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Financial Frictions, Labour Markets, and the Macroeconomy

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Dedicated to my two boys, Linus and David.

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Abstract

In the first chapter, we use detailed Danish micro-data and study how a credit-driven boom in consumer demand affects firm dynamics. We exploit the introduction of interest-only mortgages in 2003 to establish a structural break in Danish households' spending capacity. A difference-in-differences approach indicates that the reform sharply increases consumers' expenditure. This demand shock generates revenues and profits for Danish firms and results in the creation of at least 2,500 additional jobs between 2004 and 2010. These positions are concentrated in the non-tradable sector. Our results indicate that mortgage markets shape the size and composition of real economic activity during expansion phases.

The second chapter shows that the supply side of credit is a major factor for hampered monetary policy transmission in monopolistic banking markets. Our data covering all 1,555 small and medium sized banks in Germany provides a clear way to partial out demand shocks; we are thus able to show that while market-power banks charge higher loan rates, they spare their borrowers a part of exogenous monetary policy contractions and furthermore withhold a substantial part of rising rates from their depositors. Because high market-power banks are relatively more profitable, these banks seem to be able to insure their relationship-customers against adverse shocks.

In the third chapter, I develop a model where firms need to borrow the wage bill under financial frictions. I discuss the implications of intraperiod fi-

nancial contracts for real and financial variables in a most simple model without capital. Financial variables such as the external finance premium in this setup behave perversely. Real variables' responses are hampered compared to a standard Real Business Cycle model. Then, I implement intraperiod financial contracts and show this can eliminate the problems to some extent. Financial variables now move as observed in the data. Unlike in the original model by Bernanke et al. (1999), the responses of real variables, especially output and labour, however remain muted in response to a positive technology shock.

Lay summary

During the Great Recession, millions of people across the globe lost their jobs and homes. The bankruptcy of the American investment bank Lehman Brothers in 2008 stands for the outbreak of a *financial* crisis which already started evolving in 2007 and resulted in a severe global *economic* downturn. This highlights that the lives of ordinary people are very much affected by events happening in the seemingly distant financial sector. Real economic variables such as consumption or job creation can for instance be linked to financial markets through debt provided by banks to firms and households. In this thesis, I study some of the channels through which real business cycles, i.e. fluctuations in e.g. consumption and employment over the course of time, can be affected by shocks or frictions in the financial sector.

In the first chapter, I study, jointly with Alessia De Stefani, how rising levels of household credit over the years leading up to the Great Recession may have played a role in creating vulnerabilities in the Danish economy. Various researchers have argued that household credit can boost demand but that the following rise in employment is unsustainable if, for instance, workers move from more productive to less productive sectors. Once the positive trend reverses, the economy is weaker than before the boom which results in many lay-offs and a deep recession. In Denmark, a mortgage reform which tremendously lowered monthly instalments left many households with extra cash on their hands. We show that the reform is likely to have increased consumption

but that the resulting job creation was unequally distributed across sectors. In particular, employment expanded in less productive sectors such as services or retail while manufacturing did not at all respond to the boost in household consumption.

In the second chapter, I am interested in the relationship between market power of banks and the way they charge interest rates from their borrowers (i.e. households and firms) and offer them to their savers. In particular, together with Lotta Heckmann-Draisbach, I examine if market power determines how banks pass on a shock in which the central bank raises the policy rate. Market power signifies the extend to which a bank can charge a price above its costs such that it can make profits. Alternatively, market power can be measured by a bank's importance in a geographical area compared to other banks within the same region. I show that banks with market power charge higher loan rates in Germany, but once the central bank raises interest rates, these banks follow the central bank's lead to a smaller extent. For borrowers this means that the loan rate they need to pay does not rise as much if they are customers of a high market-power bank. However, for savers this is detrimental, since the interest they get on their savings does not rise as much as it would at a bank with lower market power.

In the third chapter, I write a theoretical model in which firms cannot pay their workers without borrowing funds externally. To study interactions of labour and credit markets, I completely abstract from capital and study two versions of the financial contract. In the first version, firms can contact their lender right after they observe a sudden improvement in economic conditions and the contract is resolved within the same period. As this generates an unrealistically procyclical premium on external funds, I introduce a different timing of the financial contract. In the second version of the model, firms need to fix contract terms at the end of a period, before the aggregate state evolves. Inter-

period financial contracts can generate an empirically consistent countercyclical premium on external funds. However, in both versions, real variables such as output depict a muted response compared to a model without borrowing. This is mainly due to the sluggish response in firms' equity.

Contents

Chapter 1

Real effects of Relaxing Financial Constraints for Homeowners – Evidence from Danish Firms

1.1 Introduction

The events unfolding around the Global Financial Crisis have stressed how a contraction in credit availability can drastically reduce households' spending capacity and, through this channel, have adverse and long-lasting consequences on firm-level activity (Mian et al., 2013; Mian and Sufi, 2014; Di Maggio and Kermani, 2017).

Can real economic activity be traced back to credit expansions during boom phases? History teaches us that recessions which follow credit booms tend to be prolonged, and characterised by amplified job losses (Jordà et al., 2013, 2016; Mian et al., 2017). Credit growth tends to be accompanied by a rise in housing valuations, to which firms often react by increasing employment levels and prices (Di Maggio and Kermani, 2017; Stroebel and Vavra, 2019). Credit expansions are also marked by an inflation of the non-tradable sector relative to the tradable one, and by real appreciation, developments which can severely amplify economic downturns (Mian et al., 2020). Yet, we know very little about the channels through which credit growth contributes to real economic activity or to the buildup of vulnerabilities during upswings.

This chapter presents novel evidence on the extent to which financial innovation can increase households' borrowing and spending capacity and, through this channel, spill over to the activity of firms. To pin down the mechanisms underlying these patterns, we exploit detailed micro-data covering the entire population of Danish households and firms, which we observe between 2004 and 2010.

This period presents several characteristics that suggest a credit-driven expansion was underway in the Danish economy. Between 2004 and 2010, mortgage credit and household spending expanded dramatically, and so did employment growth in the non-tradable sector (Figure 1.C.1 in Appendix 1.C). This period is also characterised by a major innovation in the Danish mort-

gage market: the introduction of interest-only (IO) mortgages in October 2003. This reform allowed Danish borrowers to avoid repayment on the principal of their mortgage for up to ten years from origination. The choice of an IO loan thus significantly reduces monthly instalments, temporarily freeing resources for non-housing consumption. Interest-only mortgages quickly became a mass product, reaching about half of the outstanding mortgage stock within a couple of years (Figure 1.C.2 in Appendix 1.C).

Our results indicate that the introduction of IO loans had significant implications for real economic activity in Denmark over this time frame. We show that the reform sharply increased Danish households' spending capacity. This demand shock increased revenues and profits for Danish firms and created a significant amount of jobs, particularly in the non-tradable sector.

Our empirical analysis unfolds in two steps. We begin by estimating how household consumption reacts to the introduction of IO mortgages. To do so, we follow the methodology proposed by Leth-Petersen (2010) and apply a difference-in-differences strategy based on the distribution of liquid savings across Danish households.[1] Due to higher administration margins and higher overall interest repayments, non-amortising loans tend to be more expensive than equivalent amortising mortgages. Thus, these loans are unlikely to appeal equally to all households. Consumers with low levels of liquid savings relative to their income are likely to benefit the most from the temporary reduction in instalments granted by non-amortising loans, and they are also more likely to use the additional liquidity to finance non-housing expenditure. Using a proprietary dataset, Larsen et al. (2018) indeed find that Danish households who choose IO loans are likely to have low levels of liquid savings to income and to increase consumption levels after loan inception. Many of these constrained borrowers maintain high levels of expenditure throughout the loan lifecycle,

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[1]Leth-Petersen (2010) studies the behaviour of Danish consumers in the aftermath of another mortgage reform, the introduction of home-equity lines of credit in 1992.

to the point that some of them are forced to cut spending once amortisation begins (Andersen et al., 2019).

We find that on average liquidity-constrained homeowners significantly shift their consumption after the reform, compared to a similar group of non-liquidity-constrained households.[2] This effect occurs only after 2003 and is not driven by housing wealth, or other time-varying shocks affecting differentially the two groups of homeowners. Our estimates indicate that, for the average Danish homeowner, the increase in yearly expenditure is worth up to DKK 10,900 (or USD 2,000), at peak. A simple back of the envelope calculation indicates that the aggregate demand effect amounts to at least DKK 15 billion (USD 2 billion), or 2% of household expenditure levels in 2002.

In the second step, we estimate how this spending shock affects firm dynamics. To do so, we develop a panel dataset that links all establishments operating in the country to their parent firms and municipality. Geographical identifiers allow us to link regional spending shocks to the activity of local firms. To address endogeneity between household expenditure and firm-level outcomes, we employ an instrumental variable strategy. We develop a municipality-based, time-varying measure of the consumption shift originating from the reform, inspired by Bartik (1991) instruments. This variable is constructed as the interaction between the expenditure response of the average homeowner at any given point in time, estimated in the first step, and the number of liquidity-constrained homeowners living in a given municipality in 2002. This instrument is based on a simple intuition: municipalities which hosted a higher number of liquidity-constrained households before 2003 are likely to be subject to larger demand shocks, following the introduction of IO loans.

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[2]Bäckman and Khorunzhina (2020) use an empirical approach similar to ours and show that Danish consumers who had larger housing wealth relative to their income in 2002 react to the introduction of IO loans by increasing their expenditure levels, after the reform.

Our most conservative estimates indicate that for a 10% increase in consumer expenditure, Danish firms experience a 0.2% increase in revenues and profits, within the same year. Firms react to this demand shock by increasing employment by a similar margin, albeit we register no significant short-run effect on investment. These results are robust to controlling for several ex-ante characteristics of regions, time-varying house price shocks, and aggregate dynamics.

The granularity of the data allows us also to address a major identification challenge: separating the role of local demand from the effect of a shift in credit supply to firms. The IO reform could, potentially, increase firms' borrowing capacity and thus drive the firm-level outcomes directly. To address this issue, we include firm-by-year fixed effects, thus relying only on cross-establishment variation within a given firm and year. Given that credit lines are negotiated at the firm level, this strategy allows us to isolate the role of local demand.

A regionally-weighted back-of-the-envelope calculation based on our most conservative estimates suggests that the introduction of IO loans accounts for the creation of at least 2,500 jobs between 2004 and 2010.

The shift in demand expands revenues, profits and employment in non-tradable firms and sectors, but not in tradable ones. In line with earlier literature (Mian et al., 2020), we interpret this finding as suggesting that firm activity was driven by local demand, rather than by an improvement in the local economy's productive capacity. Expansions driven by household demand tend to reverse more quickly during downturns and expose economies to longer-lasting recessions (Jordà et al., 2016; Mian et al., 2020).

A second potential negative spillover of a relative expansion of the non-tradable sector tends to be real appreciation: rising labour demand may drive up wages above productivity levels and reduce the competitiveness of local exporters (Mian et al., 2020). However, we find no significant effect of the

demand shock on changes in wages across Danish firms. Consistently, we measure no significant changes in labour productivity, or in the trade balance. Albeit these results cannot speak to aggregate changes in wages or competitiveness, this evidence is indicative that real appreciation is likely to have been less severe in Denmark than in other countries (Mian et al., 2020). Possibly, this difference can be explained through the prevalence of collective bargaining systems in the Danish labour market, which may have played a role in keeping wages aligned across the country, and in check with productivity growth.

Our main contribution is to highlight the real effects of a credit-induced expansion in consumer demand. We provide evidence that mortgage markets have the power to shape the size and composition of economies during an expansion phase. Most of the existing literature has focused on the Great Recession, either by estimating the real implications of the credit crunch (Mian et al., 2013; Mian and Sufi, 2014; Di Maggio and Kermani, 2017; Garcia, 2020), or by showing how countercyclical monetary policy transmits to household spending via the structure of the outstanding mortgage stock (Di Maggio et al., 2017; Cumming, 2018; Luck and Zimmermann, 2020).

So far, there is very little evidence about the role of mortgage credit in shaping real economic outcomes during an expansion phase. One exception is Mian et al. (2020), who show how credit market deregulation in the US generates regional booms which increase the size of the non-tradable sector and predict more severe contractions in economic activity, ex-post. This chapter complements their results in several ways. First, Mian et al. (2020) rely on an indirect measure of consumption, credit growth at the regional level. Instead, we observe household spending directly and can therefore estimate elasticities of firm-level outcomes to consumption. Methodologically, the granularity of our data allows us to shut down many potential confounders, such as the direct effects of credit expansion on firms. Furthermore, a general credit market

deregulation can affect consumer demand through many channels, including, for example house price growth (Di Maggio and Kermani, 2017). We identify a cash-flow effect on consumption that would be active even in absence of a significant change in house prices.

Finally, we also draw inspiration from the vast applied literature which has emerged in recent years, assessing how household consumption reacts to innovations in mortgage markets and house prices (Hurst and Stafford, 2004; Leth-Petersen, 2010; Mian and Sufi, 2011; Paiella and Pistaferri, 2017; Kaplan et al., 2016; Andersen et al., 2016; Aladangady, 2017; Jensen and Johannesen, 2017; Larsen et al., 2018; Andersen et al., 2019).

This chapter proceeds as follows. Section 1.2 briefly describes our data sources. Section 1.3 provides some institutional context and describes our empirical approach. Section 1.4 outlines how household spending shifted in the aftermath of the IO reform and section 1.5 estimates the effects of this spending shock on firm activity. Section 1.6 concludes.

1.2 Data

The data used in this chapter stems from several administrative registries covering the entire population of households and firms living and operating in Denmark. These are collected and administered by Statistics Denmark.

1.2.1 Individuals, households and consumption imputation

Each person who is tax liable in the country can be identified in the individual registries through an anonymised version of CPR number, the Danish equivalent of social security numbers. This number can be used to match the population registries to their income, taxes, wealth and the balance sheet components across registries. Data on income and assets comes directly from the Central

Customs and Tax Administration (SKAT) and is available on an annual basis.

Individuals can be mapped to households, defined as one adult or two adults co-habiting plus dependent children. Household-level income and balance sheets can be used to impute annual household expenditure, defined as the sum of disposable income minus changes in net wealth, following the work of Browning and Leth-Petersen (2003), Browning et al. (2013), Leth-Petersen (2010), Andersen et al. (2016) and Hviid and Kuchler (2017). We define disposable income as the sum of wage income, capital income and social benefits minus taxes, alimony payments and tax-exempted interest expenses on mortgages and student loans.[3] The change in net wealth consists of net income from pension schemes as well as the change in stock assets and deposits from the previous to the current year-end, respectively. Changes in deposits include not only changes in cash holdings but also evolution in the market value of bonds and mortgage deeds from one year to the next. The latter aims at approximating payments on mortgage debt which are to be deducted from disposable income when imputing consumption. Payments on other forms of bank debt are similarly calculated as the yearly change in a household's outstanding debt.[4]

A general caveat of the procedure is that changes in asset prices affect imputed consumption, even though asset revaluations might not affect actual spending. The data does not allow us to distinguish between changes in net wealth due to innovations in stock prices and realised capital gains or losses from trading activities. For example, if a household invests in stocks, this decision will correctly reduce spending in that year, all else held equal; but imputed expenditure will also decline when the price of existing stocks increases, in absence of any active investment behaviour. However, Jensen and

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[3]The definition of disposable income also includes the calculated rental value of own housing. However, we deduct this again when imputing household spending.

[4]Since data on private pension savings is unavailable before 1999, we exclude private pension contributions from our consumption imputation. The imputation of consumption with and without pension savings is substantially different for self-employed workers, which we therefore exclude from the sample.

Johannesen (2017) ensure that adding changes in the general stock market index back into imputed consumption, or excluding all stock owners from the sample, does not make a substantial difference for imputed consumption over the period 2003–2011. To prevent an analogous bias arising from changes in house values, we exclude housing assets from the imputation just as Browning et al. (2013), Leth-Petersen (2010), Jensen and Johannesen (2017) and Hviid and Kuchler (2017).

Another potential bias stemming from the imputation procedure relates to the measurement of mortgage debt. In Denmark, mortgages are funded through callable bonds, issued by mortgage credit institutions. Bonds match the maturity of the loan, and interest rates are determined by market rates rather than by the lending bank. Mortgages can be refinanced at any time by the borrowers, by buying the underlying bond(s) at par and issuing a new one. In this institutional setting, a drop in market rates generally increases the outstanding bond value, for fixed-rate mortgage (FRM) holders. Since we only observe the market value of the underlying bond in our data, a drop in market rates would induce a mechanic reduction in net wealth for FRM borrowers and increase their imputed expenditure, even if actual household spending remained unchanged. However, market rates remained stable until the end of 2005, after which they gradually rose until the fourth quarter of 2008.[5] Furthermore, adjustable rate mortgages (ARMs) are naturally unaffected by changes in market rates and the share of ARMs rose significantly over this time frame (Larsen et al., 2018).

We restrict our estimations to a balanced panel of households continually observed between 1996 and 2010. We exclude self-employed people and households who change tenure status at any point during this time frame (switching from renting to owning, or vice versa) as the expenditure impu-

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[5]See e.g. http://www.nationalbanken.dk/en/marketinfo/official_interestrates/Pages/Default.aspx, viewed 12 February 2020.

tation for these categories of consumers is not reliable (Leth-Petersen, 2010).

As a result, our sample is composed of homeowners who remained home-owners between 2002 and 2010, or equivalent renters. Finally, we limit the sample to households in which the eldest person must be at least 24 and younger than 66 in order to study the decisions independent from extreme life-cycle dynamics.

1.2.2 Firms and establishments

The Central Business Register (*CVR, Det Centrale Virksomhedsregister*), owned by the Danish Business Authority (*Erhvervsstyrelsen*), assigns each legal entity in Denmark a unique (anonymised) identifier (CVR Number). For each firm we observe detailed balance sheet information at an annual frequency as well as the count of employees (in full-time equivalent) and sector of operation. We exclude firms without any employees at the end of the year (sole proprietors) and firms with balance sheets that originate in part or in total from imputation procedures. Other than these exclusions, we work with the entirety of employer firms operating in Denmark between 2004 and 2010.

We link firms (i.e. headquarters) to all of their establishments (i.e. plants/workplaces) and location (municipality) of operation. We collect information on the revenues, profits, employment and investment for each firm as well as each establishment. If a firm is a single-establishment firm, the firm and establishment are by definition identical. We mostly rely on firm-level information, since this data is readily available for all firms and allows us to distinguish between real and imputed balance sheets.

The registry-based data matches reasonably well the aggregate figures on the number of firms provided by Statistics Denmark in any given year and its trend over time. We observe that the number of employer firms (i.e active firms with at least one employee, excluding self employed entrepreneurs) is lower

than the aggregate figures by about 5,000 units out of 120,000, a difference that is roughly consistent across the years (Figure 1.C.3 in Appendix 1.C). This is explained by the fact that our data excludes financial companies and firms active in the agricultural sector. The year 2009, however, shows a discontinuity, which can be attributed to the change in definition of non-employer firms for the purpose of compiling aggregate statistics in the year 2008.

1.3   Background and empirical approach

This section presents background information on the IO reform in Denmark, its expected effect on consumption, and the empirical methodology.

1.3.1   Interest-only mortgages in Denmark

Denmark experienced a major mortgage reform in 2003. From the first of October, interest-only mortgages were made available to the public, allowing current and prospective homeowners to delay payment towards the principal of their mortgage for up to ten years. This mortgage typology quickly became very popular: the market value of outstanding IO mortgages accounted for close to half of total mortgage volume already in 2006 and has remained fairly stable ever since (Figure 1.C.2 in Appendix 1.C).

Interest-only mortgages can significantly reduce initial debt-servicing costs compared to canonical amortising mortgages.[6] As a result, not only these loans facilitate access to the housing market for new buyers, but, through a refinancing channel, can also alleviate monthly repayments for existing homeowners. However, they tend to carry higher costs than an equivalent amortising loan: this is due to higher administration margins and to higher overall interest repayments, since for the first ten years the outstanding principal remains un-

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[6]Currently, an ARM IO mortgage reduces initial monthly instalments by about 75%, compared to an amortising loan of the same size and maturity.

changed.

Thus, IO loans should appeal mainly to households for whom it seems optimal to defer amortization to the future, such as those bound by temporary liquidity constraints. Indeed, Larsen et al. (2018) leverage a proprietary dataset to document that uptake of IO mortgages in Denmark is prevalent among young consumers, who are likely to expect a steep income growth path; or older hand-to-mouth households. They show that IO borrowers do not tend to store the additional liquidity in savings but rather increase expenditure, which suggests a consumption smoothing motive.[7]

This behaviour is consistent with a simple life-cycle model where a fraction of households is liquidity constrained. Since these households are not constrained by lifecycle wealth but rather by current income, they do not optimise intertemporarily and hence always consume their entire budget.[8] In contrast to a standard consumption savings model without such households, even temporary gains in disposable income which are to be followed by higher costs in the future translate into higher consumption. In Appendix 1.A, we present in detail a stylised model which is closely related to Galí et al. (2007) who study the impact of a temporary increase in government spending on consumption. We make some crucial alterations and incorporate borrowing into the model. In particular, we assume that each period liquidity constrained households can borrow funds and show that a temporary relaxation of credit (and thus liquidity) constraints will immediately generate a positive response in aggregate consumption. Furthermore, the magnitude of the shift in consumption depends positively on the number of constrained households in the economy.

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[7]However, a significant fraction of Danish IO borrowers do not fully smooth consumption over the loan lifecycle and as a result they are forced to significantly cut expenditure, once the loan resets (Andersen et al., 2019).

[8]For early work on life-cycle models with liquidity constraints, see Dolde (1978); Muellbauer (1983); Alessie et al. (1997).

1.3.2 Effect of the reform on consumption: Identification

Household debt and expenditure increased significantly in Denmark after 2003 (Figure 1.C.1 in Appendix 1.C). In assessing how the mortgage reform affected these developments, we are faced with a limitation: our dataset does not contain information on the loan typology held by individual households. Thus, we follow the methodology adopted by Leth-Petersen (2010), who studies how Danish consumers reacted to a different mortgage reform: the introduction of home equity loans in 1992.

Leth-Petersen (2010) uses the ratio of liquid savings to income right before the 1992 reform was announced as a proxy for the likelihood to use home equity loans and shows that constrained households significantly increase spending in the subsequent years. Consumers with low levels of liquidity ex-ante should be generally more likely to use a mortgage product that provides them with higher levels of liquidity ex-post, like IO loans. Our theoretical framework predicts that access to additional liquidity should induce household consumption to increase.

Hence, we split our sample of homeowners into two groups, based on their ex-ante liquid savings-to-income ratios. Homeowners are allocated to the liquidity-constrained (treatment) group if they have less than 1.5 months of a year's disposable income stored in liquid assets at the end of 2002, the year before the reform was announced. Otherwise, they enter the control group.[9] We choose this specific threshold to be consistent with the existing literature (Leth-Petersen, 2010) and to obtain common support between the two groups, since this value splits our sample roughly half (Figure 1.C.4 in Appendix 1.C). This threshold is also highly correlated with IO ownership, measured ex-post.[10]

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[9]Liquid assets are defined as the sum of stocks, bonds and bank deposits held at year-end.

[10]We observe the typology of mortgage holdings only starting in 2009, through the mortgage registry. The relationship between liquid savings to income in 2002 and IO mortgage holdings in 2009 is highly non-linear; up to two months of income held as liquid savings, the correlation is strongly positive and declines afterwards (Figure 1.C.5 in Appendix 1.C).

Homeowners in the control group may have been affected by the reform as well, but we rely on the intuition that for constrained homeowners the treatment *probability*, or IO uptake, is larger. Also, constrained households with an IO mortgage should experience greater treatment *intensity*, or consumption response, due to their higher marginal propensities to consume out of additional liquidity.[11]

The identifying assumption is that assignment to the respective group, in this case the share of liquid savings to income, is exogenous to the reform. This assumption would be violated if people self-assigned into treatment, by adjusting their saving rates already in 2002 in anticipation of the mortgage reform. However, the bill regarding IO mortgages was first debated in Parliament only in the spring of 2003, and subsequently approved in June. Hence, an anticipation effect seems unlikely.

The difference-in-differences equation is defined as follows:

$$\frac{1}{k}\left(\sum_{i=1}^{k} Y_{h,2003+k} - \sum_{i=1}^{k} Y_{h,2003-k}\right) = \alpha_0 + \alpha_1 D_{h,2002} + \alpha_2 \mathbf{X}_{h,2002} +$$
$$\psi_m + \epsilon_h \quad \forall k \in \{1,...,7\}$$

(1.1)

where Ys define outcome variables for household h in year t, such as household expenditure or debt. In line with Leth-Petersen (2010), we use expanding averages of differences in outcomes. In particular, $\sum_{i=1}^{k} Y_{h,2003+k}$ is the sum of a given household-level outcome over k years after the reform and $\sum_{i=1}^{k} Y_{h,2003-k}$ the respective sum over k years preceding the reform. This difference is then divided by the number of years, k. The year 2003 is excluded, thus resulting in a set of seven different yearly outcomes for every Y_h.[12]

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[11]Kaplan et al. (2014) show that consumption of households with low levels of liquid assets is more responsive to transitory income changes.

[12]For each k on household-level, the dependent variable is calculated as:

for $k = 1$: $Y_{h,2004} - Y_{h,2002}$,

for $k = 2$: $[(Y_{h,2005} + Y_{h,2004}) - (Y_{h,2002} + Y_{h,2001})]/2$,

for $k = 3$: $[(Y_{h,2006} + Y_{h,2005} + Y_{h,2004}) - (Y_{h,2002} + Y_{h,2001} + Y_{h,2000})]/3$, etc., up until $k = 7$.

Expanding averages help removing noise from imputation procedures, as year-on-year changes often exhibit discrete jumps (Leth-Petersen, 2010). Furthermore, this procedure takes into account that the effect of IO uptake on expenditure is likely to have been smoothed over a number of years.

In all estimations, the treatment indicator $D_{h,2002}$ takes value one if a household was liquidity-constrained in 2002, and zero otherwise. For each k, α_1 estimates the average effect of the IO reform on the change in outcomes of liquidity-constrained vis-à-vis unconstrained households. The sequence of α_1's then yields a time-varying average reform effect, spanning over the years 2004-2010.

We condition on a set of ex-ante household characteristics: age, income, family composition and house value, captured in the vector $\mathbf{X}_{h,2002}$, and include municipality fixed effects, ψ_m.[13] While the inclusion of individual-level characteristics aims at comparing similar households across the two groups, the fixed effects rule out that time-invariant regional characteristics may cause them to react differently to the same reform.

Naturally, constrained and unconstrained households might have been differently exposed to other time-varying shocks after 2003. To mitigate these concerns, we run a number of placebo tests.

1.3.3 Impact of household consumption on firm dynamics: Identification

To link the behaviour of households to the decisions of firms, we exploit geographical variation in the magnitude of the spending shock across Danish municipalities.[14]

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[13]We follow Leth-Petersen (2010) and choose ex-ante values of the household characteristics because their evolution ex-post could be affected by the reform. In a robustness test, we control for their contemporaneous equivalents.

[14]In doing so, we follow a strand of applied literature which estimates firms' response to shocks in household demand. For examples of recent contributions, see Giroud and Mueller

The baseline equation, aimed at measuring how regional spending shocks affect local firms, is expressed as follows:

$$log(Y_{ifmt}) = \beta_0 + \beta_1 log(C_{mt}) + \theta_f + \phi_t + \epsilon_{ifmt} \tag{1.2}$$

where Y_{ifmt} measures a given outcome, such as revenues, profits or employment, for establishment i, located in municipality m and belonging to firm f, at the end of year t.[15] The variable C_{mt} is the municipality-level sum of imputed household consumption at the end of year t.[16] To account for the skewed distribution in both dependent variables and consumption levels, we log-linearise both sides of this equation. This choice allows us to interpret β_1 as an elasticity. Firm fixed effects, θ_f, account for time-invariant characteristics of firms and reduce this estimation to a model in changes. Year fixed effects, ϕ_t, capture the effect of aggregate macroeconomic shocks. We cluster standard errors at the municipality-level, to take into account correlation in error terms across firms operating in the same city over time.

This model effectively compares changes in outcomes as firms are exposed to differential demand shocks in the same year, resembling a difference-in-differences approach. However, Equation (1.2) is subject to numerous criticisms. To begin with, the direction of causality is unclear. For instance, a positive shock to labour productivity in a particular sector may increase employment and wages and thus lead to higher consumption in regions where these sectors are prevalent. Likewise, regional consumption and employment may be simultaneously affected by numerous regional time-varying shocks, such as rising public investment, expectations, or credit conditions.

(2018) or Di Maggio and Kermani (2017).

[15]For most estimations, we rely on firm-level data, as this is a more reliable data source. Thus $i=f$.

[16]Currently there are 98 municipalities in Denmark, following a reform in 2007 that reduced their number from the 270 before the reform. Since some municipalities were merged and others were split, we assign households and firms to the new municipality codes based on the municipality code assigned to the individual building after 2007.

To address these concerns, we employ an instrumental variable strategy, by developing a measure of reform-driven spending which varies across municipalities and over time.

We define the instrument as follows:

$$Spending_{mt} = \alpha_{1,2003+k} * N_{m,2002} \tag{1.3}$$

where $\alpha_{1,2003+k}$ measures the average increase in consumption for liquidity constrained homeowners in each year between 2004 and 2010, estimated by Equation (1.1). $N_{m,2002}$ is the number of liquidity-constrained homeowners living in a municipality at the end of 2002, the year before the reform was announced.[17]

The intuition behind this measure is simple: municipalities that hosted a larger number of liquidity-constrained homeowners before the reform should experience a more pronounced increase in household expenditure after 2003. At the same time, the measure is pre-determined and cannot be affected by the evolution of local firm dynamics after the reform. Thus, $Spending_{mt}$ is a regional, time-varying measure of the change in consumption occurring after the reform, resembling a Bartik instrument (Bartik, 1991). The main difference with a standard Bartik instrument is that by interacting the average spending effect with the *number* of liquidity-constrained homeowners, we rely on ex-ante cross-regional variation in *levels*, rather than shares. However, this choice stems naturally from the fact that the estimated shifts in consumption (i.e. the α_1's from Equation (1.1)) measure changes in average *household-level* expenditure as opposed to a regional aggregate.[18]

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[17]Figure 1.C.6 in Appendix 1.C depicts the variation in the number of constrained homeowners across Danish municipalities in 2002.

[18]To provide a numerical example, the number of constrained homeowners living in Copenhagen in 2002, for whom we have observations in every year afterwards and who never bought, sold or moved, is 12,100. Hence, $Spending$ for the municipality of Copenhagen in 2004 is the product of the aggregate household-level effect as measured by α_1 for 2004 (i.e. DKK 5,100), multiplied by 12,100 which gives roughly DKK 62 million (USD 10 million).

The first-stage and second-stage equations are defined as follows:

$$log(C_{mt}) = \gamma_0 + \gamma_1 log(Spending_{mt}) + \gamma_3 \mathbf{X}_{m,2002} + \gamma_4 HP_{m,t-1} + \theta_f + \phi_t + v_{ifmt} \quad (1.4)$$

$$log(Y_{ifmt}) = \beta_0 + \beta_1 \widehat{log(C_{mt})} + \beta_3 \mathbf{X}_{m,2002} + \beta_4 HP_{m,t-1} + \theta_f + \phi_t + u_{ifmt} \quad (1.5)$$

where γ_1 in Equation (1.4) captures the relevance of the instrument, or the relationship between $Spending_{mt}$ and aggregate household consumption in a given municipality and year, C_{mt}. Y_{ifmt} in Equation (1.5) represents firm or establishment-level outcomes, such as revenues, profits, investment and employment. The coefficient of interest is β_1, which measures the effect of aggregate regional consumption on firm dynamics.

The identifying assumption requires $Spending_{mt}$ to be orthogonal to *unobserved* firm and municipality-level characteristics that affect establishment-level outcomes directly. In other words, for the instrument to be valid, the interaction between the ex-ante number of constrained homeowners residing in a given municipality and average yearly spending increase needs to have an effect on firms solely through its effect on consumption.

A potential concern with this approach is that the number of constrained homeowners, $N_{m,2002}$, is unlikely to be randomly distributed across the territory. This measure is likely to be correlated with other municipality characteristics that could drive firm activity directly, such as population size, or income levels. Also, the effect of a given demand shock is likely to depend negatively on the ex-ante aggregate levels of consumption in the region, as its relative impact will be comparatively smaller. These level effects are also likely to be correlated with the number of liquidity-constrained homeowners.

To address these issues, we control for a set of ex-ante municipality characteristics.[19] The vector $\mathbf{X}_{m,2002}$ includes population size, the average ratio of

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[19]Including the number of liquidity-constrained homeowners or municipality fixed effects would leave us with no variation, since we log-linearise the interaction term $Spending_{mt}$.

liquid assets to income among locals and aggregate household consumption, all measured in 2002. The inclusion of these variables allows us to measure how a relative change in expenditure affects firms operating in regions of similar size, where the population has comparable characteristics and exhibited similar pre-reform consumption levels.

Another potential confounder is appreciation in property values, which could simultaneously drive consumption, revenues and employment within the region.[20] To address this issue, we control for lagged house price changes at the municipality level, $HP_{m,t-1}$.[21]

Firms with different characteristics may also be distributed differently across municipalities. For instance, relatively poorer regions could be simultaneously characterised by a higher number of constrained households and a dominant presence of large grocery stores. In richer regions, smaller owner-run corner shops could instead be prevalent. If these two types of stores reacted differently to local changes in demand, for example due to their differential hiring capacity, the instrument would capture the role of unobserved firm characteristics. The inclusion of firm fixed effects, however, largely mitigates this concern by controlling for their time-invariant characteristics.

Year fixed effects, ϕ_t, ensure that our estimates do not capture aggregate shocks, such as macroeconomic policy, or business cycle variation.

The inclusion of these controls aims at insuring the validity of the exclusion restriction: $Spending_{mt}$ can be considered a valid instrument only after partialling out ex-ante regional or firm-level differences and various shocks in fundamentals. Under the assumption that the exclusion restriction holds, our IV estimation yields an elasticity of establishment outcomes to changes in

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[20]Consumption and employment are jointly explained by negative shocks to housing net worth (Mian and Sufi, 2014).

[21]The house price index is based on sales of residential properties. It is computed as the change in the average price/sqm in a given municipality between the fourth quarter of a year and four quarters before.

consumer demand.

The validity of $Spending_{mt}$ as an instrument implies a parallel-trends assumption: the number of liquidity constrained homeowners should affect consumption and firm-level outcomes only after 2003, and not before. Figure 1.C.7 and Figure 1.C.8 in Appendix 1.C suggest that this assumption is not violated.

1.4 Results: Household expenditure after 2003

Table 1.1 presents the estimates of Equation (1.1), aimed at retrieving how the expenditure of liquidity constrained homeowners changes vis-à-vis unconstrained ones in the post-reform period.

Columns 1–3 in Table 1.1 show that up to 2002, expenditure growth in our treatment group was consistently lower than in the control group, with no significant pre-trends.[22]

After 2003, this pattern reverses. The coefficients in columns 4–10 of Table 1.1 depict the seven α_1's in Equation (1.1), for each year between 2004 and 2010. The relative change in annual expenditure between 2002 and 2004 is DKK 5,100 (roughly USD 780) higher for constrained homeowners than for non-constrained ones (column 4). Assigning placebo treatment years verifies that this relative increase in expenditure occurs only after 2003, the year in which interest-only mortgages were introduced.[23]

The consumption of liquidity-constrained homeowners vis-à-vis the control group rises progressively over the years, up to DKK 10,900 (USD 1,650) in 2007 and then fades out through the crisis and recession years. In 2010, the

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[22]These pre-reform measures are defined as the averages of expenditure changes over two years. For example, $\Delta C_{2002} = [(Y_{h,2002} + Y_{h,2001}) - (Y_{h,2000} + Y_{h,1999})]/2$ and $C_{2001} = [(Y_{h,2001} + Y_{h,2000}) - (Y_{h,1999} + Y_{h,1998})]/2$. We can only impute expenditure as far back as 1997, hence we are unable to take average changes over a longer time horizon, or expand the averages further.

[23]In Table 1.B.1 in Appendix 1.B, we define three placebo treatment years (1998, 1999, 2000) and assign households into treatment and control groups according to their liquid assets to income-ratio at the time. Regressing average expenditure changes on the placebo treatment status consistently yields negative coefficients.

Table 1.1: Effect of reform on homeowners' expenditure

VARIABLES	(1) ΔC_{2000}	(2) ΔC_{2001}	(3) ΔC_{2002}	(4) ΔC_{2004}	(5) ΔC_{2005}	(6) ΔC_{2006}	(7) ΔC_{2007}	(8) ΔC_{2008}	(9) ΔC_{2009}	(10) ΔC_{2010}
	Pre Reform Years					Post Reform Years				
Constrained$_{2002}$	-6.8***	-7.2***	-6.2***	5.1***	4.5***	9.1***	10.9***	8.4***	5.9***	1.3**
	(0.84)	(1.04)	(0.99)	(1.2)	(0.95)	(0.84)	(0.78)	(0.74)	(0.69)	(0.65)
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Family Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	99,443	99,471	99,472	99,491	99,487	99,455	99,421	99,387	99,347	99,283
R-squared	0.008	0.011	0.024	0.005	0.019	0.045	0.088	0.130	0.164	0.175

Source: Registry data, Danish population, 1996-2010. *Notes*: Results include only a balanced panel of households that were recorded as homeowners for tax purposes in the year 2002 and never moved or changed tenure status through the sample period. Coefficients to be interpreted in DKK thousands. The dependent variable is the within-household change in the expanding average of imputed consumption for each given year from before and after the reform. Household level controls include the house value in 2002 (logs); annual household income (logs); age of the household head (defined as the person with the highest income); number of family members and number of children in 2002. Standard errors in parentheses are robust to heteroskedasticity and are clustered at the municipality level.*** p<0.01, ** p<0.05, * p<0.1.

effect amounts to only DKK 1,300 (USD 200).

These results show that the treatment group enters a relatively steeper consumption growth path compared to the control group, exactly in correspondence with the introduction of IO mortgages. Nevertheless, liquidity-constrained homeowners could have been subject to other time varying shocks than the IO reform, after 2003. We now turn to ruling out some of these potential confounders.

While liquidity-constrained homeowners are more indebted already before the reform, they lever up to a substantially larger extent in its aftermath, supporting the notion that growth in consumption was accompanied by a significant development in mortgage credit uptake (Table 1.B.2 in Appendix 1.B).

The spending and leverage effects could, however, also stem from differential income paths of liquidity-constrained versus unconstrained homeowners. Yet, we do not observe a relatively steeper growth path in disposable income within the constrained group, compared to the control (Table 1.B.4 in Appendix 1.B).[24] Similarly, the consumption effect holds to controlling for contemporaneous evolutions in disposable income, wealth and life-cycle dynamics (Table 1.B.5 in Appendix 1.B).

A potential further concern relates to other policy changes enacted around 2003, which could drive up the expenditure of liquidity-constrained households. For example, Denmark passed a major tax reform in 2004, which reduced labour income taxation, particularly on lower income brackets. To stave off the concern that a reduction in tax rates could be the main driver of the expenditure shift we observe among liquidity-constrained homeowners, we estimate Equation (1.1) on renters. Like in the case of homeowners, liquidity-

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[24]Exclusively in 2004, 2005 and 2006, liquidity-constrained homeowners experience an increase in disposable income vis-à-vis unconstrained ones (Table 1.B.4 in Appendix 1.B). However, the gains are only a fraction of the shifts in consumption in the respective years, in absolute terms (Table 1.1). Therefore, a shock to disposable income together with higher MPCs among the treatment group could not drive the consumption shifts alone.

constrained renters are likely to benefit comparatively more from the tax re-
form, as this is likely to increase their disposable income and thus reduce
their liquidity constraints. If the tax reform was the real driver of the change
in homeowners' spending patterns after 2003, we should observe a change
in consumption among liquidity-constrained renters as well. On the other
hand, renters' expenditure cannot be directly affected by the IO reform, in-
dependently of their degree of liquidity constraints.[25] In the pre-reform pe-
riod, liquidity-constrained renters increase consumption less than the control
group, consistently with the results on homeowners (Table 1.B.6 in Appendix
1.B). However, unlike in the case of homeowners, we observe no changes in
expenditure trends between the two groups of renters after 2003 (Table 1.B.6
in section 1.B). This evidence suggests that the tax reform is unlikely to drive
the expenditure changes we observe among homeowners, over the same time
frame.

Finally, housing wealth effects could play a role, since liquidity-constrained
homeowners may benefit more than others from the growth in house prices
occurring over this time frame. However, house valuations do not grow dif-
ferentially between the two groups of homeowners, suggesting that wealth ef-
fects are unlikely to be the main driver of the change in expenditure behaviour
(Table 1.B.3 in Appendix 1.B).[26]

A more fundamental concern relates to differential MPCs across the treat-
ment and control group. Liquidity-constrained households might display a
greater reaction both to idiosyncratic and aggregate shocks, since they are
likely to have higher marginal propensities to consume. Obtaining informa-
tion about the actual timing of IO uptake would not be sufficient to entirely
erase this concern: mortgage typology is a choice variable in itself, possibly

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[25] As discussed in section 1.2, we exclude households who change tenure status over this
time frame, including renters who become homeowners.

[26] Furthermore, the expenditure effect holds to controlling for contemporaneous changes in
housing valuation. See Table 1.B.5 in Appendix 1.B.

led by differential MPCs. To fully address this issue, we would need quasi-random assignment into IO loans around the time of their introduction.

We acknowledge this fundamental limitation posed by our empirical approach. Nevertheless, we believe that our results provide reasonable evidence in support of the claim that the spending shock we estimate is predominantly driven by the introduction of IO mortgages. First, we document a sharp increase in expenditure and leverage among liquidity-constrained homeowners in the immediate aftermath of this major mortgage reform. Second, the only other policy change we are aware of, the income tax reform in 2004, should affect liquidity-constrained renters as well. However, we observe no relative change in consumption paths for renters. Third, the effects are not explained by changes in individual observables, such as income or house price growth.[27] Finally, our findings are consistent with the results presented by Larsen et al. (2018) who, through a proprietary dataset, observe the actual timing of IO mortgage uptake in a large sample of Danish borrowers. They find that more constrained households increase leverage and expenditure after choosing this loan typology. Our results are qualitatively and quantitatively in line with theirs.

A simple back-of the envelope approach can provide an indication of the aggregate spending shock resulting from this event.

Multiplying the average yearly spending change estimated in Table 1.1 by the number of liquidity-constrained homeowners living in Denmark in 2002 yields an aggregate spending increase worth up to DKK 3.5 billion per year, at peak (Figure 1.C.9 in Appendix 1.C). The sum of these yearly spending shocks amounts to almost DKK 15 billion over the entire time frame, or about 2% of aggregate household consumption in 2002. These estimates are likely to

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[27]In addition, the placebo test in Table 1.B.1 in Appendix 1.B includes a period of mild house price growth, between of 2000 and 2001, but we not observe constrained homeowners' consumption to rise relative to the control group.

underestimate the true spending shock originating from the introduction of IO mortgages, for many reasons. First, we exclude households who switched into homeownership after the reform. These consumers probably reduced their cash-flow housing expenditure with respect to renting a similar housing unit, and therefore might have increased non-housing consumption. Furthermore, we disregard any general equilibrium effects originating, for example, from the effect of the reform on house prices.

1.5   Results: Firm-level outcomes

This section outlines how firm dynamics react to changes in household demand.

1.5.1   Baseline results

Table 1.2 presents the estimation of Equation (1.2), showing how regional household expenditure correlates with the financial and real outcomes of firms operating in the same municipality. Revenues, profits and employment rise together with spending levels (columns 1–3), albeit we register no significant correlation with investment, measured as gross-fixed capital formation (column 4).[28]

Since the correlations in Table 1.2 are likely to be spurious, in Table 1.3 we implement the instrumental variable strategy described in Equations (1.4) and (1.5). The first-stage results show that the instrument, $Spending_{mt}$, has a significant effect on aggregate household expenditure, measured at the municipality level, C_{mt} (column 1).[29]

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[28]In Table 1.B.7 in Appendix 1.B, we include control variables sequentially in order to assess their relative importance.

[29]To the extent that the instrument is a strong predictor of aggregate consumption and that consumption is related to firm-level outcomes, we should also observe a relationship in the reduced-form equation. Table 1.B.8 in Appendix 1.B ensures that this is the case.

Table 1.2: Aggregate spending and firm-level outcomes: OLS

VARIABLES	(1) Revenues Firm OLS	(2) Profits Firm OLS	(3) Employment Firm OLS	(4) Investment Firm OLS
$log(C_{mt})$	0.017***	0.018***	0.014***	-0.022
	(0.005)	(0.005)	(0.005)	(0.020)
$HPrice_{m,t-1}$	-0.017***	-0.009**	-0.014**	0.014
	(0.005)	(0.005)	(0.006)	(0.015)
$Pop_{m,2002}$	0.031**	0.036**	0.050***	-0.093*
	(0.013)	(0.014)	(0.014)	(0.049)
$Liqu./Income_{m,2002}$	0.001	0.001	0.001	0.008
	(0.003)	(0.003)	(0.003)	(0.011)
$log(C_{m,2002})$	-0.051***	-0.056***	-0.068***	0.110*
	(0.014)	(0.014)	(0.013)	(0.058)
Observations	409,847	408,676	409,987	409,898
R-squared	0.987	0.979	0.984	0.674
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Source: Data from Statistics Denmark, 2004-2010. *Notes*: The dependent variables are firm-level end-year log-linearised values of: revenues (col.1), profits (col.2), full-time equivalents (col.3), gross fixed-capital formation (col. 4). $log(C_{mt})$ measures aggregate household expenditure in a given municipality and year, measured as the sum of imputed consumption for all resident households. Municipality-level house price growth, $HPrice_{m,t-1}$, is measured as the change in the average sale price per sqm. $Pop_{m,2002}$ counts the number of individuals living in the municipality in 2002; $Liqu./Income_{m,2002}$ measures the average liquid-asset-to-income ratio in the resident population in 2002; $log(C_{m,2002})$ measures aggregate consumption levels in 2002. Standard errors, in parentheses, are clustered at the municipality-level. *** p<0.01, ** p<0.05, * p<0.1.

The second stage estimation shows the elasticity of response of firm activity to household expenditure. On average, given a 10% increase in regional household expenditure, local firms experience a 0.2% increase in revenues and profits (columns 2 and 3, respectively). We also observe significant effects on employment, as the number of full-time equivalents rises by 0.19% on average (column 3). Investment, on the other hand, appears to respond rather weakly (column 4).[30] These results are qualitatively in line with previous work de-

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[30]Panel A in Table 1.B.9, Appendix 1.B presents the same specification using establishment-level outcomes, rather than firm-level outcomes. Magnitudes in this alternative specification are much larger, but noisily estimated, likely because establishment-level variables are largely imputed. The sample size also drops significantly, as establishment-level balance sheet data

Table 1.3: Aggregate spending and firm-level outcomes: 2SLS

VARIABLES	(1) Consumption Municipality First Stage	(2) Revenues Firm 2SLS	(3) Profits Firm 2SLS	(4) Employment Firm 2SLS	(5) Investment Firm 2SLS
$log(Spending_{mt})$	0.351***				
	(0.046)				
$\widehat{log(C_{mt})}$		0.022***	0.021***	0.019***	0.044*
		(0.007)	(0.007)	(0.007)	(0.026)
$HPrice_{m,t-1}$	0.348***	-0.018***	-0.010**	-0.016***	-0.007
	(0.050)	(0.005)	(0.005)	(0.006)	(0.016)
$Pop_{m,2002}$	0.206	0.033**	0.036***	0.052***	-0.078
	(0.239)	(0.013)	(0.014)	(0.014)	(0.057)
$Liqu./Income_{m,2002}$	0.078	0.002	0.002	0.002	0.018
	(0.057)	(0.003)	(0.003)	(0.003)	(0.012)
$log(C_{m,2002})$	0.439*	-0.057***	-0.060***	-0.074***	0.029
	(0.264)	(0.015)	(0.013)	(0.015)	(0.070)
Observations	409,987	409,847	408,676	409,987	409,898
R-squared	0.968	0.039	0.012	0.020	0.032
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
F Stat	58	58	58	58	58

scribing how employment responds to credit supply expansions (Di Maggio and Kermani, 2017; Mian et al., 2020).

1.5.2 Robustness: Credit-supply shocks to firms

The IO reform allowed also companies to save on their mortgage payments by taking out non-amortising loans. One possible concern with the estimates in Table 1.3 is that they could reflect a change in credit supply to firms, rather than a shift in household demand.

In order to rule out this potential confounder, we introduce an alternative specification and include firm-by-year fixed-effects. By effectively partialling out all firm-specific shocks occurring at any given point in time, this specification allows to control for credit conditions faced by the firm, since these are negotiated at the headquarter level. The remaining variation is purely cross-sectional, comparing establishments belonging to the same firm in any given year. The main downside of this model is that it restricts the sample to the minority of firms having multiple establishments operating at the same point in time (Figure 1.C.10 in Appendix 1.C).

Despite this very restrictive specification, in Table 1.4 the results appear qualitatively in line with our baseline estimations. The first-stage equation shows that the instrument remains strongly predictive of aggregate household demand (column 1). In this specification, a 10% increase in household demand raises revenues by 1.5% and leads to a change in profits by 1.2% (columns 2 and 3, respectively). For the same shift in consumption, employment grows by 2.2% (column 4). Once again, investment does not appear to exhibit a significant response (column 5). This evidence strongly supports the notion that our estimates capture the effect of consumer demand on firm dynamics, rather than the effects of credit provision to firms.

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is only available for a subset of firms. To avoid these issues, we employ firm-level balance sheets, unless otherwise specified.

Table 1.4: Aggregate spending and establishment-level outcomes: firm-by-year fixed effects

VARIABLES	(1) Consumption Municipality First Stage	(2) Revenues Plant 2SLS	(3) Profits Plant 2SLS	(4) Employment Plant 2SLS	(5) Investment Plant 2SLS
$log(Spending_{mt})$	0.356***				
	(0.049)				
$\widehat{log(C_{mt})}$		0.155**	0.125**	0.227***	0.145*
		(0.077)	(0.062)	(0.079)	(0.081)
Observations	109,582	103,403	62,318	98,013	90,223
R-squared	0.959	0.009	0.010	0.010	0.009
Firm x Year FE	Yes	Yes	Yes	Yes	Yes
F Stat	53	53	53	53	53

The magnitude of these estimates deserves some discussion, as coefficients are significantly larger than those presented in Table 1.3. This difference can be imputed to three reasons. First, in Table 1.4 we rely on establishment-level data, a choice which yields larger magnitudes also in the baseline estimations.[31] Second, multi-establishment firms, the focus of Table 1.4, appear to generally respond more to demand shocks than the general firm population.[32] Finally, the inclusion of firm-time fixed-effects seems to improve both magnitude and significance of the estimates, compared to a model where firm and time fixed effects are included separately.[33]

1.5.3   Productive capacity versus household demand channel

Credit booms may be beneficial to the economy. However, credit expansions that affect the economy through the household demand channel can inflate the non-tradable sector, often at the expense of the tradable one, a dynamic which can amplify boom-bust dynamics and even reduce aggregate competitiveness (Mian et al., 2020; Borio et al., 2016; Bahadir and Gumus, 2016).

Non-tradable firms are likely to respond more to local demand shocks, as their revenues depend mostly on domestic spending capacity (Mian and Sufi, 2014). Thus, to test whether our baseline estimates reflect a demand-driven shock, Table 1.5 splits the firm sample across sectors.

Column 1 shows that the manufacturing sector, typically characterised as a tradable, does not display any response to an increase in household spending.[34] On the other hand, financial services, insurance and real estate (column

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[31]To see this, it is useful to compare estimates between Table 1.3 and Panel A of Table 1.B.9 in Appendix 1.B. Firm-level estimations focus on the response to spending shocks only in the region where the headquarter is located, thus underestimating the response to true "local" shocks, those affecting establishments.

[32]See difference between panel A and panel B of Table 1.B.9 in Appendix 1.B.

[33]To see this, it is useful to compare the estimates in Table 1.4 with those in Panel B of Table 1.B.9 in Appendix 1.B.

[34]This is in line with Borio et al. (2016) who find that during credit booms, growth of the manufacturing sector comes to a halt or even contracts.

Table 1.5: Aggregate spending and firm-level outcomes: sectors

	Manufacturing 2SLS Firm	FIRE 2SLS Firm	Retail 2SLS Firm	Services 2SLS Firm
Panel A				
	(1)	(2)	(3)	(4)
VARIABLES	Revenue	Revenue	Revenue	Revenue
$\widehat{log(C_{mt})}$	0.011	0.037**	0.016**	0.036**
	(0.011)	(0.016)	(0.007)	(0.016)
Observations	63,345	123,611	133,364	115,067
Panel B				
	(1)	(2)	(3)	(4)
VARIABLES	Profit	Profit	Profit	Profit
$\widehat{log(C_{mt})}$	-0.005	0.045**	0.017**	0.033**
	(0.014)	(0.022)	(0.008)	(0.015)
Observations	63,180	123,107	133,143	114,664
Panel C				
	(1)	(2)	(3)	(4)
VARIABLES	Employees	Employees	Employees	Employees
$\widehat{log(C_{mt})}$	-0.006	0.039**	0.014**	0.034**
	(0.015)	(0.018)	(0.006)	(0.016)
Observations	63,351	123,631	133,364	115,184
Panel D				
	(1)	(2)	(3)	(4)
VARIABLES	Investment	Investment	Investment	Investment
$\widehat{log(C_{mt})}$	0.035	0.022	0.037	0.094*
	(0.065)	(0.068)	(0.029)	(0.050)
Observations	63,351	123,630	133,276	115,184
Firm Fe	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Source: Data from Statistics Denmark, 2004-2010. *Notes*: 2SLS estimation. The dependent variables measure end-year log-linearised values of: revenues (panel A), profits (panel B), full-time equivalents (panel C), gross fixed-capital formation (panel D). $\widehat{log(C_{mt})}$ measures aggregate household expenditure in a given municipality and year, measured as the sum of imputed consumption for all resident households. Controls include municipality-level house price growth, number of individuals living in the municipality in 2002, average liquid-asset-to-income ratio in the resident population in 2002; aggregate consumption levels in 2002. Standard errors, in parentheses, are clustered at the municipality-level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

2), as well as retail trade (column 3) and services (column 4), exhibit significant responses to changes in local demand. These sectors can be generally characterised as non-tradable, since their business depends largely on the spending capacity of local residents. They all experience significant increases in revenues and profits in response to a shift in consumption (columns 2–4 of Panel A and B). Real effects are particularly pronounced in the financial, insurance and real estate sector, where a 10% increase in regional expenditure raises the number of full-time equivalents by 0.4% (column 2, Panel C). Given the same shift, retail trade and services also significantly increase the number of full-time employees, by 0.1% and 0.3%, respectively (columns 3 and 4). Investment is unaffected across all sectors. This is not particularly surprising, as in the short run firms might find it easier to scale up their workforce, rather than increase capital.

An alternative way to assess the relative effect on tradable versus non tradables is to use firms' balance sheets, exploiting variation across firms that display different degrees or openness to trade *within* a given sector.

When we define non-tradable firms based on their balance sheets, according to the thresholds adopted by Mian and Sufi (2014) and adding fixed effects for NACE 1 codes, the results are fundamentally unchanged (Table 1.B.10 in Appendix 1.B).[35]

1.5.4 Competitiveness

The increase in non-tradable employment and the change in relative prices between non-tradable and tradable goods are unique characteristics of household-demand driven expansions (Mian et al., 2020; Bahadir and Gumus, 2016). These episodes can be accompanied by wage hikes in the non-tradable sector, which

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[35]To be consistent with Mian and Sufi (2014), we define firms as being tradable if the sum of their import and exports at the end of the year divided by the number of full-time equivalents exceeds DKK 70,000, or USD 10,000. Firms are classified as non-tradable otherwise.

may spill over to the tradable one, leading to a loss in competitiveness (Mian et al., 2020). This real appreciation leads, in the aggregate, to a deteriorating trade balance (Bahadir and Gumus, 2016).[36]

To test whether Danish firms experienced a loss in competitiveness due to the introduction of IO loans, in Table 1.6 we analyse the developments of wage bills, productivity, imports and exports, as companies are exposed to differential demand shocks.

We find very little evidence of a loss in competitiveness among Danish firms over the years 2004–2010. The wage bill remains constant, both in the general sample and in the manufacturing sector (panels A and B, column 1). We neither observe any decline in labour productivity (column 2), measured as value added per full-time equivalent. Possibly as a consequence of this lack of real appreciation, the relative size of imports and exports also remains unchanged, both for manufacturing firms and for the overall sample (columns 3 and 4).

Firms active in the financial sectors, real estate and insurance exhibited the strongest employment response to changes in local demand (Table 1.5). Indeed, wages in these firms tend to increase significantly, in response to an outward shift in consumption (Table 1.6, panel C, column 1). Despite the fact that wage growth is not accompanied by a significant increase in labour productivity (column 2), these wage hikes do not appear to have spilled over to the tradable sector. These results differ from those presented by Mian et al. (2020), who show that U.S. states exposed to greater credit expansion exhibited higher overall wage growth.

A possible explanation for this difference may be the dominant role played by labour unions in the Danish economy. The strong collective bargaining sys-

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[36]The economy's overall competitiveness can also be hampered by labour reallocation from more productive sectors, such as manufacturing, towards less productive ones, such as construction (Borio et al., 2016). Once demand contracts, downward wage rigidities can amplify the bust (Mian et al., 2020).

Table 1.6: Aggregate spending and firm-level outcomes: competitiveness

VARIABLES	(1) 2SLS Wage/FTE	(2) 2SLS Value/FTE	(3) 2SLS Imports/FTE	(4) 2SLS Exports/FTE
Panel A				
	Overall	Overall	Overall	Overall
$\widehat{log(C_{mt})}$	0.002	-0.002	-0.001	0.044
	(0.003)	(0.005)	(0.027)	(0.040)
Observations	449,266	444,133	448,894	449,214
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
F Stat	57	57	57	57
Panel B				
VARIABLES	(1) Manufacturing	(2) Manufacturing	(3) Manufacturing	(4) Manufacturing
$\widehat{log(C_{mt})}$	0.004	0.015*	-0.150*	0.077
	(0.007)	(0.008)	(0.085)	(0.112)
Observations	63,350	62,732	63,316	63,329
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Panel C				
VARIABLES	(1) FIRE	(2) FIRE	(3) FIRE	(4) FIRE
$\widehat{log(C_{mt})}$	0.027***	0.001	-0.021	0.125
	(0.009)	(0.015)	(0.090)	(0.093)
Observations	123,596	122,298	123,497	123,622
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Source: Data from Statistics Denmark, 2004-2010. *Notes*: 2SLS estimation. The dependent variables measure end-year log-linearised values of wages per full-time equivalents (FTE) (col. 1), value added per FTE (col. 2), imports per FTE (col. 3), exports per FTE (col. 4). $\widehat{log(C_{mt})}$ measures the fitted values of aggregate household expenditure in a given municipality and year. Controls include municipality-level house price growth, number of individuals living in the municipality in 2002, average liquid-asset-to-income ratio in the resident population in 2002; aggregate consumption levels in 2002. Standard errors, in parentheses, are clustered at the municipality-level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

tem has a track record of keeping average wages aligned across the country, and in check with productivity growth. This institutional feature might explain why we do not observe regional variation in the response of wages to local demand shifts.

However, these results are to be interpreted with caution. Our empirical strategy relies on regional exposure, implying that we cannot speak to aggregate shocks. Real appreciation could still have occurred for the Danish economy as a whole, and our estimates would be unable to pick this up. Another source of vulnerability could arise from labour reallocation from more productive sectors (manufacturing) towards less productive ones (construction). Our estimates are also unable to shed light on these developments.

1.5.5 Aggregate employment effects

Danish households significantly increased their spending in the aftermath of 2003. Using a simple back-of-the envelope approach, we estimate the total increase in household consumption to be worth at least DKK 15 billion between 2004 and 2010 (Figure 1.C.9 in Appendix 1.C). This amounts to about 2% of aggregate household expenditure in 2002, and thus constitutes a sizeable increase in aggregate demand.

To retrieve the aggregate employment implications of these results, we follow a similar approach. Beraja et al. (2016) show that for the U.S., these calculations perform well in determining the impact of demand shocks on employment losses.[37] Because our analysis relies on regional variation, we follow closely Hagedorn et al. (2015) and estimate a regionally-weighted measure of the percentage change in aggregate employment that is caused by our measure of credit-induced shift in consumption:

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[37]Beraja et al. (2016) find that the responses of aggregate employment to regional variation in household demand perform equally well when calculated with back-of-the-envelope or when simulated in a heterogeneous agents model. At the same time, using regional variation outperforms those estimations that rely on aggregate data.

$$\pi_{DK} = \beta_1 * \sum_{m=1}^{N} \left[\frac{E_{m,2002}}{E_{DK,2002}} * \sum_{t=2004}^{2010} \frac{Spending_{mt}}{Consumption_{m,2002}} \right] = 0.09\% \qquad (1.6)$$

where t defines each post-reform year (2004–2010). β_1 is the coefficient in Equation (1.5), or the effect of IO expenditure on employment. We employ a conservative approach, and using the results in Table 1.3, we set this coefficient at 0.02. $Spending_{mt}$ measures the regional consumption shock originating from the reform in any given year (as defined in Equation (1.3)), expressed as a percentage change with respect to aggregate consumption in the same municipality in the year before the reform. $E_{m,2002}$ measures employment in municipality m in 2002, and $E_{DK,2002}$ is aggregate pre-reform employment in Denmark. In other words, we weight each municipality-level change in consumption for the relative relevance of the same municipality in the Danish labour market.

This methodology allows us to retrieve an estimation of the aggregate employment effect, expressed as the change in full-time equivalents respect to the pre-reform period:

$$\delta_{DK}^{E} = \frac{\pi_{DK} * E_{DK,2002}}{1 + \pi_{DK}} = 2,500 \qquad (1.7)$$

We estimate that the reform created at least 2,500 positions (full-time equivalents) between 2004 and 2010. We interpret this estimate as a lower bound, for two reasons. First, we rely on our most conservative estimated coefficient: choosing β_1 from Table 1.4 would suggest that the same spending shock could have created up to 27,000 jobs, over this time frame.

Second, $Spending_{mt}$ is likely to severely underestimate the effect of the IO reform on regional consumption. This measure only captures the cash-flow effect stemming from the refinancing of old amortising mortgages into IO ones, but neglects the effect of the reform on home-buyers, or the general equilibrium effects resulting from changes in house prices.

1.6   Conclusion

Credit supply shocks have been the object of intense scrutiny in the aftermath of the Great Recession. Negative financial shocks transmit to the real economy, generating significant losses in demand, production and employment. In this chapter, we provide evidence that this financial channel is active also in boom phases. Financial innovation, under the guise of a new mortgage product that relaxes financial constraints across the population, had a significant effect on Danish consumer demand during the 2000s. This demand shocks transmitted to firms, creating additional revenues and jobs, and shifted the composition of employment in favour of the non-tradable sector.

Our results speak to two potential vulnerabilities arising by the current macroeconomic circumstances, characterised by ultra-low interest rates and significant build-up of leverage across households and firms.

First, the fact that investment does not increase in response to a shift in consumer demand, while employment does, is puzzling. This may be a function of the sectoral shift, as non-tradable firms are less capital intensive. However, on the margin, this evidence may also suggests that firms expected the demand shock to be of temporary nature. In most cases, it is easier to layoff workers than reduce capital. This line of reasoning resonates with the literature suggesting that credit-fuelled demand boosts generate temporary gains, at the expense of longer-term losses. Second, we find no evidence of real appreciation: wages do not rise and exports do not decline, in response to larger shocks to local demand. We attribute this evidence, which contrasts with the findings of Mian et al. (2020) on the U.S. case, to the role that collective bargaining plays across the vast majority of firms in the Danish economy. In situations where regional wage growth is not kept in check by collective bargaining, real appreciation stemming from an inflation of the non-tradable sector might spill over to the tradable sector and significantly weaken current account positions.

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Appendix

1.A Model

What are the effects of a shock granting cash-constrained households access to additional liquidity?

To answer this question, we present a stylized model which is closely related to Galí et al. (2007). In an otherwise standard consumption-saving model, Galí et al. (2007) study the effect of a temporary government spending shock on consumption when a fraction of households is liquidity constrained. Similarly, the alleviation of liquidity constraints from taking up an IO mortgage is also of temporary nature. We make some crucial alterations to the model by Galí et al. (2007). Specifically, we remove the government sector and introduce lending.

The model economy is populated by a continuum of infinitely lived households of mass one. A fraction $(1 - \lambda)$ of households optimises intertemporarily (henceforth called *optimising households*) and a fraction λ is liquidity-constrained.

The utility function U of both types of households is given as:

$$U(C_t, N_t) = ln(C_t) - \frac{N^{1+\psi}}{1 + \psi} \tag{1.8}$$

where N_t denotes hours worked, C_t denotes consumption and ψ is the labour supply elasticity with $1 > \psi \geq 0$.

Optimising households. They consume, rent capital out to firms, and work. We extend the model by making these households lenders to liquidity constrained households. The budget constraint of optimising households, denoted by the superscript o, is:

$$P_t(C_t^o + I_t^o) + L_t = W_t P_t N_t^o + R_t^k P_t K_t^o + D_t + R_{t-1} L_{t-1} \qquad (1.9)$$

where the left-hand-side defines outflows; P_t is the price level (or the price of the final good), and I_t denotes investment. Optimising households lend funds L_t to constrained households in the beginning of period t. Inflows, to be found on the right-hand-side, consist of labour income $W_t P_t N_t^o$, interest for rented out capital $R_t^k P_t K_t^o$, dividends D_t from owning firms, and repayment of funds which constrained households borrowed in the previous period, $(1 + r_{t-1}) L_{t-1}$. There is no risk of default. Thus, the lending rate is equal to the risk free rate $(1 + r = R)$.

Optimising households maximise Equation (1.8) subject to the sequence of Equations (1.9) (i.e. they maximise intertemporarily), and subject to the capital accumulation equation which features investment adjustment costs, ϕ, defined as:

$$K_{t+1}^o = (1 - \delta) K_t^o + \phi \left(\frac{I_t^o}{K_t^o} \right) K_t^o \qquad (1.10)$$

with $\phi'(.) > 0, \phi''(.) < 0, \phi(\delta) = \delta, \phi'(\delta) = 1$.

When maximising for C_t and L_t, the first order conditions (FOCs) lead a standard Euler equation:

$$1 = R_t E_t \Lambda_{t,t+1} \frac{P_t}{P_{t+1}} \qquad (1.11)$$

with the k-period ahead discount factor $\Lambda_{t,t+k} = \beta (\frac{C_{t+k}}{C_t})^{-1}$.

When maximising for K_t the FOCs are:

$$Q_t = E_t \left\{ \Lambda_{t,t+1} \left[R_{t+1}^k + Q_{t+1} \left((1-\delta) + \phi_{t+1} - \left(\frac{I_{t+1}^o}{K_{t+1}^o} \right) \phi_{t+1}' \right) \right] \right\} \qquad (1.12)$$

where Q_t is the shadow price of capital:

$$Q_t = \frac{1}{\phi' \frac{I_t^o}{K_t^o}} \qquad (1.13)$$

In the perfectly competitive labour market, optimal labour supply (obtained from maximising for N_t) is:

$$W_t = C_t (N_t)^\psi \qquad (1.14)$$

Liquidity constrained households. These households, denoted by superscript l, do not optimise intertemporarily but consume their entire budget every period. Their budget constraint is given as

$$P_t C_t^l + R_{t-1} L_{t-1} = W_t P_t N_t^l + L_t^l \qquad (1.15)$$

where inflows come from labour income and liquid funds which are borrowed from optimising households, all in period t. Outflows consist of consumption in period t, and repayment of funds borrowed in the previous period $t-1$. We assume that constrained households can borrow a fraction χ of their labour income.[38]

$$L_t = \chi_t P_t W_t N_t^l \qquad (1.16)$$

where χ_t is an exogenous AR(1) process, $\chi_t = \rho \chi_{t-1} + \epsilon_t$ where ρ is the autocorrelation coefficient with $0 < \rho < 1$ and $\epsilon_X \sim \mathcal{N}(0, \sigma_X^2)$. Thus, a positive shock to χ similarly alleviates credit and liquidity constraints.[39]

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[38]Borrowing against labour income is a standard assumption when studying the effect of household credit, see e.g. Bahadir and Gumus (2016). For work on liquidity-constrained households that can borrow against home equity, see e.g. Hurst and Stafford (2004).

[39]For simplicity reasons, we model an increase in liquidity for constrained households as an exogenous shock to credit availability.

Equation (1.15) together with Equation (1.16) highlights that each period, consumption of constrained households is always equal to labour income plus liquidity from borrowing, less repayment of borrowed liquidity from last period:

$$C_t^l = W_t N_t^l + \chi_t W_t N_t^l - R_{t-1}\chi_{t-1}W_{t-1}N_{t-1}^l \frac{P_{t-1}}{P_t} \tag{1.17}$$

Following Galí et al. (2007), we assume that in steady state, consumption of the two types is equated. As a result, also steady state hours worked are equal. Consequently, we can write down Equation (1.14) for both types

$$W_t = C_t^j (N_t^j)^\psi \tag{1.18}$$

for $j = o, l$.

Aggregation gives

$$C_t = \lambda C_t^l + (1 - \lambda)C_t^o \tag{1.19}$$

which states that total consumption is the sum of both household types of consumption. And analogously for labour:

$$N_t = \lambda N_t^l + (1 - \lambda)N_t^o \tag{1.20}$$

Investment only comes from Ricardian households:

$$I_t = (1 - \lambda)I_t^o \tag{1.21}$$

$$K_t = (1 - \lambda)K_t^o \tag{1.22}$$

And the aggregate wage rule is:

$$W_t = C_t(N_t)^\psi \tag{1.23}$$

Final and intermediate goods producers. There is a perfectly competitive final goods producer and a continuum of monopolistically competitive intermediate goods firms, indexed on unit interval $j \in [0, 1]$. The final goods producing firm maximises profits:

$$max_{Y_t(j)} P_t Y_t(j) - \int_0^1 P_t(j) Y_t(j) dj \tag{1.24}$$

where $Y_t(j)$ is the quantity of intermediate goods used in the production of the final good. Maximisation gives a demand schedule for input

$$Y_t(j) = \left(\frac{P_t(j)}{P_t}\right)^{-\epsilon_d} Y_t \tag{1.25}$$

and a zero profit condition

$$P_t = \left(\int_0^1 P_t(j)^{1-\epsilon_d} dj\right)^{\frac{1}{1-\epsilon_d}} \tag{1.26}$$

Intermediate goods producing firm j has the following production function:

$$Y_t(j) = K_t(j)^\alpha N_t(j)^{(1-\alpha)} \tag{1.27}$$

with resulting cost minimisation problem

$$min_{K_t, N_t} R_t^k K_t(j) + W_t N_t(j) \quad s.t. \quad Y_t(j) = K_t(j)^\alpha N_t(j)^{(1-\alpha)} \tag{1.28}$$

which gives

$$\frac{K_t(j)}{N_t(j)} = \frac{\alpha}{1-\alpha} \frac{W_t}{R_t^k} \tag{1.29}$$

Price setting. Following Galí et al. (2007), we include Calvo (1983) sticky prices. $\theta \in [0, 1]$ defines the probability of a firm receiving a signal (in any particular time period) which forces it to keep its price unchanged. Thus, each period, a fraction of $1 - \theta$ of intermediate goods firms resets prices. When

setting its price, a firm maximises the discounted sum of its future profits over periods in which its reset price is expected to be fixed:

$$max_{P_t^*} E_t \sum_{k=0}^{k=\infty} \theta^k \Lambda_{t,t+k} Y_{t+k}(j) \left(\frac{P_t^*}{P_{t+k}} - MC_{t+k} \right) \tag{1.30}$$

s.t. the demand for input, as derived in Equation (1.25)

The FOC w.r.t. P_t^* yields

$$\theta^k \Lambda_{t,t+k} Y_{t+k}(j) \left(\frac{P_t^*}{P_{t+k}} - \frac{\epsilon_d}{\epsilon_d - 1} MC_{t+k} \right) \tag{1.31}$$

with price markup $\mu^p = \frac{\epsilon_d}{\epsilon_d - 1}$

Aggregate price level is

$$P_t = \left[\theta P_{t-1}^{1-\epsilon_d} + (1-\theta)(P_t^*)^{1-\epsilon_d} \right]^{\frac{1}{1-\epsilon_d}} \tag{1.32}$$

Monetary policy follows a simple interest rate rule

$$r_t = r + \phi_\pi \pi_t \tag{1.33}$$

where $\phi_\pi > 0$, r is steady state nominal interest rate and π_t denotes inflation.

Market clearing. The following market clearing conditions close the model

$$N_t = \int_0^1 N_t(j)dj \tag{1.34}$$

$$K_t = \int_0^1 K_t(j)dj \tag{1.35}$$

$$Y_t(j) = \int_0^1 Y_{jt}(j)dj \tag{1.36}$$

$$Y_t = C_t + I_t \tag{1.37}$$

From the log-linearised versions of Equations (1.17), (1.18), (1.19), (1.23), and (1.33), we can derive an Euler equation for aggregate consumption:

$$c_t = E\{c_{t+1}\} - \theta_n(E\{n_{t+1}\} - n_t) - \sigma(r_t - E\{\pi_{t+1}\}) - \theta_l(E\{l_{t+1}\} - l_t) + \theta_l \frac{r}{\pi}(l_t - l_{t-1})$$

(1.38)

with

$$\theta_n \equiv \lambda\Gamma(1-\alpha)(1-\psi)\psi,$$

$$\sigma \equiv (1-\lambda)\Gamma[\mu^p\psi\gamma_c + (1-\alpha)],$$

$$\theta_l \equiv \Gamma\mu^p\gamma_c\gamma_l\psi,$$

where $\Gamma \equiv (\mu^p\psi\gamma_c + (1-\alpha)(1 - \lambda(1+\psi)))^{-1}$ and $\gamma_c \equiv \frac{C}{Y}$ (the steady state ratio of consumption to output), and $\gamma_l \equiv \frac{L}{C}$ (the steady state ratio of liquidity obtained through borrowing to consumption).

Equation (1.38) highlights that in response to an increase in liquidity, consumption rises on impact. As a result, output, labour and wages increase. Similar to the model by Galí et al. (2007), there is a feedback effect between labour income and consumption: the rise in labour income raises consumption further. In this model, there exists also a feedback effect between labour income and liquidity for constrained households. When labour income rises, constrained households can obtain even more liquidity.[40]

We keep the calibrations as in the model by Galí et al. (2007) and furthermore set γ_l to 0.01. The following graph depicts impulse response functions (IRFs) to an exogenous increase in liquidity for constrained households, modelled as a positive shock to χ_t, the share of labour income that can be leveraged. The shock hits the economy in the beginning of period t and every agent understands it to be autocorrelated (with a coefficient of 0.8). The upper left

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[40]This amplification effect exhibits some similarity to the Danish economy where house prices rose after the mortgage reform allowing households to increase borrowing further (Bäckman and Lutz, 2016).

Figure 1.A.1: IRFs to a positive liquidity shock
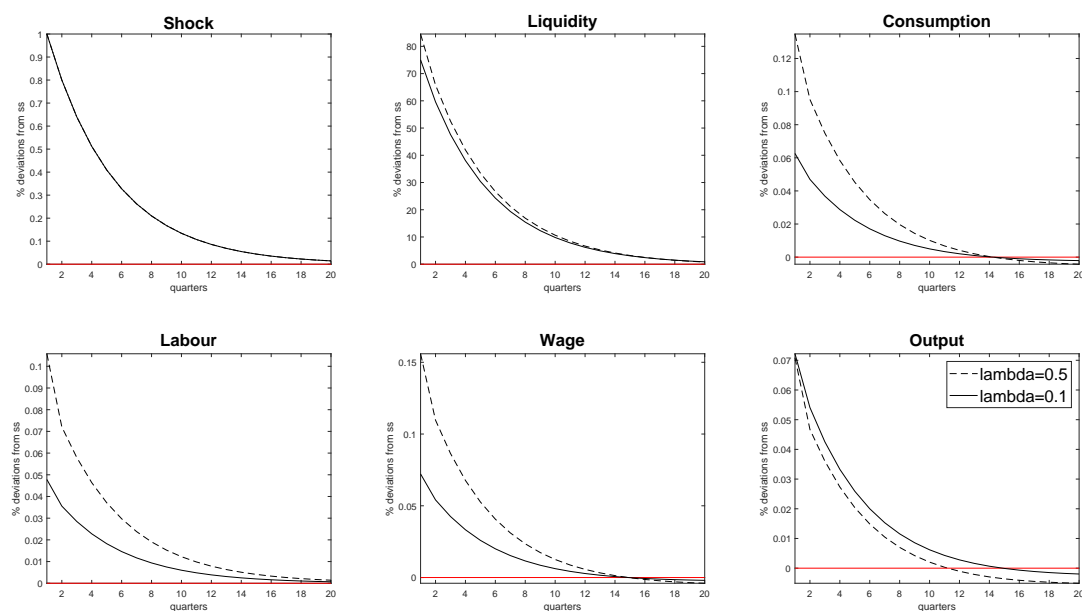
Notes: Impulse response functions to a shock which raises liquidity for liquidity constrained households, i.e. a positive shock to χ with an autocorrelation of 0.8. "lambda" denotes the share (or the number) of constrained households in the economy.

panel of Figure 1.A.1 mirrors the evolution of χ. Liquidity rises on impact (upper middle panel). Because constrained households spend all their liquidity each period, this immediately translates into higher consumption (upper right panel). Higher demand raises output, labour and wages (lower three panels of Figure 1.A.1). This reinforces constrained households' ability to raise liquidity and consumption.

Just as in Galí et al. (2007), the number (which is equivalent to the share) of constrained households in the economy is crucial for the extent to which variables respond to a boost in liquidity: the dashed line depicts IRFs when half of all households is constrained, the solid line when only 10 percent of households are constrained. The upper right panel depicts that the higher the number of liquidity constrained households in the economy, the larger is the absolute shift in consumption.

1.B Tables

Table 1.B.1: Placebo test

VARIABLES	(1) $\Delta C_{h,2000}$ Constrained in 1998	(2) $\Delta C_{h,2001}$ Constrained in 1999	(3) $\Delta C_{h,2002}$ Constrained in 2000
Constrained$_{1998}$	-23.9***		
	(0.8)		
Constrained$_{1999}$		-28.6***	
		(0.93)	
Constrained$_{2000}$			-19.7***
			(0.94)
Municipality FE	Yes	Yes	Yes
Family controls	Yes	Yes	Yes
R-squared	0.030	0.039	0.025
Observations	99,442	99,468	99,471

Source: Registry data, Danish population, 1996-2010. *Notes*: Results include only a balanced panel of households that were recorded as homeowners for tax purposes in the year 2002 and never moved or changed tenure status through the sample period. Coefficients to be interpreted in DKK thousands. The dependent variable is the average change in spending after the placebo reform years 1999, 2000 and 2001, respectively, compared to the two years before the placebo year. Assignment to treatment or control group is based on the liquid savings-to-income ratio in the respective placebo pre-reform year (i.e. 1998, 1999 and 2000). Household level controls include the house value in 2002 (logs); annual household income (logs); age of the household head (defined as the person with the highest income); number of family members and number of children in 2002. Standard errors in parentheses are robust to heteroskedasticity.*** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 1.B.2: Homeowners' mortgages

VARIABLES	(1) ΔM_{2000}	(2) ΔM_{2001}	(3) ΔM_{2002}	(4) ΔM_{2004}	(5) ΔM_{2005}	(6) ΔM_{2006}	(7) ΔM_{2007}	(8) ΔM_{2008}	(9) ΔM_{2009}	(10) ΔM_{2010}
Constrained$_{2002}$	50.6***	46.8***	32.2***	54.6***	62.5***	80.5***	98.4***	114.9***	131.8***	149.1***
	(1.44)	(1.47)	(1.48)	(1.57)	(1.70)	(1.88)	(2.07)	(2.25)	(2.44)	(2.60)
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Family Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	99,465	99,471	99,472	99,491	99,487	99,455	99,421	99,387	99,347	99,305
R-squared	0.114	0.093	0.089	0.036	0.072	0.106	0.130	0.147	0.163	0.179

Source: Registry data, Danish population, 1996-2010. *Notes:* Results include only a balanced panel of households that were recorded as homeowners for tax purposes in the year 2002 and never moved or changed tenure status through the sample period. Coefficients to be interpreted in DKK. In the post-reform period, the dependent variable is the expanding average of the change in mortgage balance from a similar period before the reform. In the pre-reform period, it is average change in mortgage balance over a two year period. Household level controls include the house value in 2002 (logs; annual household income (logs); age of the household head (defined as the person with the highest income); number of family members and number of children in 2002. Standard errors in parentheses are robust to heteroskedasticity.*** p<0.01, ** p<0.05, * p<0.1.

Table 1.B.3: House price growth

VARIABLES	(1) Delta HP 2005	(2) Delta HP 2006	(3) Delta HP 2007	(4) Delta HP 2008	(5) Delta HP 2009	(6) Delta HP 2010
Constrained$_{2002}$	0.001	0.000	0.001	-0.001	-0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)
Constant	-0.514	-0.252	0.341	0.472	0.179	-0.492
	(0.017)	(0.014)	(0.020)	(0.013)	(0.013)	(0.011)
Observations	99,393	99,425	99,416	99,457	99,427	99,406
R-squared	0.201	0.143	0.147	0.168	0.107	0.151

Table 1.B.4: Homeowners' income

VARIABLES	(1) ΔI_{2000}	(2) ΔI_{2001}	(3) ΔI_{2002}	(4) ΔI_{2004}	(5) ΔI_{2005}	(6) ΔI_{2006}	(7) ΔI_{2007}	(8) ΔI_{2008}	(9) ΔI_{2009}	(10) ΔI_{2010}
Constrained$_{2002}$	-4.3***	-5.6***	-4.9***	1.9***	2.0***	0.76*	-1.3***	-.9***	-4.0***	-4.9***
	(0.34)	(0.34)	(0.32)	(0.41)	(0.40)	(0.41)	(0.42)	(0.45)	(0.45)	(0.49)
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Family controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	99,465	99,471	99,472	99,491	99,487	99,455	99,421	99,387	99,347	99,305
R-squared	0.137	0.139	0.169	0.060	0.112	0.182	0.294	0.336	0.407	0.441

Source: Registry data, Danish population, 1996-2010. *Notes*: Results include only a balanced panel of households that were recorded as homeowners for tax purposes in the year 2002 and never moved or changed tenure status through the sample period. Coefficients to be interpreted in DKK thousands. In the post-reform period, the dependent variable is the expanding average of the change in income from a similar period before the reform. In the pre-reform period, it is the average change in income over a two year period. Household level controls include the house value in 2002 (logs); annual household income (logs); age of the household head (defined as the person with the highest income); number of family members and number of children in 2002. Standard errors in parentheses are robust to heteroskedasticity.*** p<0.01, ** p<0.05, * p<0.1.

VARIABLES	(1) ΔC_{04}	(2) ΔC_{05}	(3) ΔC_{06}	(4) ΔC_{07}	(5) ΔC_{08}	(6) ΔC_{09}	(7) ΔC_{10}
$Constr_{2002}$	5.1***	3.7***	8.5***	9.3***	7.4***	5.5***	4.4***
	(1.18)	(0.92)	(0.80)	(0.72)	(0.66)	(0.61)	(0.57)
age (head)	0.23	0.43**	0.71***	0.77***	0.79***	0.84***	0.93***
	(0.23)	(0.17)	(0.15)	(0.13)	(0.12)	(0.12)	(0.11)
No. member	-4.3***	-6.1***	-9.3***	-5.7***	-4.9***	-4.4***	-4.2***
	(1.42)	(1.12)	(0.89)	(0.78)	(0.76)	(0.84)	(0.91)
House P.	-2.6	-3.5**	-10.9***	-1.1	4.3***	5.7***	3.5**
	(0.10)	(0.78)	(0.68)	(0.61)	(0.58)	(0.53)	(0.49)
No. children	16.0***	14.3***	14.4***	8.2***	6.9***	6.1***	5.8***
	(0.20)	(0.19)	(0.13)	(0.11)	(0.11)	(0.11)	(0.11)
ΔI_{2004}	0.52***						
	(0.05)						
ΔI_{2005}		0.58***					
		(0.04)					
ΔI_{2006}			0.58***				
			(0.02)				
ΔI_{2007}				0.61***			
				(0.02)			
ΔI_{2008}					0.64***		
					(0.02)		
ΔI_{2009}						0.67***	
						(0.03)	
ΔI_{2010}							0.65***
							(0.03)
Constant	0.28	-0.22***	-0.29***	-22.38	-58.38***	-43.98***	-1.61
	(0.52)	(0.36)	(0.28)	(0.145)	(0.14)	(0.13)	(0.14)
Obs.	99,491	99,487	99,455	99,421	99,387	99,347	99,283
R-squared	0.044	0.109	0.160	0.197	0.277	0.332	0.385

Source: Registry data, Danish population, 1996-2010. *Notes*: Results include only a balanced panel of households that were recorded as homeowners for tax purposes in the year 2002 and never moved or changed tenure status through the sample period. Coefficients to be interpreted in DKK thousands. The dependent variable is the expanding average of the change in spending from a similar period before the reform. Household level controls include contemporaneous house value (logs); respective contemporaneous moving averages of household income (logs); contemporaneous age of the household head (defined as the person with the highest income); contemporaneous number of family members and number of children. Standard errors in parentheses are robust to heteroskedasticity and are clustered at the municipality level.*** p<0.01, ** p<0.05, * p<0.1.

Table 1.B.6: Effect of reform on renters' expenditure

VARIABLES	(1) ΔC_{2000}	(2) ΔC_{2001}	(3) ΔC_{2002}	(4) ΔC_{2004}	(5) ΔC_{2005}	(6) ΔC_{2006}	(7) ΔC_{2007}	(8) ΔC_{2008}	(9) ΔC_{2009}	(10) ΔC_{2010}
Constrained$_{2002}$	-2,0***	-0.92***	0.5	-3.1***	-4.3***	-2.1***	-0.3***	-0.7***	-1.4***	-1.9***
	(0.38)	(0.37)	(0.38)	(0.62)	(0.44)	(0.38)	(0.37)	(0.36)	(0.34)	(0.35)
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Family Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	98,554	98,783	98,799	98,849	98,840	98,798	98,759	98,714	98,647	98,376
R-squared	0.047	0.050	0.075	0.010	0.030	0.073	0.119	0.165	0.199	0.231

Source: Registry data, Danish population, 1996-2010. *Notes:* Results include only a balanced panel for of households that were recorded as renters for tax purposes in the year 2002 and never moved or changed tenure status through the sample period. Coefficients to be interpreted in DKK thousands. In the post-reform period, the dependent variable is the expanding average of the change in spending from a similar period before the reform. In the pre-reform period, it is the average change in spending over a two year period. Household level controls include annual household income (logs); age of the household head (defined as the person with highest income); number of family members and number of children in 2002. Standard errors in parentheses are robust to heteroskedasticity and are clustered at the municipality level.*** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 1.B.7: Aggregate spending and firm-level employment: OLS

VARIABLES	(1) Employment Firm OLS	(2) Employment Firm OLS	(3) Employment Firm OLS	(4) Employment Firm OLS	(5) Employment Firm OLS
$log(C_{mt})$	0.001	0.003**	0.003**	0.012**	0.014***
	(0.002)	(0.001)	(0.001)	(0.005)	(0.005)
$HPrice_{m,t-1}$		-0.012**	-0.012**	-0.013**	-0.014**
		(0.005)	(0.005)	(0.005)	(0.005)
$Liqu./Income_{m,2002}$			-0.002	-0.003	-0.003
			(0.002)	(0.003)	(0.003)
$Pop_{m,2002}$				-0.011**	0.042***
				(0.004)	(0.012)
$log(C_{m,2002})$					-0.059***
					(0.012)
Observations	453,273	453,273	453,273	449,309	449,309
R-squared	0.985	0.985	0.985	0.984	0.984
Firm Fe	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes

Source: Data from Statistics Denmark, 2004-2010. *Notes:* The dependent variable is establishment-level end-year log-linearised value of full-time equivalents. $log(C_{mt})$ measures aggregate household expenditure in a given municipality and year, measured as the sum of imputed consumption for all resident households. Municipality-level house price growth, $HPrice_{m,t-1}$, is measured as the change in the average sale price per sqm. $Pop_{m,2002}$ counts the number of individuals living in the municipality in 2002; $Liqu./Income_{m,2002}$ measures the average liquid-asset-to-income ratio in the resident population in 2002. Standard errors, in parentheses, are clustered at the municipality-level. *** p<0.01, ** p<0.05, * p<0.1.

Table 1.B.8: The instrument and firm-level outcomes: Reduced-form equation

VARIABLES	(1) Revenues Firm	(2) Profit Firm	(3) Employment Firm	(4) Investment Firm
$log(Spending_{mt})$	0.008***	0.007***	0.007***	0.015*
	(0.002)	(0.002)	(0.002)	(0.009)
$HPrice_{m,t-1}$	-0.010**	-0.003	-0.009**	0.009
	(0.004)	(0.004)	(0.005)	(0.013)
$Pop_{m,2002}$	0.037***	0.041***	0.056***	-0.069
	(0.013)	(0.012)	(0.012)	(0.061)
$Liqu./Income_{m,2002}$	0.004	0.003	0.004	0.022*
	(0.003)	(0.003)	(0.003)	(0.013)
$log(C_{m,2002})$	-0.048***	-0.051***	-0.066***	0.049
	(0.014)	(0.013)	(0.013)	(0.068)
Observations	409,847	408,676	409,987	409,898
R-squared	0.987	0.979	0.984	0.674
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Source: Data from Statistics Denmark, 2004-2010. *Notes*: The dependent variables measure end-year log-linearised values of: revenues (col.1), profits (col.2), full-time equivalents (col.3), gross fixed-capital formation (col. 4). $log(Spending_{mt})$ is the instrument, constructed as the interaction between the number of liquidity-constrained homeowners living in the municipality in 2002 and the average spending shock in any given year, measured by α_1. Municipality-level house price growth, $HPrice_{m,t-1}$, is measured as the change in the average sale price per sqm. $Pop_{m,2002}$ counts the number of individuals living in the municipality in 2002; $Liqu./Income_{m,2002}$ measures the average liquid-asset-to-income ratio in the resident population in 2002; $log(C_{m,2002})$ measures aggregate consumption levels in 2002. Standard errors, in parentheses, are clustered at the municipality-level. *** p<0.01, ** p<0.05, * p<0.1.

Table 1.B.9: Spending and establishment-level outcomes

VARIABLES	(1) Revenues Estab.	(2) Profit Estab.	(3) Employment Estab.	(4) Investment Estab.
PANEL A				
$\widehat{log(C_{mt})}$	0.129*	0.088	0.171**	0.138*
	(0.070)	(0.060)	(0.068)	(0.080)
Observations	443,904	259,173	431,682	165,260
R-squared	0.014	0.013	0.014	0.042
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
F Stat	57	45	57	51
PANEL B				
$\widehat{log(C_{mt})}$	0.141*	0.099*	0.196***	0.132*
	(0.072)	(0.059)	(0.072)	(0.074)
Observations	116,719	70,625	111,414	73,785
R-squared	0.011	0.010	0.009	0.024
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
F Stat	61	55	61	58

Source: Data from Statistics Denmark, 2004-2010. *Notes*. The dependent variables are measured at the establishment level, and represent end-year log-linearised values of: revenues (col.1), profits (col.2), head count of employees (col.3), gross fixed-capital formation (col.4). Panel A includes all firms for which establishment level data is available; panel B only multi-establishment firms. $\widehat{log(C_{mt})}$ measures the fitted values of aggregate household expenditure in a given municipality and year. Controls include municipality-level house price growth, number of individuals living in the municipality in 2002, average liquid-asset to income ratio in the resident population in 2002; aggregate consumption levels in 2002. Standard errors, in parentheses, are clustered at the municipality-level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 1.B.10: Aggregate spending and firm-level outcomes: tradables and non-tradables

VARIABLES	(1) Revenues Firm 2SLS NT	(2) Revenues Firm 2SLS T	(3) Profits Firm 2SLS NT	(4) Profits Firm 2SLS T
$\widehat{log(C_{mt})}$	0.032*** (0.010)	0.010 (0.006)	0.033*** (0.010)	0.007 (0.006)
Observations	283,406	115,208	282,730	114,797
Firm Fe	Yes	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

VARIABLES	(5) Employment Firm NT	(6) Employment Firm T	(7) Investment Firm NT	(8) Investment Firm T
$\widehat{log(C_{mt})}$	0.027** (0.010)	0.006 (0.005)	0.041 (0.037)	0.061** (0.031)
Observations	283,503	115,240	283,427	115,224
Firm FE	Yes	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Source: Data from Statistics Denmark, 2004-2010. *Notes*. The dependent variables measure end-year log-linearised values of: revenues (col.1-2), profits (col.3-4), full-time equivalents (col.5-6), gross fixed-capital formation (col. 7-8). Columns marked by T and NT include only tradable and non-tradable firms, respectively. Firms are defined as tradable if their ratio of imports+exports to full-time equivalents exceeds DKK 70,000 during the year, non-tradable otherwise. $\widehat{log(C_{mt})}$ measures the fitted values of aggregate household expenditure in a given municipality and year. Controls include municipality-level house price growth, number of individuals living in the municipality in 2002, average liquid-asset to income ratio in the resident population in 2002; aggregate consumption levels in 2002. Standard errors, in parentheses, are clustered at the municipality-level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.
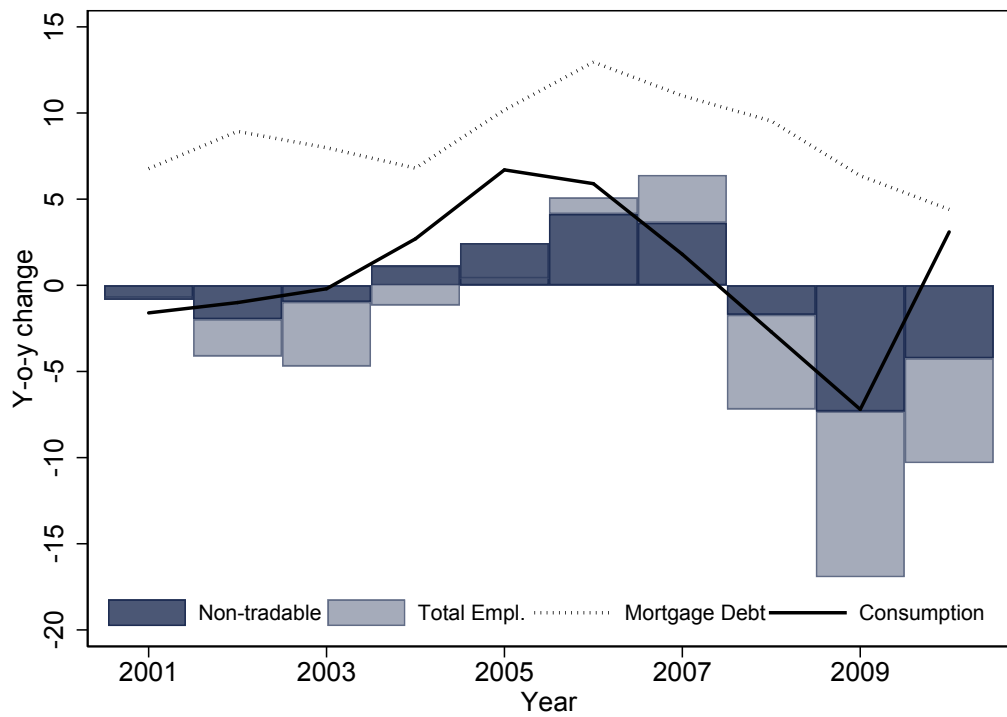
1.C   Figures

Figure 1.C.1: Macroeconomic trends: 2001 to 2010

Source: Statistics Denmark. *Notes:* Year-on-year growth rates in household expenditure, mortgage debt, aggregate employment, and employment in the non-tradable sector. The non-tradable sector excludes agriculture, government, manufacturing and the advanced part of services (management consultancy; IT).

Figure 1.C.2: Outstanding mortgage volumes, 1995 to 2020
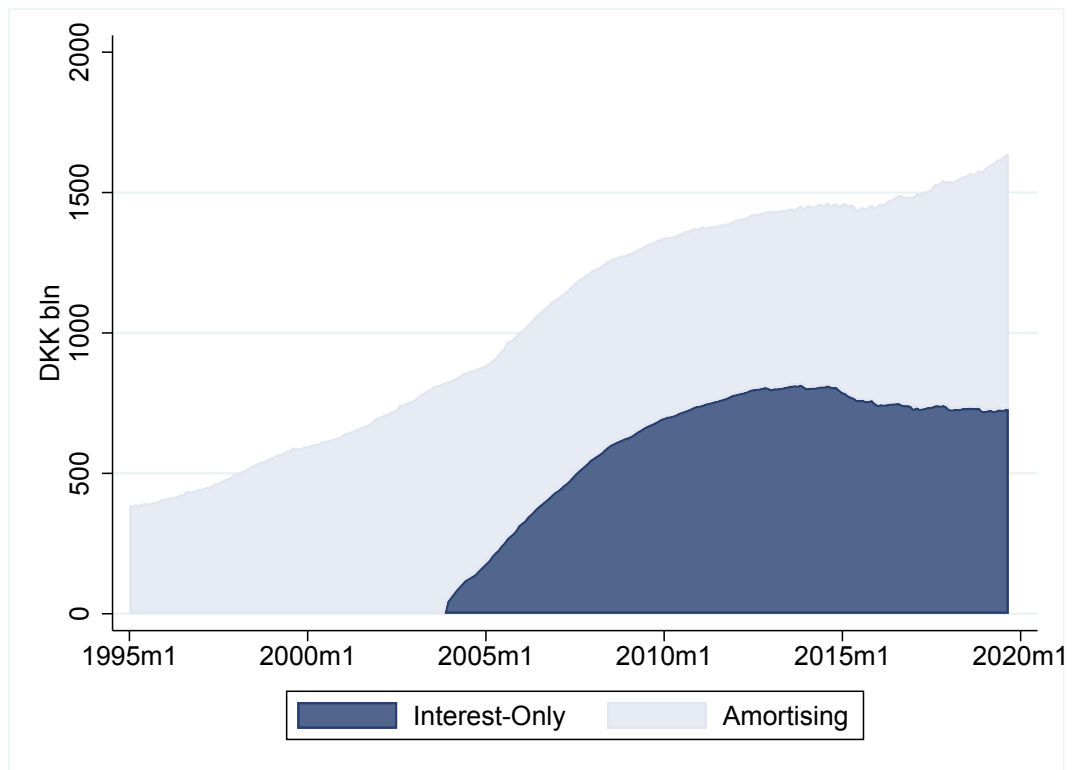
Figure 1.C.3: Performance of registry data in matching the aggregate figures

Number of Employer Firms

Source: Statistics Denmark. *Notes:* Aggregate data is based on publicly available counts of employer firms; Registry data defines the count of firms stemming from the administrative datasets.

Figure 1.C.4: Liquid savings-to-income ratio in 2002, homeowners

Liquid Savings to Income (2002)
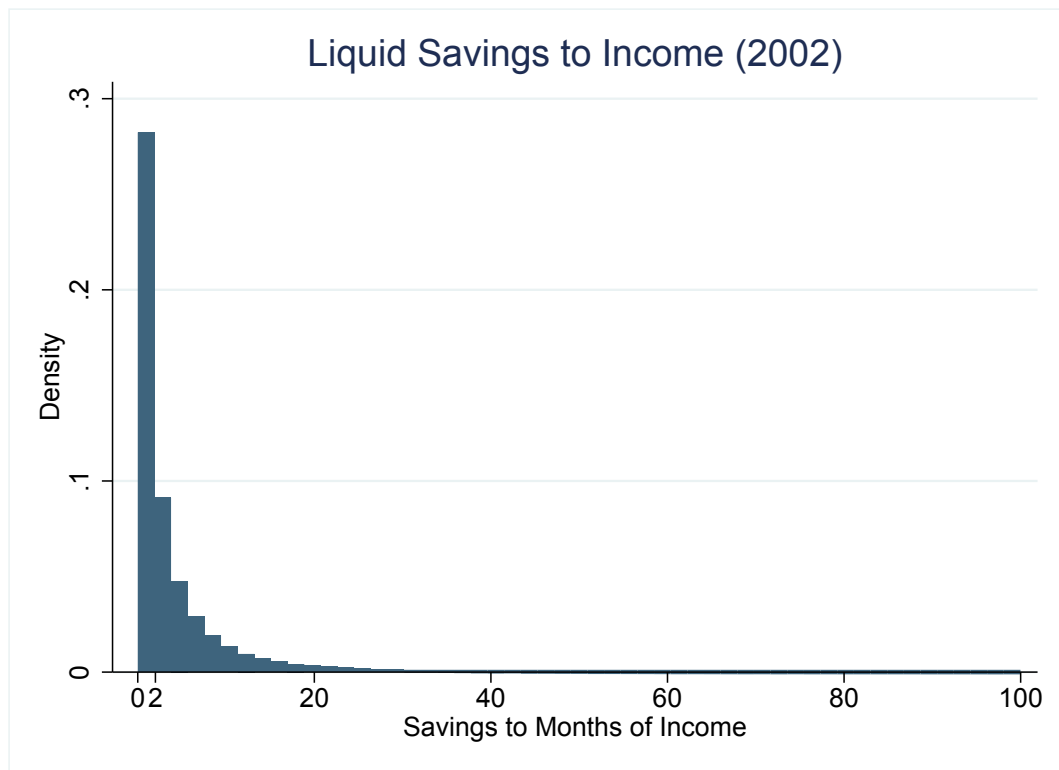
Source: Statistics Denmark. *Notes:* Distribution of the liquid savings/months of income ratio in 2002. Liquid savings are defined as the sum of cash held in bank accounts, stocks and bonds.

Figure 1.C.5: Relationship between liquid savings-to-income ratio in 2002 and IO mortgage holdings in 2009
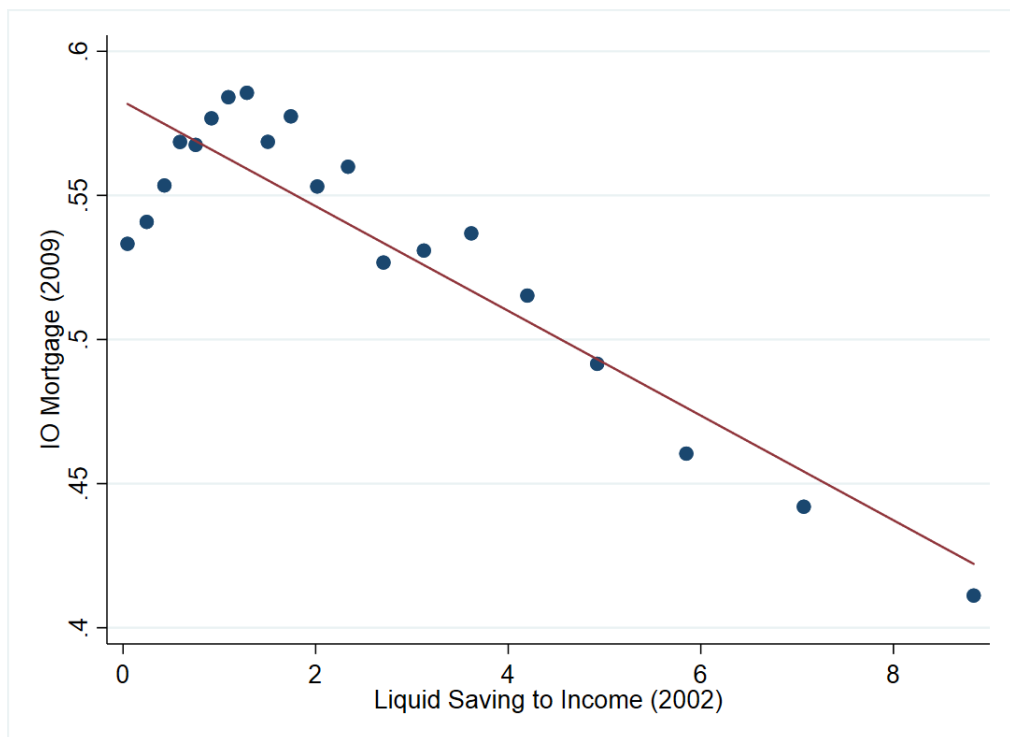
Source: Statistics Denmark. *Notes:* The regression displays the relationship between ownership of an IO mortgage in 2009 and liquid savings/months of income for the same household in 2002.

Figure 1.C.6: Number of liquidity-constrained homeowners in 2002, by munic-
ipality
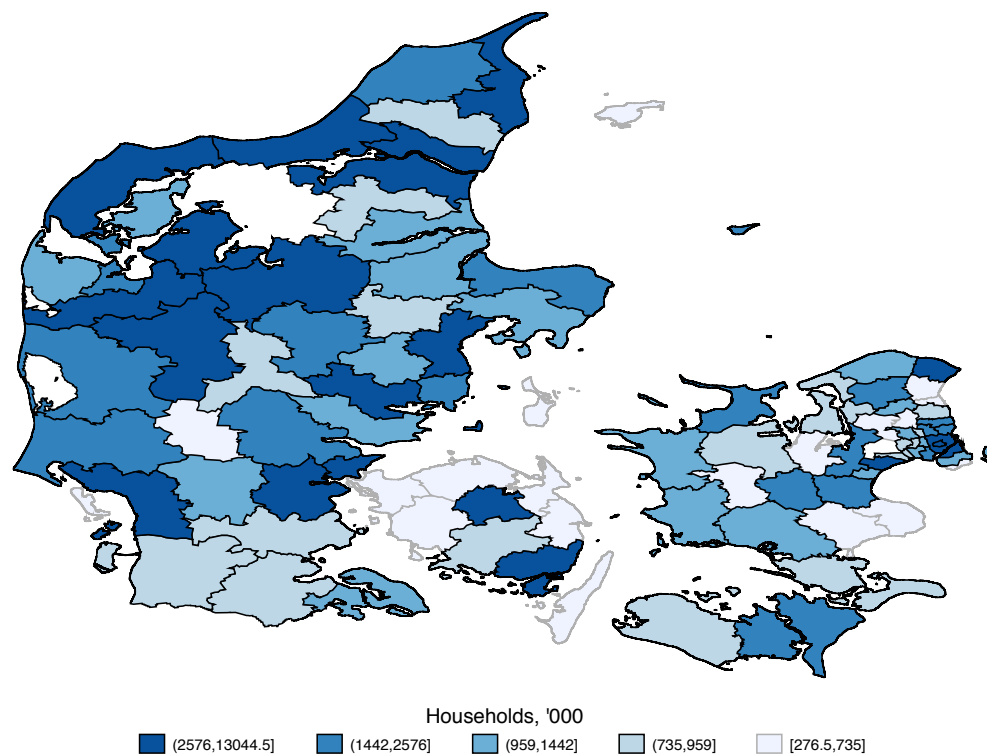
Source: Statistics Denmark. *Notes:* Count of liquidity-constrained homeowners by municipal-
ity, measured at the end of 2002. Liquidity-constrained homeowners are defined as households
having less than 1.5 months of income in liquid savings. Sample is restricted to homeowners
between the ages of 25 and 64 who are continuously observed in the registries between 2002
and 2010 and who never buy or sell their property during the same time frame.

Figure 1.C.7: Regional difference-in-differences: Expenditure
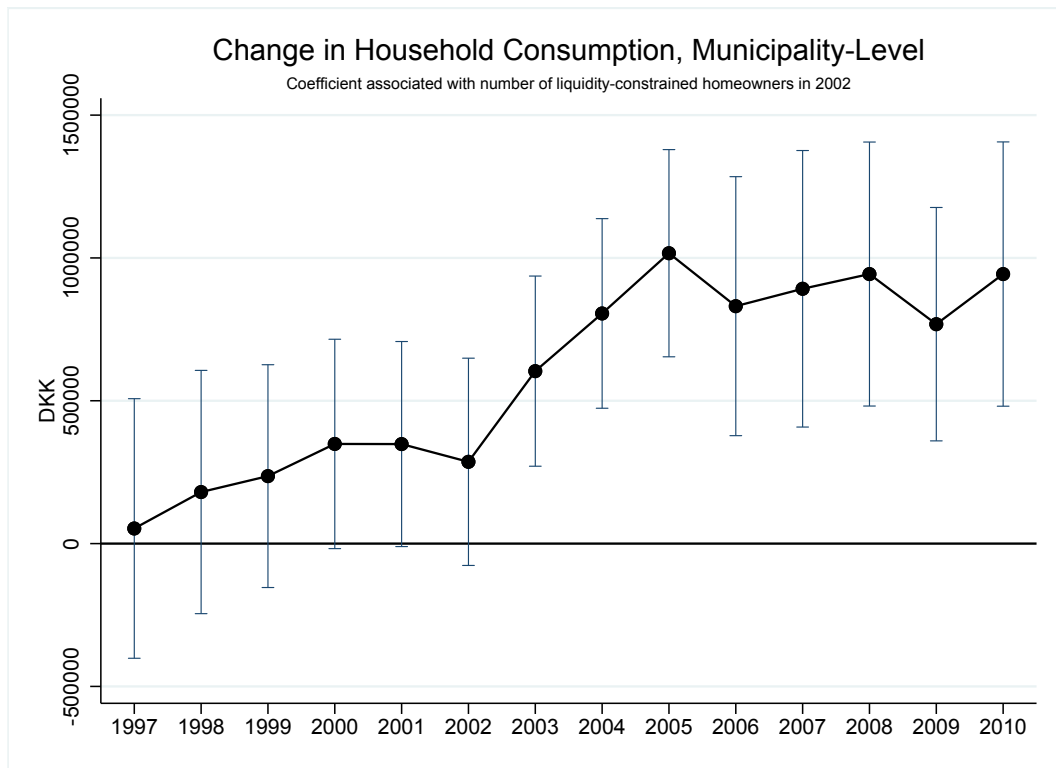
Source: Statistics Denmark. *Notes:* The dependent variable is the sum of imputed consumption for each year/municipality cell. The graph depicts the coefficients associated with the interaction between year dummies and the number of liquidity-constrained homeowners living in the municipality in 2002. Municipality and year fixed effects are included. Standard errors are robust to heteroskedasticity.

Figure 1.C.8: Regional difference-in-differences: Employment

Total Employment (log) Municipality Level
Coefficient associated with number of liquidity-constrained homeowners in 2002
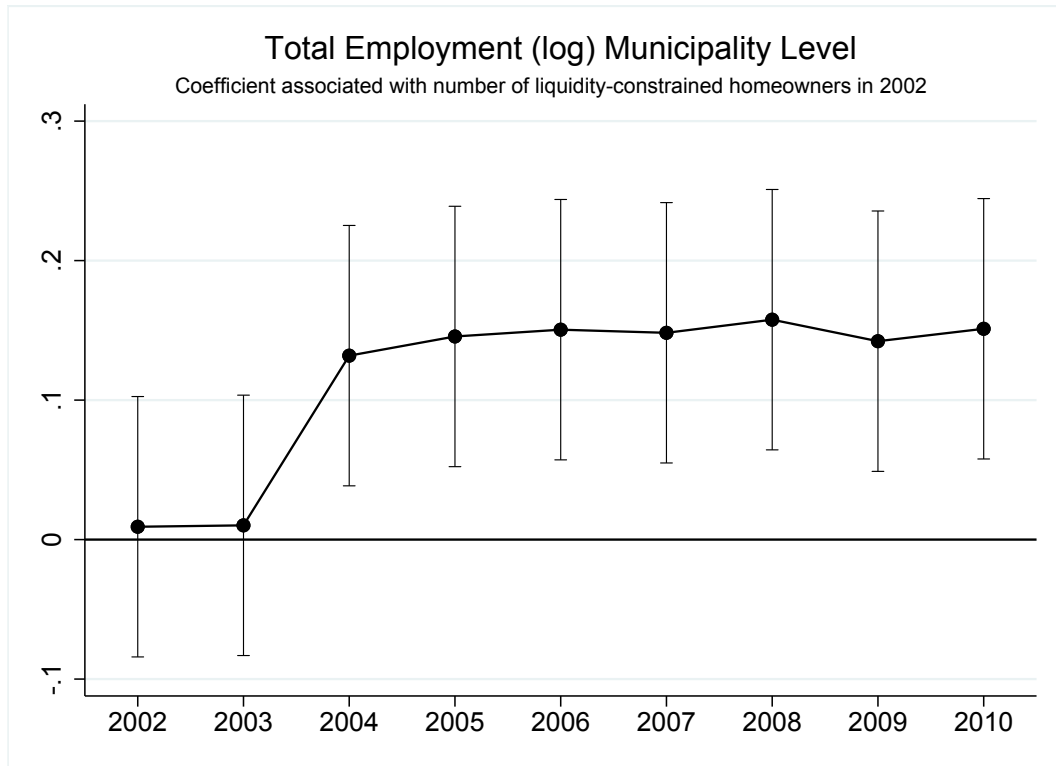
Source: Statistics Denmark. *Notes:* The dependent variable FTEs in each establishment, aggregated at the year/municipality level. The graph depicts the coefficients associated with the interaction between year dummies and the number of liquidity-constrained homeowners living in the municipality in 2002. Municipality and year fixed-effects are included. Standard errors are robust to heteroskedasticity.

Figure 1.C.9: Estimated aggregate consumption shift
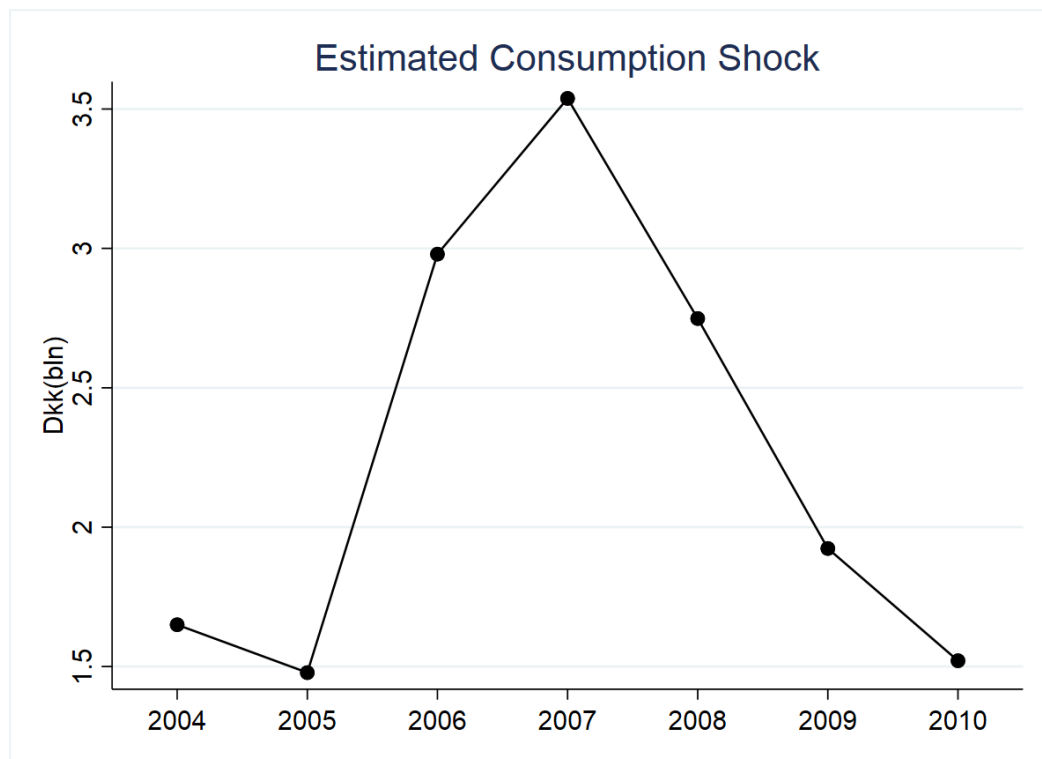
Source: Statistics Denmark. *Notes:* Total expenditure shocks due to the refinancing channel of IO loans for each year. This is computed as the average annual consumption shifts for liquidity-constrained homeowners from Equation 1.3 multiplied by the number of liquidity constrained homeowners living in Denmark in 2002.

Figure 1.C.10: Distribution of number of establishments by firm
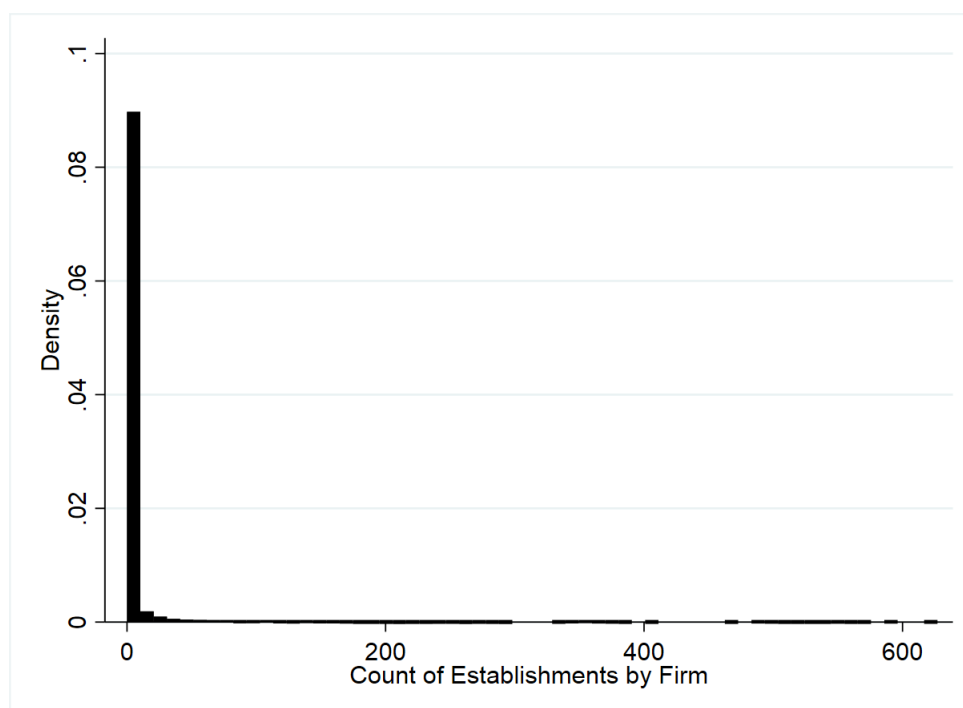
Source: Statistics Denmark. *Notes:* Count of establishments by firm, pooled sample (2004–2010).

Chapter 2

Hampered Monetary Policy Transmission – A Supply Side Story?

2.1 Introduction

During the Great Recession, central banks in the U.S. and Europe have inter-vened heavily in order to boost banks' loan provision. However, this hinges on the assumption that, apart from its effect through real interest rates, monetary policy has a direct effect on the real economy via credit supply.[1] Consequently, examining the pass-through of monetary policy and factors that hamper the transmission to financial and real variables has once again become an impor-tant topic for policy and research (Agarwal et al., 2017; Di Maggio et al., 2017; Drechsler et al., 2017).

Frictions on both the credit supply and the demand side drag on the trans-mission of monetary policy not only to lending volumes (Agarwal et al., 2017; Drechsler et al., 2017) but also to prices. In particular, imperfect competition in banking markets seems to be associated with a hampered transmission to retail rates (Adams and Amel, 2011; Fungáčová et al., 2014; Leroy, 2014; Sääskilahti, 2016; Van Leuvensteijn et al., 2013; Gropp et al., 2014). Despite a large body of literature on the topic, the question about the underlying channel has remained largely unanswered. This is because research on monetary policy transmis-sion to retail rates has so far only worked with realised interest rates over time which are however the result of a combination of shifts in credit demand and supply. Reasons for a hampered pass-through may lie *within* the banking sector making it optimal for institutions with more market power to transmit smaller fractions of positive interest rate shocks to retail rates. Alternatively, it may be the case that *across* banks with varying degrees of market power, credit demand shifts systematically differently over the business cycle. The former

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[1]Bernanke et al. (1988; 1992) motivate the *credit channel* under which banks can be crucial in transmitting monetary policy to real variables. This channel can be divided into *balance sheet* and *bank lending channel*. The former establishes the importance of *borrowers'* balance sheets in the transmission of shocks to the external finance premium and real variables (Bernanke and Gertler, 1989, 1995; Bernanke et al., 1999). The latter focuses on how monetary policy affects these variables through the side of the *lenders* (Bernanke and Blinder, 1992; Kashyap and Stein, 1994, 2000).

mechanism identifies frictions on the credit supply side; the latter instead tells a credit demand story.

We aim at filling this gap in the literature and leverage a unique supervisory data set, the *2017 low-interest-rate survey*, and determine whether imperfectly competitive banking markets impede monetary policy transmission through the supply side of credit markets. In spring 2017, the German Federal Financial Authority and Deutsche Bundesbank conducted a supervisory measure which required all small and medium-sized banks in Germany to report interest rates for loans and deposits. In particular, end-of-2017 projected retail rates for two different predefined scenarios taking place over the same time horizon were to be disclosed: i) a hypothetical exogenous and permanent monetary policy contraction and ii) no change in monetary policy as opposed to the end of 2016. This data set is exceptional for two reasons: because of its coverage (88 percent of all credit institutions in Germany[2]) and because it delivers two data points per bank, one for each scenario, which we can use as treatment and counterfactual outcome, respectively. By taking the difference between the retail rates in the shock and the constant scenario, we can partial out any other factors whose change banks expect to influence interest rates over the course of 2017. Consequently, expected shifts in credit demand unrelated to the monetary policy change are controlled for. This allows us to assess the supply-sided effect of imperfect competition among banks on the pass-through of monetary policy to loan and deposit rates.

We identify imperfect competition through two variables: an individual-level Lerner Index which measures the degree to which a bank can charge a markup on the reference rate; and a geographic measure of concentration, the Herfindahl index. Our results suggest that following a contraction in the policy rate, a bank's pass-through to loan rates is on average smaller by 4–5

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[2]The only other data source available containing interest rates at the individual level (MFI interest rate statistic) is a substantially smaller subset of all German banks (Weth, 2002).

percentage points when the bank belongs to the 90th percentile of the pricing power distribution or when operating in a highly concentrated market. Banks also exert market power in the deposit market to a substantial degree: in a highly concentrated deposit market, banks have a lower average pass-through by almost 10 percentage points.

Results are confounded if – despite the instructions – banks assume credit demand to shift differently in the two scenarios. Because bankers understand the first scenario as an adverse scenario, they might assume credit demand to contract only in the shock scenario.[3] If they do so, they are likely to base their expectations on past events. Following increases in the policy rate, demand in the EU generally falls to a larger extent at riskier banks (Altavilla et al., 2018) and riskier banks tend to have less market power (Kick and Prieto, 2014). Therefore, predicted demand shifts should be larger at banks with lower levels of market power. An expected drop in demand would counteract the upward pressure on the price from an exogenous increase in funding costs and we should therefore observe a relatively *smaller* pass-through at banks with *less* market power. The fact that we find the opposite, suggests that we are identifying a pure credit supply shift. In any case, our results provide a lower bound on the differential pass-through between banks with high versus low market power. Because German banks operate locally and we find that banks in imperfectly competitive markets have higher profits and return on assets, our results furthermore indicate that these banks are likely to have the capacity to build relationships with their borrowers and subsequently insure them against adverse shocks.

Our findings speak to various strands of the literature debating about the

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[3]In stress testing exercises, the shock scenario is the one that challenges banks' balance sheets. Often, the adverse scenario also entails a macroeconomic scenario with a predefined decline in GDP. See e.g. https://www.esrb.europa.eu/mppa/stress/shared/pdf/esrb.20180131_EBA_stress_test_scenario__macrofinancial.en.pdf?43a5f3c6c04f2daa03bd950b55d8897b, viewed 20 February 2020.

effect of imperfect competition on loan and deposit pricing. Regarding interest rate *levels*, banks may extract monopolistic rents in concentrated markets and thus set relatively lower deposit rates and higher loan rates than in a competitive market (Berger, 1995).[4] However, a conflicting hypothesis postulates that efficiency and concentration can be positively correlated leading to an opposite relationship between market power and retail rates (Berger, 1995). On a similar note, market power can facilitate relationship lending which, through a reduction in information asymmetries, may lead to more favourable outcomes for some borrowers (Rajan, 1992; Petersen and Rajan, 1995).[5] Turning to *adjustments* in retail rates, we could expect banks with more market power to raise loan (deposit) rates to a relatively larger (smaller) extent in response to contractionary monetary policy, provided that they act as standard monopolists. In contrast, bank-borrower relationships could lead pricing-power banks to smooth adjustments in retail rates, insuring in particular their borrowers against adverse events.

Macroeconomic models similarly formulate situations in which monopolistic competition leads to both amplified and mitigated responses in retail rates. Moreover, a hampering effect can feed through the demand or the supply side of credit.[6]

This paper confirms for the German context that banks in more concentrated markets charge higher loan rates and offer lower deposit rates. Furthermore, monetary policy transmission and market power are negatively related which is in line with most of the previous literature. In particular, Van Leuven-

[4]In the banking literature, this is also referred to as the *structure-conduct-performance paradigm* (Berger, 1995).

[5]While the majority of work finds results in favour of the former theory (Hannan and Berger, 1991; Sapienza, 2002), Fungáčová et al. (2017) concur that banks with market power charge less for loans to small and medium sized firms in Europe.

[6]For amplification, see e.g. Gerali et al. (2010) or Duffie and Krishnamurthy (2016). Models for a hampered pass-through via the supply side are provided by Martinez-Miera and Repullo (2018) and Corbae and Levine (2018). However the same outcome in monopolistic banking markets can occur due to constraints on the demand side (Güntner, 2011).

steijn et al. (2013) and Gropp et al. (2014) conclude an impaired pass-trough of monetary policy to realised loan and deposit rates with respect to within-banking sector competition in Europe. Schlueter et al. (2016) identify the same pattern for Germany. We contribute to the literature by showing that supply side effects dominate.

To our knowledge, only Drechsler et al. (2017) establish a direct, impeding effect of deposit market concentration on the transmission of monetary policy. Using geographical variation in the degree of concentration, they find that bank branches in more concentrated markets widen the spread between deposit rates and the Fed funds rate in response to a monetary policy contraction relative to a branch of the same bank but operating in a less concentrated market (Drechsler et al., 2017).[7] This result, however, is likely to be specific to the U.S. case. Inherent structural differences across the two banking markets as well as effects that the recent financial crisis and different extraordinary monetary policy measures had on them raise doubts on whether findings for the U.S. can be translated to Europe. In contrast to the U.S., our data for instance indicates that counties with high banking market concentration in Germany are on average smaller and populated by a lower share of people over the age of 65. Furthermore, the sovereign debt crisis in 2011/12 posed a particular challenge to Europe's unintegrated banking market and lead the European Central Bank (ECB) to target sovereign spreads of particular countries in Europe, a phenomenon which was absent in the U.S.

This paper proceeds as follows. Section 2.2 motivates the research question theoretically, section 2.3 introduces the data sets, section 2.4 outlines the measures of imperfect competition and section 2.5 specifies the empirical approach and presents results. Section 2.6 contains robustness tests and section 2.7 concludes.

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[7]This ultimately drives heterogeneities in bank lending, i.e. loan *quantities*. In contrast, we solely focus on prices.

2.2 Conceptual framework

In theoretical models, banking markets are commonly characterised by some sort of imperfect competition (Gerali et al., 2010; Martinez-Miera and Repullo, 2018). In the context of monetary policy transmission, the central bank's policy rate can furthermore be interpreted as a bank's marginal costs since banks consider it as the reference rate for their funding (Agarwal et al., 2017; Martinez-Miera and Repullo, 2018; Corbae and Levine, 2018).

The standard textbook model of monopolistic competition provides a useful and simple framework to formalise changes in prices for loans where p stands for the rate a bank charges for one unit of loan, q. Accordingly, a change in the equilibrium price can be the result of cost and/or demand shifts. A change in the equilibrium price, $\mathrm{d}p$, can then be expressed as a function of the two shocks:

$$\mathrm{d}p = \frac{\partial p}{\partial x}\mathrm{d}x + \frac{\partial p}{\partial i}\mathrm{d}i \tag{2.1}$$

where $\mathrm{d}x$ denotes an exogenous parallel cost shift (i.e. x denotes the intercept of the marginal cost curve) and $\mathrm{d}i$ a demand shift (i.e. i is the intercept of the inverse demand curve). The first term on the right-hand side of Equation (2.1) captures the equilibrium price change after a cost shock in the absence of demand shifts, and the second term the corresponding change after a demand shift when no funding costs shock is present. In the event that both shocks occur at the same time, Equation (2.1) formalises the full adjustment of the price from the old to the new equilibrium. For any functional form of demand and marginal cost curve, the analytical solution to $\mathrm{d}p$ is given in more detail by

$$\mathrm{d}p = \frac{\partial p}{\partial q}\frac{\partial q}{\partial x}\mathrm{d}x + \left(\frac{\partial p}{\partial i} + \frac{\partial p}{\partial q}\frac{\partial q}{\partial i}\right)\mathrm{d}i \tag{2.2}$$

where $\frac{\partial q}{\partial x}$ is the change in the equilibrium quantity in response to a change in costs, $\frac{\partial p}{\partial i}$ is the partial derivative of demand with respect to its intercept and $\frac{\partial q}{\partial i}$ reflects the dependence of the equilibrium quantity on the intercept of the demand curve.[8] Equation (2.2) shows that the equilibrium price adjustment to any of the shocks depends on the slope of the demand curve, $\frac{\partial p}{\partial q}$. Thus, the steepness of demand (or the elasticity of demand) determines not only the extent to which a monopolist can exert market power[9], but also the adjustment of the equilibrium price in response to shocks. If for every loan quantity borrowers are suddenly willing to pay a different price, demand shifts. Here, a productivity shock or a shock to agent's expectations about the evolution of the business cycle may be one reason. Alternatively, a monetary policy shock which causes a change in the cost of funds affects marginal costs: a monetary policy contraction increases costs and shifts the marginal cost curve up, leading to a higher equilibrium loan rate (see Figure 2.2.1). Equation (2.2) demonstrates that the size of the price adjustment always depends on the slope of demand and the according degree of the monopolist's pricing power.

Papers examining realised interest rates and their response to a change in the reference rate, observe rates over the monetary and business cycle where $\mathrm{d}p$ is the change in the price over time, $\mathrm{d}p = p_{t+1} - p_t$. According to derivations above, heterogeneities in $\mathrm{d}p$ can either stem from different supply side adjustments or from credit demand shifts unrelated to monetary policy changes. In particular, it is plausible that demand behaves systematically differently across banks with varying levels of market power; in that event, resulting heterogeneities in the transmission of monetary policy are not a result of frictions on the credit supply side.

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[8] See Appendix 2.A.1 for proof.

[9] Solving $max_q \pi = p(q)q - c(q)$ gives $\frac{\mathrm{d}p(q)}{\mathrm{d}q}q + p(q) - \frac{\mathrm{d}c(q)}{\mathrm{d}q} = 0$. Rewriting leads to $p(q)[\frac{\mathrm{d}p}{\mathrm{d}q}\frac{q}{p} - 1] = mc$ with $\frac{\mathrm{d}c(q)}{\mathrm{d}q}$ denoting marginal costs, mc. The elasticity of demand, ϵ, is $\epsilon = \frac{\mathrm{d}q}{\mathrm{d}p}\frac{p}{q}$. Rewriting once more gives $\frac{1}{|\epsilon|} = \frac{p-mc}{mc}$ which is the definition of the Lerner Index. Therefore, the less elastic demand in the old equilibrium point, the more market power a bank can exert. Note, maximising over p instead of q leads to the same results.

Figure 2.2.1: Monopolistic competition
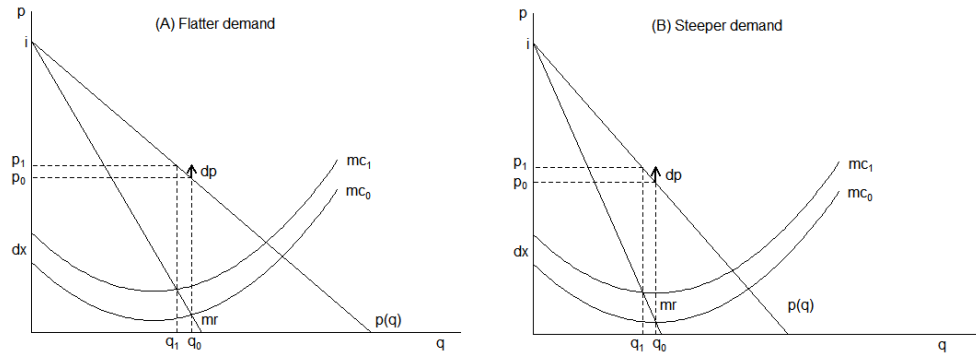
Note: The figure shows the pass-through of a cost shock to prices in two markets with monopolistic competition. Panel A considers a case with a relatively flat demand curve, i.e. a market in which a monopolist can exert relatively less market power; Panel B considers a case with a relatively steep demand curve, i.e. a market with relatively more market power. (Inverse) demand is denoted by $p(q)$, marginal revenues by mr and marginal costs by mc. A demand shock would shift $p(q)$, and accordingly mr.

In order to disentangle the role of the supply from the demand side in the transmission of monetary policy to interest rates, the ideal setting would be one where for every bank j, we have information on prices for two different counterfactual scenarios occurring at time t, one in which a monetary policy shock, dx, is zero and one in which it is equal to some (positive) value. The difference between the new loan rates in the two scenarios, both observed in $t+1$, could then be defined as the pass-through of monetary policy. Specifically, this would lead to:

$$dp_j = p_{j,t+1}|_{dx>0} - p_{j,t+1}|_{dx=0} \qquad (2.3)$$

where $p_{i,t+1}|_{dx>0}$ represents the predicted loan rate in the shock scenario and $p_{i,t+1}|_{dx=0}$ the one in the scenario where no monetary policy shock occurs. dp_j would then correspond to the pure supply-side adjustment in prices in response to an exogenous monetary policy contraction because everything else that occurs between t and $t+1$ would automatically be cancelled out. This

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would allow us to determine the direction of

$$\frac{\mathrm{d}(\mathrm{d}p/\mathrm{d}x)}{\mathrm{d}\,market\,power} >< 0. \tag{2.4}$$

by simply regressing $\mathrm{d}p_j$ on a measure of market power.[10]

In this simple model, monetary policy does not shift the demand curve. As shown in Figure 2.2.1, demand falls as a result of higher loan rates, represented by a movement *along* the demand curve. Yet, because a monetary policy contraction may affect borrowers' balance sheets, the change in credit demand could be amplified. A monetary contraction may result in declining asset prices which shrink collateral and ultimately the desire to invest (Bernanke and Gertler, 1989; Bernanke et al., 1999). Thus, it is plausible that credit demand shifts inwards in the shock as opposed to the constant scenario. This would not be cancelled out when defining the pass-through of monetary policy according to Equation (2.3) and estimating Equation (2.4) would consequently mask the influence of credit demand on the pass-through of monetary policy.

However, evidence strongly indicates that borrowers do not assign randomly to lenders (Schwert, 2018). As a result, demand shifts are likely to vary systematically across banks. Indeed, Altavilla et al. (2018) find that in response to a monetary policy contraction, loan demand in the Euro area generally falls to a smaller extent at less riskier banks.[11] In addition, banks with more market power can be considered as less risky since they can realise profits from monopoly rents while in competitive markets, banks have to search for yield in riskier investments. Kick and Prieto (2014) confirm such a negative relation-

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[10]Note that even in the simple model presented here, when market power is measured by the slope of demand, the direction is ambiguous; there exists a threshold in the slope of demand below which the above relationship is positive but turns negative above. The analytical solution to the threshold is derived in Appendix 2.A.2.

[11]Results are obtained from the bank lending survey (BLS) for a time horizon that includes our time frame, i.e. 2002Q4 to 2017Q4 (Altavilla et al., 2018). The BLS collects information on credit supply and demand conditions for 150 institutions among which 30 are German. Bank risk is measured by their CDS spreads.

ship between market power and bank risk taking for German banks.[12]

Therefore, if demand shifted inwards in the shock scenario, this shift would be relatively larger at banks with lower levels of market power, mitigating the upward pressure on the price from the monetary policy contraction. As a result, $\mathrm{d}p_j$ would ceteris paribus be smaller at less monopolistic banks. In other words, if an inward shift in demand in the constant scenario had a major contribution to the pass-through, $\mathrm{d}p_j$ would be *larger* among banks with *more* market power (giving Equation (2.4) a positive sign).

2.3   Data

We merge bank-level supervisory data of all banks in Germany with a unique dataset that contains interest rates for various product categories on banks' asset and liability sides: the *2017 low-interest-rate survey*.

2.3.1   The *2017 low-interest-rate survey*

Between April and June 2017, the German Federal Financial Authority (henceforth *BaFin*) and Deutsche Bundesbank (henceforth *Bundesbank*) conducted a supervisory measure on all 1,555 small and medium-sized German credit institutions on their profitability and resilience in the low-interest-rate environment.[13]

The data contains outcomes from various stress tests on interest rate risk, credit risk and market risk collected in a *bottom-up* exercise. Supervisory stress tests in the context of banking supervision are generally conducted in *top-down*

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[12]Precisely, using the Lerner Index to measure individual pricing power, the authors find that market power in Germany (between 1994 and 2010) is significantly negatively related to several measures of bank risk, i.e. the probability of experiencing a distress event (e.g. receiving capital support), the ratio of non-performing loans to total loans, and the z-score (Kick and Prieto, 2014).

[13]The supervisory measure was conducted on all banks which are supervised by BaFin and Bundesbank according to § 6b KWG. Significant institutions (*SIs*) under direct European Central Bank (*ECB*) supervision are excluded.

and *bottom-up* exercises. Top-down refers to tests which the supervisory institutions run based on the bank-by-bank reporting data they have on the supervised banks; in bottom-up exercises, banks are obliged to run simulations or calculations themselves using their individual risk management assumptions and parameters while complying with constraints given by the authorities. Results need to be reported to the supervisors which in turn conduct quality assurance to ensure comparable results. While the exact modelling of banks is unknown, the bottom-up approach allows a more individual and thus more meaningful reflection of the banks' vulnerabilities under a certain scenario when taking into account data that the authorities do not have at hand.

For our purpose, we work with the stress test data on interest rate risk. In particular, banks had to report retail rates for loans and deposits which they would set in response to two hypothetical scenarios taking place as of 01.01.2017. The two scenarios were specifically phrased as follows:

1. "Constant yield curve (static balance sheet assumption[14]): the yield curve as of 31.12.2016 remains unchanged for the whole time horizon. The static balance sheet assumption holds."(BaFin/Bundesbank, 2017)

2. "+200 BP shock (static balance sheet assumption): the yield curve shifts ad hoc and parallelly by 200 BP as of 01.01.2017 compared to 31.12.2016 and remains unchanged for the whole time horizon. The static balance sheet assumption holds." (BaFin/Bundesbank, 2017)

Because the upward shift in the yield curve is defined to be permanent (BaFin/Bundesbank, 2017), the shock scenario by definition implies a contractionary monetary policy shock. It is verified that banks understand the shock

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[14]For comparability reasons and to prevent implausible portfolio enhancements, banks were required to replace maturing business with equivalent new business at prevailing standards e.g. regarding probabilities of default of borrowers, contracted volumes and type of contract. This is referred to as the *static balance sheet assumption*.

to be permanent.[15]

To grant the highest possible adjustment in interest rates and to avoid that old contracts confound our results, we focus exclusively on banks' new business. For loans, this is further divided into fixed and floating rate contracts. For each scenario and bank, we then calculate the (new business) loan rate as a volume-weighted average over fixed and floating rate contracts. This aims at taking into account that banks with larger shares of fixed rate contracts might change loan rates to a smaller extent. Because deposit rates are floating rates only, volume-weighting is not necessary. Next, we calculate differences between banks' reported interest rates for the shock and the constant scenario (as outlined in Equation (2.3)) and normalise it by the size of the shock. For each bank and category (i.e. loan and deposits), this gives a measure of the pass-through of monetary policy to retail rates.

Provided that banks correctly assume $\mathrm{d}i = 0$, we observe price changes conditional on an exogenous monetary policy shock which fulfils the criteria of being able to disentangle supply from demand. Furthermore, due to the particular way in which we calculate the pass-through of monetary policy, the effect of any demand shocks which banks may potentially assume over the course of 2017 is differenced out – as long as these demand shocks are unrelated to monetary policy. Similarly, any change in other factors, which matter for the pass-through (apart from monetary policy or demand shocks), that banks might expect cancels out.

Banks are legally required to provide authentic results.[16] In a quality assurance process, stress test submissions were continuously quality-checked to ensure that all reporting banks submit meaningful data. Cross-checks with reporting data (e.g. interest income and expenses or loan volumes) and peer

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[15]Due to the permanent nature of the shock, all current and fixed assets have to be written down.

[16]§ 6b KWG and EU Regulation No. 1093/2010 (European Parliament and Council, 2010) apply.

group comparisons ensure that reported data are plausible and fulfil quality standards.[17] Furthermore, banks were advised to submit revised versions in case of poor or insufficient data. Data quality is of high importance because results provide the basis for individual (Pillar 2) capital guidance in the supervisory review and evaluation process (*SREP*) framework.[18] Remaining concerns regarding data quality and authenticity will be addressed in detail below. In particular, we provide evidence that survey responses are valid and unlikely to be biased by strategic incentives which may be correlated with market power.

2.3.2 Panel data

We select and estimate explanatory variables from balances and profit and loss accounts reported to the Bundesbank on a yearly basis. From this dataset, we take control variables and, most importantly, compute measures for market power. Because here we work on the entire population of financial institutions in Germany, we explicitly take the "big banks", i.e. SIs supervised by the ECB, in the pool of competitors into account. We keep a long time horizon (from 1994 to 2016) in order to make sure we achieve plausible results of estimated competition measures and their evolution over time. Due to mergers and acquisitions, we work with an unbalanced panel.

2.3.3 Data cleansing

Before merging the panel and the stress test data, we clean the two data sets separately. To exclude implausible bank-year observations in the panel data, we drop observations with negative or zero total assets, equity and total loans (i.e. sum of financial and non-financial loans) and impose the following condi-

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[17]For instance, the maturing portion of a certain balance sheet position is compared across banks with a similar average maturity in that portfolio.

[18]For more information, see https://www.bafin.de/SharedDocs/ Veroeffentlichungen/EN/Fachartikel/2018/fa_bj_1807_ Risikotragfaehigkeit_en.html, viewed 25 February 2020.

tions: loans-to-assets ratio and deposits-to-assets ratio must not exceed 1 and 0.98, respectively, and the equity-to-assets ratio must lie above 0.009 and below 0.5. The personnel expenses- and other administrative expenses-to-assets ratio must be in a range of 0.0005 and 0.05 (Van Leuvensteijn et al., 2013). Before we impose the latter two conditions, we winsorize the expense variables at the upper and lower percentile (Kick et al., 2015). This leaves us with more than 54,200 bank-year observations.

From the stress test data, building societies (*Bausparkassen*) are excluded as they are highly specialized. We furthermore exclude a handful of banks which, despite the elaborated quality assurance process, still appear to have provided data of insufficient quality. To deal with outliers, we winsorise interest rate levels and pass-through variables (the difference between the rates in the shock and the constant scenario, normalized by the size of the shock) at the winsorised at the bottom 1st and the top 99th percentile of the respective distribution. Finally, we only keep banks that pass the quality requirements imposed on both datasets.

2.4 Measures of competition and concentration

To examine the effect of imperfect competition on interest rate levels and monetary policy transmission, we use an individual pricing power and a market concentration index.[19] The Lerner Index is widely applied in the banking literature (Valverde and Fernandez, 2007; Berger et al., 2009; Kick and Prieto, 2014; Sääskilahti, 2016). In addition, it is to our best knowledge the only well-known measure one can compute *at the bank-level*. Because the banks in our sample operate locally, we also apply an aggregate concentration measure, the

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[19]It has been established in the literature that various competition measures may be only weakly interrelated (see e.g. Claessens and Laeven, 2004; Bikker et al., 2012 and citations therein for empirical evidence, and Lapteacru (2014) for theoretical work) which calls for the use of alternative measures.

Herfindahl-Hirschman Index.[20]

2.4.1 Individual pricing power: Lerner Index

The Lerner Index (LI) measures a firm's monopolistic power by measuring its ability to charge a markup over marginal costs. The LI for bank j at time t is defined as:

$$LI_{jt} = \frac{\frac{TOR_{jt}}{Y_{jt}} - MC_{jt}}{\frac{TOR_{jt}}{Y_{jt}}} \tag{2.5}$$

with average revenues calculated as a fraction of total revenues TOR_{jt}, to total output Y_{jt}, and marginal costs denoted by MC_{jt}.[21] We define TOR as revenues that can be attributed to loan provision in a wider sense, excluding revenues from financial transactions such as trading derivatives.[22] In particular, total revenues consist of interest income from credit and money market operations, and revenues from fee-based business. Total output is commonly defined as the sum of loans to non-financial customers (i.e. households and private firms), inter-bank loans and securities (Mester, 1996).

To derive marginal costs, we estimate total costs for each bank in our sample using a translog cost function (Christensen et al., 1973).[23] We follow the literature and account for potential cost inefficiencies that make the optimizing agent (here banks) deviate from the optimal cost-minimum, e.g. through suboptimal use of input factors. As stressed by Koetter et al. (2012), the LI may be biased downwards if perfect efficiency is assumed. We do not impose an assumption on why banks might operate inefficiently but we explicitly al-

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[20]Alternative measures would be the Boone Indicator (Kick and Prieto, 2014), or the Panzaar-Rosse H-Statistic. The latter has drawn much criticism in determining competition (Bikker et al., 2012 and Shaffer and Spierdijk, 2015).

[21]Under imperfect competition the price $P(Q)$ is equal to average revenues, i.e. $P(Q) = AR$, because $AR = avg.Profit + AC = \frac{profit}{Y} + \frac{TOC}{Y} = \frac{TOR_{jt}}{Y_{jt}}$ with TOR_{jt} denoting total revenues of bank j in year t, and TOC total costs.

[22]In a robustness check, we verified that including financial transactions does not make a substantial difference in the results.

[23]A detailed derivation of a bank's cost function can be found in Appendix 2.B.

low them to act according to the *quiet life hypothesis* which states that market power is negatively correlated with cost efficiency (Koetter and Vins, 2008).[24] Total costs are thus estimated with maximum likelihood, in a stochastic frontier model (Aigner et al., 1977; Meeusen and van Den Broeck, 1977; Greene, 2005).

Taking it to the data, we impose linear homogeneity of the total cost function with respect to input prices. Our functional form for the cost function follows Koetter et al. (2012) and Kick et al. (2015) and is:

$$
\ln \frac{TOC_{jt}}{w_{1jt}} = \alpha + \beta_1 \ln Y_{jt} + \frac{\beta_2}{2}(\ln Y_{jt})^2 + \sum_{h=2}^{3} \gamma_h \ln \frac{w_{hjt}}{w_{1jt}} + \frac{\gamma_{22}}{2}\left(\ln \frac{w_{2jt}}{w_{1jt}}\right)^2 +
$$

$$
\frac{\gamma_{33}}{2}\left(\ln \frac{w_{3jt}}{w_{1jt}}\right)^2 + \frac{\gamma_{23}}{2} \ln \frac{w_{2jt}}{w_{1jt}} \ln \frac{w_{3jt}}{w_{1jt}} + \sum_{h=2}^{3} \frac{\delta_h}{2} \ln \frac{w_{hjt}}{w_{1jt}} \ln Y_{jt} +
$$

$$
\zeta_1 \ln z_{jt} + \frac{\zeta_2}{2}(\ln z_{jt})^2 + \sum_{h=2}^{3} \frac{\eta_h}{2} \ln \frac{w_{hjt}}{w_{1jt}} \ln z_{jt} + \theta \ln Y_{jt} \ln z_{jt} +
$$

$$
\sum_{h=1}^{2} \kappa_h\, tr^h + \kappa_3\, tr \ln Y_{jt} + \kappa_4\, tr \ln z_{jt} + \sum_{h=1}^{2} \kappa_{h+4}\, tr \ln \frac{w_{h+1,jt}}{w_{1jt}} + v_j + u_j \quad (2.6)
$$

where w_{1jt}, w_{2jt} and w_{3jt} denote bank $j's$ input prices for loanable funds, labour and fixed capital, respectively. Akin to Kick et al. (2015), we calculate the input price for loanable funds as interest expenses divided by interest-paying liabilities and for labour as the ratio of personnel expenses and the number of full-time employee equivalents. Finally, we approximate capital expenses by other administrative expenses to fixed assets. Y_{jt} is as defined above. We include a bank's equity z_{jt} to control for heterogeneity in total costs across different bank sizes. Cross products between input prices and output with equity, respectively (η_2, η_3, θ), allow the effect of prices and output on total costs to vary between smaller and larger banks. We also include a linear trend, tr, single and squared, as well as interacted with input prices, output, and equity.

---

[24]Following Koetter (2013), we abstain from estimating profits before taxes taking into consideration profit inefficiencies but rather take total revenues and output directly from the data. See e.g. Kick et al. (2015) for an estimation of the LI with profit inefficiencies.

The error term of the cost function estimation consists of two components, v_j, a random, i.i.d. term ($v_j \sim \mathcal{N}(0, \sigma_v)$), and an inefficiency term u_j for which we assume an exponential distribution. Assuming that the two components are independent, the above reduced-form model is estimated with maximum-likelihood. Consecutively, we derive banks marginal costs as:

$$
\begin{aligned}
MC_{jt} &= \frac{\partial \ln TOC_{jt}}{\partial \ln Y_{jt}} \frac{TOC_{jt}}{Y_{jt}} \\
&= \left(\beta_1 + \beta_2 \ln Y_{jt} + \sum_{h=2}^{3} \frac{\delta_h}{2} \ln \frac{w_{hjt}}{w_{1jt}} + \theta \ln z_{jt} + \kappa_3 tr \right) \frac{TOC_{jt}}{Y_{jt}} \quad (2.7)
\end{aligned}
$$

Finally, one LI per bank and year can be calculated based on Equation (2.5).[25] Figure 2.4.1 depicts the evolution of the average LI over time.

Figure 2.4.1: Evolution of average pricing power over time
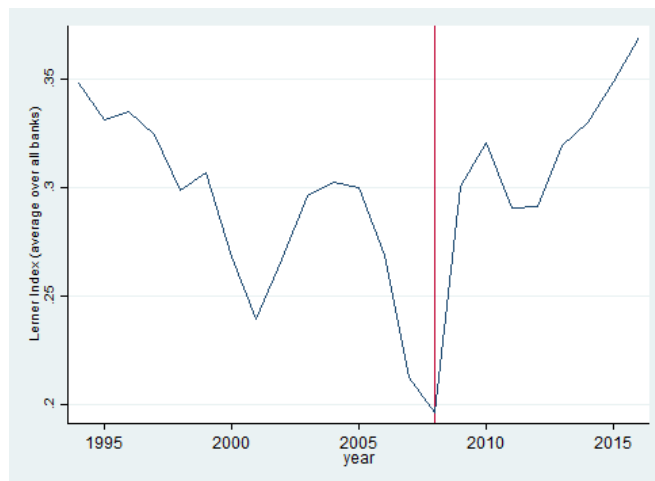
Notes: The figure shows the unweighted mean of pricing power of all German banks over time. Smaller values mean lower levels of average pricing power indicating higher competitive pressure. Vertical red line in (i.e. at the end of) 2008.

While in the final analyses we only use the 2016 values, the graph can serve as a plausibility check. Banks generally compete most severely for prices during expansions and competition in various EMU states increased until 2008 after which trends reverted (Ruckes, 2004; Brämer et al., 2013). Our calcula-

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[25]Summary statistics of all variables used or estimated in this section can be found in Table 2.B.1 in Appendix 2.B.

tions show that also in Germany, (price) competition rose in the boom years leading up to the financial crash and reached its peak at the end of 2008.[26] Lately, pricing power has been on the rise again, with average pricing power reaching an unprecedented level on our scale from 1994 – 2016. Dynamics are furthermore in line with earlier analyses for Germany (Koetter, 2013).

2.4.2 Market concentration: Herfindahl-Hirschman Index

Structural indicators seek to derive the degree of competition from market characteristics, because in strongly concentrated markets, firms should be able to exert market power (Mason, 1939; Bain, 1956). The *structure-conduct-performance paradigm* formulates that margins such as loan spreads are positively related to concentration (Coccorese, 2009). However, few firms in a market might also operate in strong competition to each other. Hence, the relationship between individual pricing power and concentration is not trivial and we challenge our estimations using these two alternative measures.

The Herfindhal-Hirschman Index which assigns a single value of concentration to a market is calculated as

$$HHI_d^p = \sum_j (LMS_{jd}^p)^2 \tag{2.8}$$

where the sum of bank-level (j) local market shares (LMS) goes over all banks that have their head quarter in administrative or urban district d.[27] In a highly concentrated market, the HHI_d^p approaches a value of 1. A bank j's local market share is the share of a specific portfolio p in the aggregate per district:

$$LMS_{jd}^p = \frac{X_{jd}^p}{\sum_i X_{id}^p} \tag{2.9}$$

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[26]During that time, average revenues dropped while marginal costs rose on average, a trend that reversed for both variables from 2009 onwards (see Figure 2.B.1 in Appendix 2.B).

[27]In 2016, Germany consists of 294 administrative districts and 107 urban districts, leading to a total of 401.

where the sum goes again over all i banks in a district; for X^p we alternatively use deposits, loans to non-financial private customers and interbank loans.

Figure 2.4.2: Geographical variation of loan market concentration
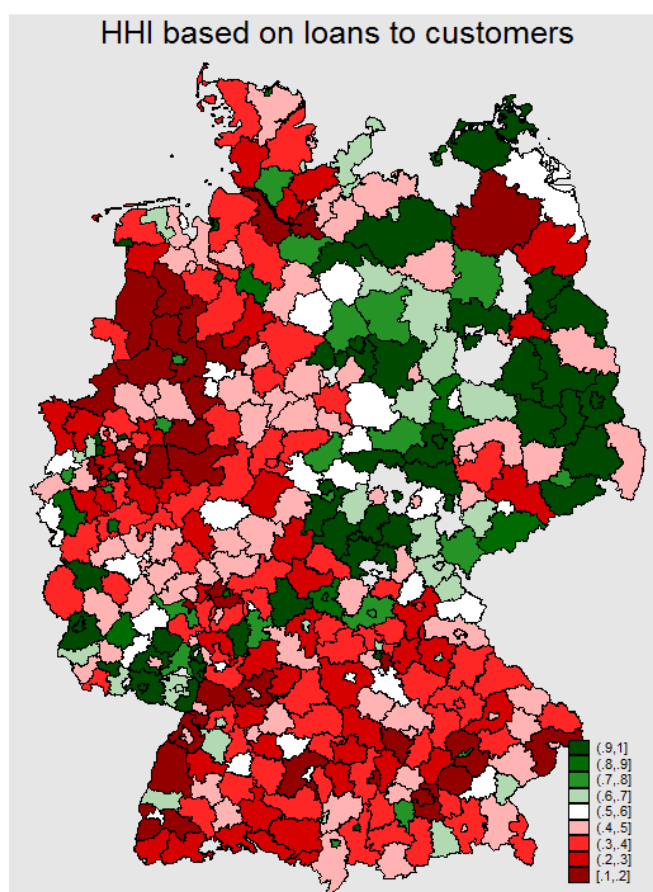
Notes: The figure shows the HHI's in the market for loans to private customers across the 401 counties (i.e. administrative and urban districts) in Germany in 2016. Dark red stands for low level of concentration, dark green for high level of concentration.

Figure 2.4.2 shows the geographic variation in loan market concentration across Germany in 2016. Markets tend to be more concentrated in the north-east of Germany, meaning that there are cases in which one single bank is located in a county (darkest green).[28]

Our approach suffers from shortcomings. When seeking to determine market concentration in a bank's relevant market, we assign the total value of deposits and loans to a bank's head-quarter which reports balance sheet informa-

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[28]Concentration in the loan and deposit market has been on a steady rise up until 2008 after which it stagnated (but never fell). See Figure 2.B.2 in Appendix 2.B.

tion to the Bundesbank. This implies the assumption that a bank conducts all business within the district of its head-quarter. This should not lead to a bias for savings and cooperative banks because they mostly report as separate entities (i.e. head-quarters) and due to the *regional principle* are bound to operate locally (Stolz and Wedow, 2011).[29] However, it significantly biases results for the big banks. If, for instance, a large private bank conducts business outside of its head-quarter district in a region and market segment where a local savings bank operates, then our measure of concentration for the district in which that savings bank is located is biased upwards. If, however, big banks compete with the small and medium-sized banks in our sample only on specific, limited markets, then the bias is limited, too. Many papers work with information on branch locations to infer a clearer picture on market concentration (Kick and Prieto, 2014; Drechsler et al., 2017). Information on branches in Germany is, however, only reliably available until 2004. Furthermore, because data are not available at the branch level, assumptions would have to be made to assign shares of exposure to the various branches, leading to a different level of insecurity and lack of precision. We therefore desist from hand-collecting all bank branches and instead run additional robustness tests below.

2.4.3 Competition and concentration

Panel A, B and C of Table 2.4.1 present summary statistics of district and bank characteristics in 2016 for the banks that were part of the stress test. Panel D looks at bank characteristics of the entire population of German banks over the period 1994–2016. In panels A and B, we look at low-LI versus high-LI districts, and low-HHI$_{loans}$ versus high-HHI$_{loans}$ districts with at least one bank in 2016, respectively. Because the LI is bank-specific, we first calculate district-

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[29]Because banks are only bound to operate locally when providing credit, the regional principle does not necessarily hold for deposits. Due to the housebank-principle in Germany and because the HHI for deposits is highly correlated with the HHI for loans, we still believe the measure to be informative.

level averages of the LI. We then divide the sample at the respective median of the (district-level) LI and the HHI distribution. Column (I) furthermore only presents data for banks for which a meaningful LI could be estimated.[30]

High-LI and high-HHI districts respectively have on average a smaller population in absolute terms and are characterised by a somewhat lower share of individuals over the age of 65 (Panel A). High-HHI counties are furthermore smaller while high-LI counties are on average larger. When averaging bank characteristics at the county level, both high-LI and HHI counties exhibit banks with on average higher return on assets and profits (Panel B). Similarly, high-LI and HHI banks are more profitable (Panel C). Over the full time period, when taking into account all banks (also the SI's), that pattern is even more pronounced (Panel D). Differences across the two measures of imperfect competition arise when looking at the banks' average exposure in the loan market: high-LI banks and counties appear to have on average lower loan volumes while high HHI banks and counties have higher loan volumes (Panels B and C). Over the full time period, when taking into account all banks, both high LI and HHI banks have smaller loan volumes (Panel D).[31]

Regarding volumes and market concentration, respectively, the pattern seems to be similar to the banking market in the U.S. There, high HHI institutions have larger portfolios regarding deposits (Drechsler et al., 2017).[32] However, high HHI counties in the U.S. are larger and have a higher population share that is older than 65.

Summing up, county-level pricing power and market concentration are related in opposite ways to county size, and county-average and bank-level size

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[30]In some occasions, the LI was negative or above one and we replaced these data entries by *missings* in the analysis and exclude them for this section.

[31]Results are qualitatively similar when applying the HHI in the deposit market and splitting the samples analogously.

[32]Patterns in our data do not change when applying the HHI for deposits and relating that to deposit volumes. Because the regional principle does not need to hold in the deposit market in Germany, we focus on loan volumes and corresponding market concentration.

Table 2.4.1: Descriptive statistics

	(I) Lerner Index			(II) Herfindahl Index		
	All	Low LI	High LI	All	Low HI	High HI
Panel A: County characteristics (2016)						
Popul. (in 1000)	210	235	185	210	265	156
Area (sq. km)	891	786	1000	891	995	791
Over 65 (%)	19.2	19.8	18.5	19.2	19.4	18.9
Obs. (counties)	385	192	192	385	192	192
Panel B: Bank characteristics by county (2016)						
Profits (mill.)	2085	1859	2294	2011	1683	2343
ROA (%)	0.77	0.67	0.87	0.74	0.72	0.76
Loans (mill.)	921	1151	685	910	859	961
LI/HHI	0.37	0.32	0.42	0.547	0.36	0.74
Obs. (counties)	385	192	192	385	192	192
Panel C: Bank characteristics (2016)						
Profits (mill.)	1,964	1,531	2,397	1,854	1,527	2,181
ROA (%)	0.77	0.60	0.94	0.72	0.007	0.75
Loans (mill.)	961	1307	615	960	886	1034
Deposits (mill.)	669	815	523	661	611	711
LI/HHI	0.37	0.29	0.45	0.43	0.28	0.58
Obs. (banks)	1,442	721	721	1,482	741	741
Panel D: Bank characteristics (all banks, 1994-2016)						
Profits (mill.)	444	379	509	425	330	520
ROA (%)	1.0	0.68	1.3	0.86	0.91	0.81
Loans (mill.)	1116	1865	367	1261	1479	1042
LI/HHI	0.30	0.23	0.37	0.36	0.22	0.5
Obs. (bank x year)	51,565	25,782	25,782	54,228	27,114	27,114

Notes: Summary statistics at the county and bank x year level. Panels break the sample into the median of the LI (I) and the HHI (II) distribution, respectively. All banks for which a plausible LI (i.e. a number between 0 and 1) could be calculated are considered for exercise (I) and only counties with at least one bank are considered for exercise (II). The HHI is concentration in the market for loans to private customers. Return on assets (ROA) is calculated as profits (i.e. the difference between total revenues and total costs) over total assets and reported in millions of Euros. Loans are the yearly reported volumes for loans to private customers in banks' balance sheets, in millions of Euros. Sources: Bundesbank supervisory data. Statistisches Bundesamt.

of the loan portfolio, respectively (in 2016). However, both higher market concentration and higher pricing power seem to indicate higher profitability. This is in line with both theory and previous empirical evidence on the relationship between local market concentration and profits (Berger and Mester, 1997; Pilloff and Rhoades, 2002).

2.4.4 Additional control variables

We control for several bank characteristics that might affect interest rate levels, and potentially the pass-through of monetary policy. Equity financing is associated with higher costs as opposed to external financing (Maudos and De Guevara, 2004). Hence, we control for a bank's *leverage* defined as the fraction of total assets over equity and expect a negative relationship with loan rate levels (Barattieri et al., 2016). On a similar note, De Graeve et al. (2007) find a positive relationship between loan spreads and capital buffers since holding equity is associated with costs e.g. in the form of forgone profit; thus, we control for excess capital over total assets, *excess capital*. We will furthermore use this variable to test whether our results on imperfect competition are driven by the fact that banks with more market power have a weaker incentive to downplay the severity of the stress effect as they already hold larger capital buffers. We also control for *liquidity* by including securities over total liabilities, a variable which is important for the pass-through of monetary policy shocks to credit volumes by banks (Kashyap and Stein, 2000). Monetary policy tightening aggravates liquidity constraints and therefore banks with lower levels of liquidity tighten lending by more. De Graeve et al. (2007) furthermore find that liquid banks have a lower pass-through. A bank's *funding* structure has been found to matter for its pass-trough of monetary policy (Weth, 2002; De Graeve et al., 2007). We thus include the ratio of deposits to interest paying liabilities to test its effect on the level of banks' interest rates. Given the low in-

terest environment and mostly negative EURIBOR rates in 2016, it is plausible that our funding variable is positively associated with interest rate levels for loans. Then again, deposits are a more stable source of funding (Hanson et al., 2015) and banks relying more on deposit funding are found to be less vulnerable to financial shocks (Jensen and Johannesen, 2017). Therefore, a negative relationship between loan rates and deposit funding could also occur. We explicitly do not control for bank size in our estimations as it has been shown that (in contrast to the U.S.) this is likely not to be adequate for the European and, in particular, the German banking market (Ehrmann and Worms, 2001; Worms, 2001). Due to the institutional structure of the German banking system, bank size is not a good predictor for access to funds via e.g. the interbank market. Small and medium sized banks mostly belong to the savings cooperative banks sector and are well interconnected within the respective sector via their central institutions (Worms, 2001). However, we do not completely abstract from potential heterogeneities related to bank size since we take it into account when estimating marginal costs.

2.5   Analysis

This section discusses the relationship between imperfect competition and interest rate levels and the pass-through of a monetary policy shock to loan and deposit rates, respectively.

2.5.1   Summary statistics

Table 2.5.1 highlights asymmetries within banks across the pricing of their products according to the *2017 low-interest-rate survey*. Column (1) displays averages and standard deviations for interest rates in the constant scenario, $ir^p_{constant}$, representing retail rates for noted categories p which reporting banks

would set in 2017 in the absence of a sudden change in monetary policy. In that occasion, average loan rates would lie at 3.2 percent and rates for inter-bank loans would be slightly negative. The average rate for deposits would be zero. Column (2) provides average retail rates for the shock scenario, ir^p_{shock}, and column (3) the pass-through of the shock in percent, $PT\ ir^p$, calculated as the difference between a bank's interest rate in the shock and in the constant scenario, normalised by the size of the shock. Following a 200 BP shock, banks would on average pass on 78 percent of the shock corresponding to an increase in loan rates by 1.57 percentage points. At the same time, banks would on av-erage only offer higher deposit rates by 0.64 percentage points which implies a pass-through of 32 percent, confirming a certain stickiness of deposit rates in general (Hannan and Berger, 1991). Interest rates for interbank loans are closest to market rates with a pass-through of 90 percent.

Table 2.5.1: Summary statistics

p	(1) $ir^p_{constant}$		(2) ir^p_{shock}		(3) $PT\ ir^p$		Obs.
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	
Loans	3.20	0.95	4.77	0.94	78.42	15.5	1,466
Bank loans	-0.025	0.30	1.79	0.46	90.24	19.56	1,433
Deposits	0.010	0.05	0.65	0.40	31.76	20.06	1,478

Notes: Summary statistics for interest rate levels and the pass-through for noted cate-gories. Interest rate levels and the pass-through are winsorised at the bottom 1st and the top 99th percentile of the distribution, respectively. In particular, *Loans* consist of loans to non-financial customers which include all customers (such as households, firms and public entities) except banks. *Bankloans* denote interbank loans. All variables to be inter-preted in percent. Source: 2017 low-interest-rate survey (BaFin/Bundesbank).

2.5.2   Market power and interest rate levels

In this section, we examine the relationship between market concentration and retail rate levels. Because the LI measures price setting power at the bank-level, it is already implied by a bank's interest rate *level*. To avoid endogeneity

issues, we therefore only work with our structural measure of imperfect competition and estimate at the bank-level j:

$$ir_j^p = \alpha_0 + \alpha_1 HHI_d^p + \sum_{m=2}^{M} \alpha_m X_{jm} + \epsilon_j \qquad (I)$$

where ir_j^p consists of 2017 interest rate levels (in percent) for different product categories p. We control for ex-ante, i.e. 2016 values of all explanatory variables, denoted by $\sum_{m=2}^{M} X_{jm}$, which we outlined in subsection 2.4.4. HHI_d^p measures the concentration in the respective product market p in district d in which a bank has its headquarter, equally measured in 2016. Our main focus lies on interest rate levels in the constant scenario. To test the quality of the survey data, we additionally run the same regression with retail rates from the shock scenario as a dependent variable. The coefficient of interest is α_1, measuring the effect of market concentration on levels of interest rates.

We find that loan rates in both the constant and the shock scenario are on average higher in more concentrated markets (columns 1 and 4 of Table 2.5.2). Deposit rates do not vary significantly across different levels of concentration in the absence of a policy contraction. This is likely to be the result of a long period of low policy rates. However, after an increase in policy rates, interest rates for deposits would on average be significantly lower in more concentrated markets (columns 3 and 6). These results are in line with the structure-conduct-performance paradigm where imperfect competition on average implies higher loan and lower deposit rates and are in line with previous analyses on the U.S. and Europe (Hannan and Berger, 1991; Maudos and De Guevara, 2004).[33] Because we do not control for borrower characteristics, our results for loans to non-banks do not rule out relationship lending as formulated by Rajan (1992) and Petersen and Rajan (1995). Accordingly, only for young firms

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[33]Note that there is also work pointing at opposite results for interest margins in the EU (Maudos and De Guevara, 2004) and corporate loan pricing in Germany (Fungáčová et al., 2017).

Table 2.5.2: Interest rates levels and market concentration

Scenario	(1) ir_{loans} constant	(2) $\mathrm{ir}_{bankloans}$ constant	(3) $\mathrm{ir}_{deposits}$ constant	(4) ir_{loans} shock	(5) $\mathrm{ir}_{bankloans}$ shock	(6) $\mathrm{ir}_{deposits}$ shock
HHI_{loans}	0.55**			0.41**		
	(0.22)			(0.21)		
$\mathrm{HHI}_{bankloans}$		-0.055			-0.047	
		(0.063)			(0.075)	
$\mathrm{HHI}_{deposits}$			0.0079			-0.25***
			(0.0094)			(0.079)
funding	-0.28	-0.25*	-0.032	-0.24	-0.12	0.27**
	(0.27)	(0.13)	(0.020)	(0.23)	(0.18)	(0.13)
excess cap.	2.34*	0.060	-0.10	3.21**	0.080	-1.29***
	(1.42)	(0.22)	(0.073)	(1.31)	(0.35)	(0.38)
liquidity	0.064	-0.0001***	-0.000	-0.033	-0.000	-0.0001*
	(0.56)	(0.0000)	(0.000)	(0.54)	(0.0000)	(0.00004)
leverage	-0.032***	-0.000	-0.0014	-0.029***	-0.0006	-0.01***
	(0.006)	(0.003)	(0.0009)	(0.0061)	(0.005)	(0.004)
Constant	3.48	0.12	0.051	5.015	1.87	0.88
	(0.21)	(0.14)	(0.023)	(0.18)	(0.20)	(0.15)
N	1466	1433	1478	1466	1433	1478
R^2	0.0591	0.0181	0.0270	0.0569	0.0023	0.0514

Notes: Results from estimating specification (I). The dependent variables are interest rates for noted categories and scenarios in percent, winsorised at the bottom 1st and the top 99th percentile of the distribution. In particular, *Loans* consist of loans to non-financial customers which include all customers (such as households, firms and public entities) except banks. *Bankloans* denote interbank loans. Standard errors clustered at the county level in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Sources: Bundesbank supervisory data & 2017 low-interest-rate survey (BaFin/Bundesbank).

with the lowest quality, credit is expected to be comparably cheaper in more concentrated markets as a result of relationship lending. Provided that borrower firms in our sample are e.g. on average rather old than young – or more generally speaking, ongoing relationships as opposed to new ones prevail – higher loan rates in more concentrated markets are in line with that theory. This is because banks in imperfectly competitive markets can back-load interest payments, making loan rates comparatively low only in the beginning of the relationship. The market for interbank loans seems to be unaffected by

local market concentration (columns 2 and 5).

Turning to the additional bank controls, despite low interbank lending rates, the fraction of stable deposit funding (*funding*) is associated with lower loan rates, as are lower shares of costly equity financing (*leverage*). As expected, capital buffers (*excess capital*) translate into on average higher loan and lower deposit rates. Effects of bank controls are furthermore largely consistent across both scenarios. This can serve as an additional plausibility check for reported rates in response to the hypothetical monetary policy shock.

2.5.3 Pass-through of monetary policy shocks

In our main analyses, we examine the transmission of monetary policy. Because the additional control variables ($\sum_{m=2}^{M} X_{jm}$) should affect interest rate levels in both scenarios in a similar way, their effects should cancel out in the pass-through regression.

We examine whether banks' pass-through is on average more or less complete the higher their individually exerted market power or the more concentrated the market environment is by estimating:

$$ PT\,ir_j^p = \alpha_0 + \alpha_1 LI_j + \epsilon_j \qquad (II) $$

$$ PT\,ir_j^p = \alpha_0 + \alpha_1 HHI_d^p + \epsilon_j \qquad (III) $$

where $PT\,ir_j^p$ denotes monetary policy transmission for bank j, calculated as $(ir_{j,shock}^p - ir_{j,const}^p)/200\,BP$ for product category p. Coefficients are to be interpreted in percentage points (henceforth *p.p.*), where in both regressions α_1 is our coefficient of interest, telling us the direction of Equation (2.4). In (II), the coefficient gives by how many p.p. the pass-through changes with a marginal unit-increase in individual pricing power, measured by the Lerner Index, LI_j, in 2016. In (III) we assess the analogous relationship between monetary pol-

icy transmission and market concentration in the respective product market, HHI_d^p, in 2016.

Table 2.5.3 provides estimation results according to specifications (II) and (III) for loans to non-financial customers and for deposits.[34] Columns (1) and (2) consistently show that monetary policy transmission to loan rates significantly falls in market power.

On average, a one-standard-deviation increase in the LI is associated with a lower pass-through to loan rates by 1.06 p.p. or 0.068 standard deviations. Furthermore, after an increase in banks' marginal cost of funds, banks in more concentrated markets ceteris paribus (henceforth *c.p.*) pass a smaller share of the shock on (column (2)): a one-standard-deviation increase in concentration on average leads to a lower pass-through by 1.17 p.p. or 0.075 standard deviations.

After partialling out banks' expectations of credit demand shifts that are orthogonal to the two scenarios, our results corroborate a relatively more incomplete pass-through to loan rates with rising levels of market power. If different bank-level predictions of demand shifts between the baseline and the shock scenario entirely drove our results, we would observe the opposite, namely a larger pass-through with more market power: as discussed above, in the shock scenario credit demand should be expected to contract more at banks with less market power, c.p. making the pass-through relatively larger at more monopolistic banks. Thus, to the extent that banks do make these different demand predictions, our results are likely to be a lower bound for the hampering effect of market power on monetary policy transmission.

Doubts may furthermore arise because according to the instructions, all banks have to replace maturing business with identical new business (static

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[34]Neither bank-level pricing power nor market concentration matter significantly for the pass-through of the monetary policy shock to interbank loan rates (see Table 2.C.2 in Appendix 2.C) and we therefore focus on loan rates for non-financial customers and deposit rates.

Table 2.5.3: Pass-through of monetary policy and market power

	(1) PT ir_{loans}	(2) PT ir_{loans}	(3) PT $ir_{deposits}$	(4) PT $ir_{deposits}$
LI	-9.86**		4.45	
	(4.84)		(6.72)	
HHI$_{loans}$		-5.85***		
		(2.11)		
HHI$_{deposits}$				-13.57***
				(4.33)
Constant	81.91	80.92	29.83	37.63
	(1.79)	(1.01)	(2.53)	(2.56)
N	1427	1466	1438	1478
R^2	0.0047	0.0057	0.0006	0.0177

Notes: Results from estimating specification (II) and (III). The dependent variable is the pass-through of the monetary policy shock to interest rates for noted categories in percent, winsorised at the bottom 1st and the top 99th percentile of the distribution. In particular, *Loans* consist of loans to non-financial customers which include all customers (such as households, firms and public entities) except banks. Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors are robust for columns (1) and (3), and clustered at the county level for columns (2) and (4), respectively. Sources: Bundesbank supervisory data & 2017 low-interest-rate survey (BaFin/Bundesbank).

balance sheet assumption). This inter alia implies that loan quantities are not allowed to adjust, neither to the new market environment nor to the change in prices. Hence, if high-market power banks consistently have higher loan exposures, our results could be driven by these banks factoring in that they would have to hold back on raising rates to keep up their high loan volumes. The positive relationship between exposure and market concentration (HHI) is indeed prevalent in our data (see Table 2.4.1). However, we have shown in Table 2.4.1 that high-LI banks on average have *lower* loan exposures. The fact that both indices still imply the same direction of imperfect competition on the pass-through of the monetary policy shock to loan rates should therefore mitigate this concern.

Results so far indicate that the supply side of credit mainly drives hindered monetary policy transmission in imperfectly competitive banking markets. An analysis of within-bank heterogeneities can potentially provide fur-

ther insights on the underlying mechanism by e.g. helping to understand potential strategic bank behaviour. In particular, distorted competition in the deposit market has been proven to be crucial for monetary policy transmission (Drechsler et al., 2017).[35] The possibility to save expenses on their liability sides may thus enable banks to smooth loan rates for their borrowers. Strong ties between credit institutions and their customers could be the mechanism which keeps depositors attached to their banks. Similarly, relationships could then lead banks to smooth loan rates over the course of the match, insuring borrowers against sudden shocks.

While individual pricing power does not seem to significantly affect the sensitivity of deposit rates to a monetary policy contraction, market concentration plays a substantial role (columns (3) and (4) of Table 2.5.3). On average, a one-standard-deviation increase in concentration leads to a lower pass-through by 0.13 p.p or 0.133 standard deviations.[36]

To get a deeper understanding of the heterogeneities and magnitudes of the coefficients, we calculate ceteris paribus effects from specifications (II) and (III) at two different percentiles of the LI and HHI distributions, respectively. That is, $\alpha_1 * LI_{10th}$ gives the c.p. effect of individual pricing power on the pass-through for a bank with a LI at the 10th percentile of its distribution in 2016, $\alpha_1 * LI_{90th}$ analogously the effect of a bank with a price setting power at the 90th percentile. The logic carries through for the HHI. In response to a contractionary monetary policy shock, a bank with a low price setting power c.p. reduces monetary policy transmission to loan rates by 2.4 p.p. while at a bank with a high LI this amounts to a reduction in the pass-through by 4.8 p.p., re-

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[35]See also Sopp (2018) who builds a model where banks strategically use deposit rates to smooth overall profits. In that set-up, deposit rates depend on a bank's return on its loan portfolio.

[36]In Table 2.C.3 in Appendix 2.C, we include the additional bank controls into the regressions. Largely confirming our hypothesis, these seem to have no interaction effect with monetary policy on our pass-through variables (in particular for loan rates) and the effect of imperfect competition remains robust throughout.

spectively compared to a bank operating under perfect competition (first row of Table 2.5.4). If a market is moderately concentrated, banks on average withhold 2.7 and 1.2 p.p. in the pass-through to deposit rates and loan rates, respectively, and this amounts to 9.6 and 4.2 p.p. in highly concentrated markets (second row of Table 2.5.4). Given an average pass-through to deposit rates of 30 percent, the effect on this market seems to be of substantial magnitude.

Table 2.5.4: Ceteris paribus effects for different percentiles of LI and HHI

(1)		(2)	
PT ir$_{loans}$		PT ir$_{deposits}$	
LI10	LI90	LI10	LI90
- 2.4	- 4.8	-	-
HHI10$_{loans}$	HHI90$_{loans}$	HHI10$_{deposits}$	HHI90$_{deposits}$
- 1.2	- 4.2	- 2.7	- 9.6

Notes: Results from estimating specifications (II) and (III). LI10 is the value of the LI at the 10th percentile of the sample distribution (in 2016), HHI10$_{loans}$ is the value of the HHI in the loan market at the 10th percentile, that logic carries through for the rest of the table. Source: Bundesbank supervisory data & 2017 low-interest-rate survey (BaFin/Bundesbank).

Presented results indicate that the pass-through of monetary policy is hampered by imperfect competition. Our estimations are in line with previous work on actual interest rate responses to monetary policy shocks for both Europe (Van Leuvensteijn et al., 2013; Gropp et al., 2014) and Germany (Schlueter et al., 2016).

We can provide suggestions for the driving mechanism. The reason could lie in the shape of banks' marginal cost curves (see section 2.2). It, however, seems more likely that strategic bank behaviour motivates banks. That is, banks operating in more imperfectly competitive markets withhold part of the increase in interest rates from those who deposit savings with them and in turn spare their borrowers a part of the general rise in funding costs. Sticky relationships could promote that objective. Because interest payments of new matches can be back-loaded in concentrated markets (Rajan, 1992), banks can more eas-

ily form long-term relationships with their borrowers the more concentrated the market is. While the two measures of imperfect competition seem to be related in opposite ways to several county and bank characteristics, both indicate that banks with higher market power have higher profits (in absolute terms and measured as return on assets). In addition, our results are largely consistent across the two measures of imperfect competition.[37] Because banks with market power on average charge higher than competitive loan rates and subsequently do not pass positive interest rate shocks on to depositors, they are likely to have the ability to absorb potential downside shocks to profits and thus insure their borrowers against such movements in the policy rate. In doing so, they also smooth their profits. Together with the *housebank* (or regional) principle in Germany, this indicates that strong ties between credit institutions and their customers could be the driving mechanism for our results.

2.6 Robustness of results

In the following section, we address potential concerns regarding strategically biased survey responses and our measure of market concentration.

2.6.1 Biased survey responses

Despite extensive data quality checks, we need to mitigate concerns that a bias due to strategic incentives correlated with market power drives our results. In particular, the positive (but insignificant) effect of the LI for the pass-through to deposit rates in combination with its significant negative effect for loan rates (columns 1 and 3 of Table 2.5.3) may give rise to this hypothesis. Certain banks (i.e. those with higher LI's) could for some reason be less concerned about

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[37]Despite the effect of individual market power (*LI*) being insignificant for the pass-through to deposit rates, the positive sign of the coefficient may give rise to the concern that differential strategic responses drive our results. We address this concern in the following robustness analyses.

the stress effect and therefore have reported a lower (higher), and thus more accurate pass-through to loan (deposit) rates.

Banks are likely to seek to avoid consequences from the stress test results which might curtail their leeway in conducting (lending) business, the most obvious example being high excess capital requirements. From the stress test, supervisors derive capital guidance which is higher the larger the resulting *stress effect* (i.e. the difference between a bank's interest incomes in the two scenarios). Banks with already larger excess capital in 2016 are likely to be less worried about the stress effect and thus might strategically report a smaller and more accurate pass-through to loan rates and a relatively more complete and truthful pass-through to deposit rates. If furthermore excess capital is systematically positively correlated with market power, our results in Table 2.5.3 could reflect these differential incentives.

Table 2.6.1: Correlations between capital buffers and market power

	LI	HHI_{loans}	$HHI_{bank\,loans}$	$HHI_{deposits}$
Capital buffer	0.10	0.03	0.03	0.06

Notes: Correlation between Lerner indices, market concentration (as measured by the Herfindahl index) and capital buffers. Capital buffer is defined as excess capital (i.e. surplus of T1 capital) over total assets. Source: Bundesbank supervisory data. Own calculations.

Indeed, banks with more pricing power tend to have slightly higher capital buffers while capital buffers and market concentration are barely correlated (see Table 2.6.1). Note that higher capital buffers can indicate lower bank risk and therefore this is also in line with our above narrative of a negative relationship between risk and market power.

Results in Table 2.6.2, however, indicate that the pass-through to loan rates does not vary significantly with excess capital buffers of banks. Moreover, the direction of the effect is opposite to what strategic behaviour would lead us to expect: in line with work on realised interest rates, the pass-through to loan rates, if anything, rises with costly excess capital (De Graeve et al., 2007). Sim-

Table 2.6.2: Pass-through to rates for loans and deposits in relation to capital buffers

	(1) PT ir$_{loans}$	(2) PT ir$_{bank\,loans}$	(3) PT ir$_{deposits}$
Capital buffer	23.84	0.43	-47.84***
	(17.50)	(15.65)	(15.87)
Constant	77.11	90.21	34.52
	(1.06)	(0.99)	(0.98)
N	1,466	1,433	1,478
R^2	0.0017	0.0000	0.0099

Notes: Results from regressing the different pass-through variables on excess capital. The dependent variable is the pass-through of the monetary policy shock to interest rates for noted categories in percent, winsorised at the bottom 1st and the top 99th percentile of the distribution. Capital buffer is defined as excess capital over risk-weighted assets. Robust standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Sources: Bundesbank supervisory data & 2017 low-interest-rate survey (BaFin/Bundesbank).

ilarly, banks tend to withhold increases in deposit rates from their customers the higher their ex-ante capital buffers are, which again falsifies a strategic bias. This should rule out that our results could be driven by differential strategic incentives to avoid additional capital guidance.[38]

2.6.2 Market concentration

Analyses regarding market concentration have hinged on the *regional principle*, implying that banks mainly conduct business in the county in which they have their head quarter. While this is likely to hold for loans provided by small and medium-sized banks, it is problematic for larger banks. To mitigate this concern, we run two types of robustness tests in this section.

We first exclude all SI's which operate nationwide and calculate market concentration solely based on the sample of small and medium sized banks which are predominantly bound to operate locally.[39] This exercise leaves our

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[38]Note also that the effect of imperfect competition remains significant after we control for ex-ante capital buffers, see Table 2.C.3 in Appendix 2.C.

[39]The new HHI's are highly correlated to the old ones (with correlation coefficients above 0.95). Still, for 890 (153) and 843 (139) banks (counties) the HHI$_{loans}$ and the HHI$_{deposits}$ changes, respectively.

main results qualitatively and quantitatively unchanged, both with and without additional controls, and monetary policy transmission remains significantly hampered in more concentrated markets (Table 2.6.3).

Table 2.6.3: Pass-through and market concentration based on small and medium sized banks only

	(1) PT ir_{loans}	(2) PT ir_{loans}	(3) PT $ir_{deposits}$	(4) PT $ir_{deposits}$
HHI_{loans}	-5.38***	-5.90***		
	(2.03)	(2.11)		
$HHI_{deposits}$			-14.10***	-13.48**
			(5.31)	(5.41)
funding		1.80		15.41**
		(4.65)		(6.05)
excess capital		43.37**		-57.61***
		(18.39)		(17.54)
liquidity		-2.73		-0.0045**
		(2.17)		(0.0021)
leverage		0.14		-0.46***
		(0.137)		(0.15)
Constant	80.76	76.14	37.84	41.20
	(0.98)	(4.27)	(2.94)	(6.75)
N	1466	1466	1478	1478
R^2	0.0047	0.0092	0.0200	0.0534

Notes: Results from estimating specification (III). Market concentration is calculated based on all small and medium sized banks only, i.e. large banks that operate nationwide are excluded. The dependent variable is the pass-through of the monetary policy shock to noted categories in percent, winsorised at the bottom 1st and the top 99th percentile of the distribution. In particular, $Loans$ consist of loans to non-financial customers which include all customers (such as households, firms and public entities) except banks. Standard errors clustered at the county level in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Sources: Bundesbank supervisory data & 2017 low-interest-rate survey (BaFin/Bundesbank).

Second, we introduce a different and very simple proxy for the competitive pressure in a bank's surrounding area: we move away from bank data and exploit that cities are usually both more densely populated and characterised by higher bank penetration as well as better access to financial services in a wider sense. For instance, outdoor advertising by online banks are likely to be more present in cities as opposed to more suburban areas. Thus, we pro-

mote that population density and competitive pressure on a bank in an area are positively correlated and include population density (in 2016) instead of the previous competition/concentration measures into $(II)/(III)$. For that purpose, we move to a more granular level and include population density at the municipality-level into our estimation.

Table 2.6.4: Pass-through to interest rates for loans to non-financial customers and deposits

	(1)	(2)
	PT ir_{loans}	PT $\text{ir}_{deposits}$
population density	2.33***	3.24*
	(0.38)	(1.81)
Constant	76.71	29.35
	(0.49)	(0.93)
N	1455	1467
R^2	0.0183	0.0217

Notes: Results from estimating (III) with municipality-level population density as measure for imperfect competition. The dependent variable is the pass-through of the monetary policy shock to interest rates for noted categories in percent, winsorised at the bottom 1st and the top 99th percentile of the distribution. In particular, *Loans* consist of loans to non-financial customers which include all customers (such as households, firms and public entities) except banks. Population density is municipality-level population density in 1000's of population per square kilometre. Standard errors clustered at the municipality level in parenthesis, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Sources: 2017 low-interest-rate survey (BaFin/Bundesbank) & Statistisches Bundesamt.

Table 2.6.4 confirms our results: more competitive pressure measured by a more dense population increases monetary policy transmission to both loan and deposit rates.[40] Higher density by 1,000 people per square kilometre in a municipality c.p. means a higher pass-through by 2.3 p.p. to loan rates and 3.2 p.p. to deposit rates. Coefficients are highly significant for loan rates but only marginally significant for deposit rates.[41] The latter could mirror that the regional principle does not exist for the deposit market.[42]

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[40]We also test the dependence of interest rate levels on population density and find that loan rates in both scenarios are lower in more competitive markets as measured by higher population density (Table 2.C.1).

[41]When we also include the additional bank controls, results are unchanged (Table 2.C.4 in Appendix 2.C).

[42]Just as the LI and the HHI are no determinants of the pass-through to interbank loan rates, population density has barely any influence (columns 5 and 6 of Table 2.C.2 in Appendix 2.C).

2.7 Conclusion

The 2017 stress test covering all small and medium sized banks in Germany provides us with an exceptional data set on the pass-through of monetary policy to various retail rates. Because the data delivers two data points per bank for the same point in time, rates for after a hypothetical policy contraction and in the absence thereof, we can to a large extent control for potential demand shifts. We show that banks in imperfectly competitive markets charge higher loan rates but pass on smaller fractions of the monetary policy tightening on to their borrowers. At the same time, these banks raise deposit rates to a relatively smaller extent. This strategic behaviour, coupled with higher profits of market-power banks and the housebank principle of the German credit market, leads us to conclude that banks in imperfectly competitive markets have the capacity to build long-term relationships. Consequently, they seem to insure their borrowers against adverse shocks – at the expense of their depositors.

Policy makers know that some degree of market power ensures financial stability. We highlight that this, however, comes at the cost of monetary policy being less effective. Because in boom phases which tend to precede financial and economic turmoil, market power seems to generally rise, monetary policy could be least effective when needed most.

Appendix

2.A   Derivations for conceptual framework

2.A.1   Proof of Equation (2.2)

For convenience, we repeat Equation (2.2):

$$\mathrm{d}p = \frac{\partial p}{\partial q}\frac{\partial q}{\partial x}\mathrm{d}x + \left(\frac{\partial p}{\partial i} + \frac{\partial p}{\partial q}\frac{\partial q}{\partial i}\right)\mathrm{d}i$$

Consider the following functional forms for the curves in a standard IO model with monopolistic competition, using common textbook notation:

Inverse demand is $p(q) = i - bq$ with $i, b > 0$, marginal revenues are $mr = i - 2bq$ and marginal costs are $mc = zq^2 - yq + x$ with $x, y, z > 0$ and $i > x$. Note, in a simpler version where marginal costs are linear, $z = 0$, $x > 0$, $y < 0$ or where marginal costs are constant, $z = 0$, $x > 0$, $y = 0$. Three parameters are of particular interest here. First, the higher b, the steeper inverse demand and the more market power a monopolist can exert by applying a mark-up on marginal costs when setting the optimal price. The slope of demand is the partial derivative of the demand function with respect to (henceforth w.r.t.) q:

$$\frac{\partial p}{\partial q} = -b. \tag{2.10}$$

Second, the value of i determines the intercept of the inverse demand curve with $q = 0$. An exogenous demand shock thus changes i and can be interpreted

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as the maximum price a (marginal) customer would be willing to pay (in the limit when $q \to 0$). The partial derivative of the demand function w.r.t. i is:

$$\frac{\partial p}{\partial i} = 1. \tag{2.11}$$

Third, x is the intercept of the marginal cost curve and therefore a shock to marginal costs changes x.

Profit maximisation leads to the equilibrium condition of $mr = mc$. As a result, the equilibrium quantity, q^*, and price, p^*, are:

$$q^* = \frac{y - 2b + \sqrt{(2b-y)^2 + 4z(i-x)}}{2z} > 0 \tag{2.12}$$

$$p^* = i - \frac{b(y - 2b + \sqrt{(2b-y)^2 + 4z(i-x)})}{2z} > 0 \tag{2.13}$$

When $z = 0$, $y < 0$

$$p^* = i - \frac{b(i-x)}{2b+y} > 0$$

and $p^* = i - \frac{i-x}{2}$ when marginal costs are constant. The corresponding equilibrium quantities are

$$q^* = \frac{i-x}{2b+y}$$

and $q^* = \frac{i-x}{2b}$, respectively.

The pass-trough of a cost shock to the price is derived as the change in the price in response to a parallel shift in the curve of marginal costs, i.e. a change in x. The total derivative of (2.13) w.r.t. x gives:

$$\frac{\mathrm{d}p^*}{\mathrm{d}x} = \frac{b}{\sqrt{(2b+y)^2 + 4z(i-x)}} > 0 \tag{2.14}$$

An increase in marginal costs results in an increase in the price. With $z = 0$, $y < 0$

$$\frac{\mathrm{d}p^*}{\mathrm{d}x} = \frac{b}{2b+y} > 0$$

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Note that the change in the equilibrium price depends on the slope of demand and hence on the level of market power. If marginal costs are constant, $y = 0$ and the pass-through simplifies to a constant, $\frac{1}{2}$.

The corresponding change in the equilibrium quantity from differentiating Equation (2.12) is:

$$\frac{\partial q}{\partial x} = -\frac{1}{\sqrt{(2b - y)^2 + 4z(i - x)}} < 0 \qquad (2.15)$$

Following a cost shock, the equilibrium quantity shrinks. Note, this is identical to the total derivative $\frac{dq^*}{di}$ since q is a (direct) function of i, x. With $z = 0$, $y < 0$

$$\frac{\partial q}{\partial x} = -\frac{1}{2b + y} < 0$$

In the case of constant marginal costs this simplifies to $-\frac{1}{2b}$.

Equations (2.10), (2.11), (2.15) are the components of Equation (2.2) when marginal costs are convex. The following derivation shows that $\frac{dp^*}{dx}$ is equivalent to the first part in Equation (2.2) which is repeated above:

$$\frac{\partial p}{\partial q}\frac{\partial q}{\partial x} = -b*\left(-\frac{1}{\sqrt{(2b - y)^2 + 4z(i - x)}}\right) = \frac{b}{\sqrt{(2b - y)^2 + 4z(i - x)}} = \frac{dp^*}{dx} \quad q.e.d.$$
$$(2.16)$$

It is easy to see that this also holds true for the cases where marginal costs are linear or constant.

The price change in response to a change in demand is derived by totally differentiating (2.13) w.r.t. i:

$$\frac{dp^*}{di} = 1 - \frac{b}{\sqrt{(2b - y)^2 + 4z(i - x)}}$$

A demand shock has a direct effect on the price which goes into the same direction of the shock, $\frac{\partial p}{\partial i} = 1$, and an indirect effect, $\frac{\partial p}{\partial q}\frac{\partial q}{\partial i}$, which works in

the opposite direction of the direct effect: in the case of a negative demand shock, the direct effect pushes the equilibrium price down. However, the more market power the monopolist has, i.e. the relatively less elastic demand (or the steeper demand), the smaller the price reduction towards the new equilibrium. When $z = 0$, $y < 0$, this is

$$\frac{\mathrm{d}p^*}{\mathrm{d}i} = 1 - \frac{b}{2b + y}$$

In the case of constant marginal costs this simplifies to $\frac{1}{2}$.

The corresponding change in the equilibrium quantity is:

$$\frac{\partial q}{\partial i} = \frac{\mathrm{d}q^*}{\mathrm{d}i} = \frac{1}{\sqrt{(2b - y)^2 + 4z(i - x)}}$$

When $z = 0$, $y < 0$, this is

$$\frac{\mathrm{d}q^*}{\mathrm{d}i} = \frac{1}{2b + y}$$

In the case of constant marginal costs this simplifies to $1/2b$.

The following derivation shows that $\frac{\mathrm{d}p^*}{\mathrm{d}i}$ is equivalent to the second part in Equation (2.2) which is repeated above:

$$\left(\frac{\partial p}{\partial i} + \frac{\partial p}{\partial q} \frac{\partial q}{\partial i} \right) \mathrm{d}i = 1 - b * \frac{1}{\sqrt{(2b + y)^2 + 4z(i - x)}} = \frac{\mathrm{d}p^*}{\mathrm{d}i} \quad q.e.d. \qquad (2.17)$$

It is easy to see that this also holds true for the cases where marginal costs are linear or constant.

2.A.2 Dependence of the pass-through on market power

The following Equation derives how the pass-through depends on the slope of demand which measures market power in this framework:

$$\frac{\mathrm{d}(\mathrm{d}p^*/\mathrm{d}x)}{\mathrm{d}b} = \frac{1}{\sqrt{(2b - y)^2 + 4z(i - x)}} - \frac{b(8b - 4y)}{2[(2b - y)^2 + 4z(i - x)]^{\frac{3}{2}}}$$

$$= \frac{y^2 - 2by + 4iz - 4xz}{[(2b + y)^2 + 4z(i - x)]^{\frac{3}{2}}} \tag{2.18}$$

The pass-through is smaller for banks with more market power, i.e. $\frac{\mathrm{d}(\mathrm{d}p/\mathrm{d}x)}{\mathrm{d}b} < 0$

if

$$b > \frac{y}{2} + \frac{2z(i - x)}{y}$$

Intuitively, when demand is "steep enough", the pass-through can fall in market power. To be precise, as long as demand does not intersect marginal costs in their increasing part of the curve, the pass-through falls in b.

Otherwise, the pass-through is larger the steeper demand, $\frac{\mathrm{d}(\mathrm{d}p/\mathrm{d}x)}{\mathrm{d}b} > 0$. Note that if marginal costs are linear($z = 0$, $y < 0$), the pass-through always increases in b:

$$\frac{\mathrm{d}(\mathrm{d}p^*/\mathrm{d}x)}{\mathrm{d}b} = \frac{y}{(2b - y)^2} > 0$$

When marginal costs are constant, the pass-through does not depend on the slope of demand. Note that in this model, a monotonic dependence of the Lerner Index on b is always given for the linear version of marginal cost, while it is a possible and plausible case in the quadratic model.

2.B Theoretical background for marginal costs

In economic theory, banks fulfil an intermediary role, hence a bank's financial assets, i.e. loans (to customers and banks) as well as securities are considered as its output. As inputs it is assumed that banks use labour, capital and loanable funds.

Following Clark (1984) we assume a (homogenous) Cobb-Douglas production function of the following form:

$$Y_i = A K_j^{\alpha_1} L_j^{\alpha_2} F_j^{\alpha_3}$$

where Y_j is bank $j's$ total output, K_j represents capital inputs, L_j labour inputs and F_j loanable funds. While the choice of the functional form may seem arbitrary, Clark (1984) discussed that the assumption of a Cobb-Douglas production function does not appear to be inappropriate.

The cost function of bank j is given by

$$TOC_j = p_j K_j + w_i L_j + r_i F_j$$

where p_j denotes bank j's price of capital, w_j the price of labour, and r_j the price of loanable funds. Total costs as a function of inputs and outputs can be derived from minimising total costs with respect to the inputs, while having the constraint of the production function:

$min\ TOC_j$ subject to $Y_j = A K_j^{\alpha_1} L_j^{\alpha_2} F_j^{\alpha_3}$

Using the method of Lagrange multipliers, the first order conditions w.r.t. labour, capital and funds, and the Lagrange multiplier λ are:

$$(K_j): p_j - \lambda A \alpha_1 K_j^{\alpha_1 - 1} L_j^{\alpha_2} F_j^{\alpha_3} \equiv 0 \tag{2.19}$$

$$(N_j): w_j - \lambda A \alpha_2 K_j^{\alpha_1} L_j^{\alpha_2 - 1} F_j^{\alpha_3} \equiv 0 \tag{2.20}$$

$$(F_j) : r_j - \lambda A \alpha_3 K_j^{\alpha_1} L_j^{\alpha_2} F_j^{\alpha_3 - 1} \equiv 0 \tag{2.21}$$

$$(\lambda) : Y_j - A K_j^{\alpha_1} L_j^{\alpha_2} F_j^{\alpha_3} \equiv 0 \tag{2.22}$$

From (2.19) and (2.20) we obtain

$$K_j = \frac{w_j}{p_j} \frac{\alpha_1}{\alpha_2} L_j$$

and from (2.20) and (2.21)

$$F_j = \frac{w_j}{r_j} \frac{\alpha_3}{\alpha_2} L_j \,.$$

Plugging these expressions into (2.22) and solving for L_j gives

$$L_j = \left[\frac{Y_j}{A} \left(\frac{p_j}{w_j} \frac{\alpha_2}{\alpha_1} \right)^{\alpha_1} \left(\frac{r_j}{w_j} \frac{\alpha_2}{\alpha_3} \right)^{\alpha_3} \right]^{\frac{1}{\alpha_1 + \alpha_2 + \alpha_3}}$$

The cost function can furthermore be written as

$$TOC_j = p_j \frac{w_j}{p_i} \frac{\alpha_1}{\alpha_2} L + w_j L_j + r_j \frac{w_j}{r_j} \frac{\alpha_3}{\alpha_2} L_j \tag{2.23}$$

After plugging in the above expression for L_j, total costs can be written as a function of output Y_j, and input prices, w_j, r_j, p_j

$$TOC(Y_j, w_j, r_j, p_j) = X A^{-\frac{1}{X}} (\alpha_1^{\frac{\alpha_1}{X}} \alpha_2^{\frac{\alpha_2}{X}} \alpha_3^{\frac{\alpha_3}{X}})^{-1} Y_j^{\frac{1}{X}} p_j^{\frac{\alpha_1}{X}} w^{\frac{\alpha_2}{X}} r_j^{\frac{\alpha_3}{X}} \tag{2.24}$$

where $X = \alpha_1 + \alpha_2 + \alpha_3$. Note, $X A^{-\frac{1}{X}} (\alpha_1^{\frac{\alpha_1}{X}} \alpha_2^{\frac{\alpha_2}{X}} \alpha_3^{\frac{\alpha_3}{X}})^{-1}$ is not bank specific. Taking logs gives

$$\log(TOC_j) = X A^{-\frac{1}{X}} (\alpha_1^{\frac{\alpha_1}{X}} \alpha_2^{\frac{\alpha_2}{X}} \alpha_3^{\frac{\alpha_3}{X}})^{-1} + \frac{1}{X} \log(Y_j) + \frac{\alpha_1}{X} \log(p_j) + \frac{\alpha_2}{X} \log(w_j) + \frac{\alpha_3}{X} \log(r_j)$$
$$\tag{2.25}$$

That translog cost function can be estimated from the data and marginal costs derived from it as the first derivative of costs with respect to total output.

Table 2.B.1: Summary statistics

variable	N	mean	sd
Total costs, TOC	54228	1.12e+08	9.48e+08
Total revenues, TOR	54228	1.21e+08	9.35e+08
Total output, Y	54228	2.34e+09	1.93e+10
Interbank loans	54228	5.87e+08	6.64e+09
Loans to non-financial customers	54228	1.26e+09	9.50e+09
Securities	54228	4.90e+08	4.27e+09
Cost of fixed labour	52540	62258.81	168385.9
Cost of borrowed funds	54170	.286	57.864
Cost of fixed assets	54228	.243	13.328
Marginal costs, MC	52525	.048	.058
Lerner Index, LI	51565	.301	.092

Notes: Summary statistics over the full time period 1994-2016. Source: Bundes-bank supervisory data. Own calculations.

Figure 2.B.1: Evolution of marginal costs and average revenues over time
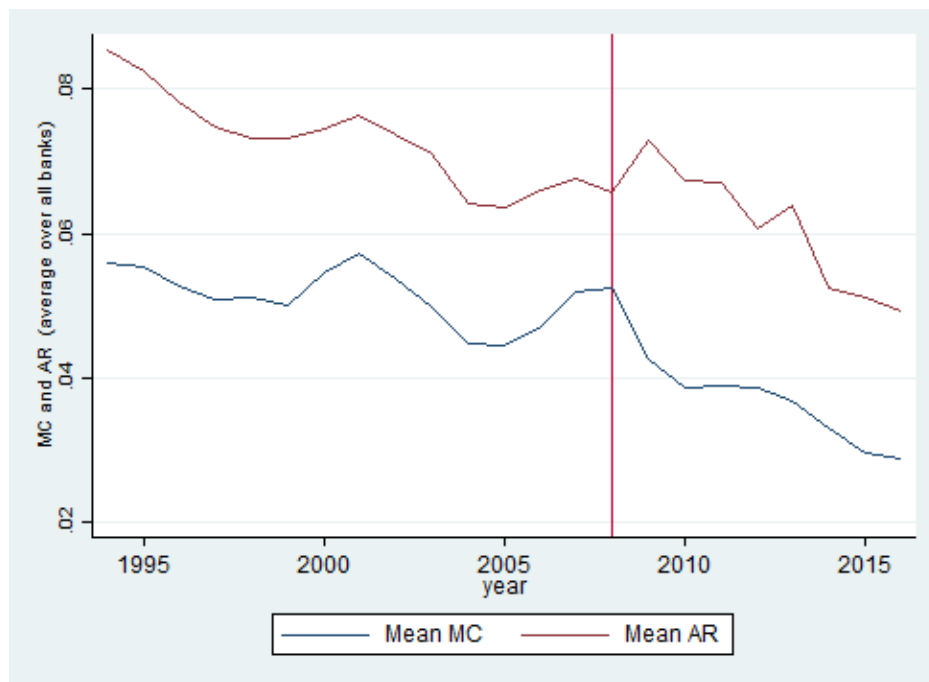
Note: Unweighted mean of marginal costs and average revenues of all German banks over time. Vertical red line in (i.e. at the end of) 2008.

Figure 2.B.2: Evolution of average concentration over time
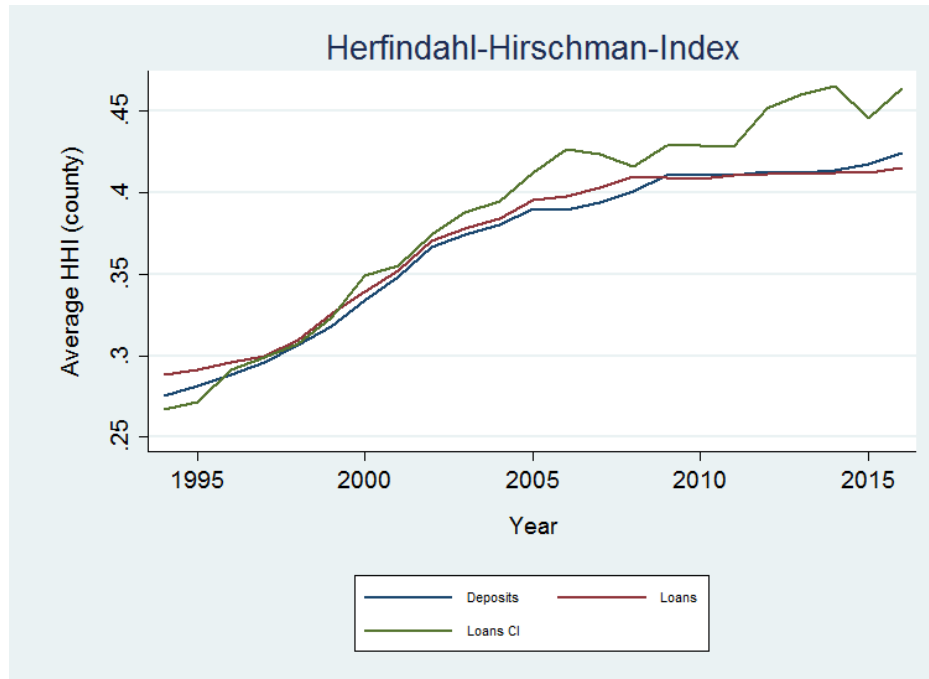
Note: The figure shows the unweighted mean of county-level concentration of all German banks over time in the deposit ("Deposits"), loan ("Loans") and interbank loan ("Loans CI") market, respectively. County reforms are taken into account.

2.C Tables

Table 2.C.1: Interest rate levels and market concentration

	(1) ir_{loans} constant	(2) $\mathrm{ir}_{bank\,loans}$ constant	(3) $\mathrm{ir}_{deposits}$ constant	(4) ir_{loans} shock	(5) $\mathrm{ir}_{bank\,loans}$ shock	(6) $\mathrm{ir}_{deposits}$ shock
pop. dens.	-0.34***	0.041	-0.0024	-0.29***	0.014	0.071*
	(0.043)	(0.035)	(0.0026)	(0.038)	(0.040)	(0.036)
funding	-0.18	-0.27**	-0.031	-0.16	-0.13	0.24*
	(0.22)	(0.13)	(0.019)	(0.20)	(0.18)	(0.13)
excess cap.	2.75*	-0.057	-0.089	3.52***	0.009	-1.63***
	(1.43)	(0.24)	(0.065)	(1.30)	(0.38)	(0.40)
liquidity	0.21	-0.0002***	-0.000	0.097	-0.000	-0.0001*
	(0.43)	(0.000)	(0.000)	(0.43)	(0.000)	(0.000)
leverage	-0.025***	-0.001	-0.001	-0.023***	-0.001	-0.013***
	(0.006)	(0.003)	(0.0009)	(0.006)	(0.006)	(0.004)
Constant	3.74	0.098	0.054	5.22	1.86	0.79
	(0.17)	(0.11)	(0.025)	(0.19)	(0.18)	(0.12)
N	1455	1422	1467	1455	1422	1467
R^2	0.1478	0.0309	0.0282	0.1259	0.0025	0.0621

Notes: Results from estimating specification (I) with municipality-level population density as only competition/concentration measure. The dependent variables interest rates for noted categories and scenarios in percent, winsorised at the bottom 1st and the top 99th percentile of the distribution. Population density is municipality-level population density in 1000's of population per square kilometre. Standard errors clustered at the municipality level in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Sources: Bundesbank supervisory data & 2017 low-interest-rate survey (BaFin/Bundesbank). Statistisches Bundesamt.

Table 2.C.2: Pass-through to rates for interbank loans

	(1)	(2)	(3)	(4)	(5)	(6)
	PT $ir_{bank\,loans}$					
LI	4.17	3.22				
	(6.40)	(6.29)				
$HHI_{bankloans}$			0.80	0.38		
			(2.44)	(2.48)		
popul. dens.					-1.098*	-1.14*
					(0.59)	(0.63)
funding		3.92		6.68		7.013
		(4.89)		(4.49)		(4.53)
excess capital		2.46		-0.12		1.80
		(18.95)		(15.84)		(16.03)
liquidity		0.004*		0.004**		0.0052**
		(0.0021)		(0.0022)		(0.0023)
leverage		0.004		-0.049		-0.033
		(0.17)		(0.17)		(0.18)
Constant	88.84	87.09	89.86	87.67	91.05	88.14
	(2.42)	(5.33)	(1.35)	(4.35)	(0.63)	(4.31)
N	1398	1398	1433	1433	1422	1422
R^2	0.0005	0.0015	0.0001	0.0027	0.0024	0.0054

Notes: Results from estimating specifications (II) and (III). The dependent variable is the pass-through of the monetary policy shock to interest rates for interbank loans in percent, winsorised at the bottom 1st and the top 99th percentile of the distribution. Standard errors in parentheses, $*$ $p < 0.10$, $**$ $p < 0.05$, $***$ $p < 0.01$. Standard errors are robust for column (1) and (3), clustered at the county level for column (2) and (4), and clustered at the municipality level for column (5) and (6). Sources: Bundesbank supervisory data & 2017 low-interest-rate survey (BaFin/Bundesbank). Statistisches Bundesamt.

Table 2.C.3: Pass-through for loans to non-financials, and to deposits

	(1) PT ir$_{loans}$	(2) PT ir$_{loans}$	(3) PT ir$_{deposits}$	(4) PT ir$_{deposits}$
LI	-9.251*		4.703	
	(5.12)		(6.69)	
HHI$_{loans}$		-6.48***		
		(2.11)		
HHI$_{deposits}$				-12.85***
				(4.26)
funding	1.638	2.118	14.64**	15.39**
	(3.98)	(4.54)	(6.20)	(6.20)
excess capital	30.16	43.59**	-72.18***	-57.94***
	(24.24)	(18.26)	(16.81)	(17.64)
liquidity	-5.281	-3.102	-0.002	-0.004*
	(4.77)	(2.14)	(0.0019)	(0.0020)
leverage	0.167	0.142	-0.467***	-0.464***
	(0.12)	(0.14)	(0.14)	(0.15)
Constant	77.84	76.21	34.59	41.03
	(4.11)	(4.37)	(5.25)	(6.55)
N	1427	1466	1438	1478
R^2	0.0100	0.0105	0.0393	0.0509

Notes: Results from estimating specification (II) and (III). The dependent variable is the pass-through of the monetary policy shock to interest rates for noted categories in percent, winsorised at the bottom 1st and the top 99th percentile of the distribution. Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors are robust for columns (1), (3) and (5), and clustered at the county level for columns (2), (4) and (6). Sources: Bundesbank supervisory data & 2017 low-interest-rate survey (BaFin/Bundesbank).

Table 2.C.4: Pass-through to rates for loans to non-financial customers and deposits

	(1) PT ir$_{loans}$	(2) PT ir$_{deposits}$
population density	2.399***	3.692*
	(0.44)	(1.91)
funding	0.962	13.85**
	(4.13)	(5.88)
excess capital	39.45**	-75.85***
	(19.18)	(18.51)
liquidity	-3.941*	-0.00520**
	(2.14)	(0.0026)
leverage	0.0752	-0.591***
	(0.13)	(0.17)
Constant	73.81	36.61
	(3.94)	(4.93)
N	1455	1467
R^2	0.0229	0.0636

Notes: Results from estimating (III) with municipality-level population density as only competition/concentration measure. The dependent variable is the pass-through of the monetary policy shock to interest rates for credit to non-financial customers in percent, winsorised at the bottom 1st and the top 99th percentile of the distribution. Population density is municipality-level population density in 1000's of population per square kilometre. Standard errors clustered at the municipality level in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Sources: Bundesbank supervisory data & 2017 low-interest-rate survey (BaFin/Bundesbank). Statistisches Bundesamt.

Chapter 3

A Model of Interactions between Labour and Credit Markets

3.1 Introduction

In this chapter, I introduce borrowing into an otherwise standard Real Business Cycle (RBC) model. Usually, firms need to pay inputs before they are able to turn output from production into revenue. The result is a time mismatch between cash-inflow and outflow and it is therefore realistic to assume that firms require external funds to smooth these funding gaps. In addition, there typically exists asymmetric information between borrower and lender, for instance regarding the borrower's productivity. Such frictions raise borrowing costs above the risk-free interest rate and can affect responses of real variables to aggregate shocks.

The aim of this paper is to highlight real effects which an incorporation of financial frictions in the most *simple* way have. I study an extreme case in which firms always need to borrow (at least part of) their payroll while they only require labour input for production. In doing so, I examine whether a model without capital accumulation of the firm can match the cyclicality of

the external finance premium and the response of real variables to aggregate shocks as observed in the data.

Evidently, the premium on external funds is counter-cyclical (Gomes et al., 2003; Levin et al., 2004). It reflects that in good times, the risk of default should be relatively low while in bad times, the premium rises with a relatively higher probability of default. Furthermore, there seems to be consensus in the empirical literature that the existence of debt amplifies real business cycles. For instance, in the Great Recession, employment dropped to a larger extent when firms were ex-ante more leveraged (Giroud and Mueller, 2017). Similarly, regions experienced a deeper recession when residing households were relatively more indebted before (Mian and Sufi, 2009, 2014).

Most theoretical papers find that financial frictions amplify responses of real variables to productivity and monetary policy shocks (Bernanke et al., 1999; Petrosky-Nadeau, 2014; Chugh, 2013). However, there are also models in which incorporating credit market frictions have a dampening effect on impulse responses (Carlstrom and Fuerst, 1998; Carlstrom et al., 2016; De Fiore et al., 2011). Most of these models either contain capital accumulation of the borrowing firm (Bernanke et al., 1999; Chugh, 2013; Carlstrom and Fuerst, 1998) and/or additional frictions in the labour market (Petrosky-Nadeau, 2014; Chugh, 2013), thus reducing the tractability of interactions between (frictionless) labour markets and borrowing constraints/financial frictions.

The general framework for the financial contract in the presented model follows Bernanke et al. (1999): agency costs arise between a borrower and a lender, leading to a premium on external funds. Similarly, I assume that a firm borrows against its net worth which consists of earnings net of debt repayment, carried over from the previous period. In contrast to Bernanke et al. (1999), I apply the mechanism to labour instead of capital, an assumption that changes the definition of net worth substantially.

I furthermore analyse two situations, one in which borrower and lender observe the aggregate state before forming a contract (*intra*-period contract) and another in which a debt contract has already been negotiated once the aggregate state changes (*inter*-period contract). The timing of the financial contract has been found to be crucial especially for the cyclicality of the premium (Carlstrom and Fuerst, 1998; De Fiore et al., 2011). For the two types of models, I study the effects of an aggregate productivity shock $i)$ on the cyclicality of the premium on external funds and $ii)$ on the response of real variables compared to a frictionless model.

The version I present first, is closely related to Carlstrom and Fuerst (1998) in which firms borrow their input bill in an intraperiod financial contract. My model differs from theirs in various ways. In Carlstrom and Fuerst (1998), firms borrow for both labour and capital and the definition of net worth is based on a firm's capital stock. In the my model, net worth is defined as operating profits (from employing labour) after loan repayment and reimbursement of shareholders, a specification akin to Petrosky-Nadeau (2014) or De Fiore et al. (2011). The household sector in the presented model is furthermore different from Carlstrom and Fuerst (1998) insofar that households are neither the lenders nor rent out capital. Furthermore, Carlstrom and Fuerst (1998) assume that firms are more impatient than households which results in the firm borrowing from the latter. To ensure that firms always need to borrow and can never accumulate enough assets to avoid external funding, I assume that firms need to pay out a fraction of their returns to households at the end of each period (Petrosky-Nadeau et al., 2018). Here, I furthermore diverge from Bernanke et al. (1999) who assume that a fraction of firms dies at the end of each period.

I find that with an intraperiod contract, the external finance premium unrealistically co-moves with the business cycle. The result is akin to Carlstrom

and Fuerst (1998) and has been subject to debates and criticisms in the theoretical literature (Faia and Monacelli, 2007; De Fiore et al., 2011). In line with Carlstrom and Fuerst (1998), the incorporation of financial frictions furthermore dampens the response of real variables to an aggregate technology shock, compared to an RBC model. In contrast to Carlstrom and Fuerst (1998), the response of labour in my model is even negative for the first four quarters and almost imperceptibly positive thereafter. I outline that this is due to the fact that borrowing is too expensive and firms' equity too unresponsive for firms to be able to hire more labour.

I then change the timing of the financial contract to an interperiod contract. The resulting version of the model is similar to De Fiore et al. (2011). However, monetary policy and government spending is absent in my model. This changes households' budget constraint. Most importantly, as my model is in real terms, inflation does not influence the evolution of net worth.

Incorporating aggregate risk into the contract leads to the desired counter-cyclical external finance premium. The rising wage, however, makes labour more costly. At the same time, net worth still reacts sluggishly and small in magnitude. As a result, the rise in labour and output is again muted. I discuss that as long as net worth does not rise sufficiently, amplification of real variables cannot occur.

The paper is structured as follows. In section 3.2, I derive the intraperiod financial contract in a partial equilibrium setting. In section 3.3, I define the firm and household sector, derive aggregate net worth and the market clearing conditions. In section 3.4, I discuss model simulations of the two versions of contracts, i.e. intraperiod and interperiod, and elaborate differences in impulse responses to a technology shock. I conclude in section 3.5.

3.2 The financial contract

The economy is populated by a large number of small firms of mass unity. The production function of firm i which uses labour as the only input factor in period t, N_{it}, is

$$Y_{it} = x_{it} X_t N_{it} \tag{3.1}$$

where Y_{it} denotes output, determined by aggregate productivity, X_t, which is exogenous and follows $log(X_t) = \rho_X log X_{t-1} + \epsilon_X$, with $0 < \rho_X < 1$, $\epsilon_X \sim \mathcal{N}(0, \sigma_X^2)$, and a firm-specific idiosyncratic productivity, x_{it}, which is distributed log-normally: $log(x) \sim \mathcal{N}(-\frac{1}{2}\sigma_{log(x)}^2, \sigma_{log(x)}^2)$, from the continuous probability distribution $F(x)$, with density $f(x)$, and with $E(x) = 1$.

In the beginning of a period firms observe the aggregate state and contact a bank in order to borrow the payroll against their net worth, $A_{i,t-1}$ (which will turn out to be pro-cyclical).[1] In that stage, the wage, W_t, of a worker is taken as given. Since the labour market is perfectly competitive, the wage is identical for all workers across all firms. Each firm has to get a loan, B_{it}, in order to pay the wage bill. All of net worth can be used to pay wages and the remaining gap in internal finances is filled externally:

$$B_{it} + A_{i,t-1} = W_t N_{it} \tag{3.2}$$

Following Bernanke et al. (1999), and as standard in the literature (e.g. in Carlstrom and Fuerst (1998) and De Fiore et al. (2011)), I assume there is free entry into the lending market and that the credit market is perfectly competitive. Each lender holds a portfolio of loan contracts. The idiosyncratic component of a firm's productivity is unknown to both a firm and its lender when a credit contract is written. Furthermore, the realisation of it is private infor-

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[1]I define the timing of a variable as reflecting the timing in which it is decided. For stock variables the timing corresponds to the stock at the end of a period. This coincides with the timing convention of the software *Dynare*, see e.g. Adjemian et al. (2011).

mation to the firm. The optimal contract is risky debt in which liquidation costs occur in the case of default (costly state verification model of Townsend (1979)). Contracts are risky because there is risk of default.

The optimal contract is then (fully) characterised by N_{it} (which determines borrowing), and a threshold value of idiosyncratic productivity, $\bar{x}_{it}$, which separates repayment from default. If $x_{it} > \bar{x}_{it}$, a firm pays back its debt in full gross of interest, an amount that was fixed in the contract, and keeps all the output in excess of the contracted loan repayment.[2] If $x_{it} < \bar{x}_{it}$, a firm defaults and the lender confiscates all the output in which case the firm keeps nothing. In the liquidation process, a bank needs to uncover the realisation of idiosyncratic productivity which comes at a cost. In expectation, it is a fraction $\mu G(\bar{x}_{it})$, defined as $\mu \int_0^{\bar{x}_{it}} x_i f(x_i) dx_i$ (where $0 < \mu < 1$), of total output. Intuitively, a fraction of total output is burned when a bank liquidates a firm. This is in line with De Fiore et al. (2011) whereas Carlstrom and Fuerst (1998) assume that liquidation costs are proportional to input costs for labour and capital. The reservation value of idiosyncratic productivity satisfies:

$$\bar{x}_{it} X_t N_{it} = R_t^l B_{it} \tag{3.3}$$

where R_t^l is the (risky) loan rate which lies above the (risk-free) real interest rate in the economy. The cut-off is such that the firm is just able to repay the loan plus promised interest (RHS), i.e. production (LHS) is just high enough to cover total loan repayment.

The expected income of the *lender* from the contract is

$$(1-\mu)E(x_i|x_i < \bar{x}_{it})Pr(x_i < \bar{x}_{it}) X_t N_{it} + Pr(x_i \geq \bar{x}_{it}) R_t^l B_{it}$$

where the first part reflects the share of final output in case of default which

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[2]See Carlstrom et al. (2016) for a criticism and alternative model of state-contingent loan repayment.

is total realised output after the deduction of liquidation costs. The second part is the fixed return in case of non-default: when idiosyncratic productivity turns out to be high enough, the firm pays back the loan plus interest (which is equivalent to $\bar{x}_{it} X_t N_{it}$, see Equation (3.3)). Now I will use that $F(\bar{x}_{it}) = Pr[x_i < \bar{x}_{it}]$ is a continuous and once-differentiable cumulative distribution function with $F(0) = 0$, i.e. $F(\bar{x}_{it})$ reflects the probability of default. Recall, f is the probability density function of x_{it} and hence, the expected income of the lender can be written as

$$(1 - \mu) \int_0^{\bar{x}_{it}} x_i f(x_i) dx_i \, X_t N_{it} + (1 - F(\bar{x}_{it})) \, R_t^l B_{it}$$

Using (3.3) shows that the expected return of the lender is a share, $g(\bar{x}_{it})$, of final output $X_t N_{it}$:

$$g(\bar{x}_{it}) X_t N_{it} \equiv \left\{ (1 - \mu) \int_0^{\bar{x}_{it}} x_i f(x_i) dx_i + (1 - F(\bar{x}_{it})) \bar{x}_{it} \right\} X_t N_{it} \qquad (3.4)$$

By substituting out the loan rate, the expected income of the lender can be written as a function of the cut-off. The share of the lender is increasing and concave in the cut-off $\bar{x}_{it}$.[3]

The expected income of the *borrower* (i.e. a firm) is

$$E(x_i | x_i \geq \bar{x}_{it}) Pr(x_i \geq \bar{x}_{it}) X_t N_{it} - \bar{x}_i Pr(x_i \geq \bar{x}_{it}) \, R_t^l B_{it}$$

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[3]The first derivative of the expected share of the lender is

$$g'(\bar{x}_{it}) = 1 - F(\bar{x}_{it}) - \mu \bar{x}_{it} f(\bar{x}_{it}).$$

There exists a value for $\bar{x}_{it}$ where the share of the lender reaches a maximum, $g'(\bar{x}_{it}) = 0$. Bernanke et al. (1999) show that when attention is restricted to non-rationing equilibria the contracted threshold lies below that value. Hence, the share of the lender is always increasing in $\bar{x}_{it}$. The second derivative is negative for a log-normal:

$$g''(\bar{x}_{it}) = -f(\bar{x}_{it}) - \mu(f(\bar{x}_{it}) + \bar{x}_{it} f'(\bar{x}_{it})) < 0.$$

and rewritten analogously

$$\int_{\bar{x}_{it}}^{\infty} x_i f(x_i) dx_i \, X_t N_{it} - (1 - F(\bar{x}_{it})) R_t^l B_{it}$$

This is *all* the output in excess of the contracted threshold value of firm-specific productivity less loan repayment which occurs with the non-default probability of $(1 - F(\bar{x}_{it})) > 0$. As already mentioned, in case of default the firm is left with nothing. The expected return can analogously be rewritten as

$$e(\bar{x}_{it}) X_t N_{it} \equiv \left\{ \int_{\bar{x}_{it}}^{\infty} x_i f(x_i) dx_i - (1 - F(\bar{x}_{it})) \bar{x}_{it} \right\} X_t N_{it} \qquad (3.5)$$

The expected share of a firm deceases in the cut-off, $e'(\bar{x}_{it}) = -(1 - F(\bar{x}_{it})) < 0$. Furthermore, $e''(\bar{x}_{it}) = f(\bar{x}_{it}) > 0$.

The presented specifications highlight that when a firm is leveraged, output is shared between the firm and the lender with the firm getting $e(\bar{x}_{it})$ of final output (in expectations). Note that $g(\bar{x}_{it}) + e(\bar{x}_{it}) = 1 - \mu \int_0^{\bar{x}_{it}} x_i f(x_i) dx_i$. Due to agency costs, on average $\mu \int_0^{\bar{x}_{it}} x_i f(x_i) dx_i$ of total output is burned.

The participation constraint (PPC) of a lender is that its expected return on the contract must equal the opportunity cost of giving out a loan:

$$g(\bar{x}_{it}) X_t N_{it} \geq R_t B_{it} \qquad (3.6)$$

The lending market is characterised by perfect competition, hence the lender's opportunity cost is equal to the interest-paying size of the loan under the contract where the relevant interest rate is the risk-free rate.

When the PPC is binding (which it always is as shown below) the (average) loan rate in excess of the risk-free rate can be derived from (3.6) and (3.3):

$$\frac{R_t^l}{R_t} = \frac{\bar{x}_{it} X_t N_{it}}{B_{it}} \frac{B_{it}}{g(\bar{x}_{it}) X_t N_{it}} = \frac{\bar{x}_{it}}{g(\bar{x}_{it})} \qquad (3.7)$$

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An intuitive dynamic of the model becomes clear when taking the first derivative with respect to $\bar{x}_{it}$: a higher cut-off which is associated with a higher probability of default translates into a higher (average) loan rate[4]. Note, since loan contracts are intra-period, $R_t = 1$.

In a CSV model an important assumption is that all agents are risk-neutral. The financial contract is written after the aggregate shock is observed and resolved before a new shock could hit (intraperiod contract). Hence, unlike in De Fiore et al. (2011), the financial contract is not exposed to aggregate risk. Idiosyncratic risk is diversified away since each lender holds an entire portfolio of loans (Carlstrom and Fuerst, 1998).

The optimal contract is given by the pair $(\bar{x}_{it}, N_{it})$ that solves

$$\max_{N_{it}, \bar{x}_{it}} e(\bar{x}_{it})X_t N_{it} \quad s.t. \quad g(\bar{x}_{it})X_t N_{it} \geq W_t N_{it} - A_{i,t-1}$$

That is, the credit contract maximises the firm's expected return in t subject to the participation constraint of the lender (where W_t is taken as given). Because next period's net worth is just a fixed fraction of today's profits, maximising current profits must also maximise future net worth and hence future profits. The first order conditions (FOC's) are (with ϕ_{it} as Lagrange multiplier denoting the shadow cost of relaxing the PPC)[5]:

$$(N_{it}): \; e(\bar{x}_{it})X_t + \phi_{it}[g(\bar{x}_{it})X_t - W_t] = 0 \tag{3.8}$$

$$(\bar{x}_{it}): \; e'(\bar{x}_{it})X_t N_{it} + \phi_{it}[g'(\bar{x}_{it})X_t N_{it}] = 0 \tag{3.9}$$

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[4] $\frac{\partial R_t^l}{\partial \bar{x}_{it}} > 0$ if $\frac{g(\bar{x}_{it}) - \bar{x}_{it}g'(\bar{x}_{it})}{(g(\bar{x}_{it}))^2} > 0$, hence if $g(\bar{x}_{it}) > \bar{x}_{it}g'(\bar{x}_{it})$. That is, if

$$(1-\mu)\int_0^{\bar{x}_{it}} x_i f(x_i)dx_i + (1 - F(\bar{x}_{it}))\bar{x}_{it} > \bar{x}_{it}(1 - F(\bar{x}_{it}) - \mu\bar{x}_{it}f(\bar{x}_{it}))$$

which holds as can be clearly seen from $(1-\mu)\int_0^{\bar{x}_{it}} x_i f(x_i)dx_i > -\bar{x}_{it}\mu\bar{x}_{it}f(\bar{x}_{it})$.

[5] The maximisation problem and resulting FOC's solely differ from De Fiore et al. (2011) in the notation and in the timing convention. I, however, present more detailed derivations, e.g. the relationship between the loan rate and the threshold of idiosyncratic productivity.

$$(\phi_{it}) : \ g(\bar{x}_{it}) X_t N_{it} - (W_t N_{it} - A_{i,t-1}) = 0 \qquad (3.10)$$

From (3.9) I can write the Lagrange multiplier as a function of the cut-off:

$$\phi(\bar{x}_{it}) = -\frac{e'(\bar{x}_{it})}{g'(\bar{x}_{it})} = -\frac{-(1 - F(\bar{x}_{it}))}{1 - F(\bar{x}_{it}) - \mu \bar{x}_{it} f(\bar{x}_{it})} > 1, \quad with^6 \ \phi'(\bar{x}_{it}) > 0. \quad (3.11)$$

Equations (3.8) and (3.11) deliver a particular relationship between the (aggregate) marginal product of labour, X_t, and the marginal cost of labour, W_t, which only depends on $\bar{x}_{it}$:

$$\frac{X_t}{W_t} = \frac{\phi_{it}}{e(\bar{x}_{it}) + \phi_{it} g(\bar{x}_{it})} \equiv \Phi(\bar{x}_{it}) \qquad (3.12)$$

I call the ratio of average marginal productivity and marginal price of labour Φ_t, the (marginal) return on labour expenditures. Thus, $e(\bar{x}_{it}) X_t N_{it}$ or equivalently $e(\bar{x}_{it}) \Phi_t W_t N_{it}$ is the expected return that accrues to the firm after production, payment of workers and loan repayment.

Furthermore, it follows from (3.11) that for a given $\bar{x}_{it}$ there is a unique ϕ_{it}. Consequently, not only the expected shares of the lender and the borrower but also the shadow cost of relaxing the PPC, ϕ_{it}, depend only on $\bar{x}_{it}$ and therefore Φ is solely a function of $\bar{x}_{it}$.

If monitoring costs are zero ($\mu = 0$), the multiplier on the constraint is one as can be seen from (3.11). When plugging the definitions for $e(\bar{x}_{it})$ and $g(\bar{x}_{it})$

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[6]The first derivative
$$\frac{\partial \phi_{it}}{\partial \bar{x}_{it}} = \frac{e'(\bar{x}_{it}) g''(\bar{x}_{it})) - e''(\bar{x}_{it}) g'(\bar{x}_{it})}{(g'(\bar{x}_{it}))^2}$$
is positive if $e'(\bar{x}_{it}) g''(\bar{x}_{it}) > e''(\bar{x}_{it}) g'(\bar{x}_{it})$. That is, if
$$-[1 - F(\bar{x}_{it})][-f(\bar{x}_{it}) - \mu(f(\bar{x}_{it}) + \bar{x}_{it} f'(\bar{x}_{it}))] > f(\bar{x}_{it})[1 - F(\bar{x}_{it}) - \mu \bar{x}_{it} f(\bar{x}_{it})]$$
which holds because
$$[1 - F(\bar{x}_{it})][\mu(f(\bar{x}_{it}) + \bar{x}_{it} f'(\bar{x}_{it}))] > -f(\bar{x}_{it}) \mu \bar{x}_{it} f(\bar{x}_{it}).$$
Furthermore,
$$\lim_{\bar{x} \to 0} \phi_{it} = 1.$$

into (3.12) it is easy to see that also the return on labour expenditures collapses to one in the absence of liquidation costs. Hence, even though the labour market may be characterised by perfect competition, the information asymmetry in the financial market (which results in monitoring costs) affects the labour market in a sense that marginal return and marginal cost of labour are unequal. Taking into account the production function, the wage will lie below its marginal product.[7] The result is in contrast to a standard RBC model where the two labour market variables are equal. Similarly, in the presented model, to increase labour input, it costs the firm the wage plus the change in agency costs due to higher borrowing per worker (to be precise, per hour worked).

From (3.8) (using (3.12)) the multiplier can alternatively be expressed as:

$$\phi(\bar{x}_{it}) = \frac{e(\bar{x}_{it})\Phi_t}{1 - g(\bar{x}_{it})\Phi_t} \tag{3.13}$$

Equations (3.11) and (3.13) together with (3.12) pin down $\bar{x}_{it}$

$$e(\bar{x}_{it})\frac{X_t}{W_t} = \frac{e'(\bar{x}_{it})}{g'(\bar{x}_{it})}(g(\bar{x}_{it})\frac{X_t}{W_t} - 1) \tag{3.14}$$

Furthermore, a firm's expected gross return on internal funds can be derived from (3.10):

$$e(\bar{x}_{it})\frac{X_t N_{it}}{A_{i,t-1}} = e(\bar{x}_{it})\frac{\Phi_t}{1 - g(\bar{x}_{it})\Phi_t} \tag{3.15}$$

This turns out to be equal to the shadow cost of relaxing the participation constraint, see Equation (3.13). First, since $\phi(\bar{x}_{it}) > 1$, the expected gross return on internal funds exceeds unity and consequently a firm will always invest all its net worth into the contract (Carlstrom and Fuerst, 1998; Faia and Monacelli, 2007). As a result, the PPC is always binding. Second, the firm leverages each unit of net worth into a project of size $\frac{\Phi_t}{1-g(\bar{x}_{it})\Phi_t}$ (in terms of value of final out-

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[7]The consequence of this in Carlstrom and Fuerst (1998) is that a firm's output needs to sell at a mark-up which is equal to Φ_t, hence they call their model the "output model".

put) from which a firm expects to keep the share $e(\bar{x}_{it})$ (Carlstrom and Fuerst, 1998).

Rewriting Equation (3.15) gives the (optimal) ratio of labour expenditures to net worth, $\frac{W_t N_{it}}{A_{i,t-1}}$:

$$\frac{W_t N_{it}}{A_{i,t-1}} = \frac{1}{1 - g(\bar{x}_{it})\Phi_t} \equiv \Psi(\Phi_t) \tag{3.16}$$

Note that according to the middle part of Equation (3.16), Ψ is a function of Φ_t and $\bar{x}_{it}$. However, as shown in relation to Equation (3.12), $\bar{x}_{it}$ can be written as a function of Φ_t and hence the proportionality factor between labour expenditures and net worth, Ψ, can be written as a function of the marginal return on labour expenditures, Φ_t, only.

Consider two firms, firm A and B, where firm B's net worth is double the size of that of firm A. Equation (3.16) states that in this case, firm B simply gets a loan that is double the size of firm A's and can therefore finance a labour force which is twice as large as that of firm A. The linear relationship between labour expenditures and net worth stems from the assumption that the production technology as well as monitoring costs are CRTS. The convenient consequence is that it allows for aggregation.[8]

3.3 General equilibrium

In this section I embed the partial equilibrium contracting problem into an otherwise standard RBC model.

3.3.1 The firm sector and aggregate net worth

It follows from aggregation that the entrepreneur's financial condition is determined by *aggregate* net worth. The aggregate stock of net worth is crucial

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[8]It is worth mentioning that (as Bernanke et al. (1999) point out), in the prominent model of Kiyotaki and Moore (1997) the proportionality factor $\Psi(.) = 1$, whereas here labour expenditures exceed net worth, i.e. the ratio is larger than unity.

as it serves as collateral and determines the size of the loan that the firm can get. Consequently, it drives the reaction of labour in response to a shock. Note, only when net worth deviates from its steady state by the same percentage as labour expenditures, the premium on external finance does not move and the resulting dynamics are identical to a baseline RBC model.

I define the financial position of the economy analogously to Bernanke et al. (1999) where net worth consists of earnings net of repayment of borrowings. In contrast to Bernanke et al. (1999), earnings are a result from *employing workers*, just as in De Fiore et al. (2011), just without government consumption which does not play a crucial role in their model anyway. In doing so, I can completely abstract from capital in the model as opposed to e.g. Carlstrom and Fuerst (1998) or Chugh (2013) in which cases net worth consists of (the market value of) capital only. I will now return to the expected profit of the firm to show how net worth is derived. For convenience I repeat

$$e(\bar{x}_t)X_tN_t = \left\{ \int_{\bar{x}_t}^{\infty} xf(x)dx - (1 - F(\bar{x}_t))\bar{x}_t \right\} X_tN_t$$

where I omit subscript i in order to move from firm-specific to aggregate variable. Thus, N_t refers to aggregate labour.

Now, with the PPC (3.6) rewritten as

$$(1 - F(\bar{x}_t))\bar{x}_tX_tN_t = B_t - (1 - \mu) \int_0^{\bar{x}_t} xf(x)dx \, X_tN_t$$

the expected pay-off can be simplified to

$$e(\bar{x}_t)X_tN_t = \left[1 - \mu \int_0^{\bar{x}_t} xf(x)dx \right] X_tN_t - B_t \tag{3.17}$$

with B_t referring to aggregate borrowing. This can be rewritten in a way that is analogous to e.g. Bernanke et al. (1999) (where firms borrow for capital invest-

ment) or Petrosky-Nadeau (2014) (where firms borrow for vacancy creation):

$$X_t N_t - \left(1 + \frac{\mu \int_0^{\bar{x}_t} x f(x) dx \, X_t N_t}{W_t N_t - A_{t-1}}\right) (W_t N_t - A_{t-1}) \qquad (3.18)$$

The fraction $\frac{\mu \int_0^{\bar{x}_t} x f(x) dx \, X_t N_t}{W_t N_t - A_{t-1}}$ is default costs over (aggregate) loan size and is an interpretation of the premium on external funds analogous to Bernanke et al. (1999) or the spread between the loan and the deposit rate in De Fiore et al. (2011). In contrast to Carlstrom and Fuerst (1998) who make firms more impatient than households or Bernanke et al. (1999) and De Fiore et al. (2011) who assume that only a fraction of firms survives into the next period, I assume that a fraction $1-\zeta$ of net worth is paid out to households at the end of t and the fraction ζ is carried over into the next period (e.g. Faia and Monacelli (2007)). This assumption – just as all the other mentioned alternatives – rules out that the firm can accumulate enough net worth but ensures that it always depends on external funds. Aggregate net worth at the *end* of period t, A_t, is

$$A_t = \zeta \left[X_t N_t - \left(1 + \frac{\mu \int_0^{\bar{x}_t} x f(x) dx \, X_t N_t}{W_t N_t - A_{t-1}}\right) (W_t N_t - A_{t-1}) \right] \qquad (3.19)$$

This stock of net worth is carried into the next period. In other words, an entrepreneur starts period t with net worth A_{t-1} which was determined at the end of $t-1$ and thus before the aggregate shock in t evolves. Therefore, the value of net worth at the beginning of period t is backward-looking rather than forward-looking and the contract bears no aggregate risk.

The particular behaviour of net worth over the business cycle is again a result of agency costs. In the absence of monitoring costs, when setting μ to zero, it gives

$$A_t = \zeta \left[X_t N_t - W_t N_t + A_{t-1} \right]$$

As shown above, in that case the marginal cost of labour would be equal to its

(average) marginal product and therefore net worth would collapse to

$$A_t = \zeta A_{t-1}$$

Hence, with a financial market characterised by asymmetric information, net worth is essential for the dynamics of the model as it moves with the aggregate state and determines the conditions a firm gets in the financial contract.

3.3.2 The household sector

The household sector is relatively standard and not directly affected by financial frictions. Unlike De Fiore et al. (2011), I abstract from money and deposits which the household hold in their model.

There is a representative household with a continuum of members (of mass one). Furthermore, the household consumes, can buy risky shares from a firm and a risk-free bond (**?**). Its utility, denoted H_t, is:

$$H_t = \max_{C_t, L_t, \chi_t} [U(C_t, L_t) + \beta E_t H_{t+1}] \tag{3.20}$$

where I define $U(C_t, L_t) = ln(C_t) + \xi ln(1 - L_t)$. L_t denotes hours worked and time is normalised to 1, so leisure is $1 - L_t$ and χ is defined below. ξ denotes the household's weight on leisure. It is the Frisch elasticity of labour supply, i.e. the elasticity of hours worked with respect to a change in the wage (keeping the marginal utility of consumption fixed). Intuitively, a worker faces some disutility of working. Here I closely follow common RBC models such as in Jermann and Quadrini (2012).

The household optimises consumption, C_t, the fraction of risky shares χ_t as well as labour supply, L_t when maximising utility subject to the following

budget constraint:

$$W_t L_t + \Pi_t - \frac{\Pi_{t+1}}{R_{t+1}^{\Pi}} = C_t \tag{3.21}$$

The dividends a household receives lump-sum at the end of each period, D_t, are included in the financial wealth, Π_t. Let $R_{t+1}^{\Pi} \equiv \chi_t(1+r_{t+1}^f)+(1-\chi_t)(1+r_t)$ be the return on wealth where r_t is the risk free interest rate known at the beginning of period t and r_{t+1}^f the return on firm shares. Π_{t+1} is a random variable. Note, all household members put their income together before choosing per capita consumption and asset portfolio, hence the above constraint is an *aggregate* budget constraint (Petrosky-Nadeau et al., 2018).

The FOC's for consumption and wealth allocation give

$$U_C(C_t, L_t) - \beta E_t \left[R_{t+1}^{\Pi} U_C(C_{t+1}, L_{t+1}) \right] \stackrel{!}{=} 0 \tag{3.22}$$

with $U_c(C_t) = \frac{1}{C_t}$ as the marginal utility of consumption. The Euler equation that needs to hold (in expectations) for all assets then is

$$1 = \beta E_t \left[\frac{C_t}{C_{t+1}} \right] (1 + r_t) \tag{3.23}$$

It determines the risk-free interest rate. Firms' and households' optimization are consistent, therefore the equilibrium stochastic discount factor is $\beta E_t(\frac{\lambda_{t+1}}{\lambda_t})$. Additionally, the first-order condition with respect to L_t determines labour supply:

$$U_L(C_t, L_t) - U_C(C_t, L_t)W_t \stackrel{!}{=} 0 \tag{3.24}$$

Equation (3.24) outlines that households equate the marginal rate of substitution between leisure and consumption (i.e. $\frac{U_L(C_t,L_t)}{U_C(C_t,L_t)}$) to the relative price of leisure (i.e. W_t). Under the characterisation of the model, labour supply is defined as:

$$\frac{W_t}{C_t} = \xi \frac{1}{1 - L_t} \tag{3.25}$$

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In order to supply more labour, the worker demands a higher wage to be compensated for the disutility associated with working. Hence, the labour supply curve is upward-sloping in W with the slope equal to the Frisch elasticity. Summing up, financial frictions do not directly affect a worker's choice. However, conditions in the financial market will do so indirectly via the wage as will be shown below when dynamic responses are analysed.

3.3.3 Market clearing

To close the model, two market clearing conditions are required, one for the labour market, stating that labour demand is equal to labour supply

$$N_t = L_t \tag{3.26}$$

and – since goods cannot be transferred between periods – an aggregate resource constraint

$$C_t = Y_t - \mu \int_0^{\bar{x}_t} x f(x) dx \, X_t N_t \tag{3.27}$$

where $Y_t = x_t X_t N_t$.

3.4 Model simulations

In the beginning of period t, a positive, autocorrelated aggregate productivity shock hits the economy (upper left panel of Figure 3.4.1). As outlined above, the threshold of idiosyncratic productivity, $\bar{x}$, is crucial for the behaviour of the (financial) variables. The upper left panel of Figure 3.4.2 depicts that in the presented set-up with intraperiod financial contracts, the threshold rises on impact. The underlying mechanism is the following. Because wages increase with higher average marginal productivity, but net worth is predetermined, the firm needs to increase borrowing (Figure 3.4.1). Debt contracts are formed

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Figure 3.4.1: Impulse responses to a positive technology shock with intra-period financial contract
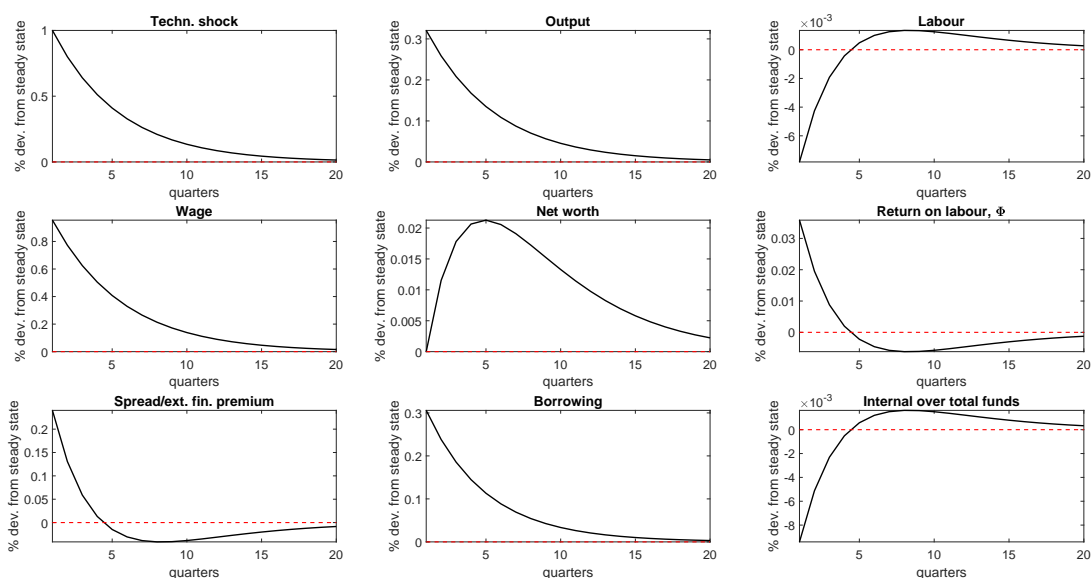
Note: Borrowing for the wage bill with intraperiod borrowing. IRF's show percentage deviations from steady state in response to a positive technology shock. Correlation of the shock: 0.9; standard deviation: 0.01. Own simulations.

right after the aggregate state evolves. Thus, credit, in contrast to equity, can respond on impact. As a result, the leverage ratio, i.e. borrowing relative to internal funds, increases (lower right panel of Figure 3.4.1). This leads to a rising bankruptcy threshold, mirroring an increasing probability of default, as shown in Figure 3.4.2. Technically, the threshold needs to move to the right in order to accommodate that firms' idiosyncratic productivity is more likely to fall below the threshold and default. Consequently, the premium for external funds, which moves in the direction of the threshold, is unrealistically procyclical (Figure 3.4.1).[9]

Let the remaining panels of Figure 3.4.2 serve as a cross-check for the derived relationships between bankruptcy threshold for idiosyncratic productiv-

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[9]Carlstrom and Fuerst (1998) also elaborate that in their model, this is due to the fact that internal funds are fixed in the period of the shock. However, I will show below that it is possible to achieve a counter-cyclical premium despite net worth being predetermined.

ity and other variables introduced in the financial contract. The probability of default is identical to the bankruptcy rate. Hence, with rising defaults, more output is burnt in the liquidation process. Furthermore, the expected share of output accruing to the firm, $e(\bar{x})$, falls in the threshold and that of the bank rises in $\bar{x}$. As highlighted before, the loan rate, R_t^l rises with the bankruptcy threshold reflecting that a higher default probability leads to higher borrowing costs.

Figure 3.4.2: Impulse responses to a positive technology shock with intraperiod financial contract
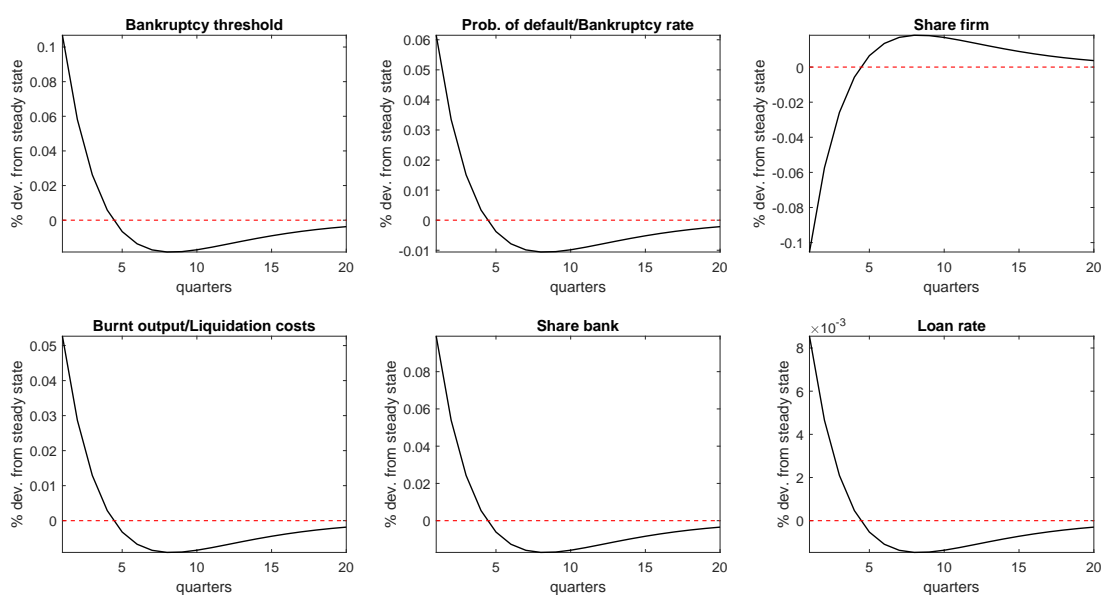
Note: Borrowing for the wage bill with intraperiod borrowing. IRF's show percentage deviations from steady state in response to a positive technology shock. Correlation of the shock: 0.9; standard deviation: 0.01. Own simulations.

Financial frictions have an effect on the competitive labour market. They drive a wedge between the (aggregate) marginal product and the marginal cost of labour, which is mirrored in the rising return on labour (Figure 3.4.1). This contrasts a standard RBC model where the return on labour is always one. After a positive productivity shock, labour should rise.[10] However, labour is

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[10]To be precise, in a standard RBC model, labour would rise. There are other models in which labour does not react to productivity shocks, for instance due to stabilising policies

too expensive in the first couple of quarters: with wages and borrowing costs going up, the levered firm cannot afford to increase labour. Moreover, net worth rises sluggishly in the periods after the shock. Hence, labour only rises once the premium on external funds and the loan rate fall below steady state. This happens once the threshold of idiosyncratic productivity is below steady state. Because the decrease in labour is quantitatively small, output rises on impact but its response is muted compared to a standard RBC model where output would follow the shock one-to-one. The sluggish response in net worth furthermore generates some persistence in labour.

Note, in Carlstrom and Fuerst (1998) labour does not decline. Again, net worth is the main driver. In their model, equity is based on the market value (at the beginning of the period) of accumulated capital and rises to a larger extent than in my model (2 percent compared to 0.02 percent).[11] Thus, it seems to rise sufficiently to allow labour to increase. However, because the response in net worth in Carlstrom and Fuerst (1998) is relatively small, there is no amplification in real variables compared to an RBC model.[12]

Several other papers have worked with intraperiod financial contracts and on a way to make the premium on external funds countercyclical. For instance, Faia and Monacelli (2007) assume that the distribution of idiosyncratic productivity shifts to the right after a positive aggregate technology shock. Intuitively, aggregate and idiosyncratic productivity are positively correlated in their model. Apart from a countercyclical premium, this generates larger responses in real variables compared to Carlstrom and Fuerst (1998).

This mechanism can also be found in the search and matching (Mortensen and Pissarides, 1994) literature: Chugh (2013) implement financial frictions

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which are included into the model (De Fiore et al., 2011).

[11]Autocorrelation of the shock in Carlstrom and Fuerst (1998) is higher than in the presented model (0.95). This however does not affect the magnitude of the response in net worth.

[12]For instance, in Bernanke et al. (1999), net worth rises by more than 8 percent in the period of the shock, see Figure 3.A.1 in Appendix 3.5.

into an otherwise standard search and matching model and achieve amplification of real variables (compared to a standard search and matching model without financial frictions). In this model, firms need to borrow to create vacancies, and to pay wages and capital rental costs. It is worth emphasising that both Faia and Monacelli (2007) and Chugh (2013) base net worth of the borrowing firm on capital.

Amplification in the response of net worth as well as a countercyclical premium on external funds, however, can also be generated without capital. For instance, Petrosky-Nadeau (2014) present a search and matching model in which firms need to borrow the costs of job creation (i.e. of filling a vacancy) in an intraperiod financial contract. Their model generates a countercyclical premium on external funds and amplified responses in real variables, both due to a large rise in net worth (Petrosky-Nadeau, 2014).[13]

3.4.1 Countercyclical premium on external funds

Another common way to ensure a countercyclical premium on external funds is to introduce aggregate risk into the financial contract as in the original model by Bernanke et al. (1999). That is, the financial contract is written *before* the aggregate shock evolves. As opposed to the presented model above, a firm now borrows funds at the end of period $t - 1$ for the use of labour for production in period t. Hence, the contract is written before both aggregate and idiosyncratic productivity become known to the firm. Thus, equation (3.2) changes to

$$B_{i,t-1} + A_{i,t-1} = W_t N_{it} \tag{3.28}$$

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[13]In Petrosky-Nadeau (2014), the premium on external funds is fixed in the period of the shock and drops in period $t + 1$ when predetermined net worth rises strongly.

and equation (3.3) changes to

$$\bar{x}_{it} X_t N_{it} = R^l_{t-1} B_{i,t-1} \tag{3.29}$$

Equation 3.29 highlights that loan repayment is not state contingent but fixed before the aggregate state evolves. The resulting model is akin to De Fiore et al. (2011) with the main difference that my model is in real terms while theirs is in nominal terms.[14]

Equation (3.28) together with equation (3.29) outline that in the period of the shock, t, the response of the threshold of idiosyncratic productivity is determined by the response of the return on labour on impact:

$$\bar{x}_{it} = \frac{R^l_{t-1} B_{i,t-1}}{A_{i,t-1} + B_{i,t-1}} \frac{W_t}{X_t} = \frac{R^l_{t-1} B_{i,t-1}}{A_{i,t-1} + B_{i,t-1}} \frac{1}{\Phi_t} \tag{3.30}$$

Total funds, $A_{i,t-1} + B_{i,t-1}$, as well as the loan rate, R^l_{t-1} are predetermined and cannot respond to the shock in t. Consequently, the threshold will move in the opposite direction of the return on labour, Φ_t.

Figures 3.4.3 and 3.4.4 show impulse responses to the same positive aggregate technology shock.

Similar to the version above, the return on labour rises on impact (Figure 3.4.3). As derived in Equation 3.30, the threshold of idiosyncratic productivity falls (Figure 3.4.4).

The intuition is simple. In the new setup, a firm cannot adjust the current loan contract on impact but only at the end of the period for the use of funds in the following period ("Borrowing" in Figure 3.4.3 depicts external funds at the beginning of a period). Similarly, net worth available at the beginning of a

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[14]I keep the household sector as derived above instead of following De Fiore et al. (2011). This, however, only mildly changes the results quantitatively while qualitatively they are identical.

Figure 3.4.3: Impulse responses to a positive technology shock with interperiod financial contract
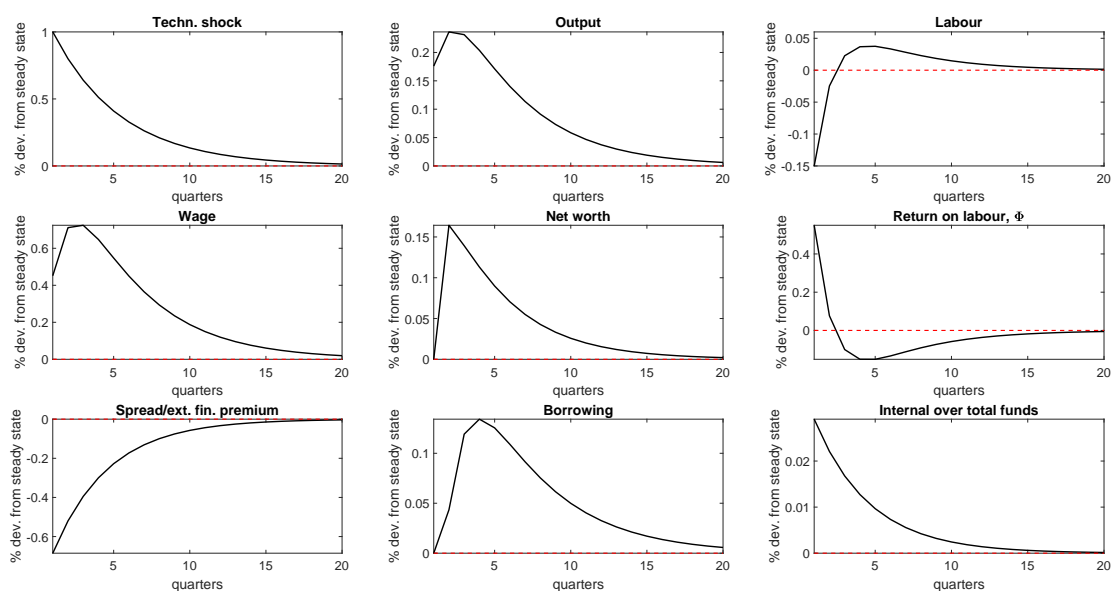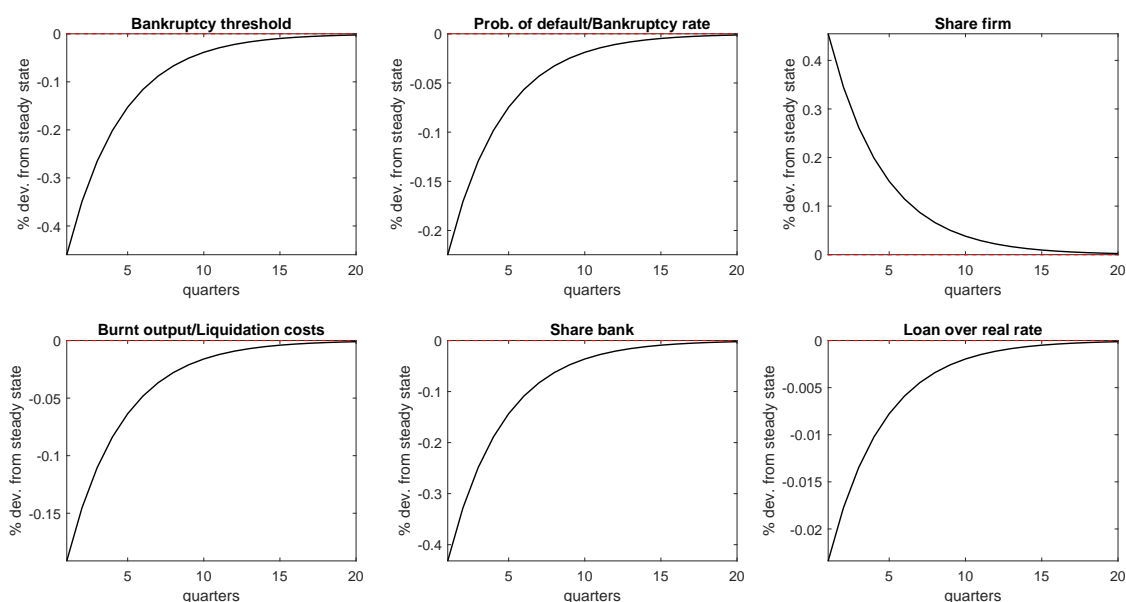

Note: Borrowing for the wage bill with interperiod borrowing. IRF's show percentage deviations from steady state in response to a positive technology shock. Correlation of the shock: 0.9; standard deviation: 0.01. Own simulations.

period responds with a delay, just as in the model above (Figure 3.4.3). Additionally, net worth rises to a larger extent than borrowing, i.e. the leverage ratio now *decreases* ("Internal over total funds" in Figure 3.4.3 depict end of period stocks). These two features translate into a falling threshold of idiosyncratic productivity.

The opposite response of the bankruptcy threshold with respect to the model above changes the remaining financial variables accordingly: the probability of default and liquidation costs fall in response to the shock (Figure 3.4.4). This can be considered as more realistic because in good times, bankruptcy rates should fall. Thus, the loan over the real interest rate falls (Figure 3.4.4) and the external finance premium is now countercyclical (Figure 3.4.3).

Again, wages rise with rising productivity (Figure 3.4.3) but funds take one quarter to start increasing. Thus, labour falls sharply in the first quarter. However, once funds are high enough, firms can built up labour input above

Figure 3.4.4: Impulse responses to a positive technology shock with interperiod financial contract

Note: Borrowing for the wage bill with interperiod borrowing. IRF's show percentage deviations from steady state in response to a positive technology shock. Correlation of the shock: 0.9; Standard deviation: 0.01. Own simulations.

steady state. With net worth being less sluggish than in the previous version, labour is above steady state already in the third quarter and the rise is larger in magnitude. Furthermore, the model can generate hump-shaped responses in real variables. These results are very similar to De Fiore et al. (2011).

However, the positive response in labour and output is still muted compared to an RBC model. An important feature of the original model by Bernanke et al. (1999) is that net worth rises by more than the underlying shock. This stimulates investment (into capital) which raises its price, spurring on the value of net worth further and thus creating amplification and persistence in the response of real variables (see Figure 3.A.1 and 3.A.2 in Appendix 3.5).[15] In contrast, this model (as the model presented above) lacks an amplified re-

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[15]In the original model by Bernanke et al. (1999) this only occurs when the technology shock is persistent with an autocorrelation of 1. Therefore, I also show IRF's for a monetary policy shock in Figure 3.A.2 in Appendix 3.5.

sponse of net worth as well as significant persistence in the response of real variables. Also in De Fiore et al. (2011), labour falls after a positive productivity shock. Inflation in their model induces a larger (and somewhat more persistent) rise in net worth which results in larger (and more persistent) responses in real variables compared to the presented model (see Figure 3.A.3 in Appendix 3.5).

3.5 Conclusion

In this chapter, I study interactions between a competitive labour market and a credit market characterised by frictions following Bernanke et al. (1999). To increase the tractability of the model, I completely abstract from capital. I start with an intraperiod financial contract which implies that the aggregate state is observed before borrower and lender form a contract and repayment takes place at the end of the same period. In such a setup, credit spreads are unrealistically procyclical. I furthermore find a muted response in real variables to a positive technology shock (compared to a standard RBC model). Introducing aggregate risk into the financial contract changes the behaviour of financial variables: when credit contracts are written before the aggregate state evolves and repayment takes place in the beginning of the following period, the premium on external funds is countercyclical. However, neither the model with intraperiod nor the version with interperiod financial contracts create amplification in real variables. This is due to the fact that firms' net worth rises sluggishly. In contrast to the original model by Bernanke et al. (1999), financial frictions in the presented setups thus have a dampening effect on the real business cycle.
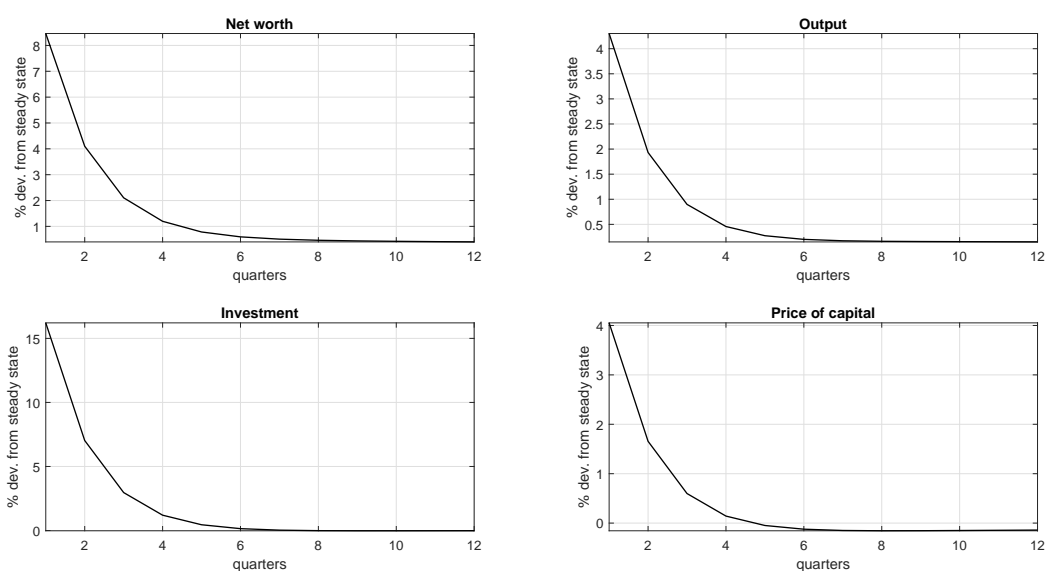
Appendix

3.A   Graphs

Figure 3.A.1: Impulse responses to a positive technology shock in the model of Bernanke et al. (1999)
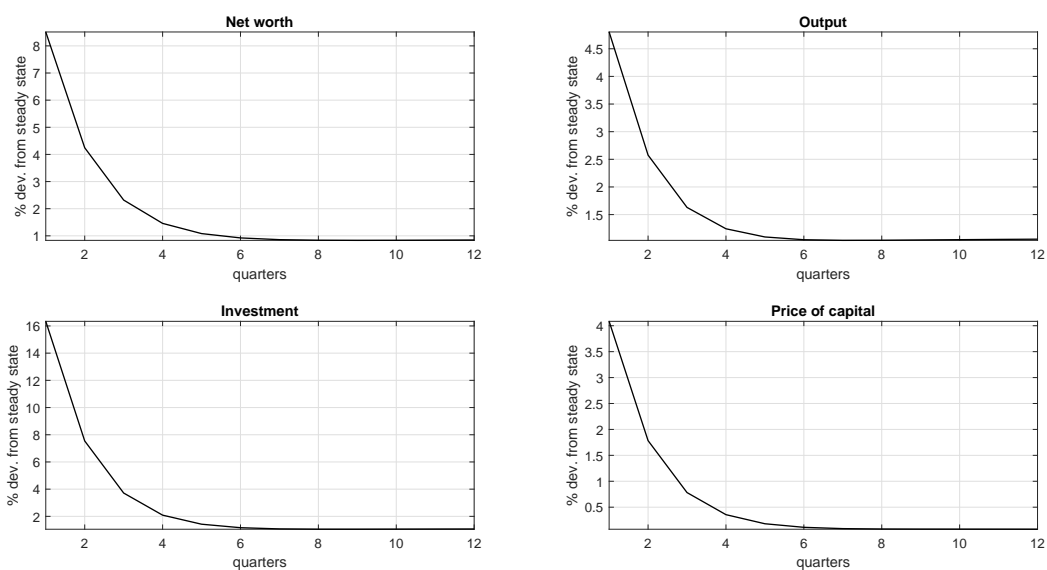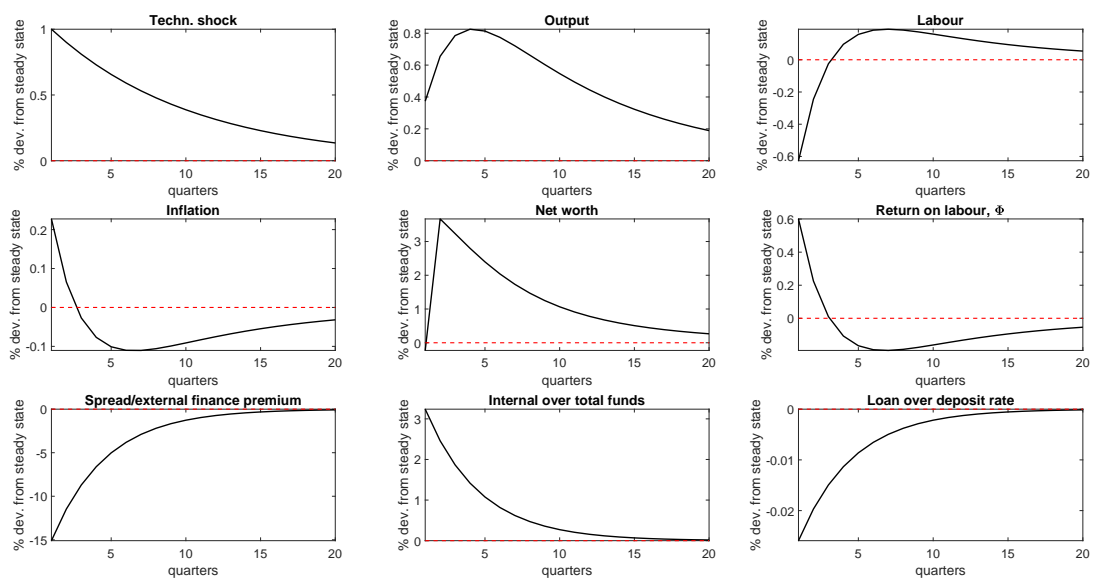

Note: IRF's of the original model by Bernanke et al. (1999).   IRF's show percentage deviations from steady state in response to a positive technology shock.   Correlation of the shock: 1; standard deviation: 0.01.   Own simulations.   Simulation code from Macroeconomic Model Data Base https://www.macromodelbase.com/, viewed 5 June 2016.

Figure 3.A.2: Impulse responses to a monetary policy shock in the model of Bernanke et al. (1999)

Note: IRF's of the original model by Bernanke et al. (1999). IRF's show percentage deviations from steady state in response to an expansionary monetary policy shock. Correlation of the shock: 0.9; standard deviation: 0.000625. Own simulations. Simulation code from Macroeconomic Model Data Base. https://www.macromodelbase.com/, viewed 5 June 2016.

Figure 3.A.3: Impulse responses to a positive technology shock in the model of De Fiore et al. (2011)

Note: Borrowing for the wage bill with interperiod borrowing. IRF's show percentage deviations from steady state in response to a positive technology shock. Correlation of the shock: 0.9; standard deviation: 0.01. Own simulations. Simulation code from Macroeconomic Model Data Base https://www.macromodelbase.com/, viewed 12 May 2017.

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