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Financial Frictions, Price Rigidities, and the Business Cycle

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FINANCIAL FRICTIONS, PRICE RIGIDITIES, AND THE BUSINESS CYCLE

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PREFACE

This dissertation was written in the period from September 2012 to November 2015 while I was enrolled as a PhD student at the Department of Economics and Business Economics at Aarhus University. I am more than grateful to the department for providing financial support and an excellent research environment. Furthermore, I would like to thank Centre for Research in Econometric Analysis of Time Series (CREATES) for generous funding and general help with numerous activities during PhD studies. I would like to thank my two supervisors: Torben M. Andersen and Niels Haldrup, for helping and advising me throughout my PhD studies. Their constructive input has been invaluable. Torben deserves special thanks for advising me all the way back to my master dissertation and always having an amazing overview. And Niels deserves thanks for encouraging me to enroll as a PhD student and advising me, all those years ago, on my bachelor dissertation. I also want to thank all participants in the Danish financial crisis commission by the fund Kraka for allowing me to work in a truly inspiring work environment. I learned so much during my time in Copenhagen.

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Special thanks also go to Jonas Nygaard and Magnus S. Jensen for sharing our office and helping me where it was most definitely needed (Latex, bootstrapping, etc.). And of course, I would like thank all my friends at the institute for making it an amazing journey. Finally, I would like to thank my family. Your support have always been essential. My loving girlfriend Laura deserves special thanks for always being encouraging and supportive.

Palle Sørensen
Aarhus, November 2015.

UPDATED PREFACE

The pre-defence was held on January 28'th, 2016. I would like to thank the members of the assessment committee, Mikael Carlsson, Emiliano Santoro, and Tom Engsted (Chairman) for thier very valuable input and constructive comments. Some of the suggestions have already been incorporated into the dissertation, while others remain for future research.

Palle Sørensen
Aarhus, February 2016.

INDHOLD

SUMMARY

English Summary

This thesis consists of three independent chapters on the interaction between financial markets and the real economy, and how the price setting behavior of firms is affected by fluctuations in exchange rate. Each chapter addresses important macroeconomic issues. Furthermore, each chapter differs in both research question and methodology. The first chapter is purely theoretical. The second chapter uses an empirical approach to test the microfoundation of competing macroeconomic models with financial frictions. The final chapter is purely empirical but also relates to various models with nominal price rigidities.

The first chapter, *Do financial innovations create more volatile housing prices?*, is a theoretical analysis of how new mortgages with lower amortization affect the stability of the housing market. The paper is a contribution to the literature on collateral constraints and housing prices (see e.g. Kiyotaki and Moore (1997) and Iacoviello (2005)). Specifically, the question is analyzed in an intertemporal two sector Savers-Spenders model for a small open economy. The paper focuses on how mortgages affect the dynamics around different steady states. The results indicate that the volatility of housing prices increases when new mortgages with low amortization are introduced. The dispersion increases not just in the transition period, when the mortgages become more/less popular, but also in a new steady state where prices are higher. The key novelty of the paper is that the model is sufficiently simplistic to be solved for the deep parameters. This renders it possible to analyze the second moment properties of the housing prices analytically.

The paper can be seen in relation to the discussion on pros and cons of interest only loans. On the one hand, new mortgages allow for further consumption smoothing which is welfare-improving for constrained households. On the other hand, if prices become more volatile, one could potentially get a loss in welfare if household are risk averse.

The second chapter, *Credit policies before and during the financial crisis*, is an empirical analysis of the microfoundation of two contending macro models with financial frictions. The paper seeks to answer whether the availability of credit depends on the financial health of banks and/or the balance sheets of borrowing firms. In

the literature these two channels of credit cycles have been termed the bank lending channel and the balance sheet channel (see e.g. Bernanke (2007)).

The bank lending channel (see e.g. Gertler and Kiyotaki, (2010)) broadly describes how shocks to banks' balance sheets might affect the cost of (or access to) finance for certain borrowers. The channel is believed to be important if the supply of bank loans is dependent on economic conditions and that bank loans are imperfect substitutes for other forms of finance. The main idea is that if banks are optimizing agents, there exist not only agency problems between banks and borrowers but also between banks and their fund providers. Fund providers, depositors or other banks, might be more reluctant to deposit their funds in banks that are struggling which thereby ultimately affects the supply of credit.

The balance sheet channel or the firm balance sheet channel describes the connection between the borrowers' financial health and the price of external credit or access to credit (see e.g. Bernanke, Gertler, and Gilchrist (1999)). It basically links credit supply to economy-wide fluctuations and generates a so-called financial accelerator effect, i.e. financial markets amplify relatively small shocks to e.g. productivity. Contrary to the bank lending channel, the balance sheet channel focuses on the balance sheets of the borrowing firm and not the balance sheet of the bank.

The paper is related to a sparse but growing literature on the importance of the two channels (see e.g. Jimenez et al. (2012) and Popov and Udell (2012)). The main contribution of the paper is that it utilizes a combination of survey, rating and register data, which is unique, to the best of my knowledge, in the current literature. The study yields the following main results: the bank lending channel seem to explain most of the changes in credit supply by Danish banks towards small and medium (SME) sized firms. However, the results show that both channels are operational, but the balance sheet channel is surprisingly weak as self-selection into the loan application process during the crisis kept struggling firms from applying for credit. The analysis also reveals that the credit supply was weaker in banks that were struggling during the crisis and indirectly that firms could not off-set this effect by changing banks. Furthermore, the evidence suggests that the financial crisis also affected the liquidity of non-financial firms, as credit demand rose immediately following the crisis.

The third chapter, *Price rigidities, currency shocks, and market shares* (co-authored with Martin Eichenbaum, Yana Gallen, and Sergio Rebelo), is an empirical study of the price setting behavior of firms in response to changes in marginal costs. We exploit the fact that currency changes pass through (potentially incompletely) to import prices, but to a large extent do not affect the firms' domestic pricing decision. Specifically, we use the variation of import prices by product over time to get a measure of the final good price change that follows directly from a depreciation/appreciation of the Danish krone with respect to 15 of the largest import markets outside the Eurozone.

The paper is related to three strands of literature. First, the paper is related to research on business cycle fluctuations as a result of nominal rigidities (see e.g. Chri-

stiano, Eichenbaum, and Evans (2005)). Second, the paper is related to the industrial organization (IO) literature focusing on the price setting behavior of firms (see e.g. Klenow and Malin (2010)). Third, it is related to a vast literature on the exchange rate disconnect (See e.g. Burstein and Gopinath (2013)).

The results show evidence of final good price rigidities with an overall pass-through of marginal cost changes of only 10-14 percent depending on IV specification. However, when we interact marginal cost changes with domestic market shares, the results reveal that firms with a market share approaching zero do not seem pass through cost changes. But, the pass-through significantly increases in the domestic market share in all specifications. Furthermore, import prices do not react 1-to-1 to changes in currencies. Our results suggest that a 1 percent depreciation of the Danish krone result in a 0.40 percent increase in import prices. Hence, this papers further supports the common conclusions in international trade regarding the exchange rate disconnect (incomplete pass-through of currency changes).

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Danish summary

Denne afhandling består af 3 uafhængige kapitler om interaktionen mellem finansielle markeder og realøkonomien, og om hvordan virksomheders prisstrategi er påvirket af fluktuationer i valutakursen. Hvert kapitel adresserer vigtige makroøkonomiske problemstillinger. Yderligere har hvert kapitel sit eget forskningsspørgsmål og metode. Det første kapitel er rent teoretisk. Det andet kapitel benytter en empirisk tilgang til at teste mikrofundamentet af to konkurrerende makroøkonomiske modeller med finansielle friktioner. Det sidste kapitel er rent empirisk, men relaterer sig til en række modeller med nominelle prisrigiditeter.

Det første kapitel, *Do financial innovations create more volatile housing prices?*, er en teoretisk analyse af hvordan nye låntyper med lavere afdrag påvirker stabiliteten på boligmarkedet. Papiret bidrager til litteraturen om belåningsgrader og boligpriser (se fx Kiyotaki and Moore (1997) og Iacoviello (2005)). Specifikt, analyseres spørgsmålet i en intertemporal Saver-Spenders model med to sektorer for en lille åben økonomi. Papiret fokuserer på hvordan låntyper påvirker dynamikken omkring forskellige steady states. Resultaterne indikerer at volatiliteten på boligpriserne stiger når nye låntyper med højere belåningsgrader (eller lavere afdrag) introduceres. Spredningen på priserne stiger altså ikke plot i transitionsperioden, hvor disse lån bliver mere populære, men også i den nye steady state, hvor priserne er højere. Det specielle ved dette papir er, at modellen er tilpas simple til at kunne løses for de dybe parametre. Dette betyder at det er muligt at analysere variansen på boligpriserne analytisk.

Papiret kan ses i sammenhæng med diskussionen om argumenter for og imod afdragsfrie lån. På den ene side, gør nye låntyper det muligt for kreditbegrænsede husholdning at udglatte deres forbrug over tid, hvilket er velfærdsforbedrende. På den anden side, hvis priserne bliver mere volatile, er velfærdskonsekvenser ikke helt så umiddelbare og kunne potentielt være negative.

Det andet kapitel, *Credit policies before and during the financial crisis*, er en empirisk analyse af mikrofundamentet af to konkurrerende makromodeller med finansielle friktioner. Papiret forsøger at besvare, om adgangen til kredit for små- og mellemstore virksomheder afhænger af bankernes finansielle helbred og/eller låntagers nøgletal. I litteraturen bliver disse to kanaler for kreditcykler kaldt henholdsvis 'the bank lending channel' og 'the balance sheet channel' (se eksempelvis Bernanke (2007)).

'The bank lending channel' (se fx Gertler and Kiyotaki, (2010)) beskriver generelt, hvordan shock to bankers balance potentielt kan have betydning for prisen på (eller adgangen til) finansiering for bestemt låntagere. Kanalen er vigtig, hvis udbuddet af banklån afhænger af økonomien som helhed, og banklån ikke er perfekte substitutter for andre former for finansiering. Hovedideen er, at hvis bankerne er optimerende agenter, eksisterer der ikke kun agentproblemer mellem bankerne og låntager, men også mellem bankerne og deres indskydere. Bankens indskydere, debitorer eller andre banker, vil måske blive mere tilbageholdende med at have deres penge i banken, hvis

banken kommer i finansielt uføre, hvilket ultimativt vil påvirke udbuddet af kredit.

'The balance sheet channel', også kaldt 'the firm balance sheet channel', beskriver sammenhængen mellem låntagers finansielle helbred og prisen på (eller adgangen til) ekstern kredit. (se fx Bernanke, Gertler, and Gilchrist (1999)). Basalt set bliver kreditudbuddet afhængigt af makroøkonomiske udsving og genererer en såkaldt finansiel accelerator effekt, med andre ord, er finansielle markeder med til at forstærke relativt små shock til fx produktiviteten. Modsat 'the bank lending channel', fokuserer 'the balance sheet channel' på låntagerens finansielle helbred og dermed ikke bankens.

Papiret er relateret til en begrænset men voksende litteratur om vigtigheden af disse to kanaler (se fx Jimenez et al. (2012) og Popov and Udell (2012)). Hovedbidraget til litteraturen kommer fra brugen af en kombination af spørgeskemaundersøgelser, rating- og registerdata, hvilket er unikt, så vidt vides, i litteraturen. Papiret har følgende hovedresultater: 'the bank lending channel' forklarer hovedparten af ændringen i kreditudbuddet til små og mellemstore virksomheder. Resultaterne indikerer også at begge kanaler er operationelle, men 'the balance sheet channel' er overraskende svag, da selvselektion i forbindelse med lånprocessen fik virksomheder som var hårdt ramt af krisen til at opgive at få et lån. Analysen viser også kreditudbuddet var mindre i banker med store tab på udlån, og indirekte at virksomheder ikke kunne opveje denne effekt ved at skifte bank. Yderligere tyder analysen på, at den finansielle krise også påvirkede likviditeten i ikke-finansielle virksomheder, da kreditefterspørgslen steg umiddelbart efter krisen.

Det tredje kapitel, *Price rigidities, currency shocks, and market shares* (skrevet i samarbejde med Martin Eichenbaum, Yana Gallen, og Sergio Rebelo), er en empirisk analyse af hvordan virksomheder sætter deres priser som konsekvens af udsving i deres marginale omkostninger. Vi udnytter det faktum at valutakursen påvirker (potentielt mindre end 1-til-1) prisen på importerede varer, men i en vid udstrækning ikke påvirker virksomhedens indenlandske beslutning om, hvordan prisen skal sættes. Specifikt bruger vi variationen i importpriserne for enkelte produkter over tid, til at konstruere et mål for ændringen i færdigvarepriserne som følger af en depreciering/appreciering af den danske krone. Specifikt bruger vi 15 af Danmarks største importmarkeder udenfor Eurozonen.

Papiret er relateret til 3 forskellige litteraturer. Først, er papiret relateret til forskning i makroøkonomiske udsving som resultat af nominelle rigiditeter (se fx Christiano, Eichenbaum, and Evans (2005)). Dernæst er papiret relateret til 'industrial organization' (IO) litteraturen som fokuserer på, hvordan virksomheder sætter deres priser (se fx Klenow and Malin (2010)). Sidst, men ikke mindst, er papiret relateret til den omfattende litteratur om 'the exchange rate disconnect' (se fx Burstein and Gopinath (2013)).

Resultaterne indikerer rigiditet i færdigvarepriserne med et gennemslag på 10-14 procent afhængigt af IV specifikation. Når de marginale omkostningsændringer interageres med indenlandske markedsandele, viser resultaterne at virksomheder med en

markedsandel gående mod nul ikke har noget gennemslag til færdigvarepriserne. På den anden side, er gennemslaget signifikant stigende i den indenlandske markedsandel i alle specifikationer. Ydermere reagerer importpriserne ikke 1-til-1 ved ændringer i valutakurserne. Vores resultater indikerer at en 1 procent depreciering af den danske krone resulterer i en 0.40 procent stigning i importpriserne. Så papiret lægger sig altså op af den almindelige konklusion i international handel med hensyn til 'the exchange rate disconnect' (Ufuldkommet gennemslag af valutakursændringer).

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CHAPTER 1

DO FINANCIAL INNOVATIONS CREATE MORE VOLATILE HOUSING PRICES?

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Abstract[1]

This paper analyzes the impact of introducing new mortgages with lower amortization in a two sector Savers-Spenders model for a small open economy. The results indicate that the stability of housing prices decreases when households are allowed to amortize less even in the new steady state and not just during the transition period. This result is found if liquidity constrained agents can not borrow in a secondary market. They are therefore forced to hold a minimum amount of savings in their house, which might not be optimal, even when they can recover their savings next period when the loan is renegotiated. Futher, the model also has the appealing feature that steady state housing prices increase when new loan contracts with lower down payments are introduced.

JEL: G21; G11; F41; E21.

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Keywords: mortgage innovations; house prices; small open economy; rule-of-thumb consumers.

1.1 Introduction

Do new mortgages such as subprime and interest only loans affect the stability of housing markets? It has been argued that the popularity of mortgages with low amortization partly caused the housing price boom in the mid 2000's, see e.g. Barlevy and Fisher (2011). However, does this mean that we should not allow these mortgages? Stated differently, if the popularity of new mortgages has increased does this by itself affect the stability of the housing market? And is the stability of housing prices affected by mortgage supply effects (if mortgage availability is tied to housing prices) and do demand effects play a significant role?

Most conventional models tell us that mortgage innovations should not have any real effects, but at the heart of this conclusion lies an assumption of perfect capital markets. While this assumption is very convenient, it is not in line with basic observations of consumption, net savings and bequest motives. However, two parsimonious approaches generate a non-trivial effect of new mortgages with lower amortization. Namely, the patient and impatient view first explored by Kiyotaki and Moore (1997) and later for the housing market in Iacoviello (2005), and the Savers-Spenders approach first explored by Mankiw (2000). This paper focuses on the latter, but draws on the insights from the former. Other noticeable papers include: Pavlov and Wachter (2011), Glaeser et al. (2010), and Favilukis, Ludvigson, and Nieuwerburgh (2012). These papers propose that mortgage innovations result in lower credit requirements, lower transaction costs, and better risk sharing, which in turn leads to higher housing prices. Generally in the Saver-Spenders model, if savers are assumed to have access to perfect financial markets they can be represented by a representative agent discounting the future at the risk free interest rate. Spenders on the other hand do not have access to perfect capital markets and live their lives paycheck to paycheck, which Mankiw (2000) suggests could result from commitment problems stemming from high intertemporal discounting. In this paper the setup is adapted to allow spenders to borrow using their house as collateral, but not having any other means of consumption smoothing. As will be shown below, this implies that spenders are focused more on the current cost of housing than future payments. This result is in line with the literature on present biases or biased preferences that also implies a disproportionally large focus on the minimum payment of servicing their debt than the actual cost of the house.

This paper adds to the literature by being the first paper, to the best of my knowledge, that focuses on how demand affects the dynamics around different steady states in a Savers-Spenders model. The results indicate that the volatility of housing prices increases when new mortgages with low down payments are introduced.

A property shared with the Kiyotaki and Moore (1997) model for land prices. The volatility increases not just in the transition period but also in a new steady state where prices are higher.

The aim of this paper is not to give an extensive analysis in an empirically relevant model, but rather to give a modeling example where the underlying intuition is very simple and traceable. This has the added advantage of allowing for an analytical analysis of the second moment implications of new mortgage products, i.e. the effects on the stability of housing markets. Specifically, the paper analyzes an intertemporal two-sector model for a small open economy. It is assumed that there exists some fraction of liquidity constrained households that can not access the market of internationally traded bonds, but they finance their houses through mortgage bonds. Further, these households roll over debt each period, but if they have to make down payments, they have to keep some amount of savings in their house. It is shown that if these households are impatient it implies that their demand for housing is affected positively by mortgages with lower down payments. There also exists a fraction of non-liquidity constrained households that have access to international traded bonds (perfect capital markets are neglected for the ease of exposition). These households are unaffected by the mortgage types available. The existence of these households ensures an appropriate interaction with foreign investors, i.e. they ensure that the economy would not have a constant inflow of foreign capital even though there are impatient households. The model generates steady state prices that are affected positively by the access to mortgages with low amortization, and further, the volatility in these steady states depends negatively on the size of the down payment needed for different mortgages. Note that this effect is found without any forms of financial distress build into the model.

The paper is structured in the following way: In section 2, the model is laid out. Section 3 considers a steady state solution of the model. In section 4, the dynamics around this steady state are discussed. In section 5, the results are compared to the model with a different utility specification, and section 6 concludes.

1.2 The model

This paper looks at a two-sector model for a small open economy. The basic idea - the Savers-Spenders approach - originates from Mankiw (2000) and the model shares characteristics with the models proposed in Andersen and Holden (2002) and Kristoffersen (2011). One sector produces an internationally traded non-housing consumption good. It is assumed throughout that the price of this good is exogenous. The other sector produces internationally non-tradable housing and the price of housing is determined endogenously. There exists a fraction, λ, of liquidity constrained households (rule-of-thumb consumers) that spend their entire income each period and do not have access to savings and borrowing to smooth consumption in

financial markets. They can, however, use their house as collateral to borrow. The explicit timing assumptions are discussed in further details below. The fraction $(1-\lambda)$ has full access to saving and borrowing. It is further assumed that there only exists an internationally traded bond with an exogenously given interest rate, i.e. there is no equity in this setup and agents own the production side of the economy.

Households

The households, both constrained and non-constrained, are assumed to supply an inelastic amount of labor $\overline{L}$ and their objective is to maximize their expected lifetime utility given by

$$U_t^i = E_t \left[\sum_{j=0}^{\infty} (1+\rho^i)^{-j} u(c_{t+j}^i, H_{t+j}^i) \right], \tag{1.1}$$

where ρ^i is the subjective discount rate, $u(.)$ is the instantaneous utility, c_t is the amount of tradable consumption, and H_t the amount of housing. $i \in \{C, NC\}$ represents the liquidity status, where C represents liquidity constrained households and NC represents non-liquidity constrained households. It is assumed that $\rho^{NC} = r$, where r is the interest on the internationally traded bond, to obey regularity conditions that satisfy the long run implications of the model, i.e. to ensure that the country does not accumulate or decumulate foreign debt, see Blanchard and Fischer (1989). Normally in the Savers-Spenders setup, it is not necessary to consider different discount rates of liquidity constrained households, ρ^C, as these households are assumed myopic and therefore choose their consumption bundle without any intertemporal considerations. However, as one of the goods is durable, this will not be assumed to be the case. Instead it is assumed that liquidity constrained households take intertemporal considerations into account when making the consumption decision, but that they discount the future at a higher rate than the interest rate, i.e. $\rho^C > r$.

It is assumed that there exists a representative household for each liquidity status, both of whom are price takers. As the focus is on the housing market the following instantaneous quasi linear utility is used

$$u(c_t^i, h_t^i) = c_t^i - \frac{a}{2}(\bar{H} - H_t^i)^2, \tag{1.2}$$

where a is a preference parameter for housing and $\bar{H}$ is some satiation point for housing. This naturally implies that there exists a continuum of consumptions paths that solve the optimization problem for the non-constrained households, however, housing consumption is pinned down which makes the analysis possible. It is further assumed that there only exists a market for owneroccupied housing which follows a durable nature given by

$$H_t^i = H_{t-1}^i(1-\delta) + h_t^i, \tag{1.3}$$

where δ is the depreciation rate of the house and h_t is the amount of housing bought at time t.

Non-liquidity constrained households

The non-liquidity constrained households are assumed to be rational in the following sense: They realize that the cost of having a house is the user cost. To see this, notice that when making a down payment these households could take an opposite position in the internationally traded bond which is assumed to have the same properties as the mortgage bond. This implies that there are no forced down payments in these households.[2] The user cost of having a house is therefore the interest payments and depreciation costs minus possible capital gains on the house. It is also assumed that there are no other costs associated with home ownership, e.g. no transaction costs.

The interest rate r is assumed to be fixed and the interest rate is common to all financial products in the model, i.e. both mortgage bonds, independent of type, and the internationally traded bond offers the same interest. Pavlov and Watcher (2011) note that this does not necessarily hold as lenders might require a premium for the interest only loan. The expenditure function for period t therefore takes the following form

$$M_t^{NC} = c_t^{NC} P_t^{NH} + \underbrace{r P_{t-1}^H H_{t-1}^{NC}}_{interest\,payments} + \underbrace{\delta P_t^H H_{t-1}^{NC}}_{depreciation\,costs} - \underbrace{\left(P_t^H - P_{t-1}^H\right) H_{t-1}^{NC}}_{Capital\,gains/loses\,on\,existing\,house},$$

where P_t^{NH} and P_t^H are prices on non-housing consumption and housing, respectively. The price of non-housing consumption serves as the numeraire i.e. P_t^{NH} is assumed to equal 1. Note that the expenditures are independent of the repayment vehicle which is consistent with literature on unconstrained households. Further, wealth is defined as the sum of internationally traded bond holdings, housing equity, and mortgage bond holdings, i.e.

$$W_t = B_t^H + B_t^{EQ} + P_t^H H_t^{NC},$$

where B_t^H is net mortgage bond holdings, B_t^{EQ} is net holdings of the internationally traded bond, and $P_t^H H_t^{NC}$ is the value of the house. A few simple steps lead to the following evolution of wealth

$$W_t = (1+r) W_{t-1} + \left(1-\lambda\right) I_t - M_t^{NC}, \tag{1.4}$$

[2] A similar result would be achieved if non-liquidity constrained households act as if there was a shadow rental market for housing.

where I_t is the time t income, independent of the liquidity status, defined by

$$I_t = P_t^{NH} y_t + P_t^H y_t^H$$

where y_{t+j} is output from the tradables sector, y_{t+j}^H is output from the housing sector, and subject to the following no ponzi game condition

$$\lim_{T\to\infty} (1+r)^{-T} W_T = 0. \tag{1.5}$$

An important implication of this setup is that the model does not reveal the loan types used by non-liquidity constrained households and the how total wealth is allocated between housing equity and bonds. These properties also indicate that the results are not directly tied to the popularity of new mortgage products, but are instead tied to the liquidity status.

The non-liquidity constrained households maximize their expected lifetime utility given in equation (1.1) by choosing $\left(c_s, h_s\right)_{s=0}^{\infty}$ s.t. (1.3) and (1.4). As the problem satisfies the Markow property it can be shown, using dynamic programming, that the optimal consumption path is governed by the following Euler equation

$$h_t^{NC} = \bar{H} - H_{t-1}^{NC}(1-\delta) - \frac{1}{a} P_t^H + \frac{1}{a} \frac{(1-\delta)}{(1+r)} E_t \left[P_{t+1}^H \right]. \tag{1.6}$$

The second Euler equation, $\rho^{NC} = r$, is always satisfied due to the linearity assumption of non-housing consumption i.e. the time path of non-housing consumption is undetermined in this model. Further, ρ^{NC} is substituted for the risk free rate, r. Note that the dual nature of housing, being both an investments good and a consumption good, can be seen from the Euler equation given in (1.6). It is seen that non-liquidity constrained households will demand housing up to its satiation point if $E_t \left[P_{t+1}^H \right] (1-\delta) = P_t^H (1+r)$ i.e. if the return on housing is equal to the return on the internationally traded bond accounting for depreciation costs.

Liquidity constrained households

Compared to the existing literature it is still assumed that constrained households do not have access to saving and borrowing in a traditional way. But now by construction these households have access to saving and borrowing through their house loan. It is, however, assumed that the capital accumulated in the house is not fully liquid, i.e. financial institutions require households to hold a minimum amount of savings in their house. For parsimony it is assumed that liquidity constrained households have no interest in saving through their house loan. An immediate consequence of this is that liquidity constrained individuals will roll over debt each period.[3] This

[3] An equivalent assumption would be to only allow for one period lending.

intuition follows that of Claeser et al. (2010). [4] The new mortgage products have two major advantages compared to traditional mortgages with higher down payments. First of all, they allow for down saving in the current housing stock in real terms. This option is expected to be exercised by older individuals that place little to no value on savings for the next generation. Secondly, mortgages with low amortization allow for further lifetime consumption smoothing. This would be of central interest for liquidity constrained households, hence everyone, given the option, would choose the loan with the lowest down payment.[5] Formally, the above yields the following nominal expenditure function

$$\begin{aligned} M_t^C &= P_t^C c_t^C + r P_{t-1}^H H_{t-1}^C (1-d) + d P_t^H \underbrace{(H_{t-1}^C (1-\delta) + h_t^C)}_{\equiv H_t^C} \\ &\quad - \left(\underbrace{P_t^H H_{t-1}^C (1-\delta)}_{Time\ t\ value\ of\ existing\ housing} - \underbrace{P_{t-1}^H H_{t-1}^C (1-d)}_{Nominal\ housing\ debt\ at\ time\ t\ less\ interest} \right), \end{aligned}$$

where d is a constant down payment rate set by financial institutions. If the housing market is rising, it is clear that the equity in their house will be considered an extra income as the loans are renegotiated each period. However, it could be argued that households would only refinance if this action reduces expenditures which is a potential weakness of this setup. As liquidity constrained individuals do not have access to internationally traded bonds the following budget constraint must be satisfied each period

$$M_t^C = \lambda I_t. \tag{1.7}$$

The liquidity constrained households maximize (1.1) by choosing $\left(h_s\right)_{s=0}^{\infty}$ s.t. (1.3) and (1.7). The solution is characterized by the following Euler equation

$$h_t^C = \bar{H} - H_{t-1}^C (1-\delta) - \frac{1}{a} d P_t^H - \frac{1}{a} P_t^H \frac{(1-d)(1+r)}{(1+\rho^C)} + \frac{1}{a} \frac{(1-\delta)}{(1+\rho^C)} E_t \left[P_{t+1}^H \right]. \tag{1.8}$$

Some preliminary comments are in order. Note that for a fixed time $t-1$ housing stocks and given prices, $\frac{\partial h_t}{\partial d} < 0$, as $(1+\rho^C) > (1+r)$, i.e. low amortization will increase housing demand only if liquidity constrained households are impatient.

[4] This is equivalent to assuming $W_t = d P_t^H H_t \ \forall t$. This implies that the marginal propensity to consume out of capital gains is one, which ideally should be endogenous. However, the assumption is shared with the patient-impatient approach, and Iacoviello (2005) shows that this will hold if shocks are not too large.

[5] Another important implication, as shown below, is that the welfare gains from new mortgages are largely going to households with high housing consumption at the time of introduction of new mortgages as the introduction is capitalized in housing prices. A formal analysis of this interesting implication could be done in a overlapping generation setup and is therefore beyond the scope of this paper.

Iacoviello (2005) demonstrates that impatience actually implies that households are liquidity constrained in the sense that they hold the minimum amount of savings in equilibrium. Liquidity constrained households are therefore expected to discount the future at a high rate. This observation was also made in the original paper of Mankiw (2000), where impatience seems to be the main motivation for myopia. Further, this property will not affect the accumulation or decumulation of foreign bond debt, as these households do not have access to internationally traded bonds. However, it will affect the trade balance so the presence of these households has non trivial effects on the interaction with foreign economies. The idea is that liquidity constrained households can not access the international bond market as they would accumulate debt. If foreign and domestic investors could observe the liquidity status they would exclude the impatient households as these would optimally run ponzi schemes on lenders. Stated differently, there is no obvious reason why some share of the households do not have access to bond markets if they were not impatient.

The Euler equation states the following basic intuition. The demand for housing is decreasing in the current housing stock due to declining marginal utility from housing and decreasing in the current relative price of housing. If households are impatient, they demand more if they do not have to make down payments as the cost of present consumption is paid in future periods. Further, demand is increasing in the expected future price, as an expected price increase yields a future capital gain proportional to housing stock in the next period.

Aggregation

The aggregate demand can simply be written as

$$c_t^{AGG} = \lambda c_t^C + (1-\lambda) c_t^{NC}$$

and the aggregate stock of housing is given by

$$H_t^{AGG} = \lambda H_t^C + (1-\lambda) H_t^{NC}. \tag{1.9}$$

Firms

There exists two types of firms: one producing the consumption good and one producing the housing good. It is assumed that both firm types are price and wage takers. It is further assumed that agents supply an inelastic amount of the labor $\bar{L}$.

Production of both housing and consumption

Representative firms produce output according to the following production function

$$y_t^j = \frac{\eta_t}{\gamma} \left(L_t^j \right)^{\gamma}, \tag{1.10}$$

where $j \in \{NH, H\}$ indicates either non-housing consumption C or housing H, η_t is an exogenously given technology, assumed similar for both housing and consumption to maintain parsimony, and L_t^C is the labor employed in consumption good firms. The parameter γ is assumed to satisfy $0 < \gamma < 1$ throughout. The log productivity is assumed to be evolving according to

$$\eta_t = \bar{\eta} + \varepsilon_t,$$

where $\bar{\eta}$ is the long-run productivity level and ε_t is the deviation. It is assumed that the error terms are serially uncorrelated and unexpected, formally

$$E_t\left[\varepsilon_{t+j}\right] = 0 \,\forall\, j > 0 \qquad E_t\left[\varepsilon_{t+k}\varepsilon_{t+j}\right] = 0 \,\forall\, k \neq j.$$

Firms maximize profits according to

$$\pi_t^j = P_t y_t^j - W_t L_t^j,$$

where W_t is the wage. Inserting (1.10) and maximizing with respect to L_t^C gives the following first order condition

$$L_t^j = \left(\eta_t \frac{P_t^j}{W_t}\right)^{\frac{1}{1-\gamma}},$$

which implies the following optimal production scheme

$$y_t^j = \frac{1}{\gamma}\eta_t^{\frac{1}{1-\gamma}}\left(\frac{P_t^j}{W_t}\right)^{\frac{\gamma}{1-\gamma}}. \tag{1.11}$$

Often, when dealing with housing production, it is taken into account that land goes into production as an intermediate good, see for instance Favilukis, Ludvigson, and Nieuwerburgh (2012). And even more often, housing is considered to be in fixed supply, which has the natural implication of a more pronounced effect of new mortgages with low amortization. The results of this analysis hold for any upward sloping supply curve even if housing prices are determined solely from the production cost in the long run.

Equilibrium

The market clearing condition for wages is

$$\bar{L} = N_{NH}\left(\eta_t \frac{P_t^{NH}}{W_t}\right)^{\frac{1}{1-\gamma}} + N_H\left(\eta_t \frac{P_t^H}{W_t}\right)^{\frac{1}{1-\gamma}}, \tag{1.12}$$

where N_{NH} is the number of firms producing the consumption good and N_H is the number of firms producing housing. Inserting W_t from (1.12) into the production function in (1.11) and finding partial derivatives implies that

$$\frac{\partial y_t^H}{\partial P_t^C} < 0, \qquad \frac{\partial y_t^H}{\partial P_t^H} > 0, \qquad \frac{\partial y_t^H}{\partial \eta_t} > 0. \tag{1.13}$$

A result that will be applied below.

The market for housing is in equilibrium when

$$H_t^{AGG} = (1-\delta) H_{t-1}^{AGG} + y_t^H \tag{1.14}$$

and the trade balance (z_t) is determined by

$$z_t = y_t - c_t^{AGG}$$

which closes the model.

1.3 Steady state

It turns out that the model has a well defined steady state solution, see appendix A for the full derivation, and that it is possible to derive the following comparative static result

$$\frac{dP^H}{dd} = \frac{\lambda \frac{\delta}{a}\left(\frac{(1+r)}{(1+\rho^C)} - 1\right) P^H}{\frac{\frac{\gamma}{1-\gamma} y^H \left(\frac{N_C}{L}\right)^{1-\gamma}}{\left(\left(\frac{N_C}{L}\right)^{1-\gamma} + \left(\frac{N_H}{L}\right)^{1-\gamma} P^H\right) P^H} + \lambda \frac{\delta}{a}\left[\frac{d(1+\rho^C)+(1-d)(1+r)-(1-\delta)}{(1+\rho^C)}\right] + (1-\lambda)\frac{\delta}{a}\left[\frac{(\delta+r)}{(1+r)}\right]}, \tag{1.15}$$

which implies that $\frac{dP^H}{dd} < 0$ as $(1+\rho^C) > (1+r)$, i.e. higher down payments will result in a lower steady state price as constrained households discount the future at a higher rate than the interest rate. Furthermore note, not surprisingly, that this change is increasing in the share oj liquidity constrained households, λ. The idea is the following: if liquidity constrained households are impatient they consider the down payment an extra cost since they would optimally like to smooth consumption even further. They therefore decrease their demand for housing when d is larger, which results in a decrease in the steady state price. As non-liquidity constraint households are not affected by the down payment requirements it is clear that the steady state prices would not be affected by the change in d if no households where liquidity constrained. Further, for a given ρ^C, a lower interest rate will amplify the increase in steady state prices from the introduction of new mortgage types. This is naturally the case as the down payment will be a larger part of the current expenditure of having a

house. This might suggest that the general trend towards mortgages with low down payments could in part be due to the historically low interest rates of the 21'st century.

1.4 The volatility of prices

The central theme of this analysis is the stability of housing prices. Housing price drops seem to spill over to real activity in a non-trivial way, causing financial distress and unwanted redistribution between generations. Hence, the stability of the housing market is central for policymakers and could call for automatic stabilizers e.g. taxation on capital gains from housing or macroprudential regulation. I therefore analyze the sensitivity of housing prices to technology shocks in this section. The simplicity of the setup allows for an analytical analysis of second moment properties around the steady state.

To obtain analytical results the system is linearized around the steady state for the production side of the economy. First of all, the first-order Taylor approximation of optimal production scheme given in equation (1.11) around the initial steady state is

$$\tilde{y}_t^H = \gamma_0 \tilde{P}_t^H + \gamma_1 \varepsilon_t, \tag{1.16}$$

where the "~" indicates deviations from the steady state values. The sign of $\gamma_0, \gamma_1 > 0$ follows from the partial derivatives found in equation (1.13). In equilibrium production must equal demand, which can be written in terms of deviations from the steady state

$$\begin{aligned} \tilde{y}_t^H &= \lambda \left[-\frac{1}{a}\left(d - \frac{(1-d)(1+r)}{(1+\rho^C)} \right) \tilde{P}_t^H + \frac{1}{a}\frac{(1-\delta)}{(1+\rho^C)} E_t\left[\tilde{P}_{t+1}^H\right] \right] \\ &+ (1-\lambda)\left[-\frac{1}{a}\tilde{P}_t^H + \frac{1}{a}\frac{(1-\delta)}{(1+r)} E_t\left[\tilde{P}_{t+1}^H\right] \right] \\ &- (1-\delta)\left[\lambda \tilde{H}_{t-1}^C + (1-\lambda)\tilde{H}_{t-1}^{NC} \right] \end{aligned} \tag{1.17}$$

and by combining equation (1.9), (1.16) and (1.17) the following result is obtained

$$\tilde{P}_t^H = -\frac{\gamma_1}{\chi_1}\varepsilon_t + \frac{\chi_2}{\chi_1} E_t\left[\tilde{P}_{t+1}^H\right] - \frac{(1-\delta)}{\chi_1}\tilde{H}_{t-1}^{AGG}, \tag{1.18}$$

where

$$\chi_1 \equiv \gamma_0 + \frac{\lambda}{a}d + \frac{\lambda}{a}\frac{(1-d)(1+r)}{(1+\rho^C)} + \frac{(1-\lambda)}{a}$$

and

$$\chi_2 \equiv \frac{\lambda}{a}\frac{(1-\delta)}{(1+\rho^C)} + \frac{(1-\lambda)}{a}\frac{(1-\delta)}{(1+r)},$$

where it is implicitly assumed that $\delta < 1$ as $\chi_2 = 0$ for $\delta = 1$. Now, it is possible to apply the method of undetermined coefficients with the following conjecture for the solution of (1.18)

$$\tilde{P}_t^H = \pi_0 + \pi_1 \varepsilon_t + \pi_2 \tilde{H}_{t-1}^{AGG} \tag{1.19}$$

In appendix B it is shown that two real solutions for π_0, π_1, and π_2 exist, and that solution can be written as a system of equations given by

$$\begin{bmatrix} \tilde{P}_t^H \\ \tilde{H}_t^{AGG} \end{bmatrix} = \begin{bmatrix} 0 & \pi_2 \\ 0 & \gamma_0\pi_2 + (1-\delta) \end{bmatrix} \begin{bmatrix} \tilde{P}_{t-1}^H \\ \tilde{H}_{t-1}^{AGG} \end{bmatrix} + \begin{bmatrix} \pi_1 \\ \gamma_0\pi_1 + \gamma_1 \end{bmatrix} \varepsilon_t. \tag{1.20}$$

It follows straight forwardly that this system is stable if and only if

$$|\gamma_0\pi_2 + (1-\delta)| < 1.$$

In appendix C it is shown that the solution (π_1^*, π_2^*) is the only solution that satisfies the stability condition. Hence, attention is restricted to this solution. The following results are all derived in appendix C. First of all,

$$\gamma_0\pi_2^* + (1-\delta) > 0 \; and \; \frac{\partial \pi_2^*}{\partial d} > 0,$$

i.e. the persistence in the housing stock is decreased if d is reduced and liquidity constrained households are impatient. Hence, prices will converge faster to the steady state value if liquidity constrained households have access to new mortgage products with lower amortization. Regarding π_1^* the following results can be derived

$$\pi_1^* < 0 \; and \; \frac{\partial \pi_1^*}{\partial d} > 0.$$

So prices become more volatile with respect to production shocks if down payments are reduced. As a last point note that

$$\gamma_0\pi_1^* + \gamma_1 > 0.$$

Implying that the initial shock to the housing stock is decreased if there is access to loans with low down payments. To sum up, prices become more volatile when households have to make lower down payments, however, prices converge faster to the steady state. In other words, there exists a trade off between persistence and volatility.

A different instantaneous utility

In the derivation above, quadratic satiation point preferences were used to get a linear demand for housing. The aim of this section is to analyze the effect of using the

more commonly used instantaneous utility of log preferences to see if the results are sensitive to the non-standard assumption of quadratic satiation point preferences. This comes at a cost, as I am no longer able to analyze the second moment properties analytically, however, it is still possible to analyze the impulse response functions for a specific parametrization. Specifically, it is assumed that the instantaneous utility is given by

$$u(c_t^i, h_t^i) = c_t^i + b\log(H_t^i), \tag{1.21}$$

where b is the preference parameter for housing. Everything else is assumed to be the same. Using this specification leads to the following proposition regarding the steady state

PROPOSITION 1 *In the steady state* $\frac{dP^H}{dd} < 0$ *if* $(1+\rho^C) > (1+r)$*, i.e. higher down payments will result in a lower steady state price if constrained households discount the future at a higher rate than the interest rate.*

PROOF. The non-liquidity constrained households maximize their expected lifetime utility given in equation (1.1) with the instantaneous utility given in (1.21) by choosing $\left(c_s, h_s\right)_{s=0}^{\infty}$ s.t. (1.3) and (1.4). Hence, the optimal consumption plan is governed by the following two Euler equations

$$h_t^{NC} = (1+r)a\left((1+r)P_t^H - \left(1-\delta\right)E_t\left[P_{t+1}^H\right]\right)^{-1} - H_{t-1}(1-\delta)$$

and

$$(1+\rho^{NC}) = (1+r).$$

The liquidity constrained households maximize (1.1) by choosing $\left(h_s\right)_{s=0}^{\infty}$ with the instantaneous utility given in (1.21) s.t. (1.3) and (1.7). This leads to the following Euler equation

$$h_t = a(1+\rho)(dP_t^H(1+\rho) + (1+r)(1-d)P_t - E_t\left[P_{t+1}^H\right](1-\delta))^{-1} - H_{t-1}(1-\delta).$$

Now combining the steady state conditions given in (1.24), (1.25), (1.28), and (1.29) with the Euler equations implicitly defines the steady state price. Computing the total differential leads to the result given in proposition 1. ■

This implies that the qualitative implications regarding the steady state are unaffected by the new choice of instantaneous utility.

The results regarding the dynamics around the steady state are less straight forward. First of all, linearizing the Euler equation for the constrained households leads to the following result

$$\tilde{h}_t^C = B_1^C \tilde{P}_t^H + B_2^C E_t\left[\tilde{P}_{t+1}^H\right] - \tilde{H}_{t-1}^C(1-\delta), \tag{1.22}$$

where

$$B_1^C = -\frac{b}{\left(dP^H + \frac{(1+r)}{(1+\rho^C)}(1-d)P^H - E_t\left[P^H\right]\frac{(1-\delta)}{(1+\rho^C)}\right)^2}\left[d + \frac{(1+r)}{(1+\rho^C)}(1-d)\right] < 0$$

and

$$B_2^C = \frac{b}{\left(dP^H + \frac{(1+r)}{(1+\rho^C)}(1-d)P^H - E_t\left[P^H\right]\frac{(1-\delta)}{(1+\rho^C)}\right)^2}\frac{(1-\delta)}{(1+\rho^C)} > 0$$

and similarly for non-constrained households

$$\tilde{h}_t^{NC} = B_1^{NC} \tilde{P}_t^H + B_2^{NC} E_t\left[\tilde{P}_{t+1}^H\right] - \tilde{H}_{t-1}^{NC}(1-\delta) \tag{1.23}$$

where

$$B_1^{NC} = -\frac{b}{\left(P^H - \frac{(1-\delta)}{(1+r)}E_t\left[P^H\right]\right)^2} < 0$$

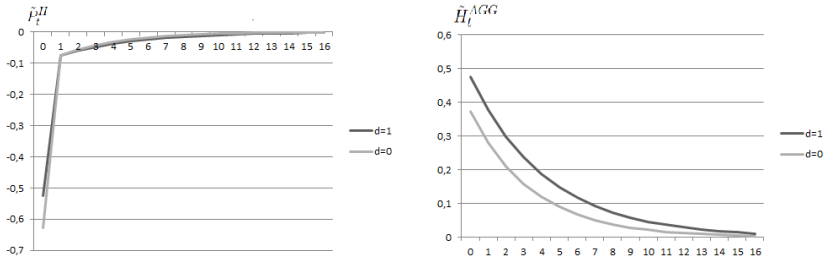
and

$$B_2^{NC} = \frac{b}{\left(P^H - \frac{(1-\delta)}{(1+r)}E_t\left[P^H\right]\right)^2}\frac{(1-\delta)}{(1+r)} > 0.$$

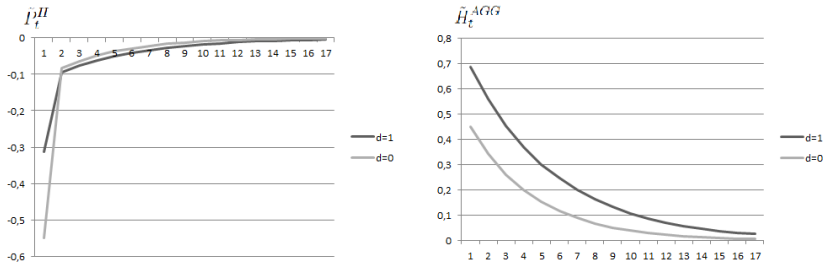
Note that the coefficients B_1^C, B_2^C, B_1^{NC}, and B_2^{NC} now depend on the initial steady state. So from an analytical point of view it is only possible to show that $\frac{\partial B_1^C}{\partial d} \lesseqgtr 0$, $\frac{\partial B_2^C}{\partial d} \lesseqgtr 0$, $\frac{\partial B_1^{NC}}{\partial d} < 0$, and $\frac{\partial B_2^{NC}}{\partial d} > 0$. Further, due to the complexity of the setup it is not possible to impose economically meaningful sufficient conditions to ensure the same unambiguous results found for the first model. Therefore attention is restricted to a specific comparable example given in figure 1.1.

Figure 1.1. Impulse response graphs

Model with satiation point utility



Model with log utility



Note: Upper left and upper right figures show the results for the model with satiation point utility with the following parameter values: $\gamma_0 = 1$, $\gamma_1 = 1$, $\lambda = 0.5$, $a = 1$, $r = 0.02$, $\rho_C = 2$, $\delta = 0.05$, and $d = 0$ or $d = 1$, respectively. The response is shown for a shock of size 1, i.e. $\varepsilon_0 = 1$. The results are found using π_1^* and π_2^* found in appendix C. Lower left and lower right figures show the results for the model with log utility with the following parameter values: $\gamma_0 = 1$, $\gamma_1 = 1$, $\lambda = 0.5$, $b = 1000$, $r = 0.02$, $\rho_C = 2$, $\delta = 0.05$, $\bar{\eta} = 1$, $\gamma = 0.8$, $N_{NH}/\bar{L} = 0.5$, $\varepsilon_0 = 1$ and $d = 0$ or $d = 1$, respectively. The results are found using the linearizations given in (1.22) and (1.23), and finding the steady state price numerically from the expression implicitly defining the steady state price found in the proof for proposition 1, and with the solutions π_1^* and π_2^* .

For the example shown in figure 1 it seems that the qualitative results regarding the dynamics around the steady state are similar for both utility specifications. Namely, that lower down payments increase the volatility of prices and that prices return faster to the steady state. There is, however, an underlying difference. In the first model with satiation point preferences, the demand for housing by the non-constrained households where unaffected by changes in d. The volatility increased only because liquidity constrained households were more responsive to price changes

when they had to make higher down payments. This is not the case for the second model with log utility. The demand for housing is affected by d for both household types. Further, for the specific example given in figure 1 it turns out that most of the extra production from the technology shock is absorbed by the non-constrained households when $d = 1$. The opposite holds when $d = 0$, i.e. the liquidity constrained households absorb most of the extra production. The intuition is that when d is high the liquidity constrained households demand very little housing which result in lower steady state prices. For low prices non-liquidity constrained households are very responsive to price changes, and this responsiveness results in the lower price volatility. On the other hand, when d is low the demand is higher which will increase the steady state price. In this case, most of the shock is absorbed by liquidity constrained households which are, compared to the former case, less responsive, even though their own responsiveness is increased when d is lowered for this specific example.

It seems that the qualitative results presented in this paper are robust to different utility specifications, at least in the quasi linear class of preferences. It is left for future research to expand on the ideas given in this paper to more general setups that incorporate e.g. income effects, and setups that analyze the welfare effects more rigorously.

1.5 Conclusion

In this paper, I have investigated how and to what extent higher loan to value requirements can affect the housing market. A connection that seems very important in most western countries as the stability of the housing market affects the economy altogether. The model suggested in this paper yields the following results: The introduction of new mortgage products will only affect demand for housing if liquidity constrained households are impatient (relative to the interest rate). The intuition is that even though down payments are really just a forced form of savings that liquidity constrained households can recover in the next period as they are allowed to renegotiate their loan, it is considered an extra cost by impatient liquidity constrained households as these households would optimally smooth consumption even further. The non-liquidity constrained households are on the other hand unaffected by the introduction of new mortgage types as they have access to internationally traded bonds which have the same features as the mortgage bonds. Stated differently, a forced down payment can be counteracted by an opposite position in internationally traded bond. Further, the analysis showed that housing was demanded above the households' satiation point if it was perceived to be a better investment than the internationally traded bond. This clearly illustrated the investment and consumption nature of housing. From the steady state solution of the model, it was found that steady state prices indeed increased if households are allowed to amortize less.

Further, the model was also analyzed around the steady state, and it was found that there exists a trade off between the price volatility and persistence. A relationship that seems robust to different specifications of the instantaneous utility.

The model adds to the existing literature by allowing for analytical analysis of second moment properties of housing prices. The results are in line with models that deal with financial liberalizations. Namely, that housing prices are indeed affected by the mortgage types available, and that the new financial products unambiguously increase prices. Further, the model suggests a new simple way to incorporate down payments into more quantitatively realistic DSGE setups, which could shed more light on the stability aspect of housing prices. However, due to the lack of risk aversion in the model, as quasi linear utility is used, it is not possible to make a meaningful welfare analysis by comparing the welfare gain from further consumption smoothing to the welfare loss from less stability. This would indeed be a very interesting path for future research.

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1.7 Appendix A

Consider a steady state where prices, production, and financial wealth of the non liquidity constrained households are constant. Note that the time subscripts are dropped for the steady state values. The steady state is analyzed in an initial situation where $\eta_t = \bar{\eta}$. Note that from equation (1.3) it must hold that

$$\delta H^C = h^C \tag{1.24}$$

and

$$\delta H^{NC} = h^{NC} \tag{1.25}$$

in the steady state. And combining these with the Euler equations in (1.8) and (1.6) yields

$$h^C = \delta \bar{H} - \frac{\delta}{a}\left[d + \frac{(1-d)(1+r)}{(1+\rho^C)} - \frac{(1-\delta)}{(1+\rho^C)}\right] P^H \tag{1.26}$$

and

$$h^{NC} = \delta \bar{H} - \frac{\delta}{a}\left[1 - \frac{(1-\delta)}{(1+r)}\right] P^H. \tag{1.27}$$

As $E\left[\eta\right] = \bar{\eta}$ and as all other endogenous variables are constant in the steady state it follows that $E\left[P^H\right] = P^H$. Further, from equation (1.14) it must hold in the steady state that

$$\delta H^{AGG} = y^H$$

and inserting (1.24), (1.25), and (1.9) yields

$$\lambda h^C + (1-\lambda) h^{NC} = y^H, \tag{1.28}$$

implying that in the steady state equilibrium the demand for housing must equal supply. Also note that rewriting the equilibrium condition for the labor market given in equation (1.12) implies that the steady state wage is given by

$$W = \left(\frac{N_C}{\bar{L}}\right)^{1-\gamma} \eta + \left(\frac{N_H}{\bar{L}}\right)^{1-\gamma} \eta P^H. \tag{1.29}$$

Finally, combining equation (1.11), (1.26), (1.27), (1.28), and (1.29), and rewriting gives

$$-\lambda\frac{\delta}{a}\left[d+\frac{(1-d)(1+r)}{(1+\rho^C)}-\frac{(1-\delta)}{(1+\rho^C)}\right]P^H$$
$$-(1-\lambda)\frac{\delta}{a}\left[1-\frac{(1-\delta)}{(1+r)}\right]P^H \quad =$$
$$\frac{1}{\gamma}\eta\left(\frac{P^H}{\left(\frac{N_C}{\bar{L}}\right)^{1-\gamma}+\left(\frac{N_H}{\bar{L}}\right)^{1-\gamma}P^H}\right)^{\frac{\gamma}{1-\gamma}}-\delta\bar{H}$$

which implicitly defines the equilibrium steady state price. Finding the total differential and simplifying yields equation (1.15).

1.8 Appendix B

From the conjecture given in equation (1.19) we have that

$$E_t\left[\tilde{P}^H_{t+1}\right]=\pi_0+\pi_1E_t\left[\varepsilon_{t+1}\right]+\pi_2E_t\left[\tilde{H}^{AGG}_t\right]=\pi_0+\pi_2E_t\left[\tilde{H}^{AGG}_t\right]$$

which combined with (1.18) implies

$$\pi_0+\pi_1\varepsilon_t+\pi_2\left(\tilde{H}^{AGG}_{t-1}-\frac{\chi_2}{\chi_1}E_t\left[\tilde{H}^{AGG}_t\right]\right)=-\frac{\gamma_1}{\chi_1}\varepsilon_t+\frac{\chi_2}{\chi_1}\pi_0-\frac{(1-\delta)}{\chi_1}\tilde{H}^{AGG}_{t-1}. \tag{1.30}$$

From the equilibrium condition given in equation (1.14) and the linearization given in (1.16) the following must hold

$$\tilde{H}^{AGG}_t=(1-\delta)\tilde{H}^{AGG}_{t-1}+\gamma_0\tilde{P}^H_t+\gamma_1\varepsilon_t. \tag{1.31}$$

Inserting this in equation (1.30), solving for $\tilde{P}^H_t$, and simplifying yields

$$\tilde{P}^H_t=\left[\frac{\gamma_1+\chi_1\pi_1-\gamma_1\chi_2\pi_2}{\chi_2\pi_2\gamma_0}\right]\varepsilon_t+\left[\frac{(1-\delta)+\chi_1\pi_2-(1-\delta)\chi_2\pi_2}{\chi_2\pi_2\gamma_0}\right]\tilde{H}^{AGG}_{t-1}+\left[\frac{\chi_1-\chi_2}{\chi_2\pi_2\gamma_0}\right]\pi_0.$$

Combined with the conjecture given in (1.19) this implies that

$$\left[\frac{\chi_1-\chi_2}{\chi_2\pi_2\gamma_0}\right]\pi_0=\pi_0\Rightarrow\pi_0=0$$

and that the direct effect on prices originating from the shock ε_t is given by

$$\pi_1=\frac{\gamma_1+\chi_1\pi_1-\gamma_1\chi_2\pi_2}{\chi_2\pi_2\gamma_0}. \tag{1.32}$$

Further, the persistence effect coming from a change in the housing stock must satisfy

$$\pi_2 = \frac{(1-\delta)+\chi_1\pi_2-(1-\delta)\chi_2\pi_2}{\chi_2\pi_2\gamma_0}. \tag{1.33}$$

Note that combining (1.19) and (1.31) yields equation (1.20). Rewriting equation (1.33) gives

$$-\chi_2\gamma_0\pi_2^2+\left[\chi_1-\chi_2(1-\delta)\right]\pi_2+(1-\delta)=0.$$

And solving for π_2 gives

$$\pi_2^{\#} = \frac{\left[\chi_1-\chi_2(1-\delta)\right]+\sqrt{\left[\left[\chi_1-\chi_2(1-\delta)\right]\right]^2+4\chi_2\gamma_0(1-\delta)}}{2\chi_2\gamma_0} \tag{1.34}$$

and

$$\pi_2^{*} = \frac{\left[\chi_1-\chi_2(1-\delta)\right]-\sqrt{\left[\left[\chi_1-\chi_2(1-\delta)\right]\right]^2+\chi_2\gamma_0(1-\delta)}}{2\chi_2\gamma_0}, \tag{1.35}$$

which are both real. Rewriting equation (1.32) yields

$$\pi_1 = \frac{\gamma_1\left[\pi_2\chi_2-1\right]}{\left(\chi_1-\pi_2\chi_2\gamma_0\right)}. \tag{1.36}$$

Inserting (1.34) and (1.35), respectively, into (1.36) and simplifying gives

$$\pi_1^{\#} = \frac{\gamma_1}{\gamma_0}\left[\frac{\left[\chi_1-\chi_2(1-\delta)\right]-2\gamma_0+\sqrt{\left[\left[\chi_1-\chi_2(1-\delta)\right]\right]^2+\chi_2\gamma_0(1-\delta)}}{\left[\chi_1+\chi_2(1-\delta)\right]-\sqrt{\left[\left[\chi_1-\chi_2(1-\delta)\right]\right]^2+\chi_2\gamma_0(1-\delta)}}\right]$$

and

$$\pi_1^{*} = \frac{\gamma_1}{\gamma_0}\left[\frac{\left[\chi_1-\chi_2(1-\delta)\right]-2\gamma_0-\sqrt{\left[\left[\chi_1-\chi_2(1-\delta)\right]\right]^2+\chi_2\gamma_0(1-\delta)}}{\left[\chi_1+\chi_2(1-\delta)\right]+\sqrt{\left[\left[\chi_1-\chi_2(1-\delta)\right]\right]^2+\chi_2\gamma_0(1-\delta)}}\right]$$

which both satisfies the conjecture and therefore constitute equilibria.

1.9 Appendix C

Recall that the dynamics can be written as

$$\begin{bmatrix} \tilde{P}_t^H \\ \tilde{H}_t^A \end{bmatrix} = \begin{bmatrix} 0 & \pi_2 \\ 0 & \gamma_0\pi_2 + (1-\delta) \end{bmatrix} \begin{bmatrix} \tilde{P}_{t-1}^H \\ \tilde{H}_{t-1}^A \end{bmatrix} + \begin{bmatrix} \pi_1 \\ \gamma_0\pi_1 + \gamma_1 \end{bmatrix} \varepsilon_t.$$

Stability requires

$$|\gamma_0\pi_2 + (1-\delta)| < 1.$$

I now show that this holds for all solutions of π_2^*. Note that

$$\gamma_0\pi_2^* + (1-\delta) = \frac{[\chi_1 + \chi_2(1-\delta)] - \sqrt{\left[[\chi_1 - \chi_2(1-\delta)]\right]^2 + \chi_2\gamma_0(1-\delta)}}{2\chi_2} > 0.$$

Using simplified notation, see that

$$A + B - \sqrt{(A-B)^2 + C} > 0$$

is equivalent to

$$4AB > C,$$

again equivalent to

$$4\chi_1\chi_2(1-\delta) > \chi_2\gamma_0(1-\delta)$$

or

$$4\left(\gamma_0 + \frac{\lambda}{a}d + \frac{\lambda}{a}\frac{(1-d)(1+r)}{(1+\rho^C)} + \frac{\left(1-\lambda\right)}{a}\right) > \gamma_0$$

which naturally holds. Note further that

$$\frac{[\chi_1 + \chi_2(1-\delta)] - \sqrt{\left[[\chi_1 - \chi_2(1-\delta)]\right]^2 + \chi_2\gamma_0(1-\delta)}}{2\chi_2} < 1$$

equivalent to

$$\chi_1 - \chi_2(1-\delta) - \sqrt{\left[[\chi_1 - \chi_2(1-\delta)]\right]^2 + \chi_2\gamma_0(1-\delta)} - 2\delta\chi_2 < 0$$

which is always satisfied. So this solution is always stable. For $\pi_2^\#$ we get an unstable solution if

$$\gamma_0\pi_2^\# + (1-\delta) = \frac{[\chi_1 + \chi_2(1-\delta)] + \sqrt{\left[[\chi_1 - \chi_2(1-\delta)]\right]^2 + \chi_2\gamma_0(1-\delta)}}{2\chi_2} > 1$$

or equivalently

$$[\chi_1 - \chi_2(1-\delta)] + \sqrt{\left[[\chi_1 - \chi_2(1-\delta)]\right]^2 + \chi_2\gamma_0(1-\delta)} - 2\chi_2\delta > 0.$$

It is there sufficient to show that

$$2[\chi_1 - \chi_2(1-\delta)] > 2\chi_2\delta$$

which simplifies to

$$\chi_1 > \chi_2$$

which is always satisfied. So all $\pi_2^{\#}$ solutions are unstable. Hence, I only consider the π_1^*, π_2^* solution. Recall further that

$$\pi_2^* = \frac{[\chi_1 - \chi_2(1-\delta)] - \sqrt{\left[[\chi_1 - \chi_2(1-\delta)]\right]^2 + \chi_2\gamma_0(1-\delta)}}{2\chi_2\gamma_0}$$

where

$$\chi_1 \equiv \gamma_0 + \frac{\lambda}{a}d + \frac{\lambda}{a}\frac{(1-d)(1+r)}{(1+\rho^C)} + \frac{(1-\lambda)}{a}$$

and

$$\chi_2 \equiv \frac{\lambda}{a}\frac{(1-\delta)}{(1+\rho^C)} + \frac{(1-\lambda)}{a}\frac{(1-\delta)}{(1+r)}.$$

We see immediately that

$$\pi_2^* < 0$$

as

$$A - B < \sqrt{(A-B)^2 + C}$$

where we know that

$$C > 0.$$

Further note that

$$\begin{aligned}\frac{\partial \pi_2^*}{\partial d} &= \frac{1}{2\chi_2\gamma_0}\left[\frac{\partial \chi_1}{\partial d} - \frac{1}{2}\frac{2\left[\chi_1 - \chi_2(1-\delta)\right]}{\sqrt{\left[\left[\chi_1 - \chi_2(1-\delta)\right]^2 + \chi_2\gamma_0(1-\delta)\right]}}\frac{\partial \chi_1}{\partial d}\right] \\ &= \frac{1}{2\chi_2\gamma_0}\left[\frac{\sqrt{\left[\left[\chi_1 - \chi_2(1-\delta)\right]^2 + \chi_2\gamma_0(1-\delta)\right]} - \left[\chi_1 - \chi_2(1-\delta)\right]}{\sqrt{\left[\left[\chi_1 - \chi_2(1-\delta)\right]^2 + \chi_2\gamma_0(1-\delta)\right]}}\right]\frac{\partial \chi_1}{\partial d} > 0\end{aligned}$$

where

$$\frac{\partial \chi_1}{\partial d} = \frac{\lambda}{a}\left(1 - \frac{(1+r)}{(1+\rho^C)}\right) > 0$$

and be aware that

$$\pi_1^* = \frac{\gamma_1\left[\pi_2^*\chi_2 - 1\right]}{\left(\chi_1 - \pi_2^*\chi_2\gamma_0\right)}$$

and

$$\pi_1^* = \frac{\gamma_1}{\gamma_0}\left[\frac{\left[\chi_1 - \chi_2(1-\delta)\right] - 2\gamma_0 - \sqrt{\left[\left[\chi_1 - \chi_2(1-\delta)\right]\right]^2 + \chi_2\gamma_0(1-\delta)}}{\left[\chi_1 + \chi_2(1-\delta)\right] + \sqrt{\left[\left[\chi_1 - \chi_2(1-\delta)\right]\right]^2 + \chi_2\gamma_0(1-\delta)}}\right] < 0$$

implying that

$$\begin{aligned}\frac{\partial \pi_1^*}{\partial d} &= \underbrace{\frac{\gamma_1}{\gamma_0}}_{>0}\left[\underbrace{1 - \frac{\left[\chi_1 - \chi_2(1-\delta)\right]}{\sqrt{\left[\left[\chi_1 - \chi_2(1-\delta)\right]^2 + \chi_2\gamma_0(1-\delta)\right]}}}_{>0}\right]\underbrace{\frac{\partial \chi_1}{\partial d}B^{-1}}_{>0} \\ &\quad -\frac{\gamma_1}{\gamma_0}\underbrace{\frac{A}{B^2}}_{<0}\left[\underbrace{1 + \frac{\left[\chi_1 - \chi_2(1-\delta)\right]}{\sqrt{\left[\left[\chi_1 - \chi_2(1-\delta)\right]^2 + \chi_2\gamma_0(1-\delta)\right]}}}_{>0}\right]\frac{\partial \chi_1}{\partial d} > 0\end{aligned}$$

where

$$A = [\chi_1 - \chi_2(1-\delta)] - 2\gamma_0 - \sqrt{\left[[\chi_1 - \chi_2(1-\delta)]\right]^2 + \chi_2\gamma_0(1-\delta)}$$

and

$$B = [\chi_1 + \chi_2(1-\delta)] + \sqrt{\left[[\chi_1 - \chi_2(1-\delta)]\right]^2 + \chi_2\gamma_0(1-\delta)}.$$

As a last point, note that

$$\gamma_0\pi_1 + \gamma_1 = \gamma_1 \left[\frac{[\chi_1 - \chi_2(1-\delta)] - 2\gamma_0 - \sqrt{\left[[\chi_1 - \chi_2(1-\delta)]\right]^2 + \chi_2\gamma_0(1-\delta)}}{[\chi_1 + \chi_2(1-\delta)] + \sqrt{\left[[\chi_1 - \chi_2(1-\delta)]\right]^2 + \chi_2\gamma_0(1-\delta)}} \right] + \gamma_1 > 0$$

equivalent to

$$\left[\frac{[\chi_1 + \chi_2(1-\delta)] + [\chi_1 - \chi_2(1-\delta)] - 2\gamma_0}{[\chi_1 + \chi_2(1-\delta)] + \sqrt{\left[[\chi_1 - \chi_2(1-\delta)]\right]^2 + \chi_2\gamma_0(1-\delta)}} \right] > 0$$

which is satisfied when

$$\chi_1 > \gamma_0$$

equivalent to

$$\frac{\lambda}{a}d + \frac{\lambda}{a}\frac{(1-d)(1+r)}{(1+\rho^C)} + \frac{(1-\lambda)}{a} > 0$$

which naturally always holds.

CHAPTER 2

CREDIT POLICIES BEFORE AND DURING THE FINANCIAL CRISIS

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Abstract[1]

This paper empirically distinguishes between the two main contending explanations for credit cycles. Namely, the bank lending channel and the balance sheet channel. This is done by using unique Danish survey, register, rating, and bank data. The results indicate that the bank lending channel explains most of the changes in credit policy by Danish banks towards small and medium (SME) sized firms. However, the results show that both channels are operational, but the balance sheet channel is surprisingly weak partly because discouragement during the crisis kept struggling firms from applying for credit. The analysis also reveals that the credit supply was

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weaker in banks that were struggling during the crisis and indirectly that firms could not off-set this effect by changing banks. Furthermore, the evidence suggests that the financial crisis also affected the liquidity of non-financial firms, as credit demand rose immediately following the crisis.

JEL-Codes: E32, E44, G21, G32.

Keywords: Business Fluctuations, Financial Markets and the Macroeconomy, Banks, and Credit Policies.

2.1 Introduction

Does the availability of credit depend on the financial health of banks and/or the balance sheets of borrowing firms? Stated differently, does the agency cost of borrowing between banks and their depositors, the so-called bank lending channel as in e.g. Gertler and Kiyotaki (2010), make lending significantly less likely during a period of low economic activity? Or do lending contract as the value of firms' assets depreciate during a recession, the so-called balance sheet channel as in Kiyotaki and Moore (1997) and Bernanke, Gertler, and Gilchrist (1999) (BGG, henceforth), which increase agency costs between firms and their banks? And, are the bank lending channel and balance sheet channel both operational, and if so, which is better at explaining credit cycles?

The main challenge is to separate the two channels because how do you disentangle credit demand from supply? Most studies focus on either macro data (e.g. Bernanke and Blinder (1992)) or on bank level data as in Kashyap and Stein (2000), and thereby potentially neglect important effects. However, a sparse but growing literature has developed different identification strategies. One strategy is to use credit register data on firms that have multiple lenders to control for demand effects, see e.g. Albertazzi and Marchetti (2010) and Iyer et al. (2014). This strategy is further extended to include loan applications and outcomes on the extensive margin in Jimenez et al. (2012). [2] However, these strategies do not take into account the changing composition of firms that demand bank loans as they do not observe which firms select themselves out of the loan application process due to discouragement. Some firms will not apply for loans as they simply have no need for credit and some firms might be discouraged from applying as the general lending environment is deteriorating. This could potentially lead to an underestimation of the true extent of the bank lending channel. Another strategy is to identify constrained firms from survey data which contains information on loan applications, outcomes, and whether firms were discouraged as in Presbitero et al. (2014), Puri et al. (2011), and Popov and Udell (2012). However, these survey based studies can only to a very limited extent

[2] Loan applications are identified from information requests on firms that have applied for a loan in a specific Spanish bank. The applications are on the extensive margin as they only observe applications made to banks in which the firm is not currently a customer.

account for declining profits of firms during the business cycle, as they lack good controls. Further, the application outcomes cannot be linked to specific banks and are therefore only linked to banks geographically.

The main contribution to the literature of this paper is to combine the advantages of survey data with the advantages of register data. Specifically, this study utilizes a credit survey from Statistics Denmark on the credit availability for small and medium sized firms before and during the financial crisis. This survey is linked using a unique firm identifier to register and credit rating data. Further, the survey can be linked to specific banks using information regarding the primary banking connection of firms provided by the credit rating company Experian. This is, to the best of my knowledge, the first study to combine the advantages of all data types to address the questions raised above.

The study yields the following main results: the bank lending channel explains most of the changes in credit policy by Danish banks towards small and medium (SME) sized firms. However, the results show that both channels are operational, but the balance sheet channel is surprisingly weak as self-selection into the loan application process during the crisis kept struggling firms from applying for credit. The analysis also reveals that the credit supply was weaker in banks that were struggling during the crisis and indirectly that firms could not off-set this effect by changing banks. Furthermore, the evidence suggests that the financial crisis also affected the liquidity of non-financial firms, as credit demand rose immediately following the crisis.

The paper is structured in the following way: section 2 discusses the two main contending explanations for credit cycles. Section 3 explains the data and section 4 includes the empirical analysis. Section 5 discusses whether credit risk can be evaluated from firm specific information and thereby disentangled from macroeconomic conditions, and section 6 concludes.

2.2 The balance sheet channel vs. the bank lending channel

This section will discuss how financial frictions are thought to affect the real economy. The overall question is how the financial crisis affected firms and/or banks and how this affected lending activities. Further, the section outlines how the theories differ and what implications they will have for the empirical analysis. For a more in-depth discussion of the different credit channels, see e.g. Bernanke (2007) or Hall (2001).

The balance sheet channel

The balance sheet channel or the firm balance sheet channel describes the connection between the borrowers' financial health and the price of external credit or access to credit. It basically links credit supply to economy-wide fluctuations and generates

a so-called financial accelerator effect, i.e. financial markets amplify relatively small shocks to e.g. productivity.

The BGG model works by linking agency costs and therefore the external finance premium, and the borrowers' financial health. In most other respects, the BGG model is a standard dynamic new Keynesian macroeconomic model. Specifically, BGG assumes that lenders face observation costs with respect to the outcome of borrowers' investments. This is the so-called 'costly state verification' (CSV) setup first analyzed by Townsend (1979) and it implies that the financial structure has a nontrivial role. As observation is costly, lenders charge a premium to cover their expected monitoring costs. The size of this premium is determined by corporate net worth or in other words the firms' financial health. Without asymmetric information, entrepreneurs would acquire capital until the expected return is equal to the cost of funds. In the BGG setup, on the other hand, if a substantial/low portion of an investment project is financed by internal finance it implies a low/high external finance premium which tends to raise/depress investment. The underlying idea is that net worth can be seen as the firms' own stake in a project and therefore increase incentive alignment between borrowers and lenders. Stated differently, lenders would only be willing to lend funds to firms if they get a premium large enough to cover the cost of the greater likelihood of default caused by the borrowers' lower stake in the project. One of the main implications of the model is that the agency cost may vary over time as financial positions fluctuate over the course of the business cycle. In the context of this paper, it is important to note that the external finance premium is therefore counter cyclical, or stated differently, the incentive problem could potentially be very pronounced in times of crisis.

The Kiyotaki and Moore (1997) model differs by looking at collateral constraints as opposed to information asymmetries. They theorize that durable assets perform an important role as collateral for lending. If agents have to put up collateral to get loans, a shock to aggregate demand would not only affect firms directly, but also limit their access to credit as the value of a firm's assets depend on economic activity. The idea is therefore closely related to that of BGG, but focuses instead on collateral constraints rather than information asymmetries. Further, the effects are to a large extent similar, namely, amplified and prolonged shocks. In general these theories are not mutually exclusive, but rather two ways of explaining the same phenomenon and therefore complement each other.

The two frameworks discussed above have been extended and modified in too many ways to be replicated here. However, the underlying logic is basically the same. Namely, that during the course of the business cycle, agency costs are dependent on the economic environment, see Christiano and Ikeda (2012) for a review of the different approaches to modeling financial frictions. To distinguish between the balance sheet channel and the bank lending channel, note that the balance sheet channel approach is related to balance sheet of borrowers. However, it is natural to

assume that the same kind of agency problems could apply to banks/lenders that obtain funds from depositors.

The bank lending channel

The bank lending channel broadly describes how shocks to banks' balance sheets might affect the cost of (or access to) finance for certain borrowers. The channel is believed to be important if the supply of bank loans is dependent on economic conditions and that bank loans are imperfect substitutes for other forms of finance. For instance, if banks face the same agency problems with depositors that firms experience with lenders, this might restrict their ability to grant new loans. For the purpose of this paper, it is important that the substitution between different types of financing could be dependent on firm size. The idea being that large firms - often highly creditworthy - can more easily shift to firm bonds or equity than SMEs as entry barriers could potentially exclude smaller firms from these markets. The empirical analysis is therefore focused on the SME segment. It is possible that the cost of bank loans for these borrowers is much greater, as the actual price is higher or the requirements following the loan (covenants, collateral requirements, etc.) are more restrictive. Further, it is also possible that smaller firms might more often experience being rationed. The tightening in loan supply is often termed as a credit crunch. It could be argued that what matters in a credit crunch is that changes in the official interest rate are no longer the only thing that matters for the cost of finance for certain borrowers. The bank lending channel can therefore be thought of as the additional adjustment to firm activities coming from changes in the degree of quantitative loan rationing (or price changes).

The bank lending channel is formalized in for instance Gertler and Kiyotaki (2010) by modeling intermediation as in Gertler and Karadi (2009) and includes liquidity risk as in Kiyotaki and Moore (2008). The main idea being that if banks are optimizing agents, there exist not only agency problems between banks and borrowers but also between banks and their fund providers. Fund providers, depositors or other banks, might be more reluctant to deposit their funds in banks that are struggling and thereby ultimately affecting the supply of credit.

The two credit channels discussed above are distinct ways where financial market imperfections affect the real economy. However, they are believed to be complementary in the sense that early theoretical studies recognized that both channels could potentially be important (see e.g. BBG), and therefore the distinction is in some ways artificial. The underlying mechanisms are the same, but the policy implications are different. For instance, if governments want to avoid a credit crunch, the source of the problem is obviously important to implement an effective policy.

2.3 Hypotheses, Data, and Empirical Strategy

The goals of this paper are similar to that of Jiménez et al. (2012) which are to disentangle the supply of credit from the demand and answering whether the bank lending channel is operational, and if so, how important is it compared to the balance sheet channel. Like in Jiménez et al. (2012) individual outcomes of loan applications are used. However, the empirical strategy is different and in some ways resembles those of Presbitero et al. (2014), Puri et al. (2011), Abildgren et al. (2013), and Popov and Udell (2012), but extended along several dimensions. The data consists of a broad range of Danish register, survey, bank, and rating data. The data is also representative of lending to firms more generally compared to Jiménez et al. (2012) who focus on the extensive margin i.e. banks lending to firms that are not currently customers. It seems natural that this is important, as the outcome in Jiménez et al. (2012) to some extent is conditioned on the firm being rejected by their current bank connections.

Hypotheses

The theory discussed above has some very important testable hypotheses: (H1) Well capitalized and liquid firms have better access to credit (see e.g. BGG), (H2) Firms access to credit is better in solid banks (see e.g. Kiyotaki and Gertler (2010)), (H3) If only the balance sheet channel is operational, there should be no significant effect on the supply of credit to firms with no change in creditworthiness during the business cycle. This hypothesis follows directly from the BGG model where the credit supply is only affected by the net worth of entreprenuers.

Data

The outcome variable, whether a bank loan is fully granted, partially granted or declined, is taken from a credit survey by Statistics Denmark. The survey was statutory (implying a response rate in excess of 90%) and consists of 2,265 representative responses of a population of 13,990 firms. The goal was to shed light on the access to credit in 2007 and 2009/2010 (April 2009 to March 2010). The survey was restricted to SMEs with 5 to 249 employees in 2005 and at least 5 employees in 2009.[3] Further, the respondents were all in the following sectors: manufacturing, natural resources, and utility, construction, trade and transport, or information and communication.[4] The information on the firms' loan applications and outcomes from both 2007 and 2009/2010 was gathered in the same survey in the spring of 2010, which could imply

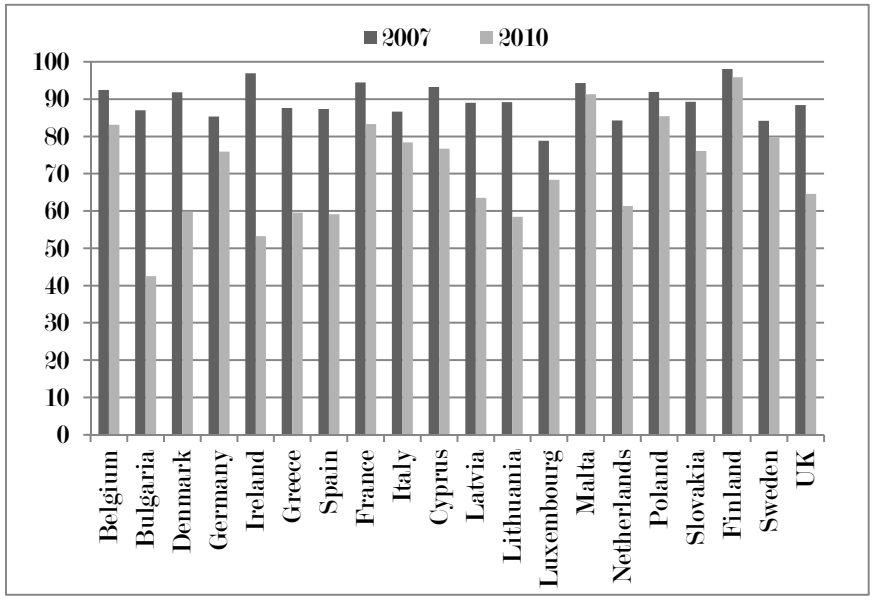
[3] Note that Danish SMEs accounts for approximately 60 percent of private employment (and revenue) and are therefore a significant part of the aggregate economy

[4] Based on the NACE code, specifically the DB07 21-groupings C, F, G, H, I, J, L, M, and N.

that the information regarding 2007 is more ambiguous than those from 2009/2010. The survey also gathered information on whether firms applied for other types of finance e.g. equity or mortgage loans, and the outcome of these applications. The specific question was: "Did the firms apply for a bank loan in year x from banks, and with what outcome? (Fully granted, partially granted, or not granted).[5] It is possible to link these answers to all of the register and rating data discussed below by a unique firm identifier (CVR-number).

The Danish credit survey was part of a European collaboration with the European Commission which made it possible to compare the results to other EU countries. It turns out that Danish SME firms were experiencing a high success rate before the crisis but very limited access to credit during the financial crisis, see figure 2.1. Furthermore, during the crisis Denmark experienced success rates comparable to Greece and Spain, far below our Scandinavian counterparts in Finland and Sweden.

Figure 2.1. Success rates of bank loan applications by country



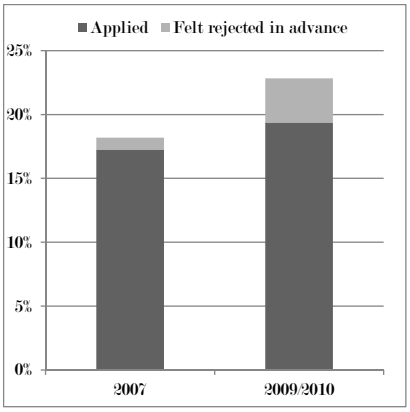
Source: Eurostat.

In the group of Danish SMEs there were 439, or approximately 19 percent, that

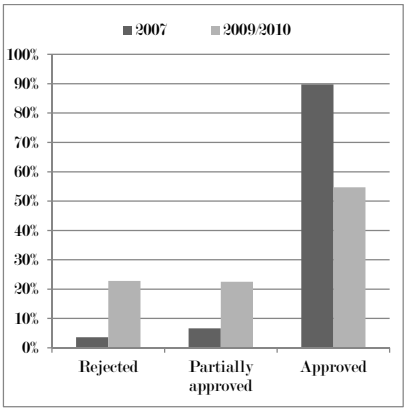
[5] A corcern regarding this question is that loan contracts can be package deals e.g. consisting of both issuing new shares, mortgage loans, and bank loans. The respondents might consider package deals as partially granted loans. However, as the ordering of the responses would still be valid, this is not believed to affect the results in any critical way. Further, the survey separately asks for the outcomes of applications of different types of finance, see the appendix.

Figure 2.2. Credit demand and outcomes of applications

2.2a: Share of firms that demand credit



2.2b: Outcomes of loan applications



Note: Author's calculations based on Statistics Denmarks credit survey.

applied for a loan in a bank in 2009/2010, see figure 2.2a. In 2007 this share was 17 percent. This implies that there is a tendency for more firms to demand credit despite the crisis, i.e. the number of firms that applied for credit rose. The fact that a larger number of firms demanded credit in a period where the economy was significantly weakened is somewhat surprising as it is often conjectured that a declining supply of credit is accompanied by declining demand. Everything else equal we would expect that an economic downturn would lead to lower investment and therefore a lower demand for credit. However, more credit could have been demanded as liquidity vanished, not only for financial institutions but also for non-financial firms. This would point in the opposite direction. By comparing the number of applications, the effect of liquidity vanishing seems to be stronger, at least in the period immediately following the crisis. Further, there was an increasing number of the respondents that did not apply for credit because they expected their applications to be declined or the terms of the loan contract would be unfavorable, see the appendix for the precise definitions. In 2009/2010, this share was 3.4 percent of the survey population compared to 1.0 percent in 2007. This also implies that the underlying demand for credit increased over time, and at the same time that the access to credit was weakened. The result should, however, be read with some caution, as it is not possible to determine how much money firms applied for and because the survey only consists of SMEs that survived until 2010. Further, the data does not contain any information on the interest rate/price of credit and willingness to pay, i.e. the analysis is limited to observing the outcome of loan applications accounting for the fact that firms might be discouraged from applying for credit.

At the same time, as more firms were applying for credit, there was apparently a large difference in how many firms successfully obtained a loan, see figure 2.2b.[6] In 2007, towards 90 percent of the loan applications were fully granted. In 2009/2010 this fell to 55 percent. This reflects that firms had relatively easy access to credit when the economy was booming in 2007, but also the credit policies of banks were significantly tightened after the financial crisis escalated in 2008.

The central question is whether the tightened credit policies were due to SMEs being less creditworthy (the balance sheet channel) in 2009/2010, i.e. whether the loan applications were rejected because the credit risk was higher due to failing profits and/or plunging asset values, or whether the tightened credit policies were due to banks being affected by the financial crisis (the bank lending channel). To answer this question the analysis includes Danish register data, bank data and Experian credit rating data. The Danish firm register (FIRM) contains information on firm equity, total assets, profits before taxes, sector, number of employees, location code and revenue. Further, the Danish firm survey (FIRE) has information on firm liquidity, financial assets, short term debt, and interest rate payments. New to the literature is to include credit ratings in this type of analysis. The credit ratings are obtained from Experian, a private credit agency, and are included in order to have a better estimate of the creditworthiness of the firms. The credit ratings are computed from firm specific information about: legal status, age, number of employees, official written remarks, secured debt obligations, and collected experience on whether firms pay their bills. Further, the ratings are based on accounting numbers. Specifically, profits before taxes, equity, profit over equity and liquid assets over total assets. The official written remarks are gathered from Statstidende and can contain information on bankruptcy, liquidation, and enforced winding up of companies. The collected experience on whether firms pay their bills stems from Experians agreement with larger Danish companies on providing information on whether bills are paid on time. This information is included in the credit rating if Experian has a minimum of 10 data points for a given firm. The credit rating is therefore based on firm specific information and not subjective information from other institutions. Further, the credit rating does not contain information of the firms' ability to offer security, macroeconomic information, sector specific information, or information on outcomes of loan applications. But, the specific algorithm used by Experian is not available. The credit rating should, however, be comparable over time and sector as the same algorithm is used every year independently of sector. Experian also provides information on the firms' primary bank connection.[7] This information is combined with the Danish

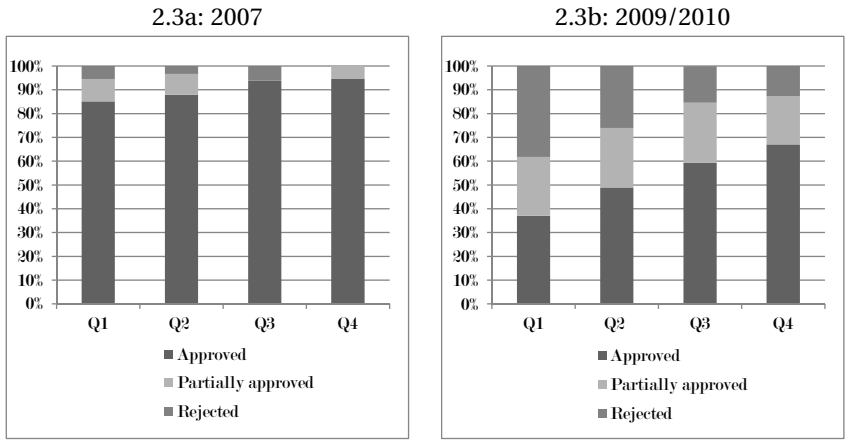
[6] Be aware that figure 2.2b only includes outcomes of loan applications where background data was available. This is done to ensure consistency throughout the paper.

[7] Using only the primary bank connection suggests that we might underestimate the effects from being a customer in an unhealthy bank. If, for instance, firms with multible banks automatically turn to their secondary or tertiary bank, if their primary bank is struggling, it is implicitly assumed that any fully/partially granted loans were coming from the primary bank. This bias would, however, further support the conclusions of this paper and is therefore not considered critical.

Financial Supervisory Authority's (FSA) public bank data.

Figure 2.3 shows the connection between the credit ratings from Experian and the outcomes of the loan applications in 2007 and 2009/2010. Specifically the firms that applied for loans divided into 4 equally sized groups ranked by their ratings such that the lowest ratings are placed on the left side of the figure. To ensure consistency over time the 25-, 50- and 75-percentiles from 2009/2010 are used in both periods. There is a clear tendency for firms with higher ratings to have a larger probability of attaining a loan. It is also apparent that the probability of attaining a loan was much higher in 2007 than in 2009/2010 regardless of whether the firm had a high or low credit rating. Credit policies in this regard seem lax in 2007 and severely tightened in 2009/2010.

Figure 2.3. Outcomes of applications allocated by credit ratings

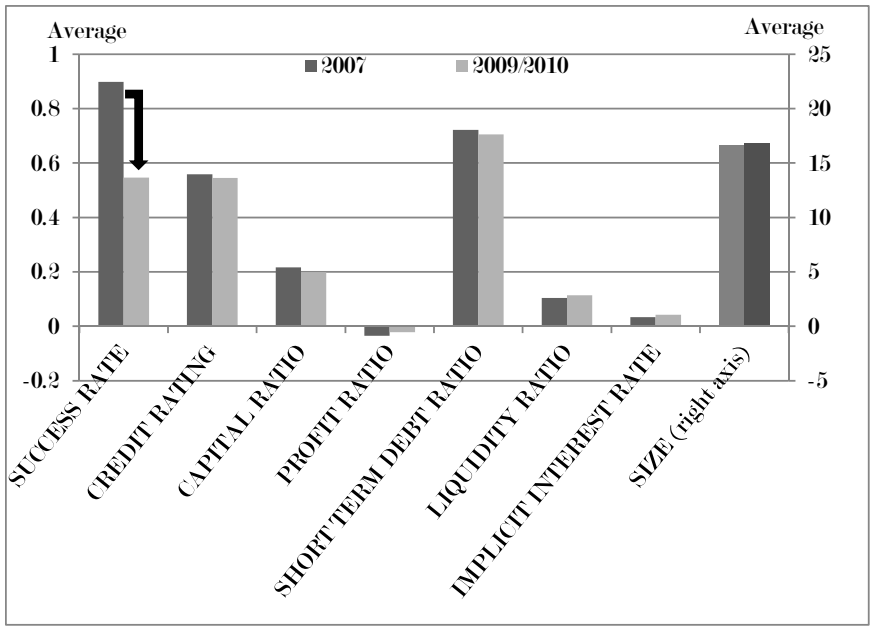


Note: Author's calculations based on Statistics Denmarks credit survey and Experian rating data. Q1, Q2, Q3, and Q4 are devided between the 25%, 50% og 75% quartiles of credit ratings in 2009/2010, respectively. Hence, Q1 is all firms with a rating lower than or equal to 0.43, Q2 a rating between 0.44 and 0.55, Q3 a rating between 0.56 and 0.67, and Q4 a rating of 0.68 or more.

A possible explanation for the large decrease in the success rate of loan applications could be that firms applying for loans experienced a significant decline in their economic performance and ratings from 2007 to 2009/2010. Figure 2.4 displays several averages of accounting numbers from 2007 and 2009/2010 for the firms in the survey, that actually applied for credit during the two years, respectively. At first glance, it seems that firms applying for a loan only had a marginally lower rating on average in 2009/2010, while their profit ratio was a little higher. They were on average

a little bit bigger, had a little less short term debt and were more liquid. The implicit interest rate increased a bit. So overall there is not much evidence that the decrease in the success rate was a consequence of significantly lower key performance indicators among those firms that applied for a loan.

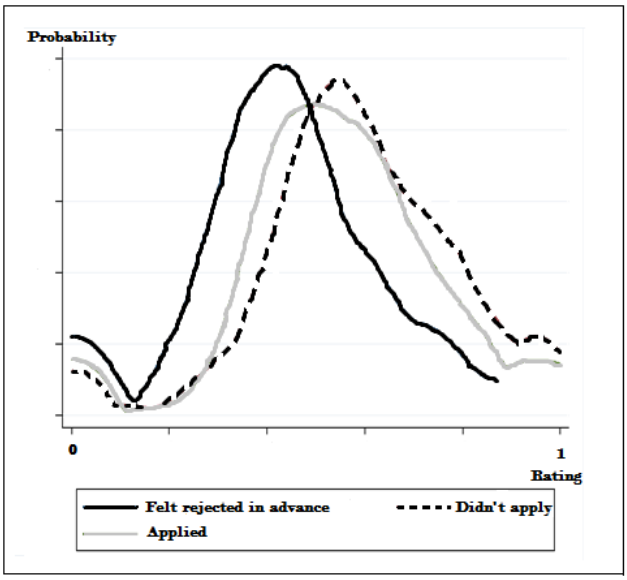
Figure 2.4. Success rates, key ratios, ratings, ect.



Note: Author's calculations based on Statistics Denmarks credit survey, firm registers, and Experian rating data. The definitions of the variables are discussed in detail below.

One reason why firms seem relatively unaffected by the financial crisis is that there is an element of selection in who applies for a loan. Firms, that do not apply for a loan if they expect to be declined or the terms of the loan contract to be unfavorable, have a tendency to have a much lower rating on average than those who do apply, see figure 2.5. It is also apparent that firms that do not apply for loans have a higher rating than those who apply for loans in their bank. To further and more precisely analyze this, the next subsection will describe the empirical approach used to explain the credit policies of banks.

Figure 2.5. The distribution of ratings



Note: Author's calculations based on Statistics Denmarks credit survey and Experian rating data. The probability (y-axis) is measured as the reciprocal unit of the rating (x-axis). The distribution is estimated using the Epanechnikocs kernel (kdensity in STATA).

Empirical strategy

The aim is to model the probability that a given firm with a given primary bank connection attain a loan, partially attain a loan or is declined. The outcome variable, y, is therefore discrete and can take on 3 values. Namely, 1 of the loan application is declined, 2 if it is partially granted, and 3 if it is fully granted. Formally, the outcome equation can be written as

$$y_j = \sum_{h=1}^{3} \nu_h 1\left(\kappa_{h-1} < x_j\beta + u_j < \kappa_h\right)$$

where x_j is the control variables if the outcome is observed, see the subsection below, $1(.)$ is an indicator function, β is a vector of coefficients, and u_j is an error term. The observed outcomes, ν_1, ν_2, ν_3, are whole numbers $(1,2,3)$ and naturally satisfy that $\nu_i < \nu_m$ for $i < m$. κ_i and $\kappa_m$are real numbers and satisfy $\kappa_i < \kappa_m$ for $i < m$. Further, $\kappa_0$takes the value $-\infty$ and $\kappa_3$takes the value ∞.

It is presumably not random which firms apply for lending. To account for this fact, selection is modelled. The firm applies for a loan if the selection variable, s_j, takes the value 1, and do not if s_j equals 0. Formally,

$$s_{jt} = 1(z_{jt}\gamma + \varepsilon_{jt} > 0)$$

where1(.) is an indicator function, z_j is the vector of variables relevant for selection, γ is a vector of coefficients and a constant α, and ε_j is the error term. The error terms are assumed to be bivariate normal i.e.

$$\begin{pmatrix} u_{jt} \\ \varepsilon_{jt} \end{pmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & \rho \\ \rho & 1 \end{bmatrix} \right)$$

where ρ is the correlation between the error terms. The above specification is the standard ordered probit model accounting for selection and can be estimated using standard ML methods, see De Luca and Perotti (2011).

Variables in the analysis

Table 2.1 defines the full list of variables employed in the analysis, see the appendix for a complete data description. As mentioned above, the dependent variable is LOAN APPLICATION that took on the values (1,2,3). The dependent variables can be divided into 2 groups: firm characteristics and bank characteristics. Firm characteristics include the following variables: the CREDIT RATING from Experian as discussed above; SIZE, log of total assets; the CAPITAL RATIO, which is the ratio of firm equity over total assets; the PROFIT RATIO, current profits over revenue; the SHORT TERM DEBT RATIO, short term debt over total debt; OTHER TYPES OF FINANCE, dummy variable for whether the firm applied for any other types of finance; the LIQUIDITY RATIO, liquid assets and financial assets over total assets; and the IMPLICIT INTEREST RATE, total interest payments over total debt. The bank characteristics include: LOAN IMPAIRMENT CHARGE RATIO, write offs over total loans; BANK GROUP 1, dummy variable for the largest banks as defined by the Danish FSA; BANK CAPITAL RATIO, equity over total assets; FAILING BANK, customer in a bank that later failed as defined in Østrup (2014); DEPOSIT DEFICIT, total loans over total deposits; and BANK Z-SCORE, the distance to insolvency, see Roy (1952).

Table 2.1. Variables in the Analysis

Variable	Units	Definition
Dependent variable:		
$LOAN\ APPLICATION_{i,b,t}$	1/2/3	= 3 if the loan application by a firm is fully approved, = 2 if the loan application by a firm is partially approved, = 1 if the loan application is denied.
Independent variables:		
Firm characteristics (i)		
$CREDIT\ RATING_{i,t-1}$	%	The Experian credit rating.
$SIZE_{i,t-1}$	-	The log of total assets.
$CAPITAL\ RATIO_{i,t-1}$	%	The ratio of equity over total assets.
$PROFIT\ RATIO_{i,t-1}$	%	The ratio of profits over total revenue.
$SHORT\ TERM\ DEBT\ RATIO_{i,t-1}$	%	The ratio of short term debt over total debt.
$OTHER\ TYPES\ OF\ FINANCE_{i,t}$	0/1	= 1, when the firm applied for other types of finance, = 0 otherwise.
$LIQUIDITY\ RATIO_{i,t-1}$	%	The ratio of liquid assets (including financial assets) over total assets.
$IMPLIED\ INTEREST\ RATE_{i,t-1}$	%	The implied interest rate from total interest payments over total debt.
$CHANGE\ IN\ MARKET\ VALUE_{i,t-1}$	%	The change in market value from $t-3$ to t of commercial buildings owned by firm i at time $t-1$.
Primary bank connection characteristics (b)		
$LOAN\ IMPAIRMENT\ RATIO_{b,t}$	%	The ratio of write offs over total loans.
$BANK\ GROUP\ 1_{b,t}$	0/1	= 1, if the primary bank is large enough to be part of bank group 1, = 0, otherwise.
$BANK\ CAPITAL\ RATIO_{b,t}$	%	The ratio of bank equity over total assets.
$FAILING\ BANK_{b,t}$	0/1	= 1, if the firm was customer at time t in a bank that later failed according to Østrup (2014).
$DEPOSIT\ DEFICIT_{b,t}$	-	The difference between total loans and total deposites over total deposites.
$BANK\ Z-SCORE_{b,t}$	-	The distance to bankruptcy, as in Roy (1952). Can be shown to be inversely proportional to the probability of insolvency - the lower the Z-SCORE the higher the probability of bankrupcy.

2.4 Results

This section provides the main results of the paper. First, the results are presented and in the final subsection the robustness of the results is discussed.

Results

A central challenge regarding this analysis is that the inclusion of additional variables reduces the number of observations due to lack of overlap in the datasets. Therefore the estimation strategy is to estimate the probability of attaining a loan, ignoring the selection effects, parsimoniously. The results are shown in table 2.2 and 2.3. The results are compared to a model with only the firm CAPITAL RATIO and PROFIT RATIO, see regression (1) in table 2.2 and 2.3. The variables that can potentially identify firm creditworthiness are CREDIT RATING, SIZE, CAPITAL RATIO, PROFIT RATIO, SHORT TERM DEBT RATIO, LIQUIDITY RATIO, and IMPLICIT INTEREST RATE, respectively. When the Experian CREDIT RATING, that contains further information than accounting numbers e.g. payment history, and SIZE are included, the other variables do not seem to significantly (even at a 10% significance level) affect the outcome of the loan application. The CREDIT RATING is however very significant in both periods, even in 2007 where CAPITAL RATIO and PROFIT RATIO are not significant at a 5% significance level. The CREDIT RATING therefore in general seems to be a more precise measure of the banks' assessment of the firms' creditworthiness. Specifically, to only include relevant information and minimize the loss of data points, the CREDIT RATING and SIZE are included in the estimation with only firm CAPITAL RATIO and PROFIT RATIO, see regression (2) in table 2.2 and 2.3. The firm size - measured as total assets - is included because size could have an independent effect and is part of the Experian CREDIT RATING (SIZE turns out to be insignificant when the analysis accounts for selection, see below). In the next step the significant variables (at a 5% significance level) from regression (1) are supplemented with SHORT TERM DEBT RATIO, LIQUIDITY RATIO, and IMPLICIT INTEREST RATE**,** see regression (3) in table 2.2 and 2.3. The stepwise procedure reflects that the number of observations declines when new variables are added. None of the added variables are significant (even at a 10% significance level) either in 2007 or 2009/2010. In the next step, information on the firms' primary bank connection is included, specifically, LOAN IMPAIRMENT RATIO, BANK GROUP 1 and BANK CAPITAL RATIO, see regression (4). There is a weak tendency for bigger banks (group 1 banks) to decline more loan applications during the crisis. The IMPAIRMENT CHARGE RATIO is however significant during the crisis at a 5% significance level. The regression including only significant variables (at a 5% significance level) is seen in table 2.3, regression (5).[8]

[8]The model selection could also have been done using Akaike's Information Criterion (AIC) with the added difficulty of varying sample sizes. A stepwise AIC criterion procedure (from the largest sample to the smallest) favors the same model, however, including the PROFIT RATIO. Including this variable does

Table 2.2. Regression results for 2007 (without selection).

Model	(1)	(2)	(3)	(4)	(5)
			.....2007.....		
Firm characteristics (i)					
$CREDIT\,RATING_{i,t-1}$	-	$2.42^{\star\star\star}$ (0.811)	$2.33^{\star\star\star}$ (0.888)	$2.70^{\star\star\star}$ (0.774)	$2.67^{\star\star\star}$ (0.759)
$SIZE_{i,t-1}$	-	$-0.23^{\star\star}$ (0.099)	-0.23 (0.141)	$-0.26^{\star\star}$ (0.121)	$-0.27^{\star\star}$ (0.121)
$CAPITAL\,RATIO_{i,t-1}$	$0.79^{\star}$ (0.423)	0.43 (0.864)	-	-	-
$PROFIT\,RATIO_{i,t-1}$	-0.01 (0.083)	-0.01 (0.087)	-	-	-
$SHORT\,TERM\,DEBT\,RATIO_{i,t-1}$	-	-	-1.02 (0.766)	-	-
$LIQUIDITY\,RATIO_{i,t-1}$	-	-	6.82 (4.325)	-	-
$IMPLIED\,INTEREST\,RATE_{i,t-1}$	-	-	-6.70 (9.573)	-	-
Primary bank characteristics (b)					
$LOAN\,IMPAIRMENT\,RATIO_{b,t}$	-	-	-	49.84 (48.050)	49.55 (46.590)
$BANK\,CAPITAL\,RATIO_{b,t}$	-	-	-	1.40 (5.679)	-
$BANK\,GROUP\,1_{b,t}$	-	-	-	0.01 (0.431)	-
κ_1	$-1.66^{\star\star\star}$ (0.149)	$-4.38^{\star\star\star}$ (1.495)	$-5.14^{\star\star}$ (2.488)	$-4.76^{\star\star}$ (1.922)	$-4.89^{\star\star\star}$ (1.824)
κ_2	$-1.12^{\star\star\star}$ (0.121)	$-3.79^{\star\star}$ (1.487)	$-4.51^{\star}$ (2.479)	$-4.23^{\star\star}$ (1.914)	$-4.36^{\star\star}$ (1.816)
Number of observations	337	288	152	202	202

Note: Standard errors in parentheses.***Significant at a 1 percent level, **Significant at a 5 percent level, and *Significant at a 10 percent level.

With the chosen modelling strategy, firm accounting numbers become redundant when CREDIT RATING and SIZE are included. Further, information about the primary bank connection also seems to matter as the LOAN IMPAIRMENT RATIO is significant at a 5 percent significance level in 2009/2010. Stated differently, if the primary banks had large provisions during the crisis, it was ceteris paribus harder to attain a loan. The LOAN IMPAIRMENT RATIO is probably a reasonable proxy for how healthy a bank is, and therefore implies that firms that were customers in banks that were hit hard by the crisis had a harder time obtaining a loan. This also implicitly implies that firms can not just apply for a loan in a secondary bank if their primary bank connection is struggling. If this was the case we would not be able to observe any effects from the primary bank. Anecdotal evidence also suggests that changing bank is not cost free, as the new bank does not have the credit history and therefore tends

not seem to affect the results below.

Table 2.3. Regression results for 2009/2010 (without selection).

Model	(1)	(2)	(3)	(4)	(5)
			.....2009/2010.....		
Firm characteristics (i)					
$CREDIT\,RATING_{i,t-1}$	-	$2.29^{\star\star\star}$ (0.453)	$1.92^{\star\star\star}$ (0.512)	$2.12^{\star\star\star}$ (0.451)	$2.11^{\star\star\star}$ (0.442)
$SIZE_{i,t-1}$	-	$-0.18^{\star\star\star}$ (0.054)	$-0.13^{\star}$ (0.071)	$-0.14^{\star\star}$ (0.064)	$-0.144^{\star\star}$ (0.064)
$CAPITAL RATIO_{i,t-1}$	$0.47^{\star\star\star}$ (0.189)	-0.28 (0.315)	-	-	-
$PROFIT\,RATIO_{i,t-1}$	$0.63^{\star\star}$ (0.320)	0.24 (0.325)	-	-	-
$SHORT TERM DEBT RATIO_{i,t-1}$	-	-	-0.30 (0.376)	-	-
$LIQUIDITY\,RATIO_{i,t-1}$	-	-	-0.09 (0.793)	-	-
$IMPLIED INTEREST RATE_{i,t-1}$	-	-	-2.22 (3.013)	-	-
Primary bank characteristics (b)					
$LOAN IMPAIRMENT RATIO_{b,t}$	-	-	-	$-5.05^{\star\star}$ (2.187)	$-3.33^{\star\star}$ (1.568)
$BANK\,CAPITAL\,RATIO_{b,t}$	-	-	-	-3.02 (2.787)	-
$BANK\,GROUP\,1_{b,t}$	-	-	-	$-0.45^{\star}$ (0.256)	-
κ_1	$-0.62^{\star}$ (0.080)	$-2.62^{\star\star\star}$ (0.818)	$-2.24^{\star}$ (1.200)	$-2.67^{\star\star}$ (1.043)	$-2.20^{\star\star}$ (0.986)
κ_2	$0.04^{\star}$ (0.075)	$-1.91^{\star\star}$ (0.814)	-1.48 (1.197)	$-1.92^{\star}$ (1.039)	-1.46 (0.982)
Number of observations	386	335	193	236	236

Note: Standard errors in parentheses. ***Significant at a 1 percent level, **Significant at a 5 percent level, and *Significant at a 10 percent level.

to be more cautious when dealing with new customers. This behavior can also be rationalized by banks dealing with a lemon problem, i.e. shifting bank might reveal latent information on the creditworthiness of the firm. The LOAN IMPAIRMENT RATIO is insignificant in 2007, which is probably due to the fact that loan losses were very small before the crisis, and that internal bank characteristics back then were not particularly limiting to lending activities. The CREDIT RATING was also significant in 2007, but computing the marginal effect (evaluated at the mean) of a loan application being fully successful reveals that the marginal effect is smaller in 2007 than 2009/2010. This could indicate that banks, during the boom in 2007, put less emphasis on the economic performance of firms when forming their credit policy.

The regressions above estimate the probability of obtaining a loan for those firms that actually applied for a loan. By ignoring the selection effect, the fact that loan

Table 2.4. Regression results with selection.

Outcome equation	2007	M.E.	2009/2010	M.E.
$CREDIT\,RATING_{i,t-1}$	$1.28^{\star\star\star}$	0.45	$1.24^{\star\star\star}$	0.44
	(0.41)		(0.40)	
$LOAN\,IMPAIRMENT\,RATIO_{b,t}$	51.85	18.24	$-3.32^{\star\star}$	-1.18
	(42.38)		(1.58)	
Selection equation (the probability that a firm applies for a loan)				
Firm characteristics (i)				
$OTHER\,TYPES\,OF\,FINANCE_{i,t}$	$1.05^{\star\star\star}$	-	$1.34^{\star\star\star}$	-
	(0.12)		(0.10)	
$CAPITAL\,RATIO_{i,t-1}$	$-0.80^{\star\star\star}$	-	$-0.50^{\star\star}$	-
	(0.27)		(0.24)	
$CREDIT\,RATING_{i,t-1}$	-0.14	-	-0.39	-
	(0.33)		(0.30)	
$SIZE_{i,t-1}$	$0.09^{\star\star}$	-	$0.11^{\star\star\star}$	-
	(0.04)		(0.04)	
Primary bank characteristics (b)				
$LOAN\,IMPAIRMENT\,RATIO_{b,t}$	16.08	-	$2.15^{\star\star}$	-
	(16.00)		(0.98)	
α	$-2.25^{\star\star\star}$	-	$-2.83^{\star\star\star}$	-
	(0.62)		(0.57)	
κ_1	-0.23	-	$0.48^{\star}$	-
	(0.39)		(0.25)	
κ_2	0.23	-	$1.16^{\star\star\star}$	-
	(0.35)		(0.24)	
ρ	$0.55^{\star\star\star}$	-	$0.53^{\star\star\star}$	-
	(0.17)		(0.10)	
Number of observations	1203		1253	

Note: M.E. is the marginal effect on $P(y_{j,t} = 3|s_{j,t} = 1)$ (the probability that the loan application is successful) evaluated at the mean. Standard errors in parentheses.***Significant at a 1 percent level, **Significant at a 5 percent level, and *Significant at a 10 percent level.

applications are not random is not accounted for. On one hand, economically strong firms are expected to finance their projects and operations using internal capital. This group of firms has a tendency to not apply for external funds. On the other hand, some struggling firms, in need of funds, do not apply as they expect to be declined or the terms to be unfavorable. This heterogeneity can affect the estimates above. Further, it is likely that the selection is different before and during the crisis. As mentioned above, it is possible to identify the group of firms that did not apply for a loan because they expected to be declined. This group of firms will for now be excluded from the selection analysis but they will be included below in the robustness analysis.

The selection mechanism can be interpreted as a model for the probability of applying for a loan. To successfully address the selection problem all variables de-

scribed in the data section were included. The results are shown in table 2.4 and only includes those variables that were significant at a 5 percent significance level in the total regression. It appears that the CREDIT RATING is still significant in the outcome equation, but that the coefficient is smaller when accounting for selection. The coefficient on the IMPAIRMENT RATIO is, however, to a large extent unchanged. It is also apparent from table 2.4 that correcting for selection is relevant as the correlation between the error terms, given by the parameter, ρ, is significant. The results also indicate that SIZE in both 2007 and 2009/2010 no longer has any independent significant effect on the outcome of loan applications. Firm size do however indirectly have a positive effect of the outcome through the positive effect on the CREDIT RATING. The estimated coefficients in the selection equation reveal that larger firms (in the SME segment) ceteris paribus are more prone to apply for loans than smaller firms. Further, firms with a high CAPITAL RATIO (and to some extent CREDIT RATING) are less inclined to apply for a loan, while those firms that apply for other types of finance on the other hand often also apply for loans at their banks. As a last point, primary bank characteristics also seem to affect the probability of applying for a loan. The higher the LOAN IMPAIRMENT RATIO, the more likely the firms are to apply for a loan. This could reflect that firms in struggling banks are forced to find new bank connections and therefore have to renegotiate/apply for new loans. The negative sign on the CAPITAL RATIO supports the observation that credit demand is counter cyclical as accounting numbers typically decline during a recession. This could reflect special conditions during the financial crisis, e.g. that non-financial firms are also concerned about their liquidity and that the SME segment was under pressure by supplier credit drying up. It could also reflect that some firms needed liquidity to cover temporary deficits during the crisis. The counter cyclical tendency of credit demand in the SME segment is, however, an interesting insight into the otherwise reasonable argument that credit demand is normally assumed to be procyclical due to a lower propensity to invest during a recession.

Returning to the hypotheses above, hypotheses 1 and 2 are both confirmed. (H1) As firms' CREDIT RATINGS significantly affect the outcome of loan applications and (H2) As the health of primary bank connections, as proxied by IMPAIRMENT CHARGE RATIO, also seems to affect the outcome. This indicates that both the bank lending channel and the balance sheet channel are operational. However, their relative magnitude and relevance are hard to evaluate from the results so far. To evaluate (H3) and to grasp the relative magnitude of the two channels, it is possible to compare how much of the change in credit policy from 2007 to 2009/2010 can be explained by changes in applicants' characteristics. (H3) States that if only the balance sheet channel is operational, there should be no significant effect on the supply of credit to firms without any change in creditworthiness during the business cycle. This would be equivalent to the change in outcomes being fully explained by declining profit and liquidity, i.e. increasing credit risk. To answer the question, the identifying

Table 2.5. Application outcomes in 2007 given the estimated credit policy in 2009/2010.

Outcome	Rejected	Partially approved	Approved
Actual outcome in 2007	4,0%	5,9%	90,1%
Actual outcome in 2009/2010	22,0%	24,6%	53,4%
Difference	18,1%	18,6%	-36,7%
In 2007 with credit policy from 2009/2010	15,1%	22,0%	62,9%
Change from tighter credit policy	11,2%	16,1%	-27,2%
Change from ratings, impairment charge ratio, and selection	6,9%	2,6%	-9,5%

Note: Formally computed as:

$$P(y = v_h|x_{2007}, \beta_{2010}, \kappa_{1,2010}, \kappa_{2,2010}, \gamma_{2010}, s_{2010}|z_{2007} = 1) = \frac{1}{n}\sum_{j=1}^{n} P(y_j = v_h|s_j = 1)$$

Using the results from table 3 above.

assumption is that the credit policy is given as estimated in 2009/2010, and then use the characteristics of the firms that applied for credit in 2007. Stated differently, had the banks had the same credit policy before the crisis as in 2009/2010, how many firms would have been granted a loan back in 2007. The results are shown in table 2.5. The success rate in 2007 was approximately 90 percent. With the estimated credit policy from 2009/2010, the success rate would have only amounted to approximately 64 percent. Stated differently, 27 percentage points more firms would have had their application declined fully or partially. At the same time, this implies that the decline in the success rate is mainly (approximately 3/4) due to a tightened credit policy. The counter factual success rate in 2007 (with the credit policy from 2009/2010) is only 9.4 percentage points higher than the success rate in 2009/2010. This implies that firm and bank characteristics - the development in the firms' economy and bank losses - only explains approximately 1/4 of the fall in the success rate. Further, of the 9.4 percentage points decline in the success rate, 4.5 percentage points of the decline result from a higher LOAN IMPAIRMENT RATIO in the banks compared to if the banks' credit policy had been independent of individual bank characteristics. This implies that we reject H3 and further illustrates that the magnitude of the bank lending channel seems bigger than the effects of the balance sheet channel. Some of the main concerns about this result are addressed in the robustness section below.

As argued in the balance sheet channel literature, a larger incentive for firms to hold internal capital could minimize credit cycles. Policymakers could adjust the tax system to incentivize SMEs to hold capital or postpone tax claims so that SMEs would have more liquidity. To evaluate such policies, CREDIT RATING has been

regressed on CAPITAL RATIO and CAPITAL RATIO squared. From this regression we get an approximate relationship between CREDIT RATING and CAPITAL RATIO.[9] This suggests that a 10 percentage points increase in the CAPITAL RATIO is equivalent to a 5.2 percent points increase in the CREDIT RATING. Firms that applied for a loan in 2009/2010 had a CAPITAL RATIO of approximately 20 percent on average. If all firms' CREDIT RATINGs were 5.2 percentage points higher in 2009/2010, then 56.6 percent would have successfully obtained a loan using the estimated model in table 3. That is equivalent to 3.2 percentage points more than the actual amount. The results, therefore, imply that increasing SME capital will minimize the credit cycles, but the effects appear relatively small compared to the effects from bank losses and especially the general tendency of banks to tighten their credit policy.

Robustness

This section discusses different aspects of the results' robustness. First, which measures are better at measuring bank health. Second, the effects of including firms that did not apply for credit because they expected to be declined or the terms of the contract to be unfavorable are analysed. Third, the distinction between market and accounting values is discussed. Fourth, the problem of timing and the use of lagged and non-lagged values.

Measures of bank health

Jiménez et al. (2012) find that the bank capital ratio and bank liquidity ratio significantly affects the outcome of loan applications. This study indicates that the LOAN IMPAIRMENT CHARGE RATIO better captures the effect of bank health. However, different measures have been analyzed with the central challenge that measures are very correlated. This, combined with the fact that the sample size is relatively small, implies that the variables describing bank health are added one at a time to the regression for 2009/2010 in table 2.4, excluding LOAN IMPAIRMENT CHARGE RATIO. Table 2.6 shows the estimated coefficients for credit policy (the banks probability of granting loans) and the coefficient in the selection mechanism (the probability of applying for loans) in 2009/2010.

The coefficients in the selection equation indicate that customers in struggling banks are more prone to apply for loans. As argued above, this could be due to the fact that firms in struggling banks might be forced to apply for loans in a different bank. However, in the outcome equation, it is only the IMPAIRMENT CHARGE RATIO

[9] Approximated by:

$$\triangle CREDIT\ RATING = \beta_1 \triangle CAPITAL\ RATIO + \beta_2 \left(\left(\overline{CAPITAL\ RATIO} + 10\% \right)^2 - \left(\overline{CAPITAL\ RATIO} \right)^2 \right)$$

where $\overline{CAPITAL\ RATIO}$ is the average capital ratio in the sample.

Table 2.6. Coefficient estimates for different measures of banking health

Outcome equation	Outcome equation	Selection equation
$LOAN\ IMPAIRMENT\ RATIO_{b,2010}$	$-3.32^{\star\star}$	$2.15^{\star\star}$
	(1.58)	(0.98)
$FAILING\ BANK_{b,2007}$	0.007	$0.372^{\star\star\star}$
	(0.193)	(0.131)
$FAILING\ BANK_{b,2010}$	-0.081	$0.481^{\star\star\star}$
	(0.191)	(0.133)
$BANK\ GROUP\ 1_{b,2010}$	-0.118	$-0.208^{\star\star}$
	(0.141)	(0.090)
$BANK\ Z-SCORE_{b,2007}$	0.108	-0.036
	(0.102)	(0.060)
$BANK\ Z-SCORE_{b,2010}$	$0.188*$	-0.065
	(0.102)	(0.0630)
$DEPOSIT\ DEFICIT_{b,2010}$	-0.283	0.199
	(0.366)	(0.228)
$BANK\ CAPITAL\ RATIO_{b,2010}$	-1.324	-0.493
	(1.523)	(1.095)

Note: Standard errors in parentheses.***Significant at a 1 percent level, **Significant at a 5 percent level, and *Significant at a 10 percent level. The variables with the time subscript, 2007, indicates that the variable is measured in 2010, but with the primary banking connection from 2007.

that significantly affects the probability of obtaining a loan (at a 5 percent significance level). The Z-score of the primary bank in 2010 is only significant at a 10 percent significance level. The Z-score can be interpreted as the distance to bankruptcy (it can be shown that it is inversely proportional to the probability of insolvency - the lower the Z-score the higher the probability of bankruptcy). So if the firm's primary bank is far from insolvency then the probability ceteris paribus of obtaining a loan is higher.

The effects of including firms that did not apply for credit because they expected to be declined or the terms of the contract were expected to be unfavorable

As mentioned above, some firms did not apply for credit because they expected to be declined or the terms of the contract (duration, interest rate, or general conditions) would be unfavorable. This group of firms grew from 2007 to 2009/2010. It is relevant to investigate, which effects it would have to include these firms in the group of firms of declined firms.

In 2009/2010, 78 out of the 2265 respondents answered that they did not apply for this reason. This group is therefore relatively large in 2009/2010. To compare, there were 100 declines in 2009/2010. In 2007, there were only 21 that did not apply because they expected to be declined. This kind of selection could be one of the reasons that the average accounting numbers of the firms that applied for a loan did

not fall significantly enough to explain the rapid decrease in the acceptance rate from 2007 to 2009/2010. The estimation results are shown in table 2.7 with the extended sample.

Table 2.7. Regression results with selection including individual firms that did not apply because they believed they would be declined.

Outcome equation	2007	M.E.	2009/2010	M.E.
$CREDIT\,RATING_{i,t-1}$	$2.05^{\star\star\star}$	0.47	$1.75^{\star\star\star}$	0.69
	(0.52)		(0.35)	
$LOAN\,IMPAIRMENT\,RATIO_{b,t}$	41.57	18.24	$-3.07^{\star\star}$	-1.21
	(40.80)		(1.50)	
Selection equation (the probability that a firm demands credit)				
Firm characteristics (i)				
$OTHER\,TYPES\,OF\,FINANCE_{i,t}$	$1.00^{\star\star\star}$	-	$1.18^{\star\star\star}$	-
	(0.12)		(0.10)	
$CAPITAL\,RATIO_{i,t-1}$	$-0.80^{\star\star\star}$	-	$-0.53^{\star\star}$	-
	(0.27)		(0.24)	
$CREDIT\,RATING_{i,t-1}$	-0.32	-	$-0.78^{\star\star\star}$	-
	(0.32)		(0.29)	
$SIZE_{i,t-1}$	$0.089^{\star\star}$	-	$0.13^{\star\star\star}$	-
	(0.04)		(0.92)	
Primary bank characteristics (b)				
$LOAN\,IMPAIRMENT\,RATIO_{b,t}$	15.05	-	$-1.87^{\star\star}$	-
	(15.64)		(0.55)	
α	$2.16^{\star\star\star}$	-	$-2.71^{\star\star\star}$	-
	(0.62)		(0.55)	
κ_1	-0.16	-	$0.57^{\star\star}$	-
	(0.43)		(0.24)	
κ_2	0.14	-	$1.15^{\star\star\star}$	-
	(0.42)		(0.24)	
ρ	0.06	-	0.13	-
	(0.28)		(0.15)	
Number of observations	1217		1293	

Note: M.E. is the marginal effect on $P(y_{j,t} = 3|s_{j,t} = 1)$ (the probability that the loan application is successful) evaluated at the mean. Standard errors in parentheses.***Significant at a 1 percent level, **Significant at a 5 percent level, and *Significant at a 10 percent level.

It turns out that this does not affect the results above in any critical ways. The effect of the CREDIT RATING increases a little bit, while the effect of the IMPAIRMENT CHARGE RATIO decreases a little. The most interesting thing is that accounting for selection no longer seems to be necessary, as the coefficient, ρ, is no longer significantly different from 0. Generally, as the results do not seem to be sensitive to

including the observations, these results seem to support the conclusions above.

Market vs. accounting values

The Experian credit rating is a measure of a firm's creditworthiness based on, among others things, accounting numbers, but do not account for market and macro information. However, it might be plausible that the market value of, for instance, real estate is different from the accounting value. This could imply that we underestimate the decline in the actual value of the firm's assets. However, banks might not be able to access this information either and therefore base their credit policy on accounting values. And, accounting values might be relevant when assessing credit risk as they focus on liquidation value.

One way of evaluating the importance of market values is to look at real estate owned by firms. The Danish register data contains detailed information on every building in Denmark such as: who owns it, where it is placed, and the public valuation for taxation purposes. From this, it is possible to estimate how exposed the SMEs are to the real estate market. Next, note that Denmark is devided into 5 regions. In each region, the average changes in prices of commercial buildings from 2005 to 2007, and 2008 to 2010 were collected. The idea is if the market value of assets is not captured by the firms' books, then firms with large capital gains/losses from their real estate would find it easier/more difficult to obtain a loan relative to other firms. However, doing this excise does not seem to significantly (even at a 10 percent significance level) explain the outcome of loan applications in either 2007 or 2009/2010. This could imply that market values are not relevant for the outcome of loan applications or that banks to some extent disregard this information. However, it is also possible that the proxy is too noisy and therefore does not capture the actual difference between market and accounting values.

Lagged and non-lagged variables

The whole analysis of this paper is based on lagged information about firm specific characteristics. Specifically, information from 2007 for the 2007 sample and information from 2009 for the 2009/2010 sample. For most parts, this is the relevant information for the periods in question and would also be the information available to banks. But, especially in 2009/2010, banks might have had updated accounting numbers for parts of the period. The advantage of using lagged variables to avoid endogeneity[10] might lead us to underestimate the effects of the balance sheet channel. However, inconsistently using data from 2008 and 2010, when estimating the model, does not seem to affect the results in any crucial way. Further, above we saw that success rates were relatively insensitive to changes in CREDIT RATINGs.

[10] Specifically, the outcome of the loan application could affect the explanatory variables if these are not lagged.

Therefore the balance sheet effects would still be limited relative to the bank lending effects even if the actual accounting numbers, available to banks at the time of the application, were lower.

The analysis is based on non-lagged bank specific information. The main reason is that using lagged information would imply using pre-crisis data for the 2009/2010 sample and thereby make it disproportionately difficult to evaluate which banks were struggling during the crisis. Further, this is generally believed to be reasonable as outcomes of loan application to specific SMEs during the crisis are unlikely to affect the overall health of the bank. Stated differently, a high impairment charge ratio during the crisis is beleived to be the consequence of decisions made before the crisis, not a consequence of a conservative lending policy during the crisis. However, this could potentially imply that I am underestimating the effect of bank health as banks health was actually worse than what is observed as a conservative lending strategy implies very few write offs on new activities. Again, this would support the conclusions of this paper as this bias point towards underestimating the size of the bank lending channel.

2.5 Discussion

A major concern is whether ignoring macro economic information when evaluating credit risk significantly affects the conclusions. According to Experian, their ratings are objective and comparable over time, thus implying, that including sector or macro evidence is not useful when evaluating credit risk. Jiménez et al. (2012) find that negative changes in the interest rate increase the chance of obtaining a loan, and that it is generally easier to obtain a loan when the economy is booming, i.e. when GDP is rising. However, the main concern is whether this feeds through the balance sheet or the bank lending channel. Further, if firm specific characteristics measure the current state of a firm's financial health, does evidence about the state of the whole economy have implications for the future health of firms as aggregate demand is expected to decline? Unfortunately, the structure of the data does not allow for a formal analysis of this. However, Jiménez et al. (2012) conclude that the negative effect of higher short-term interest rates or lower GDP growth on credit availability is stronger for banks with low capital or liquidity. Hence, the monetary policy and the business cycle effect work through a bank lending channel. This generally favors the results above and leaves the bank lending channel as the main contributor to the credit cycles generated in our sample.

The above points reveal valid limitations of the analysis. However, it seems unlikely that these would completely change the main conclusion. Namely, that the bank lending channel seems to be the main reason for the decline in credit access for Danish SMEs during the crisis.

2.6 Concluding remarks

Which channel is better at explaining credit cycles during the recent financial crisis? This analysis indicates that the bank lending channel explains most of the differences between credit policies before and during the crisis.

This paper adds to the literature by including a very rich set of variables to explain on one side firm characteristics and on the other side bank characteristics. To the best of my knowledge, the analysis is also the first to utilize both register, survey, rating and bank connection data to analyze these questions. This has obvious advantages and generally validates the emerging evidence that bank lending channel plays a significant role during the business cycle.

The best policy to limit credit cycles should therefore focus on the bank lending channel. Ensuring that banks are robust and therefore do not have to limit their credit supply seems obvious. Further, and also suggested by Jiménez et al. (2012), lowering the interest rate in times of crisis could be an effective tool to limit the likelihood of a credit crunch. However, the analysis also indicates that other policies might be useful as the low interest rate during the financial crisis did not seem to effectively prevent the cyclical credit supply. However, focusing policy solely on the balance sheet channel seems fruitless in minimizing credit cycles due to the very modest effects estimated in this paper.

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2.8 Appendix

This appendix gives a full description of the data used in the analysis. Table 2.8 summerizes the underlying variables used to compute the controls used in the analysis. Table 2.9 defines the variables used in the analysis in terms of the underlying variables.

The following changes were made to underlying variables. If rating_(time) was in ('810' (Undergoing liquidation), '830' (Cannot be computed as the share of equity does not satisfy the minimum requirements set by law), '834' (Cannot be computed as equity is negative), '836' (Cannot be computed as equity (including subordinated loan capital) is negative), and '840' (Cannot be computed as the firms annual accounts have not been submitted and the deadline has not been met)) then the rating was set to 0. All ratings in this group are classified as 'very high risk'. As argued above, it is natural to devide the Danish real estate market into 5 regions. This is done by using a stardard mapping from the KOMNR to the regions. The regional price changes $\triangle P_{r,t}$ is the regional price change for commerical buildings (excluding farms) indexed using the Statistics Denmarks regional sales price data[11] from 2005 to 2007, and 2008 to 2010.

[11] See: http://www.statistikbanken.dk/statbank5a/default.asp?w=1440.

Table 2.8. Underlying variables in the analysis

Variables from the FIRM register	
Total assets	GF_AT
Equity	GF_EGUL
Profits (before taxes)	GF_RFEP
Revenue	GF_OMS
Variables from the FIRE survey	
Other short term debt	AKG
Short term debt to suppliers	KGL
Total assets (end of year)	PAST
Liquid assets	LIBE
Total liquid and financial assets	VKT
Long term debt to suppliers	LGL
Total interest cost	RUDG
Other long term debt	ALG
Variables from the Statistics Denmarks credit survey	
Outcome of loan application (in banks)	lfkil_(time)_banker
Applied for equity from owners	lfkil_(time)_ejer
Applied for equity from employees	lfkil_(time)_ansatte
Applied for equity from family	lfkil_(time)_familie
Applied for equity from other firms	lfkil_(time)_andrevirk
Applied for mortgage loan	lfkil_(time)_realkredit
Applied for equity from other sources	lfkil_(time)_andre
Didn't apply: Expected to be declined	lfnej_(time)_ikkemuligt
Didn't apply: The interest rate was expected to be too high	lfnej_(time)_kunmuligt
Didn't apply: Terms of the contract unfavorable e.g. loan period	lfnej_(time)_betingelser
Variables from the Experian dataset	
Experian credit rating	rating_(time)
Primary bank	Bank1_(time)
Secondary bank	Bank2_(time)
Tertiary bank	Bank3_(time)
Variables from the Danish FSA dataset	
Total loans	AS02051
Profits (before taxes)	AS0116
Total deposits	AS02251
Impairment of loans and receivables (et cetera)	AS0113
Total equity	AS0255
Total assets	AS0256
Variables from BBR, EJER, and EJVK registers (Real estate registers)	
Building ID	ejendomnummer
Owner ID	ejdnr
Public value (for taxation purposes)	EJDVBLB
Location (Municipality)	KOMNR
Ownership of building (in percentages)	EJERPCT

Table 2.9. Variables in the analysis in terms of the underlying variables

Variable	Definition
Dependent variable:	
$LOAN\ APPLICATION_{i,b,t}$	= 3 if lfkil_(time)_banker = 1, = 2 if lfkil_(time)_banker = 2, = 1 if lfkil_(time)_banker = 3.
Independent variables:	
Firm characteristics (i)	
$CREDIT\ RATING_{i,t-1}$	= rating_(time)
$SIZE_{i,t-1}$	= ln(GF_AT)
$CAPITAL\ RATIO_{i,t-1}$	= GF_EGUL / GF_AT
$PROFIT\ RATIO_{i,t-1}$	= GF_RFEP / GF_OMS
$SHORT\ TERM\ DEBT\ RATIO_{i,t-1}$	= (AKG + KGL) / PAST
$OTHER\ TYPES\ OF\ FINANCE_{i,t}$	= 1, if lfkil_(time)_ejer > 0, lfkil_(time)_ansatte >0, lfkil_(time)_familie > 0, lfkil_(time)_andrevirk > 0, lfkil_(time)_realkredit > 0, or lfkil_(time)_andre > 0. = 0, otherwise.
$LIQUIDITY\ RATIO_{i,t-1}$	= VKT / PAST
$IMPLIED\ INTEREST\ RATE_{i,t-1}$	= RUDG / (LGL + ALG + KGL + AKG)
$CHANGE\ IN\ MARKET\ VALUE_{i,t-1}$	$= \sum_{k=1}^{h} EJDVBLB_{k,i,t-1} \cdot EJERPCT_{k.i,t-1} \triangle P_{r,t}$. (The sum of all h commercial building owned by firm i times the price change in region r. The regional price change is defined in the text above.)
Primary bank connection characteristics (b)	
$LOAN\ IMPAIRMENT\ RATIO_{b,t}$	= AS0113 / AS02051
$BANK\ GROUP\ 1_{b,t}$	= 1, if firms primary bank was: Danske Bank, Jyske Bank, Nordea Bank, Nykredit Bank, Sydbank. = 0, otherwise.
$BANK\ CAPITAL\ RATIO_{b,t}$	= AS0255 / AS0256.
$FAILING\ BANK_{b,t}$	= 1, if the firm was customer at time t in a bank that later failed according to Østrup (2014).
$DEPOSIT\ DEFICIT_{b,t}$	= (AS02051 - AS02251) / AS02251
$BANK\ Z-SCORE_{b,t}$	= (AS0116 / AS0256 + AS0255 / AS0256) / σ(AS0116 / AS0256), where $\sigma(.)$ is the standard deviation on the return on assets estimated from a sample from 2000 to 2012.

CHAPTER 3

PRICE RIGIDITIES, CURRENCY SHOCKS, AND MARKET SHARES

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Abstract[1]

This paper exploits variation in the exchange rate to analyze the pass-through of marginal costs to final goods prices. Using Danish product-level prices matched with import/export data and firm register data, we find incomplete pass-through of marginal cost changes. Exchange rate shocks differentially affect firms both because of variation in the role of imports in total costs and because of differences in the source of imports. Though currency shocks do pass through (incompletely) to the price of imported goods, these cost changes only partially pass through to final goods

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prices on average. Our results suggest that firms with small market shares have nearly zero pass-through. However, as market share increases, so too does the pass-through of marginal cost changes to final domestic goods prices. Firms with a substantial market share have complete pass-through of marginal cost to final goods prices.

JEL-Codes: E3, L16, F4.
Keywords: Price Setting, Business Cycles, Exchange rates, Micro Data.

3.1 Introduction

A key feature of many dynamic stochastic general equilibrium (DSGE) models is that nominal rigidities, often in prices and wages, cause nominal shocks to have real effects. While the models share a substantial amount of features, they differ in assumptions of how firms set prices. However, the empirical evidence on the relevance of these different approaches is rather limited, with important exceptions e.g. Carlsson and Skans (2012). In this paper we use detailed Danish data on final good prices and import/export data merged on the firm level to evaluate how currency shocks affect marginal costs and ultimately how marginal cost changes affect the price setting behavior of firms. The evidence suggests that the low pass through of marginal cost changes to prices partially originates from firms with a low market share, measured as the firms share of total revenue in the sector, not passing through cost changes, which could potentially be an attribute of the competitive setting in which firms operate. More specifically, firms with a large market share tend to pass through marginal cost changes while firms with a low market share tend to keep prices fixed even when their production costs change.

The key novelty of this paper is that we can evaluate the role of a firm's market share at the micro level. We do this using detailed Danish data of producer prices and import/export data matched with firm registers and surveys containing detailed information on the activities of the firms. First, the combination of data sets allows us to focus on domestic prices as we have by product total sales value and quantities which can be cleaned for exports as we have by product (and destination) export values and quantities. This is essentially with respect to our instrumentation. Second, having the firm-level by product and destination import values and quantities, we can construct a measure of the change in marginal cost. While similar data on total sales values and quantities, and firm registers have been analyzed by Carlsson and Skans (2012) and similar data for import and exports by Amiti, Itskhoki, and Konings (2014) and Hummels et al. (2014), we believe that this is the first study to use a combination of data sets from a broad sample of firms. The matched dataset contains 87232 import price change observations (with a spell length of at least 2 periods) across 5679 unique intermediate product codes by 1404 industrial firms combined with 20355 domestic final good price change observations (again with a spell length of at least 2 periods) across 2051 unique final good product codes from 1999-2011.

As marginal cost is potentially an endogenous variable, we use an instrumental variable (IV) approach. We exploit the fact that currency changes pass through (potentially incompletely) to import prices, but to a large extent do not affect the firms' domestic pricing decision. Specifically, we use the variation of import prices by product over time to get a measure of the price change that follows directly from a depreciation/appreciation of the Danish krone with respect to 15 of the largest import markets outside the Eurozone: Sweden (SE), Great Britian (GB), China (CN), Norway (NO), the United States of America (US), Poland (PL), Russia (RU), Switzerland (CH), Japan (JP), Czech rep. (CZ), Korea (KR), India (IN), Lithuania (LT), Hungary (HU), and Canada (CA), accounting for 82.9 percent of total non-Eurozone imports. The projected price changes are then scaled by lagged firm-level exposure to specific products to obtain a measure for change in marginal cost. Furthermore, Denmark is an interesting country to study as the Danish krone is pegged to the euro (the euro was introduced on the 1st of January 1999, which also marks the beginning of our sample) and therefore currency changes might not necessarily reflect the state of the economy. However, we extend our analysis to deal with the potential problem of the currency moving with the business cycle.

Our results show clear evidence of final good price rigidities with an overall pass-through of marginal cost changes of only 10-14 percent depending on IV specification. However, when we interact marginal cost changes with domestic market shares the results reveal that firms with a market share approaching zero do not seem to pass through cost changes. But, the pass-through significantly increases in the domestic market share in all specifications. Furthermore, import prices do not react 1-to-1 to changes in currencies. Our results suggest that a 1 percent depreciation of the Danish krone result in a 0.40 percent increase in import prices. Hence, this paper further supports the common conclusions in international trade regarding the exchange rate disconnect (incomplete pass-through of currency changes).

The paper is structured in the following way: section 2 gives a short discussion of the related literature. Section 3 introduces the dataset and describes the empirical strategy. Section 4 describes our main empirical findings, section 5 discusses the robustness of the results and section 6 concludes.

3.2 Related Literatures

Our paper is related to three branches of literature. First, our paper is related to research on business cycle fluctuations as a result of nominal rigidities. This literature traditionally focuses on staggered contracting at the micro level implying a forward-looking price-setting behavior i.e. Calvo pricing, see Taylor (1980) and Calvo (1983). This is an approach used in New Keynesian full system settings in Christiano, Eichenbaum, and Evans (2005), Smets and Wouters (2007), and many other papers. Furthermore, a literature has emerged that focuses on information, rather

than prices, being sticky, see e.g. Mackowiak and Wiederholt (2009) and Mankiw and Reis (2002). While the models have been empirically successful at explaining inflation dynamics and effects of monetary policy, little evidence on the relevance of the different microfoundations exists, with the important exception of Carlsson and Skans (2012).

Second, our paper is related to the industrial organization (IO) literature focusing on the price setting behavior of firms. The research has focused on the behavior of price adjustment with respect to size and frequency of changes, and its implications for different models of price setting, see e.g. Klenow and Malin (2010), Nakamura and Steinsson (2008), and Álvarez et al. (2006). Further, Bils and Klenow (2004) find that goods sold in concentrated markets adjust prices more frequently, a finding complementary to ours. This strand of literature has also explored the price setting behavior of firms by questionnaires, see e.g. Blinder et al. (1998) and Fabiani et al. (2006). However, while these studies are with no doubt informative about price-setting behavior in general, they are lacking good controls for changing costs.

Third, our paper is related to a vast literature on the exchange rate disconnect. See for instance the handbook chapter by Burstein and Gopinath (2013) which gives a summary of recent developments in this area. Generally the literature has explored 3 channels leading to incomplete pass through of currency changes. The first channel is Pricing-To-Market strategies (PTM, henceforth) that explains salient features of international relative prices, see e.g. Atkeson and Burstein (2008). Here the firms' market shares are endogenized to explain incomplete pass through of marginal cost changes and it seems to explain a wide range of observations regarding international trade. The second channel is often labeled Local Currency Pricing (LCP) that explores the effects of nominal rigidities in the local currency. Under LCP some firms have zero short-run pass through giving rise to incomplete pass through at the aggregate, see Engel (2003) for a review. The third channel investigates the effect of local distribution costs to explain the incomplete pass through, see e.g. Burstein, Neves, and Rebelo (2003) and Goldberg and Campa (2010). This third strand of literature is the foundation of our analysis of how domestic prices move in response to currency changes. Additionally, our empirical approach to modeling currency pass-through (the IV step) shares key characteristics with Amiti, Itskhoki, and Konings (2014).

3.3 Data and empirical strategy

We start this section by discussing the data used in the analysis. Next, we turn to the instrumentation and we end the section by discussing the empirical strategy.

Data

Our main data source is Statistics Denmark, that provides comprehensive panel data of both trade flows (UHDI) and industrial final good prices (VARS) by firm, product

(CN 8-digit code), exports by destination and imports by source country. These panels are then merged by a unique firm identifier (CVR number) with the firm level characteristics in the firm register (FIRM) and firm survey (FIRE), which we use to construct measures of domestic market shares and total variable costs. The sample includes trade and final good price data from 1999-2011. The VARS data set contains quarterly observations of both total sales values and quantities from both domestic sales and exported goods. As the Danish trade data is annual, we aggregate the quarterly VARS data. Specifically, annual total sales values and quantities are simply the sum of the quarterly data. However, in case of missing within year observations we compute the quarterly average value and quantity and multiply by 4. To get domestic (Danish) sales values and quantities, we simply deduct the total export values and quantities by firm and product (from all export destinations) from the annualized VARS data. On the import side we focus on 15 of the largest markets outside the Eurozone: Sweden (SE), Great Britian (GB), China (CN), Norway (NO), the United States of America (US), Poland (PL), Russia (RU), Switzerland (CH), Japan (JP), Czech rep. (CZ), Korea (KR), India (IN), Lithuania (LT), Hungary (HU), and Canada (CA), accounting for 82.9 percent of total non-Eurozone imports.[2] A more detailed description of the data sources can be found in the data appendix.

Our dependent variable in this analysis is log change in the domestic (Danish) final good price of firm j's product i at time t i.e.

$$\triangle P_{j,i,t} \equiv \triangle \log \left(\frac{Value_{j,i,t}^{VARS} - \sum_{s \in S_{j,t}} Export\,Value_{j,i,s,t}^{UHDI}}{Quantity_{j,i,t}^{VARS} - \sum_{s \in S_{j,t}} Export\,Quantity_{j,i,s,t}^{UHDI}} \right),$$

where quantities are measured as weight in kilograms, s is the destination country, and $S_{j,t}$ is the set of countries that firm j export to at time t (we include all countries, both Eurozone and non-Eurozone countries). Note that we only include observations that have comparable units in both the VARS and UHDI data i.e. we only include observations measured in kilograms. Furthermore, note that the data only allows us to follow a very closely defined group of products over time and not necessarily a specific product. The Combined Nomenclature (CN) includes 9300 different product categories with fairly precise definitions e.g. 48189090 is paper and paperboard; articles of paper pulp, of paper, or of paperboard. However, we recognize this typical drawback of using trade data, as some changes in prices could potentially be due to composition changes within product codes. There could also be measurement error in both quantities and values. We attempt to minimize these problems by excluding the top and bottom 1,5 percent of final good price changes (a similar strategy for cleaning the data is found in Carlsson and Skans (2012)).

[2] We have excluded Turkey, Taiwan, Argentina and Thailand, as we do not have macro data for these countries, see the data appendix.

A key variable in our analysis is market share. We define the domestic market share of firm j at time t as:

$$MS_{j,t} = \frac{total\ revenue_{j,t}}{\sum_{j \in J_{k,t}} total\ revenue_{j,t}},$$

where $J_{k,t}$ is the set of firms that has sector k as their main sector. We use fairly narrow definition of sectors using the DB07 6-digit (NACE) sector code.[3] Total revenue is taken from the Danish firm register (FIRM).

The main variable of interest is change in marginal cost which is defined as the log change in per unit values of firm j's imports from source country m weighted by the respective expenditure shares:

$$\triangle mc_{j,t} = \sum_{i \epsilon I_{j,t}} \sum_{m \in M_{j,t}} \omega_{i,j,m,t-1} \triangle \log P^{IM}_{i,j,m,t}, \tag{3.1}$$

where $P^{IM}_{i,j,m,t}$ is the import price (potentially instrumented) in Danish kroner (per unit import measured in kilograms) of firm j's imports of intermediate good i from country m at time t. The weights $\omega_{i,j,m,t-1}$ are the respective import values as a share of total variable cost lagged. Stated differently, we take the composition of imported goods as predetermined. This common but nontrivial assumption is basically equivalent to assuming a J-curve effect at the firm level. We will return to this discussion of substitution effects in the robustness section. Total variable cost are taken from the firm survey FIRE using the definition of total variable cost used in Bagger, Christensen, and Mortensen (2014) excluding any imputed observations. See the data appendix for a more detailed description. $I_{j,t}$ and $M_{j,t}$ is the set of all imported intermediate goods and import source countries for every firm at time t. Our measure of marginal cost change is only a proxy as we limit our analysis to 15 of the largest sources of import outside the eurozone and omit information on domestic inputs, wages and firm productivity. However, as we attempt to isolate an exogenous change in marginal costs and because common measures of marginal cost change of other inputs are often highly endogenous, we limit the analysis to the above measure.[4] Furthermore, note that our measure of marginal cost change is firm specific. Ideally we would like to have a product specific measure of change in marginal costs. However, as no such mapping between inputs and outputs exists we rely on our firm level measure.

The matched dataset contains 87232 import price change observations (i.e. with a spell length of at least 2 periods) across 5679 unique intermediate product codes

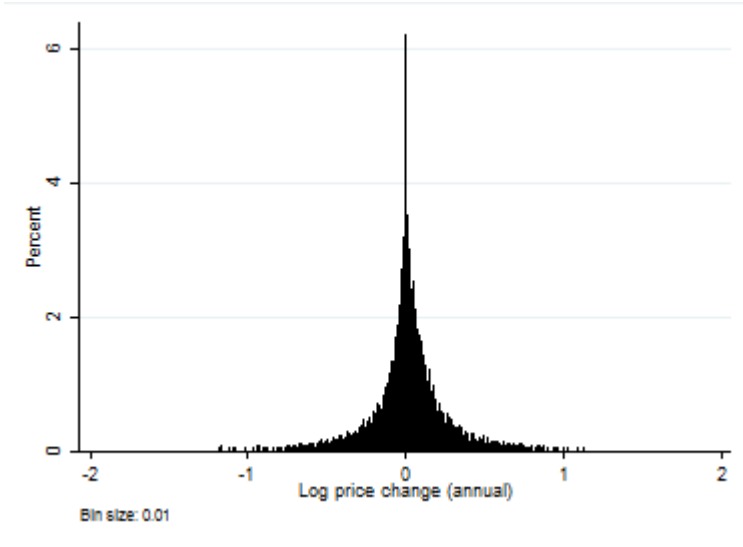
[3] Note that we have limited our sample to industrial firms i.e. firms with a main sector code of 2 using the DB93 9-grouping for data from 1999 and a main sector code 2 using the DB07 10-grouping for data from 2000-2011. This is by far the main part of the VARS data.

[4] In general this could potentially be problematic. However, in the frictionless model in Carlsson and Skans (2012) with isoelastic demand, the cost associated with each possible margin of adjustment, e.g. the cost changes of imported goods, should be the same at the optimum due to cost minimization. Further, a similar result apply if the production function is separable in inputs.

by 1404 industrial firms combined with 20355 domestic final good price change observations (again with a spell length at least 2 periods) across 2051 unique final good product codes from 1999-2011.

We plot the log changes in final good prices of the final sample in figure 3.1. The price changes have a mean of 1.9 percent (s.e. 0.35) which is a little below the average producer price inflation of 2.7 percent (at the aggregate) for the sample period in Denmark. Further, the distribution is a little left skewed but with a moderate skewness coefficient of -0.11, but highly leptokurtic with a kurtosis coefficient of 7.157. Note that there is a spike in price changes in the bin around 0. In fact, 1256 observations or 6.1 percent of the sample is in the ± 0.5 percent bin (the median price change is 0.012). This could potentially indicate nominal price rigidities but could naturally also reflect that marginal costs have not changed.

Figure 3.1. Distribution of log changes in final good prices

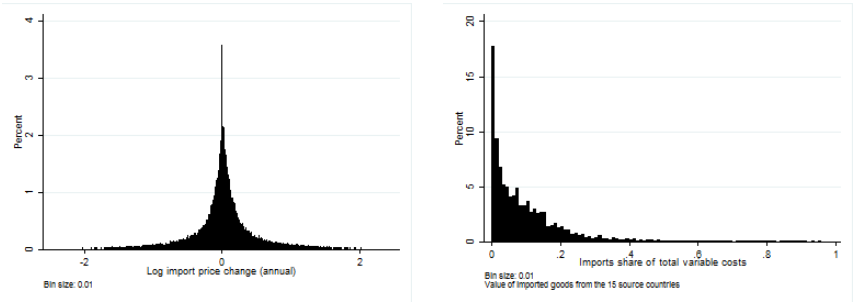


Notes: The figure plots the distribution of log price changes across 20355 observations of 1136 different firms and 2051 different products. Bin size 0.01.

Figure 3.2 plots the import price changes and import shares (total value of imports from the 15 source countries over total variable cost). The import price changes have a comparable average of 2.2 percent (the median import price change is 0.013) but are more widely dispersed with a standard error of 0.88. Import price changes are moderately right skewed, with a skewness coefficient of 0.05, and highly leptokurtic with a kurtosis coefficient of 8.634. Note that the higher kurtosis coefficient of import

prices compared to final good prices is partly a result of less cleaning of the import price data (we only exclude the top and bottom 0.5 percent), as we deal with potential measurement error indirectly by applying an IV approach. Again, we see a spike around zero with 3626 observations, or 4.2 percent of sample, in the ± 0.5 percent bin around zero. This could again potentially suggest that there are also nominal rigidities in the prices of imports.

Figure 3.2. Distribution of log changes in import prices and import as a share of total variable cost



Notes: The left figure plots the distribution of log import price changes across 87232 observations of 1404 different firms and 5679 different intermediate products. Bin size 0.01 (Plot region: -2.5 to 2.5). The right figure shows total value of import from the source countries as a share of total variable cost across 20355 observation for the 1404 different firms.

The right hand panel in figure 3.2 shows the imports share of total variable cost (sometimes termed import intensity). The mean share is 0.099 (s.e. 0.12) in our sample. Note that we condition our sample on the import share being strictly larger than zero. Furthermore, a significant portion of the sample, 18.1 percent, has an import share of less than 1 percent. This has the natural implication that the average changes in marginal cost will be relatively small compared to change in prices of final goods.

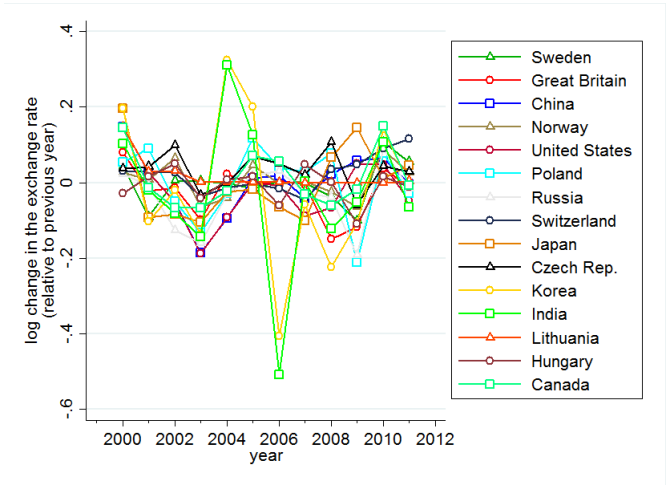
Prices of imports could potentially be endogenous and might not reflect actual changes in marginal costs. A simple example would be new light bulbs that might be more expensive, but are more efficient and therefore actually decrease in marginal costs. We therefore continue this section by discussing the instrumentation.

Instrumentation

To deal with the potential endogeneity of import prices, we have developed an IV approach to capture variation in prices of imports that result from variation in the ex-

change rate. The raw variation we are exploiting is in Figure 3.3 below. As mentioned above, since different firms have different exposure to imports from these different countries, we are able to use cross-sectional variation in import exposure in addition to the time-series variation displayed in figure 3.3.

Figure 3.3. Yearly log change in the exchange rate



Notes: We use the calendar year average exchange rates.

We estimate the relationship between the log import price change, $\triangle \log P^{IM}_{i,j,m,t}$, and the log change in the relevant currency of source country m, i.e.

$$\begin{aligned}\triangle \log P^{IM}_{i,j,m,t} &= \gamma_0 + \gamma_e \triangle e_{m,t} + \gamma_{MS\times e} MS_{j,t-1} \triangle e_{m,t} + \gamma_{MS} MS_{j,t-1} \\ &\quad + \delta_t + \delta_j + \delta_m + u_{i,j,t},\end{aligned} \tag{3.2}$$

where $e_{m,t}$ is the log nominal exchange rate, measured as the number of Danish kroner for one unit of the foreign currency, in source country m at time t. δ_t,δ_j and δ_m are time, firm, and source country fixed effects, respectively. The domestic market share, $MS_{j,t}$, of firm j is included to make sure that what we are capturing with respect to market share and final good prices in our final regression is not a direct consequence of heterogeneity in currency pass-through to import prices.[5] From regression (3.2), we obtain the predicted log import price change, $\triangle \log \hat{P}^{IM}_{i,j,m,t}$,

[5]The lagged level of the market shares is include to ensure the cross sectional consistency. However, this implies the that long-run implications of the regressions are inconsistent. However, the coefficient, γ_{MS}, is insignificant in all regressions below and very close to zero.

which combined with our definition of marginal cost given in equation (3.1) yields the predicted marginal cost change from currency cost shock, $\triangle \widehat{mc}_{j,t}$.

A valid concern about the above specification is whether currency changes are truly exogenous to the domestic price setting behavior at the firm level. A major concern is whether the exchange rate moves with fluctuations in aggregate demand. Stated differently, a depreciation of the Danish krone reflects a slowdown in the Danish economy thus affecting aggregate demand and therefore demand for firm j's products. However, the relevance of this concern is not obvious. The Danish currency is pegged to the euro and therefore the Danish monetary policy (assumedly affecting the exchange rate) might not necessarily reflect the state of the economy.[6] Furthermore, currency changes are often argued to be random walks which could potentially imply that there is little co-movement between the exchange rate and aggregate demand. However, we address this concern directly by using residual exchange rate changes from a regression of exchange rate changes on contemporaneous changes in domestic and foreign aggregates i.e.

$$\begin{aligned} \triangle e_{m,t} &= \mu + \eta_{dk,GDP} g^{GDP}_{DK,t} + \eta_{dk,U} \triangle log(U_{DK,t}) + \eta_{dk,\pi} \pi_{DK,t} \\ &\quad + \eta_{m,GDP} g^{GDP}_{m,t} + + \eta_{m,U} \triangle log(U_{m,t}) + \eta_{dk,\pi} \pi_{m,t} + \hat{\varepsilon}_{m,t} \end{aligned} \tag{3.3}$$

where $g^{GDP}_{m,t}$ is the real percentage growth rate in gross domestic product in country m from time $t-1$ to t, $U_{m,t}$ is the unemployment rate, $\pi_{m,t}$is the inflation rate (measured as the percentage change in a standard Consumer Prices Index). The macro data is taken from the OECD database, see the data appendix for a full description. $\hat{\varepsilon}_{m,t}$ is the residual exchange rate change orthogonal to movements in macro aggregates. We test the robustness of our results by replacing $\triangle e_{m,t}$ with $\hat{\varepsilon}_{m,t}$ in regression (3.2) above. Note that the coefficients in (3.3) are estimated separately for each currency using annual observations from 1990 to 2011. There could potentially be problems with simultaneity and reverse causality, but we generally believe that the specification would at least partially deal with the potential concerns raised above.[7]

Another concern, that we essentially do not address, is that domestic producers are potentially competing with foreign firms. Given e.g. a depreciation of the Danish krone and full currency pass-through by foreign competitors, result not only in higher import costs for the Danish firm, but also raises prices of foreign products. This could potentially imply that we are overestimating the pass through of the marginal cost channel, if domestic firms follow the prices of the competing foreign products. However, given that foreign firms use PTM strategies, the problem might be less

[6] The Danish krone is formally pegged using the ERM2 framework. However, the Danish central bank has agreed to a fluctuation band of ± 2.25 percent. In practice the exchange rate towards the euro is much more stable.

[7] Note that traditional economic theory suggests a reverse causality. Further, we are assumining that the coefficients in (3.3) are time independent. This is naturally not completely trivial as, e.g. speculative attacks on the Danish Krone would imply momentary disruption of the relationship.

pronounced. But the structure of our data, which only includes observations of Danish firms, does not allow for a formal analysis of the extent of this problem.

Final goods prices

Next, we turn to the empirical estimation of the price setting behavior at the firm level in response to changes in marginal costs. In our main empirical specification we regress nominal domestic price changes of final goods on changes in marginal costs, interacted with market shares:

$$\begin{aligned} \triangle \log P_{j,i,t} &= \alpha + \beta_{mc} \triangle \widehat{mc}_{j,t} + \beta_{mc \times MS} \left[\triangle \widehat{mc}_{j,t} \times MS_{j,t-1} \right] \\ &\quad + \beta_{MS} MS_{j,t-1} + \theta_t + \theta_j + \varepsilon_{j,i,t}, \end{aligned} \tag{3.4}$$

where $\triangle \widehat{mc}_{j,t}$ is the change in marginal cost of firm j at time t, $MS_{j,t-1}$ is the market share of firm j at time $t-1$ i.e. we take the market share as given. θ_t and θ_j are time and firm fixed effects. We generally use three measures of marginal cost change. First, we use the observed changes in import prices from the 15 source countries which essentially gives us the same measure of marginal cost change as Amiti, Itskhoki, and Konings (2014). With this specification marginal cost pass-through can be estimated using OLS. Next, we use the actual exchange rate changes as an instrument for marginal cost changes and apply a two-step IV estimation procedure. Specifically, we estimate (3.2) using the actual changes in the exchange rate. From this regression, we get the predicted import price changes which combined with (3.1) give the predicted marginal cost change. We then finally use the predicted marginal cost change in the estimation of (3.4). In our last specification, we apply three steps. We start by obtaining the residual change in the exchange rate from (3.3). We then use the residual exchange rates in estimation of (3.2) which again combined with (3.1) give the predicted marginal cost change. The predicted marginal cost change is then used in the estimation of (3.4).

3.4 Results

We start by exploring how currencies move with macro aggregate fluctuations. The relationships are generally not very strong, see table 3.1. Except for the coefficients on the growth rate of Danish GDP, Danish inflation and Chinese inflation, all coefficients are insignificant even at a 10 percent significance level. There is, however, a tendency for the Danish krone (and therefore the Euro) to depreciate relative to most of the currencies when the Danish inflation is high. We naturally do not expect this to be a causal relationship. But, as economic activity could potentially affect domestic demand we obtain the residuals from these regressions to test the robustness of our results.

Table 3.1. Exchange rate changes and macro aggregates.

Dependent variable:	$\triangle e_{SE,t}$	$\triangle e_{GB,t}$	$\triangle e_{CN,t}$	$\triangle e_{NO,t}$	$\triangle e_{US,t}$
$g^{GDP}_{DK,t}$	0.007	0.030**	−0.016	0.009	0.006
	(0.018)	(0.015)	(0.023)	(0.008)	(0.026)
$\triangle log(U_{DK,t})$	0.155	0.105	−0.182	0.039	0.011
	(0.165)	(0.160)	(0.298)	(0.118)	(0.249)
$\pi_{DK,t}$	0.072*	−0.003	0.012	0.048*	0.017
	(0.029)	(0.032)	(0.062)	(0.024)	(0.050)
$g^{GDP}_{m,t}$	0.019	−0.015	−0.003	−0.003	0.008
	(0.014)	(0.140)	(0.020)	(0.009)	(0.029)
$\triangle log(U_{m,t})$	0.118	−0.213	N/A	−0.030	0.101
	(0.156)	(0.260)		(0.091)	(0.355)
$\pi_{m,t}$	−0.009	−0.001	−0.011*	−0.020	−0.013
	(0.009)	(0.014)	(0.005)	(0.012)	(0.032)
N	21	21	19	21	21

Dependent variable:	$\triangle e_{PL,t}$	$\triangle e_{RU,t}$	$\triangle e_{CH,t}$	$\triangle e_{JP,t}$	$\triangle e_{CZ,t}$
$g^{GDP}_{DK,t}$	0.035	0.043*	0.004	0.022	−0.006
	(0.038)	(0.019)	(0.007)	(0.026)	(0.011)
$\triangle log(U_{DK,t})$	0.084	0.008	0.102	0.392	−0.067
	(0.497)	(0.200)	(0.102)	(0.283)	(0.109)
$\pi_{DK,t}$	0.039	0.042	0.036*	0.054	0.025
	(0.049)	(0.035)	(0.018)	(0.048)	(0.020)
$g^{GDP}_{m,t}$	−0.030	−0.010	−0.001	−0.006	0.002
	(0.029)	(0.010)	(0.007)	(0.020)	(0.008)
$\triangle log(U_{m,t})$	−0.328	N/A	N/A	0.245	−0.115
	(0.379)			(0.354)	(0.112)
$\pi_{m,t}$	0.001	−0.004	−0.007	0.021	0.000
	(0.010)	(0.004)	(0.007)	(0.023)	(0.000)
N	14	12	21	21	16

Dependent variable:	$\triangle e_{KR,t}$	$\triangle e_{IN,t}$	$\triangle e_{LT,t}$	$\triangle e_{HU,t}$	$\triangle e_{CA,t}$
$g^{GDP}_{DK,t}$	0.043	0.041	0.010	−0.008	0.006
	(0.034)	(0.043)	(0.009)	(0.015)	(0.017)
$\triangle log(U_{DK,t})$	0.591	0.499	−0.084	−0.079	0.093
	(0.398)	(0.511)	(0.123)	(0.159)	(0.209)
$\pi_{DK,t}$	−0.029	−0.037	0.016	0.005	−0.003
	(0.072)	(0.101)	(0.021)	(0.034)	(0.027)
$g^{GDP}_{m,t}$	0.007	−0.007	−0.004	0.007	0.039
	(0.016)	(0.012)	(0.003)	(0.010)	(0.027)
$\triangle log(U_{m,t})$	−0.255	N/A	N/A	−0.088	0.517
	(0.182)			(0.232)	(0.502)
$\pi_{m,t}$	−0.014	−0.006	N/A	−0.008	0.027
	(0.020)	(0.018)		(0.005)	(0.021)
N	21	16	16	15	21

Note: Standard errors are in parentheses. *, **, and *** are 10, 5, and 1% significance levels, respectively. In the above regressions we use data from 1990 to 2011 from OECD database if it is available, see the data appendix for a full description.

Table 3.2. Nominal import price change and the actual and residual exchange rate

Dependent variable: $\triangle \log P^{IM}_{i,j,m,t}$	(1)	(2)	(3)	(4)
$\triangle e_{m,t}$	0.398^{***}	0.250^{***}	0.489^{***}	0.280^{***}
	(0.058)	(0.072)	(0.074)	(0.095)
$\triangle e_{m,t} \times MS_{j,t-1}$		0.541^{***}		0.760^{***}
		(0.158)		(0.220)
$MS_{j,t-1}$		0.004		-0.006
		(0.036)		(0.036)
Exchange rate:	Actual	Actual	Residual	Residual
Fixed effects:				
δ_t	Yes	Yes	Yes	Yes
δ_j	Yes	Yes	Yes	Yes
δ_m	Yes	Yes	Yes	Yes
Observations	87232	87232	87232	87232

Note: Observations are at the product-firm-source country-year level. Standard errors are in parentheses. *, **, and *** are 10, 5, and 1% significance levels, respectively.

Next we explore the currency pass-through to import prices for the firms in our sample. Table 3.2 reports the result. In column (1), we find a pass-through of 39.8 percent when we do not include the interaction term. Stated differently, our data also shows sign of the exchange rate disconnect discussed in the section on related literature. Furthermore, the interaction term with market share of the importing firm is significant, see column (2). This could potentially reflect that firms with large market shares, generally large firms, have different purchasing strategies or on average import from different countries. We include these interaction terms when computing the predicted log import price to make sure that what we are capturing in the final regression is not due to heterogeneity in this preliminary step[8]. Column (3) shows the results using residual exchange rate changes. Here the pass-through is 48.9 percent, a little above the pass through estimated using the actual exchange rate. Furthermore, using residual exchange rate changes gives the same conclusions regarding the domestic market share of the importing firm, see column (4). Finally, to compute the predicted marginal cost change we use the results in column (2) and (4) combined with the definition of marginal cost given in (3.1).

Finally we explore the domestic price setting behavior of firms. The results are

[8]Note that using the results in columns (1) and (3) to compute the predicted import price changes, do not affect the results regarding market shares and pass-through to final good prices, that we explore below, in any significant way.

Table 3.3. Marginal cost, market share, and pass-through

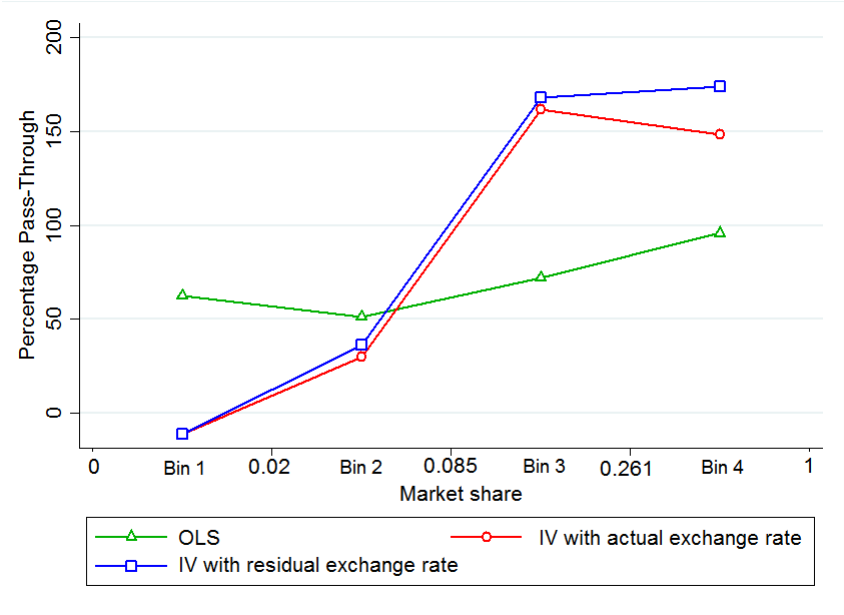
Dependent variable:	OLS		IV		IV	
$\triangle \log P_{i,j,t}$	(1)	(2)	(3)	(4)	(5)	(6)
$\triangle mc_{j,t}$	0.748^{***}	0.596^{***}	0.141	-0.084	0.099	-0.103
	(0.090)	(0.058)	(0.222)	(0.236)	(0.223)	(0.237)
$\triangle mc_{j,t} \times MS_{j,t-1}$		0.675^{**}		2.592^{***}		3.248^{***}
		(0.302)		(0.926)		(1.143)
$MS_{j,t-1}$		0.003		-0.0003		-0.003
		(0.033)		(0.033)		(0.032)
Exchange rate:	None	None	Actual	Actual	Residual	Residual
Fixed effects:						
δ_t	Yes	Yes	Yes	Yes	Yes	Yes
δ_j	Yes	Yes	Yes	Yes	Yes	Yes
Observations	20355	20355	20355	20355	20355	20355

Note: Observations are at the product-firm-year level. Standard errors (1-step) are in parentheses. *, **, and *** are 10, 5, and 1% significance levels, respectively.

found in table 3.3. Columns (1) and (2) show the results when using the actual import price changes in computing the marginal cost change. In column (1), we see significant evidence of price rigidities with pass through from marginal cost of 74.8 percent as the coefficient is significantly different from 1 (the predicted coefficient in the frictionless model in Carlsson and Skans (2012)). When using the IV approach with actual exchange rate changes, the pass through is only 14.1 percent, see column (3), compared to 9.9 percent using the residual exchange rate changes, see column (5). However, the results become very interesting when we include the interaction term with market shares. The results suggest that there is significant heterogeneity in the pass-through of marginal cost changes depending on the domestic market share of the firm. This holds for all three specifications, see column (2), (4) and (6). Furthermore, the IV results suggest that marginal cost pass through is close to zero when the market share of the firm approaches zero. On the other hand, the higher the market share the larger the pass through.

A possible theoretical explanation for price rigidities is menu costs. Given that menu costs explain price rigidities we would expect the size of the marginal cost change to matter for the pass-through. Furthermore, as the pass-through to import prices is bigger for firms with a high market share, menu costs could potentially explain the results above. However, including squared marginal cost change terms to the regressions in column (1), (3) and (5) in table 3.3 yields insignificant coefficients.

Figure 3.4. Pass-through by quartiles of market share



Notes: Equal-sized bins in terms of firm-product-year observations, sorted by market share. Bin 1 includes all observations of firm with a market share up to (equal to) 2.0 percent, Bin 2 is from 2.0 to 8.5 percent, Bin 3 from 8.5 to 26.1, and Bin 4 from 26.1 percent to 100 percent. The full regression results are printed in table 3.7 in the appendix.

Furthermore, splitting the sample by shock size yielded no conclusive evidence i.e. we find no clear evidence for menu costs given the above specifications.

The empirical finding in table 3.3 suggests that the pass-through of marginal cost changes depends on the domestic market share. To ensure that this result is smooth (e.g. not driven by outliers) and not a direct consequence of the linear specification, we apply a standard nonparametric approach. We split the sample into quartiles of the market share and estimate the pass-through coefficient separately for each quartile. The results are plotted in figure 3.4. The estimated coefficients and standard errors can be found in table 3.7 in the appendix. The plot generally shows that the pass-through is increasing in the market share for all three specifications. The green line shows coefficient estimates using the actual import price changes when computing the marginal cost. Here firms with a market share lower than 8.5 percent in bin 1 and 2 seem to have a pass-through of approximately 50-60 percent. In bin 3 we estimate a pass-through of 72 percent increasing to 98 percent in bin 4. Using the

Table 3.4. Summary statistics by market share quartiles

	Full sample Mean	Bin 1 Mean	Bin 2 Mean	Bin 3 Mean	Bin 4 Mean
$\lvert\triangle \log P_{i,j,t}\rvert$	0.216	0.209	0.202	0.218	0.234
$\lvert\triangle mc_{j,t}\rvert$ using actual import prices	0.013	0.014	0.014	0.012	0.011
$\lvert\triangle \widehat{mc}_{j,t}\rvert$ using actual exchange rates	0.007	0.008	0.007	0.006	0.006
$\lvert\triangle \widehat{mc}_{j,t}\rvert$ using residual exchange rates	0.007	0.008	0.007	0.006	0.006
Size	18.98	17.27	18.38	19.42	20.84
Import intensity	0.099	0.092	0.106	0.107	0.088
Market share	0.206	0.009	0.046	0.156	0.612
Observations	20355	5086	5027	5144	5088

Note: Bin 1 includes all observations of firm with a market share up to (equal to) 2.8 percent, bin 2 is from 2.8 to 10.7 percent, bin 3 from 10.7 to 31.3, and bin 4 from 31.3 percent to 100 percent. $'|.|'$ implies absolute values. Size is measured as log total assets.

IV approach with the residual exchange rate change (blue line) yields monotonically increasing coefficients in the market share. Note that we cannot reject complete (unity) pass-through for the firms in bin 3 and 4 for either IV approach. However, the results are only suggestive as splitting sample by market power decreases the precision of the coefficient estimates i.e. we cannot statistically discriminate between e.g. bin 1 and 2.

To make sure that the results regarding the market share are not driven by other factors e.g. import intensity, we compute summary statistics for the different bins used in figure 3.4, see table 3.4. The only clear relationship is between market share and size, measured by log total assets from the FIRM register. Generally, firms with a large market share experience a bit smaller changes in marginal cost using all three measures. This implies that the relationship between market shares and pass through is unlikely to be driven by heterogeneity in import intensity among firms.

This concludes our main empirical findings. We proceed by discussing the robustness of the results and comment on some of the fundamental assumptions made in the above.

3.5 Robustness

In this section we address two central problems with the analysis above. We start by addressing the problem of substitution and taking the composition of imports as predetermined. Next, we discuss the dynamics of price changes.

Substitution and currency changes

If currency rates are random walks and the composition of imports is fixed, we are dealing with permanent shocks to marginal cost. However, it seems intuitive that firms will substitute to different source countries (or input substitutes) if the price of imported intermediate goods goes up following a depreciation of the local currency. The question is whether this effect is quantitatively important and happens immediately or with some lag. The so-called J-curve effect describes the short-run deterioration and long-run improvement of the trade balance following a depreciation of the local currency. A general interpretation of this phenomenon is that quantities of both imports and exports are fixed in the short-run. The nature of our data actually allows us to test directly whether the firms in our data tend to lower their import quantities following a depreciation of the Danish krone. We simply use the by product-firm-source country-year import quantities as our dependent variable i.e.

$$\triangle \log Q^{IM}_{i,j,m,t} \equiv \log\left(\frac{Import\,Quantity^{UHDI}_{j,i,m,t}}{Import\,Quantity^{UHDI}_{j,i,m,t-1}}\right).$$

We proceed by estimating the relationship between the log import quantity change, $\triangle \log Q^{IM}_{i,j,m,t}$, and the log change in the relevant currency of source country m, i.e.

$$\begin{aligned}\triangle \log Q^{IM}_{i,j,m,t} \quad = \quad & \gamma_0 + \gamma_e \triangle e_{m,t} + \gamma_{MS\times e} MS_{j,t-1} \triangle e_{m,t} \\ & + \gamma_{MS} MS_{j,t-1} + \delta_t + \delta_j + \delta_m + u_{i,j,m,t},\end{aligned}$$

following the notation from above. Again, we include the interaction term with market share to ensure that what we observed in our main specification is not a result of heterogeneity in substitution rates. The results from this regression are shown in table 3.5. In column (1) we see that, excluding the interaction with market share, there is little evidence of substitution. However, when we use the residual changes in the exchange rate that are orthogonal on macro aggregates, the coefficient is significant at a 10 percent significance level, see column (3). Including the interaction terms yields no significant coefficients, see columns (2) and (4), i.e. there is no evidence that substitution effects are driving the market share results in our main specifications. Ignoring the standard errors, the quantitative size of the substitution effect is also encouraging. E.g. the coefficient from column (3) implies that a 10 percent depreciation of the local currency implies that import quantities go down by 2.7 percent. Stated differently, firms seem to keep their composition of imports fairly stable.

In table 3.5, we used contemporaneous changes in the exchange rate. In table 3.8 in the appendix we explore the effects of including lagged changes in the exchange rates. The idea is that the J-curve observed at the aggregate is a consequence of firms

Table 3.5. Import quantity change and the actual and residual exchange rate

	IV		IV	
Dependent variable: $\triangle \log Q^{IM}_{i,j,m,t}$	(1)	(2)	(3)	(4)
$\triangle e_{m,t}$	−0.076	−0.113	−0.272*	−0.268
	(0.114)	(0.142)	(0.144)	(0.187)
$\triangle e_{m,t} \times MS_{j,t-1}$		0.136		−0.014
		(0.310)		(0.433)
$MS_{j,t-1}$		−0.056		−0.056
		(0.071)		(0.071)
Exchange rate:	Actual	Actual	Residual	Residual
Fixed effects:				
δ_t	Yes	Yes	Yes	Yes
δ_j	Yes	Yes	Yes	Yes
δ_m	Yes	Yes	Yes	Yes
Observations	87232	87232	87232	87232

Note: Observations are at the product-firm-source country-year level. Standard errors are in parentheses. *, **, and *** are 10, 5, and 1% significance levels, respectively.

adjusting their inputs slowly. However, the results are generally inconclusive. Including 3 lags of actual/residual exchange rate changes yields no significant coefficients at a 5 percent significance level and there is no evidence of time lagged adjustments to import quantities.

One caveat in analyzing substitution effects is that we only observe total imports and not import used for production of products for domestic sales. If importers are simultaneously exporters, a depreciation of the local currency could potentially imply that the demand for imports increases for products with no close substitutes, as the firm can more easily sell their products abroad. This would lead us to underestimate the substitution effect. In general, substitution effects would lead us to overestimate the marginal cost change and therefore give a downward bias of our coefficients of pass-through. However, this effect seems to be an unlikely explanation for the heterogeneity found in pass-through based on market shares.

Dynamics

Are prices sticky, meaning that marginal cost changes do not affect prices immediately? We address this question by looking at different versions of our main specification including lagged changes in marginal cost. Table 3.6 shows the results of including lagged marginal cost changes using the actual import price changes. Note that the results in table 3.6 are only consistent if the shock to marginal cost is perma-

Table 3.6. Dynamics and pass-through

Dependent variable: $\triangle \log P_{i,j,t}$	(1)	(2)	(3)	(4)
$\triangle mc_{j,t}$	0.748***	0.875***	0.691***	0.591***
	(0.090)	(0.102)	(0.128)	(0.146)
$\triangle mc_{j,t-1}$		−0.084	−0.076	0.091
		(0.110)	(0.128)	(0.165)
$\triangle mc_{j,t-2}$			−0.106	−0.233
			(0.132)	(0.159)
$\triangle mc_{j,t-3}$				−0.136
				(0.164)
Fixed effects:				
δ_t	Yes	Yes	Yes	Yes
δ_j	Yes	Yes	Yes	Yes
Observations	20355	13562	9341	6498

Note: Observations are at the product-firm-year level. Standard errors are in parentheses. *, **, and *** are 10, 5, and 1% significance levels, respectively.

nent. If there is a transitory element to the shocks or an element of substitution, we are omitting the autoregressive part of the variation.

As is apparent from column (2), (3) and (4) in table 3.6, there is no tendency for marginal cost changes to pass through with a time lag. Note that the sample size decreases rapidly by requiring a spell length of 2, 3 and 4 periods, respectively. We therefore find no tendency for marginal cost changes affecting prices going forward.

3.6 Concluding remarks

In this paper, we show that market shares are key to understanding variation in marginal cost pass-through across firms. We do this using detailed Danish micro data on prices by product and firm, linked with export-import data, and firm registers and surveys. To handle the fact that marginal costs may be endogenous, we apply an IV approach. We exploit that at least part of the variation in prices of imported goods is due to variation in the exchange rate, a feature demonstrated in the vast literature on the exchange rate disconnect. Relying on this insight, we construct a measure of firm level marginal cost change based on the lagged exposure to different currencies (by product).

In the frictionless model by Carlsson and Skans (2012), the price elasticity with respect to marginal costs equals unity. However, our results show clear evidence of price rigidities with a general pass-through of only 10-14 percent depending on IV specification. This suggests that nominal frictions play a central role in understanding

the price setting behavior of firms. Furthermore, when we interact marginal cost changes with domestic market shares the results reveal that firms with a market share approaching zero do not seem to pass-through cost changes. However, the pass through is significantly increasing in the domestic market share in all specifications. This could suggest that market leaders set price as a markup over marginal cost, but that small firms, measured by market share, are essentially price takers.

We believe that this insight could be helpful in understanding the nominal frictions observed at the aggregate level and furthermore that it adds to the literature in industrial organization on the price setting behavior of firms.

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3.8 Data appendix

The data is constructed from multiple Danish administrative registers and surveys. First of all, the average sales prices are obtained from a sales price survey (VARS). Second, to account for the fact that currency changes naturally affect the price setting behavior abroad, the prices are cleaned by product and firm for exports using the import and export register (UHDI). The UHDI dataset also contains information on imports by product which we use to measure change in marginal costs. The domestic price and import data is then merged with the firm-based survey (FIRE) that contain detailed information on operating costs, book value of capital, cost of intermediate goods, and many other accounting measures. To get a measure of market share we rely on information from the firm register (FIRM).

The VARS data set contains firm-specific information on sales measured by total value in Danish kroner and total quantity/weight (in kilograms) for every product using the CN classification code. The data is collected quarterly in surveys for industrial firms with at least 10 employees, which amounts to approximately 3000 firms. The quarterly data is made annual by summing over quarterly figures or by taking the average quarterly value and weight and multiplying by 4 in case of missing observations. The VARS dataset also contain information sector specific codes where we limit our analysis to firms in Construction, Manufacturing and natural resources, specifically, firms with a sector code of 2 using the 9-grouping DB93 (NACE) classification in 1999 and firms with a sector code of 2 using the 10-grouping DB07 (NACE) classification from 2000-2011. Some data cleaning is conducted at the collection stage of the data. This includes seasonal corrections, for specific classes of products, which should generally not be a problem as we aggregate the data annually, but also includes imputation of some missing observations. Unfortunately, we have no way of excluding imputed observations in the final data.

The UHDI data is made from two registers, Extrastat and Intrastat. Extrastat contains information on value in Danish kroner and weight of specific products, again using the CN classification code, bought/imported or sold/exported by specific firms by source/destination country. The Extrastat register has almost all transactions between Danish firms and non-EU-countries and is considered of good quality at all levels of disaggregation. On the other hand, Intrastat, which contains the same information, does not have all transactions with EU-countries. Instead the collection is made up using cut-off values to ensure that at least 93 percent of total EU-import in Denmark are registered and 97 percent of total EU-exports. This naturally introduces some uncertainty about imports and exports from EU countries. However, we generally believe that the effects are minor.

As we are interested in how exposed specific firms are to cost changes due to currency changes we merge the price data above with the firm based survey FIRE. We use these data to compute total variable costs following the definition in Bagger, Christensen, and Mortensen (2014), see table 3.9 and 3.10 for the specific definition.

Firms are surveyed based on the number of employees. Firms with more than 50 employees are surveyed annually, firms with 20-49 employees are surveyed every other year, firms with 10-19 employees are surveyed every 5th year, and firms with 5-9 employees are surveyed every 10th year. We limit this analysis to only using actual observations and therefore ignore all imputed values. This implies that approximately 9000 firms are surveyed in each year.

To compute the market share we rely on total revenue from the firm register "general firm statistics" (FIRM). This register has close to complete coverage of all active firms in Denmark. The macro data is taken from the OECD database online. Specifically, we use the real growth in GDP, inflation rate, and the harmonized unemployment rate. The data on the unemployment rate is not available for all countries. Further, for some countries we do not have data all the way back 1990. Hence, the "N/A" coefficient estimates and lower number observations for some countries in table 3.1.

Table 3.7. Pass-through for different quartiles of market share

			OLS	
Dependent variable: $\triangle \log P_{i,j,t}$	Bin 1	Bin 2	Bin 3	Bin 4
$\triangle mc_{j,t}$	0.626^{***}	0.514^{***}	0.720^{***}	0.958^{***}
	(0.181)	(0.190)	(0.200)	(0.194)
Exchange rate (instrument):	None	None	None	None
			IV	
Dependent variable: $\triangle \log P_{i,j,t}$	Bin 1	Bin 2	Bin 3	Bin 4
$\triangle mc_{j,t}$	-0.113	0.302	1.618^{*}	1.482^{*}
	(0.252)	(0.882)	(0.945)	(0.779)
Exchange rate (instrument):	Actual	Actual	Actual	Actual
			IV	
Dependent variable: $\triangle \log P_{i,j,t}$	Bin 1	Bin 2	Bin 3	Bin 4
$\triangle mc_{j,t}$	-0.108	0.364	1.681^{*}	1.737^{*}
	(0.252)	(0.895)	(0.960)	(0.965)
Exchange rate (instrument):	Residual	Residual	Residual	Residual
N	5086	5027	5154	5088

Note: Equal-sized bins in terms of firm-product-year observations, sorted by market share. Bin 1 includes all observations of firm with a market share up to (equal to) 2.8 percent, bin 2 is from 2.8 to 10.7 percent, bin 3 from 10.7 to 31.3, and bin 4 from 31.3 percent to 100 percent. *, **, and *** are 10, 5, and 1% significance levels, respectively. All regressions above include firm and time fixed effects.

Table 3.8. Import quantity change and lagged currency changes

Dependent variable: $\triangle \log Q^{IM}_{i,j,m,t}$	(1)	(2)	(3)	(4)
$\triangle e_{m,t}$	−0.076	−0.072	−0.009	0.003
	(0.114)	(0.114)	(0.120)	(0.071)
$\triangle e_{m,t-1}$		−0.036	−0.075	−0.119
		(0.140)	(0.114)	(0.118)
$\triangle e_{m,t-2}$			0.194*	0.218*
			(0.115)	(0.117)
$\triangle e_{m,t-3}$				−0.159
				(0.119)
Exchange rate:	Actual	Actual	Actual	Actual
Dependent variable: $\triangle \log Q^{IM}_{i,j,m,t}$	(1)	(2)	(3)	(4)
$\triangle e_{m,t}$	−0.272*	−0.269*	−0.219	−0.212
	(0.144)	(0.145)	(0.151)	(0.151)
$\triangle e_{m,t-1}$		−0.036	−0.061	−0.107
		(0.140)	(0.142)	(0.147)
$\triangle e_{m,t-2}$			0.168	0.197
			(0.146)	(0.148)
$\triangle e_{m,t-3}$				−0.164
				(0.137)
Exchange rate:	Residual	Residual	Residual	Residual
Observations	87232	87232	87232	87232

Note: Observations are at the product-firm-source country-year level. Standard errors are in parentheses. *, **, and *** are 10, 5, and 1% significance levels, respectively. All regressions above include firm, source country, and time fixed effects.

Table 3.9. Underlying variables in the definition of total variable cost

Variables from the FIRE survey	
Purchase of raw materials, finished goods, and packaging	KRH
Cost of energy	KENE
Purchase of contracting work, subcontracting	KLOE
Expenditure on rent	UDHL
Purchase of minor equipment	UASI
Secondary costs	SEUD
Expenses for temporary employment agencies	UDVB
Payments for long term rental and operational leasing	ULOL
External costs in general (except secondary items)	ANEU
Purchase of goods for resale (commodities)	KVV
Purchase of raw materials, finished goods, and packaging	KRHE

Table 3.10. Definition of total variable cost

1999-2003:
$TVC = KRH + KENE + KLOE + UDHL + UASI + UDVB + ULOL + ANEU + SEUD$
2004-2011:
$TVC = KRHE + KVV + KENE + KLOE + UDHL + UASI + UDVB + ULOL + ANEU + SEUD$

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