The UK mortgage market and credit conditions: macro-, micro and policy perspectives

The UK Mortgage Market and Credit Conditions: Macro-, Micro- and Policy Perspectives

Adiya Belgibayeva

A thesis submitted for the degree of
Doctor of Philosophy

Department of Economics, Mathematics and Statistics
Birkbeck, University of London

May 2020

Abstract

The mortgage market plays a crucial role in the UK economy. It enables hundreds of thousands of consumers every year to buy their homes or to refinance existing mortgages. In this thesis, we try to understand the mortgage market and general credit conditions, from macro-, micro- and policy perspectives.

First, we look at the mortgage market from a macro angle. We aim at identifying the relative role of demand and supply conditions in driving the erratic evolution of UK mortgage credit. We aim at distinguishing demand from supply using a disequilibrium econometric model to then compare and contrast credit cycles for the past 20 years. We found that the periods of recession coincide with credit rationing and the periods of economic growth coincide with excess supply.

Second, we look at the mortgage market from a micro perspective. In particular, we analyse the role of mortgage intermediaries and whether their incentives are misaligned with consumers they serve in terms of finding the best deal. For example, mortgage intermediaries need to spend time and resources to identify the right product for the borrower in terms of price, suitability and likelihood of approval by the lender. Lenders pay commissions (procuration fees) to intermediaries potentially distorting incentives of the intermediaries. Moreover, borrowers have little information or do not have tools to compare intermediaries. So we analyse how the price of similar mortgage products for like-for-like consumers varies across intermediary firms and what the drivers of the dispersion are. We find that the difference in average price of mortgage products can be as high as £800 over the incentivised rate period for the median loan amount. We find little evidence that intermediaries selling highly priced mortgages also receive high procuration fees and that the average price of the mortgages an intermediary sells is negatively correlated with the number of lenders used.

Third, we evaluate impacts of the Financial Policy Committee (FPC) policy that aims at reducing risks of financial instability in the economy by limiting excessive household leverage in mortgages and unsustainable credit growth. It recommends that "mortgage lenders do not extend more than 15% of their total number of new residential mortgages at Loan to Income ratios at or greater than 4.5". We are interested in understanding whether it has any impact on consumers in terms of the redistribution consequences and price. The paper finds that after implementation of the recommendation the average loan size for high LTI mortgages increased by 4-7%. This suggests that lenders originated high LTI loans for borrowers with higher incomes. As a result, we find robust evidence of changes in composition of high LTI borrowers: 1) an increase in the proportion of home movers; 2) a decrease in the proportion of first-time buyers; 3) an increase in the proportion of joint income applicants. After implementation, although the overall proportion of high LTI mortgages

to the total number of sales in the market stays around 10%, lenders' individual exposure to high LTI mortgages changed. Some lenders, whose share of high LTI mortgages had been closer to the 15% limit, reduced their proportion of high LTI. In contrast, some lenders that previously had a low share of high LTI mortgages increased their proportion of them. After controlling for borrower, product, and lender characteristics, we find that post-implementation the mortgage price for high LTI mortgages on average decreased. The fall in the mortgage price was stronger for lenders that used to be closer to the 15% constraint.

Fourth, we take a step back and look at the monetary and fiscal policies in the context of New Keynesian models with real rigidities and an economy at the zero lower bound. In this chapter, we are particularly interested in identifying optimal fiscal and monetary policies under strategic interaction among price- and wage-setting agents under zero lower bound. We found that the optimal length of the forward commitment concerning interest rates at the zero bound and key outcomes such as the magnitude of expected inflation or the depth of the recession under optimal policy depend crucially on the assumed degree of real rigidity in the model. In addition to simple parametric assumptions, more fundamental structural assumptions about the nature of the labour market play an important role in this regard. Labour market segmentation and the presence of staggered wage adjustment were shown to have particularly significant consequences for the type of policy one might wish to implement in an economy hit by a large shock that depresses demand. In those circumstances, it is a good idea for governments to lean against the wind in two different ways. First, an increase in government spending when output is low (and vice versa) stabilises output (and prices) but this policy can be justified almost wholly with reference to static public finance considerations. Second, an increase in taxes when output is low (and vice versa) stabilises prices via their impact on marginal cost. The results interact in interesting ways with the initial conditions in the economy. With higher inherited debt, fiscal sustainability considerations matter more for monetary and tax policy and the explained differences across market structures grow larger.

Declaration

I wish to declare that:

- The third chapter, titled "The Choice of Intermediary in the UK Mortgage Market" is a joint work with Dr. Tommaso Majer. It is published as the FCA Occasional Paper *Belgibayeva A., and Majer, T. (2018). Six of One...? The Choice of Intermediary in the UK Mortgage Market. FCA Occasional Paper 35.* I certify that I designed and carried out the empirical analysis of the chapter.

- The fourth chapter, titled "Impacts of the LTI Flow Limit in the UK Mortgage Market" is published as the FCA Occasional Paper *Belgibayeva A. (2020). Changes in the mortgage market post 4.5 limit on loan to income ratios. FCA Occasional Paper 53.*

- The fifth chapter, titled "Real Rigidities and Optimal Stabilisation at the Zero Lower Bound in New Keynesian Economies" is a joint work with Dr.Michal Horvath. The first version of the paper, which differs significantly from the version in this thesis, was submitted for the degree of Master in Philosophy at the University of Oxford. The thesis version has been published in Macroeconomic Dynamics: *Belgibayeva, A., and Horvath, M. (2019). Real rigidities and optimal stabilisation at the zero lower bound in New Keynesian economies. Macroeconomic Dynamics, 23(4), 1371-1400.* I certify that I scoped the research question and carried the analysis of the chapter.

Adiya Belgibayeva, May 2020

Acknowledgements

I would like to thank Professor Ron Smith for supervising me and for playing an important part in my studies. I am very grateful for his the support and understanding. I am thankful to Professor John Driffill and Professor Yunus Aksoy for accepting me on the programme and supervising me during my first years at Birkbeck, to Professor Joao Cocco for invaluable advice on various chapters and encouragement, to Dr. Michal Horvath for an inspiration to pursue a research degree. I would like to thank Professor John Gathergood and Professor Christian Hilber for comments and suggested amendments for the thesis. A big thank to the PhD students in the Economics Department at Birkbeck, to my colleagues at the FCA, and to my husband, mother, sister, and parents-in-law. Financial support from the Economic and Social Research Council is gratefully acknowledged. The views expressed are those of the author and should not be attributed to the FCA. Any errors or omissions should be attributed to the author.

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Part I

Introduction

The mortgage market plays a crucial role in the UK economy. It enables hundreds of thousands of consumers every year to buy their homes or to refinance existing mortgages. In 2016 gross lending in the regulated first-charge residential mortgage market was around £300bn and for many consumers a mortgage represents a very significant financial commitment.[1]

The UK mortgage market have specific features that are different from other mortgage markets researched in the academic literature (eg. US or Danish markets). Before turning to research questions of the thesis, we are going to highlight the main features of the UK mortgage market that are relevant to our study.

In recent years the vast majority of mortgage products sold in the UK have a short-term introductory deal. Typically, the introductory period lasts two years during which the interest rate is fixed. In 2016, for example, 62% of originated mortgages were two-year fixed mortgages and variable (or discounted variable) rates represent a small proportion of the market (a large literature investigates the choice between fixed and variable rate mortgages, for example, Campbell and Cocco (2003), Coulibaly and Li (2009) and Van Hemert (2010)).

The initial interest rate is mainly driven by the loan-to-value (LTV) ratio and jumps discretely at different LTV thresholds (Best et al. (2015)). After the introductory deal the rate changes to a reversion rate, typically the lender's standard variable rate (SVR).

In addition to the interest rate, some mortgages have product fees, which could be seen as hidden costs. A recent literature suggests that, when shopping around, consumers may focus on salient features of the product and ignore hidden costs (for example, Gurun et al. (2016) specifically on the mortgage market and Gabaix and Laibson (2006) and Bordalo et al. (2013) more generally). An example of a typical two-year fixed rate mortgage with a maximum LTV of 85%, has an initial rate of 3.25% and product fees of £999. The price of a mortgage is captured by the Annual Percentage Rate of Charge (APRC) that takes into account interest rates and fees of the product.

Borrowers may also have to pay fees to intermediaries and other third parties, such as surveyors or conveyancers. Unlike in other countries, for example in Canada, borrowers in the UK do not typically negotiate the terms of the product (Allen et al. (2014b)).

At the expiry of the introductory deal consumers often transfer to a new mortgage product, either with their existing lender (remortgage internally) or a new

[1] In 2016 the median loan size for first-time buyers was around £135,000 with a median initial term of around 30 years FCA (2018b).

lender (remortgage externally). The FCA estimated that around three quarters of customers switch to a new deal within six months of moving onto a reversion rate (FCA (2018b)). A growing number of papers investigate refinancing behaviour and possible drivers of inertia (for example Agarwal et al. (2013), Bajo and Barbi (2015) and Andersen et al. (2018)).

The process of obtaining a mortgage is complex and consumers often rely on mortgage intermediaries who guide them through the mortgage application and provide advice. The number of intermediated sales has increased over the past years from 48% in 2012 to 69% in 2016.[2] In 2016 over 800,000 borrowers used a mortgage intermediary. Intermediaries need to find a suitable deal that the consumer is likely to be accepted for. This is a complex task because i) borrower characteristics and circumstances vary widely and ii) lenders' lending criteria may not be always transparent. Brokers receive a commission from lenders for whom they originate a mortgage. Borrowers may also pay a fee to the broker, but this is not common.

In the UK mortgage market borrower characteristics and circumstances vary widely and different lenders may target specific types of borrowers. Mainstream lenders typically focus on borrowers with standard circumstances and good credit history, or only minor adverse credit. Specialist lenders, instead, typically focus on borrowers with non-standard circumstances, such as complex income sources or poorer credit history ranging from County Court Judgement to defaults or arrears. Specialist lenders are also more likely to focus on the self-employed. We calculated that while there are around 20% of self-employed borrowers in the whole market, their share rises to 40% among specialist lenders. The higher price of a mortgage offered by a specialist lender typically reflects the higher risk associated with the borrower. In 2015 the aggregate market share of specialist lenders was small (around 1% of all mortgage sales).

The mortgage market is important for financial stability and consumer protection considerations. Regardless of circumstances, borrowers need to meet affordability criteria and prove income, unless they remortgage internally without change in loan amount or mortgage term (FSA (2012)). Borrowers also need to pass interest rate stress test, unless he/she takes out a mortgage with 5-year or longer introductory period deal.[3]

The household debt is also an important driver of macroeconomic fluctuations. The household debt cycle could predict severity of the slowdown Mian et al. (2017) or credit supply driven by household demand could be a lead indicator of a recession (eg. Mian and Sufi (2010)). Moreover, a recent paper by Garriga et al. (2019) introduces mortgages into the New Keynesian model to analyse effects of monetary policy.

[2] Between 2009 and 2014 the FCA introduced the Mortgage Market Review (MMR) that has increased the take up of advice and intermediation. See FCA (2018b).

[3] https://www.fca.org.uk/firms/interest-rate-stress-test

In this thesis, we try to understand the mortgage market and general credit conditions, from macro-, micro- and policy perspectives.

First, we look at the mortgage market from a macro angle. The first question that we look at is to identify the relative role of demand and supply conditions in driving the erratic evolution of UK mortgage credit. Did the lending to individuals halt because of banks' inability to issue loans or because household reduced demand? We aim at distinguishing demand from supply using a disequilibrium econometric model to then compare and contrast credit cycles for the past 20 years. To the best of our knowledge, this is the first study looking at credit conditions in the UK mortgage market using disequilibrium econometric model. We found that the periods of recession coincide with credit rationing and the periods of economic growth coincide with excess supply. Interestingly, prior the financial crisis there is some evidence of equilibrium in the market, while the first year of the crisis is found to be determined by depressed demand rather than credit rationing.

Second, we look at the mortgage market from a micro perspective. In particular, we focus on the role of mortgage intermediaries and whether their incentives are misaligned with consumers they serve in terms of finding the best deal. For example, mortgage intermediaries need to spend time and resources to identify the right product for the borrower in terms of price, suitability and likelihood of approval by the lender. Lenders pay commissions (procuration fees) to intermediaries potentially distorting incentives of the intermediaries to find the best deal. Moreover, borrowers have little information or do not have tool to compare intermediaries. So we analyse how the price of similar mortgage products for like-for-like consumers varies across intermediary firms and what the drivers of the dispersion are. We find that the difference in average price of mortgage products can be as high as £800 over the incentivised rate period for the median loan amount. We find little evidence that intermediaries selling highly priced mortgages also receive high procuration fees and that the average price of the mortgages an intermediary sells is negatively correlated with the number of lenders used. On average, intermediaries placing business with a greater number of lenders sell cheaper products compared to intermediaries that use fewer lenders.

Third, we evaluate impacts of the Financial Policy Committee (FPC) policy that aims at reducing risks of financial instability in the economy by limiting excessive household leverage in mortgages and unsustainable credit growth. This policy is commonly known as 'LTI flow limit'. It recommends that "mortgage lenders do not extend more than 15% of their total number of new residential mortgages at Loan to Income ratios at or greater than 4.5". While the core objective of the FPC recommendation is macro-prudential, we am interested in understanding whether it has any impact on consumers in terms of the redistribution consequences and price. The paper finds that after implementation of the recommendation the average loan size for high LTI mortgages increased by 4-7%. This suggests that lenders originated high LTI loans for borrowers with higher incomes. As a result, we find robust evidence of changes in composition of high LTI borrowers: 1) an increase in the proportion of home movers; 2) a decrease in the proportion of first-time buyers; 3) an increase in the proportion of joint income applicants. After implementation, although the overall proportion of high LTI mortgages to the total number of sales in the market stays around 10%, lenders' individual exposure to high LTI mortgages changed. Some lenders, whose share of high LTI mortgages had been closer to the 15% limit, reduced their proportion of high LTI. In contrast, some lenders that previously had a low share of high LTI mortgages increased their proportion of them. After controlling for borrower, product, and lender characteristics, we find that post-implementation the mortgage price for high LTI mortgages on average decreased. The fall in the mortgage price was stronger for lenders that used to be closer to the 15% constraint.

Fourth, we take a step back and look at the monetary and fiscal policies in the context of New Keynesian models with real rigidities and an economy at the zero lower bound. This chapter, though distinct from the rest of the thesis, has two important links to the rest of the thesis. First, the environment of a zero interest rate is associated with the recent financial crisis (perhaps, except Japan), which was triggered by events in the US mortgage market. Second, similar to the disequilibrium concepts discussed in the first chapter, real rigidities do not allow markets to clear at the competitive prices, though the New Keynesian models assume general equilibrium whereas the disequilibrium models do not. In this chapter, we are particularly interested in identifying optimal fiscal and monetary policies under strategic interaction among price- and wage-setting agents under zero lower bound. We found that the optimal length of the forward commitment concerning interest rates at the zero bound and key outcomes such as the magnitude of expected inflation or the depth of the recession under optimal policy depend crucially on the assumed degree of real rigidity in the model. In addition to simple parametric assumptions, more fundamental structural assumptions about the nature of the labour market play an important role in this regard. Labour market segmentation and the presence of staggered wage adjustment were shown to have particularly significant consequences for the type of policy one might wish to implement in an economy hit by a large shock that depresses demand. In those circumstances, it is a good idea for governments to lean against the wind in two different ways. First, an increase in government spending when output is low (and vice versa) stabilises output (and prices) but this policy can be justified almost wholly with reference to static public finance considerations. Second, an increase in taxes when output is low (and vice versa) stabilises prices via their impact on marginal cost. The results interact in interesting ways with the initial conditions in the economy. With higher inherited debt, fiscal sustainability considerations matter more for monetary and tax policy and the explained differences across market structures grow larger.

Part II

Credit Conditions in the UK Mortgage Market: A Disequilibrium Approach

1 Introduction

In this chapter of the thesis we look at the UK mortgage market through a macroeconomic lens. One of the prolonged debates in macroeconomics is to identify whether demand or supply drive the evolution of credit. Did lending to individuals halt because of banks' inability to issue loans (credit rationing) or because households reduced demand? In this chapter, we aim to discern demand and supply in the UK mortgage market for the past 20 years using an econometric disequilibrium model to then compare and contrast credit conditions across business cycles.

While to the best of our knowledge this is the first study to understand credit conditions in the UK mortgage market using disequilibrium econometric technique, Fernandez-Corugedo et al. (2006) research, for example, aims to answer a very similar question but with a different methodology. Fernandez-Corugedo et al. (2006) create a credit conditions index (CCI) from the Survey of Mortgage Lenders to then understand changes in credit supply from 1975 to 2001. The index is identified from a ten-equation system with sign restrictions that takes into account various economic and demographic variables affecting demand and supply of credit. The study reports marked fluctuations of credit supply conditions over time. There was an increase in the index in 1980s, peaking by the end of the decade (ie. loosening of credit supply), then a fall in early 1990s (ie. tightening of credit supply), before increasing again (ie. loosening of credit supply).

There is also a strand of literature to understand how changes in credit conditions drive business cycles. For example, Aron et al. (2012) estimate housing collateral (or 'wealth' effect) on consumption for UK, US and Japan economies using a modified version of the Ando-Modigliani style consumption function. Authors use the Fernandez-Corugedo et al. (2006) credit conditions index, which measures exogenous shifts in credit supply, to capture effects of credit liberalisation on housing collateral. They conclude that the 'wealth' effect differs across the countries and varies over time because of the changes in the credit conditions. Loser credit supply conditions reinforce positive housing wealth effect - consumers face a lower down-payment constraint and are allowed to borrow against housing equity, as a result, they save less and consume more.[4]

1.1 Theoretical rationale behind disequilibrium

Disequilibrium models (or 'quantity rationing models') have been studied from both theoretical and empirical perspective. The literature blossomed in 70s and 80s, but with the prevalence of the idea of the general equilibrium, it had not received much attention. However, the recent financial crisis highlighted the issue that markets might not necessarily clear, ie. prices might be relatively rigid resulting in oversupply/shortage of credit. The disequilibrium theory has been mainly concerned about macroeconomic effects of disequilibrium and its micro-economic rationale including why prices might be rigid and might not allow markets to clear. The empirical literature on the other hand has been mainly looking at different estimation techniques and application of these methodologies to different markets across different countries.

The disequilibrium describes persisting excess supply or demand without any tendency for price to correct the market imbalance. The comparison between underpinnings of clearing and non-clearing market will closely follow Bénassy (2005) and the rationale behind rigid prices not allowing a credit market to clear will be discussed in accordance with Stiglitz and Weiss (1981).

To understand the difference between clearing markets (Walrasian theory) and non-clearing markets (non-Walrasian theory), it is worth scrutinising the main assumptions of both theories. The Walrasian theory assumes that all agents in the market receive price signals and maximise their objective function to get the Walrasian demand/supply, which depends on the price signals only. Exchange in the market happens freely, i.e. suppliers can sell as much as they want, buyers can receive as much as they want. There is also an auctioneer who changes the price using unspecified mechanism ('tatonnement' process) until demand is equal to supply. Resulting price is the equilibrium price in the market and demand equals to supply.

The non-Walrasian theory abandons assumption of a centralised auctioneer, who determines the equilibrium market price. While in the Walrasian theory an equilibrium price is determined by an intersection of demand and supply, in the non-clearing market, equilibrium prices are assumed to be set by one side of the market or bargained between the two sides, such that none of the agents have incentives to change their actions. Quantities exchanged in the market are either supply or demand constrained. Markets do not clear and it is characterised by rationing.

An important element to the non-Walrasian theory is relationship between demand, supply and quantity transacted. Agents form desired demand ($\widetilde{d}_i$) and desired

[4] Similarly, Muellbauer and Murphy (2008) argues that a housing collateral and down-payment constraints (ie credit supply conditions) are key in explaining how fluctuations in house prices affect consumption.

supply ($\widetilde{s}_i$) from maximising their objective functions. However, the exchange that agents wish to carry out does not necessarily match the resulting market transactions. An accounting identity ensures that the amount sold ($\mathring{d}_i$) and purchased ($\mathring{s}_i$) is equal, that is in aggregate $\mathring{D} = \sum_{i=1}^{n} \mathring{d}_i = \sum_{i=1}^{n} \mathring{s}_i = S$, but desired purchases do not necessarily equal to desired sales $\widetilde{D} = \sum_{i=1}^{n} \widetilde{d}_i \neq \sum_{i=1}^{n} \widetilde{s}_i = \widetilde{S}$.

If in addition such market is frictionless, i.e. there cannot be both rationed sellers and buyers at the same time, and exchange happens voluntarily, i.e. no agent can be forced to purchase more than he demands or sell more than he supplies, transacted purchases or sales are determined by the 'short-side rule', or in aggregate, the 'rule of the minimum'. That is, quantities transacted are equal to minimum of desired demand and desired supply:

$$\mathring{D} = \mathring{S} = min(\widetilde{D}, \widetilde{S})$$

The 'short-side rule' plays a crucial role in identifying demand and supply schedules in the disequilibrium econometric model. The 'short-side rule' of the disequilibrium econometric model could split observations into three categories: 1) excess demand, interpreted as desired demand being higher than desired supply; 2) excess supply, interpreted as desired supply being higher than desired demand; 3) equilibrium, when desired demand equal to desired supply.

Stiglitz and Weiss (1981) provide micro-foundation to existence of excess demand and excess supply in a credit market. Their model rationalises existence of credit rationing– a situation, when some borrowers receive credit and others do not, including these borrowers, who are willing to pay more than the prevailing interest rate. In other words they provide micro-foundation to why interest rate does not rise or fall to clear excess demand.

Their explanation focuses on banks' objective to maximise expected return, which is determined by the interest rate and the riskiness of the loan, and on the interest rate ability to separate 'risky' and 'safe' applications. The necessary condition for existence of excess demand is non-monotonicity of the bank expected return. Non-monotonicity implies that the bank expected return does not always increase with an increase in interest rate and there should exist an interest rate that maximises the bank expected return.

Stiglitz and Weiss (1981) explain impact of adverse selection on expected bank return. High interest rate discourages safe applicants and only risky applicants remain. For example, if an applicant is willing to borrow at a very high interest rate, it implies that he could not find a lender willing to supply a loan at lower price or such applicant has low chances to repay the loan and therefore is not concerned about paying a high interest rate. High interest rate might also encourage risky behaviour ('moral hazard'). Therefore, with an increase in interest rate the riskiness of banks investment rises and expected return falls. There could be an interest rate maximising bank return, which is lower than the Walrasian interest rate, at which demand equals to supply. At this rate there will be excess demand, but it will be still an equilibrium because banks have no incentives to change it.

Stiglitz and Weiss (1981) also briefly discuss the micro-economic mechanism of keeping interest rate from falling in a situation of excess supply. Assume banks can identify credit worthy customers among its clients, from which they receive higher expected return, and competing banks cannot. A competing bank might be willing to reduce interest rate to attract profitable customers. However, the low interest rate that it offers will be countered by an equally low interest rate from the customer's bank. The 'risky' customers on the other hand will now be offered a matching low interest rate. Therefore, by lowering interest rate competing banks will attract a pool of least profitable customers and their expected return will fall. Therefore, banks with an excess supply of loanable funds will consider that a decrease in interest rate lowers their expected return and will not adjust it to encourage more demand.

In the case of the mortgage market, for the same reasons when banks have excess supply they might not be willing to lower interest rate. Low interest rate makes mortgages more affordable and might attract borrowers with lower chances of repayment. In case of excess demand, banks might be less willing to increase interest rate because they are likely to attract risky and overconfident borrowers, who might not realise that high interest rate puts a bigger burden on loan repayment.[5]

1.2 Econometric disequilibrium models and applications

In this section, we will describe various econometric disequilibrium models and their applications. Broadly speaking econometric disequilibrium models can be distinguished by two features: 1) static vs dynamic and 2) models with unknown vs known sample separation.

Applied literature on econometric disequilibrium models is scant. Applications vary in term of countries, markets, estimation methodologies and whether a researcher uses micro-level or macro-level data. Due to work of Stiglitz and Weiss (1981) that provided a theoretical rationale on why interest rate does not have to clear demand and supply of credit the disequilibrium models became relevant to apply for credit markets. Most of the applications use a canonical specification, which is a static model with unknown separation, to find evidences of credit rationing or to determine whether supply or demand factors drive evolution of credit.

[5]In addition to the interest rate, banks set loan-to-value ratio. The value of collateral is determined by a value of a house to purchase. While lower loan-to-value indicates safer investment, it reduces profit per loan issued. Therefore, banks might not be willing to lower loan-to-value ratio to reduce the excess demand for loans. Similarly, in case of shortage of demand/excess supply either banks already offer 100% loan-to-value mortgages, or they might not be willing to increase loan-to-value ratio as it attracts risky borrowers, or because there is a regulatory barrier to increase loan-to-value higher.

1.2.1 Static models with known and unknown sample separation

The canonical static econometric disequilibrium model with unknown sample separation is Maddala et al. (1974) (MN) representation:

$$
\begin{aligned}
D_t &= \beta_1 P_t + X_{1t}\beta_2 + u_{1t} \\
S_t &= \alpha_1 P_t + X_{2t}\alpha_2 + u_{2t} \qquad (MN) \\
Q_t &= min(D_t, S_t)
\end{aligned}
$$

It consists of stochastic demand and supply schedules and a deterministic 'min' condition. The 'min' condition implies that the observed quantity is equal to supply ($Q_t = S_t$), when there is excess demand ($D_t > S_t$), and the observed quantity is equal to demand ($Q_t = D_t$), when there is excess supply ($D_t < S_t$). X_{1t} and X_{2t} are weakly exogenous determinants of demand and supply schedule respectively. Both vectors include P_t and can have common variables but have to differ at least in one variable (the exclusion restriction). X_{1t}, X_{2t}, P_t and Q_t are observed variables and S_t and D_t are unobserved latent variables. The contemporaneous prices P_t are assumed to be exogenous. The error terms u_{1t} and u_{2t} are generally assumed to be normal and independent over time with mean zero and variances σ_1^2 and σ_2^2.[6]

In applied literature MN canonical representation competes with an alternative specification proposed by Ginsburgh et al. (1980) (GTZ), which assumes that demand and supply schedules are deterministic and 'min' condition is stochastic:

$$
\begin{aligned}
D_t &= X_{1t}\beta_1 \\
S_t &= X_{2t}\alpha_1 \qquad\qquad (GTZ) \\
Q_t &= min(D_t, S_t) + u_t
\end{aligned}
$$

Pros and cons of the two specifications are discussed in details in Stenius (1986). In summary, both representations compete in terms of intuition, statistical properties and computational intensity. The stochastic demand and supply schedules have a simple and intuitive economic interpretation that there are supply and demand shocks. The stochastic 'min' condition in combination with deterministic supply and demand could also be interpreted as uncertainty whether 'demand or supply can be traded in the market' (Stenius (1986)). GTZ specification is not identified in case all observations belong to either demand or supply, whereas MN canonical specification is. However, both specifications are prone to the unboundedness of a likelihood function, though GTZ maximum likelihood is argued to be easier to handle. Assumption of normality of the error terms is not testable in MN specification, but it is in GTZ. In applications GTZ specification is claimed to simplify

[6] It is argued that estimates are consistent even if there is serial correlation (Gourieroux et al. (1987).)

estimation of dynamic disequilibrium models, where a lagged transacted quantity Q_{t-1} is included as a determinant of demand and supply (Vouldis (2015)).

The econometric disequilibrium models with unknown sample separation offer some degree of generalisation, but at a cost of a considerable loss of information and potential statistical issues (Goldfeld and Quandt (1975) and Kiefer (1979) as cited in Maddala (1986)).[7] However, if a researcher wants to establish periods of excess supply and excess demand endogenously, only the models with unknown sample separation could be used, unless prices imperfectly signal about sample separation.

The static disequilibrium models with known sample separation asserts that prices identify observations into demand and supply. Fair and Jaffee (1972) representation (FJ) adds a price-adjustment equation the canonical MN specification:

$$\begin{aligned} D_t &= X_{1t}\beta_1 + u_{1t} \\ S_t &= X_{2t}\alpha_1 + u_{2t} \\ \triangle P_t &= \gamma(D_t - S_t), \gamma > 0 \qquad (FJ) \\ Q_t &= min(D_t, S_t) \end{aligned}$$

where γ is a parameter that captures price sensitivity to excess demand or supply. When there is excess demand (excess supply), price has a tendency to adjust upward (downward). This price-adjustment formulation implies that disequilibrium exists because prices do not adjust fully to the equilibrium levels. The price adjustment equation is deterministic and therefore restrictive. The demand and the supply schedules are identified because the model contains an explicit equation for P_t.

Laffont et al. (1977) took another view on the price-adjustment equation. In contrast to Fair and Jaffee (1972), they assumed that prices rise and fall in response to disequilibrium and prices adjust differently to excess demand and excess supply. The Laffont et al. (1977) (LG) model is represented like:

$$\begin{aligned} D_t &= X_{1t}\beta_1 + u_{1t} \\ S_t &= X_{2t}\alpha_1 + u_{2t} \\ \Delta P_{t+1} &= \gamma_1(D_t - S_t) \quad if \quad D_t > S_t \quad and \quad \gamma_1 > 0 \qquad (LG) \\ \Delta P_{t+1} &= \gamma_2(D_t - S_t) \quad if \quad D_t < S_t \quad and \quad \gamma_2 > 0 \\ Q_t &= min(D_t, S_t) \end{aligned}$$

In this formulation P_{t+1} is endogenous and P_t is exogenous. Further extensions

[7]The statistical issues is related to a potential unboundedness of likelihood function. This problem, though does not occur very frequently in applications (Maddala (1986)), arises when variance of one of the error terms u_{1t} or u_{2t} is close to zero. For example, the error u_{1t} will have a zero variance when the model identifies only one observation as belonging to demand and the rest to supply and vice verse for the error u_{2t}.

of the models with known separation include a stochastic specification of the price-adjustment equation including a vector of additional determinants (Fair and Kelejian (1974))). The Fair and Kelejian (1974) (FK) specification is:

$$
\begin{aligned}
D_t &= X_{1t}\beta_1 + u_{1t} \\
S_t &= X_{2t}\alpha_1 + u_{2t} \\
\Delta P_t &= \gamma_1(D_t - S_t) + X_{3t}\gamma_2 + u_{3t} \qquad (FK) \\
Q_t &= min(D_t, S_t)
\end{aligned}
$$

The directional disequilibrium model, a variation of the models with known sample separation, assume that $\triangle P_t \gtrless 0$ classifies observations into supply ($>$) or demand ($<$). However, demand and supply schedules are not identified if a contemporaneous price P_t is included among determinants. There are just not enough equations to determine the joint density of P_t and Q_t (Maddala (1986)).

1.2.2 Dynamic econometric disequilibrium models

Dynamic models have an advantage of capturing a dynamic structure of data and are particularly helpful when errors are serially correlated. Estimation of dynamic disequilibrium models received some attention from researchers. The main challenge is to include unobserved latent variables D_{t-1}, D_{t-2}, ... and S_{t-1}, S_{t-2}, ... as determinants. Laffont and Monfort (1979) propose to use the price adjustment equation as in Laffont et al. (1977) to obtain a tractable likelihood function. The Laffont and Monfort (1979) (LM) specification looks like:

$$
\begin{aligned}
D_t &= X_{1t}\beta_1 + \beta_2 D_{t-1} + \beta_3 S_{t-1} + u_{1t} \\
S_t &= X_{2t}\alpha_1 + \alpha_2 D_{t-1} + \alpha_3 S_{t-1} + u_{2t} \qquad (LM) \\
Q_t &= min(D_t, S_t) \\
\triangle P_t &= \gamma(D_t - S_t), \gamma > 0 \qquad or \\
\triangle P_{t+1} &= \gamma(D_t - S_t), \gamma > 0
\end{aligned}
$$

The price-adjustment equation identifies demand and supply observations over the whole sample period, allowing to include lagged values of the latent variables in the model. Laffont and Monfort (1979) argue that the likelihood function is well-behaved and two-stage least squares provides consistent estimates, which can serve as initial values for the maximisation iteration procedure.

Lee (1997) took a step forward and proposed a tractable recursive algorithm for simulated likelihood to estimate the dynamic version of the MD specification (Lee (1997) model denoted as L):

$$D_t = X_{1t}\beta_1 + \beta_2 D_{t-1} + u_{1t}$$

$$S_t = X_{2t}\alpha_1 + \alpha_2 S_{t-1} + u_{2t} \qquad (L)$$

$$Q_t = min(D_t, S_t)$$

Without sample separation information or some specific structural specification, the likelihood function usually involves multiple integrals of very high dimension. That is, in case of T observations, there will be 2^T possible paths of regimes (at each period an observation belongs either to demand or supply) and each path will be T-fold integrals. There should be a tractable simulation method to obtain maximum likelihood function. Lee (1997) argues that in the dynamic models with one lag latent-dependent variable, where demand depends on its one own lagged demand and supply depends on its one own lagged supply, simulation of only certain paths is required. For example, at $t = 3$, simulated demand d_3 following a path d_1, s_2 and a path s_1, s_2 will be the same because d_3 only depends on d_2, which in the two paths has not realized at the second period. Similarly for simulated supply s_3 will be the same for a path d_1, d_2 and a path s_1, d_2, because supply observation has not realized at the second period. Therefore, according to Lee (1997) the problem is reduced from 2^T simulations to $T(T+1)$ and becomes more tractable. The simulated likelihood function is smooth in parameters and estimates are accurate in moderate sample sizes. Lee (1997) suggested that asymptotic properties of the estimators are still to be established.

Bauwens and Lubrano (2007) adopted a different view on the dynamic structure of the disequilibrium models. Instead of having own lagged latent-dependent variable in the demand and supply specifications, they included an observed quantity of previous transactions Q_{t-1}:

$$D_t = X_{1t}\beta_1 + \beta_2 Q_{t-1}$$

$$S_t = X_{2t}\alpha_1 + \alpha_2 Q_{t-1} \qquad (BL)$$

$$Q_t = min(D_t, S_t) + u_t$$

1.2.3 Empirical applications

Laffont et al. (1977) paper is among the first one to analyse supply of and demand for business loans. They looked at the Canadian market for a period from 1968 to 1973 and constructed a model of demand and supply of business loans to determine possibility of credit rationing. The results of the study concluded that business loans for the period under consideration is mainly demand driven.

Sealey (1979) argues that the disequilibrium models are not only useful in establishing existence and measuring a magnitude of excess demand or supply, but also in analysing implications of credit rationing for monetary policy. They fit the model for quarterly data on US commercial loans from 1952 to 1977 and, in contrast with Laffont et al. (1977), the results suggest that the market is mainly supply driven. The resulting discrepancy between estimated demand and estimated supply is large. Therefore, the authors argued that effects of credit rationing on effectiveness and speed of monetary policy are not symmetric during expansionary and contractionary regimes. Under periods of tight monetary policy there are strong evidences of excess demand, that is, a further tightening of credit conditions will have a great impact on business investments. On the other hand, during periods of loose monetary policy, the market experience large surpluses of credit with no strong implications for demand.

Laffont et al. (1977) and Sealey (1979) researches set a benchmark for analysis of credit conditions using the econometric disequilibrium models. Similar studies also focus on finding evidences of credit rationing (eg. Bauwens and Lubrano (2007) for Polish market of corporate loans, Oulidi and Allain (2009) for Moroccan credit market, Chen and Wang (2008) for Taiwan's bank loans market after the Asian financial crisis, Čeh et al. (2011) for Croatia market for loans to households and enterprises).

More recent studies of credit conditions focus on finding evidences of credit rationing during the recent financial crisis. For example, Schmidt and Zwick (2012) analysed German market for private sector loans. They identified five categories of lenders that differ by their exposure to international shocks. Such separation allowed the authors to look at effects of financial crisis on each of the categories and attribute any differences to variation in exposure of these lenders to external shocks. Schmidt and Zwick (2012), however, found no evidence of credit rationing or credit crunch and attributed such results to adjustments from a demand side and to a strong recovery of supply in banks that were affected the most.

Laffont et al. (1977) argues that separate analysis of loans to individuals and firms is crucial for analysis of macroeconomic effects, as behaviour of both agents is different. Vouldis (2015) attempts to fix the gap of the existing literature that has looked at either loans for enterprises or aggregated loans to both household and enterprises. Vouldis (2015) analysed separately short- and long-term business loans, consumer credit and mortgages in Greece from 2003 to 2011. The author argues that during good times, loans across all categories were supply driven. During the crisis mortgages, consumer loans and long term business loans remained driven by supply in spite of supply constraints. The short term loans, on the other hand, are estimated to be driven by demand, i.e. demand was lower than supply. In addition to that, Vouldis (2015) argues that mortgages and consumer loans have a very high elasticity to lending capacity and GDP, which are the main determinants of supply and demand respectively, suggesting that mortgages and consumer credit is very responsive to macroeconomic conditions.

Applications of the disequilibrium models on firm level or household level data have gained momentum in the recent years. Atanasova and Wilson (2004) are among the first applications of the canonical static disequilibrium models on micro-level data. The objectives of the study are to find determinants of supply and demand for bank loans to small and medium enterprises in the UK from 1989 to 1999.

Determinants include not only firms' characteristics but also indicators of a business cycle in order to establish evidences of credit channel of a monetary policy transmission mechanism. The disequilibrium model also allows to endogenously classify firms into credit rationed, which is a notable advantage over existing literature that splits firms into the categories exogenously. The results suggest that among various determinants, firms' existing assets affect loans availability via collateral channel. It also shows that firms tent to substitute bank loans with internal financing or inter-firm credit. The authors also found evidence of the credit channel of monetary policy. That is, there are evidence that availability of loans for the SMEs decreases when monetary policy is tight.

A more recent application of the disequilibrium model to firm-level data is conducted by Kremp and Sevestre (2013). The analysis is focused on identifying potential credit rationing in the SMEs loans market in France from 2000 to 2010. The results do not provide evidence of the claims that firms faced borrowing constraints in the years of the financial crisis, the result which is in line with the conclusions of the various surveys on access to finance. While Kremp and Sevestre (2013) application is very similar to Atanasova and Wilson (2004), the main contribution of the paper is a proposition of alternative likelihood function for data prone to a selection bias. The selection bias arises because firms with no bank loans are either fully rationed or just haven't applied for the loan. Moreover, for the firms that are fully rationed interest rate is not observed. Therefore, a data sample is restricted to only these firms that are either not rationed or only partially rationed.

Burlon et al. (2016) use confidential data from Italian credit bureau together with data sources on bank-level and firm-level balance sheets to construct a unique dataset on bank-firm-contract level. It allows to have supply and demand schedule to be determined by both banks' and firms' characteristics as well as characteristics of a bilateral loan contract.

This chapter has the following structure. In the section 2, we describe methodology and give details about the data used in this study. In section 3, we present results including robustness checks and discuss the evolution of credit conditions over the past 20 years. The section 4, we conclude.

2 Research design

2.1 Methodology

The main aim of the research is to endogenously identify periods of excess demand and excess supply in the mortgage market. Therefore, a model with unknown sample separation is preferred. Due to complications involved with the dynamic disequilibrium models with unknown sample separation, including non-tractability of simulated likelihood function discussed above and non-trivial implementation of algorithm (Lee (1997)), the static specification is preferred. The static model highlights the long-run relationship of supply and demand determinants. Due to non-stationary properties of the data, demand and supply schedules should be checked for co-integrating relationships with its determinants. If there is a co-integrating relationship, the estimates of the static equation is super-consistent. That is, evidence of long run relationships will dismiss concerns of spurious results (Engle and Granger (1987)). However, due to switching nature of the disequilibrium model, there is no straightforward test for co-integration. In the later section indicative tests for co-integration will be discussed. It will be further assumed that there are separate demand and supply shocks, therefore, the Maddala-Nelson (MN) specification is preferred over Ginsburgh-Tishler-Zang (GTZ). The MN model will be estimated using classical maximum-likelihood approach.

The likelihood function for observations Q_t in the canonical Maddala-Nelson specification

$$\begin{aligned} D_t &= X_{1t}\beta_1 + u_{1t} \\ S_t &= X_{2t}\beta_2 + u_{2t} \qquad (MN) \\ Q_t &= min(D_t, S_t) \end{aligned}$$

is

$$L = \prod_t h(Q_t)$$

where $h(Q_t)$ is the unconditional density of observation Q_t.

Define a joint probability of D_t and S_t as $g(D_t, S_t)$, which is derived from a joint density of errors u_{1t} and u_{2t}. If observation t is on demand function, according to the model $D_t < S_t$ and $D_t = Q_t$. Hence,

$$h(Q_t|Q_t = D_t) = \frac{h(Q_t\, and\, Q_t = D_t)}{Pr(D_t < S_t)} = \frac{\int_{Q_t}^{\infty} g(Q_t, S_t) dS_t}{Pr(D_t < S_t)}$$

Similarly, if observation t is on supply function, according to the model $D_t > S_t$

and $S_t = Q_t$. Hence,

$$h(Q_t|Q_t = S_t) = \frac{h(Q_t \, and \, Q_t = S_t)}{Pr(D_t > S_t)} = \frac{\int_{Q_t}^{\infty} g(D_t, Q_t) dD_t}{Pr(D_t > S_t)}$$

The unconditional density of observation Q_t can be written as:

$$\begin{aligned} h(Q_t) &= h(Q_t|Q_t = D_t)Pr(Q_t = D_t) + h(Q_t|Q_t = S_t)Pr(Q_t = S_t) \\ &= h(Q_t|Q_t = D_t)Pr(D_t < S) + h(Q_t|Q_t = S_t)Pr(D_t > S_t) \\ &= \int_{Q_t}^{\infty} g(Q_t, S_t) dS_t + \int_{Q_t}^{\infty} g(D_t, Q_t) dD_t \end{aligned}$$

Note that independence and normal distribution of errors u_{1t} and u_{2t} implies that,

$$g(D_t, S_t) = \frac{1}{2\pi\sigma_1\sigma_2} exp\left\{-\frac{1}{2}\left(\frac{D_t - X'_{1t}\beta_1}{\sigma_1}\right)\right\} * exp\left\{-\frac{1}{2}\left(\frac{S_t - X'_{2t}\beta_2}{\sigma_2}\right)\right\}$$

Denote $\phi_1(.)$ as a probability density function of $N(X_{1t}\beta_1, \sigma_1)$, $\Phi_2(.)$ as a cumulative density function of $N(X_{2t}\beta_2, \sigma_2)$, hence,

$$\begin{aligned} \int_{Q_t}^{\infty} g(Q_t, S_t) dS_t &= \tfrac{1}{2\pi\sigma_1\sigma_2} \int_{Q_t}^{\infty} exp\left\{-\tfrac{1}{2}\left(\tfrac{Q_t - X_{1t}\beta_1}{\sigma_1}\right)\right\} * exp\left\{-\tfrac{1}{2}\left(\tfrac{S_t - X_{2t}\beta_2}{\sigma_2}\right)\right\} dS_t \\ &= \tfrac{1}{\sqrt{2\pi}\sigma_1} exp\left\{-\tfrac{1}{2}\left(\tfrac{Q_t - X_{1t}\beta_1}{\sigma_1}\right)\right\} * \tfrac{1}{\sqrt{2\pi}\sigma_2} \int_{Q_t}^{\infty} exp\left\{-\tfrac{1}{2}\left(\tfrac{S_t - X_{2t}\beta_2}{\sigma_2}\right)\right\} dS_t \\ &= \phi_1(Q_t) * (1 - \Phi_2(Q_t)) \end{aligned}$$

Denote $\phi_2(.)$ as a probability density function of $N(X'_{2t}\beta_2, \sigma_2)$, $\Phi_1(.)$ as a cumulative density function of $N(X'_{1t}\beta_1, \sigma_1)$, hence,

$$\begin{aligned} \int_{Q_t}^{\infty} g(D_t, Q_t) dD_t &= \tfrac{1}{2\pi\sigma_1\sigma_2} \int_{Q_t}^{\infty} exp\left\{-\tfrac{1}{2}\left(\tfrac{D_t - X'_{1t}\beta_1}{\sigma_1}\right)\right\} * exp\left\{-\tfrac{1}{2}\left(\tfrac{Q_t - X'_{2t}\beta_2}{\sigma_2}\right)\right\} dD_t \\ &= \tfrac{1}{\sqrt{2\pi}\sigma_2} exp\left\{-\tfrac{1}{2}\left(\tfrac{Q_t - X'_{2t}\beta_2}{\sigma_2}\right)\right\} * \tfrac{1}{\sqrt{2\pi}\sigma_1} \int_{Q_t}^{\infty} exp\left\{-\tfrac{1}{2}\left(\tfrac{D_t - X'_{1t}\beta_1}{\sigma_1}\right)\right\} dD_t \\ &= \phi_2(Q_t) * (1 - \Phi_1(Q_t)) \end{aligned}$$

Therefore,

$$h(Q_t) = \phi_1(Q_t) * (1 - \Phi_2(Q_t)) + \phi_2(Q_t) * (1 - \Phi_1(Q_t))$$

$$L = \prod_t h(Q_t)$$

The log-likelihood function of the model is:

$$L = \sum_t log(h(Q_t))$$

For each period probabilities of excess supply or excess demand conditional on data can be calculated:[8]

$$\Pi_t = Pr(S_t > D_t|Q_t) = \frac{\int_{Q_t}^{\infty} g(Q_t, S_t) dS_t}{h(Q_t)} = \frac{\phi_1(Q_t) * (1 - \Phi_2(Q_t))}{\phi_1(Q_t) * (1 - \Phi_2(Q_t)) + \phi_2(Q_t) * (1 - \Phi_1(Q_t))}$$

Existing software packages do not have the disequilibrium model built in. Therefore, we built the maximisation procedure on MATLAB using Quasi-Newton algorithm.[9]

The asymptotic properties of the MLE estimators are the following:

$$\hat{\beta_{mle}} \overset{A}{\sim} N(\beta,\ \hat{I}\ (\hat{\beta_{mle}}|Q_t)^{-1})$$

That is, the maximum-likelihood estimator $\hat{\beta_{mle}}$ is asymptotically consistent estimator and normally distributed, where $\hat{I}(\hat{\beta_{mle}}|Q_t)^{-1}$ is the sample Fisher information matrix.

To test the following hypothesis: $H_0 : \hat{\beta_{i,mle}} = \beta_{i,0}\ vs\ \hat{\beta_{i,mle}} \neq \beta_{i,0}$ the t-test is employed:

$$t = \frac{\hat{\beta_{i,mle}} - \beta_{i,0}}{se_{\beta_{i,mle}}} \sim N(0,1)$$

where $se_{\beta_{i,mle}}$ is the square room of the $i - th$ diagonal element of the variance-covariance matrix $\hat{I}\ (\hat{\beta_{mle}}|Q_t)^{-1}$

The choice of initial values for the optimisation algorithm is determined using the two-step OLS procedure proposed by Hurlin and Kierzenkowski (2007), which is found to yield estimates close to the true parameters in a simulation exercise.[10] The procedure consists of the following steps. The first step requires regressing observed quantity on demand determinants $Q_t = X_{1t}\gamma_1 + \mu_{1t}$ and supply determinants $Q_t = X_{2t}\gamma_2 + \mu_{2t}$ using OLS. This gives first approximation of demand $\hat{D}_t = X_{1t}\hat{\gamma}_1$ and supply $\hat{S}_t = X_{2t}\hat{\gamma}_2$. The second step requires splitting the sample into implied demand and supply observations. If an indicator function $1(\hat{D}_t > \hat{S}_t)$ equals to 1 it puts all variables into the supply category, denote them as Q_t^s, X_{2t}^s and X_{1t}^s, and if it equals to 0, the variables are allocated into the demand category denote them Q_t^d, X_{1t}^d and X_{2t}^d. The last step requires applying OLS to the two blocks of data: $Q_t^d = X_{1t}^d\beta_1 + \mu_{1t}^d$ and $Q_t^s = X_{2t}^s\beta_2 + \mu_{2t}^d$. Resulting coefficient $\hat{\beta}_1$ and $\hat{\beta}_2$ are used as initial values for the iteration procedure.

[8]Kiefer (1980) argues that unconditional probabilities do not capture all sample information and therefore conditional probabilities are preferred (as cited in Maddala (1986)).

[9]Maximisation of a likelihood function could be a challenging task. Therefore, Bayesian inferences that do not rely on finding maximum of the function became popular in the empirical literature. Bauwens and Lubrano (2007) estimated the Ginsburgh et al. (1980) specification using Bayesian approach. Vouldis (2015) applied Bayesian inferences to the Maddala et al. (1974) canonical specification.

[10]The choice of the initial values is important for the maximisation procedure. Depending on initial values, the optimisation algorithm could find sub-optimal values of parameters (Myung (2003)).

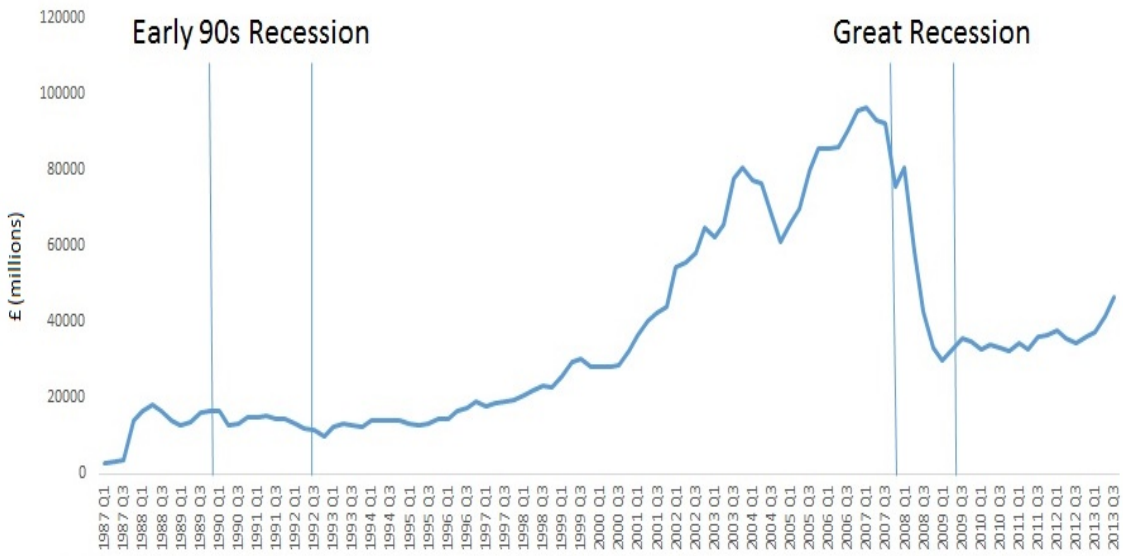
2.2 Data

This section describes variables used in the model. To select variables used in the model, we closely follow literature on applications of disequilibrium models discussed in the previous sections.

Figure 1 depicts the value of total sterling approvals of secured lending to individuals from early 90s to up to 2013. The total value of secured lending includes mortgages (comprising 80 % of the total value), remortgages and additional lending from an existing mortgage contract for general purposes, including house improvement, car purchases, debt consolidation etc.[11]

The data period is between 1987Q2 to 2013Q4 and it covers the recession in early 90-s and the recent financial crisis. The earlier data is not available. We also prefer to stop before 2014 as that was the year when the major regulatory changes in the mortgage market were implemented (eg. Mortgage Market Review and the FPC recommendation on interest rate stress testing and the LTI flow limit (FSA (2012), FCA (2014a))). The two recessions have its similarities and differences; both are characterised by a sharp fall in secured lending, high unemployment and a sharp fall in house prices. However, in the early 90s the interest rate was high, which did not allow households to relieve a burden of interest repayment, inflation was high and there was no crisis in banking. The great recession on the other hand, is characterised by low interest rate, low inflation, and the government bailout of the systemic banks.

Figure 1: **Total value of approvals for secured lending.**



Supply determinants are discussed in line with the portfolio management theory. These factors could be broadly grouped into a price structure of loans, lending

[11]The data and definitions are obtained form the Bank of England http://www.bankofengland.co.uk/statistics/Pages/iadb/notesiadb/ltoi.aspx

capacity, rates of alternative assets, the cost of available lending resources, and expectation indicators.

Across the literature lending capacity is approximated by available lending resources. Laffont et al. (1977) used term deposits and demand deposits, Chen and Wang (2008) and Sealey (1979)-total deposit, Oulidi and Allain (2009), Vouldis (2015)-total deposits adjusted for required reserves, Schmidt and Zwick (2012) - sum of bank equity and saving, demand and time deposits. We use the total bank deposits to approximate lending capacity in the economy.

Rates of alternative investments include interest rates on various instruments that bank can use to diversify its resources. Laffont et al. (1977) used interest rate on government bonds as a proxy to an alternative long term investment. Sealey (1979) used interest rate on treasury bills. Vouldis (2015) argues that a long-term investment could be determined by an interest rate on a short-term investment to capture banks propensity to substitute across different maturities. In line with the literature, we use the interest rate on long term government bonds as a rate for an alternative asset.

Cost of available resources is generally captured by interest rate paid on deposits. Sealey (1979) approximated a cost per dollar of deposit as a maximum interest rate on time deposit multiplied by a ratio of time deposits over demand deposits. Laffont and Monfort (1979) initially considered to use time deposit rate as a determinant on its own, but due to potential correlation with the price structure of loans, instead used the difference between the loans interest rate and the time deposit rate. This interest rate spread captures the profitability of loan investment and enters the supply equation with negative sign. That is, if loans yield a return lower than the price of resources, issuance of loans should be decreased. Other authors including Schmidt and Zwick (2012) and Oulidi and Allain (2009) also approximated profitability with interest rate spread. Similarly to the existing research, the difference between the time deposit rate and the mortgage rate is used here.

Expectations about future conditions have been successfully approximated by indices of industrial production (Laffont et al. (1977), Sealey (1979)) and stock market indices (Vouldis (2015) and Chen and Wang (2008)). The index of industrial production is used here.

A price structure of secured lending is approximated by the mortgage rate. The descriptions of the data, including the unit root test, and its sources are in the Appendix A Table 18 and Table 19.

Most of the literature focused on applications of the disequilibrium models for business loans. However, Vouldis (2015) and Kent (1980) provide some guidance on the choice of determinants for a demand for mortgages. The main consideration to keep in mind is that explanatory variables must not include these variables that reflect eventual credit rationing (Laffont et al. (1977)). Vouldis (2015) assumes a very general formulation of the demand schedule for mortgages, which includes only lending rate and nominal GDP. Kent (1980) provides some theoretical argumentation to the determinants of mortgage demand. That is, the author assumes that for every desired level of housing services there is desired demand for mortgages. He further assumes that the net change of mortgage holdings Δmh is determined by the difference between desired level of mortgage holdings mh^* and mortgage holdings as of the previous period mh_{-1}, that is $\Delta mh = \beta(mh^* - mh_{-1})$. In turn the desired level of mortgage holdings depends on desired level of housing services, which is pinned down by the theory of consumption choice. Thus, the desired level of housing services depends on permanent income, implicit price of the housing services and price of rental housing as the closest substitute for owner-occupied housing. Due to data limitations, the determinants of the demand curve are chosen to be the mortgage rate and the index of consumer confidence for major purchases, which is used to approximate the desired level of housing services directly and does not affect banks decision to credit ration. The description of the data, including the unit root test, and its sources are in the Appendix A Table 18 and Table 19.

3 Results

3.1 The model's point estimates

The following disequilibrium model is fitted to the data.

$$\log(\text{demand of new loans})_t = \alpha_0 + \alpha_1 \text{mortgage rate}_t + \alpha_2 \text{consumer's confidence}_t + u_{2t}$$

$$\log(\text{supply of new loans})_t = \beta_0 + \beta_1 \text{mortgage rate}_t + \beta_2 \text{long term government bond rate}_t +$$
$$\beta_3 \text{index of industrial production}_{t-1} + \beta_4 \log(\text{total deposits})_t + \beta_5 (\text{time deposit rate}_t\text{-mortgage rate}_t) + u_{1t}$$

$$\log(\text{value of loans approved})_t = min(\log(\text{supply})_t, \log(\text{demand})_t)$$

Results are presented in the Table 1.[12] The coefficients of the model have intuitive and statistically significant signs. As expected, the desired demand for mortgages decreases with the mortgage interest rate. The coefficient is negative and statistically significant. The desired supply of mortgage increases with the mortgage interest rate. The coefficient is positive and statistically significant.

[12] An alternative specification, which takes into account two trending variables, house prices and income, is reported in the Appendix A Table 20. The point estimates are not economically intuitive, but the probabilities of excess supply are robust across the main and the alternative specifications (see Figure 19).

The point estimates of semi-elasticities and elasticities are in line with the existing literature. The demand semi-elasticity is -0.0685 and the supply semi-elasticity is 0.1569, meaning that a 1% decrease in the mortgage interest rate results in a fall of the supply of loans by 15% and an increase in the loans demanded by 6.8%, everything else constant. That is, supply is more elastic than demand, which is in line with Chen and Wang (2008). The loan supply could be more elastic because banks have different alternative instruments to invest into. The slopes of the demand and the supply schedule are important for a static comparison.

The elasticity of the lending capacity is 0.9830, close to 0.998 as in Chen and Wang (2008) and 0.88 as Oulidi and Allain (2009). The lending capacity coefficient implies that a 1% increase in total bank deposits results in about 1% increase in the supply of secured loans to individuals ceteris paribus.

The measure of profitability captured by the spread between the mortgage rate and the rate on deposits are similar to the estimates from the static specification of Schmidt and Zwick (2012). The point estimate for the profitability measure is -0.0771, which implies that a 1% increase of time deposits rate over the mortgage interest rate leads to a reduction in loans by 7.7%.

Table 1: **The coefficients estimates of the MN canonical specification.**

Supply Equation		
Variables	Coefficients	Standard Errors
constant	-6.8114***	(1.3910)
mortgage rate, adjusted for inflation	0.1569***	(0.0202)
long term government bond rate, adjusted for inflation	-0.1230***	(0.0213)
index of industrial production, lagged	0.0446***	(0.0038)
log(total bank deposits, adjusted for inflation)	0.9830***	(0.1940)
Δ(time deposits-mortgage rate), adjusted for inflation	-0.0771**	(0.0331)
Demand Equation		
Variables	Coefficients	Standard Errors
constant	4.8875***	(0.1062)
mortgage rate, adjusted for inflation	-0.0685***	(0.0141)
consumers confidence for major purchases	0.0040*	(0.0024)
Log-Likelihood=60.89		

*** statistically significant at 1%, ** statistically significant at 5%, * statistically significant at 10%

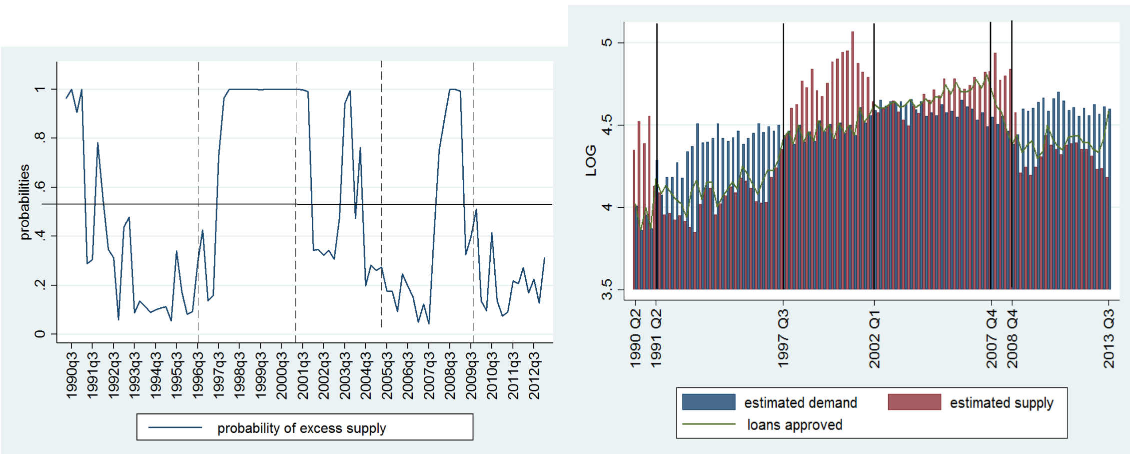
3.2 Periods of credit rationing

The disequilibrium methodology endogenously splits periods into excess supply and excess demand, i.e. it identifies potential periods of credit/quantity rationing. The probabilities of excess supply $\Pi_t = Pr(S_t > D_t|Q_t)$, which are derived in the methodology section, are presented in the Table 2. Due to stochastic nature of the demand and the supply equation, we categorise observations as excess supply only when $\Pi_t > 0.5$. The graphical visualisation of the probabilities is presented in the Figure 2 alongside with a graph depicting the estimated desired demand $\hat{D}_t$ and the estimated desired supply $\hat{S}_t$ obtained form the model and the actual quality of newly loans approved Q_t.[13]

The pattern of the probabilities identifies prolonged periods of excess demand, i.e. probable periods of credit (quantity) rationing, and periods of excess supply. From the start of available data, in particular, from 1990 Q3 to 1991 Q2, the market reveals some evidences of excess supply, which is mainly driven by high availability of credit.

From the time of the economic recession in the UK up to around 1997 Q3, there are evidences of excess demand, which was mainly driven by the depressed supply of loans. That period coincides with high write-off and provisions set up by the banks. Thus, during that period the mortgage market was supply driven and that was a period of potential credit (quantity) rationing.

Figure 2: **Probabilities of excess supply, loans approved, implied demand for and implied supply of loans.**



From 1997 Q3 to 2002 Q1, there are clear evidences of excess supply and it is caused by rapid expansion of the credit, which coincides with the Golden era in the banking industry (Haldane (2009)). The growth of actual transacted credit was restrained by the demand for loans.

From 2002 Q1 up to about 2007 Q4, the evidences are mixed. On one hand,

[13] The scaling of the variables remains in logarithms as in the model specification.

Table 2: **Probabilities of excess supply.**

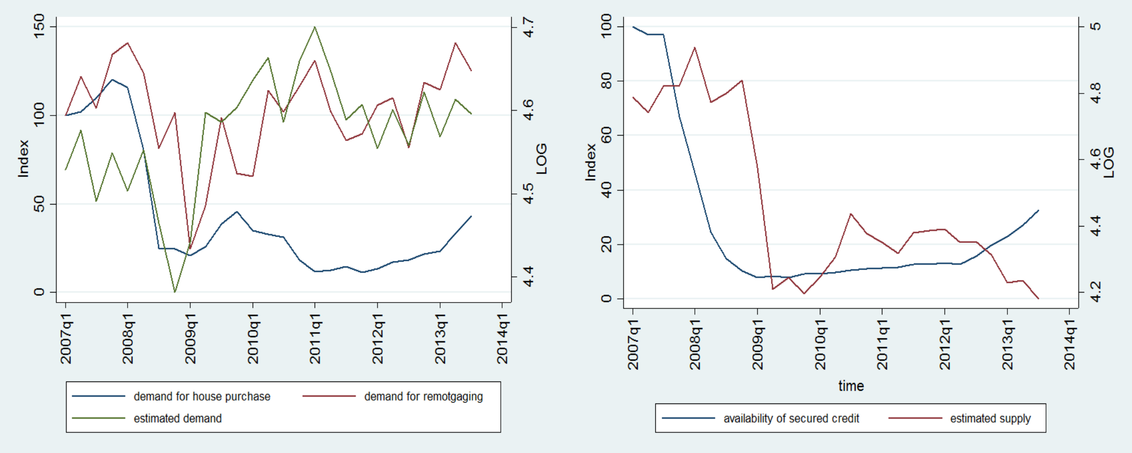
Year	Prob.	Year	Prob.	Year	Prob.	Year	Prob.	Year	Prob.
		1995:I	0.1131	**2000:I**	1.0000	**2005:I**	0.2608	**2010:I**	0.1352
1990:II	0.9642	**1995:II**	0.0537	**2000:II**	1.0000	**2005:II**	0.2738	**2010:II**	0.0950
1990:III	0.9998	**1995:III**	0.3401	**2000:III**	1.0000	**2005:III**	0.1763	**2010:III**	0.4149
1990:IV	0.9057	**1995:IV**	0.1725	**2000:IV**	1.0000	**2005:IV**	0.1752	**2010:IV**	0.1358
1991:I	0.9996	**1996:I**	0.0814	**2001:I**	1.0000	**2006:I**	0.0922	**2011:I**	0.0733
1991:II	0.2879	**1996:II**	0.0928	**2001:II**	0.9999	**2006:II**	0.2457	**2011:II**	0.0903
1991:III	0.3044	**1996:III**	0.2955	**2001:III**	0.9984	**2006:III**	0.1976	**2011:III**	0.2172
1991:IV	0.7817	**1996:IV**	0.4248	**2001:IV**	0.9900	**2006:IV**	0.1529	**2011:IV**	0.2058
1992:I	0.5500	**1997:I**	0.1349	**2002:I**	0.3422	**2007:I**	0.0487	**2012:I**	0.2723
1992:II	0.3460	**1997:II**	0.1590	**2002:II**	0.3457	**2007:II**	0.1233	**2012:II**	0.1685
1992:III	0.3122	**1997:III**	0.7231	**2002:III**	0.3223	**2007:III**	0.0420	**2012:III**	0.2248
1992:IV	0.0577	**1997:IV**	0.9642	**2002:IV**	0.3424	**2007:IV**	0.4245	**2012:IV**	0.1259
1993:I	0.4366	**1998:I**	0.9999	**2003:I**	0.3058	**2008:I**	0.7499	**2013:I**	0.3116
1993:II	0.4784	**1998:II**	0.9998	**2003:II**	0.4765	**2008:II**	0.8789	**2013:II**	0.4655
1993:III	0.0861	**1998:III**	1.0000	**2003:III**	0.9427	**2008:III**	0.9997	**2013:III**	0.9724
1993:IV	0.1349	**1998:IV**	1.0000	**2003:IV**	0.9946	**2008:IV**	1.0000		
1994:I	0.1136	**1999:I**	1.0000	**2004:I**	0.4721	**2009:I**	0.9934		
1994:II	0.0890	**1999:II**	0.9996	**2004:II**	0.7617	**2009:II**	0.3235		
1994:III	0.0986	**1999:III**	0.9971	**2004:III**	0.1979	**2009:III**	0.3978		
1994:IV	0.1069	**1999:IV**	1.0000	**2004:IV**	0.2829	**2009:IV**	0.5100		

the estimated supply of credit is somewhat higher than the estimated demand and the actual credit was following closely supply. On the other hand, the probabilities indicate that that period was characterised by excess demand. Moreover, the estimated probabilities move around 0.5 threshold line during that period, indicating that early 2000s could be characterised as a period of equilibrium.

At around 2007 Q4 the demand for loans dropped, while the supply was still high. For about a year from 2007 Q4 to 2008 Q4, the model reveals that there is an excess supply of credit. Later with the crisis deepening in the financial system, the supply dropped significantly reducing availability of credit to households, while the household demand recovered. Up until the last observation in the data, 2013 Q3, there are no evidences of improving conditions on the credit market and households might have been experiencing credit/quantity rationing.

Some of the existing studies discern demand from supply using answers from bank officers to surveys on lending conditions (for example, Del Giovane et al. (2011)). The credit conditions survey (CCS) commissioned by the Bank of England gives an indicator of the demand and the supply conditions for secured and unsecured lending to individuals and corporate firms in the UK. Therefore, we would like to compare the results of the disequilibrium model with the survey indicators. The Figure 3 presents two graphs. The first one depicts estimated demand from the disequilibrium model and evolution of demand for mortgage and remortgages from answers of the bank officers on the following two questions "How has demand for secured lending

Figure 3: **Credit condition survey vs the MN disequilibrium model.**



for house purchase from households changed in the past three months?" and "How has demand for secured lending for remortgaging from households changed in the past three months?". The second plot depicts estimated supply and evolution of supply of secured credit from answers of the bank officers on the following question "How has the availability of secured credit provided to households changed in the past three months?".[14] While the overall dynamic of the results of the disequilibrium model and the answers of the bank officers are in line, the CCS suggests that the availability of credit had dropped first and then demand followed, whereas the results of the disequilibrium model suggest that demand had fallen first and then supply followed. The CCS also suggests that the recovery in the demand is mainly driven by an increase in the demand for remortgages.

In addition, the disequilibrium model split between the demand and the supply is compared against results of the multiple breakpoints test in a specification containing both demand and supply determinants. The break points identified could be interpreted as switches between demand and supply schedules. [15] Therefore, the following specification is fitted to the data.

$$\begin{gathered}\log(\text{value of loans approved})_t = \gamma_0 + \gamma_1 \text{mortgage rate}_t + \gamma_2 \text{long term government bond rate}_t + \\ \gamma_3 \text{index of industrial production}_{t-1} + \gamma_4 \log(\text{total deposits})_t + \gamma_5 (\text{time deposit rate}_t - \text{mortgage rate}_t) + \\ \gamma_6 \text{consumer's confidence} + \epsilon_t\end{gathered}$$

The multiple breakpoints test identified the following dates: 1996Q2, 2001Q2,

[14] The baseline 2007 Q1 and indexed to 100, the indices for the following quarters are calculated as $I_{t-1} * (1 + \%_t/100)$.

[15] The model is also checked for the coefficients stability using CUSUMQ test in line with Hwang (1980) who used CUSUM test. CUSUMQ is preferred because it has a stronger power when there are changes in the slopes of the coefficients or variances of the error term (Turner (2010)). The CUSUMQ plot is presented in the Appendix A Figure 20.

2005Q3, 2009Q4. The vertical lines in the Figure 2 represent the break point dates identified by the multiple break-point test. Visually they seem to be coinciding with the split between the demand and the supply as per the results of the disequilibrium model.

3.3 Testing for stationarity

The static disequilibrium model has been applied to time series data, which often exhibit non-stationary properties. In applications the most popular approach is to check for a co-integrating relationship for both demand and supply schedules and to estimate long run relationships under the static formulation (Ghosh and Ghosh (1999)). In absence of a co-integrating relationship Hurlin and Kierzenkowski (2007) argues that non-stationary data could results in spurious results and non-intuitive sample separation.

It is difficult to conduct a formal quantitative test on existence of a co-integrating relationship, because both the desired demand and the desired supply are latent variable and the error terms in the two schedules u_{1t} and u_{2t} are not observed. However, there are some informal tests, which will be discussed in this chapter.

Ghosh and Ghosh (1999) suggested to find one co-integration relationship between the estimated implied demand and the actual quantity transacted and the estimated implied supply and the actual quantity transacted. Other studies, including Oulidi and Allain (2009) and Čeh et al. (2011), followed that test. However, a potential problem with that test is that the actual quantity transacted belong to either the demand schedule or the supply schedule. Instead, the first informal test is suggested here analyses residuals $\hat{e}_t = Q_t - \hat{Q}_t$, where $\hat{Q}_t = Pr(S_t > D_t|Q_t) * \hat{Q}_t^d + (1 - Pr(S_t > D_t|Q_t)) * \hat{Q}_t^s$, Q_t is the actual quantity transacted, $\hat{Q}_t^d$ is the estimated implied quantity demanded, $\hat{Q}_t^s$ is the estimated implied quantity supplied and $Pr(S_t > D_t|Q_t) = \mathit{\Pi}_t$ are the implied conditional probabilities as derived above.

A time series plot of these residuals and a scatter plot of the residuals with its own lag are depicted in the Figure 4. The Dickey-Fuller and Phillips-Perron tests (no lags) of the residuals gives the MacKinnon approximate p-values as 0.0011 and 0.0028 respectively with $Z^{df}(t)$=-4.056 and $Z^{pp}(t)$=-3.809, thus rejecting the null hypothesis of unit-root.[16] These results should be treated with caution, because the Engle and Granger (1987) test for co-integration has non-standard critical values. Co-integration relationship between $Q_t$and $\hat{Q}_t$ is also checked using Johansen co-integration test with 2 lags optimally selected by AIC, HQIC, SBIC criteria. The trace test detects one co-integrating vector (results are presented in Table 3).

[16]The p-value of the ADF(1) is 0.0274. The second lag is not statistically significant, therefore ADF(1) is preferred.

Figure 4: **Residuals from the static disequilibrium model, Q- $\hat{Q}_t$, where $\hat{Q}_t = Pr(S_t > D_t|Q_t) * \hat{Q}^d_t + (1 - Pr(S_t > D_t|Q_t)) * \hat{Q}^s_t$.**

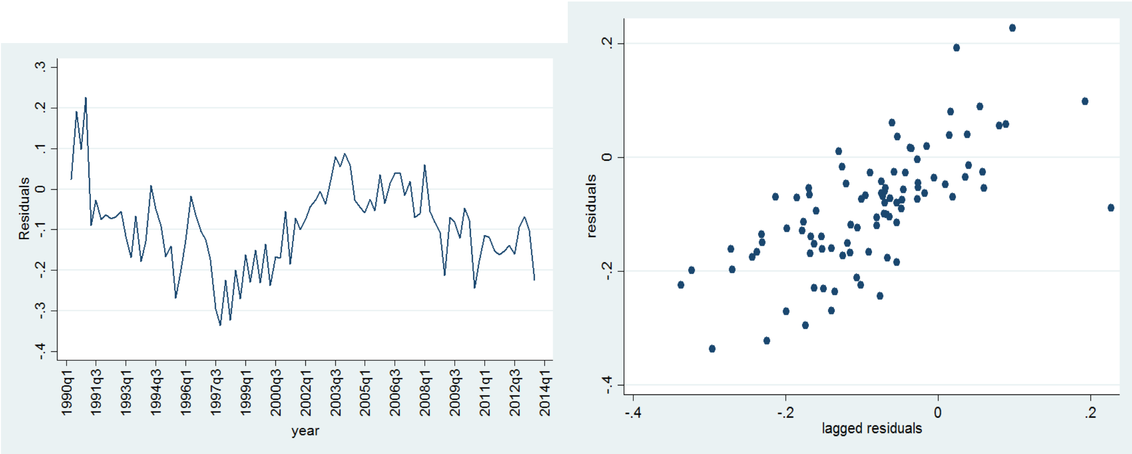


Table 3: **Test for co-integration between Q and $\hat{Q}_t = Pr(S_t > D_t|Q_t) * \hat{Q}^d_t + (1 - Pr(S_t > D_t|Q_t)) * \hat{Q}^s_t$.**

Maximum Rank	Eigenvalue	Trace Statistics	5% Critical Value
0	.	16.9872	15.41
1	0.14305	2.7851*	3.76
2	0.02982		

The second informal test of the long run relationship is based on literature testing for co-integrating relationship in the regime switching models (for example, Gregory and Hansen (1996)). The disequilibrium model estimates implied conditional probabilities $Pr(S_t > D_t|Q_t) = \Pi_t$ that can be used to separate quantity transacted into the demand and the supply regimes using an arbitrary threshold of 50%. Since both the demand and the supply schedules are stochastic, regimes cannot be exactly determined. Therefore, the threshold of more than 50 % chance to be either on demand or supply seem to be justifiable. Thus, when $\Pi_t = Pr(S_t > D_t|Q_t) > 0.5$, there is excess supply and the quantity transacted is determined by the explanatory variables of the demand schedule. When $\Pi_t = Pr(S_t > D_t|Q_t) < 0.5$, there is excess demand and the quantity transacted is determined by the explanatory variables of the supply schedule. According to Gregory and Hansen (1996), the standard ADF test for co-integration is performed on errors from a regime-switching model. The specification of such model stipulates that the quantity transacted switches between supply and demand regimes. The switches are captured using a dummy variable D.

$$D = \begin{cases} 1, & \Pi_t < 0.5 \\ 0, & otherwise \end{cases}$$

The following model specification is estimated using OLS:

$$\log(\text{value of loans approved})_t = \gamma_0 * D + \gamma_1 \text{mortgage rate}_t * D + \gamma_2 \text{consumer's confidence}_{t-1} * D + \beta_0 * (1-D) + \beta_1 \text{mortgage rate}_t * (1-D) + \beta_2 \text{long term government bond rate}_t * (1-D) + \beta_3 \text{index of industrial production}_{t-1} * (1-D) + \beta_4 \log(\text{total deposits})_{t-1} * (1-D) + \beta_5 (\text{time deposit rate}_t - \text{mortgage rate}_t) * (1-D) + \epsilon_t$$

The results of the estimation are presented in Table 4. The standard errors are robust to potential heteroskedasticity. The estimated coefficients of the regime-switching model are similar to ones of the disequilibrium model. All signs are as expected, the magnitudes are with small discrepancies. The results for the two models are similar, because the split between demand and supply regimes is determined by the results of the disequilibrium model. The results are not exactly the same, because the stochastic nature of demand and supply schedule does not allow to determine regimes exactly but only with some probability.

Table 4: **The model of regime switches.**

Variables	Coefficients	Standard Errors
constant*D	4.6194***	(0.0486)
mortgage rate, adjusted for inflation*D	-0.0462***	(0.0064)
consumers confidence for major purchases*D	0.0019*	(0.0011)
constant*(1-D)	6.0551***	(1.1917)
mortgage rate, adjusted for inflation*(1-D)	0.1434***	(0.0190)
long term government bond rate, adjusted for inflation*(1-D)	-0.1159***	(0.0206)
index of industrial production, lagged*(1-D)	0.0426***	(0.0038)
log(total bank deposits, adjusted for inflation)*(1-D)	0.8953***	(0.1708)
Δ(time deposits-mortgage rate), adjusted for inflation*(1-D)	-0.0738**	(0.0305)

*** statistically significant at 1%, ** statistically significant at 5%, * statistically significant at 10%

The informal test on co-integration is performed on the residuals from this regime-switching model. A time series plot of the residuals are depicted in Figure 5. The plot of the residuals show some similarities to the stationary process. The DF and the ADF(1) tests, results of which are summarised in Table 5, give the t-statistics of -5.4435 and -4.4958 respectively. Gregory and Hansen (1996) tabulated the critical values for the ADF test for models with breaks in up to 5 coefficients including one constant. The ADF critical value for 95% level two-sided test for 5 coefficients is -6.64. Since there are 7 independent variables and two dummies, neither ADF(1) nor DF t-statistics reject a null hypothesis of the unit root. However, these tests have lower power and are unlikely to reject the null of the unit root, even if in both tests the coefficient γ is about 0.5, which is far from 0.

Figure 5: **Residuals from the regime-switching model.**

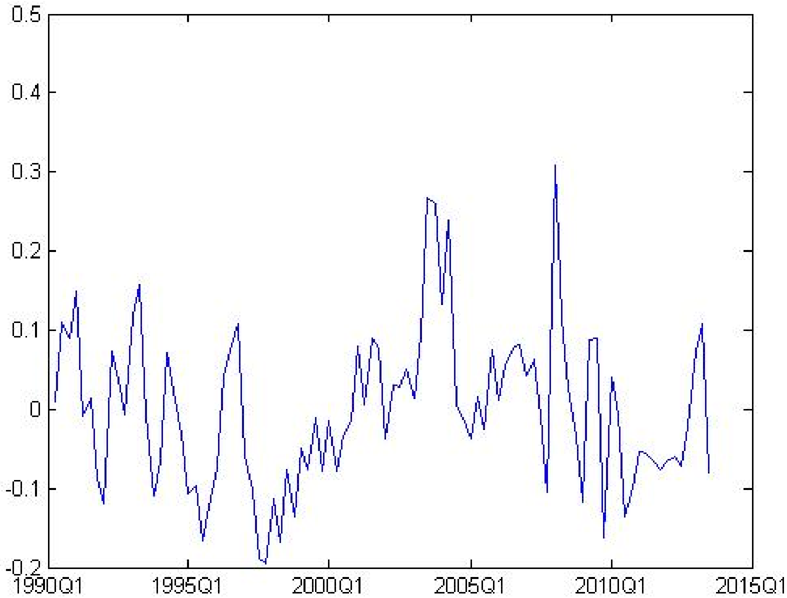


Table 5: **Unit root test for residuals.**

	DF	**ADF(1)**
γ	-0.4989	-0.4732
se	0.0916	0.1053
t-stat	-5.4435	-4.4958

DF: $\triangle\hat{\epsilon}_t = c + \gamma * \hat{\epsilon}_{t-1} + u_t$
ADF(1): $\triangle\hat{\epsilon}_t = c + \gamma * \hat{\epsilon_{t-1}} + \eta * \triangle\hat{\epsilon_{t-1}}$

While the tests discussed above do not provide a robust conclusions on stationarity, we consider there is enough evidence to suggest that there is co-integrating relationships for the supply and demand schedule. However, it is worth stressing that these results serve as an indication rather than a formal test of the validity of the static model on non-stationary data.

4 Conclusion

In this chapter we use disequilibrium econometric model to discern demand and supply in the UK mortgage market. We discussed why theoretically there could be a non-clearing price in the mortgage market and different econometric models and their applications. We then used the canonical econometric disequilibrium model to identify periods of credit rationing. To the best of our knowledge, this is the first study looking at credit conditions in the UK mortgage market using disequilibrium econometric approach. We found that the periods of recession coincide with the periods of credit rationing (or depressed supply) and the Golden era in banking coincides with the period of supply expansion. Interestingly, the period prior the financial crisis (from 2002 Q1 to 2007 Q4) exhibit some evidence of equilibrium in the market and in the first year of the crisis (from 2007 Q4 to 2008 Q4) credit conditions were driven by depressed demand. We also conducted econometric tests for stationarity to justify the use of the static disequilibrium model rather than a dynamic model.

Part III

Choice of Intermediary in the UK Mortgage Market

1 Introduction

1.1 Intermediaries

The process of obtaining a mortgage is complex and consumers often rely on mortgage intermediaries who guide them through the mortgage application and provide advice.

There are around 4000 active mortgage intermediaries in the market and they differ in a number of ways (FCA (2018a)). From a regulatory point of view, intermediaries may be Directly Authorised (DAs) by the FCA or may be Appointed Representative (ARs) of a Principal that is directly authorised. DAs are responsible for compliance monitoring and other functions, while ARs rely on the oversight of the Principal.

Intermediaries differ by the type of borrowers they tend to serve or by other type of specialisations. For example, there are intermediaries specialising in high-income or near prime borrowers, in mortgages on newly built properties or operating within specific regional areas or operating solely online (eg Habito).[17]

Intermediary firms also vary in size, measured by volume or value of business. While larger intermediaries may have hundreds of employees, there are also many sole practitioner advisory firms. The sector is not particularly concentrated.

Some intermediaries use panels of lenders (ie a list of firms with which one firm expects to do business), the sizes of which vary. Intermediaries receive a commission from lenders (called 'procuration fees') for whom they originate a mortgage. In the UK the structure of procuration fees is agreed between the intermediary firm and the lender (FCA (2018b)). Lenders typically set procuration fees as a percentage of the loan amount and some also set a minimum and/or a maximum amount. Different lenders pay different procuration fees and some lenders pay different fees to different intermediaries. Lenders may base their pricing structure on how important the intermediary is to their distribution strategy or the quality of the intermediary's applications. Quality may take into account the ratio of applications that arrive to completion or a fraud measure.

[17] There has been very little innovation in the mortgage advice space and only a few online brokers are present in the market. According to FCA (2018a) 'there is little appetite among established intermediaries and lenders to develop online advice services. Commercial incentives for doing this appear limited. The responses also indicated a perception that the sector does not see a role for online mortgage advice.'

Procuration fees paid by lenders that cater for borrowers with non-standard circumstances are typically higher than those for mortgages for standard borrowers. Anecdotal evidence from intermediaries and lenders suggests that applications from borrowers with less straightforward circumstances, such as the self-employed or contractors with complex income sources, may require intermediaries to collect more information to satisfy lending criteria.

Contracts between lenders and intermediaries do not allow variations in procuration fees depending on LTV or the volume of business an intermediary generates. Additionally, mortgage intermediaries in the UK do not typically receive trail commissions (ie commissions paid over the lifetime of the product).

Procuration fees of a number of lenders increased around the end of 2014 and the beginning of 2015. Some firms stated that this happened as a result of the Mortgage Market Review and lenders focusing more on intermediated sales (FSA (2012)).

Borrowers may also pay a fee to the intermediaries, but this is not common. Borrowers execute transaction with one intermediary firm only, but they do not need to use the same intermediary to get a new mortgage deal.

Intermediaries search deals on behalf of borrowers. They need to find a suitable deal that the consumer is likely to be accepted for. This is a complex task because i) borrower characteristics and circumstances vary widely and ii) lenders' lending criteria may not be always transparent. Due to frictions in the market, intermediaries may be motivated to act in their own best interest, which may be in conflict with those of borrowers and result in borrowers paying more for a mortgage.

Mortgage intermediaries need to spend time and resources to identify the right product for the borrower in terms of price, suitability and likelihood of approval by a lender. Intermediaries are unlikely to have access to the lenders decision-making criteria on credit risk or affordability. For example, the FCA found evidence that lender criteria and affordability models are opaque (FCA (2018b)). While lending criteria are publicly available, the finer detail may be less clear and the cost of searching across lenders to be certain they will accept the consumer is high. In addition to this, intermediaries may not be able to see, for example, the credit score of consumers before sending a mortgage application. As a result, intermediaries may decide to reduce search costs and recommend a product from a lender with less strict criteria or that they are familiar with. This may result in some consumers paying a higher price for their mortgage.

A potential misalignment of intermediaries incentives to find the best deal for consumers could be exacerbated because borrowers have little information or do not have tools to shop for intermediaries. The FCA found that there is little information available to help consumers assess and compare intermediaries (FCA (2018b)). If borrowers are not able to search for and compare intermediaries, some borrowers may pay a higher price than others for their mortgage product depending on the intermediary used. Moreover, procuration fees may distort incentives of the intermediaries to find the best deal to consumers.

1.2 Research questions

The first question we address is how the price of similar mortgage products for like-for-like consumers varies across intermediary firms. Price dispersion in credit markets is well documented and it can often be attributed to credit risks and the ability of lenders to price borrowers accordingly (for example Edelberg (2006), Adams et al. (2009), Einav et al. (2013) and Allen et al. (2014a)). However, to the best of our knowledge this is the first paper that investigates whether the choice of intermediary has an impact on the price consumers pay for their mortgage.

When looking at the price borrowers pay, we recognise that mortgage cost can differ because of borrower individual characteristics. For example, if one intermediary sells mortgages to borrowers who are on average riskier, then the price these borrowers pay will on average be higher because of the higher risk. To take this into account, we build a model for mortgage pricing to compare similar products for like-for-like consumers. It captures factors that may have an effect on the mortgage price, such as loan-to-value (LTV), loan-to-income (LTI), credit risk and property postcode.

We find that the choice of intermediary led to economically significant differences in the price of the mortgage. Looking at the cost of 2-year fixed rate mortgages sold by different intermediaries to like-for-like consumers, we find a 27 basis points difference in the average borrowing cost. This amounts to about an £800 difference calculated on the median loan size over the introductory period.

We focus on a specific mortgage type (ie. two-year fix with capital and interest repayments) because this reduces the likelihood that there is unobservable variation in the make-up of the borrower pool. Also, two-year fixed products represent around 60% of the products sold between January 2014 and June 2016. We replicate the analysis for 5-year fixed rate products (which account for over 20% of the mortgages sold) and we still find significant price differences across intermediaries.

Despite controlling for an extensive range of characteristics of products, properties and borrowers, there may be characteristics that we cannot observe that may affect the price paid and therefore our results. For example, the price variation may be driven by unobservable factors that lead some intermediaries to choose more expensive lenders or some borrowers may prefer or need a certain lender for reasons that are unobservable to us. To address this point, we run two robustness checks.

Firstly, we calculate the conditional price of mortgages sold to borrowers with standard characteristics (ie, excluding self-employed and borrowers with poorer credit history). Price dispersion is slightly smaller but still statistically and economically significant. We find a 20 basis point difference in the average borrowing cost.

Secondly, we calculate the price variation across intermediaries of products of the same lender sold to like-for-like consumers. We find that the price variation is around 18bps. For the median loan amount and the median interest rate, the difference amounts to £600. This suggests that the price of the same mortgage product provided by the same lender for like-for-like consumers varies materially across different intermediaries.

The second question we investigate are potential reasons why the cost of borrowing varies across intermediaries. A large body of literature investigates the drivers of poor broker advice on investment products (see Inderst and Ottaviani (2012b) and Inderst and Ottaviani (2012a) for a theoretical framework).

A strand of the literature investigates how poor advice is a result of recommending the same product to all consumers, as advisors may have incentives to reduce search costs and not to shop around extensively for the best product. For example, Foerster et al. (2017) use data from the Canadian retail investment market and find that advisers sell clients similar portfolios, independently from their clients' risk preference and stage in the life cycle. They also find that the adviser's own portfolio is a good predictor of what portfolio her clients hold.

Sometimes financial advisers might provide advice based on rule of thumbs popularised in financial advisers handbooks. For example, Agarwal et al. (2013) derived a closed-form solution for optimal refinancing strategy and rules of thumb used by financial advisers could only provide rough approximation to the optimal solution and result in sub-optimal advice. We contribute to this literature by considering whether intermediaries that use fewer, familiar lenders on average sell more expensive products to consumers.

We find significant differences in the number of lenders that intermediaries use during the period of time we looked at. Even when intermediaries use a similar number of lenders, we observe a range of strategies. For example, some intermediaries concentrate most of their business with a few lenders while others place it more evenly with many. Some intermediaries use panels of lenders (ie a list of firms with which one firm expects to do business), the sizes of which vary. Irrespective of whether they operate panels, the number of lenders that intermediaries place their business with varies: some intermediaries source products from a few lenders while others source products from many.

Table 6 shows the number of lenders each intermediary uses. In 2015, around 16% of intermediaries used only one lender and around 33% used between two and five lenders. This is partly due to either intermediaries that are small or the fact that mortgages are not a main business line. If we restrict the analysis to those that sold at least 50 mortgages in 2015, the proportion of intermediaries using five or fewer lenders falls to 4%.

Such differences in the number of lenders used are reflected in how intermediaries spread business across lenders. To assess this, based on the Herfindahl-Hirschman Index (HHI), we build a measure that takes into account the amount of business placed with each lender. HHI is typically used by competition and regulatory authorities to measure market concentration.[18] We use HHI to measure how intermediaries source mortgage business from different lenders. 1/HHI is proportional to the number of lenders used – a higher HHI typically indicates that an intermediary uses fewer lenders.

HHI takes values between zero and one. Low values indicate that an intermediary sources mortgages from many lenders, while high values indicate that it places most of the business with few lenders. The HHI-based measure is equal to one when all the products sold by an intermediary are sourced from one lender.

Figure 6 shows how the HHI-based measure varies across intermediaries. Figure 6 also shows that the market for providing mortgage intermediation is very fragmented. Around 62% of intermediaries sold just 10% of all intermediated mortgages in 2015. Smaller intermediaries, with low numbers of sales, typically use a smaller number of lenders on average.

We also calculate the proportion of business an intermediary sources from each lender. A high proportion suggests that an intermediary is familiar with a lender. Figure 7 shows the proportion of sales that each intermediary placed with familiar lenders. We order intermediaries so that on the left of Figure 7 we have those intermediaries that source a large proportion of their mortgages from the most familiar lender and to the right those sourcing a small proportion of mortgages from the most familiar lender.

The line made up of green circles shows the proportion of business placed with the most familiar lender for each intermediary. As one can expect, the line is downward sloping and mimics the HHI-based measure in Figure 6. Figure 7 shows, for example, that around 50% of the intermediaries source at least 40% of the mortgages they sell from one lender.

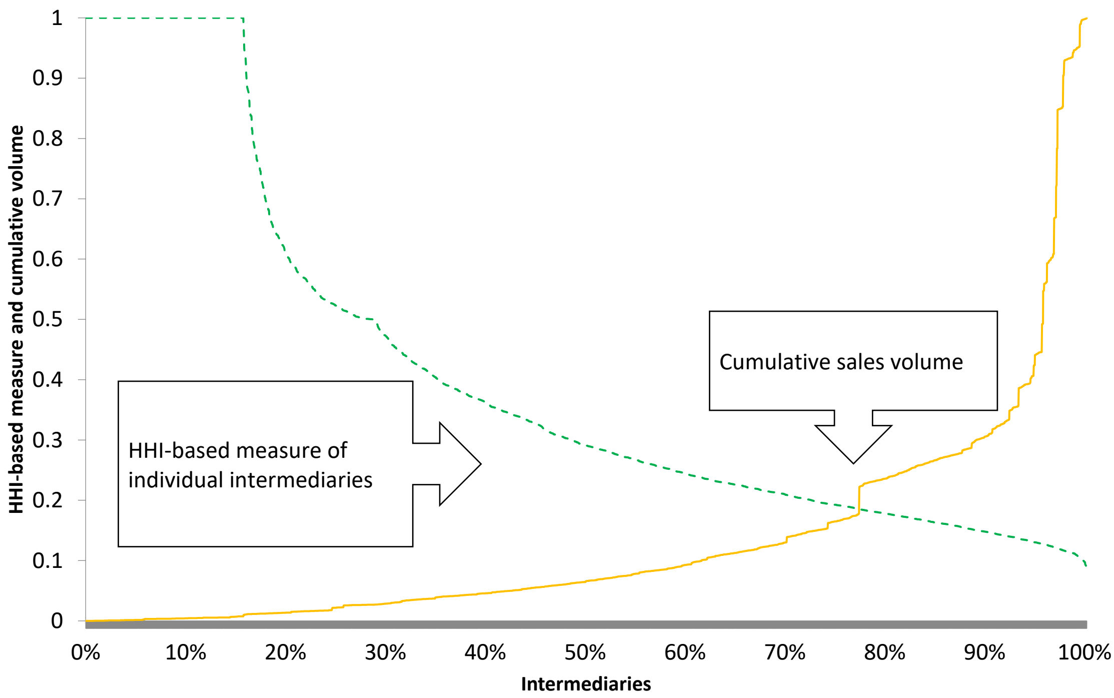
We also calculate the proportion of business that each intermediary places with both the two most familiar lenders and the three most familiar lenders. The former

[18] HHI is generally calculated as follows $HHI = \sum_i s_i^2$, where s_i is the market share of entity i. While competition and regulatory authorities use HHI to measure market concentration, we use HHI to assess how intermediaries place business across lenders. In our context, s_i is the amount of business placed with lender i by a given intermediary.

Table 6: **Number of lenders used by each intermediary in 2015.**

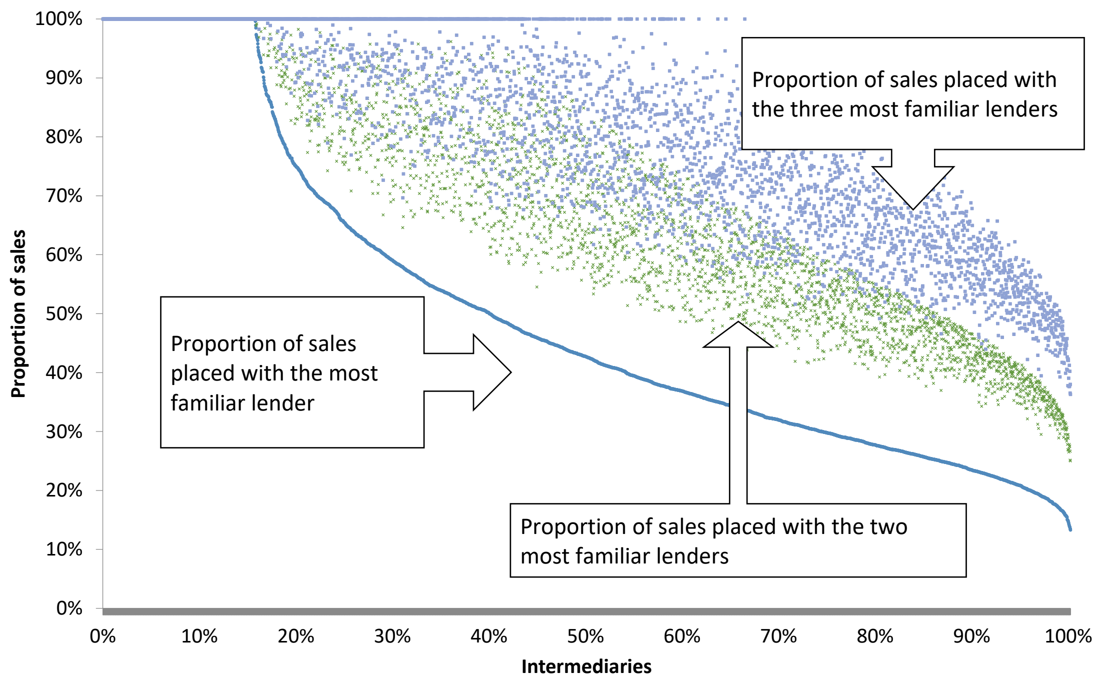
	Number of lenders used					
	1	2-5	6-10	11-15	>15	Total
% of intermediary firms	16%	33%	33%	13%	5%	100%
% of intermediary firms (>=50 sales)	2%	2%	32%	42%	21%	100%

Figure 6: **HHI-based measure for each intermediary and cumulative sales volume in 2015**.



is indicated by the yellow crosses and the latter by the brown squares in Figure 7.

Figure 7: **Proportion of sales by each intermediary with the most familiar lenders in 2015**.



After controlling for borrower, product and property characteristics, we find that intermediary firms that place business with a larger number of lenders sell on average cheaper products, while those that use fewer lenders sell on average more expensive products. We also find that products sourced from familiar lenders are on average more expensive compared to products sourced from less familiar lenders.

These findings can be interpreted in several ways. For example, intermediaries might be tempted to use a smaller number of lenders to reduce search costs. As a result, they might be unable to pick a cheaper deal because they are using a limited range of products. Alternatively, intermediaries might use fewer, familiar lenders to minimise the risk of rejection, as they have a better understanding of the lending criteria of particular lenders. They might therefore trade-off the risk of rejection with higher product prices.

The last question we investigate in this chapter is whether high procuration fees lenders pay to intermediaries are associated with intermediaries selling more expensive products to consumers. If the differences between these procuration fees are large, intermediaries face a conflict of interest. They may be tempted to maximise the income from procuration fees, rather than recommend a cheaper or more suitable product. This may result in some consumers paying a higher price for their mortgage. Thus we consider whether intermediaries that receive higher procuration fees on average sell more expensive products to consumers.

A strand of the literature investigates whether commissions lead to poor advice by creating incentives for advisers to recommend products that are not in the best interest of consumers. Indeed, Mullainathan et al. (2012) using audit methodology to test the quality of advice and find that advisers push for actively managed funds that have higher fees, even if the client starts with a well-diversified, low-fee portfolio. Anagol et al. (2017) conducted field studies in India to assess quality of advice for insurance products. The study finds that financial advisers recommend unsuitable, strictly dominated products, which provide high commissions to the agent. Other studies, like Christoffersen et al. (2013) or Barber et al. (2005) also study impacts of commissions on recommendations.

Robles-Garcia (2019) is the only paper we are aware of that also studies the relationships between commissions and mortgage recommendations in the UK. It finds a strong correlation between procuration fees and lender's market share with a broker. As the commission to a broker increases, lenders' market share with that broker increases as well. It further argues that intermediaries allow challenger banks (usually small and new lenders with lower brand recognition that offer on average higher procuration fees) to increase their market share and to improve competition. It finds that borrowers that use an intermediary are 7% more likely to choose a product of a challenger bank.

The role of commissions in also an important topic for regulatory authorities. For example, in 2009 the FSA looked at the mortgage market and did not find evidence that the remuneration model and potential commission bias in the mortgage market caused poor outcomes (FSA (2009)). In 2017 ASIC conducted a review of mortgage intermediary remuneration and found that upfront commission may represent a way to increase loan flow (ASIC (2017)).

We find little dispersion of procuration fees. The difference between the 10th and the 90th percentile is around 0.08%. Calculated on the median loan amount of around £147,000, this results in a gross difference of less than £120. However, specialist lenders that offer products for borrowers with non-standard circumstances and characteristics typically pay higher procuration fees.

We recognise that, offered a range of significantly different fees, intermediaries may choose the products and lenders that pay the most. However, we find little evidence that intermediaries selling highly priced mortgages actually also receive high procuration fees. In the few cases where this does happen, we do not consider that higher procuration fees adversely affect consumers because other factors may play a significant role. These factors include, for example, unobservable borrower characteristics (such as the length of trading history for self-employed) that may lead intermediaries to recommend a specialist lender.

The remainder of the paper is organised as follows. Section 2 describes the data we use and the methodology to assess our three questions and Section 3 describes the results. Section 4 concludes.

This research was conducted alongside the FCA mortgage market study and the findings contributed to the mortgage market study interim report.[19]

2 Research design

2.1 Data

We use an extensive dataset which includes a number of borrower, property and product characteristics. Product Sales Data 001 (PSD001), which provides transaction-level data on all first-charge residential mortgages completed in the UK, is matched to the MoneyFacts dataset (that includes additional product characteristics), a credit reference dataset (that includes additional borrower characteristics such as credit score), the Financial Services Register (that includes additional information on mortgage intermediaries) and the HM Land Registry (that includes additional property characteristics). We provide details of each dataset below.

The main source of data is PSD001, which is a regulatory dataset the FCA

[19]The UK Financial Conduct Authority (FCA) began a review of the mortgage market in 2015. The FCA published a Call for Input inviting views from market participants on areas in which competition issues may exist and merit further investigation (FCA (2015)). The FCA issued a feedback statement and it launched a market study to investigate competition in the mortgage market (FCA (2016a), FCA (2016b))

collects quarterly. PSD001 is a transaction-level dataset that covers all regulated first-charge mortgage transactions in the UK since April 2005. It includes information collected from each lender at point of origination on product characteristics (eg loan amount, property value, mortgage term, interest rate type, initial interest rates and procuration fees), borrower characteristics (eg age, income, employment status) and on the intermediary that sold the product, if relevant.

Data from 2015 onwards is more comprehensive because of changes to reporting fields made between January and June 2015. The dataset before July 2015 is supplemented with a data request to the largest lenders in the market, whose total sales made up over 90% of the market. The data request covers the period January 2014 to June 2015. The additional data request included missing information on interest rate, lender fees, procuration fees and the date when the incentivised rate period ended. PSD001 is matched to the mortgage MoneyFacts dataset. The MoneyFacts dataset provides additional information on mortgages. The dataset at our disposal covers mortgage products available in the market from 11 October 2011 to 30 November 2016.

We are particularly interested in the product characteristics, such as lender fees and initial period of fixed rate for fixed interest rate mortgages, where the PSD001 returns have missing values, and the reversion rate, as that is not recorded in the PSD001 returns. PSD001 is also matched to credit reference data which include credit score and a number of other variables on borrower credit history (eg past County Court Judgement or other marks in the credit history, such as arrears), on borrower indebtedness and on borrower usage of other financial products (eg whether the borrower holds a Personal Current Account (PCA) with the mortgage lender) at the time the mortgage was taken out. In some cases, this information can affect the price of the mortgage, for example because lenders sometimes offer preferential price to their PCA customers. The credit reference dataset covers the borrowers that completed a mortgage transaction between July 2012 and June 2016.

To supplement our information on intermediaries, PSD001 is matched to the Financial Services Register information on intermediaries' authorisation status (eg whether the intermediary is an Appointed Representative or a Directly Authorised firm) and, if applicable, the name of their directly authorised Principal. Finally, PSD001 is further matched to the HM Land Registry to include additional property characteristics, such as whether the mortgaged property is a new build or an older property.

2.2 APRC-based price measure

We compare mortgage products using an APRC-based price measure that takes into account both the initial interest rate and the fees each consumer paid to the lender to set up their mortgage. As a starting point, we use the definition of the Annual

Percentage Rate of Charge (APRC) as described in the Mortgage Credit Directive (MCD), introduced and transposed into the FCA Handbook in March 2016. See the Appendix B for more details on how we calculate the price of a mortgage.

We adjust the APRC by not including the fees paid by consumers to the intermediary. This is because we are interested in assessing the price of products sold by the intermediary rather than the total cost of borrowing for the consumers. Also, given a consumer can pay a lender's fees either up-front or over the life of the loan (ie 'roll-up' the fee), we assume fees are rolled-up.[20] Finally, we calculate the price of the mortgage using two different time periods: over the initial incentivised rate period and over the mortgage term.

In the baseline analysis, we base our cost measure on the initial interest rate charged over the initial incentivised rate period (eg, two years). This is equivalent to assuming consumers only take into account the initial interest rate and switch to a new deal as soon as or shortly after the mortgage reverts to the reversion rate. In other words, we assume that consumers expect they will have repaid the loan with the original lender in full at the point of remortgaging to another lender. We follow this approach because we want to assess the price of a mortgage, regardless of consumers' switching decisions. In support of our approach, we also find that the large majority (around 80%) of consumers on fixed and variable mortgages with two-year and five-year incentivised rate period expiring in 2015 either switched to a new product with their existing lender, or redeemed their mortgage (FCA (2018b)).

In the Appendix B we also calculate the cost measure over the mortgage term, including the reversion rate (typically the lender's Standard Variable Rate (SVR)) in the calculations. Note that our analysis focuses on the price paid by the borrowers and does not assess whether the product sold by the intermediary is suitable or not.

2.3 Sample construction

In this section we provide details on how we construct the sample we use for the analysis. As our work focuses on intermediaries, we limit the analysis to intermediated mortgages sales, which in 2016 accounted for around 67% of the market.

We exclude equity release mortgages, bridging loans, business loans and mortgages for high net worth individuals. We also exclude offset mortgages, shared ownership mortgages, low start mortgages, mortgages on self-build, shared appreciation mortgages and guarantor mortgages. These types of mortgages account for a small proportion of the market.

We limit the analysis to First Time Buyers, Home Movers and Remortgagors (where there is a change of lender). We exclude Right-to-Buy and other types of

[20] According to the ESRO consumer research many consumers opt to roll up their product fee into the loan to reduce upfront costs. The research is available at www.fca.org.uk/publication/research/understanding-consumer-expectations-of-themortgage-sales-process-esro.pdf

borrowers, which account for less than 1% of the market. We further restrict the analysis to mortgages with capital and interest repayment methods, which account for over 96% of all transactions.

We also restrict the analysis to mortgages with an incentivised rate period of two years. Additionally, we conduct robustness checks on mortgages with a fixed interest rate over an initial period of five years. Mortgages where the interest rate is fixed for two or five years make up the majority of the market – accounting for around 81% of all mortgages sold in 2016. We do not include variable rate products as they represent a small proportion of the market (see Table 7). Moreover, procuration fees for each intermediary-lender pair do not vary by repayment method or by borrower or interest rate type.

Focusing on a specific mortgage type (ie two-year fix with capital and interest repayments) reduces the likelihood that there is unobservable variation in the make-up of the borrower pool. The restriction to two-year fixed deals also has the additional advantage that the initial rate becomes a natural cost measure to consider, given that the vast majority of borrowers re-finance at the end of the incentive period.

Table 7: **Number of transactions by type.**

Total intermediated sales (Jan 2014 to Jun 2016)	1,430,503
Mortgages by borrower types	100%
First Time Buyer	33%
External Switchers	32%
Home Movers	34%
Other borrower types (eg, Right to Buy)	1%
Mortgages by repayment method	100%
Capital and interest	96%
Interest only	3%
Mix of 'capital and interest' and 'interest only'	1%
Mortgages by interest type	100%
Two-year fixed	59%
Three-year fixed	6%
Five-year fixed	22%
Other fixed rate	6%
Other interest types (eg, variable, tracker)	6%

Finally, given that the credit reference dataset only covers transactions until June 2016, we restrict the analysis to mortgages completed between January 2014 and June 2016. We refer to the sample resulting from the above cuts as the full sample.

To run robustness checks, we build a second sample which is a subset of the full sample and excludes mortgages completed by the self-employed and borrowers with poorer credit history. We refer to the second sample as the mainstream sample.

From the mainstream sample we exclude the self-employed because we do not observe a number of important factors about these borrowers (eg the length of the trading history). These factors may affect the likelihood of getting a mortgage and/or the price. For example, specialist lenders are typically willing to lend to borrowers with shorter trading history, so these factors may force some self-employed to use a specialist lender and thus pay a higher price for their mortgage.

We also exclude borrowers with County Court Judgments (CCJ), mortgage arrears, Individual Voluntary Arrangements (IVA), bankruptcy and borrowers with credit score in the lowest 20th percentile.

To ensure the results are consistent, we limit the analysis to those intermediaries and those intermediary-lender 'pairs' that sold at least, respectively, 50 and 30 mortgages over the period. Table 8 shows the different cuts and the number of observations available for the analysis.[21] We conduct robustness checks on the thresholds used.

Table 8: **Number of observations** .

	Cleaned sample	Intermediaries with more than 50 sales (Baseline, Model 1-3)		Intermediary-lender pairs with more than 30 sales at a given level of procuration fees (Model 4)	
	Number	Number	%	Number	%
Full sample					
Observations	782,810	742,018	95%	507,024	65%
Lenders	63	62	98%	31	49%
Intermediaries	4,268	1,068	25%	437	10%
Mainstream sample					
Observations	500,545	461,962	92%	308,769	62%
Lenders	62	61	98%	28	45%
Intermediaries	4,013	707	18%	235	6%

The descriptive statistics for the full sample, after dropping the intermediaries with less than 50 sales, are presented in Table 9. Our full sample includes 742,018 mortgages, sold between January 2014 and June 2016 by more than 60 lenders. The sample includes 288,159 first time buyers, 250,711 external switchers and 203,148 home movers. The median loan amount is around £147,000 and the median income is £46,000.

Unsurprisingly, first time buyers have on average smaller loans and lower income while home movers have larger loans and higher incomes. The median LTV is around 80% and the median LTI is 3.4. As one may expect, first time buyers have higher median LTV and LTI than other borrower types. The median age of borrowers in the sample is 34.[22] The median level of procuration fees paid is around 0.4% of the

[21] This sample includes two-year fixed mortgage products with Capital and Interest repayment sold to First Time Buyers, Home Movers and Remortgagors, after removing non-standard mortgage products and outliers. Overall, the cleaned full and the mainstream samples represent respectively 55% and 35% of all intermediated sales

[22] If the mortgage is on a jointly basis, the table shows the average age of the borrowers

loan amount. The difference between the 10th and the 90th percentile (respectively 0.33% and 0.41%) is around 0.08%. Based on the median loan amount of £147,000, choosing a product with a high procuration fee instead of a low procuration fee product could result in less than £120 extra in remuneration before tax per sale. This is a measure of the potential gain when selling a high procuration fee product.

Table 9: **Descriptive statistics, full sample** .

		Number of observations 742,018		
Number of observations broken down by	Borrower type	First Time Buyers	Home Movers	External Switchers
		288,159	250,711	203,148
	Income basis	Joint	Single	
		426,326	314,761	
	Employment status	Full time	Self-employed	
		665,333	76,685	
	Building type	New build	Older property	
		85,851	634,575	
Variables	1st quartile	median	3rd quartile	mean
Price (%)	2.29	2.78	3.71	3.07
Loan value (£)	104,550	147,250	212,329	174,204
Total gross income (£)	32,988	45,795	65,000	54,559
Loan-to-value	68%	80%	87%	75%
Loan-to-income	2.65	3.37	4.04	3.32
Mortgage term (months)	264	300	360	316
Age (years)	29	34	41	35
Procuration fees (% of the loan amount)	0.35%	0.40%	0.40%	0.38%

2.4 Methodology

In this section we present the methodology to investigate the following questions. First, whether the average price of similar mortgage products for like-for-like borrowers varies materially across intermediaries. Second, whether intermediaries that receive higher procuration fees on average sell more expensive products to consumers. Finally, whether intermediaries that use fewer, familiar lenders on average sell more expensive products to consumers.

We start by building a model for mortgage pricing that captures factors that may affect the price of the mortgage. To take into account that mortgage costs may vary because of borrower, product and property characteristics, the model controls for a number of factors such as LTV, LTI, loan size, age, credit risk, whether the lender is the PCA provider and property postcode.[23]

The following baseline specification is fitted to the data:[24]

$$Price_{libt} = \theta X_i + \phi Y_p + \gamma Z_d + f_t + f_a + e_{libt} \quad (1)$$

where $Price_{libt}$ is the price of the mortgage provided by lender l, sold to a borrower i by intermediary b at time t. X_i are borrower characteristics such as age

[23] See the Appendix B for a comprehensive list of the controls used

[24] See Best et al. (2015) and Eckley et al. (2017) for alternative pricing models for the UK mortgage market. Our model is richer and controls, for example, for credit score and for whether the borrower has a personal current account with the lender.

brackets, LTI and LTV bands, credit score (specific for mortgages), levels of monthly payments for unsecured debt, whether the application is filed by a self-employed or a employed borrower, on single or joint basis, and whether the borrower is a first time buyer, a home mover or a remortgagor. Y_p are product characteristics such as mortgage term, loan value and whether the mortgage is taken with the borrower's provider of a personal current account. Z_d are property characteristic of whether it is newly built or not.

These variables are important as they control for observable characteristics that could explain difference in the riskiness of the underlying mortgages and prices. It means that the model compares prices for borrowers that are like-for-like across these dimensions. If we don't control for these characteristics, their effects would misleadingly end up in the intermediary fixed effects, that we will use later to compare performance of intermediaries.

f_t are year-month dummies. Controlling for a time dimension is important to allow comparison of like-for-like borrowers overtime. These dummies take into account all macroeconomic factors that were changing overtime, for example, a steady fall in mortgage interest rates or a general economic activity.

f_a are dummies for regional areas (using outward postcode).[25] The regional areas fixed effects will control for the local demand volatility and long-run supply constraints in housing markets, which in turn jointly explain price volatility in these markets (Hilber and Vermeulen (2016)). Location specific price volatility affects location specific default risk and because intermediaries will have a local presence, unless area fixed effects are controlled for, these effects would misleadingly end up in the intermediary fixed effects. Again, we want to compare differences in the performance of intermediaries, and not observed differences in the riskiness of the underlying mortgages.

We use outward postcode as it is the most granular classification to control for geographical areas characteristics that does not cause the multicollinearity problem.

θ, ϕ, γ are the regression coefficients.

We consider four additional specifications, which take into account a combination of time-invariant intermediary specific, lender specific, as well as intermediary-lender pair specific characteristics, which are captured by corresponding fixed effects (see Table 10).

The intermediary fixed effects f_b capture common variation in the price of the products sold by the same intermediary. These fixed effects will reflect differences in intermediaries business models (for example, firms that use a limited set of lenders vs firms that use a wider range of lenders, or small vs large firms) and how these features result in variation of prices that consumers pay.

The lender fixed effects f_l capture common variation in the price of the products

[25] The outward code is the part of postcode before the space in the middle and it is between two- and four-character long

of the same lender.

The intermediary-lender pair fixed effects f_{lb} capture intermediary-lender specific characteristics, that is, any common variation of the price of the products sold by a given intermediary-lender pair. This includes common variation due to, eg commercial agreements between the intermediary and the lender, such as procuration fees.

In the next section we discuss how we use these models to assess the three questions. In the Annex we discuss how much variation is captured by borrower, product and property characteristics. We also compare their explanatory power to the explanatory power of lender and intermediary attributes.

Table 10: **Fixed effects used**.

	Fixed effects	Specification
Model 1	Intermediary fixed effects	$Price_{libt} = \theta X_i + \phi Y_p + \gamma Z_d + f_t + f_a + f_b + e_{libt}$
Model 2	Lender fixed effects	$Price_{libt} = \theta X_i + \phi Y_p + \gamma Z_d + f_t + f_a + f_l + e_{libt}$
Model 3	Lender and intermediary fixed effects	$Price_{libt} = \theta X_i + \phi Y_p + \gamma Z_d + f_t + f_a + f_b + f_l + e_{libt}$
Model 4	Intermediary-lender pair fixed effects	$Price_{libt} = \theta X_i + \phi Y_p + \gamma Z_d + f_t + f_a + f_{bl} + e_{libt}$

To ensure consistency of the fixed effects, in the baseline and in Model 1, 2 and 3 the analysis is restricted to the mortgages sold by intermediary firms that sold more than 50 mortgages. In the model with the intermediary-lender pair specific fixed effects (Model 4), we only analyse the intermediary-lender pairs with more than 30 transactions at a given level of procuration fees. We implement robustness checks on the threshold to ensure results are robust to different cut-off thresholds. The models are estimated using OLS, with standard errors clustered by intermediary to account for correlation in the behaviour of mortgagors using the same intermediary.

We assess how average mortgage price varies by intermediary for like-for-like consumers by calculating the intermediary fixed effects from Model 1. This model controls for borrower, product and property characteristics to take into account factors that may affect mortgage cost. For example, if an intermediary sells mortgages to borrowers who are on average riskier, then the price these borrowers pay for their mortgages will on average be higher because of the higher risk. Therefore, the coefficients of intermediary fixed effects from Model 1 indicate the average mortgage price per intermediary of similar products provided by different lenders and sold to like-for-like consumers.

We use two robustness checks. Firstly, we estimate Model 1 on the mainstream sample, which excludes self-employed and borrowers with poorer credit history. Secondly, we calculate the intermediary fixed effects from Model 3. In addition to the control variables in Model 1, Model 3 includes lender-specific characteristics. Therefore the coefficients of intermediary fixed effects indicate the average mortgage price per intermediary of similar products provided by a given lender and sold to like-for-like consumers. Model 3 mitigates possible effects from unobserved factors that lead either intermediaries to specialise in certain lenders or some borrowers to prefer a certain lender.

We then investigate the two remaining hypotheses by considering procuration fees and number of lenders each intermediary uses. We assess these hypotheses by using the intermediary-lender pair fixed effects from Model 4. We are particularly interested in how characteristics of the relationship between intermediaries and lenders (eg contractual level of procuration fees agreed between them or the number lenders used by an intermediary) explain the price dispersion of mortgages across intermediary-lender pairs.[26]

The following model is fitted to the data:

$$\hat{f_{bl}} = a + \theta proc.fees_{bl} + \phi N_b + e_{bl} \tag{2}$$

where the $\hat{f_{bl}}$ is the estimate of the intermediary-lender pair fixed effects for a given level of procuration fee between the pair, $proc.fees_{bl}$ is the procuration fees paid by lender l to intermediary b and N_b are characteristics of the intermediary (eg, the number of lenders used in a year, HHI-based measure or size of the intermediary).[27] θ and ϕ are the regression coefficients. The standard errors are adjusted to be robust to heteroscedasticity.[28] As a robustness check we estimate this model on both the full and mainstream sample.

3 Results

In this chapter we present the assessment of the three questions we investigate. See the Annex for a description of the pricing model we developed and a discussion of how mortgage price varies for different consumer, product and property characteristics.

3.1 The average price for like-for-like borrowers varies materially across intermediaries

The estimates of the coefficients of the intermediary fixed effects from the model with intermediary fixed effects only (Model 1) are plotted in Figure 8.[29]

Conditional on borrower, product and property characteristics, we find that the price of a mortgage varies materially across intermediaries. Intermediaries on the right hand side of Figure 8 sell on average more expensive products and those on

[26]For similar methodological approach see, for example, Foerster et al. (2017)

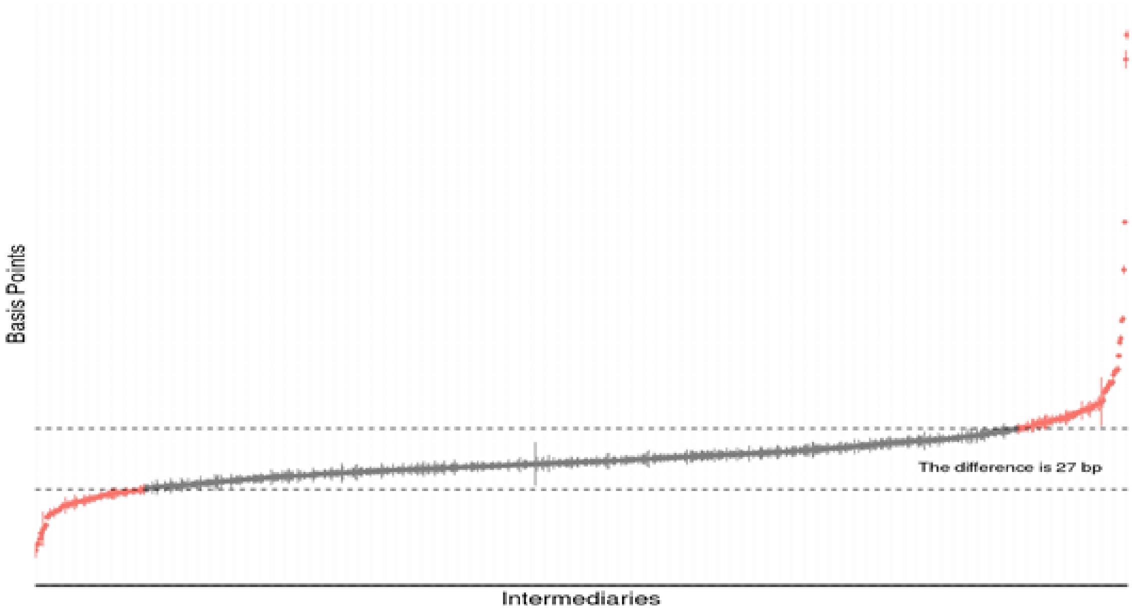
[27]Over the relevant period some lenders have changed the level of the procuration fees. Therefore, we observe multiple levels of procuration fees for the same intermediary-lender pair. In the analysis we treat intermediary-lender pairs with different levels of procuration fees as separate fixed effects.

[28]The heteroscedasticity robust standard errors controls for unknown structure of heteroscedasticity in error terms. If there is no heteroscedasticity, the robust standard errors will become conventional OLS standard errors.

[29]Figure 8 also shows the confidence interval for each individual fixed effect.

the left hand side sell cheaper products.

Figure 8: **Estimates of intermediary fixed effects (full sample)**.



Comparing the cost of two-year fixed rate mortgages for like-for-like consumers, the difference in the average price between the 10th percentile and the 90th percentile intermediary is around 27 basis points.[30] This represents a 10% price increase over the median mortgage price (which is 2.78% in our sample).

Table 11 shows the monetary amount corresponding to 27 basis points for different loan values. 27 basis points correspond to extra £778 for the median loan value over the two-year incentivised rate period (assuming the mortgage is held until the end of the incentivised rate period and consumers refinance after that).[31] The extra payment is around £553 for the 25th percentile loan value and around £1,122 for the 75th percentile loan value.

These findings suggest that the intermediary a consumer uses has a significant impact on the cost of the mortgage.[32][33]

The price variation across intermediaries cannot be explained by characteristics of the borrower, product and property included in the regression in equation (1), such as LTV, LTI, credit risk, age, employment status or loan size. The Appendix B gives a comprehensive list of the characteristics included in the regression. However, there

[30] The price difference between the 25th percentile and the 75th percentile intermediary is around 12bps. This corresponds to around £346 more for the median loan value. Differences are statistically and economically significant.

[31] We calculate the additional cost on the median size of the mortgage of around £147,000. £800 is the difference in the total interest paid over the two years period between two products with a 27 basis points difference in the price (ie, 2.78% vs. 3.05%).

[32] We consider whether intermediaries selling cheaper product also charge higher fees to borrowers, as they may compensate for the time and resource they use to find cheaper products. However, we do not find evidence that intermediaries selling cheaper products charge higher fees to borrowers.

[33] We obtain similar results by cutting intermediaries with less than 100 sales.

Table 11: **27 bps correspond to different monetary amounts for different loan sizes**.

Distribution of the loan value (quartiles and average)	Loan values	27 bps correspond to the following monetary amounts for different loan values
25th	£104,550	£553
50th	£147,250	£778
Average	£174,204	£921
75th	£212,329	£1,122

may be characteristics that we cannot observe that may affect the price paid and therefore our results. For example, the price variation may be driven by unobservable factors that lead some intermediaries to choose more expensive lenders or some borrowers may prefer or need a certain lender for reasons that are unobservable to us.

To address this point, we run two robustness checks. Firstly, we calculate the intermediary fixed effects of the Model 1 using the mainstream sample, which excludes self-employed and borrowers with poorer credit history. The variation of intermediary fixed effects in the mainstream sample is smaller, which is to be expected given the more homogenous nature of borrowers in the mainstream sample. However, it is still statistically and economically significant. The difference between the 10th and the 90th percentile intermediary is around 20bps (see Figure 21 in the Appendix B).

Secondly, we calculate the price variation across intermediaries of products of a given lender sold to like-for-like consumers. In other words, we calculate the coefficient of the intermediary fixed effects from the model with lender fixed effects (Model 3). We find that the price variation between the 10th and the 90th percentile intermediary is around 18bps. For the median loan amount and the median interest rate, the difference amounts to £600. This suggests that the price of the same mortgage product provided by the same lender for like-for-like consumers varies materially across different intermediaries.

The evidence of price variation across intermediaries becomes even more important given the evidence of consumers' limited shopping around for intermediaries. The FCA Financial Lives Survey 2017 found that many consumers use only one source of information (from the options given by the survey) to help with their decision making. The most common reasons given as influencing the choice of those who have taken out, or switched, a residential mortgage in the last three years, arranged through an intermediary, include recommendations from a friend or relative (29%) or having used the intermediary before and being happy with the service (26%).[34] There is very little information or tools available to help consumers identify and

[34] FCA (2018b)

compare the quality of intermediaries, making choosing an intermediary difficult.[35]

We find that intermediaries that on average sell more expensive products do so persistently over the time period we consider. To assess this, we divide the full sample into two 15-month sub-samples. The first sub-sample includes transactions completed between January 2014 and March 2015. The second includes transactions completed between April 2015 and June 2016. We recalculate the intermediary fixed effects from Model 1 and compare the ranking of intermediaries in the two sub-samples.

To ensure consistency of coefficients of the fixed effects, the analysis is restricted to intermediaries that appear in both samples and that sold at least 50 mortgages during in each 15-month period. Figure 9 shows that more than 40% of the intermediaries that were in the top quartile between January 2014 and March 2015 (ie that on average sold the cheapest products) are also in the top quartile between April 2015 and June 2016. Similarly, more than 40% of the intermediaries in the bottom quartile between January 2014 and March 2015 are also in the bottom quartile between April 2015 and June 2016.

The Spearman's rank correlation coefficient of the fixed effects estimates between the two periods is 0.33 and it is statistically different from zero. This suggests that intermediaries that sold cheaper or more expensive products in one period are likely to continue to do so in the subsequent period. The result holds when using the mainstream sample. This result suggests that the differences in price across different intermediaries are less likely to be the result of chance.

The variation in the intermediary fixed effect coefficients, which show what impact intermediaries have on the cost of the mortgage for consumers, could be explained by a variety of factors. For example, it could in part reflect the different business models of intermediaries (face-to-face intermediaries vs online brokers), the difference in sizes (small vs large firms), the number of lenders brokers use (a restricted set or a wide range of lenders), how familiar brokers with lenders and what level of procuration fees brokers receive. In the next section we investigate potential underlying economic mechanisms that could drive this price dispersion: procuration fees and number of lenders each intermediary uses.

[35] FCA (2018b)

Figure 9: **Persistence of intermediary fixed effects (full sample).**

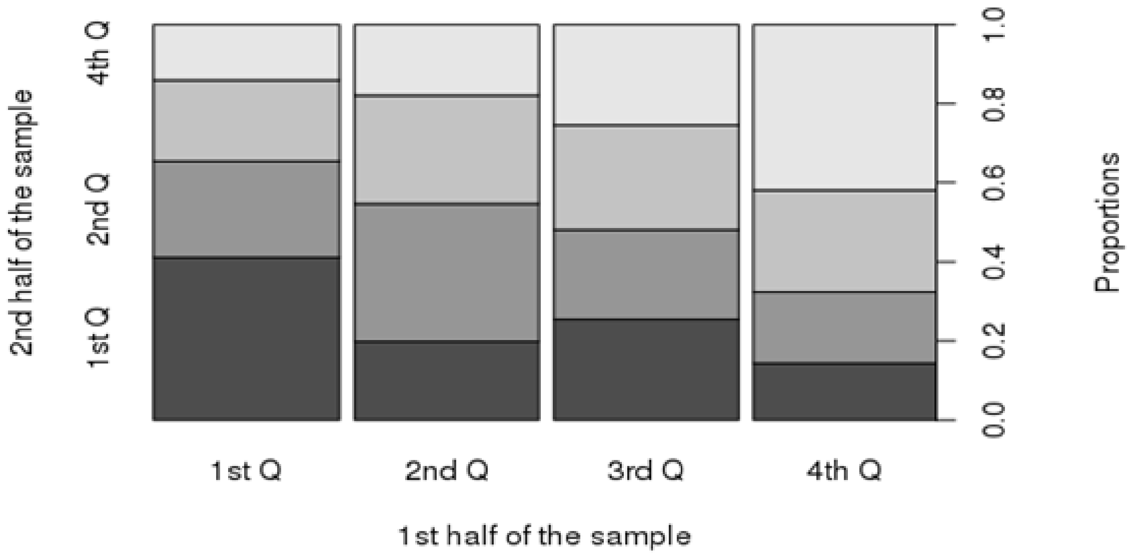


Table 12: **Drivers of price variability**.

	Full sample Baseline	Mainstream sample Baseline
Intercept	-1.7453^{***}	-0.4925
	(0.2699)	(0.3435)
Procuration fees, % of loan amount	4.7752^{***}	0.7612
	(0.8319)	(1.0032)
N. of lenders used by intermediary (between 4 and 8)	-0.0778^{***}	-0.0736^{***}
	(0.0261)	(0.0252)
N. of lenders used by intermediary (between 9 and 12)	-0.2022^{***}	-0.1417^{***}
	(0.0407)	(0.0458)
N. of lenders used by intermediary (between 13 and 16)	-0.2612^{**}	-0.219^{**}
	(0.0607)	(0.0917)
N. of lenders used by intermediary (between 17 and 20)	-0.1844^{***}	-0.1804^{***}
	(0.0668)	(0.0599)
N. of lenders used by intermediary (more than 20)	-0.1597^{*}	-0.1338^{*}
	(0.0587)	(0.0701)
Tot number of sales of the intermediary, log	-0.0008	0.0137
	(0.0101)	(0.0103)
R-squared	20.42%	2.38%
Number of observations	1752	1106

Standard errors are clustered at intermediary level and reported below the estimates. $***$ significant at 1%, $**$ significant at 5%, $*$ significant at 10%

3.2 Intermediaries using fewer, familiar lenders sell on average more expensive products

In the previous section, we showed that different intermediary firms use different numbers of lenders. Some intermediary firms place their business with only a few lenders, while others may use many more. In this section we consider the results of the regression in equation (2) and focus on coefficients that show how the number of lenders each intermediary uses correlated with the prices consumer pay. Results are reported in Table 12.[36]

Results indicate that the average price of the products intermediaries sold over the time period is negatively correlated with the number of lenders used. That is, intermediaries that use a greater number of lenders, also sell on average cheaper products, while those that use fewer lenders sell on average more expensive products. The number of lenders intermediaries use is captured by dummies to allow for non-linearity. We also control for the size of an intermediary firm, as, on average small intermediaries place business with a lower number of lenders (see Table 6). The regression results indicate that the price difference could be as high as 27 basis points, which correspond to around £800 on the median loan amount over the two-year incentivised rate period. Importantly, this result holds when controlling for the size of the intermediary.

Moreover, as a proxy for familiarity we calculate the proportion of business an intermediary sources from each lender. A high proportion suggests that an intermediary is familiar with a lender. We find that products sourced from familiar lenders are on average more expensive compared to products sourced from less familiar lenders. Table 13 show that results do not depend on the size of the lender or on the size of the intermediary.[37]

There may be several interpretations of this finding. Intermediaries need to spend time and resource to identify the right product for the borrower in terms of price, suitability and likelihood of lender approval. For example, advisers may have to research lending criteria and assess whether borrower circumstances match them. Intermediaries may be tempted to reduce search cost by using fewer, familiar lenders. In fact, whilst incentives to match borrowers to a lender that will accept them might be strong, incentives to find the cheapest suitable deal seem weaker. As a result, intermediaries using many lenders may be able to pick a cheaper deal from a wider product offering. Intermediaries have incentives to minimise the risk of rejection. By

[36] We also run the analysis on the sample resulting from removing intermediary-lender pairs with i) less than 40 sales and ii) less than 10 sales. Results remain robust.

[37] We define familiarity as the proportion of mortgages sold by intermediary b sourced from lender l, or:

$$\frac{Volume_{bl}}{Volume_b}$$

Where $Volume_{bl}$ is the volume of mortgages sold by intermediary b sourced by lender l and $Volume_b$ is the total volume of mortgages sold by intermediary b.

doing so, intermediary firms may trade-off price with reducing the risk of rejection. The use of familiar lenders may lower the risk that an application is rejected and ensure that the borrower successfully takes out a mortgage. Unfortunately, we do not have data on the number of rejected applications. We also have limited information on intermediaries and cannot control for other characteristics. For example, if we expect intermediaries with online outreach to work with more lenders because they incur lower search costs, we should control for this characteristic of a business model to disentangle it from the number of lenders used.

The result is robust to different specifications and different measures of lender concentration per intermediary. In particular, we find similar results when replacing the number of firms used with the HHI-based measure. The results of the regression in Table 13 suggest that higher values of the HHI-based measure (which indicate that an intermediary concentrates the majority of the business with few lenders) are correlated with higher average prices.

One could argue that results are driven by borrowers with non-standard circumstances, as the potential for unobservable borrower characteristics that affect the price of the mortgage is much higher for non-mainstream borrowers. For example, borrowers with poorer credit history may use specialist lenders whose products may increase the average price per intermediary. To check this, we run the same analysis on the mainstream sample. Table 13 shows that results are robust. Even using the mainstream sample, intermediaries selling more expensive products use on average a smaller number of lenders.[38]

Interestingly, such tendency of mortgage intermediaries to use a restricted number of lenders has been observed also by the Australian Securities and Investment Commission (ASIC). In 2017 ASIC found that the number of lenders actually providing mortgages may be significantly smaller than the number of lenders on an intermediary's panel. ASIC did not conclude on whether this practice results in higher prices for borrowers (ASIC (2017)).

We find that the difference between the coefficients of the dummies is not significant when the number of lenders used is large. This suggests that compared to an intermediary that is already using a large number of lenders, intermediaries using additional lenders do not sell on average cheaper products. In other words, correlation between number of lenders used and mortgage price tails off when number of

[38] As an additional robustness check we also include lender fixed effects in equation (2) to control for unobservable characteristics of lenders. The negative correlation between number of lenders and price is weaker but still statistically significant for higher number of lenders bands (ie, intermediaries selling using more than 17 lenders sell on average cheaper products compared to intermediaries using fewer lenders). Note that the interpretation using equation (2) with lender fixed effects is different, as in this case the coefficient represents the correlation between the number of lenders used by an intermediary and the price of the products of a given lender. Given that some intermediaries place all their business with one lender, lender fixed effects capture part of the effect of the number of lenders used and therefore the correlation is not statistically significant for lower number of lenders bands (ie, less than 17 lenders used).

lenders is large. See Table 26 for details on the methodology. We obtain the same result in the specification including the HHI-based measure.

3.3 Little evidence that intermediaries selling highly priced mortgages also receive high procuration fees

In this section we consider the results of the regression in equation (2) on procuration fees. The result on the mainstream sample suggests that there is no statistically significant evidence that intermediaries receiving higher procuration fees sell on average more expensive products.

We consider that the positive correlation between procuration fees and price in the regression on the full sample may be spurious. The difference in the results between the mainstream and the full sample is driven by products for borrowers with non-standard circumstances or poorer credit history. These borrowers are more likely to be served by specialist lenders.

Specialist lenders typically offer significantly higher initial interest rates and pay higher procuration fees compared to mainstream lenders. Positive correlation on the full sample may be spurious if we do not capture factors that lead consumers to specialist lenders. For example, we lack of data on self-employed borrowers may explain why some of them are served by specialist lenders (eg we do not have data on their trading history). Given that the effect of unobservable borrower characteristics on the price of the mortgage is much higher for the non-mainstream borrowers, we consider that conclusions based only on non-mainstream borrowers would be likely to be misleading.

Overall, given that it is unlikely that unobservable factors have a significant impact on the results of the mainstream sample, we conclude from this that there is little evidence that intermediaries receiving higher procuration fees sell on average more expensive products. [39]

4 Conclusion

As part of the FCA Mortgage Market Study we use a transactional-level dataset that includes detailed information on borrower, product and property characteristics to investigate whether: i) the price of mortgage products varies materially across intermediaries; ii) intermediaries that receive higher procuration fees on average sell more expensive products to consumers; iii) intermediaries that use fewer, familiar lenders on average sell more expensive products. We find that the average price of

[39] Moreover, we do not find significant differences between intermediaries that equalise procuration fees for their employees, which reduces incentives to recommend a lender based on procuration fees income), and intermediaries that do not equalise procuration fees. In fact, intermediaries that equalise procuration fees have similar fixed effects associated with specialist lenders as intermediaries that do not equalise procuration fees.

mortgage products sold varies across intermediaries. The difference can be as high as £800 over the incentivised rate period for the median loan amount.

The relationship between borrower and mortgage intermediary is a well-known example of misaligned incentives: intermediaries may be motivated to act in their own best interest, which may be in conflict with those of borrowers. We investigate whether we have evidence compatible with potential conflict of interests.

While we recognise that, in theory, there is potential for procuration fee bias where intermediaries see large differences in procuration fees across lenders, we find little evidence that intermediaries selling highly priced mortgages also receive high procuration fees. We find that the average price of the mortgages an intermediary sells is negatively correlated with the number of lenders used. On average, intermediaries placing business with a greater number of lenders sell cheaper products compared to intermediaries that use fewer lenders.

These results imply that intermediaries take advantage of information asymmetries by spending less effort finding the best deal for consumers (for example, to minimise search costs), but the cost of their mortgage recommendations does not appear to be associated with levels of procuration fees. These results do not mean that brokers do not respond to procuration fee-induced incentives. According to Robles-Garcia (2019), as procuration fees to a broker increase, the lender's market share with that broker increases as well. In combination with our results, it means that brokers tend to respond to commission-induced incentives, but that does not result in a worse outcome for consumers in terms of price. In the data we observe a variety of pricing strategies and there is not clear relationship between procuration fees and prices. Some lenders appear to pay higher procuration fees and charge consumers higher price. Others instead pay higher procuration fees and charge lower prices, potentially in an attempt to gain market shares. Finally, we also observe some lenders paying lower procuration fees and higher prices. For example, Robles-Garcia (2019) finds that challenger banks usually pay higher commission but on average sell cheaper products, ie driving the correlation coefficient θ down.

Our analysis is based on an extensive dataset which includes a number of borrower, property and product characteristics and it should not suffer from any measurement errors. Nevertheless, while we have tried to capture as many of the characteristics of borrowers, products and properties as possible, there may be characteristics that we cannot observe that may affect outcomes and therefore our analysis results.

Results may be affected by borrowers' unobservable characteristics. For example, we do not have information on the wealth of consumers or the length of the trading histories of self-employed borrowers. Moreover, in the UK there is no single credit score universally applied to lending decisions, like a FICO score in the USA. As a result, we might not be able to perfectly control for risk of default even though we used credit scores generated specifically for mortgages. Nevertheless, we think we mitigate these potential issues by replicating the analysis on the mainstream sample.

Moreover, we do not know customers preferences, such as changes in employment, plans to start a family or move area, which may have influenced intermediaries' recommendations. For example, borrowers may trade-off price for speed of service, and be willing to pay a higher price to get the mortgage offer as quickly as possible. However, a need for speed cannot explain why consumers use specialist lenders, as these firms tend to take longer to process a mortgage application.

Other unobservable lender characteristics include the quality of customer service, such as brand popularity. We control for whether the mortgage is provided by the PCA provider, as this allows us to take into account the convenience of having several financial products provided by the same firm. However, it is possible that borrowers have a strong preference for a particular lender. We mitigate the risks above by controlling for unobservable attributes of lenders as a robustness check.

Results may also be driven by unobservable characteristics of the property, such as whether the mortgaged property is next to a property licensed for commercial use. We mitigate this risk by using data from the HM Land Registry and PSD001 to control for some characteristics of the property and whether it is a new build or an older property. We also control for the outward postcode. We do not expect unobservable characteristics of the property to significantly affect results.

Moreover, we do not observe many other characteristics of intermediaries. For example, a type of business model they operate: online, face-to-face or a combination of both. However, we would only be concerned about characteristics that are correlated with our variable of interest: level of procuration fees, number of lenders intermediaries use or intermediaries' familiarity with lenders.

Additionally, it should be noted that the results are correlations and should not be interpreted as causation. The coefficient of the procuration fees θ in equation (2) indicates the correlation between procuration fees and price. Procuration fees represent a cost for lenders, which they may pass through to consumers by charging them higher prices. Therefore the coefficient θ may capture potentially two things; the pass-through rate and the role played by intermediaries in recommending products with high procuration fees. If pass-through is positive, correlation between procuration fees on intermediaries' recommendations might be strengthen. Even then, we do not expect that the interpretation of the results and conclusions are affected.

Finally, the analysis is based on the products sold, rather than products available to intermediaries when they make a recommendation. This may affect results, as intermediaries may only recommend, for example, products with high procuration fees or with low interest rates. To overcome this problem, we would need to construct the choice set of each intermediary. However we do not have information on the composition of the panel of each intermediary and the procuration fees paid by each lender. Moneyfacts does not include information on how procuration fees vary across intermediary-lender pairs.

Table 13: **Robustness checks**.

	Full sample			Mainstream sample		
	Baseline	Fit1: Baseline with HHI (instead of n. of lenders)	Fit2: Baseline + size of providers and measure of concentration	Baseline Baseline	Fit1: Baseline with HHI (instead of n. of lenders)	Fit2: Baseline + size of providers and measure of concentration
Intercept	-1.7453***	-1.7878***	-1.9246***	-0.4925	-0.4834	-0.7106**
	(0.2699)	(0.2694)	(0.2771)	(0.3435)	(0.3257)	(0.3514)
Procuration fees, % of loan amount	4.7752***	4.7284***	4.8357***	0.7612	0.6749	0.8153
	(0.8319)	(0.8333)	(0.8313)	(1.0032)	(0.9824)	(1.0035)
N. of lenders used (between 4 and 8)	-0.0778***		-0.0630**	-0.0736***		-0.0510**
	(0.0261)		(0.0256)	(0.0252)		(0.0250)
N. of lenders used (between 9 and 12)	-0.2022***		-0.2051***	-0.1417***		-0.1431***
	(0.0407)		(0.0407)	(0.0458)		(0.0461)
N. of lenders used (between 13 and 16)	-0.2612**		-0.2926***	-0.2190**		-0.2759***
	(0.0607)		(0.0632)	(0.0917)		(0.0937)
N. of lenders used (between 17 and 20)	-0.1844***		-0.2237***	-0.1804***		-0.2180***
	(0.0668)		(0.0702)	(0.0599)		(0.0620)
N. of lenders used (more than 20)	-0.1597*		-0.2060***	-0.1338*		-0.1859**
	(0.0587)		(0.0635)	(0.0701)		(0.0737)
HHI, 2nd quartile		-0.0076			0.0076	
		(0.0349)			(0.0207)	
HHI, 3rd quartile		0.1223***			0.0908***	
		(0.0383)			(0.0275)	
HHI, 4th quartile		0.1126***			0.0923***	
		(0.0462)			(0.0317)	
Tot number of sales, intermediary, log	-0.0008	-0.0132	0.0179	0.0137	-0.001	0.0370***
	(0.0101)	(0.0087)	(0.0128)	(0.0103)	(0.0073)	(0.0122)
Familiarity			0.1156***			0.1467***
			(0.0355)			(0.0368)
R-squared	20.42%	19.92%	20.67%	2.38%	1.87%	3.29%
Number of observations	1,752	1,752	1,752	1,106	1,106	1,106

Standard errors are clustered at intermediary level and reported below the estimates. *** significant at 1%, ** significant at 5%, * significant at 10%

Part IV

Impacts of the LTI flow limit in the UK mortgage market

1 Introduction

The June 2014 Financial Stability Report noted that the recovery in the UK housing market over that year was linked to a rise in the share of mortgages extended at high loan to income (LTI) ratios (BOE (2014)). Increased household indebtedness may be associated with a higher probability of household defaults, which cause economic instability and the risk of financial crisis. It may also be associated with a sharp fall in consumer spending after a negative shock, leading to subdued economic activity and macroeconomic volatility. In June 2014 the Financial Policy Committee (FPC) recommended that the Financial Conduct Authority (FCA) and the Prudential Regulation Authority (PRA) 'ensure that mortgage lenders do not extend more than 15% of their total number of new residential mortgages at Loan to Income ratios at or greater than 4.5' (BOE (2014)). This recommendation is commonly referred to as the 'LTI flow limit'. The core objective of the LTI flow limit is macro-prudential. It aims to reduce risks of financial instability in the economy by limiting the risk of excessive household leverage and curbing unsustainable credit growth. This in turn should ensure the integrity and good functioning of the UK mortgage market. The LTI flow limit took effect in October 2014 and applies to lenders that extend residential mortgage lending greater than £100 million per year.

According to the November 2016 Financial Stability Report (FSR), since implementation of the recommendation, the allocation of credit across LTI ratios has changed. Lenders increased new mortgages extended at LTI ratios just below 4.5 and restricted lending at LTI ratios above 4.5 (high LTI ratios). This has resulted in 'bunching' below the 4.5 cut-off (BOE (2016)). Using a unique transaction-level mortgage dataset and the difference-in-difference methodology, our objective, in this paper, is to document the changes in consumer outcomes and lenders' market dynamics in response to the recommendation. Our findings will be of interest to a wide community of policy makers and academics to help understand the impact of LTI ratio policies.

The paper focuses on the following question:

- Is there evidence that high LTI mortgages are originated for bigger loans and as a result are there any borrower composition changes?
- Are there changes in mortgage price for like-for-like high LTI borrowers?

- Are there are changes in lenders' exposure to high LTI mortgages post- implementation and does the lender proximity to the 15% constraint drive changes in mortgage price?

The LTI recommendation imposes a 15% limit on the total number of new mortgage sales rather than on their total value. This restriction on supply could result in lenders choosing to optimise their credit allocation of high LTI mortgages. Post-implementation, lenders may have incentives to extend high LTI mortgages on bigger loans, because the lender may wish to: 1) maintain interest income; and/or 2) maintain the level of the total value of new mortgages. We could expect to see an average increase in the loan size for high LTI mortgages post implementation. This would indicate that lenders may prefer to cater for borrowers with higher income. For example, if borrower A has an income of £10k and a borrower B has income of £20k. For an LTI ratio of 4.5 a lender offers a loan of £45k to borrower A and a loan of £90k to borrower B. To assess whether lenders cater for borrowers with bigger loans, we examine whether there is a change in the average loan size of high LTI mortgages compared to lower LTI mortgages, post implementation of the LTI flow limit.

We also consider whether the composition of borrowers at high LTI ratios has changed post implementation; this may indicate that some types of borrowers were more affected by the policy than others. For example, the FCA Guidance Consultation on the LTI recommendation outlined that young first-time buyers and applicants on sole income may be more affected by the introduction of the LTI flow limit (FCA (2014a)).

The price of high LTI mortgages may have been affected post-implementation and there could be many mechanisms. For example, the 15% constraint may have represented a negative supply shock, restricting the number of high LTI mortgages available in the market and driving prices up. Alternatively, the recommendation may have restricted competition among lenders thereby increasing the price for high LTI mortgages. For example, some lenders might have been closer to the limit and therefore had limited capacity to compete in the market for high LTI mortgages. The constraint may have also affected lenders' pricing strategies, for example, because lenders might have changed their risk attitude towards high LTI mortgages. We document whether there is any evidence of a change in mortgage price for like-for-like high LTI borrowers after the LTI flow limit was implemented.

Before the recommendation, lenders' exposures to high LTI mortgages, measured as the percentage of high LTI sales to their share of all mortgage sales, varied considerably. Some lenders were close to the 15% limit, but other lenders had very low proportions of high LTI mortgage sales. We examine how lenders appear to have changed their exposure to high LTI loans post-implementation and whether changes in mortgage price depends on lender proximity to the 15% constraint.

This paper contributes to the literature on macro-prudential tools, including maximum limits on loan-to-value (LTV), loan-to-income (LTI) and debt-to-income (DTI) ratios. Policy ratio limits (for example, maximum LTV of 85% in Sweden and 90% in Norway) are designed to protect consumers from excessive household leverage and to curb house price appreciation; this highlights their financial stability objective. Theoretical literature has evaluated the impact of these policies and the consensus is that they restrict credit, reduce household leverage and improve loan performance (e.g. Allen and Carletti (2010)). There are few empirical assessments of housing macro-prudential policies. Our paper is closely related to DeFusco et al. (2017) analysis of the impacts of the U.S. mortgage market policy restricting excessive household leverage (DTI). Their paper evaluated the Dodd-Frank 'Ability-to-Repay' rule and its effect on the price and availability of credit in the US mortgage market.

By looking at the changes in mortgage performance our paper also contributes to the literatures on broader consumer protection (Campbell et al. (2011), Posner and Weyl (2013); Jambulapati and Stavins (2014), and Agarwal et al. (2015)). It also contributes to the literature on ex-post evaluation by looking at the changes in the UK mortgage market post-implementation of the FPC recommendation (Agarwal et al. (2014) and Agarwal et al. (2017)).

We use a unique transaction-level dataset covering mortgage transactions from July 2012 to June 2016 to test these research questions. These are our key findings. The average loan size for high LTI mortgages increased by 4-7% post implementation of the LTI flow limit. For a given LTI ratio, an increase in the average loan size suggests that lenders migrated towards borrowers with higher incomes. Our results show that this change occurred at the 4.5 cut-off, which could be attributed to the FPC recommendation. There were also changes in the composition of the high LTI borrowers. Our results indicate that these changes are also associated with the FPC 4.5 cut-off. Specifically, above the 4.5 cut-off there is:

- an increase in the proportion of home movers;
- a decrease in the proportion of first-time buyers;
- an increase in the proportion of joint income applicants;

These changes in the borrowers composition are consistent with the increase in average loan size for high LTI mortgages. Home movers and joint income applicants are more likely to have higher incomes. The average loan size for home movers, joint income applicants, first-time buyers, and single income applicants, is around £190k, £180k, £150k, and £140k, respectively.

After controlling for borrower, product, and lender characteristics, we find that post- implementation the mortgage price for high LTI mortgages on average decreased. The price is measured as either the initial interest rate or the Annual

Percentage Rate (APR) based metric, which considers the initial interest rate and the lender fees.

Before the recommendation lenders differed in their exposure to high LTI mortgages, measured as the proportion of their number of high LTI mortgage sales to their number of all mortgage sales. After implementation, although the overall proportion of high LTI mortgages to the total number of sales in the market stays around 10%, lenders' individual exposure to high LTI mortgages changed. Some lenders, whose share of high LTI mortgages had been closer to the 15% limit, reduced their proportion of high LTI. In contrast, some lenders that previously had a low share of high LTI mortgages increased their proportion of them. We find that lenders proximity to the 15% constraint is correlated with how strong there is a fall in mortgage price for high LTI mortgages.

2 Policy background

In July 2014 the FPC recommended that the FCA and the PRA 'ensure that mortgage lenders do not extend more than 15% of their total number of new residential mortgages at Loan to Income ratios at or greater than 4.5' (BOE (2014)). The recommendation took effect on 1 October 2014. The FCA Guidance Consultation outlines details of the policy, but here we highlight the main aspects relevant for our research purpose (FCA (2014a)).

Not all mortgage products are in scope of the recommendation. Some categories of mortgages are excluded from the total number of mortgages completed or the percentage of mortgages completed with an LTI ratio of 4.5 or higher. Both internal and external remortgages, as well as ported products, with no increase in principal are excluded from the LTI flow limit, because they do not constitute an increase in indebtedness. Remortgages with an increase in principal are included. Non-regulated mortgages at the time of the publication of the recommendation, that is, second charge mortgages and buy-to-let mortgages, are exempt from the rule. Lifetime mortgages and equity release products are excluded, because they do not conform to this measure.

Not all mortgage lenders are in scope of the recommendation. A size threshold condition means that only large lenders qualify for the policy. The recommendation stipulates that lenders who completed more than 300 regulated mortgage contracts (excluding remortgaging with no increase in principal, lifetime mortgages, and other mortgages excluded) worth more than £100 million in 4 consecutive quarters preceding 1 October 2014 (ie from Q4 2013 to Q3 2014) are subject to the recommendation on the date the policy came into effect (ie lenders in scope on the date the policy came into effect (Condition A)).

Lenders could move in and out scope after the recommendation applies. Post-implementation of the recommendation, mortgage lenders are monitored on whether they continue to meet the size threshold of selling per annum more than 300 regulated contracts worth more than £100 million. Mortgage lenders that were not subject to the recommendation at the outset of the recommendation could move in scope if they sold over 2 consecutive rolling periods of 4 quarters more than 300 regulated contracts worth £100 million per year. They would become subject to the recommendation 2 quarters after satisfying the size threshold. Similarly, if a lender stopped selling more than £100 million worth of mortgages or sold less than 300 regulated contracts per annum over 2 consecutive rolling periods of 4 quarters, it would exit the recommendation (Condition B). For a diagrammatic explanation of Condition A and Condition B and a worked example refer to the FCA Guidance Consultation (FCA (2014a)).

Our analysis of the Product Sales Data (PSD) regulatory returns shows that 36 mortgage lenders became subject to the recommendation from 1 October 2014 and remained in scope for the period we analyse (ie until June 2016). These 36 mortgage lenders represented 98% of high LTI mortgage lending over our data period. 10 lenders dipped in and out of the recommendation as per the Condition B. 148 mortgage lenders have never been in scope of the recommendation. Those lenders outside the scope of the recommendation account for less than 1% of all mortgage sales.

Regardless of when a mortgage offer may have been made, all mortgages at an LTI at or above 4.5 completed after 1 October 2014 were counted towards the 15% limit. The 15% limit applies to the number of mortgages completed (volumes) not to the value of mortgages completed (pound sterling basis). The limit applies at the regulated entity level, but lenders are allowed to allocate all or part of its high LTI allowance to any other regulated entity within the same group as stated in the FCA Finalised Guidance (FCA (2014b)).

The PRA does not stipulate any explicit regulatory cost associated with exceeding 15% threshold, but the FCA Guidance Consultation (FCA (2014a)) states that 'if a firm exceeds 15% or more of its total number of new residential mortgages at LTI ratios at or greater than 4.5, we may, on our own initiative, require the firm to stop entering into high LTI mortgage contracts'.

3 Data and summary statistics

The main data source for our research is Product Sales Data (PSD001). All lenders selling regulated first-charge mortgage contracts in the UK must complete this template on a quarterly basis. The dataset includes information collected at point of origination on product characteristics like: loan amount, value of the property, mortgage term, variable vs. fixed rate, initial interest rates and borrower characteristics including age, income, employment status. We complement PSD001 data with information from additional data sources. Missing interest rates are replaced with interest rates from the Product Sales Data (PSD007), which contains information on mortgage performance for all existing mortgage balances since 2015. Additional borrower characteristics like mortgage performance, credit scores, information on property type are obtained from the Credit Reference Agency data. The Credit Reference Agency data covers mortgage products available in the market from July 2012 to June 2016. Finally, where possible, the data is matched to the MoneyFacts mortgage product dataset. This includes product characteristics, borrowers' eligibility criteria, and products' effective date. The MoneyFacts dataset at our disposal covers mortgage products in the market available from 11 October 2011 to 30 November 2016.

The period of the combined dataset is from July 2012 to June 2016. Non-standard and non-regulated mortgage products are excluded from our research sample. Examples of non-standard and non-regulated mortgages are buy-to-let, lifetime mortgages, business loans and bridging loans. Mortgage products that are not subject to the recommendation are also excluded from the analysis; these are re-mortgages without an increase in principal. Excluded mortgages account for 15% of the total number of originated mortgages.

This research focuses on those mortgage lenders that have always been in scope of the recommendation. They account for about 95% of all mortgage sales and 98% of all high LTI mortgage sales over the period analysed. This 98% proportion has not changed overtime suggesting that high LTI mortgage lending has not shifted (or 'leaked') from lenders in scope of the recommendation to those outside scope. Within this sample of mortgage lenders, around 10% of all mortgage sales were at or above the 4.5 LTI ratio cut-off.

Table 14 presents descriptive statistics on borrowers' main characteristics before and after implementation of the recommendation, grouped by LTI bucket.[40] The difference in composition of borrowers across different LTI buckets could be driven by various factors including regional discrepancies in income and house prices, bank internal risk policies, and regulatory environment.

The summary statistics indicate that borrowers with LTI ratios at and above 5 are very different in comparison to borrowers with lower LTI ratios and we separate these borrowers into different buckets. There are anecdotal and data evidence that some lenders have internal LTI limits. Some lenders do not lend above LTI ratios of around 4.7-4.8 and so for borrowers with LTI ratios between 4.5 and 5, we separate them into 2 buckets, [4.5-4.7) LTI bucket and [4.7-5) LTI bucket.[41]

[40] The table focuses on selected borrower characteristics. We looked at other borrower and product characteristics and these summary statistics are available on request.

[41] For example, https://www.moneymarketing.co.uk/borrowers-face-mass-confusion-as-mmr-and-/lti-cap-conflict/. Data tabulation also shows that some lenders have not originated mortgages above a certain LTI thresholds.

Borrowers in the LTI >=5 bucket are more likely to be home movers and higher income borrowers. Interestingly, the proportion of joint income borrowers is noticeably lower in this LTI bucket, suggesting that a lot of high LTI loans could be high income individuals. Mortgages in the >=5 LTI bucket have on average lower LTVs (in the mid-to-high 60p.p. compared to lower 70p.p. for all other LTI buckets) and pay lower interest rates. These individuals also take much larger loans and have higher mortgage payment to income ratio. Their credit scores are higher, which suggests that on average banks offer extremely high LTI mortgages to consumers that have lower credit risk. We find that the relationship between LTV and LTI is nonlinear- mortgages with higher LTI ratio are associated with lower LTV ratios (Figure 22 in Appendix C).

On average, borrower in the LTI buckets between 4.5 and 5 are similar to the borrowers in the LTI buckets just below 4.5. However, before the recommendation these borrowers have slightly lower average income and larger average loans. These borrowers pay on average lower initial interest rate than borrowers just below 4.5 cut-off, though their average loan to value ratio and credit scores are not very different. High LTI mortgages are not necessarily riskier. For example, on average they have the same or lower LTV, and credit score.

There are some clear trends when we compare borrower characteristics before and after implementation of the recommendation. Most notably, for all LTI buckets at or above 4.5, the proportion of mortgages to home movers rises but the proportion of mortgages to first-time buyers falls. This phenomenon does not occur for mortgages in LTI buckets below 4.5. Post-implementation the proportion of joint income applicants rises across all LTI buckets, except for a small 1% decrease for bucket LTI=>5. Table 14 also highlights that over our sample period for all LTI buckets the average mortgage term increases by around 7-13 months, the loan value increases and the average initial interest rate falls.

Some of these findings could be symptomatic of more general trends in housing markets and not related to the implementation of the LTI recommendation. We collect evidence that suggests whether this is the case in the following sections of the paper. In particular, to formally test the changes in the outcome variable after implementation of the policy we use the difference-in-difference (DD) methodology. This compares loans in the affected buckets (LTI ratio at and above 4.5) and loans in the unaffected buckets (LTI ratio below 4.5) before and after the implementation of the recommendation. We will give more details to the difference-in-difference models in the following sections.

Table 14: **Summary statistics on consumer features before and after the recommendation by different LTI buckets**.

LTI bucket	[3.5, 3.7)		[3.7, 4)		[4, 4.3)		[4.3, 4.5)		[4.5, 4.7)		[4.7, 5)		>=5	
Before/After implementation	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
Proportion of home movers	0.43	0.41	0.42	0.40	0.40	0.40	0.39	0.39	0.39	0.44	0.38	0.45	0.45	0.52
Proportion of first time buyers	0.41	0.41	0.44	0.44	0.46	0.46	0.49	0.48	0.48	0.43	0.51	0.42	0.40	0.32
Proportion of remortgagors	0.15	0.17	0.13	0.15	0.12	0.13	0.11	0.12	0.12	0.13	0.10	0.12	0.13	0.15
Age	35.57	35.14	35.06	34.55	34.50	34.00	34.01	33.49	33.91	33.73	33.34	33.38	34.89	34.38
Total gross income	49068.61	53753.10	47079.74	52148.93	45231.75	50097.63	43790.17	48247.81	41951.30	48953.37	40408.85	47659.95	44356.34	47271.18
Proportion of joint income applicants	0.54	0.59	0.50	0.57	0.46	0.55	0.48	0.52	0.33	0.46	0.25	0.40	0.40	0.39
Mortgage term	314.10	321.33	320.76	330.95	329.57	340.33	335.31	347.59	339.51	349.58	347.54	356.34	337.57	349.67
LTV	0.75	0.75	0.75	0.76	0.75	0.76	0.75	0.74	0.74	0.73	0.72	0.71	0.67	0.66
Loan value	176538.2	193399.2	181063.8	200676.3	187393.0	207647.1	192786.9	212519.9	192747.3	224921.0	196112.1	230828.0	235455.1	243624.4
Interest rate gross	3.27	2.86	3.26	2.88	3.21	2.81	3.13	2.71	3.15	2.57	3.07	2.48	2.92	2.34
Credit score	473.04	478.37	471.81	477.29	470.70	477.20	470.27	476.70	468.12	476.92	466.28	477.00	473.02	478.24
Initial payment to income ratio	0.22	0.20	0.23	0.21	0.24	0.22	0.25	0.23	0.26	0.23	0.26	0.24	0.29	0.26
Initial payment	873.55	894.62	880.39	909.66	892.35	916.97	900.29	915.51	894.20	944.56	890.12	947.84	1071.27	1004.39
Number of observations	25505	27913	34431	40062	28822	34443	17106	21273	11400	13127	15640	15844	7147	3627

Note: based on mortgages originated in a 6-month window that ends 6 months before the announcement of the policy, ie originated between July 2013 to December 2013, and mortgages originated in a 6-month window that starts 6 months after implementation of the policy, ie originated between April 2015 to September 2015.

4 Research design and results

4.1 Redistribution consequences

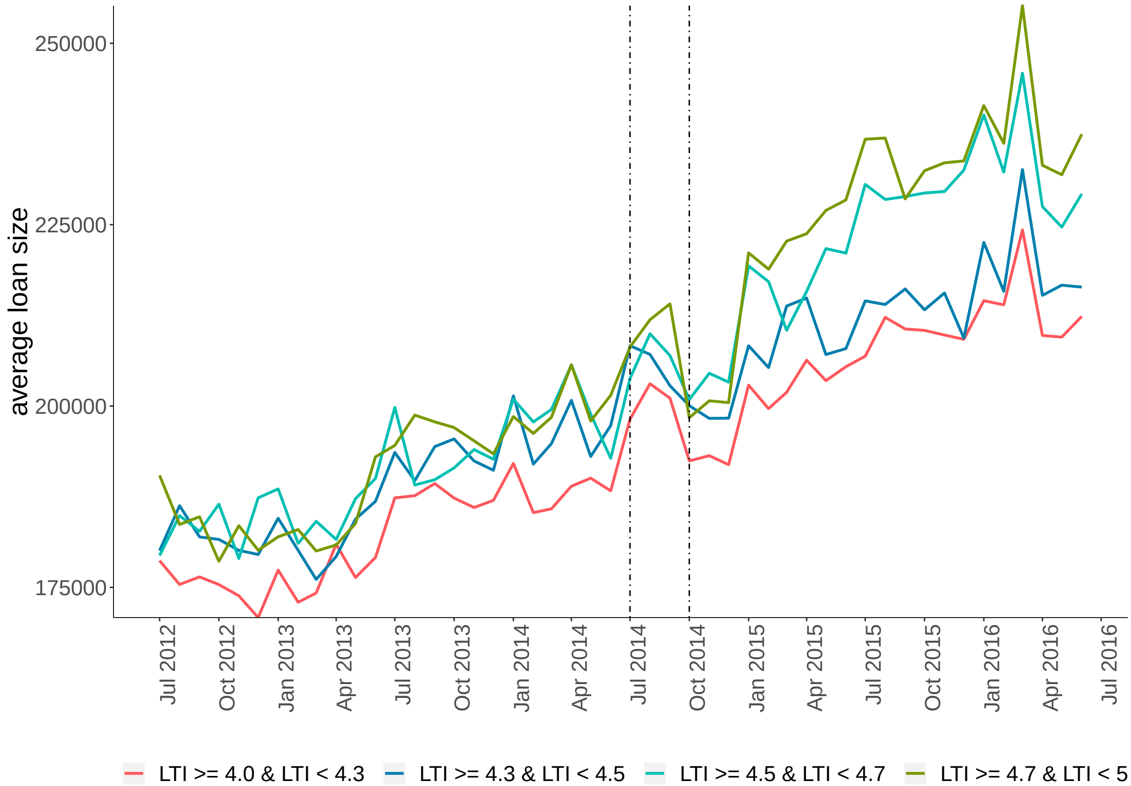
The 15% limit on the number of high LTI mortgages could have triggered changes in credit allocation across LTI buckets. According to November 2016 Financial Stability Report, there is evidence of these changes happening since the implementation of the recommendation (BOE (2016)). On the one hand, the number of high LTI mortgages decreased, ie lenders might have started rejecting high LTI borrowers. On the other hand, the number of high LTI mortgages just below the 4.5 cut-off increased, ie lenders might have started shifting borrowers from just above to just below the FPC cut-off. If lenders rejected high LTI borrowers or shifted them below cut-off non-randomly, we are likely to observe distributional changes for high LTI mortgages. Moreover, the recommendation imposes the 15% limit on the total number of sales rather than the total value of sales. Post-implementation, lenders may have incentives to lend high LTI mortgages for bigger loans, catering for borrowers with higher incomes. This strategy could reduce the impact of the 15% limit, because lenders could start substituting smaller loans with bigger loans to maintain interest income and/or the total value of new mortgages.

Figure 10 shows the average loan size before and after implementation of the recommendation for the LTI buckets [4,4.3), [4.3,4.5), [4.5,4.7), [4.7,5). Before the recommendation, the affected (ie LTI buckets [4.5-4.7) and [4.7-5)) and unaffected (ie [4-4.3) and [4.3-4.5)) buckets were moving in parallel. After implementation, there is a noticeable increase in the unconditional average loan size for the LTI buckets above the 4.5 cut-off in comparison to the trend of the average loan size for the LTI buckets below the 4.5 cut-off.

This increase in average loan size for high LTI mortgages implies that these mortgages were originated for bigger loans. For a given LTI ratio a bigger loan would be originated for a borrower with a bigger income. As the 4.5 LTI cut-off applies universally to all types of borrowers, some groups of borrowers with smaller incomes are more likely to be affected the most. For a given LTI ratio, a loan size for joint income applicants is more likely to be bigger. Sole income applicants may be more likely to be affected by the recommendation. Given the upward sloping income profiles over age, younger borrowers may be more likely to have smaller incomes and more likely to be affected by the recommendation. The first- time buyers (FTB) may be more likely to be affected by the recommendation than home movers (HM) or re-mortgagors with an increase in principle (RMTG). Before implementation of the recommendation the average income for home movers is £55,000 the average income for joint income applicants is £61,000.

We use an econometric approach to determine whether high LTI mortgages are originated for bigger loans, and if so, whether there are corresponding changes in

Figure 10: **Average loan size before and after the implementation of the recommendation** .



Note: the average loan size before and after the implementation of the recommendation on winsorised sample of loan values has the same pattern.

borrowers' composition. We are also interested in whether ex-ante risk characteristics, such as payment-to-income ratio, credit score, and LTV, have changed since the implementation of the LTI flow limit. To do so we compare loans in the affected buckets (LTI ratio at and above 4.5) and loans in the unaffected buckets (LTI ratio below 4.5) before and after the implementation of the recommendation.

We choose mortgages with LTI ratios [4.5, 4.7) as the treatment group and mortgages with LTI ratios [3.5, 3.7) as the control group. As has been discussed above, some lenders do not extend mortgages with LTI ratios above 4.7-4.8. The statistics in Table 14 suggest that borrowers with LTI ratios above 5 are likely to be a very different group of borrowers. Therefore, we consider LTI bucket [4.5, 4.7) as a treatment group. These LTI buckets will be our baseline case.

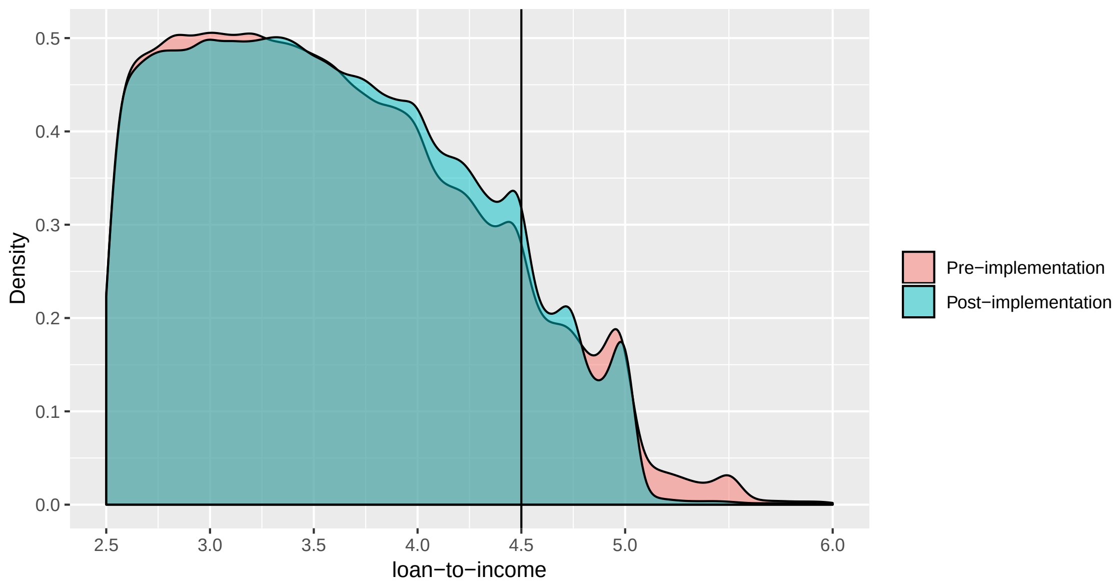
The recommendation has changed credit allocation around the 4.5 threshold (BOE (2016)). In Figure 11, we show distribution of LTIs in the pre-implementation and post-implementation periods. There are evidence of 'bunching' below 4.5 threshold (ie lenders credit ration on intensive margin and originate smaller mortgages to move them below the 4.5 cut-off) and 'missing mass' above 4.5 threshold (ie lenders credit ration on extensive margin and stop originate large mortgages above the 4.5 cut-off). However, as we go further away from the threshold, the difference in the two distribution becomes smaller. To avoid contamination of the estimates from reallocation of credit around the threshold, we do not use LTI buckets close to the 4.5 cut-off as a baseline control group. For the baseline case our control group is mortgages with LTI ratio [3.5, 3.7). We carry out robustness checks using various buckets, including just below the 4.5 threshold, because they are more likely to be more similar to the one just below the 4.5 cut-off.

The baseline case represents mortgages originated in a 6-month window that ends 6 months before the announcement of the policy (ie originated between July 2013 to December 2013), and mortgages originated in a 6-month window that starts 6 months after implementation of the policy (ie between April 2015 to September 2015). Both periods are sufficiently far from the implementation date. We also carry out robustness checks using different intervals. The following model is fitted to the data:

$$y_{it} = \alpha + \beta_0 * 1[LTI_i = [4.5, 4.7)]_i + \beta_1 * Post_t + \beta_2 * 1[LTI_i = [4.5, 4.7)]_i * Post_t + e_{it} \qquad (M1)$$

where y_{it} comprises of characteristics that may have changed after the recommendation was implemented. In this section, for example, these characteristics are loan value, gross income, borrower types, age, and ex-ante riskiness characteristics like credit score, payment-to-income ratio and LTV. $1[LTI_i = d]$ is a dummy variable for LTI buckets, which takes value 1 for the treatment LTI bucket d = [4.5,4.7) and 0 for the control LTI bucket d = [3.5,3.7). $Post_t$ is a dummy variable that

Figure 11: **Distribution of LTIs in the pre- and post-implementation periods**.



Note: For presentation purposes, the LTI distribution is shown between values of 2.5 and 6. Pre-implementation period is a 6-month window that ends 6 months before the announcement of the policy (ie from July 2013 to December 2013) and post-implementation period is a 6-month window that starts 6 months after implementation of the policy (ie from April 2015 to September 2015).

takes value 0 if a mortgage is originated between July 2013 to December 2013 or 1 if a mortgage is originated between April 2015 to September 2015. The parameters are estimated by the ordinary least squares (OLS) method. It is possible that y_{it} is correlated over time, which means that error terms e_{it} are likely to be serially correlated. In this case, standard errors may lead to serious over-estimation of t-statistics and significance. Bertrand et al. (2004) demonstrated importance of using cluster-robust standard errors in the difference-in-difference settings. To account for serial correlation and any area-specific random shocks, we cluster standard errors at a postcode area level in this and all following models. This approach is in line with DeFusco et al. (2017). We chose property area level because it strikes a good balance in the bias-variance trade-off that arises: in many estimation problems, larger and fewer clusters have less bias but more variability (Cameron and Miller (2015)). There are around 120 area levels and these areas are quite large.

The β_2 coefficient is the parameter of interest. It measures the difference between the average change in the variables of interest in the treatment group and the average change in the variables of interest in the control group before and after the implementation of the recommendation. The estimates of β_2 coefficients for the baseline case are reported in Table 15 Col A.

As robustness checks, the β_2 coefficient is estimated against different time periods before and after the recommendation, using the same control and treatment groups.

Table 15 Col B shows the estimated β_2 coefficients for a 6-month period that ends just before the announcement of the recommendation (ie from January to June 2014). Here the post-implementation period is the same as in the baseline case. Table 15 Col C shows the estimated β_2 coefficients for a different pre-implementation period, which is a 12-month period that ends just before implementation of the recommendation (ie from October 2013 to September 2014), and for a different post-implementation period, which starts immediately after implementation of the recommendation (ie from October 2014 to September 2015).

The house price inflation in an environment of stagnating wages could shift borrowers' demand for high LTI mortgages and change borrowers' composition. To avoid this compounding effect from the house price inflation, Table 15 Col D shows the estimated β_2 coefficients for a sample of English regions that experienced low house price inflation and low ratio of median house price to gross annual earnings. These regions are North East, North West, Yorkshire and The Humber, East Midlands, and West Midlands. [42] The Model 1 is estimated for the baseline sample.

The results in Col A, Col B and Col C in Table 15 suggest that unconditional average loan size has increased by around 4-7% for the treatment LTI bucket [4.5,4.7) relative to the control LTI bucket [3.5,3.7) after the implementation took effect. Prior to the recommendation, an average loan size for LTI bucket [4.5-4.7) was around £190,000. An increase by 4-7% implies that the average loan size post implementation for high LTI mortgages, in this case in the LTI bucket [4.5, 4.7), increase by £7,600-£13,300. As expected, the unconditional gross income has also increased similarly to the unconditional loan size by around 4-7%. For an average gross income of £40,000 it is an increase of £1,600-£2,800 per year.

The estimates of β_2 coefficient for different borrower characteristics suggest that there have been changes after the implementation of the recommendation for the treatment LTI bucket in comparison to the control bucket. The proportion of home movers increased by about 4-7%, the proportion of joint income applicants increased by about 6-10%, and the proportion of first-time buyers decreased by about 2-5%.

Like the robustness checks for the unconditional changes in the average loan size, the β_2 coefficient is estimated against different time periods before and after the recommendation and for English regions that experienced low house price inflation and low ratio of median house price to gross annual earnings. Table 15 Col B, Col C, Col D suggest that the results on joint income applicants, home movers, and first-time buyers are robust. Other characteristics are either not robust or the changes are not economically meaningful. For example, credit risk characteristics like credit score, payment to income and LTV in the treatment group in comparison

[42] ONS statistics on house prices and housing affordability are available at https://www.ons.gov.uk/economy/inflationandpriceindices/bulletins/housepriceindex/december2017#house-price-index-by-uk-local-authority-district and https://www.ons.gov.uk/peoplepopulationandcommunity/housing/bulletins/housingaffordabilityinenglandandwales/2017

Table 15: **Changes in average loan value, total gross income and borrower composition** .

Variable of interest	Col A Baseline specification		Col B Robustness to different pre- implementation period		Col C Robustness to different pre- and post- implementation period		Col D Robustness to regions with low house price inflation	
Loan value, log	0.0697	***	0.0552	***	0.0424	***	0.0330	***
	(0.009)		(0.0089)		(0.007)		(0.013)	
Gross income, log	0.0702	***	0.0557	***	0.0427	***	0.0337	**
	(0.009)		(0.0089)		(0.007)		(0.01236)	
Proportion of home movers	0.0692	***	0.0590	***	0.0381	***	0.0528	***
	(0.008)		(0.0090)		(0.0066)		(0.0156)	
Proportion of first time buyers	-0.0508	***	-0.0415	***	-0.0212	***	-0.0538	***
	(0.0077)		(0.009)		(0.006)		(0.0140)	
Proportion of re-mortgagors	-0.0148	***	-0.0160	***	-0.0155	***	0.0002	
	(0.006)		(0.006)		(0.005)		(0.0097)	
Proportion of other borrowers	-0.0035	**	-0.0014		-0.0014		0.0009	
	(0.002)		(0.0015)		(0.0010)		(0.0026)	
Age	0.2559	**	0.0679		0.0564		0.6157	**
	(0.1328)		(0.1500)		(0.098)		(0.2377)	
Proportion of joint income applicants	0.0724	***	0.0967	***	0.0678	***	0.0565	***
	(0.008)		(0.0080)		(0.0057)		(0.0113)	
Payment to income ratio	-0.0095	***	-0.0096	***	-0.0073	***	-0.0061	
	(0.0007)		(0.0007)		(0.0004)		(0.0014)	
LTV	-0.0158	***	-0.0068	***	-0.0044	***	-0.0178	***
	(0.0024)		(0.0026)		(0.0017)		(0.0038)	
Credit score	3.4698	***	1.3334		0.7205		2.8002	
	(1.1135)		(1.118)		(0.7496)		(2.321)	

Note: Standard errors are clustered at property postcode area level, in parentheses, *p<0.1; **p<0.05; ***p<0.01. Col A is the baseline case, where mortgages are originated in a 6-month window that ends 6 months before the announcement of the policy (ie from July 2013 to December 2013), and mortgages originated in a 6-month window that starts 6 months after implementation of the policy (ie from April 2015 to September 2015). Col B is a robustness check, where the pre-implementation time period is a 6-month period that ends just before the announcement of the recommendation (ie from January 2014 to June 2014) and the post-implementation period is the same as in the baseline case. Col C is a robustness check, where the pre-implementation time period is a 12-month period that ends just before implementation of the recommendation (ie from October 2013 to October 2014), and the post-implementation time period starts immediately after implementation of the recommendation (ie from October 2014 to September 2015). Col D is a robustness check on a sample of regions that experienced low house price inflation. The model is estimated for the baseline sample.

to the control group, though in some cases statistically significant, have changed only marginally after the recommendation took effect.

The results of Table 15 shows that there are changes in the composition of home movers and first-time buyers, as well as joint income applicants. However, to provide evidence that changes in the borrowers' composition are related to the LTI 4.5 cut-off rather than other changes in the market, we should expect that changes will show at the 4.5 cut-off point. If instead there are other market-wide impacts on borrower composition, then we should expect any changes to vary smoothly for all LTI buckets. In line with DeFusco et al. (2017), we fit the following flexible DD specification:

$$y_{it} = \alpha + \beta_0 * Post_t + \sum_{d=3.3}^{>5} \left[\beta_1^d * 1[LTI_i = d] + \beta_2^d * 1[LTI_i = d] Post_t \right] + e_{it} \qquad (M2)$$

In this specification a dummy for LTI bucket [3, 3.3) is omitted so that the coefficients β_1^d estimate the d-specific LTI bucket change in the variable of interest relative to the loans in the omitted LTI bucket after the implementation of the policy. The model is estimated using OLS. Standard errors are clustered at postcode area level.

The results of this model are summarised in Figure 13, which plots β_1^d coefficient estimates (the coefficient for the interaction term between LTI bucket and the Post dummy) from the flexible DD specification and its 95% confidence interval. The coefficient of the baseline LTI bucket [3, 3.3) is normalised to 0. All coefficients can be interpreted as the change in the variable of interest for a given LTI bucket following the implementation of the FPC recommendation relative to the LTI bucket [3, 3.3).

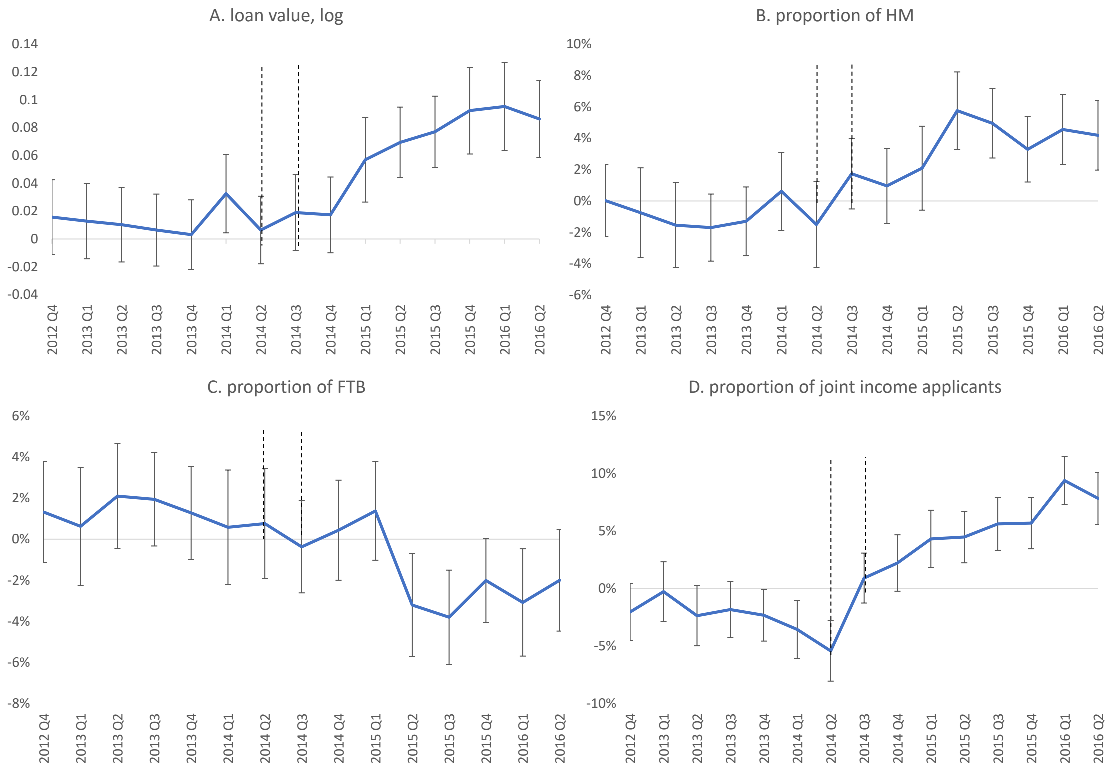
The Figure 13A makes clear that an economically significant increase in the proportion of home movers occurs for mortgages above the FPC 4.5 LTI cut-off. Figure 13B shows that there is an economically significant decrease in the proportion of first-time buyers and Figure 13D shows an economically significant increase in the proportion of joint income applicants for mortgages above the FPC cut-off of 4.5. Figure 13C shows no change in the proportion of people remortgaging above the FPC 4.5 LTI cut-off. This is in line with the findings of the simple DD approach of Model 1. These results are also robust to different time window, from the pre-implementation period of January 2014 to June 2014 and from the post-implementation period of October 2014 to September 2015. Figure 13 shows that after implementation of the FPC recommendation, the changes in proportions of home movers, first-time buyers and joint income applicants are associated with the FPC 4.5 cut-off.

These changes in borrowers' composition are consistent with the increase in average loan size for high LTI mortgages. However, the results might not be entirely driven by the fact that these categories of borrowers (ie FTB, and single income applicants) have lower income. It could be that, even conditional on the same income and other characteristics, some groups are being offered fewer mortgages, possibly because they are perceived as riskier. To disentangle these two stories, we would need to compare borrowers that differ only in the variables of interest. This conditional analysis is outside the scope of this paper. Instead we check whether income alone could explain the compositional changes, by including it as a regressor in the baseline specification (ie Model 1). Once we include the income variable, our results show that the coefficient β_2^d for the variables of interest became smaller in absolute levels but remain statistically significant.

Furthermore, we can provide evidence that the changes in the borrowers' composition are related to the time when the FPC recommendation was introduced. In Figure 12 we plotted unconditional averages over time for the baseline control and treatment groups for selected outcomes. This shows that the changes in the market are related to the recommendation. This is also a crucial test of the validity of the difference-in-difference design. That is, in the absence of treatment, the difference between the treatment and control group is constant over time. Figure 12 shows that the trend assumption holds for loan value, proportions of home movers, first-time buyers and joint income applicants. The test on parallel trends controls for an overall time trend and will take into account any UK specific changes in house price.

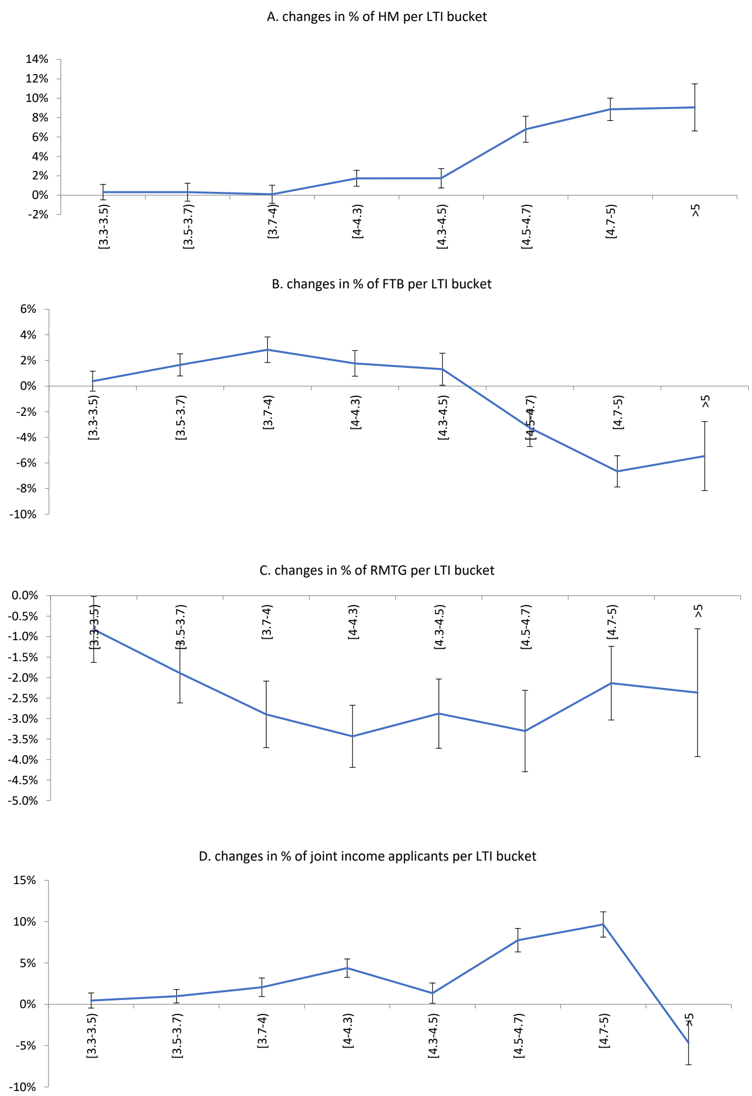
However, to further check sensitivity of the above results to house prices, we run the parallel trends test test on loan value and the flexible DD specification on borrowers' composition using a sample of regions with the low house price inflation (results are reported in Figure 23 and Figure 24 in Appendix C). The previous findings are robust, ie the average loan size increases after the implementation of the recommendation and there are changes in the borrowers' composition beyond the 4.5 cut-off.

Figure 12: **Testing for the parallel trend assumption, selected variables**.



Note: baseline specification where the LTI bucket d=[4.5, 4.7) is a treatment group and the LTI bucket d=[3.5, 3.7) is a control group.

Figure 13: **Flexible DD estimates of the changes in borrowers' composition**.



Note: All coefficients can be interpreted as the change in the variable of interest for a given LTI bucket following the implementation of the FPC recommendation relative to the LTI bucket [3, 3.3). An economically significant change in the proportion of home movers, first-time buyers and joint income applicants happens at the FPC 4.5 cut-off. This shows that changes in the composition of borrowers are related to the LTI 4.5 cut-off rather than other changes in the market. According to the flexible DD results on loan value and gross income (in logs) an increase for the treatment groups happens at 4.5 cut-off.

4.1.1 Discussion

The increase in unconditional average loan size for high LTI mortgages is consistent with our observed changes in borrower composition. There are different mechanisms of how these changes may have happened, and we discuss a few in this section. We showed that there are changes in the proportions of different types of borrowers for high LTI mortgages. However, we want to know whether it also resulted in changes in absolute levels, ie changes in number of a certain type of borrowers for high LTI mortgages. Figure 25 in Appendix C shows that the number of mortgages sold with

LTI bucket [3.5, 3.7) (control group) and the number of mortgages with LTI bucket [4.5, 4.7) (treatment group) move in parallel before and after the intervention. The increase in the proportion of home movers and joint income applicants between the treatment and the control groups could be interpreted as an increase in the number of such borrowers. The decrease in the proportion of first-time buyers could be interpreted as a decrease in number of such borrowers. There is some evidence that high LTI mortgages are extended more to home movers and joint income applicants and less to first-time buyers, which is partially driven by income differences between these groups.

One mechanism that reduces the number of borrower type for high LTI mortgages is lenders' direct credit rationing, either on extensive or intensive margins. The November 2016 Financial Stability Report (BOE (2016)) sets out evidence of redistribution of mortgages across LTI ratios, which suggests that there could be rationing of credit. Intensive credit rationing means that borrowers get smaller loans than they applied for. Extensive credit rationing means that borrowers are rejected for a loan. Rationing could make borrowers buy a smaller house, postpone their purchase until they accumulate a larger deposit, or re-apply with a different lender. Unfortunately, we do not have rejection or application data to analyse lenders credit rationing behaviour.

A second mechanism is that intermediaries may steer certain type of borrowers towards high LTI mortgages after implementation of the recommendation. We compared the redistribution results between intermediated and direct sales and they seem similar across the 2 categories. A third mechanism is that lenders may change the menu choice, offering high LTI mortgage to certain type of borrowers. Some lenders have explicit LTI limits. For example, according to Mortgage Strategy (2017), for Barclays' applicants with incomes of less than £55,000 will get income multiples of up to 4.49 x income'. In many cases there is a lack of transparency around LTI limits for mortgage products and it is difficult to pin down changes in menu choice from available data (FCA (2018b)).

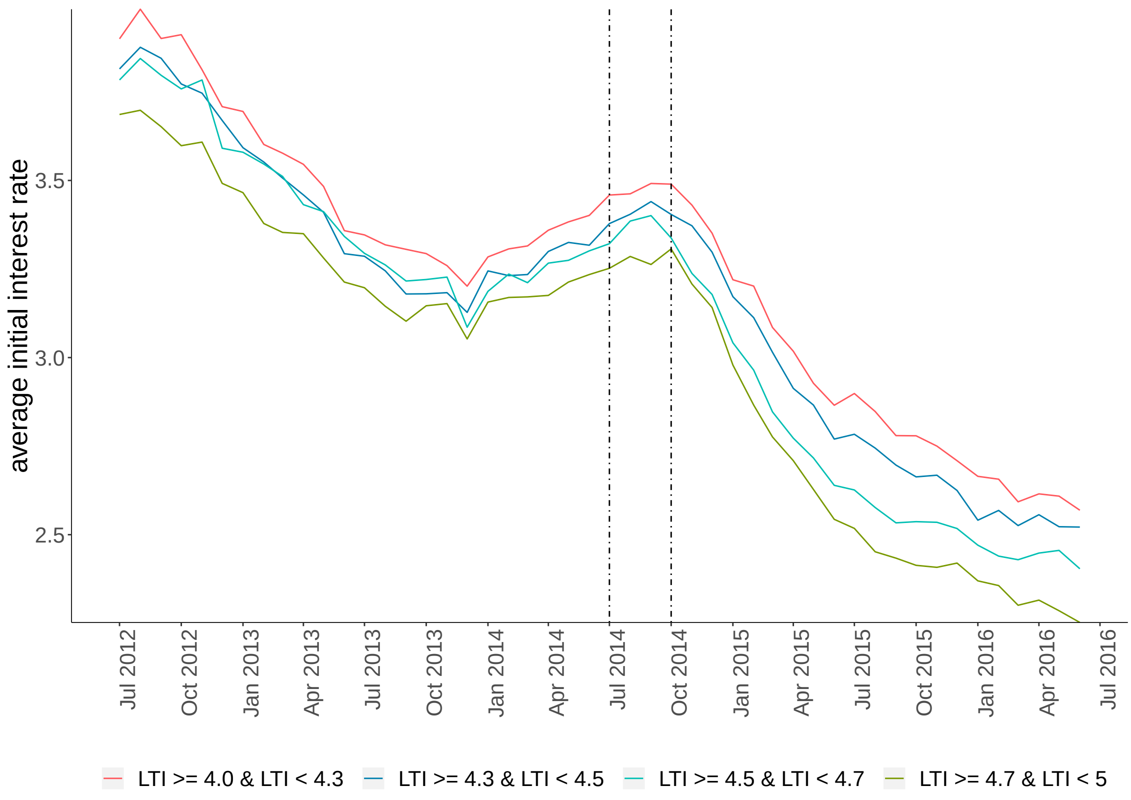
The changes in average loan size and composition of borrowers for high LTI mortgages raise interesting questions. For example, whether these changes are driven solely by the 15% limit being set on the volume rather than value of sales, and whether the redistribution consequences could be mitigated if the 15% limit was instead set on the value of sales.

4.2 Price and market dynamics

In addition to the distributional effects, the 15% constraint may have changed market dynamics and prices for high LTI mortgages. For example, the 15% constraint may have represented a negative supply shock, restricting the number of high LTI mortgages available to borrowers, and so may have increased prices. And, if the recommendation restricted competition among lenders, this could also lead to increased prices. On the other hand, the 15% constraint might not have been binding at all, and so mortgage prices might have been unaffected. The recommendation may have also changed lenders' pricing strategies. In this section, we document whether there are any changes in the mortgage price for like-for-like high LTI borrowers and changes in the market dynamics.

Figure 14 shows the average initial interest rate before and after implementation of the recommendation for the LTI buckets [4,4.3), [4.3,4.5), [4.5,4.7), [4.7,5). After implementation of the recommendation, there is a decrease in the unconditional average interest rate for the LTI buckets above the 4.5 cut-off in comparison to the trend of the average interest rate for the LTI buckets below the 4.5 cut-off. The figure also confirms that affected and unaffected buckets were moving in parallel before the announcement of the recommendation in July 2014, after which the trends diverge.

Figure 14: **Average initial interest rate before and after the recommendation**.



To assess how mortgage prices changed for like-for-like high LTI borrowers we can use a DD methodology that compares loans above 4.5 LTI and below 4.5 LTI before and after the implementation of the recommendation. Our baseline specification is a simple DD regression estimated at transaction level over the entire sample period.

The following baseline regression model is estimated:

$$r_{itpk} = \beta_0 + \beta_1 * 1[LTI_i = [4.5, 4.7)]_i + \beta_2 * 1[LTI_i = [4.5, 4.7)]_i * Post_t + \\ X_i\gamma + \gamma_k + \rho_p + \delta_t + \rho_p * \delta_t + e_{itpk}(M3)$$

where r_{itpk} is the initial interest rate on loan i originated in month t. $1[LTI_i = d]$ is a dummy variable for LTI buckets, which takes the value of 1 for the LTI bucket d = [4.5,4.7) and 0 for the LTI bucket d = [3.5,3.7). $Post_t$ is the dummy variable takes the value of 1 if a mortgage is originated after October 2014 or 0 if before. e_{itpk} are error terms.

The specification controls for borrower and product characteristics (X_i) – these are LTV bands, borrower age, credit score, whether a mortgage is issued based on single or joint income application, employment status of the main borrower, mortgage terms, and loan value. It also controls for time trends (δ_t is origination fixed effects) to account for any time varying changes in the market, for time invariant geographical factors (γ_k), and for factors that are specific to a lender (ρ_p). The model also includes an interaction term between credit score and LTV bands. The model is estimated using OLS. Standard errors are clustered at postcode area level.

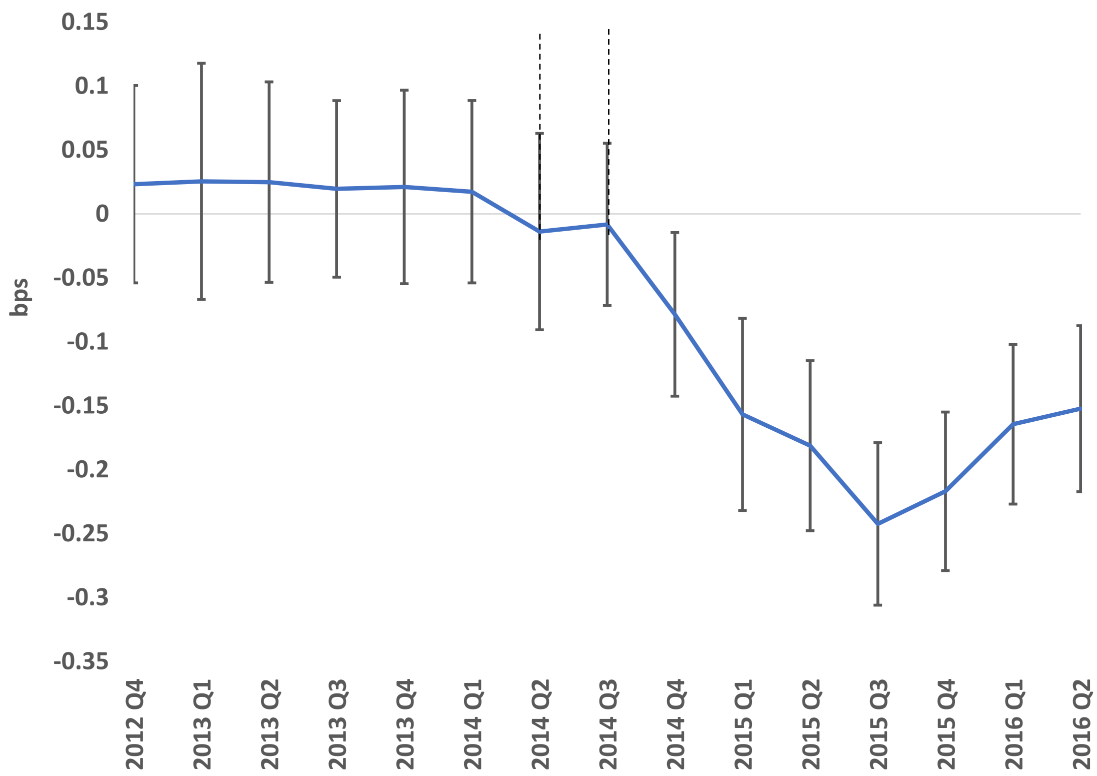
We are interested in the coefficients β_2, which estimates a change in an interest rate specific to the LTI bucket relative to the control group of mortgages. To see if the price of mortgages with LTIs above 4.5 changed, we used different control groups as a robustness check. These groups are mortgages with LTI between [4.3, 4.5), [4, 4.3), [3.7, 4). The model is run on 2-year fixed mortgages, the most popular product in the market.

The DD methodology relies on the assumption of parallel trends for the control and the treatment groups before any intervention. Figure 15 plots unconditional average initial interest rate over time for the baseline control and treatment groups, which are mortgages with LTI between [3.5, 3.7) and between [4.5, 4.7) respectively. It shows that there is a parallel trend between the 2 groups before the recommendation.

The coefficients of the interaction term $1[LTI_i = [4.5, 4.7)] * Post_t$ for 2-year fixed interest rate mortgages is negative and statistically significant (Table 16). These results are robust across different control groups. The specification considers fixed effects of lenders, regions and LTV bands, as well as credit and LTV interactions fixed effects. This suggests that after the recommendation was implemented, the interest rate for mortgages with LTI ratio between 4.5 and 4.7 was lower than the interest rate of mortgages in the control group. These results are statistically significant, and the magnitude of the coefficients suggests that the impact on the initial interest rate is around 6-8bps.

The price of the fixed rate mortgages is not only determined by the initial interest rate but also by the lender fees each consumer pays to set up their mortgage. We

Figure 15: **Testing for the parallel trend assumption, initial interest rate**.



Note: baseline specification where the LTI bucket d=[4.5, 4.7) is a treatment group and the LTI bucket d=[3.5, 3.7) is control group.

run the Model 3 on an APR based measure that calculates the mortgage cost on initial interest rate and lender fees (see Chapter II for details on how this measure is constructed). The results are presented in Table 27 in the Appendix C. It shows that the APR based measure in the treatment buckets decreased relative to the control buckets after implementation of the recommendation by around 4-7 bps. Results are robust to different control buckets of the LTI.

We also provide supporting evidence that the changes in the initial interest rate for 2-year fixed mortgages are related to the LTI limit recommendation, rather than other changes in the market. Similar to Model 3, we fit the following flexible DD specification:

$$r_{itpk} = \beta_0 + \sum_{d=3.3}^{>5} \left[\beta_1^d * 1[LTI_i = d] + \beta_2^d * 1[LTI_i = d] Post_t \right] + X_i\gamma + \gamma_k + \rho_p + \delta_t + \rho_p\delta_t + e_{itpk} \quad (M4)$$

In this specification a dummy for LTI bucket [3, 3.3) is omitted so that the coefficients β_1^d estimate the d-specific LTI bucket change in the interest rates relative to the loans in the omitted LTI bucket after the recommendation is implemented. The results of Model 4 for the 2-year fixed rate mortgages are summarised in Figure 16, which plots β_1^d coefficients estimates (the coefficient for the interaction term between LTI bucket and the Post dummy) from the flexible DD specification and its 95% confidence interval. The coefficient of the baseline LTI bucket [3, 3.3) is normalised to 0 so that all coefficients can be interpreted as the change in interest rates for a given LTI bucket after the FPC recommendation is implemented relative to the baseline. Figure 16 shows that a significant interest rate shift occurs for mortgages above the FPC LTI limit of 4.5.

Contrary to expectations that the 15% supply restriction should drive prices up, the analysis shows robust evidence that post-implementation the average price for high LTI mortgages dropped, keeping everything else constant (based on the 2-year fixed mortgages). In the next sub-section, we analyse whether this reduction in price is associated with lenders' exposure to high LTI mortgages before the recommendation and in sub-section 4.2.2 we discuss alternative drivers.

Table 16: **DD specification, 2-year fixed mortgage initial interest rate** .

Initial interest rate	Baseline: control [3.5, 3.7)		Robustness: control [3.7, 4)		Robustness: control [4-4.3)		Robustness: control [4.3-4.5)	
LTI [4.5;4.7) * Post	-0.0754	***	-0.0799	***	-0.0661	***	-0.0569	***
	(0.0081)		(0.0072)		(0.0070)		(0.0082)	
Year-month Fes	Yes		Yes		Yes		Yes	
Lender Fes	Yes		Yes		Yes		Yes	
Regions Fes	Yes		Yes		Yes		Yes	
LTV Fes	Yes		Yes		Yes		Yes	
LTV*credit score Fes	Yes		Yes		Yes		Yes	
Lender*Year-month Fes	Yes		Yes		Yes		Yes	
Adjusted R-squared	0.68		0.67		0.65		0.65	
Number of observations	108,329		142,512		130,754		96,390	

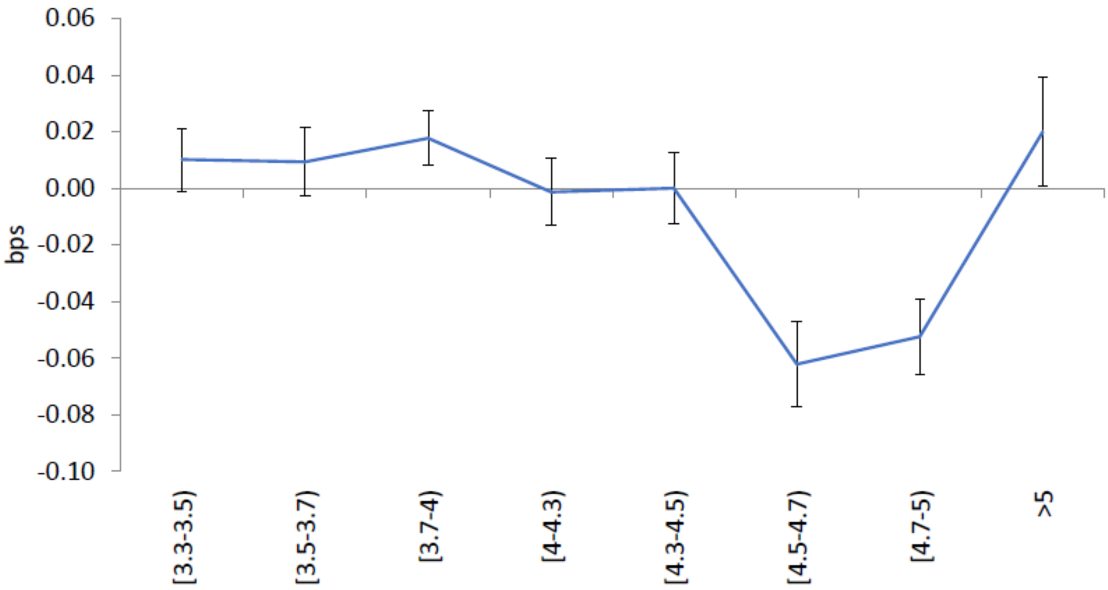
*p<0.1; **p<0.05; ***p<0.01, standard errors are clustered at property area level. These results are robust to winsorisation.

4.2.1 Lenders' proximity to the 15% constraint

Before the recommendation lenders differed in their proportion of high LTI mortgages.[43] Figure 17, Panel A shows that mortgage lenders in scope of the recommendation were either far away from the 15% limit imposed by the FPC policy or very close to it. The figure captures the average exposure of lenders to high LTI mortgages before the recommendation and does not capture whether the 15% limit was binding at the time of announcement or implementation. The share of high LTI

[43] To obtain lenders' exposure to high LTI mortgages, for each lender we calculate: a) the share of high LTI mortgages in total sales for each quarter in the period before the LTI recommendation was implemented; and b) average these quarterly values. These values represent lenders' average exposure to high LTI mortgages before the recommendation. The baseline calculations are based on the period from July 2012 to October 2014. Any seasonal variation should be averaged over this period. For robustness, we also calculated the measure over two time periods before the LTI recommendation was implemented (from April 2013 to March 2014; and from January 2013 to July 2014). The pairwise spearman rank correlation between these three measures is high, between 80% and 95%. This means that a lender's exposure to high LTI mortgages relative to other lenders does not vary between the three time periods.

Figure 16: **Flexible DD estimates of the FPC recommendation on interest rates, 2-years fixed mortgages**.



Note: all coefficients can be interpreted as the change in the variable of interest for a given LTI bucket following the implementation of the FPC recommendation relative to the LTI bucket [3, 3.3). An economically significant change in the initial interest rate happens at the FPC 4.5 cut-off. This shows that changes in the initial interest rate are related to the LTI 4.5 cut-off rather than other changes in the market.

mortgages in total sales is averaged over quarters in the period from July 2012 to October 2014.

The 15% constraint may have affected lenders differently, or not at all. For example, mortgage lenders that were closer to the 15% limit before the recommendation could have become more cautious about their exposure to high LTI mortgages once the policy was announced, and subsequently scale back this lending. In contrast, lenders that were further away from the 15% may have interpreted the implementation of a 15% high LTI lending limit as a signal of an acceptable level of risk and increased their exposure to high LTI mortgages. Alternatively, the 15% may not have been binding for some lenders.

Figure 17, Panel B shows how lenders' exposure to high LTI mortgages varies after implementation of the recommendation. The period before implementation is from January 2013 to October 2014. Some lenders that were closer to the 15% constraint (measured by volume of sales) reduced the proportion of high LTI loans in their new sales afterwards. Other lenders that were further from the limit increased the proportion of high LTI mortgages in their new sales afterwards.

Here we would like to see whether the fall in mortgage price depended on how constrained lenders were to the 15% policy. We modify Model 4 to allow the DD coefficient to vary by lenders' exposure to high LTI loans. In Model 5, we capture the differential impact of the policy on interest rates for those mortgages affected by the LTI limit.

$$\begin{aligned} r_{itpk} = \beta_0 + \beta_1 * 1[LTI_i = [4.5, 4.7)]_i + \beta_2 * 1[LTI_i = [4.5, 4.7)]_i * Post_t + \\ \beta_4 * Post_t * exposure_p + \beta_3 * 1[LTI_i = [4.5, 4.7)]_i * exposure_p + \\ \beta_5 * 1[LTI_i = [4.5, 4.7)]_i * Post_t * exposure_p + \\ X_i\gamma + \gamma_k + \rho_p + \delta_t + \rho_p\delta_t + e_{itpk} \end{aligned} \tag{M5}$$

β_5 is a triple difference coefficient of the interaction term $1[LTI_i = [4.5, 4.7)] * Post_t * exposure_p$. It measures whether the difference in the initial interest rate (r_{itpk}), before and after the recommendation ($Post_t$), between the treatment and control groups, depended on lenders' exposure to high LTI mortgages prior the recommendation ($exposure_p$).

The β_5 coefficients for the 2-year fixed interest rate mortgages is negative and statistically significant (Table 17). These results are robust across different control groups, except the baseline case. There is some evidence that after the implementation of the recommendation, the decrease in interest rates for mortgages with LTI ratio between 4.5 and 4.7 relative to the control group is bigger for lenders that were closer to the 15% constraint and constrained by the policy.

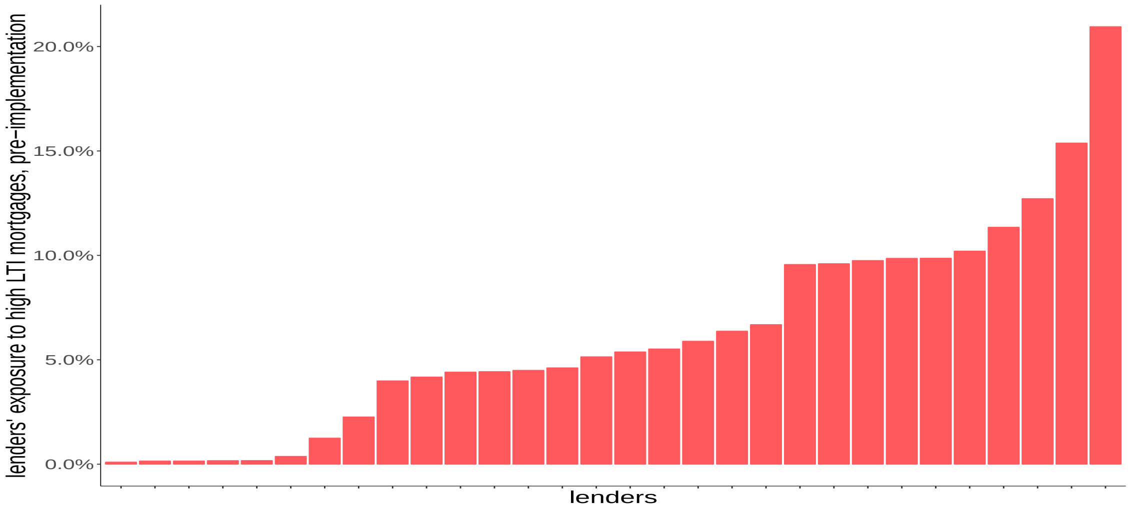
Table 17: **DD specification, 2-year fixed mortgage initial interest rate** .

Initial interest rate	control [3.5, 3.7)	control [3.7, 4)	control [4-4.3)	control [4.3-4.5)
LTI [4.5;4.7) * Post	-0.0691 ***	-0.0491 ***	-0.0131	0.0036
	(0.0206)	(0.0174)	(0.0165)	(0.0215)
LTI [4.5;4.7) * Post*exposure	-0.1672	-0.4371 ***	-0.6259 ***	-0.6871 ***
	(0.1990)	0.1691	(0.1592)	(0.2022)
LTV FEs	Yes	Yes	Yes	Yes
LTV*credit score FEs	Yes	Yes	Yes	Yes
Year-month FEs	Yes	Yes	Yes	Yes
Lender FEs	Yes	Yes	Yes	Yes
Regions FEs	Yes	Yes	Yes	Yes
Lender*year-month FEs	Yes	Yes	Yes	Yes
Adjusted R-squared	0.68	0.67	0.65	0.65
Number of observations	108,329	142,512	130,754	96,390

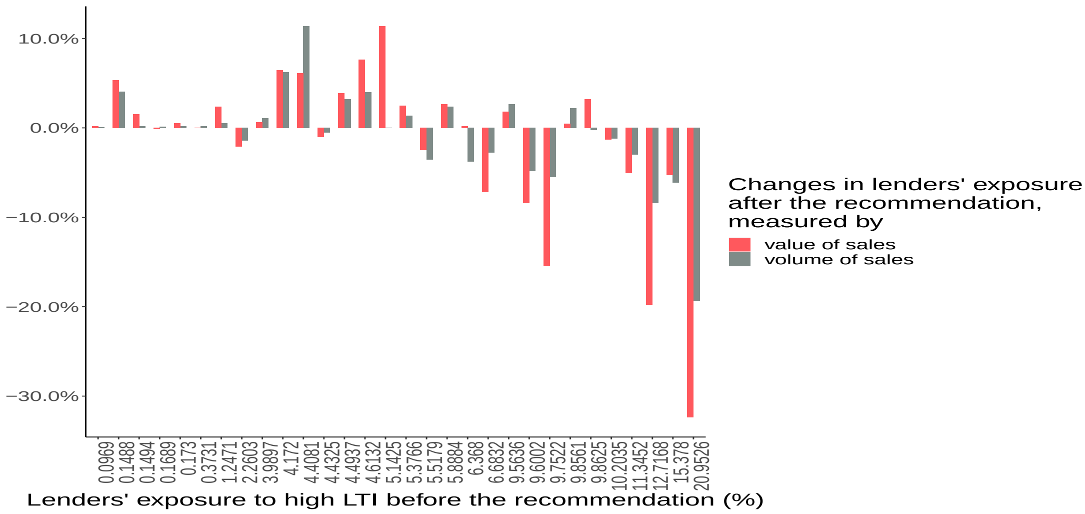
*p<0.1; **p<0.05; ***p<0.01, standard errors are clustered at property area level. These results are robust to winsorisation.

Figure 17: **Average % of high LTI mortgage sales in total number of sales prior to the recommendation and its changes after the recommendation is implemented.**.

Panel A



Panel B



Note: The period before implementation is from July 2012 to October 2014, the period after the implementation is from October 2014 to June 2016. % of high LTI mortgages in total number of sales (or in total value of sales) are calculated over each quarter by each lender, these values are then averaged over the quarters before and after the implementation.

4.2.2 Discussion

In this section we analysed changes in mortgage prices for high LTI mortgages after the recommendation was implemented. The 15% constraint represents a restriction of supply, and such a negative shock should have driven up prices. However, the analysis finds the opposite effect, ie robust evidence that post-implementation prices for high LTI mortgages decreased. In this section, we discuss potential reasons for this.

We looked at the market dynamics and found that post-implementation of the recommendation some lenders whose share of high LTI mortgages had been closer to the 15% limit, reduced their proportion of high LTI mortgages and some lenders that had a low share of high LTI mortgages subsequently increased their proportion of high LTI mortgages. We also found a meaningful relationship between a lender's proximity to the 15% constraint prior to the recommendation and the fall in the mortgage price. Lenders that were closer to the 15% constraint had a larger reduction in the initial interest rate.

The decrease in the price for mortgages could also be explained by other drivers, including changes in competition, lenders' pricing strategies, and unobservable risk characteristics.

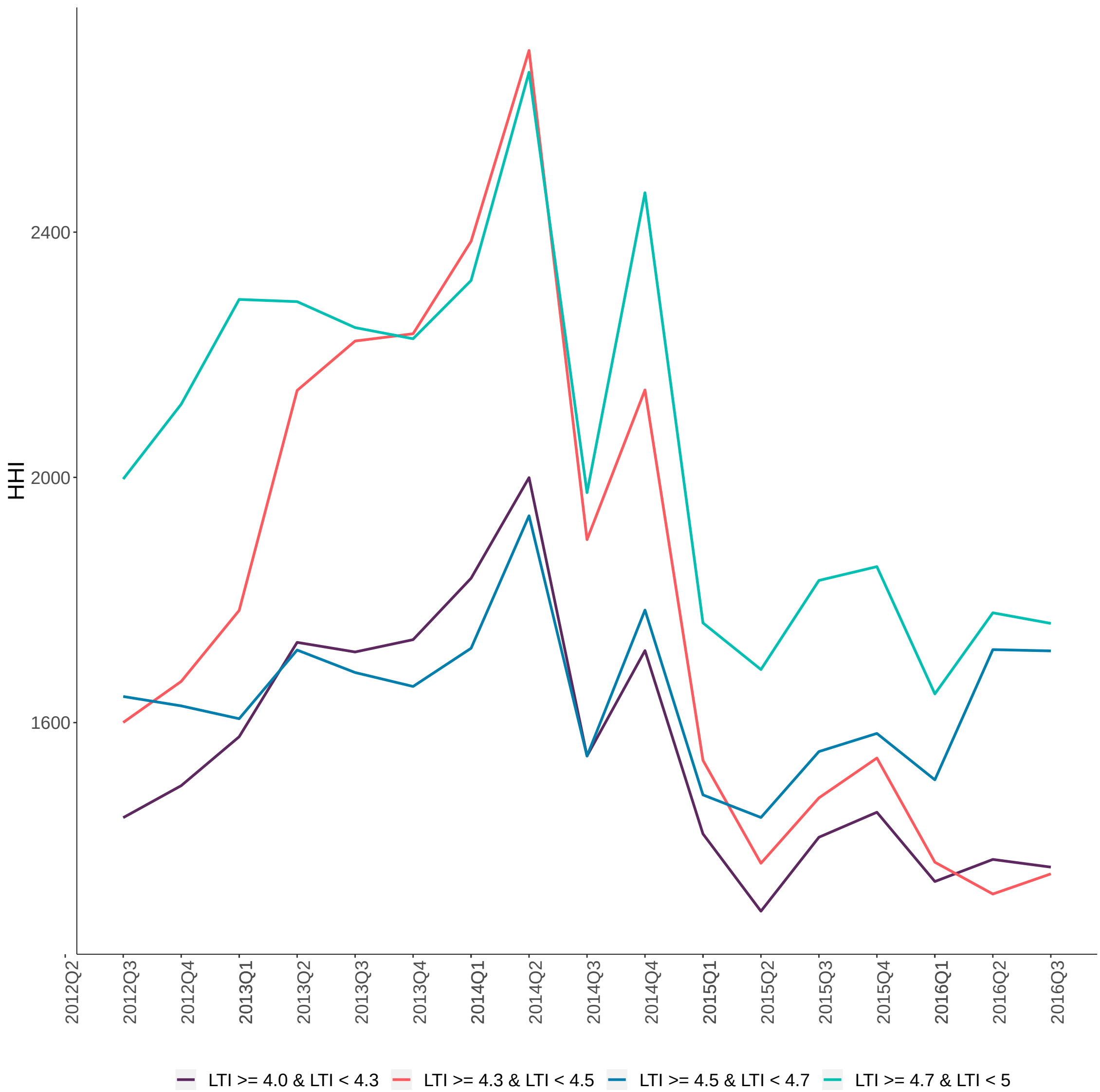
We looked at the evolution of market concentration, a proxy for competition, by identifying mortgages of different LTI buckets as a market segment, and calculating the Herfindahl-Hirschman Index (HHI) for each segment. The Figure 18 shows the calculated HHI, which suggests that the concentration measure for mortgages with LTI bucket [4.3-4.5) and [4.7-5) fell by more compared to mortgages with LTI buckets [4-4.3). The concentration for mortgages with LTI bucket [4.5-4.7) increased. Unfortunately, these patterns cannot be reconciled with the fall in price for high LTI mortgages. If market concentration was related to the reduction in price, we would have seen a reduction in the HHI measure for the segment of mortgages with LTI above 4.5 relative to the segment of mortgage with LTI below 4.5. However, it may also be the case that the threat of increased competition in the high LTI segment, even if there was not a significant decrease in concentration, was the reason for the interest rate changes. This hypothesis needs further investigation.

The fall in the price could not be explained by any observable risk characteristics or changes in borrower composition. The regression models 4 and 5 control for difference in product, borrower, provider and regional characteristics and potential non-linearities, like LTV and credit score buckets, including their interaction effects. If we control for provider and regional characteristics only, omitting product and borrower characteristics, the fall in the initial interest rate is around 16bps compared to 6-8bps in the full Models 4 and 5. It means that borrower and product characteristics already account for about 10bps reduction in initial interest rate post-implementation of the recommendation.

Table 15 already showed that ex-ante credit risk characteristics like credit score, payment to income and LTV in the treatment group in comparison to the control group changed only marginally (towards lower risk) after the recommendation took effect. However, the fall in prices could reflect changes in unobservable borrowers' characteristics. Lenders could have become very selective and offered high LTI loans to less risky consumers on dimensions we cannot observe. This hypothesis matches the lack of transparency in eligibility criteria, which allows lender to choose at their discretion what type of borrowers are approved for high LTI mortgages.

Another potential explanation is that lenders changed their pricing strategies for high LTI mortgages. Accordingly, our analysis indicates a fall in mortgage price.

Figure 18: **HHI by LTI buckets**.



5 Conclusion

This paper provides evidence of changes in the market for high LTI mortgages post-implementation of the FPC recommendation. We used DD and flexible DD research methodologies and a unique mortgage transaction-level dataset to document changes in the mortgage market after the introduction of the recommendation with a particular focus on consumers. The paper finds that after implementation of the recommendation the average loan size for high LTI mortgages increased by 4-7%. This suggests that lenders originated high LTI loans for borrowers with higher incomes. As a result, we find robust evidence of changes in composition of high LTI borrowers: 1) an increase in the proportion of home movers; 2) a decrease in the proportion of first-time buyers; 3) an increase in the proportion of joint income applicants. After implementation, although the overall proportion of high LTI mortgages to the total number of sales in the market stays around 10%, lenders' individual exposure to high LTI mortgages changed. Some lenders, whose share of high LTI mortgages had been closer to the 15% limit, reduced their proportion of high LTI. In contrast, some lenders that previously had a low share of high LTI mortgages increased their proportion of them. After controlling for borrower, product, and lender characteristics, we find that post-implementation the mortgage price for high LTI mortgages on average decreased. The fall in the mortgage price was stronger for lenders that used to be closer to the 15% constraint.

Here we also highlight some research limitations, which might weaken the strength of our findings. We also discuss our approach to overcome these limitations.

The main challenge was that other policy interventions were happening at a similar time as the FPC recommendation on LTI, making it difficult to isolate individual policy impacts. The Mortgage Market Review (MMR) rules came into effect in April 2014, 6 months before implementation of the FPC recommendation. The biggest change was that borrowers looking to take out a mortgage now had to undergo an affordability assessment. In addition to the MMR rules, in June 2014 the FPC recommended that mortgage lenders should apply an interest rate stress, when assessing borrowers' affordability (BOE (2014)). The affordability assessment may have a much larger effect for borrowers with LTIs of 4.5 and above than for borrowers with lower LTIs. Borrowers' affordability should be tested using reversion rate + 300bps. For a borrower with a 25-year term and a reversion rate of 4%, an LTI of 4.5 would imply a stressed Debt Service Ratio (DSR) of 35-45%. If a borrower has a stressed DSR above 35-40%, it is more likely they will fail the affordability test. Our treatment and control groups might have been affected differently by these changes and it is challenging to rule out that the findings in the paper are just because of the FPC recommendation on LTI. However, the flexible DD methodology showed that changes in borrower composition and initial interest rate happened exactly at the 4.5 FPC cut-off. It is also important to note that the changes in payment-to-income ratio, which could serve as a proxy for affordability, before and after the recommendation was implemented, for high LTI mortgages changed only by 1% (Table 15).

There could also be an issue of potential endogeneity if, for example, the recommendation were a response to trends already happening with loans at LTI above 4.5. Besley and Case (2000) discussed an example of policy endogeneity. However, one can argue that the FPC recommendation on LTI was exogenous, because it was designed as an 'insurance' policy and was not 'expected to have a material impact on mortgage lending and housing transactions' (BOE (2014)). Nevertheless, this paper also addressed any potential issue of endogeneity by showing that changes in loan value, borrowers' composition and price happen exactly at the 4.5 cut-off (the flexible DD results in Figure 13) and at the time the recommendation was implemented (the test on the parallel trend assumption in Figure 12). This is in line with the findings of DeFusco et al. (2017), and this paper closely follows their methodology. Similar to the flexible DD approach, and to avoid any contamination of the estimation due to a shift of borrowers from just below 4.5 to just above 4.5, this paper uses buckets further away from the 4.5 cut-off as a control group. We carry out further robustness checks using buckets just below 4.5 cut-off.

The government also launched the help-to-buy (HTB) scheme in October 2013 and restricted it to new mortgages with LTIs below 4.5 from October 2014. The HTB scheme was designed to help first-time buyers to buy a home or home movers with limited equity to move houses. Under the HTB scheme, buyers only needed to provide 5% of a home's value as a deposit. This scheme could have affected our control group of borrowers with LTI ratios below 4.5. That is, borrowers that previously could not afford a mortgage were more likely to enter the HTB scheme and (until October 2014) be borrowers with high LTI and LTV ratio. We checked if the scheme was affecting our findings by choosing a control group of borrowers with LTIs well below 4.5 and crossed checked the results to borrowers with LTIs just below 4.5 (flexible DD approach), and as discussed above the results are robust. Another approach was to re-run the main findings on the data excluding mortgages provided under government initiatives. However, this data field is only available after 2015.

The fast growth in house prices relative to incomes could also have affected distribution of borrowers across LTI buckets. We offset this impact by performing robustness checks on regions with low house price inflation, and by controlling for regional characteristics in our regression analyses.

Part V

Real Rigidities and Optimal Stabilization at the Zero Lower Bound in New Keynesian Economies

1 Introduction

Keeping the nominal interest rate at zero even after the natural rate has recovered to positive values, enacting an increase in government spending or, more controversially, introducing tax increases have all been discussed as viable stabilisation policy strategies in New Keynesian economies subject to deep recessions. This paper studies the extent to which the desirability of such strategies is affected by the nature of interaction among firms and households in the product and labour markets. It highlights that both the optimal length of time spent at the zero bound, the strength of policy responses, and the magnitude of observed macroeconomic outcomes under optimal policy (such as inflation rates) are significantly affected by the degree of strategic complementarity in price- and wage-setting. We show that the structure of the labour market (in particular, whether or not labour markets are segmented) has a profound effect on both optimal policy and macroeconomic outcomes.

The importance of strategic complementarity between price- or wage-setters has received considerable attention in the context of the ability of New Keynesian models to replicate observed persistence in the real economy following monetary policy shocks.[44] However, the literature on stabilization policy at the zero lower bound has so far largely ignored the implications of strategic interaction in price and wage setting for policy under the specific circumstances presented to policy makers by the presence of this nonlinearity.[45] Exploring the interaction between strategic complementarity and optimal policy at the zero lower bound is important, as seemingly innocuous assumptions about market structure or structural parameters often taken in the literature have non-trivial implications for the way we should think about 'good' policy and what is desirable to achieve in terms of outcomes in the economy.

[44] See Edge (2002), Woodford (2011) or Ascari (2003), for example.

[45] Most recently, Eggertsson and Singh (2019) discuss sector specificity of labour markets in a paper on zero-lower-bound issues. They concentrate on the analytical usefulness of this assumption, and do not explore the implications for policy or economic dynamics.

In this paper, we study a New Keynesian setup in which prices and/or wages are sticky, and the labour market can be either non-segmented (or economy-wide) or segmented (sector-specific). Government spending is valued and the income tax policy is determined endogenously. This economy is subject to a large fundamental shock as a result of which optimally set nominal interest rates hit the zero lower bound.[46] While Correia et al. (2013) have shown that a sufficiently rich set of policy instruments can completely circumvent the liquidity trap problem, and may even enable policy makers to implement the first best outcome, in this paper we study a world in which solutions that are costless in welfare terms are ruled out. In addition to setting the tax on wage income and government spending, the authorities can use forward commitment concerning interest rates to stabilize the economy in a liquidity trap.[47] Eggertsson and Woodford (2004) and Nakata (2011) have also studied a simultaneous determination of optimal monetary and fiscal policy in a deep recession but did not consider in greater depth the role of wage stickiness and, in particular, strategic complementarities. Christiano et al. (2011) and Christiano (2010), whilst including wage stickiness, only examined the functioning of ad hoc (tax) policies and concentrated on the implied real economy effects.

We find that the optimal response in the inflation rate to a given large shock varies by as much as one order of magnitude depending on whether we assume sector-specific labour markets or an economy-wide labour market. We also highlight the importance of key parametric assumptions for policy and outcomes at the zero lower bound. In particular, we show that depending on the nature of nominal wage adjustment in the economy, a linear production technology may justify relatively high expected inflation or—at the other extreme—strict price-level targeting strategies. The differences are smaller with a concave production function.

Intuitively, in the presence of nominal price and/or wage rigidities (à la Calvo), features that force price- or wage-optimizers to consider more carefully the potential adverse implications of demand reallocations for their profits act to supress relative price adjustment following shocks. It matters, in particular, if real wage changes are

[46]The policy prescriptions obtained in our framework are standard given that the source of the downturn in our model is also standard—a shock to the rate of time preference of agents. Schmitt-Grohé and Uribe (2004) and Mertens and Ravn (2014) have questioned the usefulness of such conventional policy advice if the cause of the severe downturn in the economy is that expectations are not well-anchored. We believe this discussion is beyond the scope of the intended contribution of this paper.

[47]Such a set of policy tools better reflects the policy decisions implemented by central banks and governments around the developed world in the wake of the most recent severe recession. See, for example, EC (2009) or CEA (2009). Only the United Kingdom have on a one-off basis implemented a policy concerning the general VAT rate that is vaguely in line with Correia et al. (2013).

seen as an economy-wide phenomenon or something that affects particular industries only. In the latter case, sectoral price determination needs to take into account the consequences of price-change-induced demand re-allocation for sectoral wages (and profits). An implication of this is more caution in price re-optimization, less inflation volatility and more volatility in real variables. The latter is manifested in both larger response magnitudes and longer duration of adjustment following shocks. Such considerations are, understandably, exacerbated by factors such as the intersectoral substitutability of different types of products and labour, and the nature of the production technology. This is something we demonstrate in the paper too.

The optimal policy response in the presence of conditions for dampened adjustment is to act more forcefully. In terms of monetary policy action, the commitment to keep interest rates at zero lasts longer after the zero bound ceases to bind once real rigidities are taken into account. Krugman et al. (1998) famously argued that monetary policy is not ineffective in a liquidity trap as long as it is able to affect inflation expectations. Expectations of higher inflation lower the current real interest rate and act to stimulate demand even if the short-term nominal interest rate is stuck at zero. It has been shown in the context of standard New Keynesian models that the monetary policy consistent with such evolution of prices involves a commitment to keep the nominal interest rate at zero for some time after the zero bound ceases to bind. Eggertsson and Woodford (2004), Jung et al. (2005) and Adam and Billi (2006) have shown this formally, whilst arguing for very modest rates of expected inflation. Our paper demonstrates that the optimal duration of the commitment to keep interest rates at zero as well as the implied inflation rates vary considerably depending on the assumed degree of strategic complementarity in price and wage setting decisions. Contrary to what one might expect, longer forward commitment does not translate into larger inflation responses. It merely mitigates their absence. The point of a stronger monetary policy response is primarily to engineer a larger boom in the real economy in the future which reduces desired savings and stimulates demand in the short run. This is consistent with a thought experiment in Werning (2011) who examined the case of a simple economy in a liquidity trap with artificially fixed prices. We show that such a simple exercise is a close approximation of optimal dynamics in a sticky-price sticky-wage New Keynesian economy with a linear production technology.

When real rigidities are stronger, other tools in the conventional stabilization toolbox are applied more forcefully too: the desired short-term government spending expansion is larger and the government must commit itself to greater cuts in the future. A policy strategy of 'leaning against the wind' in which government spending is first raised and then cut whilst the nominal interest rate is at the zero bound has been proposed by Gertler (2003) due to its impact on the natural rate of interest. Nakata (2011) and Werning (2011) have shown this to be a feature of optimal policy in a liquidity trap. Werning (2011) argues that the mentioned strategy is almost entirely 'opportunistic' and the motivation for it has little to do with stabilization.[48] We provide evidence supporting this view too. Since we study optimal policy from a timeless perspective, in line with Schmidt (2013), we do not find large gains in terms of the stability of nominal or real variables as a result of the deployment of government spending.

The idea that an income tax hike is desirable at the zero bound due to its effect on (expected) inflation and the real interest rate has been discussed in Eggertsson (2011) and Nakata (2011). In Correia et al. (2013), tax policy is best thought of as a price stabilization tool given its impact on the marginal cost in the economy. In our model, we also observe gains in price stability once tax policy is activated in addition to the other tools in the policy maker's toolbox. Overall, the budgetary impact of stabilization measures is close to zero in the short term.

We also examine the state-dependency of our results as in Burgert and Schmidt (2014). We find that higher initial indebtedness tends to amplify the differences across economies with different labour market structures. In particular, the optimal inflation response is even larger in the economy with economy-wide labour markets relative to the alternatives considered when initial debt is high. Tax policy deployed more forcefully bears the brunt of the initial adjustment in debt. This can be an increase or a cut depending on where the economy starts relative to its steady state.

The rest of the paper is organized as follows. Section 2.1 introduces different versions of a baseline model that form the basis for our analysis of the design of optimal monetary and fiscal policies in a liquidity trap. This model is parameterized and solved using the nonlinear method explained in great detail in Nakata (2011). The results of the numerical exercise are presented and related to the existing literature in Section 3. Section 4 concludes.

[48] In a public finance context, 'opportunistic' policy makers will seek to increase the provision of public goods when the marginal rate of transformation between public and private goods falls.

2 Research design

2.1 The model

This section describes a model of an economy with sticky nominal wages and prices akin to Benigno and Woodford (2005) which builds on Erceg et al. (2000). The government authorities in our economy set the interest rate, government spending and the distortive labor income tax rate to stabilize the economy. Shocks to the discount factor are the only source of disturbance in the model, and we examine the economy's adjustment under perfect foresight along a deterministic path following a single large innovation to the discount factor. If this innovation was small, it could be fully offset by a cut in the nominal interest rate, and other policy instruments would not play a role in stabilizing the economy.

Whilst the model is closer to the widely used medium-scale setups than the more common simple stylized frameworks in terms of its complexity, it should still be thought of only as a relatively tractable environment for the study of policy interactions. The quantitative results from this model are especially subject to this caveat. The main lessons concerning policy coordination should, however, apply more generally, as the circumstances we examine are implicit in all larger-scale models.

2.1.1 The discount factor shock

An exogenous shock to the discount factor of agents, representing a change in their preferences in terms of consumption and savings, is used to capture the idea of a severe demand-led contraction in the economy.

As in Nakata (2011), we assume that the discount factor at time $t+s$ is defined as $\beta\delta_s$, i.e. δ_s shows the relative difference between discount factors at time $t+s$ and $t+s+1$. The following assumptions about the discount factor shock hold in the model

$$\begin{aligned}
\delta_0 &= 1, \\
\delta_1 &= 1+\varepsilon_{\delta,1}, \\
\delta_s &= 1+\rho_\delta\left(\delta_{s-1}-1\right) \text{ for } s \geqslant 2.
\end{aligned}$$

The discount factor shock is realized before optimization decisions are made. It holds that $\varepsilon_{\delta,1} > 0$ and the shock persists, but decays with the time at the rate $0 < \rho_\delta < 1$.

2.2 Households and the labour market

There is a continuum of monopolistically competitive households located on the unit interval $[0,1]$. Those of type j choose private consumption of a final good $C_t(j)$ and holdings of one-period risk-free nominal government bond $B_t(j)$ to maximize welfare given by

$$E_t \sum_{s=0}^{\infty} \beta^s \prod_{k=0}^{s} \delta_k \left[\frac{C_{t+s}(j)^{1-\chi_C}}{1-\chi_C} - \chi_{N,0} \frac{N_{t+s}(j)^{1+\chi_{N,1}}}{1+\chi_{N,1}} + \chi_{G,0} \frac{G_{t+s}^{1-\chi_{G,1}}}{1-\chi_{G,1}} \right]$$

subject to the constraint

$$P_{t+s} C_{t+s}(j) + \frac{B_{t+s}(j)}{R_{t+s}} \leqslant (1-\tau_{n,t+s}) W_t(j) N_{t+s}(j) + B_{t+s-1}(j) - T_{t+s}^{LS} + D_{t+s} \quad (3)$$

The variable P_t is a price of a final good, R_t stands for the gross nominal return on the bond, while $\tau_{n,t}$ is the labor income tax rate. T_t^{LS} refers to the lump sum taxes (transfers) that may be paid by (to) the households. The profits generated by monopolistically competitive firms are transferred to households in the form of lump-sum dividends D_t. This maximization exercise yields the Euler equation

$$C_t^{-\chi_C} = E_t \beta \delta_t R_t C_{t+1}^{-\chi_C} \Pi_{t+1}^{-1}, \quad (4)$$

where $\Pi_t = P_t/P_{t-1}$ is price inflation. The Euler equation is not indexed by the households, as we assume completeness of insurance market against idiosyncratic shocks and that the initial holdings of assets are the same across households.[49] Therefore, $C_t(j) = C_t$ and $B_t(j) = B_t$ for all j and t.[50]

Households of type j supply a differentiated labor service $N_t(j)$ at a wage rate $W_t(j)$. There is a perfectly-competitive employment agency that aggregates the supplied differentiated labor in an index according to the standard Dixit-Stiglitz formula

$$N_t = \left[\int_0^1 N_t(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right]^{\frac{\varepsilon}{\varepsilon-1}},$$

in which ε is the elasticity of substitutions between differentiated labour. The perfectly-competitive employment agency sells aggregated labour to producers of final goods at an aggregate wage index W_t. The agency chooses $N_t(j)$ to maximize nominal profits $W_t N_t - \int_0^1 W_t(j) N_t(j)$, taking the wage rate $W_t(j)$ and the aggregate price index W_t as given. In optimum, the employment agency's demand for type-j

[49] An implication of the former is that the exact distribution of shares across firms does not matter. Hence, we do not specify dividends D in detail.

[50] Notice here that if δ is small enough, it can be fully offset by a change in R, leaving the rest of the economy unaffected.

labour is given by

$$N_t\left(j\right) = N_t\left[\frac{W_t(j)}{W_t}\right]^{-\varepsilon}. \tag{5}$$

The aggregate wage index is then given by

$$W_t = \left[\int_0^1 W_t\left(j\right)^{1-\varepsilon} dj\right]^{\frac{1}{1-\varepsilon}}.$$

To introduce wage stickiness, the model assumes a system of staggered wage contract for the households: households of a certain type are able to change their wages with probability $1-\xi_w$ at any given period of time. Whenever the households are allowed to re-optimize their wage, they choose optimal W_t^* to maximize expected discounted sum of utilities, taking into account that they may not be allowed change the wage rate, subject to the demand for labor equation and the budget constraint. For simplicity, we do not consider wage indexation. The households thus choose the wage rate to maximize

$$E_t \sum_{s=0}^{\infty} (\xi_w \beta)^s \prod_{k=0}^{s} \delta_k \left[\frac{C_{t+s}^{1-\chi_C}}{1-\chi_C} - \chi_{N,0}\frac{N_{t+s}\left(j\right)^{1+\chi_{N,1}}}{1+\chi_{N,1}} + \chi_{G,0}\frac{G_{t+s}^{1-\chi_{G,1}}}{1-\chi_{G,1}}\right]$$

subject to (3) and (5). This problem gives us the wage setting equation

$$\left(w_t^*\right)^{1+\varepsilon\chi_{N,1}} = \frac{\varepsilon}{\varepsilon-1}\frac{N_{n,t}}{N_{d,t}}, \tag{6}$$

where $w_t^* = W_t^*/W_t$ with

$$N_{n,t} = \chi_{N,0} N_t^{1+\chi_{N,1}} + E_t \beta \delta_t \xi_w \left(\Pi_{t+1}^w\right)^{\varepsilon\left(1+\chi_{N,1}\right)} N_{n,t+1}, \tag{7}$$

$$N_{d,t} = w_t N_t C_t^{-\chi_C}\left(1-\tau_{n,t}\right) + E_t \beta \delta_t \xi_w \left(\Pi_{t+1}^w\right)^{\varepsilon-1} N_{d,t+1}. \tag{8}$$

We have defined $\Pi_t^w = W_t/W_{t-1}$ and $w_t = W_t/P_t$. Given our wage setting mechanism, the evolution of the aggregate wage index follows

$$1 = \left(1-\xi_w\right)\left(w_t^*\right)^{1-\varepsilon} + \xi_w\left(\Pi_t^w\right)^{\varepsilon-1}. \tag{9}$$

2.2.1 Firms

There is a continuum of intermediate differentiated goods indexed i. Firms operating in sector i use a linear production technology to produce output

$$Y_t(i) = N_t\left(i\right)^{1/\alpha}. \tag{10}$$

with $\alpha \geqslant 1$. The price of an intermediate good i is $P_t(i)$. The representative final goods producer that operates in a perfectly competitive environment sells Y_t which is an aggregate of $Y_t(i)$ according to

$$Y_t = \left[\int_0^1 Y_t\left(i\right)^{\frac{\theta-1}{\theta}}\, di\right]^{\frac{\theta}{\theta-1}}, \tag{11}$$

in which θ is the elasticity of substitutions between the differentiated intermediate products. The representative final goods producing firm sells its product to the consumers at a price P_t. It chooses the quantity of each differentiated good to maximize its profit $P_t Y_t - \int_0^1 P_t(i) Y_t(i) di$. As a result, demand for intermediate good i is given by

$$Y_t\left(i\right) = Y_t\left[\frac{P_t(i)}{P_t}\right]^{-\theta}. \tag{12}$$

The aggregate price index is given by

$$P_t = \left[\int_0^1 P_t\left(i\right)^{1-\theta}\, di\right]^{\frac{1}{1-\theta}}.$$

Price adjustment is assumed to be staggered too. It is assumed that in any given period, the intermediate goods producing firms operating in a given sector are able to re-optimize their price with a probability $1-\xi_p$. Whenever the firms are able to re-optimize their price, they choose the optimal P_t^* to maximize expected discounted sum of profits subject to the demand for their product defined in equation (11). The problem of the firms is thus

$$\begin{array}{l} \max\limits_{P_t^*} E_t \sum\limits_{s=0}^{\infty} \left(\xi_p \beta\right)^s \prod\limits_{k=0}^{s} \delta_k \left[P_{t+s}^* Y_{t+s}\left(i\right) - W_{t+s} Y_{t+s}(i)^{\alpha}\right] \\ s.t.\ (12). \end{array}$$

The solution for the optimal price is given by

$$\left(p_t^*\right)^{1+\theta(\alpha-1)} = \frac{\theta}{\theta-1}\frac{C_{n,t}}{C_{d,t}}, \tag{13}$$

where $p_t^* = P_t^*/P_t$ with

$$C_{n,t} = \alpha w_t Y_t^{\alpha} C_t^{-\chi_C} + E_t \beta \delta_t \xi_p \Pi_{t+1}^{\theta\alpha} C_{n,t+1}, \tag{14}$$

$$C_{d,t} = Y_t C_t^{-\chi_C} + E_t \beta \delta_t \xi_p \Pi_{t+1}^{\theta-1} C_{d,t+1}. \tag{15}$$

The dynamic of the aggregate price index follows

$$1 = (1 - \xi_p) (p_t^*)^{1-\theta} + \xi_p \Pi_t^{\theta-1}. \tag{16}$$

2.2.2 Government

Monetary and fiscal authorities coordinate their action to maximize social welfare. The monetary branch of the central government sets the nominal interest rate R_t, and is constrained by the zero lower bound

$$R_t \geqslant 1 \text{ for all } t. \tag{17}$$

The fiscal authority sets the tax rate $\tau_{n,t}$ and decides about government spending G_t. The government flow budget constraint tracking the evoution of debt is then given by

$$\frac{b_t}{R_t} = \frac{b_{t-1}}{\Pi_t} - \tau_{n,t} w_t N_t + G_t - T_t^{LS} \tag{18}$$

with $b_t = B_t / P_{t.}$

2.2.3 Further equilibrium conditions

Given the intermediate goods producing firms' production function (10), the demand for intermediate goods (12), and the labor market clearing condition $N_t = \int_0^1 N_t(i)\, di$, it can be shown that

$$s_t Y_t^\alpha = N_t \tag{19}$$

where

$$s_t = \int_0^1 \left[\frac{P_t(i)}{P_t} \right]^{-\theta\alpha} di = (1 - \xi_p) (p_t^*)^{-\theta\alpha} + \xi_p \Pi_t^{\theta\alpha} s_{t-1} \tag{20}$$

stands for price dispersion. The resource constraint is given by

$$C_t + G_t = Y_t. \tag{21}$$

An important equilibrium condition is the identity describing the evolution of real wages in the economy

$$\frac{w_t}{w_{t-1}} = \frac{\Pi_t^w}{\Pi_t}. \tag{22}$$

Chugh (2006) highlights the importance of this identity in generating endogenous persistence in a sticky-price, sticky-wage economy.

Finally, the economy must satisfy the transversality condition

$$\lim_{t\to\infty} \frac{b_t}{\prod_{s=0}^{t} \frac{R_s}{\Pi_s}} = 0.$$

2.2.4 Alternative versions of the model

We consider two versions of this model in which wages will be flexible but the steady state is the same as in the economy set out above. These versions are distinct in one crucial aspect: labour market segmentation. This has a key implication for the price determination in the economy and ultimately for the degree of sluggishness in the response of the real economy to shocks and policy action.

No labour market segmentation

When intermediate goods producing firms hire labour from the economy-wide market, their pricing decision still affects the demand for the differentiated goods produced by these firms but they consider the economy-wide real wage rate as being unaffected by their decision. This significantly increases the sensitivity of prices to shocks and accelerates real adjustment following disturbances and policy action. This version of the model is the same as the one presented in the sections above with ξ_w set to zero and relative wages set to one at all times. In the presence of perfect insurance against idiosyncratic risk, we also need not consider differentiated types of labour and write N_t and W_t instead of their sector-specific values in the households' problem.

Segmented labour markets

In this version of the model, which is close to the setup of Woodford and Eggertsson (2003) and Adam and Billi (2006), the intermediate goods producing firms internalize the consequence of their pricing decision for demand for the specific type of good, and the subsequent implications for the sectoral wage rate through the demand for sector-specific labour. The firms' problem gets modified in a fundamental way. We now have firms choosing the optimal price to maximize

$$\max_{P_t^*} E_t \sum_{s=0}^{\infty} (\xi_p \beta)^s \prod_{k=0}^{s} \delta_k \left[P_{t+s}^* Y_{t+s}(i) - W_{t+s}(i) Y_{t+s}(i)^{\alpha} \right]$$
$$s.t.\ (12)$$

and the definition of the real wage rate coming from the household problem.[51] Following Woodford (2011), by symmetry between i and j, we can write

$$W_t\left(i\right)=\frac{\chi_{N,0}Y_t^{\alpha\chi_{N,1}}\left(\frac{P_t^*}{P_t}\right)^{-\theta\alpha\chi_{N,1}}}{(1-\tau_{n,t})C_t^{-\chi_C}}.$$

Equations (13) to (15) now become

$$\left(p_t^*\right)^{1+\theta\left[\alpha\left(1+\chi_{N,1}\right)-1\right]}=\frac{\theta}{\theta-1}\frac{C_{n,t}}{C_{d,t}},$$

where $p_t^*=P_t^*/P_t$ with

$$\begin{aligned}C_{n,t} &= \alpha Y_t^{\alpha\left(1+\chi_{N,1}\right)}C_t^{-\chi_C}+E_t\beta\delta_t\xi_p\Pi_{t+1}^{\theta\alpha\left(1+\chi_{N,1}\right)}C_{n,t+1},\\ C_{d,t} &= Y_tC_t^{-\chi_C}+E_t\beta\delta_t\xi_p\Pi_{t+1}^{\theta-1}C_{d,t+1}.\end{aligned}$$

2.2.5 The policy problems

We shall consider the alternative versions of the model with different elements of the policy maker's toolbox switched on and off. In all cases, the objective will be to find sequences of endogenous variables that maximize an unweighted average of welfare across households

$$W_t=E_t\sum_{s=0}^{\infty}\left(\beta\right)^s\prod_{k=0}^{s}\delta_k\left[\frac{{C_{t+s}}^{1-\chi_C}}{1-\chi_C}-\chi_{N,0}\frac{{N_{t+s}}^{1+\chi_{N,1}}}{1+\chi_{N,1}}m_{t+s}+\chi_{G,0}\frac{G_{t+s}^{1-\chi_{G,1}}}{1-\chi_{G,1}}\right],$$

where

$$\begin{aligned}m_t &= \int_0^1\left[\frac{W_t(j)}{W_t}\right]^{-\varepsilon\left(1+\chi_{N,1}\right)}dj\\ &= \left(1-\xi_w\right)\left(w_t^*\right)^{-\varepsilon\left(1+\chi_{N,1}\right)}+\xi_w\left(\Pi_t^w\right)^{\varepsilon\left(1+\chi_{N,1}\right)}m_{t-1}\end{aligned}\tag{23}$$

is a measure of wage dispersion. This is equal to one for all t when wages are flexible. Moreover, in the case of the flexible-wage economy with sector-specific labour markets, the disutility of labour supply is expressed as

$$\chi_{N,0}\int\frac{N_t\left(j\right)^{1+\chi_{N,1}}}{1+\chi_{N,1}}dj=\frac{\chi_{N,0}}{1+\chi_{N,1}}Y_t^{\alpha\left(1+\chi_{N,1}\right)}s_t^{SLM}$$

[51]The introduction of sector-specificity raises questions about wage formation. In order to avoid the need to consider monopsony in the labour market, we are implicitly assuming that there are many firms and many households in each sector in the economy, i.e. a 'double continuum' of firms and households, as explained in Woodford (2011) (Chapter 3). Hence, we have used the plural form 'firms' and 'households' of a certain type throughout the text.

with $s_t^{SLM} = \int \left[\frac{P_t(i)}{P_t}\right]^{-\theta\alpha\left(1+\chi_{N,1}\right)} di$.

We shall be looking for policies that are optimal from a timeless perspective (Woodford (2011)). In other words, we will be solving for time-invariant policy rules assuming that preferences in the initial period are augmented so that the policy maker does not take advantage of the fact that there had been no expectations formed about the initial outcomes. The equilibrium conditions and the first-order conditions for each version of the model are listed in the Appendix D.

2.3 Parameterization and solution

We parameterize the model with values commonly used in the literature.[52] We refer to the model under this parameterization as our 'baseline' case. The discount factor β is assumed to be 0.99. The discount factor shock $\varepsilon_{\delta,1}$ is set to 0.02 to make sure the economy hits the zero bound. The persistence of the innovation ρ_δ is 0.9. Thus, to determine when the natural rate of interest exceeds zero, one needs to check at what quarter the product of $\beta\delta_t$ falls below 1. For the parameters of the shock process, the discount factor and the persistence, the natural rate of interest is above zero from t>7.[53] We assume preferences are logarithmic in government spending, set χ_C to 1/6 and the inverse Frisch elasticity of labour supply to 1.[54] The preference parameters $\chi_{N,0}$ and $\chi_{G,0}$ are set to 1 and 0.2 respectively. This parameterization implies that steady-state government spending is close to 20 percent of steady-state output and the steady-state public debt is at 50 percent of annualized GDP. The elasticity of susbstitution for goods θ is set to 11. We follow Chugh (2006) in setting the elasticity of substitution in the labour market ε to 21. The measure of price stickiness ξ_p is 0.75 implying an average four-quarter duration or price contracts. The same value is used to parameterize the duration of wage contracts when wages are sticky.[55] The production function is assumed to be linear in labour in the baseline case (as in Nakata (2011) or Fernández-Villaverde et al. (2015)).

When conducting sensitivity tests, the steady-state of our model is going to change. We maintain comparability by ensuring that in all cases the steady-state debt-to-GDP ratio remains at 50 percent of GDP.

[52] The parameter values are summarized in Table 28 in the appendix.

[53] Werning (2011) shows this need not be equivalent to the point in time when the zero bound stops binding, as the optimal interest rate reaction function may involve other terms that are non-zero at the zero bound in addition to the natural rate. We only have a numerical solution for the interest rate, and so cannot be more precise here.

[54] The value for χ_C was also used in Jung et al. (2005), Nakata (2011), and is close to the estimate of Rotemberg and Woodford (1997).

[55] In the flexible-wage case, we set this parameter to zero but retain imperfect competition in the labour market so that the flexible-wage and sticky-wage economies are easier to compare.

Given that we consider an event in which the economy departs far from its steady state, and an inequality constraint becomes binding, we solve the model in its non-linear form. We use the procedure described in detail in Nakata (2011), which embeds the modified Newton method of Juillard et al. (1998) into a shooting algorithm. As shown in Nakata (2011) there are significant accuracy gains from using a nonlinear solution relative to piecewise linear methods. Fernández-Villaverde et al. (2015) also argue in favour of explicitly considering nonlinearities. Our approach here is thus different from the approach of Kollmann (2008) that relies on approximations and studies simple implementable rules.[56]

3 Results

There are two ways of dissecting our results. We shall look at comparisons across different labour market arrangements. At the same time, we can understand a lot about the intuition behind the various policy interventions and the transmission of policy decisions by inspecting the same economy under different policies and parameterizations. In this section, we draw conclusions from both of these approaches. First, we look at the baseline model. Later, we demonstrate the robustness of our intuition by conducting sensitivity tests.

3.1 The model under baseline parameterization

Our first set of results is shown in Figure 26 in which impulse response functions to a discount factor shock for three types of economic settings are compared (a model with flexible wages and an economy-wide labour market, a model with flexible wages and segmented labour markets labelled 'SLM', and a model with sticky wages). Here, we assume that monetary policy is the only available tool to stabilize the economy and that the fiscal solvency constraint is satisfied through lump-sum taxes.

The model's simulation suggests that the optimal inflation volatility at the zero lower bound is significantly affected by the nature of the labour markets in the economy. When labour market sector specificity is introduced into the model with flexible wages, the optimal inflation response to a given shock drops by as much as one order of magnitude. In the model with sticky wages, inflation volatility drops even further. For all practical purposes, the dynamic of the optimal sticky-wage economy is the same as the dynamic of an economy without price or nominal wage inflation. The figure also shows that in all three models, it is optimal to keep

[56] For the sake of balance, we mention that Eggertsson and Singh (2019) tend to downplay the importance of the differences arising from approximation accuracy in a model similar to ours.

the nominal interest rate at zero even after the zero bound ceases to bind. This result is in line with the earlier literature. However, our key contribution is to show that it is optimal to keep the interest rate at zero for even longer when labour markets are segmented or nominal wage rigidities are present. This policy—as we demnonstrate—is associated with smaller rather than larger expected inflation in the economy.

The intuition for this result is best understood in the context of the literature that investigates the ability of New Keynesian models to generate realistic degrees of output persistence (Edge (2002), Ascari (2003), Woodford (2011)). Changing the nature of the labour markets affects the way price-setting firms and/or wage-setting households respond to a demand contraction or expansion in important ways. In a flexible-wage economy, a shock with negative implications for demand implies lower demand for labour and hence a downward pressure on real wages (and, by implication, on marginal cost). In an economy with flexible wages and economy-wide labour markets, optimizing firms would reflect the effect on wages to a large extent in their pricing decision. They would consider the fact that they may not be able to change the price soon as demand recovers (and in fact overshoots) which will limit the extent to which prices drop. The firms also consider that lowering prices induces substitution of demand from goods for which prices remain unchanged. They can, however, recruit additional labour at the prevailing economy-wide real wage rate, which is a cost unrelated to the industry they operate in. With labour market segmentation, the firms need to consider that price-change-induced intersectoral re-allocation of demand needs to be met by hiring additional labour from a specific market with a specific wage rate. This will be affected by the need to meet the extra demand. This additional wage effect—which would eat into firms' profits—introduces an element of caution in price setting. As a consequence, there is a dampened price response in the first place, and a more persistence in the adjustment of the real economy. This mechanism explains the much more subdued inflation dynamic under segmented labour markets as depicted in Figure 26. With sticky nominal wages, marginal cost adjusts sluggishly by construction. In addition, optimizing households consider the broader implications of their wage decisions. Cutting (raising) wages too much, whilst other households keep wages constant, might re-allocate demand towards (from) their speciality, and the welfare cost of labour supply increases on the margin. This reinforces wage stability already introduced via staggered wage-setting. Overall, wages and, as a consequence, prices react little to shocks.

The downside of such price stability is that it imples a higher path for real interest rates. In the absence of significant expected inflation, the future real boom would be more subdued ceteris paribus and discounted more heavily. Relatively low wealth implies lower consumption in the short run.

The monetary policy maker mitigates subdued price inflation by keeping the interest rate at zero for longer. This induces a greater real economy boom. It is in this sense that we argue, following Werning (2011), that monetary policy in the liquidity trap is geared towards generating an expected real economy boom rather than inflation per se.

Overall, we still observe a significantly larger drop in output and consumption under segmented labour markets and nominal wage rigidity than with economy-wide labour markets. However, an optimizing policy maker will be comfortable with achieving more price stability at the expense of larger consumption (and output) volatility. This is because strategic complementarity affects not only the degree to which marginal cost pressures translate into price movements (the slope of the Phillips curve) but also the relative costliness of inflation and output variability from a welfare perspective. With more strategic complementarity, a flatter Phillips curve implies that there is larger misallocation of resources arising from a given rate of inflation.

Introducing government spending as a policy tool does not change the overall picture markedly, which can be inferred from Figure 27. This is consistent with Schmidt (2013). In fact, as argued in Werning (2011), government spending policy may have little to do with stabilization in the economy and instead be driven by public finance considerations. In an economy with depressed private demand, the marginal disutility of labour is low. An 'opportunistic' policy maker deciding on the optimal amount of public spending within the period following the Samuelson rule will observe a small marginal rate of transformation between the public and private goods (a drop in the relative price of public good), and will seek to increase provision of valued G. The reverse holds in boom time.

To get a feel of the relative contribution of such considerations for government spending policy, we do the following comparison. We take the output dynamic from the optimal economy without fiscal variables in use as given, and ask ourselves the question: What would an optimizing policy maker driven purely by public finance considerations do if he/she saw output dynamic from the economy stabilized only by monetary policy? Our objective is thus to find $G^{PF} = \arg\max_G (C, C+G, G)$ with

C taken as given.[57] We then compare the result of this exercise with the optimal dynamic of G in the various versions of our New Keynesian economies with tax rates fixed. We report the results in Figure 28. In line with Werning (2011), it is clear that the time profile as well as the magnitude of the response in G is very well explained by public finance considerations. One effect of such leaning against the wind via G is that output becomes more stable but by not too much. Figure 30 which depicts optimal dynamics in the sticky-wage economy under different policy options makes this point clear.

Finally, we add tax policy to our set of policy instruments used to stabilize the economy (see Figure 29). The tax in our economy is labour income tax levied on household earnings. This tax directly affects marginal cost, and therefore, is an effective instrument deployed to deliver the desired evolution of prices. This view of the role of tax policy is the same as in Correia et al. (2013). In our model, taxes generally rise in the short-term which is consistent with the demand-side considerations found in the literature. In particular, Eggertsson (2011) and Nakata (2011) sought to justify tax increases through their impact on (expected) inflation and the real interest rate. This is in turn different from Bils and Klenow (2008) who concentrated on the income effect of a tax cut, which is the reasoning probably closest to the philosophy behind similar real-world stimulus measures. In our model, taxes lean against the wind: they counteract the dynamic of marginal cost resulting primarily in a more stable inflation rate. This is best seen in the case of the sticky wage economy, as shown in Figure 30, but the intuition is valid in our flexible wage economies as well. In a sticky-wage economy, with only a fraction of wage-setters reacting to tax policy (affecting the net gains from employment), tax policy needs to act more robustly to achieve the desired aggregate outcome.

The overall budgetary impact of stabilization measures is close to zero initially and public debt gradually falls towards a new lower steady state level. It is a feature of the model that there is a continuum of steady states indexed by tax rates with a corresponding debt level. As in Nakata (2011), the welfare-maximizing tax rate is negative (eliminating the distortions to the steady state), and the corresponding steady state features a higher output level, more government spending and government holding net assets. Following the shock, the economy moves into a

[57] We adjust the preferences of the policy maker with respect to G so that in the steady state, he would choose the G/Y ratio that prevails in the steady state of our economies.

steady state located closer to such an outcome.[58]

3.2 Sensitivity analysis

In this section, we explore the sensitivity of our results to parameters that determine the degree of strategic complementarity in the economy. By looking at parameters that drive the extent to which (downward) marginal cost pressures arising from the a shock with severe demand implications are reflected in price- and wage-setting decisions of optimizing firms and households, we can verify if the intuition set out in the previous section is correct. Finally, we check how the results are affected if the economy has an inherited public debt level significantly above and below the steady-state level.[59]

3.2.1 Concave production function

The link between the shape of the production function and strategic complementarity is subtle. When the production function is no longer linear, changes in the amount of labour are no longer proportional to the changes in demand for production. Even in a non-segmented labour market, a profit-maximizing price setter has to consider the situation that his production costs will be more-than-proportionately affected if additional demand comes his way as a result of re-setting prices, whilst others keep theirs unchanged. This, again, introduces caution into the price setting. As a consequence, we observe reduced price volatility and increased output response in the economy with a non-segmented labour market. The peak of the inflation response drops by almost a half of what it was with a linear production function and the time spent at the zero bound lengthens in this economy to 10 periods versus the 9 periods in the baseline version (see Figure 31). This result confirms that real rigidity—whether induced by a particular labour market structure or other factors such as the shape of the production function—is an important determinant of the magnitude of the desired inflation response to shocks at the zero bound, and the time spent at the zero lower bound.

[58] The optimal debt dynamic would likely differ in a model with a different role for government expenditures (see Gomez (2004), Futagami et al. (2008) or D'Auria (2015), for example), given that the zero-rate interest policy would likely affect public sector investment decisions, for example, were they included in the model. Nevertheless, the model is relevant for real-world considerations in the sense that it shows that stabilization and reduction of debt levels towards a lower efficient level can go hand in hand.

[59] The results are quite predictably sensitive to parameters driving nominal rigidity. When the degree of wage stickiness is lowered (from four to two quarters on average), inflation volatility increases somewhat, and real volatility drops. Also, interest rates are kept at zero for only one period longer than otherwise (two periods in the baseline calibration). However, the main intuition still holds, and the quantitative impact is moderate.

Somewhat counterintuitively, in the sticky-wage model, inflation volatility increases moderately when production function is modelled to be concave. Inflation now behaves similarly to the economy with segmented labour markets. The reason for this dynamic can be traced back to what happens in the labour market in the flexible price and wage version of our economy. The natural level of output in the economy is determined as the intersection between labour supply and labour demand functions in a (Y, w) plane (equations (6) and (13) with the left-hand sides equal to one and the ξ's equal to zero). With a linear production function, the demand function is horizontal at a level determined by the steady-state markup. The labour supply function is upward sloping. If a shock affects labour supply, the equilibrium (natural) real wage rate will stay unaffected. With a concave production function, labour supply still slopes upwards. The labour demand schedule, however, becomes downward sloping in the (Y, w) plane. Marginal cost now depends on the quantity of production and the equilibrium real wage rate thus must fall when output (labour supply) increases.

In the full version of the model, it is a feature of our economy that a future boom is generated to stabilize the economy in the short term. In this boom, labour supply needs to expand, and real wages need to fall as they loosely track the natural rate. A mild inflation facilitates this adjustment. This is shown in Figure 32. The role of inflation in facilitating real wage adjustment in an economy with sticky nominal wages has been highlighted in Schmitt-Grohé and Uribe (2004).[60]

3.2.2 Degree of competition

With lower substitutability across sectors, one would expect strategic complementarity to play a smaller role in the price setting decision. Firms should not be wary of bold moves, as sizeable demand shifts from or to sectors where prices are not re-optimized happen less easily. If our story about strategic complementarity is true, we should expect larger swings in inflation, smaller volatility in real variables, and a shorter time spent at the zero lower bound. Figure 33 confirms the intuition. It shows that the optimal economy with a concave production function reverts back towards our baseline model with linear production technology in terms of policies and outcomes once the degree of competition (elasticity of subsitution in the goods market) is lowered.

[60] The shape of the production function may indeed be one of the main contributing factors to the opposite findings concerning optimal inflation volatility by Chugh (2006).

3.2.3 Other parameters

In addition to the parameters reported above, we also checked the sensitivity with respect to the elasticity of substitution in the labour market ε and the elasticity of labour supply (the inverse of which is $\chi_{N,1}$). The results confirm the intuition conveyed above but in comparison with the analysis of different forms of the production function, the sensitivity to changes in the elasticity was less pronounced for plausible values of parameters. This is consistent with Ascari (2003) who makes a similar point.

The intertemporal elasticity of substitution χ_C affects the model in a variety of ways, making sensitivity tests less straightforward. It affects the transmission of the shock and monetary policy in the model, and the wealth effect of labour supply (and hence the slope of the Phillips curve). A shock of a given magnitude has smaller real consequences as before and policy action has to be more forceful to have impact. In our sensitivity analysis, we have increased the magnitude of the shock so that the depth of the contraction is similar to the one observed in the flexible-wage economy non-segmented labour markets above. The key messages from our paper survive this modification. The differences across specifications, however, become relatively small both in terms of policy and outcomes. Hence, we conclude that the characterization of what constitutes 'good' policy in a New Keynesian setup at the zero lower bound is most robust when the intertemporal elasticity of substitution is relatively small.[61]

3.2.4 Initial level of debt

Burgert and Schmidt (2014) demonstrated that inherited debt level matters for both monetary and fiscal policy at the zero lower bound. We examined the state-dependency of dynamics in our baseline economy by considering the following two cases. In the 'high debt' scenario, the initial level of public debt was set at twice the steady-state level of debt, i.e. at 100 percent of GDP. In the 'low debt' scenario, the inherited indebtedness was half of the steady-state level of debt. As in Burgert and Schmidt (2014), we find that the magnitude of the inflation response is increasing, the initial increase in government spending is falling, and the initial response in the tax rate is increasing in the level of inherited debt. Their conclusions obtained under discretionary policy thus carry over into an economy with time-consistent policy of the 'timeless perspective' type. In line with much of the New Keynesian literature (see, for instance, Schmitt-Grohé and Uribe (2004)), the initial deviation

[61] For the sake of brevity, the results from these exercises are not displayed here but are available upon request from the authors.

of debt from its steady-state level is never fully undone.[62] This is a manifestation of intertemporal smoothing of welfare in tax and government spending policy.

As regards the interaction between the initial level of debt and labour market structure, our results show that higher initial indebtedness tends to amplify the differences observed across economies with different structures when it comes to inflation volatility, in particular. In the economy with non-segmented labour markets, a larger inflation response (a deeper fall in the real interest rate)—the consideration behind which is to a great extent fiscal (directly and indirectly through the tax rate)—enables a smoother adjustment in real variables. In line with that, government spending barely moves (there is a slight contraction). Overall, as shown in Figure 34, we see debt level falling well below its initial level, and stabilizing at a level that is much higher than the calibrated steady-state level.

4 Conclusion

We have shown that the optimal length of the forward commitment concerning interest rates at the zero bound and key outcomes such as the magnitude of expected inflation or the depth of the recession under optimal policy depend crucially on the assumed degree of real rigidity in the model. In addition to simple parametric assumptions, more fundamental structural assumptions about the nature of the labour market play an important role in this regard. Labour market segmentation and the presence of staggered wage adjustment were shown to have particularly significant consequences for the type of policy one might wish to implement in an economy hit by a large shock that depresses demand. In those circumstances, it is a good idea for governments to lean against the wind in two different ways. First, an increase in government spending when output is low (and vice versa) stabilizes output (and prices) but this policy can be justified almost wholly with reference to static public finance considerations. Second, an increase in taxes when output is low (and vice versa) stabilizes prices via their impact on marginal cost. The results interact in interesting ways with the initial conditions in the economy. With higher inherited debt, fiscal sustainability considerations matter more for monetary and tax policy and the explained differences across market structures grow larger.

The emphasis in the paper is on theory and intuition. Nevertheless, it should be of interest to modellers working with medium-scale models in which sticky wages are

[62] In the case of low inherited debt, the debt-to-GDP ratio falls further, for the same reason as debt falls below its steady-state level in the baseline economy. To economize on space, we do not display this case.

a standard feature. Different estimations of such models often yield diametrically different parameter estimates. Our paper highlights that such shifts in parameter values need not be inoccuous modifications of the setup but may require a different way of thinking about policy, particularly at the zero lower bound.

There is a lot more work to be done in the broadest sense to build better models to study economic cycles and their welfare consequences. The smallest departure from the present setup would be to have a model with a better account of the welfare costs of unemployment or financial market failures. Nevertheless, our paper allows the reader to have a better understanding of how market structures matter for macroeconomic policy and outcomes.

Part VI

Conclusion

In this thesis, we try to understand the mortgage market and general credit conditions, from macro-, micro- and policy perspectives. In the first chapter we use disequilibrium econometric model to identify credit conditions in the market over the business cycles. We found that the periods of recession coincide with the periods of credit rationing (or depressed supply) and the Golden era in banking coincides with the period of supply expansion.

We then looked at the role of brokers in the mortgage market and whether there are evidence of misaligned incentives with consumers they serve in term of finding the best deal. In particular, we investigated whether: i) the price of mortgage products varies materially across intermediaries; ii) intermediaries that receive higher procuration fees on average sell more expensive products to consumers; iii) intermediaries that use fewer, familiar lenders on average sell more expensive products. We find that the average price of mortgage products sold varies across intermediaries. The difference can be as high as £800 over the incentivised rate period for the median loan amount. We also found little evidence that intermediaries selling highly priced mortgages also receive high procuration fees and that the average price of the mortgages an intermediary sells is negatively correlated with the number of lenders used. On average, intermediaries placing business with a greater number of lenders sell cheaper products compared to intermediaries that use fewer lenders.

In the following chapter, we looked how macro-prudential policy could have an impact on consumers' outcomes. We found that after implementation of the recommendation the average loan size for high LTI mortgages increased by 4-7%. This suggests that lenders originated high LTI loans for borrowers with higher incomes. As a result, we find robust evidence of changes in composition of high LTI borrowers: 1) an increase in the proportion of home movers; 2) a decrease in the proportion of first-time buyers; 3) an increase in the proportion of joint income applicants. After implementation, although the overall proportion of high LTI mortgages to the total number of sales in the market stays around 10%, lenders' individual exposure to high LTI mortgages changed. Some lenders, whose share of high LTI mortgages had been closer to the 15% limit, reduced their proportion of high LTI. In contrast, some lenders that previously had a low share of high LTI mortgages increased their proportion of them. After controlling for borrower, product, and lender characteristics, we find that post-implementation the mortgage price for high LTI mortgages on average decreased. The fall in the mortgage price was stronger for lenders that used to be closer to the 15% constraint.

In the last chapter, we look at the monetary and fiscal policies in the context of New Keynesian models with real rigidities and an economy at the zero lower bound. We have shown that the optimal length of the forward commitment concerning interest rates at the zero bound and key outcomes such as the magnitude of expected inflation or the depth of the recession under optimal policy depend crucially on the assumed degree of real rigidity in the model. In addition to simple parametric assumptions, more fundamental structural assumptions about the nature of the labour market play an important role in this regard. Labour market segmentation and the presence of staggered wage adjustment were shown to have particularly significant consequences for the type of policy one might wish to implement in an economy hit by a large shock that depresses demand. In those circumstances, it is a good idea for governments to lean against the wind in two different ways. First, an increase in government spending when output is low (and vice versa) stabilizes output (and prices) but this policy can be justified almost wholly with reference to static public finance considerations. Second, an increase in taxes when output is low (and vice versa) stabilizes prices via their impact on marginal cost. The results interact in interesting ways with the initial conditions in the economy. With higher inherited debt, fiscal sustainability considerations matter more for monetary and tax policy and the explained differences across market structures grow larger.

Appendicies

A Credit Conditions in the UK Mortgage Market: A Disequilibrium Approach

Table 18: **Data sources and description.**

Variable	**Source**	**Description**
Value of loans approved	Bank of England	Quarterly value of total sterling approvals for secured lending to individuals (in sterling millions) net of cancellations seasonally adjusted; Mnemonic LPQVTVQ
Mortgage interest rate	DataStream	Interest rate on building society mortgages; Mnemonic UKXRMBS.R; NSA
Household disposable income	DataStream	Household's disposable income; Mnemonic UKPERDISD; SA; Constant Prices
House prices	Nationwide	House prices adjusted for retail prices; NSA
Consumer's confidence for major purchases	European Commission	Average of monthly consumer's confidence for major purchases at present; CONS.UK.TOT.8.BS.M; SA
Long term government bond rate	DataStream	Long-term interest rate on government bonds (AR) DS; Mnemonic UKOCFILTR; SA
Index of industrial production	ONS	DIOP Detailed Index of Production, IOP: B-E: PRODUCTION; Mnemonic CVMSA; SA; Constant Prices
Time deposit rate	DataStream	Rate of return sterling time deposits from corporates DS; Mnemonic UKB5F5Q; SA
Bank deposits	Bank of England	Sum of sterling and foreign foreign currency deposits from private sector, public sector and non-residents (LPQVYAX+LPQVYAY+ LPQVYAZ+LPQVYBA+ LPQVYBB+LPQVYBC); NSA

Table 19: **Data summary statistics.**

Variable	Mean	Std. Dev.	Min	Max	DF test p-values
log(value of loans approved, adjusted for inflation)	4.31	0.25	3.89	4.76	0.5975
mortgage rate, adjusted for inflation	5.91	2.54	1.95	13.86	0.4003
log(house prices, adjusted for inflation)	5.15	0.14	4.94	5.36	0.6875
log(household disposable income, adjusted for inflation)	5.36	0.08	5.20	5.45	0.0823
consumer confidence for major purchases	0.06	16.03	-35.47	25.23	0.5387
long term government bond rate, adjusted for inflation	5.08	2.26	0.59	10.64	0.8548
index of industrial production	105.29	5.72	95.50	113.80	0.5287
log(total bank deposits, adjusted for inflation)	6.25	0.20	5.93	6.57	0.6401
$\triangle$ (time deposits rate-mortgage rate), adjusted for inflation	-1.46	0.67	-2.61	-0.18	0.0677

Table 20: **The disequilibrium model, an alternative specification.**

Supply Equation		
Variables	**Coefficients**	**Standard Errors**
constant	-0.7725	(2.1778)
mortgage rate, adjusted for inflation	0.0649***	(0.0364)
long term government bond rate, adjusted for inflation	-0.1039***	(0.0405)
index of industrial production, lagged	0.0369***	(0.0057)
log(total bank deposits, adjusted for inflation)	0.2763	(0.2741)
$\triangle$(time deposits-mortgage rate), adjusted for inflation	0.1218***	(0.0661)
Demand Equation		
Variables	**Coefficients**	**Standard Errors**
constant	-5.6147***	(1.3584)
mortgage rate, adjusted for inflation	0.0069	(0.0062)
log(households disposable income, adjusted for inflation)	0.2444	(0.3420)
house prices, adjusted for inflation	1.6704***	(0.1221)
consumers confidence for major purchases	0.0074***	(0.0004)
Log-Likelihood=142.13		

Figure 19: **Probabilities of excess supply, an alternative specification.**

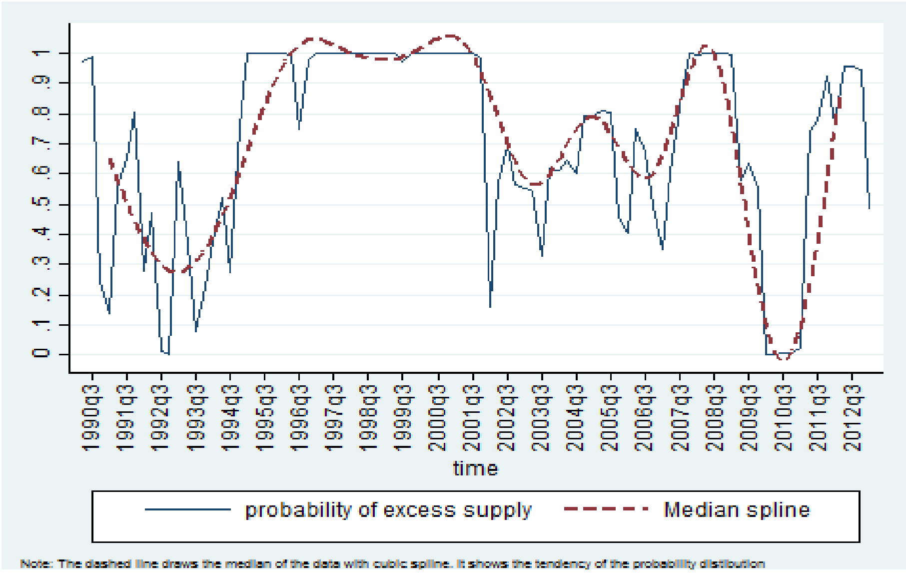
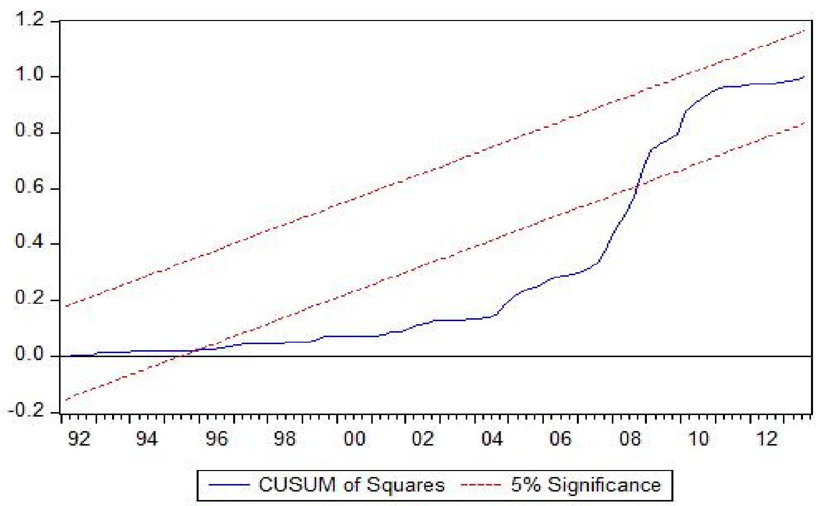


Table 21: **The multiple breakpoints test.**

Break Test	F-statistic	Scaled F-statistic	Critical Value**
0 vs. 1 *	44.51	311.59	21.87
1 vs. 2 *	7.34	51.35	24.17
2 vs. 3 *	5.12	35.81	25.13
3 vs. 4 *	3.88	27.16	26.03
4 vs. 5	0	0	26.65

Figure 20: **CUSUMQ test for the coefficients stability.**



B Choice of Intermediary in the UK Mortgage Market

B.1 Results of the regression and robustness check

In this section we present the main results of the regression on the full sample. We have five specifications in total. As explained, each specification has a different combination of intermediaries and lenders fixed effects. Table 22 shows the regression estimates of the different specifications. We discuss the explanatory power of each combination of fixed effects in Table 23. Here we only discuss the main results of the regression. Estimates and their interpretation do not vary across specifications, unless it is explicitly stated. Straightforward results (as those on loan-to-value) suggest that the econometric model is well-specified. Table 22 shows the results of the regression.

- Loan-to-value - As one can expect, the price of a mortgage increases with LTV with greater coefficients for higher LTV bands. The coefficients are economically and statistically significant particularly for high LTV levels. As one can expect, mortgage products with LTV above 85 % may be several percentage points more expensive than products with lower LTV.

- Borrower type - All else being equal, a First Time Buyer pay on average more than a Home Mover or a Remortgagor. This result is plausible, as lender may consider First Time Buyers as riskier customers (for example, because it is their first time they take a mortgage out). Another possible interpretation is that borrowers may become familiar with the mortgage process refinancing or taking a new mortgage contract when moving home. All else being equal, Remortgagors pay on average less than Home Movers. One possible interpretation is that the refinancing process is simpler where consumers do not move house. There may also be a smaller focus on price among Home Movers (and First Time Buyers) who trade financial gains in favour of certainty or speed of service.

- Major adverse marks in credit history - We find that borrowers with major adverse marks in their credit history such as a County Court Judgment (CCJ), mortgage arrears or Individual Voluntary Arrangements (IVA) pay on average significantly higher prices for their mortgage.

- Credit scores - We find that borrowers with better credit history pay, on average, a lower price. This is plausible, as clean credit history may give borrowers access to cheaper products.

- Personal Current Account (PCA) - We find that borrowers who hold a PCA with the lender pay on average less for their mortgage. In fact, we observe several large lenders offering preferential rates to their existing PCA customers.36 Results suggest that the latter effect dominates the former.

- Loan size - The results of the regression also indicate that, on average, larger loan sizes are associated with lower prices. One possible interpretation is that borrowers (or intermediaries on borrower' behalf) who borrow larger amounts shop around more for a good deal or may trade-off unobservable characteristics of the mortgage for a cheaper price.

- Loan-to-income - We find that the price of the mortgage is correlated with LTI in a non-linear fashion. The average price increases with LTI when it is below 4.5. It then decreases with LTI for mortgages with the ratio above the 4.5. This pattern might suggest that banks lend high LTI mortgages to less risky consumers, resulting in the average price being smaller for these borrowers. The result holds after controlling for consumers' credit scores.

- Joint applications - Joint applicants pay on average higher prices on average than single applicants.

- Self-employed - The coefficient of the self-employed dummy changes sign across specifications. On the one hand, in the Baseline and Model 2, comparing across lenders and keeping everything else constant, self-employed consumers get more expensive deals than non-self-employed. On the other hand, in Models 1, 3 and 4, when controlling for the lender, self-employed consumers get on average a cheaper deals keeping everything else constant. This suggests that there exist some unobserved characteristics that makes self-employed less risky. For example, when interacting the self-employed dummy with credit score, in the Baseline and Model 2 specifications we find that self-employed with higher credit score on average pay a lower price. As discussed earlier the amount of accounting information a self-employed is able to provide is one proxy for her riskiness and unfortunately this is an unobservable factor. We know that different lenders have different risk appetite that may result in lending to certain types of self-employed.

- Older borrowers - Keeping everything else constant, we find that older borrowers pay on average higher prices for their mortgage than younger borrowers. Some lenders may have strict criteria on how to take into account retirement income to repay the mortgage and therefore older borrowers may pay, on average, higher prices if they have to use a lender with less strict criteria.

- New build - The model controls for whether the mortgage is secured on a new build property or on an older property. We also interact the new build dummy with LTV, as some lenders have strict LTV criteria for mortgages on new build. We find that mortgages on new build are on average more expensive than those on older properties when LTV is low. For higher LTVs, mortgages on new build result cheaper than mortgages on older property.[63]

- Indebtedness - We control for the amount of unsecured debt borrowers hold. We find that borrowers with higher levels of debt pay on average higher price for their mortgage. Different lenders may have different methods to calculate the disposable income net of debt and, on average, lenders with less strict criteria may offer more expensive products.

- Maturity - Finally, mortgages with longer maturity are likely to have, on average, higher price than shorter maturity.

We now discuss the role of lender and intermediary attributes in explaining price variation in the full sample. We do so by firstly assessing the explanatory power of different combinations of intermediary and lender fixed effects. Table 23 shows that borrower and product characteristics explain around 59.24 % of the variation. The explanatory power of lenders attributes is large. Lender fixed effects explain an additional 10.73 % of the variation. This is expected, as lender attributes capture different business models including different funding costs and distribution strategies, as well as whether these banks are specialist or mainstream lenders. Intermediary attributes explain a smaller proportion of the variation, adding around

[63] Intermediaries take into account additional factors when recommending a lender for a mortgage on a new build property, such as i) Loan-to-value restrictions (many lenders do not allow for smaller deposits (sub 20%) on new build site), ii) speed to offer (many lenders service levels do not process their applications fast enough to meet the builders exchange of contracts deadlines), iii) over-exposure on a site (lenders typically limit the number of apartments in a new building or neighbourhood), iv) mortgage offer validity (consumers typically buy new build properties several months before they are completed. However, many lenders' mortgage offers are only valid for 3 or 6 months) and v) Governmental schemes (some lenders do not accept borrowers who use government schemes to help home buyers). See the FCA Mortgage Market Study interim report for more details (FCA (2018b)).

Table 22: **Regression results (full sample).**

	Baseline	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Intercept	7.758***	6.823***	7.633***	6.678***	6.830***
	(0.0684)	(0.0501)	(0.0588)	(0.0454)	(0.0729)
LTV band, 65%-75%	0.149***	0.1451***	0.147***	0.1438***	0.1478***
	(0.004)	(0.0026)	(0.0038)	(0.0027)	(0.0037)
LTV band, 75%-85%	0.4554***	0.4466***	0.452***	0.4446***	0.4221***
	(0.0045)	(0.0033)	(0.0045)	(0.0034)	(0.0039)
LTV band, 85%-95%	1.346***	1.343***	1.341***	1.339***	1.3470***
	(0.0087)	(0.0071)	(0.009)	(0.0034)	(0.0079)
LTV band, >95%	2.329***	2.456***	2.329***	2.455***	2.4310***
	(0.0114)	(0.01)	(0.0114)	(0.0102)	(0.0129)
LTI band, 2-3.5	0.0426***	0.0069***	0.043***	0.0056*	0.0169***
	(0.0041)	(0.0033)	(0.004)	(0.0033)	(0.0033)
LTI band, 3.5-4.5	0.0376***	−0.0202***	0.0389***	−0.0217***	−0.0093***
	(0.0049)	(0.0049)	(0.0048)	(0.0049)	(0.0049)
LTI band, >4.5	−0.0337***	−0.0945***	−0.0322***	−0.096***	−0.0861***
	(0.0061)	(0.0062)	(0.006)	(0.0063)	(0.0066)
Loan value, log	−0.3712***	−0.3432***	−0.3693***	−0.3386***	−0.3285***
	(0.0064)	(0.0046)	(0.055)	(0.0044)	(0.0060)
Age, 30-40 yo	0.0313***	-0.0017	0.0306***	-0.0008	0.0001
	(0.0024)	(0.0022)	(0.0025)	(0.0022)	(0.0027)
Age, 40-50 yo	0.0838***	0.0235***	0.0836***	0.0261***	0.0309***
	(0.0038)	(0.0029)	(0.0038)	(0.0029)	(0.0036)
Age, >50 yo	0.1268***	0.0567***	0.1287***	0.0616***	0.0575***
	(0.007)	(0.0058)	(0.0067)	(0.0057)	(0.0066)
Self-employed, dummy	0.4066***	−0.037*	0.398***	-0.0344	−0.0825***
	(0.052)	(0.0217)	(0.0513)	(0.0216)	(0.0289)
Credit score	−0.0014***	−0.000075***	−0.0013***	−0.000075***	−0.000036**
	(0.0001)	(0.000015)	(0.0001)	(0.000015)	(0.000019)
Credit score*Self-employed, dummy	−0.0008***	-0.000005	−0.0008***	-0.000005	0.0001
	(0.0001)	(0.000044)	(0.0001)	(0.000044)	(0.0001)
Impaired credit history, dummy	0.9088***	0.0886***	0.889***	0.0872***	0.0292
	(0.066)	(0.0185)	(0.0656)	(0.0185)	(0.0243)
Home Mover, dummy	−0.1188***	−0.1257***	−0.1196***	−0.1252***	−0.1442***
	(0.0045)	(0.0038)	(0.0044)	(0.0038)	(0.0037)
Remortagor, dummy	−0.2921***	−0.3036***	−0.2916***	−0.3008***	−0.3079***
	(0.0054)	(0.0043)	(0.0051)	(0.0041)	(0.0047)
Joint income, dummy	0.0481***	0.0289***	0.0496***	0.0281***	0.0371***
	(0.0027)	(0.002)	(0.0025)	(0.0019)	(0.0023)
Personal current account, dummy	−0.0262***	−0.0194***	−0.0265***	−0.0196***	−0.0185***
	(0.0059)	(0.0023)	(0.0058)	(0.0022)	(0.0021)
Monthly payments unsecured debt	0.000071***	0.000043***	0.00007***	0.000044***	0.000048***
	(0.000005)	(0.000003)	(0.000005)	(0.000003)	(0.000004)
New build, dummy	0.11***	0.1149***	0.1077***	0.1065***	0.1131***
	(0.0102)	(0.0106)	(0.0102)	(0.0118)	(0.0118)
New build, dummy*LTV band, 65% -75%	−0.0669***	−0.0519***	−0.062***	−0.0486***	−0.0271***
	(0.012)	(0.0112)	(0.0114)	(0.0105)	(0.0097)
New build, dummy*LTV band, 75% -85%	−0.2972***	−0.2677***	−0.2912***	−0.264***	−0.2570***
	(0.013)	(0.0123)	(0.0128)	(0.0123)	(0.0125)
New build, dummy*LTV band, 85%-95%	−0.2289***	−0.236***	−0.2272***	−0.2366***	−0.1940***
	(0.0317)	(0.0311)	(0.0307)	(0.0301)	(0.0329)
New build, dummy*LTV band,>95%	-0.1272	−0.2161***	-0.1179	−0.2115***	−0.2116*
	(0.0848)	(0.0795)	(0.0896)	(0.081)	(0.1278)
Mortgage term	0.0008***	0.0008***	0.0009***	0.0008***	0.0009***
	(0.000032)	(0.000024)	(0.000031)	(0.000024)	(0.000030)
N. of observations	525,038	525,038	525,038	525,038	376,926
Intermediary FE	no	no	yes	yes	no
Lender FE	no	yes	no	yes	no
Intermediary-Lender FE	no	no	no	no	yes
Postcode FE	yes	yes	yes	yes	yes
Month and Year FE	yes	yes	yes	yes	yes
R-squared	59.24%	70.07%	59.54%	70.15%	70.27%

0.3 % to the adjusted R-squared. Nevertheless, the tests on joint significance of the intermediary fixed effects, comparing with models with lender fixed effects and without lender fixed effects, are statistically significant. The marginal explanatory power of the intermediary fixed effects suggests that they do not capture the lender fixed effects. That is, intermediaries are not perfectly matched to lenders. This means that, for example, there are no intermediaries that specialise only in specialist providers, otherwise intermediary fixed effects would capture characteristics of the specialist lender and its explanatory power would be larger.

Table 23: **Explanatory power of intermediary and lender attributes (full sample)**.

Intermediary FE	Lender FE	Adjusted R-squared
No	No	59.24%
Yes	No	59.54%
No	Yes	70.07%
Yes	Yes	70.15%
Intermediary-lender pair FE		
Yes		70.27%

The additional explanatory power of the lender fixed effects in the mainstream sample (see Table 24) drops from 13 % to 1.8 %. This result is plausible given the sample construction, as the mainstream sample includes more homogeneous consumer characteristics. The intermediary fixed effects add to explanatory power only marginally, but remain jointly statistically significant. In the remaining of the section we present further robustness checks on the specification of the baseline regression.

B.2 Results using mainstream sample

Table 24 shows the explanatory power of intermediary and lender attributes in the regression using the mainstream sample. As discussed above, lender fixed effects have a smaller explanatory power because of the construction of the sample.

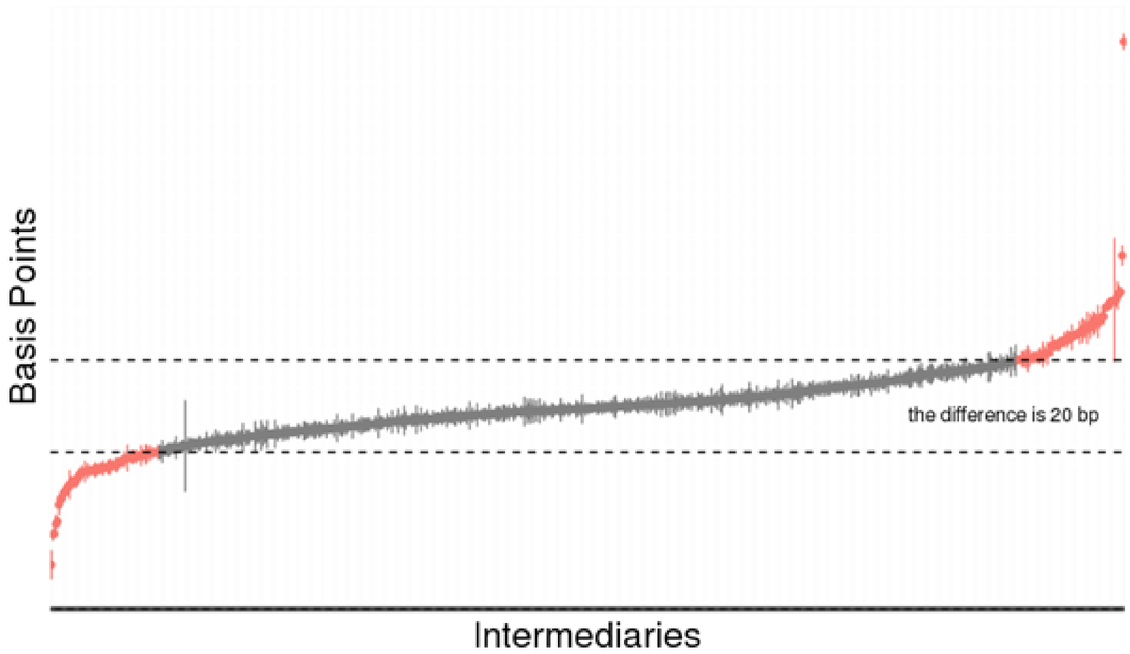
Figure 21 shows the variability of intermediary fixed effects on the mainstream sample. The variation of intermediary fixed effects in the mainstream sample is smaller than using the mainstream sample but still economically significant. The difference between the 10th percentile and the 90th percentile intermediary is around 20bps.

Finally, Table 13 shows how the result on the number of lenders used by intermediaries does not rely on the borrowers with non-standard characteristics (who are more likely to use a specialist lender). In fact, even in the mainstream

Table 24: **Explanatory power of intermediary and lender attributes (mainstream sample).**

Intermediary FE	Lender FE	Adjusted R-squared
No	No	64.00%
Yes	No	64.17%
No	Yes	68.32%
Yes	Yes	68.41%
Intermediary-lender pair FE		
Yes		69.40%

Figure 21: **Estimates of intermediary fixed effects (mainstream sample).**



sample, intermediaries using fewer lenders sell on average more expensive products.

B.3 Results for five-year fixed vs. two-year fixed products

We run the same analysis on five-year fixed rate mortgages. Results do not change significantly.

- We find a significant mortgage price variation across intermediaries, which is persistent over time. The correlation coefficient of the fixed effects estimates when we split the sample into two subsamples is 0.63 and it is statistically different from zero.

- We do not find evidence that intermediaries selling more expensive mortgage products also receive higher procuration fees. In particular, we find that the coefficient of the procuration fees is negative and significant. One possible interpretation for this result is that lenders that want to increase their market share may use either low price for consumers or high procuration fees for intermediaries. This result is consistent with the hypothesis whereby some lenders use both these instruments to increase market share.

- Finally, we find that intermediaries that use a large number of lenders sell on average cheaper mortgage products.

B.4 Price measure and APRC formula

In this section we provide more details about the methodology to calculate the price measure, including sensitivity checks on some of the assumptions used. According to the MCOB 10A.2.1, the APRC is the total cost of the credit to the consumer and defined as the annual rate of charge which equates, on an annual basis, the total present value of drawdowns on the one hand and the total present value of repayments and payments of charges on the other. Given that we are interested in calculating the cost for the two-year fixed mortgages and the drawdown of funds happens once when the mortgage is completed, under the assumption of rolled-up fees the mathematical formula of the APRC based price is:

$$C = \sum_{i=1}^{23} D_i (1+X)^{-1} + D_f (1+X)^{-24}$$

where:

- C is the total amount of credit excluding lender fee,

- X is the APRC based price measure,
- D_f is the last payment for the 24^{th} month and it is the outstanding capital to repay,
- D_i is the monthly payment (constant for 23 months) calculated using the following formula:

$$D_i = \frac{(C + f)(1 + r)^n}{r(1 + r)^n}$$

where:

- r is the initial interest rate in monthly terms (since mortgage is repaid monthly),
- n is the number of monthly instalments,
- f is the lender fee,

To calculate annual cost of mortgage (APR), the following formula is applied:

$$APR = (1 + X)^{12} - 1$$

B.5 Results using the price measure that takes into account the reversion rate

In this section we discuss an alternative price measure that takes into account the reversion rates (which is typically the Standard Variable Rate) and it is calculated over the whole term of the mortgage. This is equivalent to assume that the mortgage product is held until maturity. The price measure taking into account the reversion rate is fitted to the Baseline and Models 1-4. Table 25 presents the adjusted R-squared of each specification. We find that only 17 % of the variation of the measure is captured by borrower, product and property characteristics. This is significantly lower than the adjusted R-squared of the regression using the price measure that takes into account only the incentivised rate (around 60 %).

The adjusted R-squared increases to more than 90 % when the model controls for lender-specific characteristics. In other words, lender attributes explain around 75 % of the price variation (compared to around 11 % in the regression using the price measure that takes into account only the incentivised rate). This may be because of several reasons.

- Firstly, reversion rates are typically significantly higher than the rate charged during the initial period.

Table 25: **Adjusted R-squared of different specifications using the price measure that includes the reversion rate**.

Intermediary FE	Lender FE	Adjusted R-squared
No	No	16.76%
Yes	No	18.57%
No	Yes	91.70%
Yes	Yes	91.73%
Intermediary-lender pair FE		
Yes		93.33%

- Secondly, given that the mortgage product is assumed to be held until maturity, the effect of the reversion rates on the price measure is very prominent and makes the level of the initial rate negligible.

- Thirdly, lenders typically have one (or a few) reversion rates for all their products. This suggests that lender-specific characteristics capture the effect of the reversion rate.

As a result, lender attributes explain most of the price variation while borrower, product and property characteristics explain very little. Furthermore, while the measure implicitly assumes that a borrower holds the product until maturity, we observe that this is not true. In fact, the FCA found that the large majority (around 80 %) of consumers on fixed and variable mortgages with 2 year and 5 year incentivised rate period expiring in 2015 either switched to a new product with their existing lender, or redeemed their mortgage. All the above suggests that the price measure including the reversion rate does not properly capture the price of a mortgage.

B.6 Non-linear relationship between price and the number of lenders

Table 26 reports the difference between coefficients of the dummies of the number of lenders used. We also report the F-test statistics to check whether the differences are statistically different from zero.

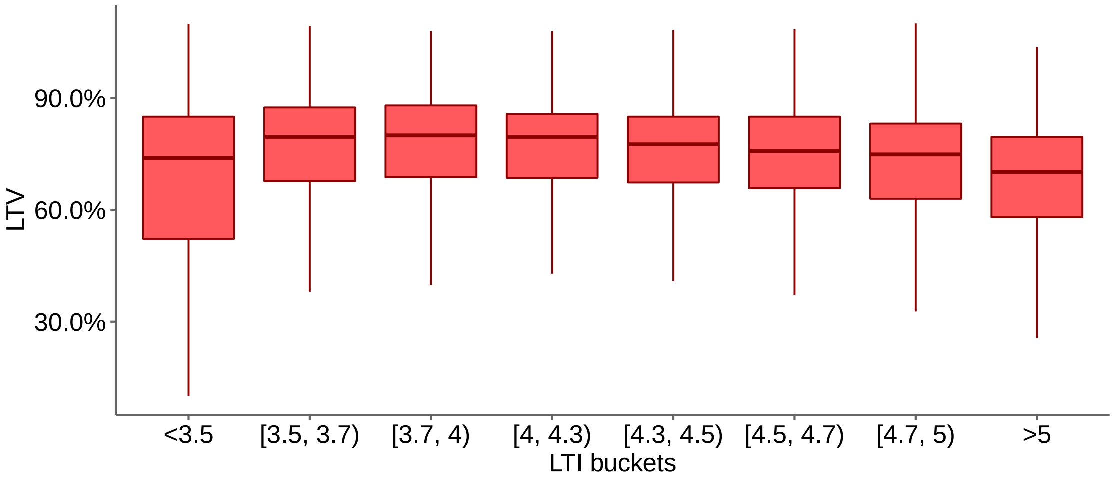
Table 26: **F-test to assess whether the dummies on number of lenders are statistically different from each other (mainstream sample)**.

Number of lenders (baseline)	Number of lenders 5-8	9-12	13-16	17-20	>20
5-8		-0.0681**	-0.1454*	-0.1068**	-0.0602
		(4.25)	(3.46)	(5.54)	(1.04)
9-12			-0.0773	-0.0387	0.0079
			(1.78)	(2.07)	(0.02)
13-16				0.0386	0.0852
				(0.61)	(1.26)
17-20					0.0466
					(0.73)
>20					

*** significant at 1%, ** significant at 5%, * significant at 10%

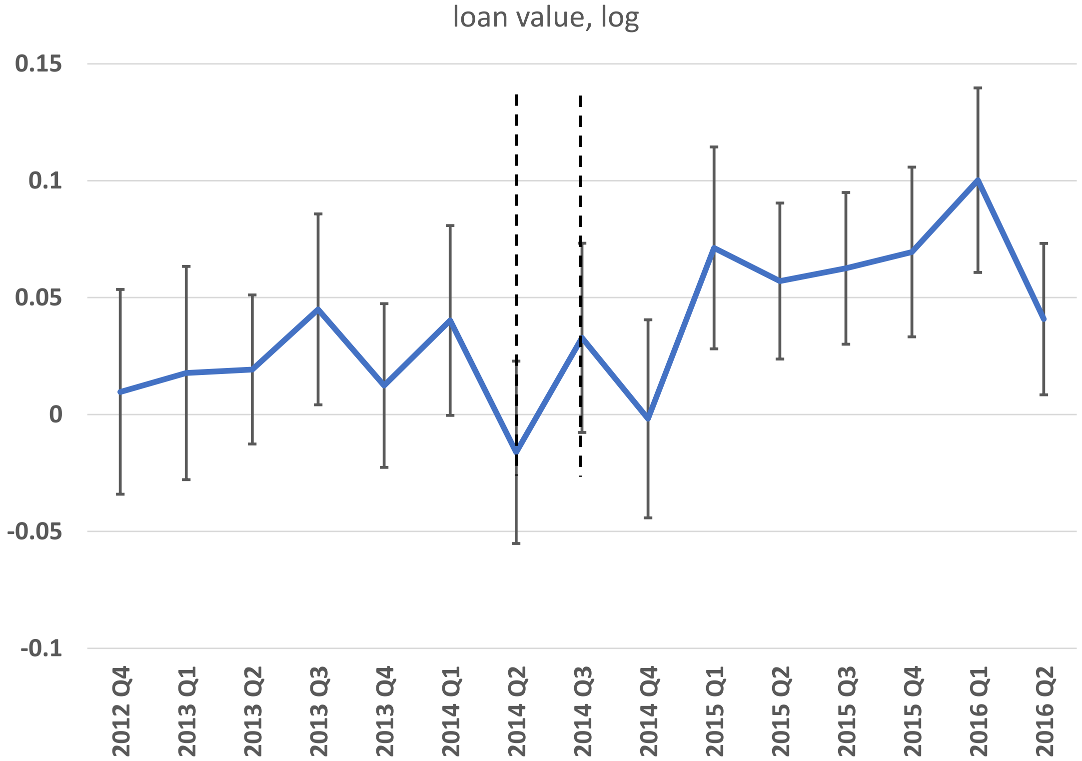
C Impacts of the LTI Flow Limit in the UK Mortgage Market

Figure 22: **Relationship between LTV and LTI**.



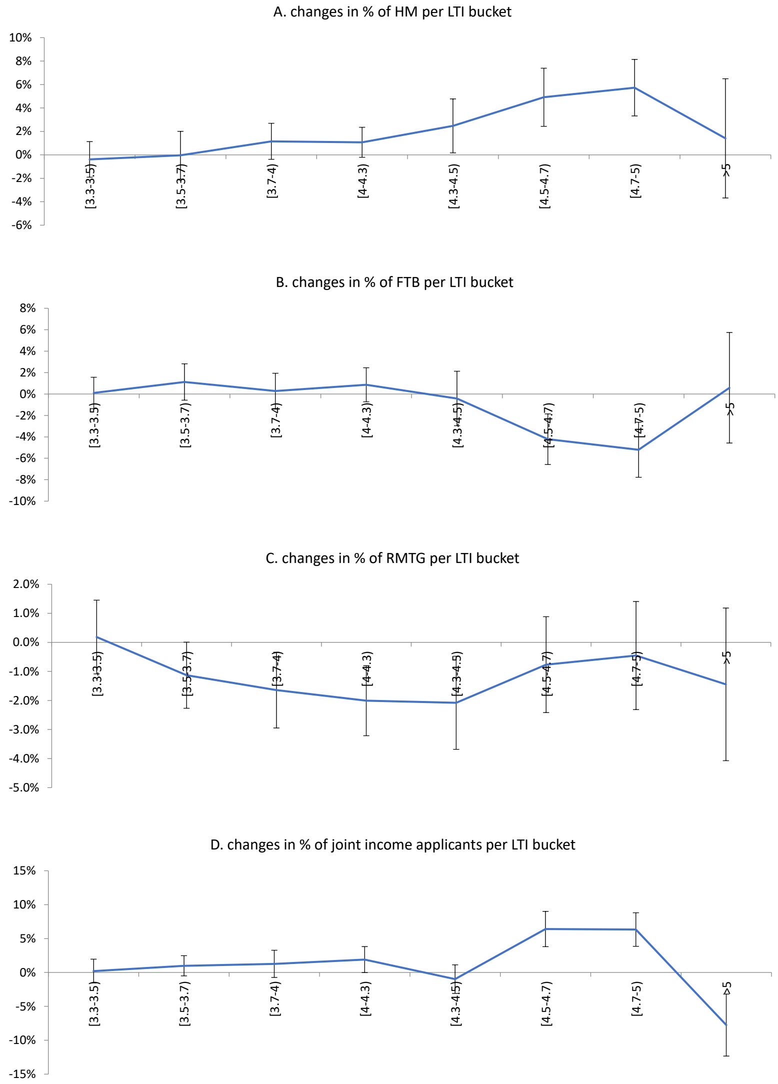
Note: this figure shows distribution of LTVs for different LTI buckets. Relationship between LTI buckers and LTVs are nonlinear. Very high LTI mortgages (above 5) and low LTI mortgages (below 3.5) are associated with lower LTVs. Lenders balance risk of high LTIs with bigger down payment.

Figure 23: **Testing for the parallel trend assumption, loan value, a sample of regions with low house price inflation**.



Note: baseline specification where LTI bucket d=[4.5,4.7) is a treatment and LTI bucket d=[3.5,3.7) is a control. Regions with the low house price inflation are North East, North West, Yorkshire and The Humber, East Midlands, and West Midlands..

Figure 24: **Flexible DD estimates of the changes in borrowers' composition, a sample of regions with low house price inflation**.



Note: all coefficients can be interpreted as the change in the variable of interest for a given LTI bucket following the implementation of the FPC recommendation relative to the LTI bucket [3, 3.3). An economically significant change in the proportion of home movers, first-time buyers and joint income applicants happens at the FPC 4.5 cut-off. This shows that changes in the composition of borrowers are related to the LTI 4.5 cut-off rather than other changes in the market.

Figure 25: **Number of sales for the control and treatment buckets.**

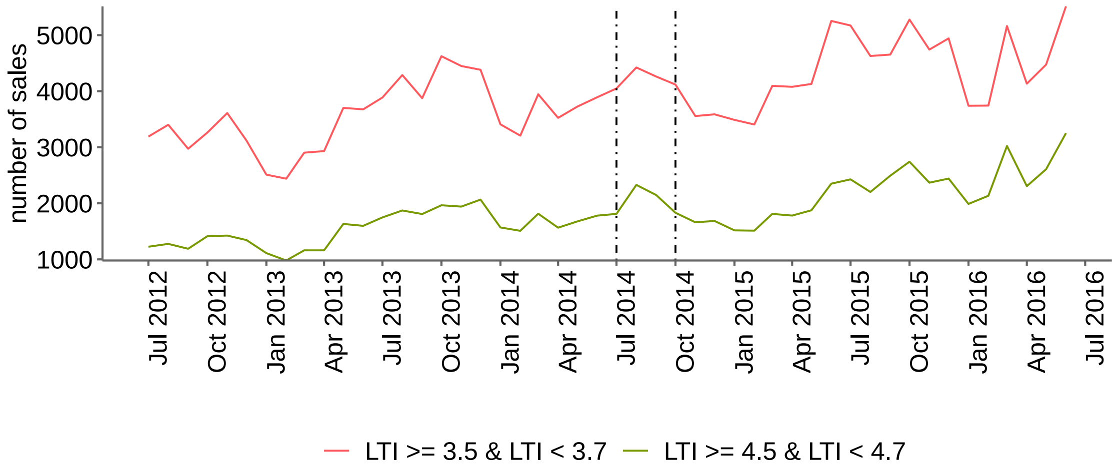


Table 27: **DD specification, 2-year fixed mortgage, APR** .

Initial interest rate	Baseline: control [3.5, 3.7)	Robustness: control [3.7, 4)	Robustness: control [4-4.3)	Robustness: control [4.3-4.5)
LTI [4.5;4.7) * Post	-0.0522 ***	-0.0760 ***	-0.0571 ***	-0.0437 ***
	(0.0083)	(0.0067)	(0.0068)	(0.0074)
Year-month Fes	Yes	Yes	Yes	Yes
Lender Fes	Yes	Yes	Yes	Yes
Regions Fes	Yes	Yes	Yes	Yes
LTV Fes	Yes	Yes	Yes	Yes
LTV*credit score Fes	Yes	Yes	Yes	Yes
Lender*Year-month Fes	Yes	Yes	Yes	Yes
Adjusted R-squared	0.68	0.67	0.65	0.65
Number of observations	108,329	142,512	130,754	96,390

*p<0.1; **p<0.05; ***p<0.01, standard errors are clustered at property area level. These results are robust to winsorisation.

D Real Rigidities and Optimal Stabilisation at the Zero Lower Bound in New Keynesian Economies

Table 28: **Baseline parameter values.**

Notation	Description	Value
β	discount factor	0.99
χ_C	coefficient of relative risk aversion	1/6
$\chi_{N,0}$	leisure preference parameter	1
$\chi_{N,1}$	inverse Frisch elasticity of labour supply	1
$\chi_{G,0}$	government spending preference parameter	0.25
$\chi_{G,1}$	government spending preference parameter	1
θ	elasticity of substitution in the goods market	11
ε	elasticity of substitution in the labour market	21
ξ_p	probability of no price adjustment	0.75
ξ_w	probability of no wage adjustment	0.75
α	production function parameter	1
$\varepsilon_{\delta,1}$	shock to the discount factor	0.02
ρ_δ	persistence of the shock	0.90

Figure 26: **Optimal response of the baseline economy with fiscal variables held constant and solvency issues ignored (SLM denotes segmented labour markets).**

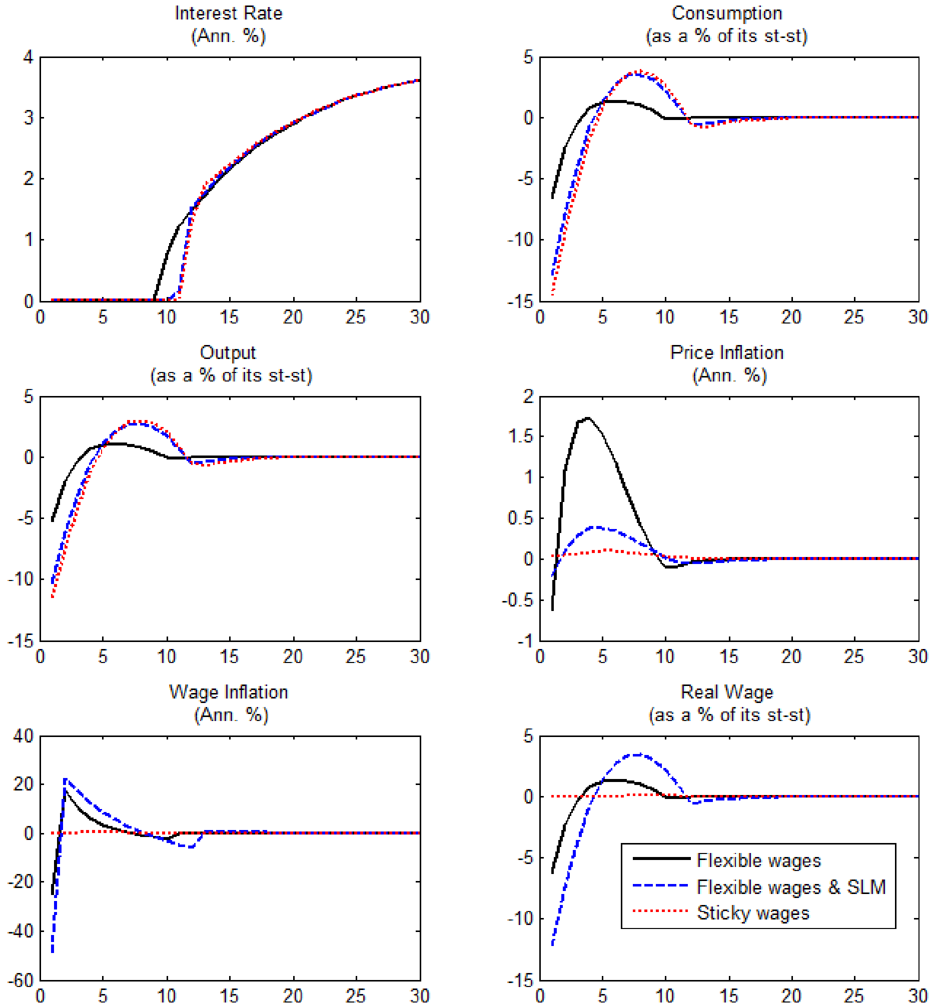


Figure 27: **Optimal dynamics in economies in which the tax rate is held constant.**

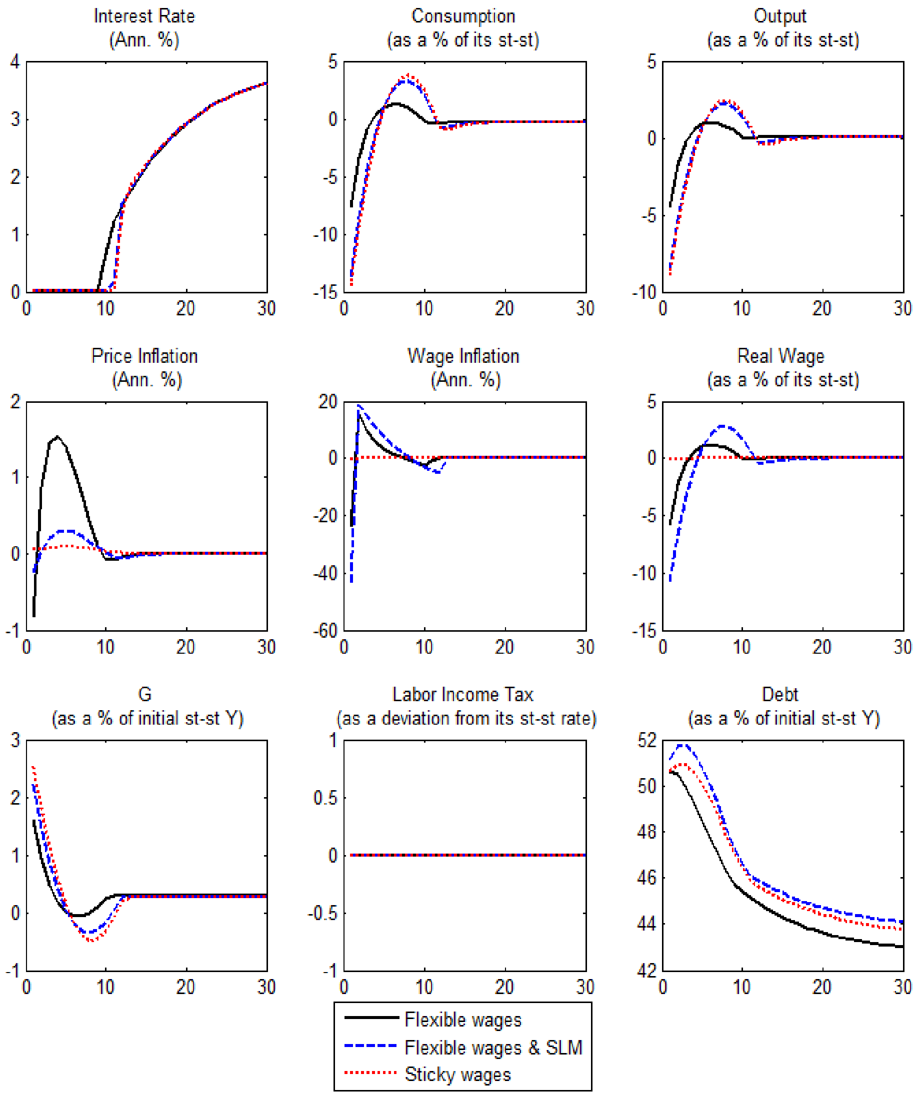


Figure 28: **'Opportunistic' versus optimal G.**

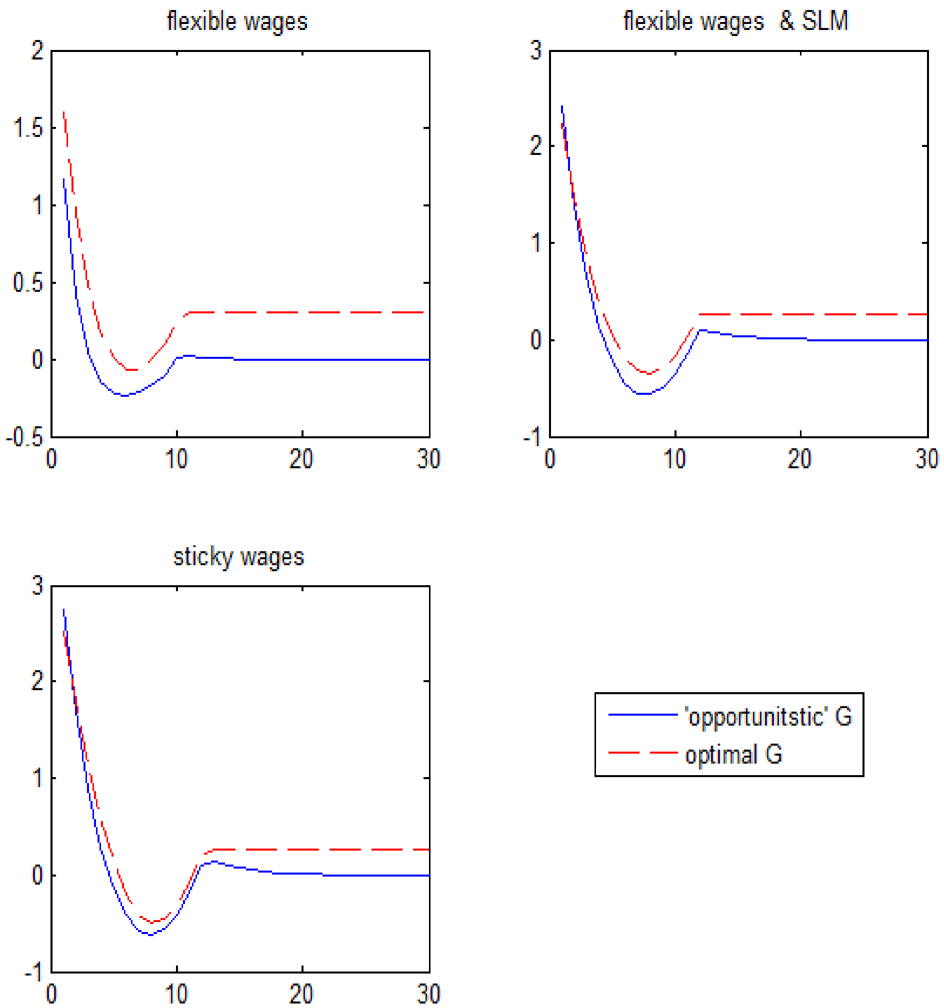


Figure 29: **Optimal dynamics with all policy instruments switched on.**

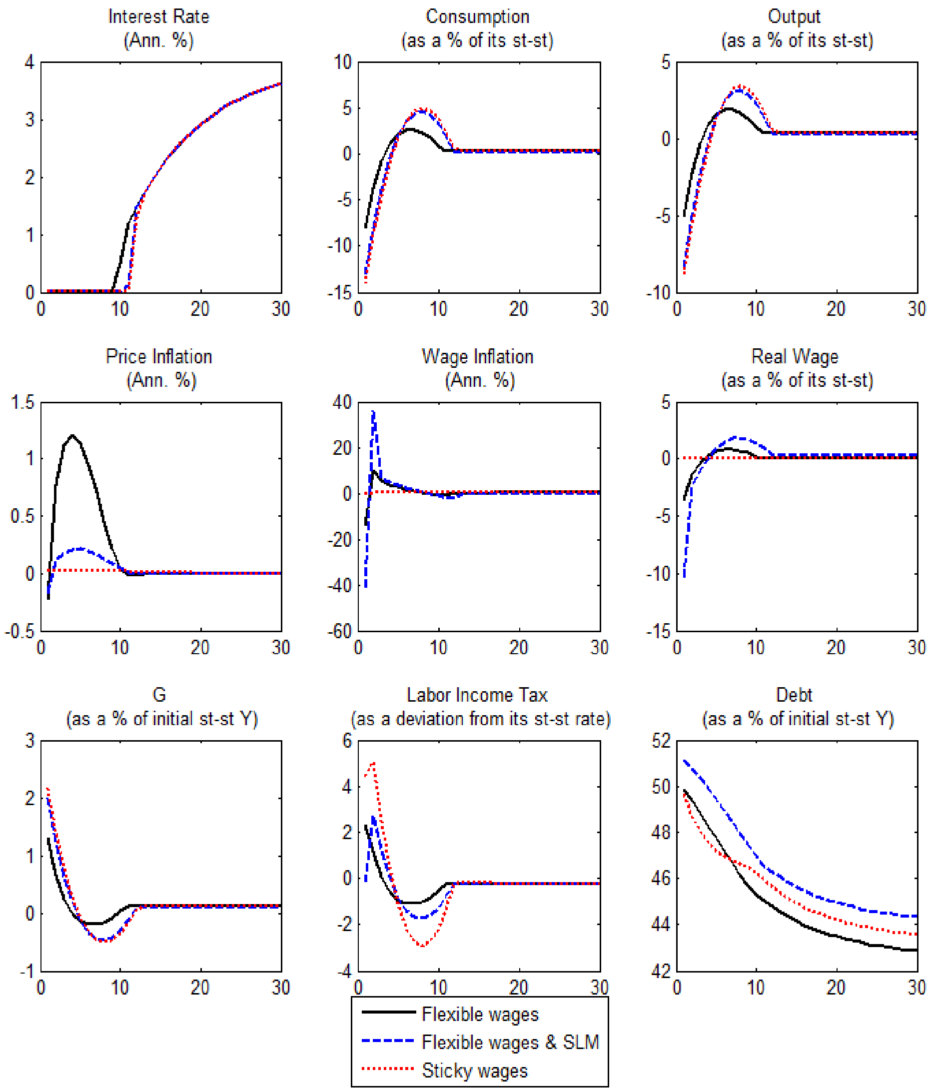


Figure 30: **The sticky-wage economy under various policy scenarios.**

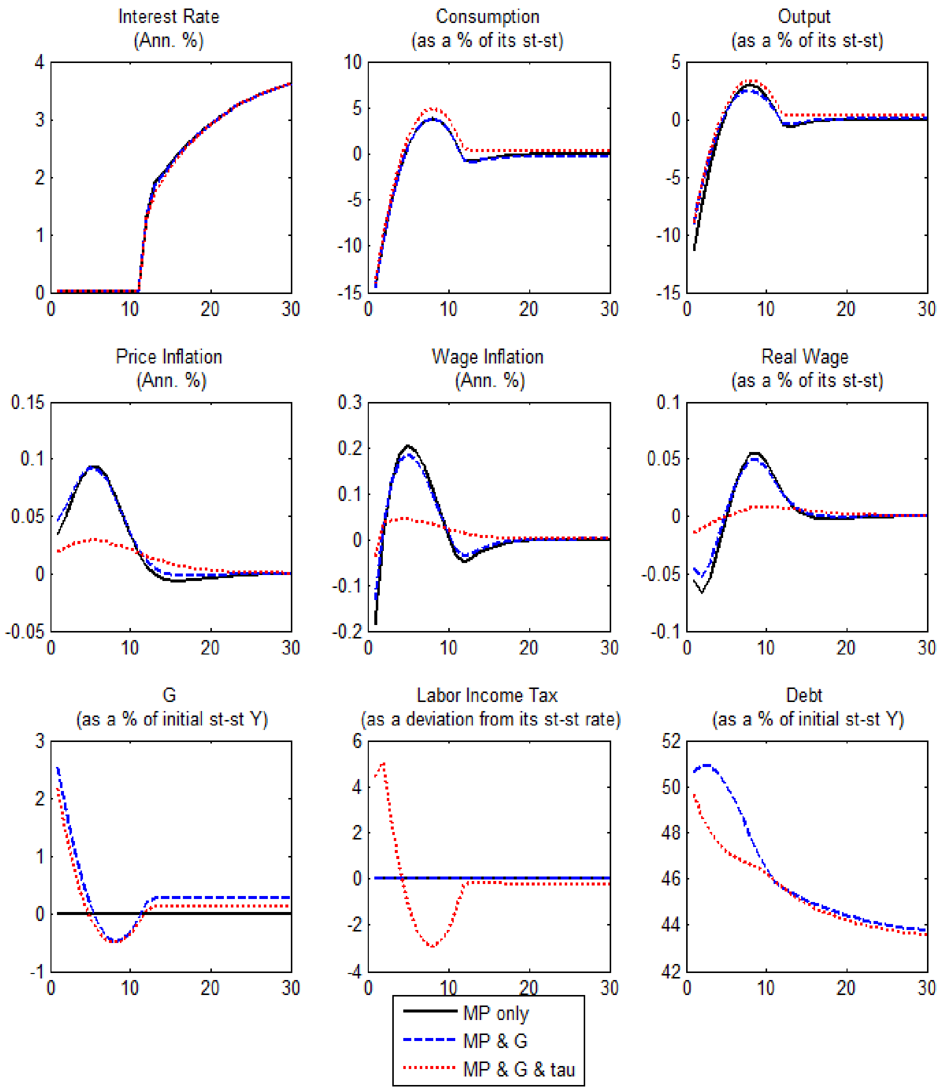


Figure 31: **Optimal dynamics when production function is concave.**

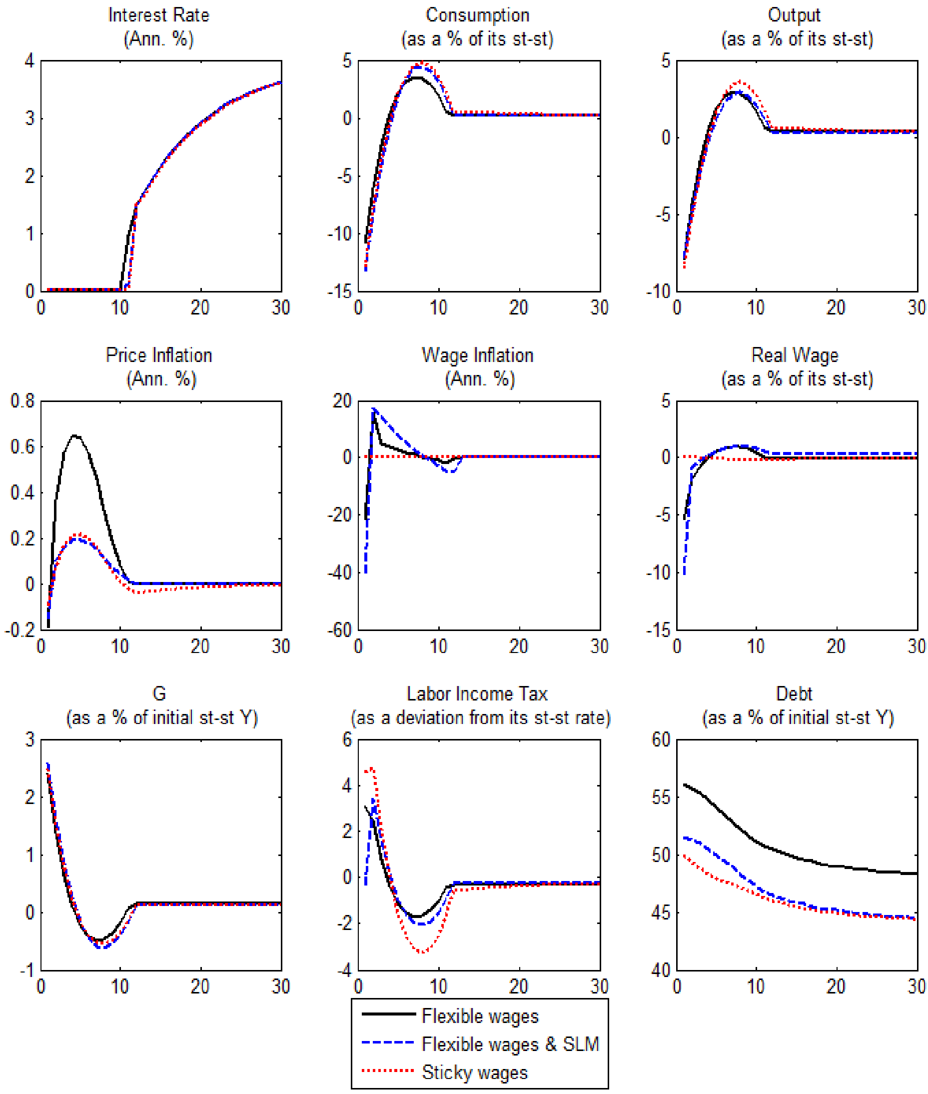


Figure 32: **Optimal dynamics in the sticky wage economy with different production functions.**

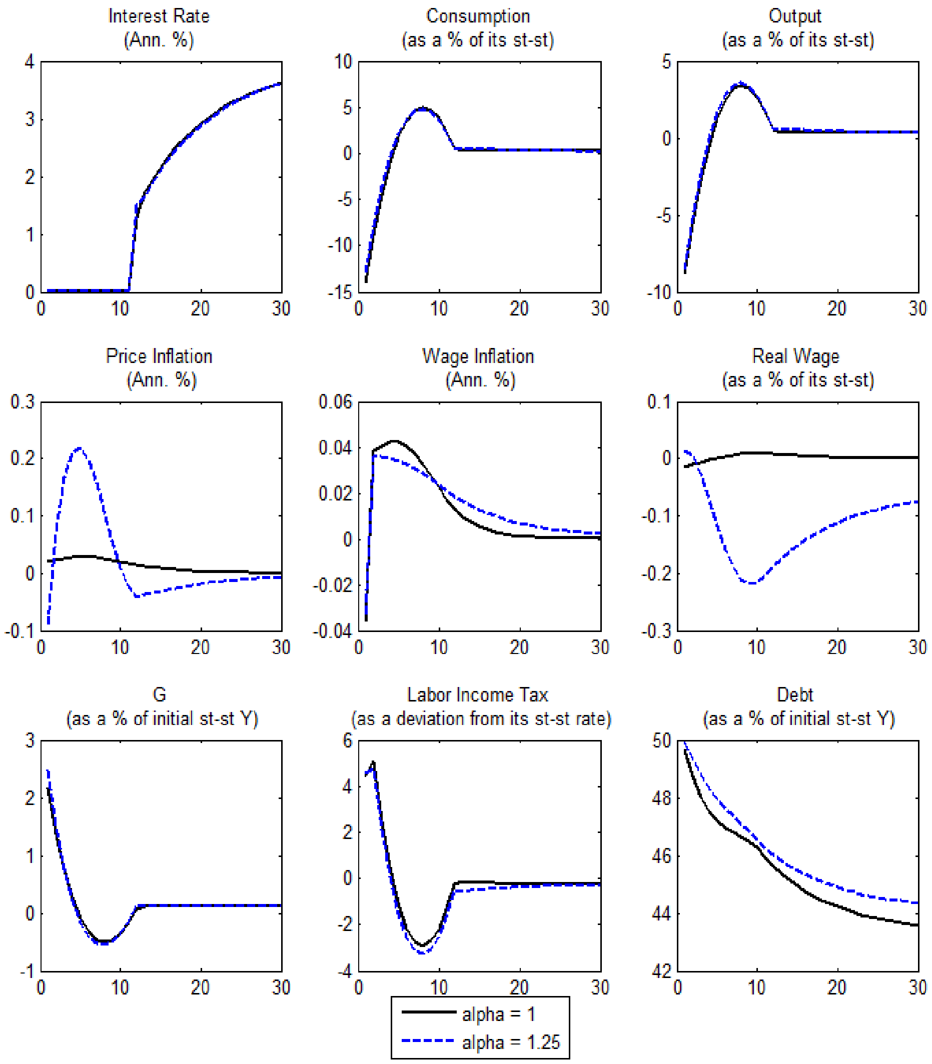


Figure 33: **Optimal dynamics in the flexible-wage economy with economy-wide labour markets under different degrees of product market competition.**

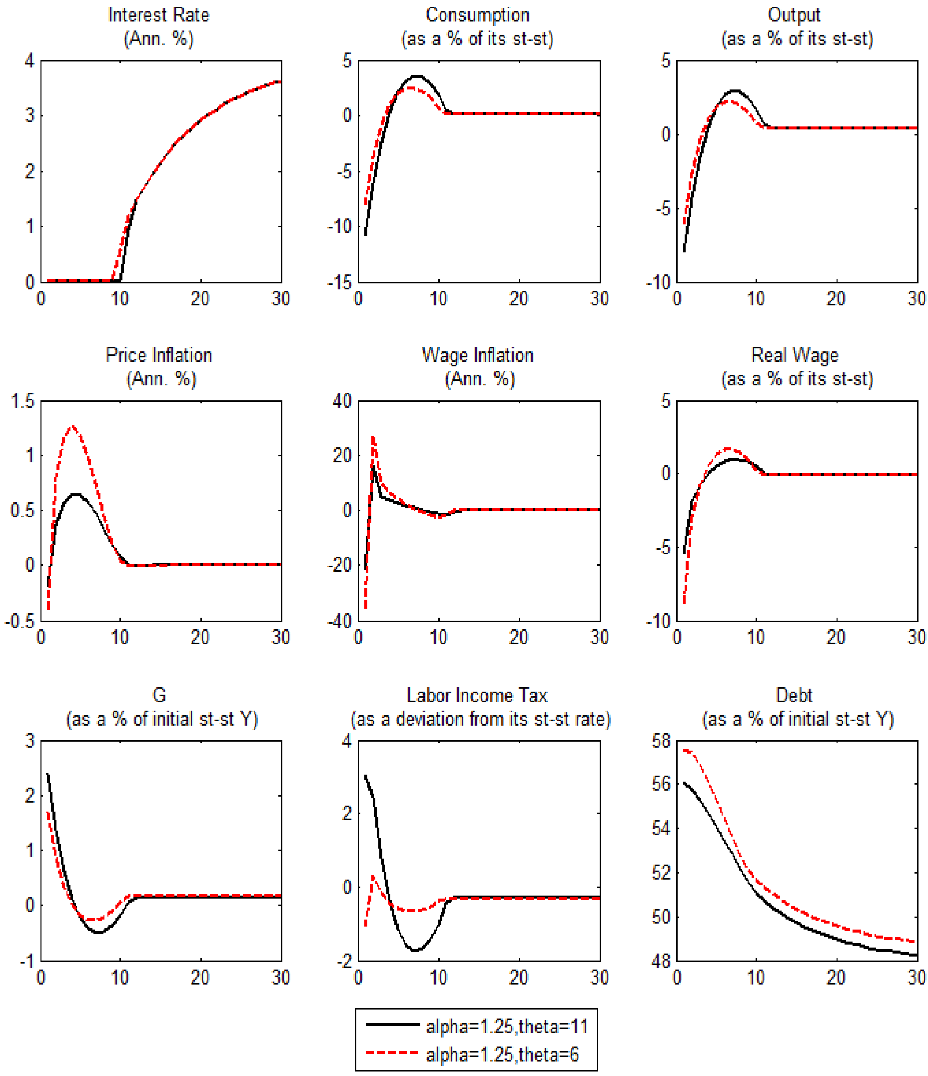
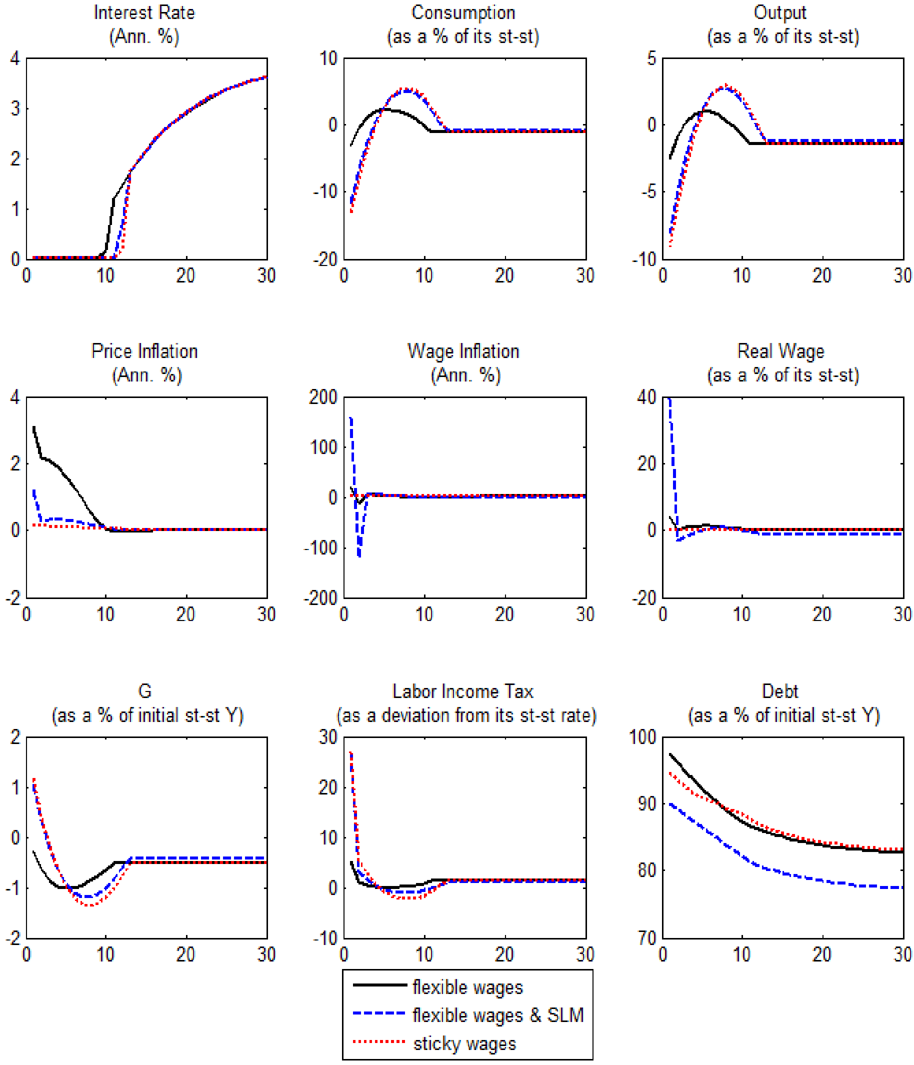


Figure 34: **Optimal dynamics when initial public debt is twice the steady-state value.**



D.1 Optimality conditions

This section lists the equilibrium conditions defining the evolution of the optimal economy under the various scenarios we consider.[64] When fiscal policy instruments are held constant, the respective first-order condition from the Ramsey problem is replaced by an equation that holds the value of the variable constant at its initial steady-state level. Moreover, when nominal interest rates are the only tool used, we assume that lump-sum taxes are available to satisfy the solvency constraint. The conditions are time-invariant due to the fact that we automatically include the terms that appear as a result of the penalty terms added to the objective function under the timeless perspective approach. Such penalty terms summarize the commitments concerning the initial period that a policy maker would adhere to should he be implementing policies he would have set for the current period in the distant past. See Benigno and Woodford (2012) for details.

[64] The ω's are Lagrange multipliers associated with the constraints of the Ramsey problem.

D.2 Flexible wage economy

$$
\begin{array}{ll}
\omega_1: & C_t^{-\chi_C} = E_t \beta \delta_t R_t C_{t+1}^{-\chi_C} \Pi_{t+1}^{-1} \\
\omega_2: & (1-\tau_{n,t})\, w_t = \frac{\varepsilon}{\varepsilon-1} \chi_{N,0} N_t^{\chi_{N,1}} C_t^{\chi_C} \\
\omega_3: & s_t = (1-\xi_p)\,(p_t^*)^{-\theta\alpha} + \xi_p \Pi_t^{\theta\alpha} s_{t-1} \\
\omega_4: & 1 = (1-\xi_p)\,(p_t^*)^{1-\theta} + \xi_p \Pi_t^{\theta-1} \\
\omega_5: & (p_t^*)^{1+\theta(\alpha-1)} = \frac{\theta}{\theta-1} \frac{C_{n,t}}{C_{d,t}} \\
\omega_6: & C_{n,t} = \alpha w_t Y_t^{\alpha} C_t^{-\chi_C} + E_t \beta \delta_t \xi_p \Pi_{t+1}^{\theta\alpha} C_{n,t+1} \\
\omega_7: & C_{d,t} = Y_t C_t^{-\chi_C} + E_t \beta \delta_t \xi_p \Pi_{t+1}^{\theta-1} C_{d,t+1} \\
\omega_8: & s_t Y_t^{\alpha} = N_t \\
\omega_9: & C_t + G_t = Y_t \\
\omega_{10}: & \frac{b_t}{R_t} = \frac{b_{t-1}}{\Pi_t} - \tau_{n,t} w_t N_t + G_t \text{ (-}T_t^{LS}\text{ when monetary policy only)} \\
\omega_{11}: & R_t \geqslant 1 \\
C: & C_t^{-\chi_C} - \omega_{1,t}\chi_C C_t^{-\chi_C-1} + \omega_{1,t-1}\chi_C R_{t-1} C_t^{-\chi_C-1}\Pi_t^{-1} - \omega_{2,t}\frac{\varepsilon}{\varepsilon-1}\chi_C \chi_{N,0} N_t^{\chi_{N,1}} C_t^{\chi_C-1} \\
 & +\omega_{6,t}\chi_C \alpha w_t Y_t^{\alpha} C_t^{-\chi_C-1} + \omega_{7,t}\chi_C Y_t C_t^{-\chi_C-1} - \omega_{9,t} = 0 \\
Y: & \omega_{6,t}\alpha^2 w_t Y_t^{\alpha-1} C_t^{-\chi_C} - \omega_{7,t} C_t^{-\chi_C} + \omega_{8,t}\alpha s_t Y_t^{\alpha-1} + \omega_{9,t} = 0 \\
N: & -\chi_{N,0} N_t^{\chi_{N,1}} - \omega_{2,t}\frac{\varepsilon}{\varepsilon-1}\chi_{N,0}\chi_{N,1} N_t^{\chi_{N,1}-1} C_t^{\chi_C} - \omega_{8,t} - \omega_{10,t}\tau_{n,t} w_t = 0 \\
w: & \omega_{2,t}(1-\tau_{n,t}) - \omega_{6,t}\alpha Y_t^{\alpha} C_t^{-\chi_C} - \omega_{10,t}\tau_{n,t} N_t = 0 \\
\Pi: & \omega_{1,t-1} R_{t-1} C_t^{-\chi_C} \Pi_t^{-2} - \omega_{3,t}\theta\alpha\xi_p \Pi_t^{\theta\alpha-1} s_{t-1} - \omega_{4,t}(\theta-1)\,\xi_p \Pi_t^{\theta-2} \\
 & -\omega_{6,t-1}\theta\alpha\xi_p \Pi_t^{\theta\alpha-1} C_{n,t} - \omega_{7,t-1}(\theta-1)\,\xi_p \Pi_t^{\theta-2} C_{d,t} - \omega_{10,t}\frac{b_{t-1}}{\Pi_t^2} = 0 \\
s: & \omega_{3,t} - E_t \omega_{3,t+1}\beta\delta_t \xi_p \Pi_{t+1}^{\theta\alpha} + \omega_{8,t} Y_t^{\alpha} = 0 \\
p^*: & \omega_{3,t}\theta\alpha(1-\xi_p)\,(p_t^*)^{-\theta\alpha-1} + \omega_{4,t}(\theta-1)(1-\xi_p)\,(p_t^*)^{-\theta} \\
 & +\omega_{5,t}\left[1+\theta(\alpha-1)\right](p_t^*)^{\theta(\alpha-1)} = 0 \\
C_n: & -\omega_{5,t}\frac{\theta}{\theta-1} C_{d,t}^{-1} + \omega_{6,t} - \omega_{6,t-1}\xi_p \Pi_t^{\theta\alpha} = 0 \\
C_d: & \omega_{5,t}\frac{\theta}{\theta-1}\frac{C_{n,t}}{C_{d,t}^2} + \omega_{7,t} - \omega_{7,t-1}\xi_p \Pi_t^{\theta-1} = 0 \\
R: & \omega_{1,t}\beta\delta_t C_{t+1}^{-\chi_C}\Pi_{t+1}^{-1} + \omega_{10,t}\frac{b_t}{R_t^2} + \omega_{11,t} = 0 \\
G: & \chi_{G,0} G_t^{-\chi_{G,1}} - \omega_{9,t} + \omega_{10,t} = 0 \\
\tau_n: & -\omega_{2,t} - \omega_{10,t} N_t = 0 \\
b: & -\omega_{10,t} R_t^{-1} + E_t \omega_{10,t+1}\beta\delta_t \Pi_{t+1}^{-1} = 0
\end{array}
$$

D.3 Flexible wage economy with segmented labour markets

$$
\begin{array}{ll}
\omega_1: & C_t^{-\chi_C} = E_t \beta \delta_t R_t C_{t+1}^{-\chi_C} \Pi_{t+1}^{-1} \\
\omega_2: & (p_t^*)^{1+\theta\left[\alpha\left(1+\chi_{N,1}\right)-1\right]} = \frac{\theta}{\theta-1}\frac{\varepsilon}{\varepsilon-1}\frac{C_{n,t}}{C_{d,t}} \\
\omega_3: & C_{n,t} = \frac{\alpha \chi_{N,0} Y_t^{\alpha\left(1+\chi_{N,1}\right)}}{(1-\tau_{n,t})} + E_t \beta \delta_t \xi_p \Pi_{t+1}^{\theta\alpha\left(1+\chi_{N,1}\right)} C_{n,t+1} \\
\omega_4: & C_{d,t} = Y_t C_t^{-\chi_C} + E_t \beta \delta_t \xi_p \Pi_{t+1}^{\theta-1} C_{d,t+1} \\
\omega_5: & 1 = (1-\xi_p)(p_t^*)^{1-\theta} + \xi_p \Pi_t^{\theta-1} \\
\omega_6: & s_t = (1-\xi_p)(p_t^*)^{-\theta\alpha\left(1+\chi_{N,1}\right)} + \xi_p \Pi_t^{\theta\alpha\left(1+\chi_{N,1}\right)} s_{t-1} \\
\omega_7: & C_t + G_t = Y_t \\
\omega_8: & \frac{b_t}{R_t} = \frac{b_{t-1}}{\Pi_t} - \frac{\tau_{n,t}}{(1-\tau_{n,t})}\frac{\varepsilon}{\varepsilon-1}\chi_{N,0} Y_t^{\alpha\left(1+\chi_{N,1}\right)} C_t^{\chi_C} s_t + G_t \text{ (-}T_t^{LS}\text{ when monetary policy only)} \\
\omega_9: & R_t \geqslant 1 \\
C: & C_t^{-\chi_C} - \omega_{1,t}\chi_C C_t^{-\chi_C-1} + \omega_{1,t-1}\chi_C R_{t-1} C_t^{-\chi_C-1}\Pi_t^{-1} + \omega_{4t}\chi_C Y_t C_t^{-\chi_C-1} \\
 & -\omega_{7,t} - \omega_{8,t}\frac{\varepsilon}{\varepsilon-1}\chi_C \frac{\tau_{n,t}}{(1-\tau_{n,t})} Y_t^{\alpha\left(1+\chi_{N,1}\right)} C_t^{\chi_C-1} s_t = 0 \\
Y: & -\chi_{N,0}\alpha Y_t^{\alpha\left(1+\chi_{N,1}\right)-1} s_t - \omega_{3,t}\frac{\alpha^2\left(1+\chi_{N,1}\right)\chi_{N,0} Y_t^{\alpha\left(1+\chi_{N,1}\right)-1}}{(1-\tau_{n,t})} - \omega_{4,t} C_t^{-\chi_C} + \omega_{7,t} \\
 & -\omega_{8,t}\frac{\varepsilon}{\varepsilon-1}\frac{\tau_{n,t}}{(1-\tau_{n,t})}\left[\alpha\left(1+\chi_{N,1}\right)\right] Y_t^{\alpha\left(1+\chi_{N,1}\right)-1} C_t^{\chi_C} s_t = 0 \\
\Pi: & \omega_{1,t-1} R_{t-1} C_t^{-\chi_C}\Pi_t^{-2} - \omega_{3,t-1}\theta\alpha\left(1+\chi_{N,1}\right)\xi_p \Pi_t^{\theta\alpha\left(1+\chi_{N,1}\right)-1} C_{n,t} \\
 & -\omega_{4,t-1}(\theta-1)\xi_p \Pi_t^{\theta-2} C_{d,t} - \omega_{5,t}(\theta-1)\xi_p \Pi_t^{\theta-2} \\
 & -\omega_{6,t}\theta\alpha\left(1+\chi_{N,1}\right)\xi_p \Pi_t^{\theta\alpha\left(1+\chi_{N,1}\right)-1} s_{t-1} - \omega_{8,t}\frac{b_{t-1}}{\Pi_t^2} = 0 \\
s: & -\chi_{N,0}\frac{\alpha Y_t^{\alpha\left(1+\chi_{N,1}\right)}}{\left(1+\chi_{N,1}\right)} + \omega_{6,t} - E_t \omega_{6,t+1}\beta\delta_t\xi_p \Pi_{t+1}^{\theta\alpha\left(1+\chi_{N,1}\right)} \\
 & -\omega_{8,t}\frac{\varepsilon}{\varepsilon-1}\frac{\tau_{n,t}}{(1-\tau_{n,t})}\chi_{N,0} Y_t^{\alpha\left(1+\chi_{N,1}\right)} C_t^{\chi_C} = 0 \\
p^*: & \omega_{2,t}\left\{1+\theta\left[\alpha\left(1+\chi_{N,1}\right)-1\right]\right\}(1-\xi_p)(p_t^*)^{\theta\left[\alpha\left(1+\chi_{N,1}\right)-1\right]} - \omega_{5,t}(\theta-1)(1-\xi_p)(p_t^*)^{-\theta} \\
 & +\omega_{6,t}\theta\alpha\left(1+\chi_{N,1}\right)(1-\xi_p)(p_t^*)^{-\theta\alpha\left(1+\chi_{N,1}\right)-1} = 0 \\
C_n: & -\omega_{2,t}\frac{\theta}{\theta-1}\frac{\varepsilon}{\varepsilon-1} C_{d,t}^{-1} + \omega_{3,t} - \omega_{3,t-1}\xi_p \Pi_t^{\theta\alpha\left(1+\chi_{N,1}\right)} = 0 \\
C_d: & \omega_{2,t}\frac{\theta}{\theta-1}\frac{\varepsilon}{\varepsilon-1}\frac{C_{n,t}}{C_{d,t}^2} + \omega_{4,t} - \omega_{4,t-1}\xi_p \Pi_t^{\theta-1} = 0 \\
R: & \omega_{1,t}\beta\delta_t C_{t+1}^{-\chi_C}\Pi_{t+1}^{-1} + \omega_{8,t}\frac{b_t}{R_t^2} + \omega_{9,t} = 0 \\
G: & \chi_{G,0} G_t^{-\chi_{G,1}} - \omega_{7,t} + \omega_{8,t} = 0 \\
\tau_n: & -\omega_{3,t}\alpha - \omega_{8,t}\frac{\varepsilon}{\varepsilon-1} C_t^{\chi_C} s_t = 0 \\
b: & -\omega_{8,t} R_t^{-1} + E_t \omega_{8,t+1}\beta\delta_t \Pi_{t+1}^{-1} = 0
\end{array}
$$

D.4 Sticky-wage economy

$$
\begin{aligned}
\omega_1 &: \quad C_t^{-\chi_C} = E_t \beta \delta_t R_t C_{t+1}^{-\chi_C} \Pi_{t+1}^{-1} \\
\omega_2 &: \quad s_t = (1-\xi_p)(p_t^*)^{-\theta\alpha} + \xi_p \Pi_t^{\theta\alpha} s_{t-1} \\
\omega_3 &: \quad 1 = (1-\xi_p)(p_t^*)^{1-\theta} + \xi_p \Pi_t^{\theta-1} \\
\omega_4 &: \quad (p_t^*)^{1+\theta(\alpha-1)} = \tfrac{\theta}{\theta-1} \tfrac{C_{n,t}}{C_{d,t}} \\
\omega_5 &: \quad C_{n,t} = \alpha Y_t^{\alpha} w_t C_t^{-\chi_C} + E_t \beta \delta_t \xi_p \Pi_{t+1}^{\theta\alpha} C_{n,t+1} \\
\omega_6 &: \quad C_{d,t} = Y_t C_t^{-\chi_C} + E_t \beta \delta_t \xi_p \Pi_{t+1}^{\theta-1} C_{d,t+1} \\
\omega_7 &: \quad s_t Y_t^{\alpha} = N_t \\
\omega_8 &: \quad C_t + G_t = Y_t \\
\omega_9 &: \quad \tfrac{b_t}{R_t} = \tfrac{b_{t-1}}{\Pi_t} - \tau_{n,t} w_t N_t + G_t \text{ (-}T_t^{LS} \text{ when monetary policy only)} \\
\omega_{10} &: \quad (w_t^*)^{1+\varepsilon\chi_{N,1}} = \tfrac{\varepsilon}{\varepsilon-1} \tfrac{N_{n,t}}{N_{d,t}} \\
\omega_{11} &: \quad N_{n,t} = \chi_{N,0} N_t^{1+\chi_{N,1}} + E_t \beta \delta_t \xi_w \left(\Pi_{t+1}^w\right)^{\varepsilon\left(1+\chi_{N,1}\right)} N_{n,t+1} \\
\omega_{12} &: \quad N_{d,t} = w_t N_t C_t^{-\chi_C}(1-\tau_{n,t}) + E_t \beta \delta_t \xi_w \left(\Pi_{t+1}^w\right)^{\varepsilon-1} N_{d,t+1} \\
\omega_{13} &: \quad 1 = (1-\xi_w)(w_t^*)^{1-\varepsilon} + \xi_w (\Pi_t^w)^{\varepsilon-1} \\
\omega_{14} &: \quad m_t = (1-\xi_w)(w_t^*)^{-\varepsilon\left(1+\chi_{N,1}\right)} + \xi_w (\Pi_t^w)^{\varepsilon\left(1+\chi_{N,1}\right)} m_{t-1} \\
\omega_{15} &: \quad \tfrac{w_t}{w_{t-1}} = \tfrac{\Pi_t^w}{\Pi_t}
\end{aligned}
$$

$$
\begin{aligned}
C: \quad & C_t^{-\chi_C} - \omega_{1,t}\chi_C C_t^{-\chi_C - 1} + \omega_{1,t-1}\chi_C R_{t-1} C_t^{-\chi_C - 1}\Pi_t^{-1} + \omega_{5t}\chi_C \alpha w_t Y_t^{\alpha} C_t^{-\chi_{C-1}} \\
& + \omega_{6,t}\chi_C Y_t C_t^{-\chi_{C-1}} - \omega_{8,t} + \omega_{12,t}\chi_C w_t N_t C_t^{-\chi_C}(1-\tau_{n,t}) = 0 \\
Y: \quad & -\omega_{5,t}\alpha^2 w_t Y_t^{\alpha-1} C_t^{-\chi_C} - \omega_{6,t} C_t^{-\chi_C} + \omega_{7,t}\alpha s_t Y_t^{\alpha-1} + \omega_{8,t} = 0 \\
N: \quad & -\chi_{N,0} N_t^{\chi_{N,1}} m_t - \omega_{7,t} - \omega_{9,t}\tau_{n,t} w_t - \omega_{11,t}\chi_{N,0}\left(1+\chi_{N,1}\right) N_t^{\chi_{N,1}} \\
& -\omega_{12,t} w_t C_t^{-\chi_C}(1-\tau_{n,t}) = 0 \\
w: \quad & -\omega_{5,t}\alpha Y_t^{\alpha} C_t^{-\chi_C} - \omega_{9,t}\tau_{n,t} N_t - \omega_{12,t} w_t C_t^{-\chi_C}(1-\tau_{n,t}) \\
& + \omega_{15,t} w_{t-1}^{-1} - E_t \beta \delta_t \omega_{15,t+1} \tfrac{w_{t+1}}{w_t^2} = 0 \\
\Pi: \quad & \omega_{1,t-1} R_{t-1} C_t^{-\chi_C} \Pi_t^{-2} - \omega_{2,t}\theta\alpha\xi_p \Pi_t^{\theta\alpha-1} s_{t-1} - \omega_{3,t}\left(\theta-1\right)\xi_p \Pi_t^{\theta-2} \\
& -\omega_{5,t-1}\theta\alpha\xi_p \Pi_t^{\theta\alpha-1} C_{n,t} - \omega_{6,t-1}\left(\theta-1\right)\xi_p \Pi_t^{\theta-2} C_{d,t} - \omega_{9,t}\tfrac{b_{t-1}}{\Pi_t^2} + \omega_{15,t}\tfrac{\Pi_t^w}{\Pi_t^2} = 0 \\
s: \quad & \omega_{2,t} - E_t \omega_{2,t+1}\beta\delta_t \xi_p \Pi_{t+1}^{\theta\alpha} + \omega_{7,t} Y_t^{\alpha} = 0 \\
p^*: \quad & \omega_{2,t}\theta\alpha\left(1-\xi_p\right)\left(p_t^*\right)^{-\theta\alpha-1} + \omega_{3,t}\left(\theta-1\right)\left(1-\xi_p\right)\left(p_t^*\right)^{-\theta} \\
& + \omega_{4,t}\left[1+\theta\left(\alpha-1\right)\right]\left(p_t^*\right)^{\theta(\alpha-1)} = 0 \\
C_n: \quad & -\omega_{4,t}\tfrac{\theta}{\theta-1} C_{d,t}^{-1} + \omega_{5,t} - \omega_{5,t-1}\xi_p \Pi_t^{\theta\alpha} = 0 \\
C_d: \quad & \omega_{4,t}\tfrac{\theta}{\theta-1}\tfrac{C_{n,t}}{C_{d,t}^2} + \omega_{6,t} - \omega_{6,t-1}\xi_p \Pi_t^{\theta-1} = 0 \\
w^*: \quad & \omega_{10,t}\left(1+\varepsilon\chi_{N,1}\right)\left(w_t^*\right)^{\varepsilon\chi_{N,1}} - \omega_{13,t}\left(1-\xi_w\right)\left(1-\varepsilon\right)\left(w_t^*\right)^{-\varepsilon} \\
& + \omega_{14,t}\left(1-\xi_w\right)\varepsilon\left(1+\chi_{N,1}\right)\left(w_t^*\right)^{\left[-\varepsilon\left(1+\chi_{N,1}\right)-1\right]} = 0 \\
\Pi^w: \quad & -\omega_{11,t-1}\xi_w\varepsilon\left(1+\chi_{N,1}\right)\left(\Pi_t^w\right)^{\varepsilon\left(1+\chi_{N,1}\right)-1} N_{n,t} - \omega_{12,t-1}\xi_w\left(\varepsilon-1\right)\left(\Pi_t^w\right)^{\varepsilon-2} N_{d,t} \\
& -\omega_{13,t-1}\xi_w\left(\varepsilon-1\right)\left(\Pi_t^w\right)^{\varepsilon-2} - \omega_{14,t}\xi_w\varepsilon\left(1+\chi_{N,1}\right)\left(\Pi_t^w\right)^{\varepsilon\left(1+\chi_{N,1}\right)-1} m_{t-1} \\
& -\omega_{15,t}\Pi_t^{-1} = 0 \\
N_n: \quad & -\omega_{10,t}\tfrac{\varepsilon}{\varepsilon-1}\tfrac{1}{N_{d,t}} + \omega_{11,t} - \omega_{11,t-1}\xi_w\left(\Pi_t^w\right)^{\varepsilon\left(1+\chi_{N,1}\right)} = 0 \\
N_d: \quad & \omega_{10,t}\tfrac{\varepsilon}{\varepsilon-1}\tfrac{N_{n,t}}{N_{d,t}^2} + \omega_{12,t} - \omega_{12,t-1}\xi_w\left(\Pi_t^w\right)^{\varepsilon-1} = 0 \\
m: \quad & -\chi_{N,0}\tfrac{{N_t}^{1+\chi_{N,1}}}{1+\chi_{N,1}} + \omega_{14,t} - E_t\beta\delta_t\omega_{14,t+1}\xi_w\left(\Pi_{t+1}^w\right)^{\varepsilon\left(1+\chi_{N,1}\right)} = 0 \\
R: \quad & \omega_{1,t}\beta\delta_t C_{t+1}^{-\chi_C}\Pi_{t+1}^{-1} + \omega_{9,t}\tfrac{b_t}{R_t^2} + \omega_{16,t} = 0 \\
G: \quad & \chi_{G,0} G_t^{-\chi_{G,1}} - \omega_{8,t} + \omega_{9,t} = 0 \\
\tau_n: \quad & -\omega_{9,t} + \omega_{12,t} C_t^{-\chi_C} = 0 \\
b: \quad & -\omega_{9,t} R_t^{-1} + E_t\omega_{9,t+1}\beta\delta_t\Pi_{t+1}^{-1} = 0
\end{aligned}
$$

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