trading history and private account traders. High frequency algorithms execute millions of trades within seconds, implying that individual trade gains and losses hardly register with management before average profitability of the trading strategy is revealed. In this environment, realizing a loss on an individual trading position generally does not impact trader reputation with his employer. Equally, one may speculate that established traders with a long trading record have effectively revealed their trading skill. These traders should therefore not fear reputational consequences from closing trading positions at loss. Finally, traders that use their own private accounts are not in an agency relationship with a financial institution. Career concerns per-se therefore do not influence their trading decisions. In the first two cases, taking a loss on individual trading positions does not impact trader reputation with his employer. In the latter case, the trader does not have an employer to signal high trading skill to. For all three trader types, the third ingredient of the career concerns theory for loss aversion appears to be missing.

This subsection aims to sketch out how a slightly broader interpretation of the theory developed in this paper in fact allows the framework to also speak to these three special cases.

Considering high frequency trading, once a computer algorithm has been designed, the key decisions of the trader are whether to take the algorithm online and when to withdraw it from the market. These actions offer direct counterparts to the model decisions to enter and close a trading opportunity. Building on this analogy, closing a trading opportunity at loss is equivalent to taking a trading algorithm offline while recording an overall trading loss for the strategy. Trader reputation at the financial institution takes a hit, since he should have shown judgement and rejected the trading idea ex-ante. The predictions developed in this paper therefore have a natural cousin in the world of high frequency trading: career concerns make algorithmic traders too reluctant to withdraw loss-making algorithms and they make them too reluctant to try new algorithms that are on expectation profitable for fear of eventually having to withdraw the product at a trading loss.

Considering traders with long trading history, the model would indeed predict that these trader types should be less career-concerned. However, there are various reasons to believe that trader type is never revealed perfectly and reputational concerns therefore continue to matter even for established market participants. Whether entering a trading opportunity was a good or bad idea can take years to establish (think of trading against the stock bubble in the late 1990s or trading against the subprime mortgages in the 2000s). Even once a range of trades are closed successfully, considerable market noise may make it difficult to distinguish between a lucky unskilled trader and a skilled stock-picker. Finally, it may well be that the skill of a trader is time-varying (in stochastic and unobservable ways). Traders may learn about how to evaluate trading opportunities as they gain experience, or they may become less perceptive as they age. Traders may inherently stay the same, but their skills and thought processes become unsuitable to a new market environment. For all these reasons, it is unclear whether reputational concerns really disappear even for veterans of the trading industry. The career concerns theory of loss aversion may continue to apply (though in weakened form) for this class of actors.

Finally, by definition, private investors are not employed by a financial institution - the agency relationship at the core of this paper is missing. Yet, in practice, the judgmental eye of an employer may often be replaced by the judgmental eye of a spouse, children and friends (and maybe once own self) for these types of traders. In this setting, the threat of losing a trading job or taking a wage cut may be replaced by the social cost of being seen as the market fool. Reputation continues to matter, albeit for a different reason. The career concerns theory of loss aversion developed in this paper is therefore not necessarily silent on why homeowners are reluctant to sell houses below the price at which they bought (Genesove and Mayer (2001)) or why private stock traders exhibit a disposition effect (Odean (1998)).

Overall, the theory developed in this paper undoubtedly applies best to traders such as corporate bond dealers: they face high stake, low frequency trading opportunities as employees of large financial institutions. However, as this subsection suggests, the three core ingredients behind the theory can be found in many trading situations (indeed probably in most situations in which people have to decide on whether to take an action or not). The career concerns theory developed in this study can be applied more generally than first meets the eye.

4.4.2 What Do these Results Imply for the Literature on Loss Averse Preferences?

A pessimistic reading of this paper suggests an important caveat for empirical work on loss aversion: finding empirical evidence for a trader disposition effect does not necessarily imply that loss averse preferences are at play. In certain market situations, trader career offer a rational explanation for such phenomena.

However, this subsection would like to offer a more positive take-away for research on loss averse preferences: the rational career concerns theory of loss aversion developed in this paper may help explain why people have adopted loss aversion heuristics in the first place. Humans are inherently social animals. In various forms, we depend on how our actions are perceived by our superiors and peers. In this context, the broad message of this paper is that it is optimal to (i) avoid taking action if the likelihood of an outcome interpreted as loss relative to status quo is high and (ii), once an action is taken, to invest considerably in making sure the outcome is interpreted as gain. Societal pressure could therefore explain why people have developed loss aversion bias in preferences. In evolutionary terms, agents with loss aversion bias may have an edge in defending their place in society. Constant repetition of career concerns may have led to automation (a short-cut) in the initially conscious decision to avoid outcomes perceived as "loss"- to the point that these heuristics are today applied even in situations in which no principal is directly evaluating agent decisions.

Overall, this argument suggests that the career concerns theory of loss aversion does not have to be seen in confrontation with loss averse preferences. Instead, the two mechanisms may co-exist and feed on each other.

4.4.3 What Do these Results Imply for Best Practice on the Trading Floor?

From the perspective of the financial institution, career concerns lead traders to deviate from profit-maximizing trade entry and exit decisions. They become too reluctant to enter trades and they become too reluctant to close positions once they are trading at loss. A natural question to ask is therefore how trading floors should be organized to mitigate the distorting effects of this agency problem. The paper concludes by discussing three such proposals.

First, the career concerns effect could be eliminated if financial institutions would commit to long-term contracts. By retaining traders for the length of the contract and delinking wage rises from trader reputation, traders would stop worrying about the short-term reputational consequences of realizing losses. In practice, this benefit of long-term contracts would of course have to be weighed up against the flexibility of being able to fire traders as they reveal themselves to be low-skilled and incentive effects from the latent threat of losing ones job. Whether the current hire-fire culture at financial institutions strikes an optimal compromise remains an open empirical question.

Second, the career concerns distortion could be mitigated by rotating portfolios across the firm. Traders would face no career concerns in selling the position of a predecessor at loss, since they were not the one making the decision to enter in the first place. While such a policy at first appears highly unconventional, in fact Hertzberg, Liberti and Paravisini (2010) document that banks do use a very similar scheme in rotating loan officers across corporate clients over time: credit officers are more likely to signal that a loan arrangement is failing if they were not the ones that agreed to give the loan in the first place.

Finally, in the context of this model, it appears natural to promote skilled traders to the management of trading desks. By definition, such managers can recognize ex-ante whether a trading opportunity is attractive or not. In evaluating traders, they can therefore use soundness of investment decision rather than relying solely on outcome variables. This diminishes the ability of unskilled traders to mimic skilled traders and dampens the career concerns mechanism for loss aversion.[31] This argument may offer one explanation for why banks are so willing to promote top-performing traders into management. Though the promotion detracts skilled manager-traders from making profitable trades for the bank, they may make up for this by imposing discipline on the behaviour of their peers on the trading desk.

[31] For example, once an unattractive trading opportunity is entered, a skilled trader-manager is aware of the blunder and the agent cannot hide by "fishing" to sell at gain. Equally, an opportunity may appear highly promising ex-ante and, once the trading position is opened, new information may reveal that the trade will results in a loss. A skilled manager-trader would recognize that the agent demonstrated judgement despite ending up losing the bank money.

Appendix A

Appendix To Chapter 2

A.1 Robustness Checks for Section 2.1

This section considers two robustness checks for the results in section 2.1. It confirms that the strong response of housing sales rate to monetary policy is not purely an artefact of the Romer and Romer (2004) monetary policy shock identification scheme. It also confirms that the new housing sales rate is not the only measure of housing liquidity that rises substantially given expansionary monetary policy.

To tackle the first point, figure A.1 replicates the results in section 2.1 using a quarterly recursive Vector-Autoregressions identification scheme (this method is reviewed for example in Christiano, Eichenbaum and Evans (1999)). The identification ordering assumes that output and price level do not respond contemporaneously to monetary policy. The housing variables can respond contemporaneously. The VAR includes a constant, a linear trend and seasonal dummies.

Romer and Romer (2004) find that their identification scheme leads to large estimates for the macroeconomic response to monetary policy (relative to the recursive identification scheme). Figures 2.3 and A.1 reveal that this finding carries over to the housing market response. Key however is that the sales rate response remains significantly more pronounced than the response of transaction prices under the recursive identification scheme.

To tackle the second point, figure A.2 shows the response of other proxies for housing liquidity to Romer and Romer (2004) monetary policy shocks. The data sources are summarized in section A.2. Notice first that the strong response of new housing sale rates is reflected in an actual increase in transaction volumes both for new and existing properties.[1]

Equally, figure A.2 shows that the dampening of the new housing sales rate response after two years roughly coincides with a substantial rise of for-sale new housing on the market. The construction sector responds to a hot housing market by raising supply. This response is not captured in the DSGE model of section 2.3 where a constant total housing supply is assumed. Note however that, from the standpoint of the lender decision in the model, the ratio of sales to for-sale housing is key to evaluate the security provided by housing collateral.

Finally, figure A.2 also reports the response of the median months new houses are reported for sale. This measure behaves very similarly to the housing sales rate considered in the main text.

A.2 Data Sources

Table A.1 summarizes the data sources used in this study.[2,3]

A.3 Characterizing Optimality Conditions for the Consumer in Section 2.3

Consider the consumer problem described in section 2.3. The associated first order conditions are key drivers of the macroeconomic mechanism behind this paper. First, for

[1]The fact that existing housing responds with a lag, while new housing sale numbers jump on impact of the monetary policy shock, reflects differences in the way these two statistics are collected. The new housing sales measure captures when the sales contract is signed, while an existing housing sale is recorded at the close of the sale (when the mortgage has been approved and the transfer of funds has taken place). This can explain a response lag of a month or two.

[2]Alternative popular house price indexes such as the FHFA index and the S&P/Case-Shiller index are available only starting in the early 1990s, precluding their use in conjunction with the Romer and Romer (2004) policy shocks. Using the U.S. Census Bureau index of purchase prices on new single-family homes (available since 1963) leads to a larger peak response of house prices at 4%. The FMHPI index is used in the main text, since (i) its repeat-sales methodology controls for variation in the quality of housing sold and (ii) it considers the value of both new and existing housing.

[3]House prices are reported in real terms by deflating with the CPI price index measure

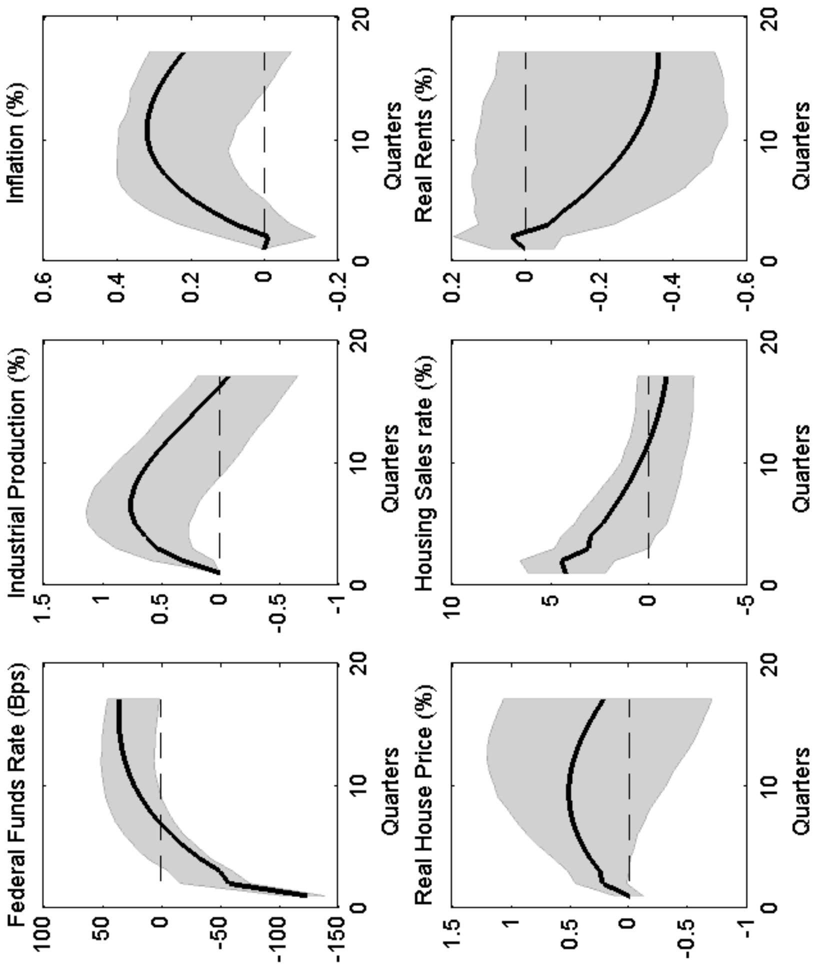

Figure A.1: Response of the housing market (Recursive identification VAR; in log dev. from trend; 95% confidence intervals)

Variable	Source
Federal funds rate	Federal Reserve Board (FRB) H.15
Output	Ind. prod. (major ind. groups) (FRB) G.17
Price level	Bureau of Labour Statistics (BLS) CPI
House prices	Freddie Mac House Price Index (FMHPI)
Rents	Bureau of Labour Statistics (BLS) CPI
New housing sales rate	US Census New residential housing
Sales volume (existing housing)	National Association of Realtors
Sales volume (new housing)	US Census new residential housing
Sales volume (existing housing)	National Association of Realtors
For-sale housing (new housing)	US Census new residential housing
Med. for-sale months (new housing)	US Census new residential housing

Table A.1: Data sources

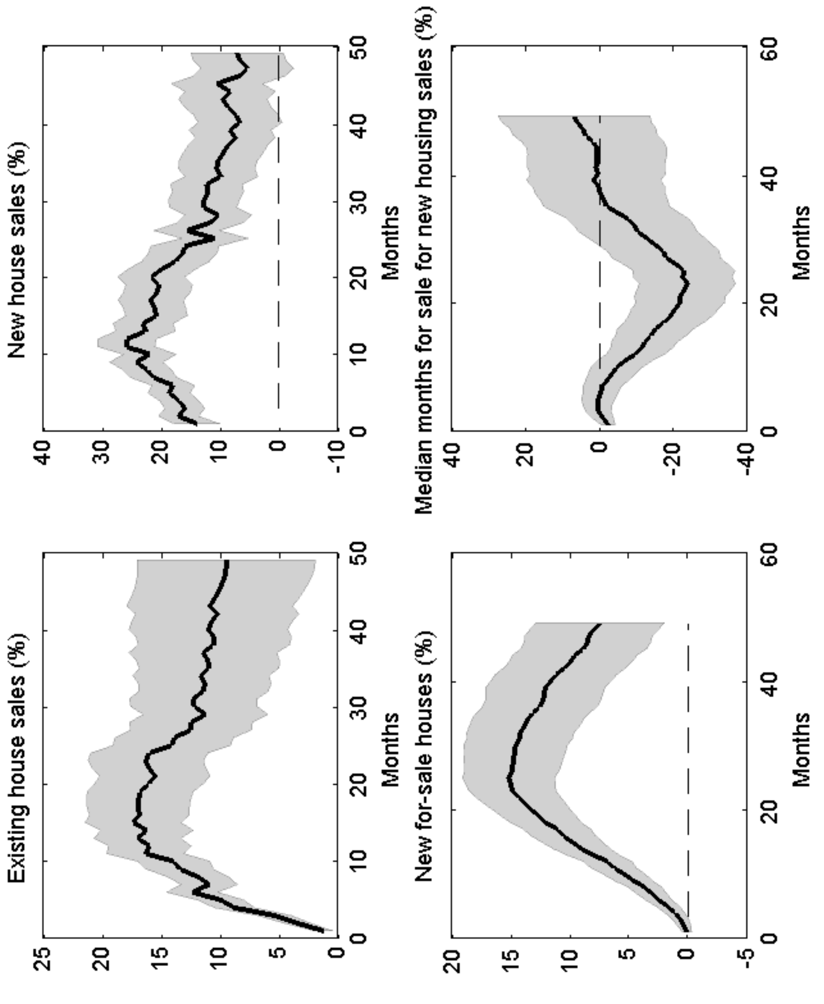

Figure A.2: Response of other housing liquidity measures (Romer and Romer (2004) shocks; in log dev. from trend; 95% confidence intervals) notation, it is useful to introduce the shadow price of vacant housing before search in period t ($q_{vb,t}$). Irrespective of consumer type, this is given by:

$$q_{vb,t} = -m - \tau + P_s(\theta_t)q_{m,t} + (1 - P_s(\theta_t))q_{v,t} \qquad \text{(A.3.1)}$$

Second, for any type i, either the price of a vacancy at the end of period t equals the present discounted value of a vacancy at the start of period $t+1$, or no vacant property is held by that type at the end of period t.

$$q_{v,t} \geq E_t(Q^i_{t+1}q_{vb,t+1});\ v^i_t \geq 0;\ (q_{v,t} - E_t(Q^i_{t+1}q_{vb,t+1}))v^i_t = 0 \qquad \text{(A.3.2)}$$

Third, the fundamental (shadow) value of occupied housing V^f_t equals its current consumption-equivalent service value, its present discounted future value (either as matched house or as newly unmatched house) as well as its value as collateral asset to access debt finance (where the Lagrangian λ_t denotes the consumption-equivalent value of collateral).

$$V^{f,i}_t = j\frac{c^i_t}{h^i_t} + E_t(Q^i_{t+1}(-m - \tau + zq_{vb,t+1} + (1-z)V^{f,i}_{t+1})) + \lambda^i_t \frac{1}{E_t(Q^i_{t+1}\frac{R_t(1-z)}{\pi_{t+1}})} q_{v,t} \qquad \text{(A.3.3)}$$

Fourth, consumers undertake search effort for housing up to the point where marginal benefit equals marginal cost. In effect, this links equilibrium sales probability to the difference between fundamental housing value and the current bargained transaction price when housing fit for occupation is found.[4] Note that, if both patient and impatient consumers have put effort into search, then in equilibrium the free entry condition must equalize perceived fundamental value across types. As will be shown, this condition will hold in the neighbourhood of the deterministic steady state.

$$V^{f,i}_t \leq \frac{\kappa_b}{Pr_b(\theta_t)} + q_{m,t};\ e^i_t \geq 0;\ (V^{f,i}_t - (\frac{\kappa_b}{Pr_b(\theta_t)} + q_{m,t}))e^i_t = 0 \qquad \text{(A.3.4)}$$

Fifth, the Euler equation ensures consumption is optimally allocated across time, given rates of return available and the borrowing constraint.

[4]Note this condition offers an analogue to the free entry condition for vacancy posting in the labour market search literature (see Pissarides (2000)).

$$1 = E_t(Q^i_{t+1}\frac{R_t}{\pi_{t+1}}) + \lambda^i_t \tag{A.3.5}$$

Sixth, in equilibrium, either the stock price equals the present discounted value of future dividend and capital gain for consumer type i, or no equity is held by that subgroup of the population.

$$q_{o,t} \geq E_t(Q^i_{t+1}(q_{o,t+1} + \Pi_{t+1}));\ o_t \geq 0;\ (q_{o,t} - (E_t(Q^i_{t+1}(q_{o,t+1} + \Pi_{t+1}))))o_t = 0 \tag{A.3.6}$$

Seventh, the intratemporal labour-consumption first order condition ensures workers optimally trade-off the utility cost of providing additional labour against the consumption gains from greater labour income.

$$\frac{w_t}{c^i_t} = \chi(l^i_t)^\eta \tag{A.3.7}$$

Eighth, the Lagrangian for the borrowing constraint is zero if the borrowing constraint does not bind:

$$E_t(Q^i_{t+1}\frac{R_t}{\pi_{t+1}})b^i_t \leq q_{v,t}h^i_t;\ \lambda_t \geq 0;\ (E_t(Q^i_{t+1}\frac{R_t}{\pi_{t+1}})b^i_t - q_{v,t}h^i_t)\lambda_t = 0 \tag{A.3.8}$$

The first order conditions of the wholesale producer and retailer follow the standard textbook.

A.4 Characterizing the Steady State in Section 2.3

This section describes the steady state (the deterministic solution of the model in a setting without stochastic shocks) of section 2.3 in a series of propositions. Denote steady state variables by a star subscript.

Proposition 7. *In any steady state of the model, the patient consumer is not credit constrained.*

Proof of proposition 7: Assume the patient consumer credit constrained. Then we have $(b^p)^* > 0$ and, using A.3.8, the shadow value of funds is strictly positive for patient consumers ($(\lambda^p)^* > 0$). Note now by the bond market clearing this implies $(b^{ip})^* = -(b^p)^* < 0$ and, using A.3.8, the shadow value of funds for the impatient must be zero ($(\lambda^{ip})^* = 0$). Subtract now the Euler equations A.3.5 of the two types to get:

$$0 = (\beta^p - \beta^{ip})R^* + (\lambda^p)^* \tag{A.4.1}$$

Since $R^* > 0$ in a well-defined steady state, this implies $\beta^{ip} > \beta^p$. This contradicts the definition of patient and impatient consumers ($\beta^{ip} < \beta^p$).

Proposition 8. *In any steady state of the model, the impatient consumer is credit constrained.*

Proof of proposition 8: Assume the impatient consumer is not credit constrained in steady state. Since we have established that the patient consumer must not be credit constrained in steady state, by equation A.3.8, the shadow value of funds is zero for both types: $\lambda^{ip} = \lambda^p = 0$. Using equation A.3.5 this implies $1 = \beta^p R^*$ and $1 = \beta^{ip} R^*$. Subtracting these two statements yields $0 = (\beta^p - \beta^{ip})R^*$. Since $R^* > 0$ in a well-defined steady state, this implies $\beta^p = \beta^{ip}$. But this contradicts the assumption that there is a patient and impatient consumer type ($\beta^p > \beta^{ip}$).

Proposition 9. *In any steady state of the model, both consumer types search for new housing for occupation.*

Proof of proposition 9: Assume consumer of type i did not search in steady state $(e^i)^* = 0$. By the dynamic equation for occupied housing held by type i consumers 2.3.3, this implies that the consumer does not occupy any housing in steady state ($(h^i)^* = 0$). But then the fundamental value of housing is undefined, since the fundamental housing value equation A.3.3 implies $lim_{(h^i)^* \downarrow 0}(V^{i,f})^* = +\infty$. The first order condition A.3.4 ($(V^{i,f})^* \leq \frac{\kappa_b}{Pr_b(\theta_t)} + q_{m,t}$) cannot hold.

Proposition 10. *In any steady state of the model, both consumer types occupy housing.*

Proof of proposition 10: The proof for this statement follows straightforwardly combining proposition 9 and the equation for housing dynamics 2.3.3.

Proposition 11. *In any steady state of the model, both consumer types have the same fundamental valuation of housing.*

Proof of proposition 11: Since $(e^i)^* > 0$ for both types, free entry condition A.3.4 implies that $(V^{i,f})^* = \frac{\kappa_b}{Pr_b(\theta_t)} + q_{m,t}$. Subtracting the statement across types yields: $(V^{p,f})^* = (V^{ip,f})^*$.

Proposition 12. *In any steady state of the model, the patient agent holds all firm equity.*

Proof of proposition 12: At least one consumer type must hold all equity, since the equity market clears in equilibrium and equity is in positive supply. Assume now that both types hold equity in steady state. Then first order condition A.3.6 implies: $(q_o)^* = \beta_i((q_o)^* + \Pi^*)$. Subtracting this equation by consumer type yields: $0 = (\beta_p - \beta_{ip})((q_o)^* + \Pi^*)$. Since $((q_o)^* + \Pi^*) > 0$ in a well-defined steady state, this implies $\beta_p = \beta_{ip}$. But this contradicts the assumption that there is a patient and impatient consumer type $(\beta_p > \beta_{ip})$.

Proposition 13. *In any steady state of the model, the patient agent holds all end-of-period vacant property and physical capital.*

Proof of proposition 13: The proof of this proposition follows directly the pattern of the argument for proposition 12.

A.5 Derivation of Section 2.2.1 Log-Linearization Result

Taking a first order (log) Taylor approximation of equation 2.2.1 yields equation A.5.1.

$$q_v^* \hat{q}_{v,t} = q_v^* \hat{Q}_{t+1} + [Q^*(q_m^*(1-F_s) - q_v^*)]\hat{P}^{s,t+1+[Q^* P_s^*(1-F_s)]\hat{q}_{m,t+1}} + Q^* q_v^*(1-P_s^*)\hat{q}_{v,t+1} \quad \text{(A.5.1)}$$

Defining $\rho_1 = \frac{Q^*(q_m^*(1-F_s)-q_v^*)P_s^*}{q_v^*}$, $\rho_2 = \frac{Q^* P_s^* q_m^*(1-F_s)}{q_v^*}$ and $\rho_3 = Q^*(1-P_s^*)$ we can rewrite this as equation A.5.2.

$$\hat{q}_{v,t} = E_t(\hat{Q}_{t+1} + \rho_1 \hat{P}_{s,t+1} + \rho_2 \hat{q}_{m,t+1} + \rho_3 \hat{q}_{v,t+1}) \quad \text{(A.5.2)}$$

Log-linearization of expression 2.2.2 yields expression A.5.3. Inserting A.5.3 in A.5.2 an iterating forward yields expression 2.2.3 in the main text.

$$E_t(\hat{Q}_{t+1}) = -\hat{r}_{f,t+1} \tag{A.5.3}$$

Appendix B

Appendix To Chapter 3

B.1 Numerical Methods

This section outlines the numerical simulation procedure used in this paper. This broadly follows Bloom (2009).

1. Compute firm policy function: The three state variables in the firm problem are (i) business condition factor $a_{i,t}$, (ii) employees carried over from the previous period $l_{i,t}$, (iii) $T_{\tau,t}$ the number of periods since announcement of the tax cut. Given the log-linear structure of the demand process, the study keeps track of business conditions and employment state variables in logs. If the tax cut is not yet announced or has already expired, set $T_{\tau,t}$ to 0. Note the firm does not need to keep track separately of macro and idiosyncratic business condition shocks, since both subcomponents follow an autoregressive order 1 process (AR1) with identical persistence parameter. Since hiring and firing is subject to time-to-build and hours choice is contemporaneous, the hours choice can be computed analytically and simplified out of the problem. The policy choice of the firm at time t is therefore reduced to choosing employment level at $t+1$ subject to period t state variables

   To solve the problem, first use numerical Bellman value function iteration on an evenly spaced grid in $a_{i,t}$ and $l_{i,t}$ space to solve for value function and policy function of the firm when $T_{\tau,t} = 0$. Expectations over future business conditions faced by the firm are computed discretizing the assumed autoregressive process using

Tauchen approximation. Given $T_{\tau,t} = 0$ value function, the study iterates backwards (starting with the last period of the tax cut), to back out value function and policy function during the period in which the tax cut is implemented and the period in which it is announced. During backward iteration, wage and payroll tax are adjusted depending on whether a temporary wage response is assumed and whether the tax cut is announced or already implemented.

In practice, the grid for $a_{i,t}$ and $l_{i,t}$ is defined as $\pm 50\%$ of non-stochastic steady state solution for the two variables. The grid is discretized with 200 cells. This ensures that firms virtually always stay inside the specified grid space during the simulation runs.[1] Results are insensitive to local changes in these discretization choices.

2. Draw business condition shocks: For each parameterization, 1000 macro simulations are drawn (for 100 periods). For each macro simulation, 1000 firm-specific business condition shocks are drawn (implying a total of 1 million firm-specific shock series). Macro and idiosyncratic shocks are added multiplicatively. All business condition shocks are initialized at the non-stochastic steady state of 1.

3. Compute macroeconomic response: given policy functions and business condition time series, firm-level employment responses are computed. After a warmup period ensuring distributions have converged, the tax cut is announced in period $T_1 = 60$ and then implemented for periods T_2 to T_3. For the baseline simulation, the study sets $T_2 = 61$ and $T_3 = 64$. Employment, hours, output and tax revenue are then aggregated to the macroeconomic level (the 1000 macro business cycles analyzed). Statistics shown in the paper give expected values based on an average over these macro draws.

[1] In the rare event that a firm does want to leave the edges of the grid, the algorithm effectively assumes that forces push it to remain on the grid (returning the firm to the point on the grid closest to its actual optimal choice). These occurrences however are only very rare and are not driving the macro results this study puts focus on. The procedure follows other studies in the literature such as Bloom (2009).

B.2 Historical Background: The US Payroll Tax

As part of the New Deal, President Roosevelt signed the Social Security Act into law in 1935. Among other programs, this policy established unemployment insurance and retirement benefits.

> *Today a hope of many years' standing is in large part fulfilled. The civilization of the past hundred years, with its startling industrial changes, has tended more and more to make life insecure. Young people have come to wonder what would be their lot when they came to old age. The man with a job has wondered how long the job would last.*
>
> *This social security measure gives at least some protection to thirty millions of our citizens who will reap direct benefits through unemployment compensation, through old-age pensions and through increased services for the protection of children and the prevention of ill health.*
>
> *We can never insure one hundred percent of the population against one hundred percent of the hazards and vicissitudes of life, but we have tried to frame a law which will give some measure of protection to the average citizen and to his family against the loss of a job and against poverty-ridden old age.*
>
> Statement by President Roosevelt on Signing of the Social Security Act, August 14 1935

To pay for social security, Congress passed the Federal Insurance Contributions Act. This effectively established the payroll tax structure the United States still faces today. It mandates a proportional wage tax (up to a specified maximum taxable earnings level) that is shared equally between employers and employees. As figure B.1 shows, expansion of social security raised this tax from a relatively modest level of 2% in 1937 to reach a plateau of 15.3% by 1990. Maximum taxable earnings were raised gradually from 3000 dollars to reach 106,800 dollars in 1990.

The passage of the Medicare Program in 1965 (providing health coverage for the above-65) stands out in this expansion. Concerning the payroll tax, this program established a separate HI wage tax (health insurance) without maximum taxable earnings limit. For distinction, HI tax is therefore generally reported separately from the traditional OASDI payroll tax (Old-Age, Survivors and Disability Insurance programs). Figure B.1 follows this convention.[2]

While, in this period of gradual increases, payroll taxes were not used as countercyclical fiscal tool, the events of 2008 and 2009 have radically changed this. With unemployment still clinging stubbornly above the 9% level, the US government has lowered the employee payroll tax contribution from 6.2% to 3.1% in the fiscal year 2011. For fiscal year 2012 a centre piece of the President Obama's "American Jobs Act" was a proposal to half employer payroll tax cuts for 98% of businesses (the tax cut would apply to the first 5 million dollars in payroll). Furthermore, there would be a complete employer payroll tax holiday for payroll increases due to newly hired workers or higher wages.

This brief review of payroll tax history illustrates several points. First, our historical experience using employer payroll tax cuts to stimulate the economy is limited. The simulation analysis in this paper aims to shed light on the consequences and workings of such a policy given limited empirical data for the US. As shown in section 3.4.1, the historical structural adjustments in payroll tax cannot be used to directly infer the multiplier associated with a temporary tax cut measure. Second, the payroll tax in the model abstracts from some important features of the real-world payroll tax. Notably, it does not feature a maximum taxable earnings limit. The tax cut considered in this study treats the entire firm payroll uniformly. It does not allow for payroll tax breaks limited to new employment (as Obama's "American Jobs Act" proposes). Presumably, such alternative tax cuts would be more cost-efficient in creating jobs than the across-the-board tax cut considered in this study.[3] Third, there is growing recognition that payroll tax can be an important lever of government fiscal stimulus programs. This study offers a contribution towards better understanding the stimulus consequences of this policy tool.

[2]Besides HI and OASDI payroll tax, employers generally also pay tax under the Federal Unemployment Tax Act (FUTA). This rate is currently set at 6.2% on the first 7000 dollars by each employee in the first calendar year. The simulations also do not explicitly model state level taxes. The implicit working assumption is that these taxes are not changed as part of the stimulus considered. They are then part of the normalization of wages and productivity in section 3.1.

[3]A tax cut on payroll additions only could encourage firms to churn labour to reap tax benefits (firing worker A and hiring worker B instead, "recycling" worker A in the following tax year). Legislation would need to implement safeguards against such distorting incentive effects from the stimulus policy.

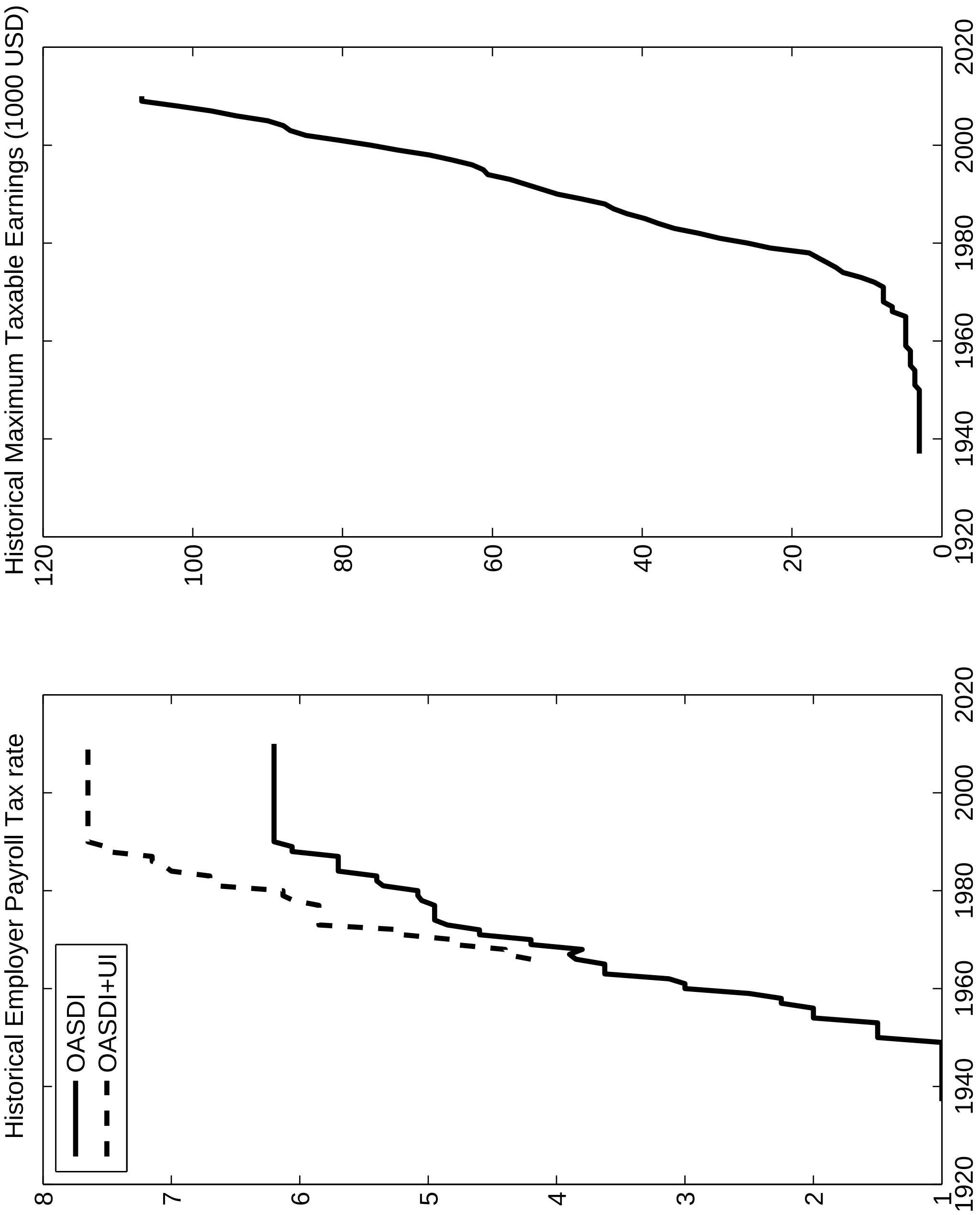

Figure B.1: Historical payroll tax and maximum taxable earnings

Appendix C

Appendix To Chapter 4

C.1 Model A General Properties: Formal Proof

Assume there exists market condition m^* and resale price p_s^* such that the skilled trader enters the period 1 trade given resale market condition m^*, the skilled trader subsequently accepts to close the trade given resale opportunity p_s^* and closing the trade at p_s^* implies a loss ($p_s^* < p_b$). Since the outside option of the skilled trader is not better than staying in the game ($(o_1^1/\omega) - \pi_2^1 \leq 0$) and $r(.)$ is an indicator function, since the resell price offer is accepted (condition 4.1.12), since the trade is entered by the skilled trader (proposition 4.1.9), the inequality chain C.1.1 holds. This contradicts that the sale takes place at a loss. Given the period 2 optimal strategies determined in 1, in any equilibrium of model A, the skilled trader therefore never resells at loss.

$$p_s^* \geq p_s^* + (\frac{o_1^1}{\omega} - \pi_2^1)r_1(e_1, p_s) \geq V_1^1(m^*) \geq p_b \tag{C.1.1}$$

By implication, a period 1 trade closed at loss always reveals that the trader is unskilled. Since firing costs are not too large ($\gamma\pi_2^1 + (1-\gamma)\pi_2^1 - \frac{c_f}{1-\omega} > \pi_2^0$), the financial institution fires the trader if a loss is incurred in period 1.

To show the unskilled trader is endogenously loss averse in equilibrium, this study proceeds in two steps. First, it shows there exists equilibrium market condition m^* and resale price offer p_s^* such that an unskilled trader would not close an open position at resale price offer p_s^* if and only if faced with career concerns (in other words, in period 1 of the game, but not in period 2) and closing the position at p_s^* would imply selling at a loss ($p_s^* < p_b$). The regularity conditions on the distribution of m_t and $p_{s,t}$ ensure the existence of an m^* such that $V_1^0(m^*) + \pi_2^0 - \frac{o_1^0}{\omega} < p_b$ where the trader sometimes accepts to sell at loss and to be fired. This, in turn, implies strict inequality C.1.2 (using the definition of option value in periods 1 and 2). By implication, there exists a p_s^* such that $V_2(m^*) < p_s^* < V_1^0(m^*) + \pi_2^0 - \frac{o_1^0}{\omega}$. Given an unskilled trader opens a market position given resale condition parameter m^*, he accepts to close the position at p_s^* if and only if he faces no career concerns (in period 2 only).

$$V_1^i(m^*) + \pi_2^0 - \frac{o_1^0}{\omega} = -c_s + \int_0^{\bar{p_s}} max(V_1(m^*) + \pi_2^0 - \frac{o_1^0}{\omega}, p_s - (\frac{o_1^0}{\omega} - \pi_2^0)r_1(e_1, p_s))dF(p_s|m_1)$$
$$> V_2(m^*) \qquad \text{(C.1.2)}$$

Consider now the second step of the argument for endogenous loss aversion. Suppose there exist m^* and p_s^* such that the trader would close an open position at resale price offer p_s^* if only if faced with career concerns (in other words, in period 1 of the game, but not in period 2) and closing the position at p_s^* would imply selling at a loss ($p_s^* < p_b$). Since the resell price is below purchase price, since the optimal exit condition 4.1.12 holds, since inequality C.1.2 holds, we must have that inequality C.1.3 holds. But this contradicts that reselling in period 2 would not be optimal (condition 4.1.8).

$$p_b > p_s^* \geq V_1^0(m^*) + \pi_2^0 - \frac{o_1^0}{\omega} > V_2(m^*) \qquad \text{(C.1.3)}$$

C.2 Baseline Model A Equilibrium with Signal on Resale Draws

Proposition 14. *In a version of model A in which the financial institution observes a finite partition signal on the number of resale draws the trader takes in period t* ($\hat{j}_t =$

$k(j) : j \mapsto \{1, 2, ..., N\}$), *define*

$$V_1^i(m_1) = -c_s + \int_0^{\bar{p_s}} max(V_1(m_1), p_s + (o_1^i - \pi_2^i)1(p_s < p_b))dF(p_s|m_1) \tag{C.2.1}$$
$$V_2^i(m_2) = -c_s + \int_0^{\bar{p_s}} max(V_2(m_2), p_s)dF(p_s|m_2)$$

$$\pi_2^1 = \int_0^{\bar{m}} max(V_2^1(m_2) - p_b, 0)dG(m_2) \tag{C.2.2}$$
$$\pi_2^0 = \int_0^{\bar{m}} (V_2^0(m_2) - p_b)dG(m_2)$$

$$q^1(m_1, \hat{j}_t) = 1(p_{s,1} \geq V_1^1(m_1) \geq p_b)(\sum_{j \in \{j : k^{-1}(\hat{j}_t)\}} (1 - \int_0^{\bar{p_s}} 1(p_s \geq V_1^1(m_1))dH(p_s|m_1))^{j-1}) \tag{C.2.3}$$
$$q^0(m_1, \hat{j}_t) = 1(p_{s,1} \geq V_1^0(m_1))(\sum_{j \in \{j : k^{-1}(\hat{j}_t)\}} (1 - \int_0^{\bar{p_s}} 1(p_s \geq V_1^0(m_1))dH(p_s|m_1))^{j-1})$$

$$\hat{\mu}_1(e_1, p_{s,1}, \hat{j}_t) = \begin{cases} 0 & if\ e_1 = 1, p_{s,1} < p_b \\ 1 & if\ e_1 = 0 \\ \frac{\int_0^{\bar{m}} q^1(m_1, \hat{j}_t)\gamma dG(m_1)}{\int_0^{\bar{m}} (q^1(m_1, \hat{j}_t)\gamma + q^0(m_1, \hat{j}_t)(1-\gamma))dG(m_1)} > 0 & if\ e_1 = 1, p_{s,1} \geq p_b, \hat{j}_t \end{cases} \tag{C.2.4}$$

$$\bar{\mu} = \min_{p_{s,1} \geq p_b, \hat{j}_t} (\hat{\mu}_1(e_1 = 1, p_{s,1}), \hat{j}_t) \tag{C.2.5}$$

assume that,

1. *the set of trade outcomes observed by the financial institutions is bounded*
   - $p_{s,t}|m_t$ *and* m_t *has support on* $[0, \bar{p_s}]$ *and* $[0, \bar{m}]$ *where* $\bar{p_s} \in \Re^+$ *and* $\bar{m} \in \Re^+$
2. *the outside options of both trader types are not better than staying in the game*

$$\frac{o_1^i}{\omega} \leq \pi_2^i \tag{C.2.6}$$

3. entry incentive for unskilled traders is high enough

$$\int_0^{\bar{m}} (V_1^0(m_1) - p_b) dG(m_1) \geq 0 \tag{C.2.7}$$

4. the costs that financial institutions face in firing a worker are large

$$\bar{\mu}\pi_2^1 + (1-\bar{\mu})\pi_2^0 \geq \gamma\pi_2^1 + (1-\gamma)\pi_2^1 - \frac{c_f}{1-\omega} > \pi_2^0 \tag{C.2.8}$$

then there exists a (weak) perfect Bayesian equilibrium in which:

1. the strategy of the skilled trader hired in period 1 ($i = 1$, $h = 1$) is:

$$e_t^{1,1} = \begin{cases} 1 & \text{if } V_t^1(m_t) \geq p_b \\ 0 & \text{if } V_t^1(m_t) < p_b \end{cases} \quad \forall t = 1, 2 \tag{C.2.9}$$

$$x_{1,j}^{0,1} = \begin{cases} 1 & \text{if } p_{s,1,j} + (\frac{o_1^1}{\omega} - \pi_2^1)1(p_{s,1,j} < p_b) \geq V_1^1(m_1) \\ 0 & \text{if } p_{s,1,j} + (\frac{o_1^1}{\omega} - \pi_2^1)1(p_{s,1,j} < p_b) \geq V_1^1(m_1) \end{cases} \tag{C.2.10}$$

$$x_{2,j}^{1,1} = \begin{cases} 1 & \text{if } p_{s,2,j} \geq V_2^1(m_2) \\ 0 & \text{if } p_{s,2,j} < V_2^1(m_2) \end{cases} \quad \forall t = 1, 2 \tag{C.2.11}$$

2. the strategy of the unskilled trader hired in period 1 ($i = 0$, $h = 1$) is:

$$e_t^{0,1} = 1 \forall t = 1, 2 \tag{C.2.12}$$

$$x_{1,j}^{0,1} = \begin{cases} 1 & \text{if } p_{s,1,j} + (\frac{o_1^0}{\omega} - \pi_2^0)1(p_{s,1,j} < p_b) \geq V_1^0(m_1) \\ 0 & \text{if } p_{s,1,j} + (\frac{o_1^0}{\omega} - \pi_2^0)1(p_{s,1,j} < p_b) \geq V_1^0(m_1) \end{cases} \tag{C.2.13}$$

$$x_{2,j}^{0,1} = \begin{cases} 1 & \text{if } p_{s,2,j} \geq V_2^0(m_t) \\ 0 & \text{if } p_{s,2,j} < V_2^0(m_t) \end{cases} \tag{C.2.14}$$

3. the strategy of the skilled trader hired in period 2 ($i = 1$,$h = 2$) is:

$$e_2^{1,2} = \begin{cases} 1 & \text{if } V_2^1(m_2) \geq p_b \\ 0 & \text{if } V_2^1(m_2) < p_b \end{cases} \tag{C.2.15}$$

$$x_{2,j}^{1,2} = \begin{cases} 1 & \text{if } p_{s,2,j} \geq V_2^1(m_2) \\ 0 & \text{if } p_{s,2,j} < V_2^1(m_2) \end{cases} \quad \forall t = 1, 2 \tag{C.2.16}$$

4. *the strategy of the unskilled trader hired in period 2 ($i = 0$, $h = 2$) is:*

$$e_2^{0,1} = 1 \tag{C.2.17}$$

$$x_{2,j}^{0,2} = \begin{cases} 1 & \text{if } p_{s,2,j} \geq V_2^0(m_t) \\ 0 & \text{if } p_{s,2,j} < V_2^0(m_t) \end{cases} \tag{C.2.18}$$

5. *the financial institution replacement rule for the trader is:*

$$r_1 = \begin{cases} 0 & \text{if } e_1 = 1, p_{s,1} < p_b \\ 1 & \text{if otherwise} \end{cases} \tag{C.2.19}$$

6. *financial institution belief whether the trader is skilled is given by* $\hat{\mu}_1(e_1, p_{s,1}, j_1)$

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