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Dissertation

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Renewed Macroeconomic Interest in the Role of Money and Finance. Essays on Financial Constraints, Financial Fragility and Money Demand Under Uncertainty.

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“Spiel ist ihre Gegenwehr.”

Theodor W. Adorno (Minima Moralia – Kaufmannsladen, 1951)

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Summary of the Thesis

This thesis evaluates the macroeconomic role of money and finance for the business cycle. The starting point marks the empirical observation that monetary as well as financial conditions are highly correlated with the business cycle. The chapters discuss different but linked topics on current issues related to credit constraints and investment, households' money demand behavior under uncertainty as well as the role and mandate of monetary policy for economic stability.

The second chapter analyzes the role of imperfect capital markets for investment constraints. The core contention is that a firm's financial position contributes to its access to external finance on credit markets. Special emphasizes is put on small and medium-sized firms as these are assumed to face more restrictive access to external sources of funds (Berger and Udell, 1998). The empirical part extends the approach suggested by Fazzari et al. (1988) by applying the non-linear panel threshold model as proposed by Hansen (1999) to data comprising information on private non-financial firms in Germany. This modeling framework allows one to distinguish between financially constrained and unconstrained firms in a data-driven rather than *ad hoc* manner. The results reveal strong evidence that financially fragile firms rely more heavily on retained earnings. In contrast to frequent assumptions, firm size does not seem to be a relevant grouping variable in general, with the only exception being micro firms for which the probability to fall into a financially constrained regime is higher compared to other companies. The policy consequences are that stimulating aggregate demand may foster firm-level investments, but is most likely not sufficient. Corporate indebtedness impedes investment, and thus economic policy must find instruments to deal with excessive debt and non-performing loans.

The third chapter contributes to the literature on the role of economic risk on money demand. The derived microfounded partial model of money demand explicitly takes into account both substitution as well as income effects. Additionally, the role of capital market risk as well as inflation risk is explicitly stated, even after linearization around the steady state. The model is estimated by means of the error-correction framework, and potential time-varying dynamics are analyzed using rolling-window dynamic multiplier analysis. The model's complete solution of the optimization problem leads to ambiguous effects w.r.t. to the impact of capital as well as inflation risk, thus contradicting standard results. According to the empirical results, U.S. households indeed respond in a risk-averse manner to positive changes in inflation and capital market risk by increasing their demand for safe money holdings. However, the responsiveness of households to inflation risk has decreased since 2009 in the U.S. while the effect of capital market risk on money demand has remained stable since the beginning of 2000. Interestingly, certain structural

breaks in the money demand behavior of households just coincide with recent peaks in economic uncertainty indicating another link between uncertainty and actors' behavior.

The last chapter develops a macroeconometric model embodying the key attributes of the Minskyan Financial Instability Hypothesis (Minsky, 2008). This is the first attempt to estimate a sophisticated macroeconometric model of this type. A core contention of the Financial Instability Hypothesis is that manipulation of the short-term interest rate by the central bank may contribute to the financial fragility of leveraged firms. To analyze this hypothesis, a vector error correction model is developed where the restrictions on the cointegrating space embody the central aspects of the Minskyan mechanism, following the modeling strategy as proposed by Garratt et al. (2012). The results support Minsky's contention, showing that a rate hike by an inflation targeting central bank will reduce firms' internal funds while raising the debt burden. It is argued that macro-prudential policies including countercyclical reserve requirements and caps on the loan-to-value and debt-to-income ratios may be used to check excess credit growth in a precisely targeted manner. As noted by Janet Yellen (2014) in a recent speech, such a framework would allow monetary policy to focus on its declared mandate of price level stability and full employment.

Zusammenfassung der Dissertation

Die vorliegende Dissertation befasst sich mit der makroökonomischen Rolle von Geld und Kredit zur Erklärung des Konjunkturzyklus. Die empirische Beobachtung das monetäre Größen sowie Finanzmarktvariablen hochgradig mit dem Konjunkturverlauf korreliert sind, bildet den Ausgangspunkt dieser Dissertation. Die folgenden Kapitel beschäftigen sich mit unterschiedlichen und dennoch zusammenhängen Problemstellungen. Der Themenbereich reicht von aktuellen Diskussionen um die Rolle von Kreditrestriktionen für Privatinvestitionen, über das Geldnachfrageverhalten von Haushalten unter Unsicherheit bis zu der Funktion der Geldpolitik für die wirtschaftliche Stabilität.

Im zweiten Kapitel wird der Zusammenhang zwischen unvollkommenen Kapitalmärkten und dem Aufkommen von Kreditrestriktionen für private nicht-finanzielle Unternehmen untersucht. Die zentrale Hypothese lautet, dass der Zugang einer Firma zu externen Finanzierungsmöglichkeiten auf dem Kreditmarkt erheblich von der finanziellen Position dieser Firma abhängt. Besondere Beachtung wird dabei kleinen und mittelständischen Unternehmen geschenkt, da in der Literatur die Ansicht besteht, dass Kreditrestriktionen insbesondere diesen Typus von Unternehmen betreffen (Berger and Udell, 1998). Der empirische Teil der Arbeit erweitert den von Fazzari et al. (1988) vorgeschlagenen Ansatz, Investitionsfunktionen für separate Firmengruppen zu schätzen. Anstatt die Unternehmen innerhalb eines Panels in unrestringierte bzw. restringierte Firmen mit Hilfe von *ad hoc* Kriterien zu unterteilen, kann mit Hilfe des nicht-linearen Ansatzes von Hansen (1999) die Unterscheidung zwischen Gruppen (sog. Regimen) *datengetrieben* und *endogen* vorgenommen werden. Die Ergebnisse liefern deutliche Hinweise darauf, dass in Deutschland finanziell fragile im Vergleich zu finanziell solideren Unternehmen in ihrer Investitionstätigkeit stärker von den eigenen Finanzierungsressourcen abhängen, und somit stärker auf dem Kreditmarkt restringiert werden. Im Gegensatz zu üblichen Annahmen spielt die Firmengröße keine Maßgabe für die Wahrscheinlichkeit auf dem Kreditmarkt restringiert zu werden. Die einzige Ausnahme bilden sog. Mikrounternehmen (mit weniger als 25 Mitarbeitern), die tatsächlich, nach Kontrolle von firmenspezifischen Eigenschaften, häufiger restringiert sind. Für die Wirtschaftspolitik impliziert dies, dass die Ankurbelung höherer Privatinvestitionen mittels expansiver Nachfragepolitik zwar förderlich aber nicht ausreichend ist. Dies ergibt sich daraus, dass die Höhe der Unternehmensverschuldung die Investitionstätigkeit einschränkt, so dass weitere Instrumente zur Begrenzung und Reduktion von exzessiver Unternehmensverschuldung eingeführt werden sollten.

Im letzten Kapitel wird ein makroökonometrisches Modell entwickelt, welches die wichtigsten Charakteristika der Finanziellen Instabilitätshypothese von Hyman Minsky (2008) berücksichtigt. Dieser Ansatz stellt den ersten Versuch in der Literatur dar, ein Modell dieser Größe innerhalb eines Systems zu schätzen. Eine zentrale Behauptung der Hypothese Minskys ist, dass die Anpassung des kurzfristigen Zinssatzes durch die Zentralbank negative Rückwirkungen auf die finanzielle Fragilität von verschuldeten Unternehmen hat. Um dies zu untersuchen, wird ein Vektorautoregressives Fehlerkorrekturmodell entwickelt, in dem die theoretisch fundierten Restriktionen auf den Kointegrationsraum auferlegt und auf ihre Validität getestet werden. Diese Modellierungsstrategie basiert auf der Arbeit von Garratt et al. (2012). Die empirischen Ergebnisse stützen Minskys Hypothese, und zeigen, dass der Zinsanstieg einer Zentralbank, welche ein bestimmtes Inflationsziel verfolgt, die internen Finanzierungsmittel von Unternehmen reduziert und gleichzeitig die realen Finanzierungskosten dieser Unternehmen steigert. Makroprudentielle Politikinstrumente, die u.a. antizyklische Mindestreserveanforderungen an Banken und Kredit-zu-Einkommensbeschränkungen umfassen, bilden effektive Ansätze um exzessives Kreditwachstum zu begrenzen. Wie kürzlich von Janet Yellen (2014) argumentiert, könnte solch ein regulatorischer Rahmen dazu beitragen, dass die Geldpolitik sich auf ihr deklariertes Mandat der Preisstabilität und Vollbeschäftigung beschränken kann.

Chapter 1

Introduction

1.1 Motivation of the research project

This first section provides a more general motivation for this dissertation project, before the following chapters are embedded into current policy issues in a more specific way. Lastly, a detailed description of the separate chapters is presented to the reader.

The recent great financial crisis resulted in the worst recession in advanced capitalist countries since the Great Depression of the 1930s. The associated economic, social as well as political costs are gigantic, and portray the need to understand the causes and spillovers of such episodes in order to be able to derive potential remedies. For instance, annual real GDP growth in the U.S. was about 0.2% between 2008-11 before it reached pre-crisis growth levels of about 2.3% between 2012-14. The situation looks much worse in the European Union and euro area. Among euro area countries, on average, real GDP declined annually by -0.2% between 2008-11 and negative growth rates were also realized in 2012 (-0.8%) and 2013 (-0.5%) before growth turned positive in 2014 (1.4%). World trade has plummeted (measured quarter on quarter) by 23% at the beginning of 2009. The share of long-term unemployed (unemployed for one year and longer) has substantially increased in major OECD countries. Comparing the situation in 2007 and 2014 shows that the fraction of long-term unemployed has increased from 10% to 25% in the USA, by 15%-points to almost 40% in the UK, from 20% to nearly 60% in Spain, from 50% to 65% in Italy but declined from almost 60% to 45% in Germany. Thus, the crisis had heterogeneous macroeconomic impacts on advanced economies. This heterogeneity is also reflected in trend inflation which varies at subregional levels: while the euro area currently again (after 2009) faces deflationary tendencies, the situation has remarkably stabilized for the U.S. economy (United-Nations, 2015, Ch. 1).

The Dallas FED (Luttrell et al., 2013) has tried to estimate the direct pecuniary costs of the financial crisis and its aftermath. Assuming that aggregate output eventually converges to its pre-crisis trend path, the output loss is between $6 and $14 trillion for the period between 2007 and 2012, which amounts to $50,000 to $120,000 for each household in the U.S. The sum of financial and housing wealth of U.S. households dropped by $16 trillion between end of 2007 and beginning of 2009. If one additionally takes into account the (in-)direct adverse psychological and labor productivity effects of unemployment, the estimates double. Even though the financial crisis had its origin in the U.S. economy, it quickly reached an international dimension. Recently, Ball (2014) has quantified the loss in percentage deviation of potential from its no-recession path, and finds that the average loss of 23 OECD countries, weighted by the sizes of their economies, is 8.4% — as if the entire German economy had evaporated. Looking at it country-wise reveals that while Switzerland experienced almost no loss, the loss in Spain and Greece were about 22% and 30%, respectively, between 2007 and 2014.

In the introduction of his famous book *Maniacs, Panics, and Crashes* Charles Kindleberger describes how the scope of financial crises episodes has actually become "...both more extensive and much larger than in any previous period" since the 1970s (Kindleberger, 2000, p. 2). Advanced countries including 12 euro area and 11 other OECD countries, experienced about 87 recessions between 1960 and 2010. Following the chronology of banking crisis as used by Reinhart and Rogoff (2011) reveals that these countries experienced 24 banking crises with a duration of four years on average. This implies a 8% chance that a country experiences a banking crisis in any given year (ECB, 2012, p. 71). Just to mention a few well-known financial crises events that have occurred in the 1990s are, for instance, the banking crisis in Italy between 1990-95, the Scandinavian financial crisis in Sweden and Finland in 1991-94, the Japanese banking crisis between 1992-97 (which impacts are still lasting), the Latin American crises in Mexico (1994-97), Brazil (1994-96) as well as the two crises in Argentina in 1995 and 2001, respectively, Korea 1997 and the interbanking market crisis in Russia in 1995 and another massive one in 1998-99 were about 720 banks were deemed insolvent (Reinhart and Kaminsky, 1999; Bordo et al., 2001; Reinhart and Rogoff, 2011).

This empirical evidence of increased instability is in stark contrast to the general macroeconomic debate and intellectual position of leading academics studying the sphere of advanced economies. The pre-crisis perspective on the macroeconomy and the perceived ability to *manage* instabilities, was neatly summarized by Nobel prize laureate Robert J. Lucas in his 2003 AER presidential address:

> Macroeconomics was born as a distinct field in the 1940's, as a part of the intellectual response to the Great Depression. The term then referred to the body of knowledge and expertise that we hoped would prevent the recurrence of that economic disaster. My thesis in this lecture is that macroeconomics in this original sense has succeeded: Its central problem of depression prevention has been solved, for all practical purposes.
> Lucas (2003, p. 1)

Thus, the dominant pre-crisis assumption was that macroeconomists and economic policy makers have gained sufficient insights into the underlying concepts, mechanisms and causalities such that the social costs of forthcoming depressions can be reduced through *good* economic policy.[1]

[1]The optimal economic policy implications, derived from a standard New Keynesian model, are summarized by Chari et al. (2008): First, a commitment to *rules rather than discretion* is essential for models with forward-looking agents where expectations play a vital role for the behavioral dynamics. Second, it can be shown that even under the assumption of no frictions, optimal allocations–the agents' optimal responses to shocks–is accompanied by sizable fluctuations. Thus, policy attempting to eliminate all fluctuations is bad policy. Rather policy should aim at keeping the economy at potential. Third,

Even though increasing imbalances and excesses in various financial sectors (Borio and Disyatat, 2011) and rising income dispersion (Treeck, 2014; Kumhof et al., 2015) can already be observed in advanced countries since the late 1980s, many macroeconomists did not foresee the financial crisis just before it broke out. In spring 2007, already after the burst of the U.S. housing bubble, the IMF described the conditions of the world economy as robust with little evidence of forthcoming financial market stress:

> Notwithstanding recent financial market nervousness, the global economy remains on track for continued robust growth... Moreover, downside risks to the outlook seem less threatening than at the time of the September 2006 World Economic Outlook [...] and generally benign global financial conditions have helped to limit spillovers from the correction in the U.S. housing market and to contain inflation pressures. Nevertheless, recent market events have underlined that risks to the outlook remain on the downside.
> IMF (2007, p. 1)

These two quotes raise the question whether the dominant view on macroeconomics is fundamentally flawed, or not (see among others e.g. the recent essays by Blanchard, 2008; Stiglitz, 2014). This issue is left open for debate and will, most likely, keep generations of economists busy. However, the great financial crisis and its repercussions last for almost a decade now. The failure of academics and policy makers to fully understand the causes, complexities and effects of this event as well as the absence to provide ready-made remedies, has led to a return of almost forgotten or at least widely-neglected concepts within the macroeconomic business-cycle discussion. Take for instance the academic *bible* of pre-crisis monetary policy analysis written by Woodford (2003) where the discussion of the role of imperfect capital markets for macroeconomic fluctuations is totally neglected, the role of credit and debt is not conceptualized at all and well-known (potentially destabilizing) feedback effects of debt-deflation are not considered. The crisis made clear that financial market conditions are key determinants of business cycle fluctuations which has led to *renewed macroeconomic interest in the role of money and finance*. This revival of interest in the working and instability of financial markets, and its link to business cycle dynamics marks the initial motivation of my dissertation project.

under models with sticky prices or wages, optimal monetary policy keeps inflation low and stable in order to ensure the optimal allocation of resources. The standard pre-crisis New Keynesian model consists of a forward-looking IS curve that relates the output gap to the real interest rate (derived from the consumers' saving decisions), an expectations-augmented Phillips curve (derived from staggered nominal price setting) according to which inflation is positively related to current and expected economic conditions, and a monetary policy rule that aims for convergence of inflation to its target. The private sector's behavior crucially depends in the current as well as expected course of (monetary) policy, which makes credibility of monetary policy relevant (Clarida et al., 1999).

It should be recalled that many concepts used in the current academic debate were already developed much earlier. For instance, the economists who lived through the 1930s stressed the potentially destabilizing effects of financial markets and its immanent amplifying feedback relationships with the real sector (Fisher, 1933; Keynes, 1936; Kalecki, 1937; Minsky, 1975; Tobin, 1975; Kindleberger, 2000). The emergence of information economics in the 1970s, which was accompanied by several financial crises[2], initiated a whole battery of influential formal and empirical papers on credit crunches, credit constraints and how such effects result in an amplification of small shocks. This line of modern research, starts from the observation that capital markets are imperfect in the sense that they are characterized by asymmetric information structures – which is in contrast to standard New Keynesian pre-crisis macro models, as e.g. illustrated in Galí (2008) or Walsh (2010, Ch. 5).[3] The extensive research on the consequences of imperfect and costly information (see e.g. the work by Stiglitz and Greenwald, 2003) has shown that competitive capital markets may be characterized by credit and equity rationing. Furthermore, models incorporating imperfect capital markets help to explain many observed phenomena on the micro-level as well as on the aggregate which cannot be reconciled with any model of rational behavior with rational expectations and symmetric information (Stiglitz, 2014).

1.2 The link between the financial crisis and the dissertation topics

The recent great financial crisis had its origin in 2006 in the U.S. mortgage sector and had been amplified by various events via different channels such as, for instance, the default of Lehman Brothers. The crisis has become global as many international financial institutions were directly or indirectly involved in the U.S. mortgage market. The default of numerous banks resulted in a near-collapse of the inter-banking market. These developments within the financial sector led to a credit crunch, having its roots on the supply side, with negative repercussions on the real economy: Private investment dropped both because of weak expected profitability and credit constraints causing that non-financial firms were not able to finance their investment projects or current expenses. Especially small and medium-sized firms (SMEs) heavily rely on bank loans for funding their investments: About two-thirds of SMEs in Europe use bank financing as their only or main

[2]For instance, the Third World syndicated bank loan crisis which affected the U.S. economy between 1979 and 1982, followed by a crisis between 1982-1987 in the U.S. which culminated a credit crunch and was related to the stock market, luxury housing and office buildings, the real estate bubble burst in Japan in 1990 as well as some large international crises in Mexico, Asia, Russia and Brazil (Kindleberger, 2000, p. 302)

[3]Early exceptions of macro models incorporating imperfect capital markets are e.g. outlined in Greenwald and Stiglitz (1990) and Bernanke et al. (1998).

funding instrument. Taking a European perspective reveals that 99% of all enterprises are classified as SMEs employing 66% of all employees and generating about 58% of total value added in the European business sector (Aiyar et al., 2015). However, SMEs are often discriminated on credit markets, as their business strategy and historical business record is often less transparent and/or known to potential investors, which results in more intense information asymmetries and hence higher costs of information gathering. On the aggregate level, credit constraints can trigger abrupt downturns during recessions as well as inertial recoveries. The first essay in this dissertation deals with the question whether the sluggish recovery of private fixed investment since 2010 of firms located in Germany can be explained by financial supply-side restrictions leading to credit constraints. Germany is chosen as an interesting example, as the repercussions of the recession on aggregate demand and the labor market were rather limited (which is in stark contrast to other euro area countries, as shown before). Thus, the poor investment climate in Germany does have its origin other than weak aggregate demand. Supply-side financial constraints mark an important and direct channel through which credit market imperfections can impede real activity. We use a firm-level panel dataset comprising firms of different size and legal status operating in Germany, in order to estimate investment functions and to test various hypotheses.

Despite the massive expansion of central banks' balance sheets (known as quantitative easing) in order to consolidate the financial situation of market participants and to stabilize their expectations, numerous advanced economies, as shown before, still face a lasting economic slump. For instance, in 2014 U.S. actual real GDP was still 10% below what in 2007 official institutes thought its potential would be in 2014. This means, that even seven years after the crisis, and despite the recent recovery in real GDP growth rates, the U.S. has not made progress so far in restoring GDP to its potential (Summers, 2014). Similar holds for a majority of advanced countries. This fact has initiated a revival of the discussion whether the U.S. economy will face a lasting period of secular stagnation, accompanied by low per capita growth and low real interest rates (Teulings and Baldwin, 2014). Furthermore, the unconventional monetary policy strategy of the U.S. FED, aiming to overcome a liquidity trap, led to increased actual inflationary risk[4], associated risk perceptions[5] and general asset price inflation[6]. Both inflation and capital

[4]The fluctuations in CPI inflation less food and energy items were intense between 2007 and 2013. During this period, annual inflation rates fluctuated between at minimum 0.4% and at maximum 2.3%. Since the beginning of 2013, however, actual yearly inflation remains within a tight corridor ranging between 1.4 and 1.8%. URL: http://research.stlouisfed.org/fred2/series/SUUR0000SA0L1E (29.5.2015)

[5]For instance, a look at one-year ahead expected inflation of U.S. households shows increased variance between 2008 and 2011. URL: http://research.stlouisfed.org/fred2/series/MICH (29.5.2015).

[6]A rough first indicator for a stock market inflation is the so called price-to-earning ratio (PE) as e.g. calculated by Shiller (2005). Current data provided by R. Shiller show that the PE has substantially recovered since the start of the QE program, and just reached levels comparable to the late 1990s – the period just before the NASDAQ collapsed. See also http://www.nytimes.com/2014/10/30/

market risks may cause portfolio shifts as well as hoarding tendencies by economic actors, which in turn can result in a period of secular stagnation, as recently argued by Bossone (2014). Keynes (1936) already stated that during pessimistic market sentiment periods, households hoard liquid assets such as money and use it as a buffer against economic risks. This line of argument marks another channel through which financial markets as well as monetary policy strategies can affect the real economy by influencing the household sector's consumption and saving decisions. The second essay in this dissertation seizes the regained interest in private actors' liquidity preferences, and studies the determinants of inflation risk and capital market risk for households' money holdings both theoretically and empirically on the aggregate level for the U.S. economy.

The IMF just recently discussed the question whether monetary policy should go back to its old ways.[7] Before the crisis, monetary policy had either a single (keep inflation low) or dual mandate (...and keep the economy operating at potential). Monetary policy was expected to set the key policy rate which affects the term structure of interest rates and asset prices, and hence aggregate demand. At the before-mentioned IMF conference, the former chair of the FED, Ben Bernanke, stated that once the zero-lower bound episode is over, monetary policy should again employ the federal funds rate as their main policy tool. However, interestingly, at this conference the issue was raised whether central banks should continue to supply safe assets to private market participants after this episode, which is directly related to the current discussion about the composition and size of central banks' balance sheets. Without going further into this argument, the discussion shows that leading economists and policy makers consider the implementation of another mandate which can be framed under the term *financial stability*. Partly, this is related to the pre-crisis debate on how or even whether central banks should use the short-term interest rate to prick nascent asset bubbles. Even though it is rarely stated, this controversy has some roots in the *Financial Instability Hypothesis* proposed by Minsky (2008), claiming that central banks contribute to the financial fragility of leveraged firms by following an inflation-targeting interest rate policy. Changes in the base rate then operate via different transmission channels such that a positive change in the base rate can translate into reduced (expected) cash-inflows but increased cash-outflows, thus deteriorating a firm's financial position which may result in a shift from a solid financial situation to a fragile Ponzi-finance scheme on the aggregate. In more general terms: Minsky's hypothesis implies that monetary policy can trigger destabilizing effects in the real economy by increasing financial pressure on non-financial firms which in turn affects the default probability of existing loans. This, of course, would have negative

upshot/quantitative-easing-is-about-to-end-heres-what-it-did-in-seven-charts.html?_r=0&abt=0002&abg=0 (29.5.2015). Shiller's data can be accessed at http://www.econ.yale.edu/~shiller/data/ie_data.xls (29.5.2015).

[7] Watch the IMF session on-line: URL: http://www.imf.org/external/mmedia/view.aspx?vid=4176910915001.

repercussions on the balance sheet situation of funding institutions. The proposition made by Minsky is tested empirically in Chapter 4, using aggregate data for the U.S. economy.

As briefly introduced, this dissertation covers specific aspects of the general research program on the macroeconomic role of money and finance for the business cycle. In the following, a more detailed overview of the separate chapters will be outlined.

1.3 Research questions and the dissertation outline

This dissertation covers different but related topics of a much broader research agenda which can be framed under the title *Money, Credit, and the Business Cycle*. The second Chapter contributes to the discussion of the role of financial constraints for firm-level investments with a special focus on small and medium-sized enterprises. It is an attempt to explain the weak recovery of German private fixed investments since the recovery from the recent great financial crisis. The third Chapter contributes to the regained academic interest in actors' liquidity preference, and studies the effects of inflation and stock market risks on households' money demand behavior. Concerns about future inflation due to quantitative easing policies resulting in increased central banks' balance sheets, lasting periods of secular stagnation caused by high liquidity preferences as well as bouts of elevated uncertainty seen as a major cause escalating financial stress and recession, suggest a resumption of the theoretical as well as empirical work on the determinants of money demand. The last Chapter is one of the scarce efforts to test empirically an element of the Minskyian *Financial Instability Hypothesis*. The hypothesis states that an inflation targeting central bank may actually trigger financial instability which spills over to private investments and aggregate economic activity. The economic policy implications are related to the debate on how and even whether to integrate financial and macro stability into the mandate of central banks.

1.3.1 The role of financial restrictions for firm-level fixed investment with a focus on small and medium-sized enterprises

Chapter 2 contributes to the discussion about the role of financial frictions for the availability of credit to firms. Just recently Hall (2011) and Stock and Watson (2012) stressed this open issue as a major remaining one which needs to be solved in order to boost growth dynamics. The focus is on credit constraints stemming from the relationship between banks and firms. In the first part, the origins of financial market imperfections and its linkages to financial frictions will be presented. As cross-sectional differences in firm characteristics play a crucial role in the literature on financial investment constraints, we emphasize the need to rely on micro-level data comprising observations for small and medium-sized as well as big firms.

On perfect capital markets a lender can fully protect himself against credit default while on imperfect capital markets the lender is exposed to default risk. Within a risky environment, actual and contractual repayment of a loan to the borrower may diverge either because the lender's cash-inflow is too low due to failure of the investment project, or the debtor is unwilling to repay accordingly to the contract. These possibilities expose the lender to the risk that the debtor defaults. Two important features of credit contracts emerge out of this: Limited liability of the borrower implies that the lender bears the default costs. Thus, lending becomes only feasible if existing collateral is sufficient to cover the expected loss of a risky project. Furthermore, credit rationing can emerge as an equilibrium outcome under imperfect capital markets. Both effects can have negative impacts on realized firm-level investment (Stiglitz and Greenwald, 2003).

The dominant approach to model capital market imperfections relies upon the asymmetric information framework. Asymmetrically distributed information is given, for instance, if the borrower has more information on a project's risk than the lender. This may result in principal-agent conflicts and hence conflicting interests between parties. Different types of asymmetric information settings as well as a formal model of financial frictions relying on agency costs will be presented in this chapter. Another approach explaining the emergence of imperfect capital markets, stresses the importance of a lender's risk aversion against default (Fischer, 1986). This framework does not rely on the assumption of asymmetric information but puts the default risk of the lender into the focus. The emergence of credit rationing as an equilibrium outcome is also possible in this setting.

The empirical part is an attempt to explain the sluggish recovery of private fixed investment in Germany during the recent financial crisis. We use data covering firm-level data between 2006 and 2012 comprising firms of various sizes. Typically, it is assumed that small and medium-sized firms (SMEs henceforth) are informationally more opaque and/or more exposed to economic risk, and hence are expected to face tighter financial frictions. As 98% of all firms in Germany are classified as SMEs, a firm-level analysis is important to capture such heterogeneities.

The empirical framework heavily draws upon the widely-applied work of Fazzari et al. (1988). The Fazzari-Hubbard-Petersen approach suggests the firm-level estimation of reduced form investment functions augmented by financial variables such as cash flow. As shown in the classical papers by Modigliani and Miller (1958) and Jorgenson (1963), financial variables are irrelevant for a firm's optimal investment decision under perfect capital markets. Hence, under perfect capital markets the zero restriction on the corresponding cash flow coefficient of an estimated investment regression equation cannot be rejected. A crucial part of this approach involves the distinction between financially constrained and unconstrained firms. Instead of grouping firms by means of an *a priori* criteria (for instance firm size), a data-driven but still theoretically motivated approach is applied. The incorporation of potential threshold effects indicates that a firm's financial state, measured by observable balance sheet indicators, contributes to the degree of financial constraints it actually faces.

The threshold panel-data analysis, as suggested by Hansen (1999), reveals that the weak recovery of private fixed investments can be explained by financial constraints. In particular, there is evidence for a non-linear relationship between a firm's financial state and its dependence on internal funds (e.g. cash flow). According to the results, private fixed investment of highly leveraged enterprises is more responsive to changes in (lagged) internal cash flow in comparison to financially solid firms. Contrary to common belief, on average small and medium-sized firms do not face tighter access to external funds, with the only exception being micro firms (employing less than 20 workers). The results reveal that micro firms were hit hardest during the recent crisis, as many of these firms switched from a solid to a rather fragile financial regime.

The economic policy implications are far-reaching: A mere stimulation of aggregate demand may help to increase firm-level investments, but is most likely not sufficient as the restrictive or countervailing effects of corporate indebtedness may impede the positive demand effect. Thus, economic policy must be aimed at improving the access of non-financial firms to external finance. However, in order to avoid excessive risk-taking by debtors as well as creditors, macro-prudential tools are required to accompany these strategies, as outlined in more detail in Chapter 4.

1.3.2 Households' money demand behavior under inflation and stock market risk

In the aftermath of the recent great financial crisis, academic interest in private actors' liquidity preference has regained. The first line of argument is related to the quantitative easing policies exercised by central banks which are associated with growth rates of money aggregates typically seen as incompatible with real GDP growth rates thus raising concerns about future inflation. This issue is also linked to the discussion about the determinants of demand for safe assets which are used as hedges against macroeconomic fluctuations, and hence also about the (optimal) composition and size of the balance sheet of the central bank. Just recently, these latter points were heavily discussed at the IMF conference entitled *Rethinking Macro Policy III*. Another line of argument emphasizes the risk of lasting periods of secular stagnation for the world economy with a high liquidity preference as a major cause (Bossone, 2014). All of these concerns suggest a resumption of the theoretical as well as empirical work on the determinants of money demand. However, nowadays the focus is less on the stability of the money-demand-to-income relationship but on whether and how expected inflation and its volatility affect money holdings of the non-banking sector.

The current political shift towards higher financial market supervision and regulation is accompanied by a critical reference on potential conflicts of interest between financial and price stability. In this respect, the reactions of money demand to higher capital market risk as compared to inflationary risk might gain importance for policy decisions. All these arguments suggest that forecasts of monetary demand will play a pivotal role for both the assessment of the future macroeconomic development as well as for the effectiveness of monetary policy. Obviously, the research question raised in this chapter is closely related to the new and growing literature on the linkages between uncertainty and the macroeconomy (Bloom, 2009). This line of research sees uncertainty shocks as driving the business cycle (Bloom et al., 2013), investment dynamics (Bachmann and Bayer, 2014) and asset prices (Bansal and Shaliastovich, 2012; Pástor and Veronesi, 2013). In Chapter 3, we contribute to this literature by tracing out the consequences of inflation and capital market risks on households' money demand behavior.

In the first part of Chapter 3, a microfounded partial model of money demand is derived. Rather than presenting an Euler equation, the complete solution of the optimization problem taking the intertemporal budget constraint into account is presented. This allows us to study the substitution as well as possibly countervailing income effects. In contrast to standard DSGE models, the risk parameters enter the household's objective function directly which is due consequence of using the certainty equivalent instead of expected utility. Additionally, current household's money holding is not only driven by current consumption but also by expectations about future income. Finally, different types of liquid assets, which bear the major characteristics of money by taking interest-bearing bank deposits into account, are considered.

The theoretical implications reveal complex and ambiguous results: an increase in inflationary risks may in- or decrease the demand for cash and deposits, depending on the relative strength of income and substitution effects. Under plausible parameter constellations, the effect of higher capital market risk is clear cut and leads to an increase in cash holdings.

The money demand function is estimated for the U.S. economy using macroeconomic data from 1978 to 2013. In line with the majority of existing empirical money demand studies, single-equation error-correction models considering eventual long-run relationships between the variables are estimated. However, apart from the long-run effects, we also study the short-run and possibly time-varying dynamics of money demand by means of a rolling-window dynamic multiplier analysis. The results reveal that both inflation risk and stock market risk measures significantly enter the long-run money demand relationship, indicating that the empirical steady-state is not characterized by a fixed-point with full certainty as higher moments of shocks play a role. This questions the frequent assumption that the deterministic steady-state predicted by the theoretical model incorporates no information about the stochastic nature of the economic environment.

The model dynamics reveal that, after controlling for general macroeconomic as well as economic policy uncertainty (approximated by popular measures), U.S. households respond to an increase in inflation or stock market risk by higher demand for safe assets. Furthermore, we find a general decline in the impact multiplier effect of inflation risk on money demand since the end of the 1990s accompanied by an acceleration in this downward trend since 2008. However, the recent financial crisis had no effect on the corresponding long-run multiplier which is still positive. The sensitivity of money demand to changes in stock market risk has been stable since the early 2000s. Additionally, we find that the multipliers associated with changes in the own rate of M2 and expected inflation are found being time-varying and are probably linked to the business cycle. Interestingly, the long-run effect of changes in real stock market returns has become stronger in absolute magnitude since mid-2009 – a period which coincides with the height of economic policy uncertainty in the U.S.

Our results provide another argument for the consideration of financial stability into the central bank's mandate, as the stabilization of financial markets has direct impacts on money growth, and hence can be seen as an additional pillar for ensuring price stability.

1.3.3 Minsky's Financial Instability Hypothesis and the central bank's mandate

Chapter 4 contributes to the current macroeconomic debate on how or even whether to integrate financial and macro stability into the mandate of central banks. Before the great financial crisis, the dominant view was that the short-term interest rate should not be used to prick nascent bubbles (Greenspan, 2002; Nickell, 2005; Posen, 2006; Gurkaynak, 2008). However, this perspective was early criticized by Goodhart (2001) and Roubini (2006) who favored the inclusion of financial market indicators into the monetary policy objective function. The discussion is related to the *Financial Instability Hypothesis* proposed by Hyman Minsky (2008). Minsky states that the central bank may contribute to the financial fragility of leveraged firms in its pursuit of inflation-targeting interest rate policies. Monetary policy affects investment in several ways. First, changes in the base rate pass through into the lending rate of loans, and hence affect the costs of borrowing. An indirect effect arises as changes in the base rate are associated with a change in the opportunity costs of retained earnings. Lastly, changes in the lending rate can translate into higher real debt servicing costs for firms leading to a general shift from a solid financial situation to a more fragile Ponzi-finance scheme (Minsky, 1975). Typically, an increase in the base rate reduces aggregate demand and hence firms' (expected) cash-inflows while real debt servicing costs increase. The widening gap between cash-outflow and -inflows widens and negatively affects the firms' balance sheet position, and thus its access to external funds, as studied in Chapter 2 on the firm-level.

In Chapter 4 we test this proposition using a medium-scale macroeconometric model incorporating many of the salient features of a Minskyan economy. The theoretical restrictions are imposed into a cointegrated VARX model following the long-run structural modeling framework, as suggested by Garratt et al. (2012). The results, using U.S. macroeconomic data covering the period between 1985 and 2008, support the proposition that unexpected interest rate shocks can drive a wedge between the cash-inflows of firms and their debt-servicing obligations. A positive interest rate shock is associated with an immediate increase in the real cost of debt servicing lasting about four quarters. After a short delay, this policy shock results in a permanent reduction in firms' internal funds as well as aggregate investment demand which is consistent with the balance sheet effects stressed by the credit channel literature. Additionally, there is evidence for a close linkage between speculative excesses, measured by Tobin's (1969) (average) q, and financial fragility: A shock to Tobin's q is associated with an increase in real output and real investment. However, firms' internal funds decrease in response to this shock, as dividend payouts increase more strongly than profit income in response to an asset price shock.

Overall, our work contributes to the view that the two standard tools, fiscal and monetary policy, were not the right ones to deal with financial imbalances and risks (approximated by measures of leverage, credit aggregates or asset prices). In line with the Minskyan hypothesis, our estimation results caution against the use of the base rate to influence the trajectory of asset prices because interest rate changes alter firms' cash commitments and may thereby exacerbate the frailty of firms' financing arrangements. Furthermore, as recently argued by Svensson (2014), the social costs of a *leaning-against-the-wind* monetary policy stance in terms of higher unemployment by far exceed the estimated benefits of increased financial stability.

In the aftermath of the recent great financial crisis, unconventional monetary policy instruments were applied providing an alternative tool to smooth asset cycles in a targeted fashion. Quantitative easing and forward-guidance have proven highly effective in restoring confidence in financial institutions and markets (Bernanke, 2012). Furthermore, there is growing consensus that macro-prudential policy can help to restrict excessive credit growth and restrain asset price inflation (Elliott et al., 2013; Yellen, 2014).

Chapter 2

Financial Investment Constraints in Germany. A Panel Threshold Application to Firm Level Data.

This chapter is a totally revised version of Tarassow (2014).

2.1 Introduction

Private investment growth has received much attention in recent years as a consequence of the observed low growth in advanced economies since the outbreak of the recent great financial crisis (GFC henceforth) in 2008 (IMF, 2015, Ch. 4).[1] Different contributing factors of the sharp recent downturn in investments are discussed, ranging from increased economic and political uncertainty delaying investment decisions, over a slowdown in aggregate demand resulting in a decline in expected profits, to an increase in financial constraints caused by a crash on credit markets (IMF, 2015, Ch. 4). However, the persistently low fixed private investment rates realized in Germany are not intuitive on a first glance as average bank lending rates are low, German firms have increased their capital base *on average* during the past years, measures of credit constraints have come down considerably since 2010, and energy prices are on historical lows. We argue that the weak private investment dynamics observed on the aggregate level can be traced back to financial frictions on the microeconomic level, in particular leveraged enterprises face. This is in line with recent arguments made by the ECB that the weak recovery is mainly caused by financial constraints stemming from the supply side on credit markets (ECB, 2013).

First evidence of an empirical relationship between private fixed investments and credit provided to non-financial firms operating in Germany, is displayed in Figure 2.1. Between 2000 and 2012 the annual average growth rates of real gross fixed capital formation and real gross investment into machinery are 0.28% and 1.06%, respectively. After a temporary increase in 2005, private investments sharply collapsed as a result of the GFC. Between 2008 and 2009 real gross fixed capital formation dropped by almost 15% and real gross investment into machinery even by 25%. Throughout the whole period, low private investment rates were coupled with slow credit growth to non-financial firms (around 2.3% on average). During the GFC, overall credit growth remained still positive (except in 2010 when the growth rate was about −2.5%) but at a decreasing rate. It should also be mentioned that according to Lenger and Ernstberger (2011) some firms in Germany already faced credit constraints between 2000 and 2006 which helps to explain the low investment climate since the early 2000s.

Additional evidence comes from recent ECB bank lending surveys, which indicate that hampered access of non-financial firms to external finance has intensified the weak recovery since 2008. Supply-side driven financial frictions have tightened as banks' perceptions

[1] Monetary policy decision makers are interested in investment dynamics as the efficacy of transmission mechanisms of monetary operations and its propagation effects on the business cycle crucially depend on the understandings of the determinants of firm-level investments. Furthermore, the issue of capital accumulation is also closely related to growth and innovation aspects, market competition; and hence a key variable for industrial policy decisions.

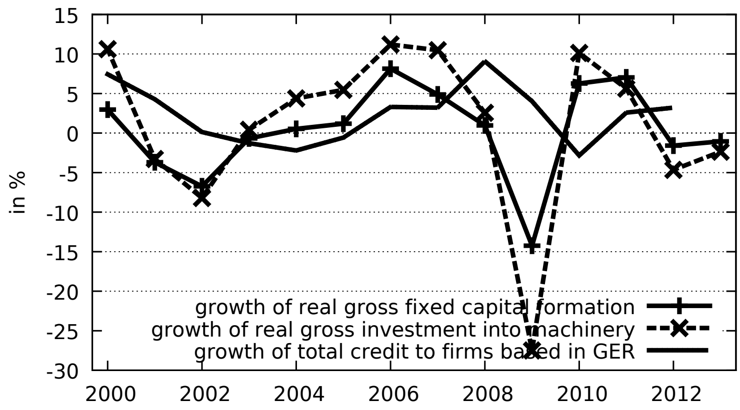


FIGURE 2.1: Growth of real private gross investment in GER, and domestic bank loans to non-financial firms in Germany. Source: Destatis and Bundesbank, own calculations. Sample: 2000–2013.

of risk increased and reached its highest level at the peak of the crisis. Lending rates as well as lending standards were tightened between 2006 and 2009. In total, this development has been a source of reduced investments (ECB, 2013). However, empirically one observes that firm-level investment dynamics show substantial cross-sectional differences over the business cycle. For instance, credit availability is more severely restricted during recession periods for small and medium-sized enterprises[2] (SMEs henceforth) compared to large firms (Duchin et al., 2010; ECB, 2014; IMF, 2015). Given that 98% of all German firms belong to the category of SMEs, employing about 55% of all employees and generating 55% of total value added in Germany[3] (Vetter and Köhler, 2014, p. 2), a firm-level specific analysis is crucial.

The literature on both capital market imperfections (Bernanke and Gertler, 1989; Stiglitz and Greenwald, 2003) and financing of SMEs (Berger and Udell, 1998) stresses the importance of a firm's financial position as well as its size as contributing factors for a firm's degree of financial constraints.[4] A key consequence of imperfect capital markets is that financial variables such as retained earnings or other balance sheet items play an important role for firm investment decisions and the availability of external funds. These theoretical implications and the empirical evidence demand an analysis of investment dynamics on the micro-level, as conducted in this study. In order to test the relevance of financial market imperfections, we closely follow the line of research initiated by Fazzari and Athey (1987) and Fazzari et al. (1988), and estimate reduced-form investment functions augmented by financial variables but additionally consider potential regime-dependencies. It can be shown that under perfect capital markets, financial variables

[2]Here SMEs are defined as firms with less than 250 employees and an annual turn of less than 44 Mil. Euro.

[3]It should be noted that the statistics are very similar across the EMU countries.

[4]These aspects are discussed in more detail in the following sections.

should have, conditional on Tobin's q, no predictive information for investments as any net-present value project could be financed by external funding (Modigliani and Miller, 1958).

In line with recent studies using panel data on the micro-level (Bond et al., 2003; Martinez-Carrascal and Ferrando, 2008; Engel and Middendorf, 2009; Lenger and Ernstberger, 2011) the main result of our article reveals that the weak private fixed investment performance of firms in Germany between 2006 and 2012 can be explained by financial constraints. We find that rather than firm size, as frequently argued, a firm's financial position crucially matters for the intensity of such constraints. For various specifications, there is statistically robust evidence that financial variables such as lagged cash flow are positively correlated with realized fixed private investments. Furthermore, the cash-flow-to-investment sensitivity depends non-linearly on a firm's financial position. We show that neglecting existing threshold effects results in biased coefficient estimates and underrates the relevance of financial constrains firms face. The capital accumulation rate of firms with short-term debt over total cash at hand ($1/liquidity$) larger than 13.6, debt-to-cash-flow ratios ($1/solvency$) above 4.2 or dynamic debt shares ($dyndebtshare$) above 0.041 depends substantially stronger on internal funds in comparison to financially solid enterprises. This indicates that financial robust firms, determined by a threshold model, are less credit constrained than fragile firms. Interestingly, firm size is not found being a reasonable predictor for a firm's degree of financial constraints. Using a measure of solvency or debt share, according to our data about 30% to 40% of all firms in the sample belong to a financially solid regime facing low levels of financial restrictions. This holds for all firm types with the only exception being micro firms (less than 20 employees), for which the share of firms operating in a solid regime is found being lower. Hence, micro firms were hit hardest during the GFC, such that many of these enterprises switched from a solid to a rather fragile financial regime.

The main contribution to the literature is twofold: First, our empirical work exploits a database which comprises listed as well as unlisted companies from various industrial sectors of different firm sizes and legal statuses in Germany using recent data. Only few previous studies have exploited such heterogeneous datasets. Second, we employ an empirical data-driven sample-split procedure to differentiate between financially constrained and unconstrained firms. This helps us to circumvent often applied but to some degree *ad hoc* methods. The procedure relies on the panel threshold regression method suggested by Hansen (1999). Hansen's framework allows us to estimate specific regimes which can be associated with different degrees of financial constraints firms' are facing. For instance, a firm could operate within the polar cases being either financially unconstrained (facing perfect capital markets) or totally constrained. As the regime is latent, one needs a signal to extract the unobservable from observables. Potential signaling variables are balance sheet items such as leverage, interest coverage ratio or measures of solvency and collateral.

This paper proceeds in five sections. In Section 2, we review the literature on credit markets imperfections and financial constraints on firm investment. Section 3 introduces the methodological approach and we selectively review the empirical literature on firm-level fixed-investments. The econometric approach and the fixed-investment estimation results are presented and discussed in Section 4. Section 5 concludes, while details of the dataset and its construction can be found in the Appendix.

2.2 Credit markets and the effect of financial constraints on investment

Before the beginning of the era on information economics in the 1970/80s, the dominant firm investment model was based on the work by Modigliani and Miller as well as Jorgenson. Modigliani and Miller (1958) derive the conditions under which financial aspects are irrelevant for firm-investment decisions. Jorgenson (1963) has pioneered the neo-classical theory of optimal investment showing that solely factor prices and technology determine its level. Financial variables play no direct role as the assumption of perfect capital markets ensures that the market valuation of capital to its replacement value captures sufficient information about a firm's investment opportunity.

In this section, the theory of imperfect capital markets and its effects on credit availability will be introduced briefly. Capital market imperfections, either rationalized by asymmetric information or lenders which are risk-averse against default, affect a firm's access to credit for investment purposes. A firm's financial position becomes important for its access to external finance under such circumstances. Credit rationing is a possible outcome of imperfect credit markets which may result in the amplification of small business cycle shocks and persistent downturns on the macroeconomic level. Early exceptions stressing financial considerations for firm investment demand are Kalecki (1937); Duessenberry (1958), Robinson (1966) and Minsky (1975). These authors argue that investment demand is constrained by the availability of financing a firm can internally generate or obtain from external sources. However, these approaches have not been explicitly derived from first-principles, which is deemed to be standard nowadays. Nevertheless, their theoretical implications share key aspects with the modern approaches to credit and investment.

In the following we present an overview of two distinct frameworks, each providing a rationale for imperfect capital markets. The first approach follows the New Keynesian research agenda on information economics, arguing that asymmetrically distributed information between creditors and debtors may give rise to market imperfections. These imperfections help to explain specific features of financial markets such as credit rationing phenomena or, more generally, the effects of financial factors on firm-level investments. Furthermore, market imperfections help to explain characteristics of debt contracts such as credit limits and the role of collateral (under *ex-post* information asymmetry) (Semmler, 2011). The second approach emphasizes the importance of risk-averse lenders. It is argued that banks operating under imperfect-capital markets and facing the possibility of unforeseen events are expected to behave risk-averse against default, which has certain implications for the working and efficacy of credit markets (Fischer, 1986; Größl-Gschwendtner, 1993).

Independent of the chosen framework, the two approaches share similar implications. In contrast to perfect capital markets where a lender can fully protect himself against credit default, imperfections on capital markets expose the lender to credit default risk. Based on the insight that a loan contract comprises the lender's agreement to transfer funds immediately to the borrower who only promises to repay in the uncertain future, actual and contractual repayments may diverge for principally two reasons: First, the borrower is unable to raise the required surplus due to failure of the investment project, second the debtor is unwilling to repay accordingly to the contract. Both possibilities expose the lender to the risk that the debtor defaults. The modern theory on credit contracts can be characterized by three important elements (Semmler, 2011, p. 37ff.): Asymmetrically distributed information is existent, for instance, if the borrower has more information on a project's risk in comparison to the lender. This poses principal-agent conflicts if the objective functions of both agents deviate which leads to conflicting interests. As already mentioned before, limited liability of the borrower leads to default risk, implying that the creditor bears the default costs. To make lending feasible in this case, the creditor will demand collateral which covers the potential loss. The third element refers to credit rationing which may occur as an equilibrium outcome.

The distinction between firm sizes takes up a crucial point in the literature on financial frictions. SMEs are more likely to face capital market imperfections due to a variety of arguments: Firm size matters for the degree of economies of scale effects, and hence for productivity and cost differences. Furthermore, SMEs have less opportunities to diversify their product portfolio, geographical business areas and access to external finance. Also SMEs are assumed to be informationally more opaque and face higher default risks. Overall, SMEs operate in a totally different economic environment compared to large companies (Berger and Udell, 1998, 2006). Typically, SMEs are more dependent on bank lending and it is harder for them to acquire alternative sources of financing such as debt issuance which is associated with high fixed costs. There is evidence that credit availability is more severely restricted during recession periods for SMEs compared to large firms (Duchin et al., 2010; ECB, 2014).

The following subsections provide some rationale for the argument that a firm's investment path is not only determined by its desired accumulation strategy. It is of similar importance to know whether the optimal investment path can be financed, or whether firms face financial supply side restrictions which affect investment (Robinson, 1966; Minsky, 1975). The restriction of available external finance, either as a consequence of asymmetric information between creditor and debtor or due to banks which are risk-averse against default, may culminate in a credit rationing situation. In this situation, the role of internal finance for funding investments should be more relevant as constrained firms cannot attract sufficient external funds. Thus, the correlation between investment and cash flow is expected to be higher for restricted firms. Under a credit rationing situation it may even happen that a firm is not able to finance a project with an expected positive net-present value, due to the lack of funds available. A firm's financial position has repercussions for its access to external funds and the level of investment, as collateral and liquid assets help to mitigate adverse selection or moral hazard issues.

First, we briefly introduce the framework stressing asymmetric information as the origin of financial market imperfections by highlighting the implications of adverse selection, moral hazard as well as monitoring and/or agency costs. Next, a framework proposing a risk-averse lender is introduced which may serve as an alternative approach to imperfections such as credit rationing.

2.2.1 Asymmetric information

The development of the economics of information in the 1970s fostered the research on information asymmetries. This agenda has worked out the role of financial factors for investment decisions using a micro-founded optimization framework.[5] Various explanations have been put forward arguing that imperfect capital markets, characterized by asymmetrically distributed information between debtors and creditors, may result in supply side bottlenecks for firm investment. The approaches range from adverse selection, moral hazard to monitoring and agency costs. All perspectives share some generally accepted implications. First, information asymmetries generate a premium on external finance unless external finance is fully collateralized (Myers and Majluf, 1984; Bernanke and Gertler, 1989; Greenwald and Stiglitz, 1993). This establishes a *hierarchy of finance* making internal funds the cheapest, followed by debt and equity finance (Myers, 1984).

[5]For an extensive survey on this literature see Hubbard (1998).

External funds are seen as an imperfect substitute for internal funds (Gertler, 1988). Secondly, the premium on external finance varies inversely with the borrower's net worth (internal funds plus collateral value) for total finance required (Bernanke and Gertler, 1989). Furthermore, under certain conditions financial market imperfections may result in credit rationing as an equilibrium outcome (Stiglitz and Weiss, 1981; Bester and Hellwig, 1987). Lastly, shocks may be amplified explaining the small-shock-large-response phenomena on the aggregate which is often modeled by means of financial-accelerator-like models (Bernanke et al., 1998). In the following, a brief overview of the various microeconomic strands based on asymmetric information will be provided.

Adverse selection Jaffee and Russell (1976) propose a framework where two types of borrowers exist – an honest agent who always repays his loan, and a dishonest one who prefers to default if default costs are sufficiently low – among which a potential lender cannot distinguish *ex ante*. In pooling equilibrium the same loan contract is offered to each borrower. The identification of each type of agent is only possible when actual default occurs. It can be shown, that the share of defaulting borrowers increases in the loan amount. As the expected return on a loan is less than the lending rate charged, the actual loan rate must be equal or higher than the opportunity cost of funds in a zero-profit environment.

Stiglitz and Weiss (1981) applied the framework by Jaffee and Russel, and derive an equilibrium credit rationing situation based on adverse selection: There is a pool of borrowers, each of them facing a given project opportunity associated with a specific level of risk but the same expected return. It can be shown that changes in the lending rate affect the composition of the pool of borrowers. With an increasing loan rate, borrowers with low-risk projects drop out earlier than the ones with more risky projects. This results in a non-monotonic relationship between the lending rate and the lender's expected profit. The equilibrium lending rate may lead to credit rationing. The lender is not willing to lend at higher loan rates, as this will reduce expected profits. For a textbook illustration see e.g. Benassi et al. (1995).

Moral hazard Credit rationing may also occur if the Stiglitz-Weiss model is changed such that the borrower's behavior, his choice between projects of differing risk, depends on the properties of the loan contract, making the project's return an endogenous outcome. As the lender cannot monitor the project choice, higher lending rates imply that the borrower decides to invest in riskier projects – moral hazard behavior arises. Again a non-monotonic relationship between the loan rate and the lender's expected return emerges, leading to the possibility of equilibrium credit rationing (Walsh, 2010, ch. 10).

Monitoring and agency costs In a series of papers Williamson (1986; 1987) applies Townsend's (1979) costly state verification framework and shows that credit rationing may emerge as an equilibrium outcome without relying on moral hazard or adverse selection problems. Townsend argues that a firm's project realization is associated with auditing costs. Accordingly, it is feasible for the lender to lend beyond the value of collateral in the case of auditing. However, the additional costs of auditing must be paid by the borrower which makes external loan financing more expensive than internal funds.

A similar vein follow Bernanke and Gertler (1989). The inability of the lender to monitor the borrower's actions gives rise to agency costs on credit markets. The authors show that the external finance premium is negatively related to a firm's net worth as the fraction on collaterized debt increases with net worth for a given credit amount. Thus, negative shocks, such as periods of monetary tightening or general recessions, reduce the firm's market value of assets resulting in less sound firm balance sheets and hence higher costs for external funds. This also stresses the imperfect substitutability between internal and external funds. Similar to Townsend, Jensen (1986) argues that there is an implicit premium on debt as debt implies monitoring and control which makes external funds relatively more costly.

In the Appendix on page 142 a simple formal model of imperfect capital markets based on agency costs is analyzed. The model assumes a risk-neutral firm as well as a risk-neutral lender under an *ex post* asymmetric information problem setting. The model shows that asymmetric information issues have impacts on the cost of external finance and may create a credit rationing equilibrium outcome. A numerical example is attached.

2.2.2 The role of risk-averse lenders

An alternative framework applies Koch's *Theorie des Sicherheitsvorbehalts* (later again re-considered by (Fischer, 1986)) on the decision making process of creditors. Koch's approach marks a critique of the statistical expectation value. It should be recalled that the statistical expectation value is only valid if a lender offers the same client the same loan contract over many times under the same states of the world, or, equivalently, provides credit to many borrowers with identical and independent risks. Only under these circumstances, expected default is an appropriate measure of risk.

However, this assumption is rather hard to meet. First, there is no reason to assume that borrowers' idiosyncratic risks are independently drawn from the same probability distribution given sector- or country-specific characteristics. Also, the recent GFC has made obvious that business performances, and hence the default risks of individual firms, are highly correlated, at least during specific periods such as downturns. Hence, the distribution of borrowers' default risks may be correlated.[6] This implies that a bank's average default may deviate from its statistical expectation. Hence, the bank may earn less than the safe rate of return on average. All these arguments stress the role of unforeseen events for the decision making process. Contrary to a risk-neutral bank that is only interested in maximizing its expected rate of return, a risk-averse bank is also concerned about possible default and seeks to reduce the likelihood of this outcome.

Following closely the work by Größl-Gschwendtner (1993) and Größl-Gschwendtner et al. (1995), a commercial bank that is not indifferent with respect to default is assumed. The assumption of a risk-averse lender implies that the bank seeks to avoid default or ruin by accepting credit default risks only up to a certain limit. The lender sets a limit of loss which he tolerates at maximum for a given probability of occurrence. In contrast to the standard Bernoulli approach, the lender will not accept to fund projects with higher loss probabilities even if the borrower would offer to pay higher lending rates in order to compensate for higher risks.[7] The imposition of an upper bound on the loan volume may result in credit rationing. The proposed model in the Appendix on page 147 implies loan rigidity as well as a rigid loan rate. The conditions under which credit rationing occurs are analyzed. This framework provides another rationale for the relevance of financial factors such as cash flow or more general collateral for firm-level investment decisions.

Both approaches presented here, indicate the relevance of cash flow for the access to external finance. This result is central for following empirical framework.

2.3 Methods to measure the degree of financial constraints and an overview of previous empirical studies

After having provided an introduction about micro-founded theories explaining the role and relevance of imperfect capital markets, we proceed with the empirical application. The focus of this section is on testing whether a firm faces financial investment constraints as a result of imperfect capital markets. Most of the literature follows one of the two widely applied methods. The first approach builds on a standard q-model of firm investment and tests the validity of the underlying Euler equation. The second approach argues that given that external finance is more costly than internal funds, other things constant, the level of firm investment should be positively correlated with profits available. This approach of testing the relevance of imperfect capital markets dates back to

[6] See for instance the recent work by Battiston et al. (2012) who study contagion effects in networks.

[7] This latter case is only plausible on perfect capital markets where banks are not exposed to insolvency risk.

Fazzari and Athey (1987) and Fazzari et al. (1988). In the following a brief overview of the two approaches will be provided.[8]

2.3.1 The Euler equation approach

Estimating Euler equations is one strategy to test for the existence of capital market imperfections. The Euler equation is derived from a dynamic optimization problem. Hence, the model is inherently structural and captures the role of expectations of future profitability (Bond et al., 2003, p. 153). The approach tests whether a firm "...is able to equate the discounted marginal rates of return on assets across time..." (Fazzari and Petersen, 1993). A financially constrained firm is not able to do so. A main advantage of the Euler equation approach is, that it does not rely on average q as a measure of expected profitability. It is well-known that Tobin's marginal q only coincides under restrictive assumptions with average q (Hayashi, 1982), and thus the often used average q is only a poor proxy variable for profit opportunities.

A typical Euler-equation model as proposed by Bond and Meghir (1994) is derived from dynamic optimization assuming symmetric and quadratic adjustment costs. Assuming competitive markets and symmetric information on financial markets, the Euler-equation can be expressed as

$$\left(\frac{I}{K}\right)_{it} - \alpha_1 \left(\frac{I}{K}\right)^2_{it} = \alpha_2 E_t \left(\frac{I}{K}\right)_{i,t+1} + \alpha_3 \left[\left(\frac{\Pi}{K}\right)_{it} - J_{it}\right] + \alpha_0 \qquad \alpha_1, \alpha_2, \alpha_3 > 0 \quad (2.1)$$

where I, K, Π, J and E_t denote gross investment, the capital stock, the financial variable gross operating profit, real user cost of capital and the expectations operator using the information set available in period t. The function states that current investment is positively correlated with expected future investment and with current marginal profitability but negatively with user cost of capital. Typically expected values are replaced by their actual realization in period $t + 1$. Furthermore, time effects and firm specific effects are added as well as a one-step-ahead investment forecast capturing relevant expectations influences. The irrelevance of financial constraints can be evaluated by imposing the over-identifying restriction that the gross-operating-profits term is zero (Bond et al., 2003, p. 161).

However, there are objections to the Euler equation approach. First, the test on over-identifying restrictions may not reject the null hypothesis of no financial constraints if

[8] There exists a third approach based on survey data. For instance, Beck et al. (2006) use a massive survey dataset and evaluate how successful *a priori* classifications are in distinguishing between financially constrained and unconstrained firms, and what are the determinants of financing obstacles. However, as the approach is very different to the one followed on this article, we do not discuss it further.

the available sample is too short in the time dimension. This is especially the case if the tightness of the constraint only marginally changes over time (Schiantarelli, 1995, p. 190). Furthermore, instability, for instance of adjustment costs over time, may lead to a rejection of the null of perfect capital markets even though firms do actually operate under such circumstances. Thus, misspecification of production technology, adjustment costs or inappropriate instruments may bias the empirical outcomes. Also the estimation of the Euler equation does not allow to quantify the degree of market imperfections (Fazzari and Petersen, 1993, p. 329). A last point concerns the "...choice of the maximand itself..." (Schiantarelli, 1995, p. 191): if the management is actually behaving in a non-value maximizing manner, the resulting Euler equation will be different as the first-order conditions change (Jensen, 1986).

2.3.2 The Fazzari-Hubbard-Petersen approach

Fazzari and Athey (1987) and Fazzari et al. (1988) have proposed an alternative way to test financial frictions by analyzing the relationship between investment, cost of capital and internal funds. According to the standard literature, Tobin's q should fully predict firm investment decisions on perfect capital markets. Financial factors such as cash flows should have no additional predictive power. In order to test this hypothesis a standard investment function augmented by financial factors is estimated. If investment depends on other financial variables, conditional on Tobin's q, this is interpreted as indirect evidence for an imperfect substitution between internal and external funds (Gertler, 1988). A general reduced-form investment equation derived under the assumption of quadratic adjustment costs used for estimation is given by

$$\left(\frac{I}{K}\right)_{it} = \alpha_0 + \alpha_1 Q_{it} + \alpha_2 \left(\frac{CF}{K}\right)_{it} + u_{it} \tag{2.2}$$

where I and K are defined as before, and Q, CF and u refer to a measure of (marginal) Tobin's q, the financial variable real cash flow and an error term.

As shown before, information asymmetries between lenders and creditors, or risk-averse lending behavior may give rise to the relevance of other variables such as firm's wealth for easing credit constraints. It is expected that the investment-to-cash-flow sensitivity increases (maybe in a non-linear manner) in the degree of information asymmetries on credit markets as well as in the degree of lender's risk-aversion against default. Hence, for unconstrained firms one expects a low cash flow sensitivity of investment or none at all, as any positive net-present value project could be fully financed by external funds.[9]

[9] The conclusions attributed to cash flow for the importance of financing constraints is seriously questioned by Gomes (2001). In his more structural approach Gomes argues that financial frictions are not sufficient to obtain cash flow effects, as a correct measure of Tobin's q should already include eventual

Of course, in reality financially constrained and unconstrained firms are present at the same time. Fazzari et al. (1988) suggest classifying firms on theoretical grounds accordingly. In their study, the authors find that the cash-flow-investment nexus is significantly stronger for apparently constrained firms, confirming the hypothesis that the premium on external finance is positively correlated with a firm's financial fragility. Thus, differences in the cash-flow-investment sensitivity between groups of firms provide information on the actual importance of financial supply side effects for investment.

Nevertheless, it should be mentioned that this strand of literature is subject to criticism. There is, which is explained in more detail below, no clear consensus on how firms can be classified into financially 'highly' constrained and 'less' constrained ones, and which criterion should be used for classification. For instance, Kaplan and Zingales (1997) and Cleary (1999) find that firms which appear less constrained show the greatest cash flow sensitivity of investment. The classification variables often used in the literature range from firm size, age, measures of leverage, dividend payout and bond rating. The choice of these variables is theoretically appealing (Berger and Udell, 1998), but may not be so from an econometric point of view as the sub-sampling may be seen as arbitrary.

We closely follow Fazzari et al.'s framework in this paper, but augment the empirical analysis by allowing for a data-driven way to group firms into constrained and unconstrained ones endogenously. The approach will be described after a brief overview of the existing empirical literature.

2.3.3 Previous studies on cash flow-to-investment sensitivity

In this section we provide a literature review of previous empirical studies which mainly apply the approach suggested by FHP. Our focus is on the issue of firm grouping in order to capture differences in the financial position of firms. The following review is not necessarily ordered in a chronological way, but according to the firm classification scheme applied. In a second part, we list recent studies using German firm-level datasets to allow for a comparison of estimation strategies, methods and results.

International studies The basic idea of testing the existence of imperfect capital markets was first outlined in a paper by Fazzari and Athey (1987). The authors use the Value Line Data Base covering a time span from 1975 to 1985 comprising information on

financial frictions a firm faces. Second, Gomes argues that cash flow may even have some predictive power in the absence of financial frictions, and third, statistically the correlation between investment and cash flow might be spurious if a linear decision rule is assumed for an actually non-linear relationship. However, the first two arguments do not question the role of risk-averse lending behavior and credit rationing in explaining the investment-cash-flow nexus.

637 manufacturing firms. The financial variables in their model specification are internal finance flow and net interest payments. These variables are supposed to capture the effect of financing constraints for fixed-investments.[10] Overall they find that "...financing variables have economic as well as statistical importance." (Fazzari and Athey, 1987, p. 485). This paper has initialized a whole series of publications using different measures to group firms.[11]

In their widely-known paper, Fazzari et al. (1988) also rely on the Value Line Data Base but on an extended sample from 1969 to 1984 including manufacturing firms. The authors classify firms according to their dividend-payout ratio which is assumed to serve as a signal for a firm's financial soundness. Unconstrained firms are supposed to payout more dividends compared to constrained ones, as the latter heavily rely on internal funds if their access to external funding is restricted or associated with high costs. Besides that, financial variables are found to be statistically relevant in all cases. The marginal response of investment to cash flow and liquidity is found to be greater for firms with high retention rates. Also Bond and Meghir (1994) have also used the dividend-payout ratio as a signal variable. They use published accounts of U.K. corporations of the manufacturing sector, provided by Datastream International for quoted companies between 1974 and 1986. The estimation results of a dynamic investment model indicate that lagged cash flow as well as firm debt play a statistically significant role for firm investment.

Hoshi et al. (1991) apply the degree of bank affiliation as another classification criteria. They emphasize the role of bank-firm relationships and argue that tight relationships may help to mitigate information asymmetries following the relationship-lending literature (Petersen and Rajan, 1994; Boot, 2000). The empirical analysis is based on panel data comprising Japanese manufacturing firms listed at the Tokyo Stock Exchange between 1965 and 1986. The authors find evidence that excess sensitivity between firm investment and liquidity is lower for firms with relationship-type linkages to banks compared to others including listed companies. This may be somehow surprising as listed companies are already assumed to be apparently informationally transparent.

A slightly different approach is chosen by Fuss and Vermeulen (2006). Instead of identifying the types of firms subject to financial constraints, the authors seek to identify periods when financial constraints are binding. According to the results, constraints become binding when firms suffer from exceptional liquidity shortages. Additionally, the authors study the access to external finance and investment spending for firms with a single bank-relationship in comparison to companies with multiple bank-relationships during critical periods. It is assumed that a firm with a single bank-relationship shares deeper

[10] Fixed investment refers to investment in physical assets such as equipment and structures as well as intellectual property rights.

[11] For additional references not cited here, see also the recent article by Kalemli-Özcan et al. (2015).

and closer links with its bank which helps to alleviate potential information asymmetries during periods of distress. The rich dataset comprises annual data for 1448 non-financial Belgian firms as well as bank information for the period between 1997 and 2002. The estimation of panel error correction models for investment, enriched by interaction terms capturing various effects, reveals that financial constraints become indeed binding when negative cash flow shocks are realized. Firms which obtain extra bank credit, are able to stabilize investment spending in comparison to the remaining firms. Lastly, the results indicate that the probability to obtain extra bank loans is higher for larger firms and less leveraged firms. However, the number of bank relationships does not seem to be an important determinant for the probability to obtain extra credit during bad times.

Whited (1992) relies on the COMPUSTAT panel database comprising U.S. manufacturing firms for the period between 1975 and 1986. Whited argues that financially unconstrained firms are those which have received a bond rating. Bond rated firms are typically less opaque as information about their business are gathered and published in a rating which provides information on the firm's creditworthiness. Furthermore, a rating is signaling that the "...firm has undergone careful scrutiny regarding its financial health and its future growth opportunities." (Whited, 1992, p. 1438). Whited also splits the sample of firms according to balance-sheet indicators such as debt-to-asset ratio and interest-coverage ratio. Whited finds that financial health affects investment decisions crucially. Financial variables matter significantly for realized investments of constrained but less so for unconstrained firms. Overall, the results confirm the excess sensitivity hypothesis.

Others have used firm size and firm age as another set of signaling variables (Hubbard, 1998; Oliner and Rudebusch, 1992; Gertler and Gilchrist, 1994). Older firms are more transparent as they can provide information on historical market records to potential investors, which helps to improve their market credibility. Additionally, most likely older firms have established close-ties with creditors as well as suppliers which also helps to increase both actors' reputation.

Studies covering Germany Harhoff (1998) studies the role of financing constraints for R&D and fixed investments in Germany. The dataset includes data from 1990 to 1994 for SMEs whose shares are not traded in the stock market. Harhoff estimates accelerator and panel error-correction models as well as Euler equations for investments and R&D. It is found that the investment-cash-flow nexus is stronger for small firms compared to larger ones. The estimation results of the Euler equation are less satisfying. Lastly, Harhoff supports his argument that especially small firms face financing constraints by means of additional survey information. Overall, the results reveal size-contingent cash flow effects for R&D as well as fixed investment expenditures in Germany.

The link between firm size and liquidity constraints in Germany is examined by Audretsch and Elston (2002). The empirics is based on the Bonn Database covering annual observations for 100 publicly traded West German firms between 1970 and 1986. Dynamic investment functions using the Tobin's q-theory are estimated. Interestingly, the dynamic panel results suggest that medium-sized enterprises experience tighter liquidity constraints compared to smaller and larger firms. Audretsch and Elston argue that this effect can be explained by the German financial and institutional landscape which is different to the Anglo-Saxon model. However, according to the results the German institutional structure does not seem to be able to reduce the level of financial constraintness for medium-sized enterprises; at least during this episode.

Chirinko and von Kalckreuth (2002) also study the German firm landscape. The authors exploit internal Bundesbank firm-level data including listed as well unlisted West German manufacturing companies from 1988 to 1997. The consideration of unlisted firms is crucial at least for two reasons: First, the majority of firms in Germany are not listed. Most listed firms can be classified as large firms operating internationally. Second, the whole argument of the relevance of imperfect capital markets mainly refers to SMEs which usually operate under a different economic environment compared to large firms, as argued before. Chirinko and Kalckreuth estimate linear dynamic panel models and apply a discriminant analysis to compile a measure of creditworthiness. Three classes of creditworthiness are derived by means of an index comprising various firm and balance-sheet information. The authors find statistical evidence that the cash flow coefficient is higher for financially constrained compared to unconstrained firms.

Bond et al. (2003) investigate the role of financial factors for investment on the cross-country level. The countries studied comprise Belgium, France, Germany and U.K. for the period between 1978 and 1989. The German data only include stock-market quoted companies and are taken from the Bonn database. One of the key findings is that financial variables (e.g. cash flow) do not play a statistically relevant role in Belgium, a rather small one in Germany and France, but are much more relevant in the market-oriented U.K. financial system. This supports the perspective that institutional aspects have repercussions on the degree of financial constraints firm face.

The study by Engel and Middendorf (2009) is closely in line with the one by Hoshi et al. (1991). The two authors also focus on the role of bank-firm relationship. This aspect is highly relevant in a bank-based system where relationship-lending is still of importance and where the majority of banks follows a non-profit-maximizing business strategy. The authors distinguish between firms that operate under a relationship-lending regime having close ties to public banks and/or cooperative banks, and others which (mainly) rely on funding from private commercial banks. A dynamic linear panel model is applied using the DAFNE database covering the years 1998 to 2004. This database is highly representable as it comprises SMEs as well as large firms with different types of legal status (e.g. stock companies and limited liability corporations). Furthermore, Engel and Middendorf use historical data from the ZEW Firm Panel comprising information on bank-firms relationships, and Moody's KMV data source for default risk measures. There is strong evidence that the marginal effect of additional cash flow on investment is higher for risky firms compared to others. Furthermore, in contrast to the study by Chirinko and von Kalckreuth (2002) excess sensitivity does not seem to differ between firms mainly funded by public banks in comparison to firms which heavily rely on private ones. However, this may be either explained by the low number of observations in this separate regression, or by the fact that also in Germany private banks follow a close-ties business strategy.

Martinez-Carrascal and Ferrando (2008) mainly refer to the work by Myers (1977). It is argued that debt generates possible externalities on the shareholders' and management's optimal investment path. Myer's debt overhang model predicts that *ex post* highly leveraged firms will not invest more due to agency conflicts, and *ex ante* it may even be optimal for low-leveraged firms to delay certain investment project. The authors use the AMADEUS dataset comprising balance sheet data on private and publicly owned firms between 1994 and 2005. The empirical results indicate that a firm's financial position, measured by cash flow, indebtedness and debt burden, respectively, affects fixed-investment. However, the marginal effects of financial indicators differ substantially across countries. Interestingly, the lowest marginal (but still significant) effects are found for German firms (which confirms the findings by Bond et al. (2003)), and the highest for Dutch and Italian ones. Furthermore, the authors find no significant differences in the marginal effects between firm size groups or industry sectors.

The most recent study on Germany, on which we are aware of, was published by Lenger and Ernstberger (2011). They also use the DAFNE database for the years 2000 to 2006. Their results mainly confirm previous studies as they find that SMEs show significant cash flow effects for business investment.

In total the results of the empirical literature strongly supports the perspective that financial frictions or generally capital market imperfections are statistically and economically relevant for firm financing. However, most of the empirical results quoted may suffer from some methodological drawbacks. First, some of the grouping-variables, for instance the dividend-to-payout ratio, are likely to be endogenous, and it may be plausible that firms adjust their dividend-payout ratio to their investment plans rather than the other way around (Schiantarelli, 1995; Hansen, 1999). Also, firms are typically classified according to a single indicator alone which is a strong assumption as other indicators may be relevant as well. However, the inclusion of further control variables may increase the dimension of the econometric model substantially affecting statistical inference negatively. Third, the belonging of a firm to a specific group is often assumed to be fixed over the sample period. It is more realistic to assume that a firm switches from one group to another during its life-time (Hu and Schiantarelli, 1998). For further issues on sample separation criteria see Schiantarelli (1995, p. 192 ff.).

Facing these critical points, Hu and Schiantarelli (1998) and Hansen (1999) have suggested alternative separation frameworks. Both authors apply methods which separate groups endogenously using a data-driven approach. More concrete, Hu and Schiantarelli estimate endogenous switching regressions. They use different balance-sheet indicators which trigger the probability of a firm being in a constrained or unconstrained regime, respectively. The cash-flow-to-investment sensitivity depends on the regime a firm operates in. Alternatively, Hansen derives the statistical properties of a piecewise-linear panel model with fixed-effects. He proposes an algorithm to test for multiple thresholds and derives the asymptotics for further inference. This threshold panel model is in fact a special case of the more general switching model but much simpler to implement and to estimate. In the following we introduce Hansen's idea in more detail before the database and econometric results are presented.

2.4 Econometric approach and estimation results

In this section a threshold model of investment is presented. The model framework offers a reasonable way to test the relevance of credit market imperfections as discussed before. Most approaches rely on a q-model based on the assumption of convex adjustment costs (Hu and Schiantarelli, 1998). As our dataset includes listed as well as unlisted companies, we do not consider a measure of Tobin's q for the estimation.

The issue we mainly address, concerns the sample-split procedure applied by Fazzari et al. (1988) and followers. As shown, various observables are used in the literature to split firms into constrained and unconstrained ones. The strategies are to some extent *ad hoc*, as the regime a firm operates in is actually latent. As argued before, this ad hoc sample-split approach suffers from several drawbacks. Instead of grouping firms according to observables, we apply a fully *data-driven* approach by assessing the signaling properties of balance sheet indicators for the cash-flow-to-investment nexus. The econometric method proposed by Hansen (1999) allows us to split the sample according to a specific threshold variable which determines so called *regimes* endogenously in a first step, before the regime-dependent as well as regime-independent parameters are estimated. In this case, the latent of being financially constrained or unconstrained is determined by a transition function which depends on a vector of firm characteristics itself. The framework enables us to *A)* estimate whether specific firm groups (regimes) actually exist or not, and *B)* to estimate and to compare the marginal effect of cash flow on investment across the regimes.

The set of threshold variables comprises various balance sheet items which serve as signaling devices providing information about firms' creditworthiness and bankruptcy risks (Semmler, 2011, ch. 5). Applied measures of bankruptcy risk are credit or debt variables, leverage or the interest coverage ratio. Others have used liquidity variables, instead. Furthermore, bankruptcy risk may be approximated by the financial market's evaluation of risk depicted by interest spreads between risky and less risky firms. On the macroeconomic level, one could use the difference between the short-term commercial paper rate and the interest rate of Treasury bonds as a proxy, instead (Semmler, 2011, p. 51). However, it remains unclear whether the commercial paper rate appropriately captures the bankruptcy risk of firms which have no access to the commercial paper market at all.

In the following sub-section the econometric modeling framework applied in this paper will be outlined in more detail.

2.4.1 A piecewise linear model

The panel model proposed by Hansen (1999) belongs to the class of static non-linear panel models. The basic idea is to split the sample into a small number of classes (regimes), before estimating the regime-dependent and -independent coefficients. The transition across regimes is assumed to be instantaneous (non-gradually) and driven by a transition variable being below or above a – to be determined – threshold value.[12] The structural equation for a 2-regime (single threshold) model, taken for illustration, is given by

$$y_{it} = \mu_i + \alpha' z_{it} + \beta'_{LOW} CF_{it} \mathbf{I}(D_{it} \leq \gamma) + \beta'_{HIGH} CF_{it} \mathbf{I}(D_{it} > \gamma) + e_{it} \tag{2.3}$$

[12] A more general class of models is known as smooth transition regression models (see Gonzalez et al. (2005); Fok et al. (2005) on panel models). The parameters are allowed to change smoothly between multiple regimes, depending on the value of a transition variable and critical location values. However, theoretically it is quite plausible to assume that lenders classify in a manner reasonable in line with threshold behavior. For instance, banks have a standard classification scheme and rank potential clients according to a vector of bankruptcy indicators which is consistent with a threshold approach. Furthermore, smooth transition models are much more complex to estimate. The estimation of the non-linear model part involves complex optimization issues and standard procedures such as grid searches may result in a local instead of a global optimum. Nevertheless, this does not rule out the application of this approach in future work.

where the dependent y_{it} is a scalar, z_{it} is a m vector of regime-independent regressors, the regressor CF_{it} is a k vector (here only cash flow), the threshold variable D_{it} is a scalar, $I(\cdot)$ denotes an indicator function and γ is the threshold value. The indicator term takes unity if the threshold variable exceeds the threshold value γ and otherwise zero. Equation (2.3) can be written compactly as

$$y_{it} = \mu_i + \alpha' z_{it} + \beta' CF_{it}(\gamma) + e_{it} \qquad t = 0, 1, ..., T \tag{2.4}$$

where $CF_{it}(\gamma) = \begin{pmatrix} CF_{it}\mathbf{I}(D_{it} \leq \gamma) \\ CF_{it}\mathbf{I}(D_{it} > \gamma) \end{pmatrix}$ and $\beta = (\beta'_{LOW}, \beta'_{HIGH})'$. The scalar μ_i denotes a unit-specific intercept. The coefficient vector α captures the regime-independent effects, whereas β depends on the regime. The subscripts LOW and $HIGH$ may refer to a low- and high-(risk-)premium regime, respectively. Creditworthy firms are expected to pay a low external finance premium, and *vice versa*. For identification it is required that CF_{it} is time-variant. The assumption that e_{it} is $i.i.d$, requires that lagged dependent values are not included (Hansen, 1999, p. 347). The regression model is estimated for $i = 1, ..., n$ firms and $t = 1, ..., T$ observations. The analysis holds for fixed T as $n \to \infty$.

For a given γ, the regime-dependent β coefficient can be estimated by OLS after the fixed effects transformation. In order to estimate γ, Chan (1993) and Hansen (1999) have shown the validity of the least square technique in this context

$$\hat{\gamma} = arg\,min(\gamma)\, S_1(\gamma) \tag{2.5}$$

where $S_1(\gamma)$, the sum of squared errors (SSE) of the model specification with a single threshold, only depends on γ through the indicator function. The sum of SSE is a step function with at most nT steps occurring at distinct values of the observed threshold variable D. A standard procedure is to sort the distinct values of the threshold variable in an ascending order and to eliminate the smallest and largest η-% values. Next, one can search for $\hat{\gamma}$ over the N remaining values of γ by running regressions over all N values. The estimate of $\hat{\gamma}$ is given for the regression with the smallest SSE. Hansen (1999) suggests to divide the N values of the set of γ values into specific quintiles which reduces the number of regressions performed but nevertheless is most likely to be sufficiently precise.

The null hypothesis of no threshold and its alternative of a single threshold are expressed as:

$$H_0 : \beta_{Low} = \beta_{High} \text{ vs. } H_1 : \beta_{Low} \neq \beta_{High}\,. \tag{2.6}$$

This hypothesis can be tested by a standard LR test. As the threshold parameter is not identified under the null hypothesis, the distribution of the test statistics is non-standard

(Andrews and Ploberger, 1994; Hansen, 1996). However, the FE model belongs to the class of models considered by Hansen (1996), and his proposed bootstrap procedure can be applied to simulate the asymptotic distribution of the LR test based on the test statistics

$$F_1 = \frac{S_0 - S_1(\gamma)}{\hat{\sigma}^2} \tag{2.7}$$

where S_0 and S_1 refer to the sum of squared errors under the null and the alternative, respectively. For more information on the inference part and determination of multiple thresholds see Hansen (1999).[13]

The described approach has two major advantages: First, the threshold values are endogenously determined allowing for the classification of firms according to their financial position in a data-driven way. Second, the different regime models are sequentially tested against each other using a bootstrap technique. This allows one to determine empirically the number of regimes or groups of firms. In fact we test for multiple thresholds in the application below. In a first step a linear model is tested against a two-regime (single threshold) model. If the null of linearity against a two-regime model is rejected, the null of a two-regime against a three-regime model is tested, and so on.

An inherent assumption of this framework is that the regime-dependent effect, which is supposed to capture cross-sectional heterogeneity across firms, is assumed to be constant over time.[14] Recently, Bordo and Haubrich (2010) have emphasized that historically the credit channel is strongest during economic downturns. This is somehow confirmed by the empirical results obtained by Gaiotti (2013) based on firm-level Italian data. Gaiotti argues that the impact of bank credit on a firm's investment is time-varying and strongest during contraction periods when alternative sources of finance also become restricted. Nevertheless, this issue is left open for future research as the simultaneous consideration of time-varying effects would require a more complex modeling framework. Additionally, as the time dimension of the panel is rather small, it remains under debate how much time-variation actually can be found in the data.

2.4.2 Industries and sample construction

The largest German credit rating agency Creditreform and Bureau Van Dijk provide the DAFNE database which is used in this paper. The database comprises historical

[13]For the following empirical applications a grid with 300 quintiles after eliminating the $\eta = 10\%$ extreme values of the threshold variable is used. To compute the simulated asymptotic distribution of the LR test, we run a bootstrap procedure (draw with replacement from the empirical distribution) with 999 iterations. All computation is done using the open-source econometric software package `gretl` (Cottrell and Lucchetti, 2013). The code is available from the author upon request. The original `GAUSS` code is provided by Bruce Hansen on `http://www.ssc.wisc.edu/~bhansen/progs/joe_99.zip`.

[14]Do not mix this with the possibility that a firm can switch between regimes over time. This is allowed in the framework.

accounting data of a representative pool of German firms for the period between 2006 and 2012. Only firms from non-financial and non-public industry sectors ranging from mining, manufacturing over construction to information and communication (for details see Table A.1 in the Appendix) are selected. The final panel includes stock companies, limited liability companies and others. Limited liability companies represent the most prevalent legal firm type in Germany. The dataset is corrected for missing values, outliers and implausible values. Again we refer to the Appendix for details on data manipulation.

The econometric analysis is based on a balanced panel for three reasons. First, the econometric technique applied requires balanced panel data (Hansen, 1999). Second, a balanced panel eliminates the problem of biased estimates of the threshold parameter due to changing sample compositions over time. Last, as we want to assess the evolution of a firm's financial position and its impact on investment, we need to monitor firms over the whole time period. The number of valid observations depends on the variables considered as the number of missing values differs among the set of potential threshold variables. In total the number of cross-sectional units ranges between 214 and 268, with the exception of the two factor variables ($factor1$ and $factor2$) for which only about 70 units are existing.

2.4.3 Variables used

In line with the literature, the dependent variable, investment rate (ik), is defined as the change in gross tangible capital over pre-period gross tangible capital.[15] This definition of capital is widely used and assumes that capital is homogeneous (Barnett and Sakellaris, 1998, p. 268). Cash flow (cf) is measured by current retained earnings re-scaled by lagged capital stock.

The set of control variables consists of information on the firm as well as macroeconomic level:

- Firm-level variables:
  - $D_{i,t-1}$, lagged value of the respective threshold variable
  - $D^2_{i,t-1}$, squared lagged value of the respective threshold variable
  - $w_{i,t-1}$, lagged number of workers, in logs
  - $gt_{i,t-1}$, lagged growth of real sales revenues
  - $roi_{i,t-1}$, lagged real return of investment
  - $roi^2_{i,t-1}$, squared lagged real return of investment

[15] For more detailed information on variable construction see the Appendix on page 139.

  - $d_{i,t}$, current depreciation rate
  - $d^2_{i,t}$, squared current depreciation rate

- Macroeconomic variables:
  - gfc_t, dummy variable taking unity for years $\geq$ 2008, otherwise zero
  - $gfc_t \cdot w_t$, interaction term
  - gdp_t, current GDP-based output gap measure

The list of applied threshold variables, D, will be presented below on page 38. Lagged values are used to circumvent possible endogeneity issues. The growth of real sales revenues captures the real side of investment decisions, and controls for various effects. For instance, the variable encompasses potential accelerator effects and thus captures relevant investment demand factors. Additionally, real return on investment and its squared value are added to the specification.[16] Both growth of real sales revenues and real rate of return also capture profit expectations on imperfectly competitive output markets (Himmelberg and Petersen, 1994; Lenger and Ernstberger, 2011). Expected profitability also approximates prospective profit opportunities of an investment project (Fazzari et al., 1988). The consideration of these information is an attempt to argue against the claim that a positive cash flow effect on investment is a pure result from omitted demand factors (Fazzari and Petersen, 1993, p. 333).[17]

The number of workers per firm (in logs), w, controls for differences in the accumulation rate due to firm size. The effect of firm size is ambiguous: it is typically positively related to firm age, and older firms are assumed to be more diversified and transparent as they may have longer track records with investors, creditors, suppliers and customers. Overall, this may make older companies less prone against bankruptcy risks, and hence associated agency costs should be relatively low. On the other hand, small firms may face lower agency costs as their ownership structure (typically a small number of managers

[16]We did not consider the squared value of gt_t as it was in none of the specifications statistically significant.

[17]A short note is provided on a related problem. The standard q-model of investment with perfect capital markets predicts that investments react to a positive output shift not due to higher levels of retained earnings today but as expected profitability increases as it makes capital more valuable. High cash flows may reflect a firm's sound market position and indicate high future profitability. Hence, current cash flow will be correlated with future profitability. This makes it hard to distinguish whether investment changes because of changes in current cash flow or due to expected profitability shifts. As a result, one will observe a positive correlation between current cash flow and investment even on perfect capital markets as cash flow simply proxies future expected profitability (see Schiantarelli (1995, p. 180ff.) for more on this). Indeed, Cummins et al. (2006) find in their firm-level study that the cash-flow-investment relationship breaks down after controlling for expected earnings. This finding is robust even among apparently financially constrained firms, and may explain why firm fundamentals are more relevant than the presence of financial constraints in the U.S. economy – at least according to these authors. The growth of real sales revenues should, however, appropriately capture these expectation effects and ensure that cash flow actually does not capture future profits and investment opportunities but current profitability.

own large portions of the firm) is less prone to conflicting interests. Current depreciation and its square value are added as another important source of internal funding next to retained earnings (Bundesbank, 2012).

The econometric specification also comprises additional macroeconomic variables to control for non-idiosyncratic effects. The contemporaneous output gap helps to account for business cycle effects, and reflects the current state or climate of the overall economy which might also affect optimal investment. The dummy variable gfc simply corrects for level shifts in accumulation rates due to the recent financial crisis. Additionally, the interaction term between gfc and w controls for different impacts of the crisis according to firm size. It might be the case that larger firms were better able to cope with the crisis, e.g. due to better market or product diversification and more business experience.

The set of threshold variables consists of standard balance sheet indicators. The variables used reflect a common selection of balance sheet items to predict corporate defaults in practice, as shown by the reviewed literature as well as the recent survey by Silva and Carreira (2012).[18] Also, it is quite standard in the macroeconomic literature to measure bankruptcy risk by balance sheet variables. Early approaches can be found in Kalecki (1937) and Minsky (1975, 2008). For more applications see e.g. Gertler and Gilchrist (1994). Additionally, we conducted a principal component analysis using seven balance sheet measures to capture eventual common factors driving a firm's financial position. Common factors may contain superior predictive information for investment decisions. Pre-period values of the following balance sheet items are separately used as threshold variables. Lagged and lagged squared values of the threshold variables enter the model specification as additional regressors.

- $lev_{i,t-1}$, Total liability to total equity ratio as a measure of leverage
- $lglev_{i,t-1}$, Total long-term liability to total equity
- $intcf_{i,t-1}$, Net interest expenditures over cash flow as a measure of interest coverage ratio
- $1/collat_{i,t-1}$, Inverse of the sum of the stock of inventory, tangible assets and cash holdings to total tangible assets as a measure of collateral
- $1/solvency_{i,t-1}$, Inverse of cash flow to total debt
- $1/liquidity_{i,t-1}$, Inverse of cash at hand over short-term debt
- $dyndebtshare_{i,t-1}$, Dynamic debt measure

[18] See for instance Moody's premier private firm probability of default model for the German market which relies heavily on financial ratios as predictor variables. URL: http://www.moodysanalytics.com/~/media/Brochures/Enterprise-Risk-Solutions/RiskCalc/RiskCalc-Germany-Fact-Sheet.ashx.

- $1/factor1_{i,t-1}$ Inverse of first factor of the principal component analysis including $lev_{i,t-1}$, $lglev_{i,t-1}$, $intcf_{i,t-1}$, $collat_{i,t-1}$, $solvency_{i,t-1}$, $liquidity_{i,t-1}$ and $dyndebtshare_{i,t-1}$.

- $1/factor2_{i,t-1}$ Inverse of second factor of the principal component analysis including $lev_{i,t-1}$, $lglev_{i,t-1}$, $intcf_{i,t-1}$, $collat_{i,t-1}$, $solvency_{i,t-1}$, $liquidity_{i,t-1}$ and $dyndebtshare_{i,t-1}$.

The inverse of $factor1$ is positively correlated with lev ($\rho \approx 0.81$), $lglev$ ($\rho \approx 0.70$), $intcf$ ($\rho \approx 0.69$) and $dyndebtshare$ ($\rho \approx 0.75$), and negatively with solvency ($\rho \approx -0.81$) but not at all with collateral. The inverse of $factor2$ is strongly positively correlated with collateral and $liquidity$ ($\rho \approx 0.67$). Thus, both factors capture specific but different balance sheet signals. For details on the principal component analysis, see Table A.2 in the Appendix. Calculating the inverse for some of the variables simply enhances interpretation, as a low value is now associated with a solid firm's balance sheet while high values (may) refer to a fragile one.

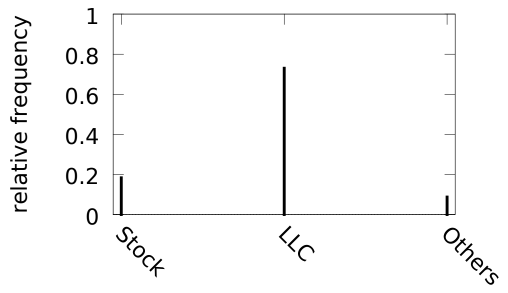
2.4.4 Descriptive statistics

In this subsection initial descriptive statistics about key variables are presented. In order to provide more details, firms are grouped according to the number of workers, w, as follows:[19]

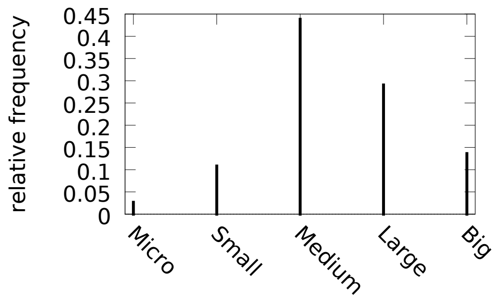
- Micro firms: $w < 20$
- Small firms: $20 \geq w < 50$
- Medium firms: $50 \geq w < 250$
- Large firms: $250 \geq w < 1000$
- Big firms: $w \geq 1000$

Figure 2.2 depicts the relative frequency of firms according to their legal status and size, respectively. About 20% of all firms in the sample are stock corporations, almost 70% are classified as limited liability companies (LLC) while other legal types account for about 10%. A decomposition according to firm size reveals that 55% of all firms fall into the category of small and medium-sized firms (SMEs) while about 5% are micro firms. Large companies represent about 30% and big ones about 15% of all firms in our sample.

[19]Note that this definition slightly deviates from the official one used by the ECB for their *Survey on the access to finance of enterprises*: micro firms employ 1-9, small enterprises 10-49, medium-sized firms 50-249, and large enterprises more than 250 employees. URL: https://www.ecb.europa.eu/stats/money/surveys/sme/html/index.en.html



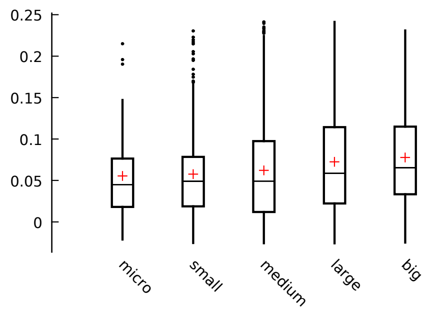
(a) Legal status



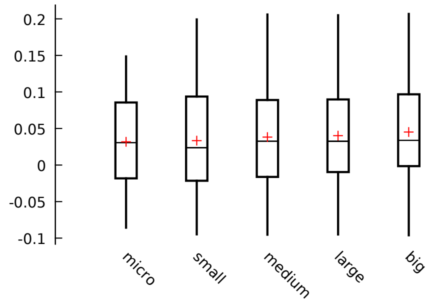
(b) Firm size

FIGURE 2.2: Relative frequency of firms by legal status and size. Sample: 2006–2012.

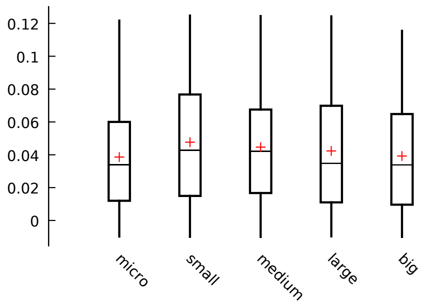
In Figure 2.3 the distribution of the investment rate, ik, growth of real sales revenues, gt, and real rate of return on investment, roi, are displayed according to firm size. The median value of the accumulation rate (Figure 2.3(a)) is positively related in size: The median accumulation rate of micro firms and SMEs is about 5%, and about 6% to 7% of large and big companies. However, given the wide inter-quartile range it seems difficult to derive general tendencies. Growth of real sales revenues (Figure 2.3(b)) is quite stable across size classes with a median value of about 4%. The median values of the real return on investments are highest for small and medium firms (4.5%) and slightly lower for the remaining ones ranging between 3.5% and 4%.



(a) ik



(b) gt



(c) roi

FIGURE 2.3: Unconditional distribution of the investment rate (ik), growth of real sales revenues (gt) and real return on investment (roi) by firm size. Sample: 2006–2012.

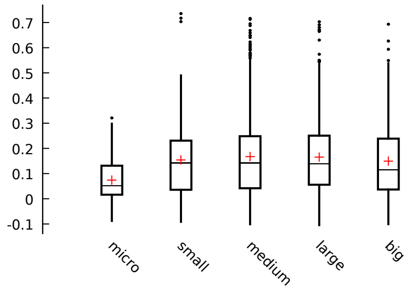
In Figure 2.4 further information on the cross-sectional distribution of the remaining variables are presented. The data indicate that big and large firms hold slightly less leverage compared to smaller companies (see Figure 2.4(e)). The median leverage of micro firms and SMEs is around 1.6 whereas the values for big and large firms are about 1.25. A similar tendency can be observed for long-term leverage where the median value is around 0.8 for micro firms, 0.75 for SMEs, 0.7 for large and big firms, as displayed in Figure 2.4(d). Thus, micro firms and SMEs issue relatively more debt and a higher share of long-term debt instruments in comparison to larger firms. This can be explained by the fact the that latter firms hold more internal funds available and/or issue more equity, instead. A similar tendency holds for the dynamic debt share measure (see Figure 2.4(g)): Again micro firms have the highest median values (about 0.07) while the median for the other firms is independent in size and about 0.05.

Interestingly, the median of the interest-coverage ratio is more or less independent of firm size with the exception of micro firms: Micro firm spend around 8% of its cash flow on interest payments while the ratio is about 14% for SMEs and large firms but slightly lower for big companies (Figure 2.4(a)). This suggests that even though the leverage of micro firms is higher in comparison to all other firms, they have to pay relatively low interests on their debt as a fraction of cash flow. The *solvency* measure captures cash flows relative to the stock of debt. We computed the inverse of solvency in order to allow for a straight comparison with the other variables (Figure 2.4(b)). A low value of $1/solvency$ refers to a solvent firm, and *vice versa*. The median of the inverse is highest for micro firms with a value of 6.5. For the remaining firms we find a median of about 5. Furthermore, according to the data, micro and small firms hold less collateral ($1/collat = 0.72$) compared to bigger ones ($1/collat = 0.6$) (see Figure 2.4(f)). Hence, micro and small firms are not able to accumulate the levels of *solvency* and collateral as bigger firms are. This may make these firms more prone to adverse shocks as their means to compensate such repercussions are lower. This interpretation is supported by the observation that big and large firms also hold more liquidity in comparison to smaller firms, as depicted in Figure 2.4(c).

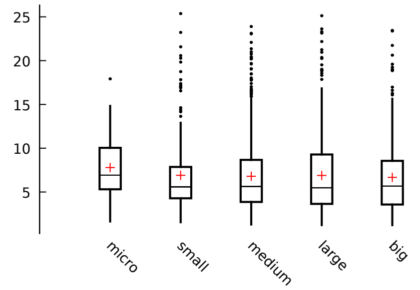
To obtain some first evidence on the relationship between a firm's accumulation rate and its financial position, we plot investment rates over time according to different levels of creditworthiness. More concretely, we compare investment rates of firms for which the respective pre-period financial indicator[20] is below the 15th percentiles (denoted by *low*), with firms for which the financial indicator is between the 40th and 60th percentile (*medium*) and firms with values above the 85th percentile (*high*).[21]

[20] The pre-period value is chosen in order to minimize the endogeneity issue.

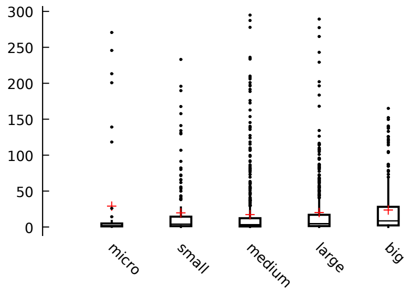
[21] For a more detailed country-wise analysis of the impact of the recent GFC on fixed-investment see ECB (2013, p. 60ff.).



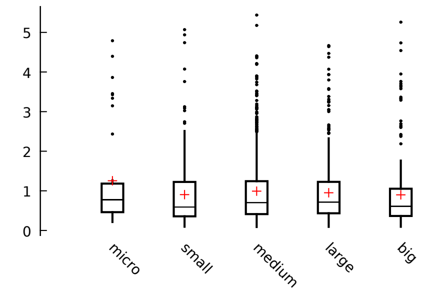
(a) *intcf*



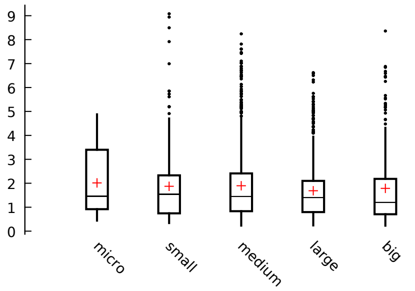
(b) 1/*solvency*



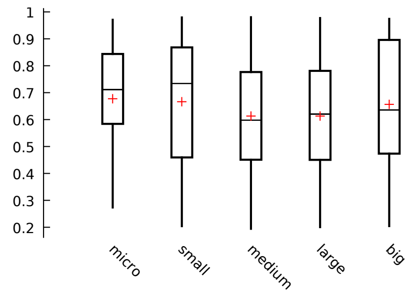
(c) 1/*liquidity*



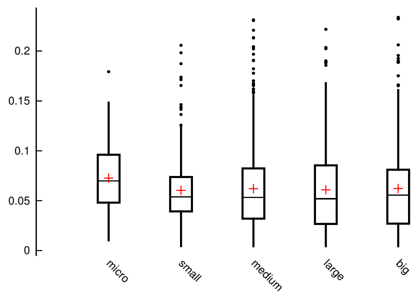
(d) *lglev*



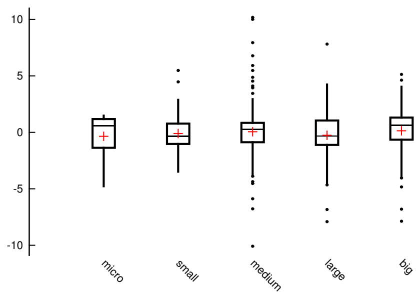
(e) *lev*



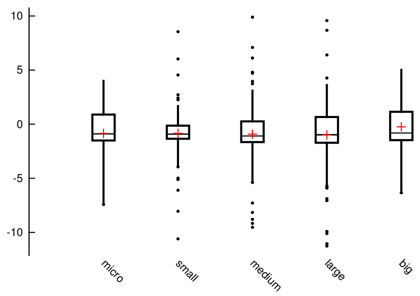
(f) 1/*collat*



(g) *dyndebtshare*

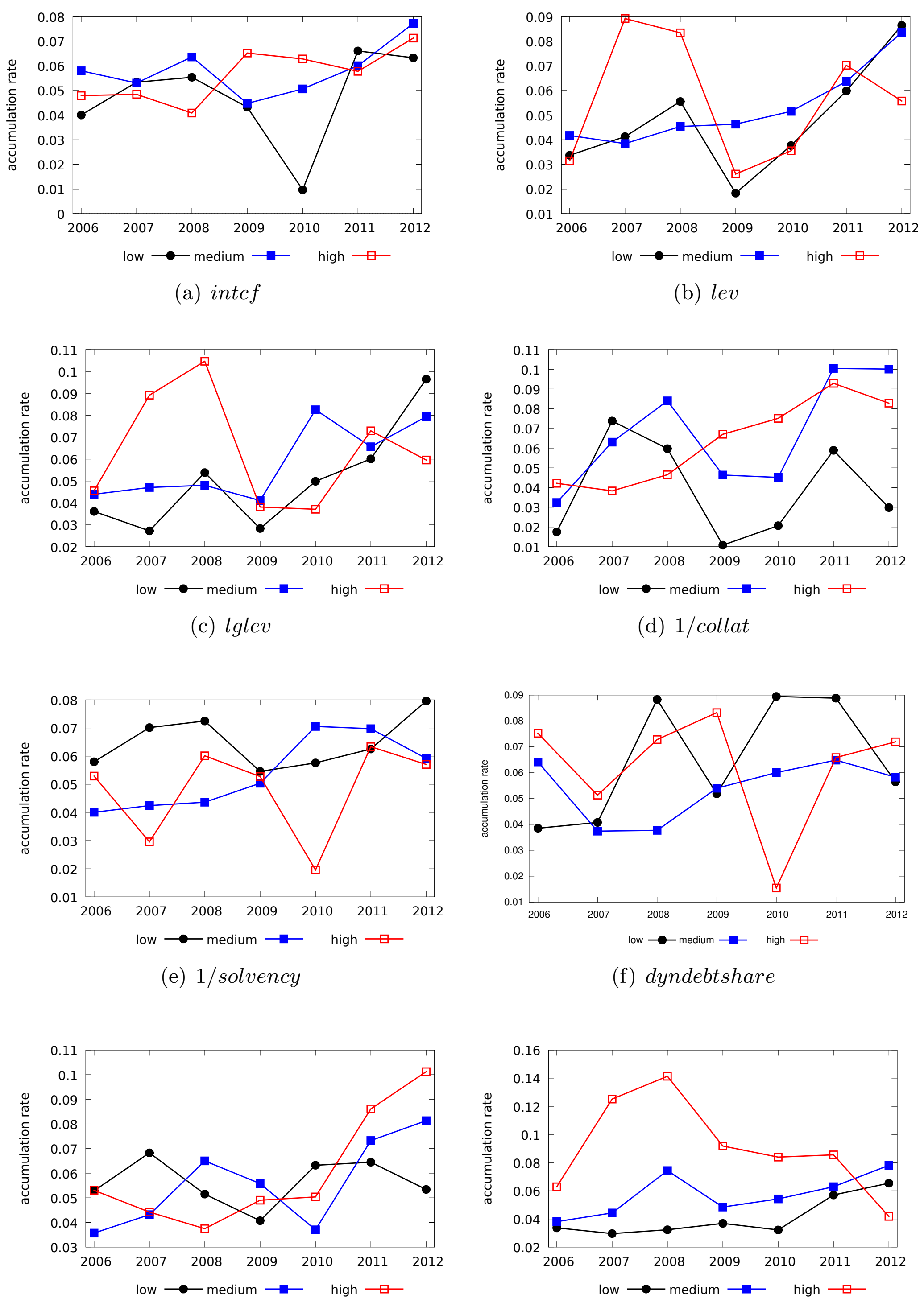


(h) 1/*factor*1



(i) 1/*factor*2

FIGURE 2.4: Distribution of various threshold variables by firm size. Sample: 2006–2012.



(a) *intcf* (b) *lev*

(c) *lglev* (d) $1/collat$

(e) $1/solvency$ (f) *dyndebtshare*

(g) $1/liquidity$ (h) *cf*

NOTES: For each of the financial indicators considered, the charts show the current median accumulation rate (*ik*) for firms for which this (one-period lagged) indicator shows a high value (above the 85th percentile), an intermediate value (between the 40th and 60th percentiles) and a low value (below the 15th percentile).

FIGURE 2.5: Development of accumulation rate of fixed tangible investment according to financial position. Sample: 2006–2012.

Figure 2.5 depicts the accumulation rate for each of the balance sheet items considered in this paper, with the only exception of the two common factors. Note, that this is a simple unconditional correlation exercise and has to be interpreted with caution. As can be seen in Figure 2.5(a), the accumulation rate is not strongly correlated with a firm's interest-coverage ratio until 2009. Interestingly, firms with low interest-coverage ratios experienced the strongest downturn in the investment rate in 2010, but the rates quickly recovered in 2011. For the remaining firms no adverse impact of the GFC can be observed.

Debt has a *dual character*: On the one hand more credit (for given equity), and hence higher leverage, allows firms to invest at higher speed but on the other hand this debt and its associated interest payments lower the internal funds available and may signal bad creditworthiness. A firm might have a low leverage either due to high equity or as its access to external credit is restricted. The dual character of debt is partly reflected in the data. The accumulation rate of highly-leveraged firms (see Figure 2.5(b)) strongly exceeds the ones of the other firms between 2006 and 2008. However, the GFC let to a more severe downturn in the accumulation rate of highly leveraged firms in comparison to medium-leveraged companies in 2009. It seems that the GFC had no adverse impact on the investment rate of medium-leveraged firms as these were even able to increase their investment speed over time. For highly-leveraged firms it took three years before reaching their pre-crisis levels again in 2011. Interestingly, low-leveraged firms invested at similar rates as medium-leveraged companies for most of the time. However, in contrast to the latter ones low-leveraged firms reduced their investment rates during 2009 and 2010. This may indicate that low-leveraged companies either were not interested to invest more or that they faced some kind of credit restrictions. The data suggest a non-linear correlation between a firm's accumulation rate and its leverage.

To a certain degree, the development looks similar using the long-term leverage measure, as depicted in Figure 2.5(c). While highly-leveraged firms experienced the highest investment ratios between 2006 and 2008, the shock of the GFC in 2008/9 has led to a much stronger and more persistent decline in capital accumulation during the following periods. This may support the perspective that lenders applied more strict lending standards making it harder for firms with a debt-overhang to obtain credit at all or at least at reasonable conditions. The investment ratio of low- and medium-leveraged firms is found being much smoother during the crisis-episode. For both low and medium leveraged firms no adverse repercussions on investment rates can be observed; their rates are even increasing. In Figure 2.5(f) the investment dynamics for firms grouped according to the dynamic debt share, *dyndebtshare*, are depicted. Firms with low levels of *dyndebtshare* have experienced the highest accumulation rates over the entire period on average, even though the variance in investment rates is substantial. For firms with medium levels of *dyndebtshare* one can observe a smooth investment path, instead. For the remaining and apparently least creditworthy firms one can see a stable accumulation rate until 2009 before a decrease from about 6% to 1.5% in 2010. However, the rates quickly recovered in the following years. The data suggest an inverse but weak relationship between the level of *dyndebtshare* and a firm's accumulation rate.

Using the inverse of collateral, 1/*collat*, as a measure of a firm's financial position does not lead to unambiguous results (see Figure 2.5(d)). On average, firms with medium levels of collateral experienced the highest investment rates over the entire time span. Most interestingly, we find that firms holding low levels of collateral show a more or less steadily rising accumulation rate between 2006 and 2012 starting with 4% before reaching 9%. Surprisingly, firms with medium and high level of collateral invested at lower rates, and most importantly, for these firms one can observe a temporary decline in their accumulation rates between 2009 and 2010. Overall, the correlation between collateral and investments is counterintuitive on a first glance.

A different picture can be obtained for the *solvency* measure, as depicted in Figure 2.5(e). Highly solvent firms (the ones with the lowest inverse values) show the highest investment rates over time. For these firms the repercussions of the GFC on investment behavior were only modest. Firms with medium levels of 1/*solvency* were even able to accelerate their accumulation rates since 2009. For low-solvent firms, however, one can observe a high variance as well as a severe downturn in realized investment rates from about 5% to 2% in 2010 followed by an immediate recovering.

Surprisingly, there is no clear-cut relationship between a firm's liquidity position and its investment rates, as displayed in Figure 2.5(g). Lastly, one can see a clear hierarchy between the level of cash flow and investments, as displayed in Figure 2.5(h). Firms with low cash flows had the lowest accumulation rates between the entire time span with around 3% p.a., followed by companies with a medium level of cash flow which experienced slightly higher investment rates during the meantime. Firms with the highest cash flow available also show the highest accumulation rates, with the only exception in 2012. Interestingly, one cannot observe strong adverse effects of the GFC for any of the firms: even though firms with high cash flows have reduced their investment rates since 2009, the level of accumulation is still high relative to the other firm groups.

Overall, this simple graphical description provides some initial evidence for an existing link between a firm's financial position and its investment rates. However, the link cannot be observed for all financial indicators. Furthermore, there may be non-linear relationships between financial pressure and fixed-investment growth which is in line with recent findings on the Euro area firm-level (ECB, 2013, p. 59). This may be explained by the dual character of debt, enhancing potential growth on the one hand but also leading to higher debt burdens accompanied by higher real debt servicing costs on the other hand. This nonlinear relationship is partly reflected in our estimation results as will be shown in the following.

2.4.5 Estimation results

In this section the estimation results are presented and discussed. The fixed investment function in eq. (2.4) is estimated for nine different specifications which deviate in terms of the underlying threshold variable. The first step of the analysis involves the determination of the number of thresholds (and hence regimes). We check whether a linear model fits the data sufficiently well or whether any threshold effects exist. For all specifications we test for up to two (three) thresholds (regimes). After the determination of the number of regimes, the actual estimation of the regime-dependent as well as -independent parameters follows. If no threshold-effects are found, a linear panel fixed-effects model is estimated, instead.

Threshold test results Table 2.1 summarizes the regime test results. In the first column the name of the respective threshold variable is reported. The test sequence starts with the null hypothesis of no threshold against a single threshold ($H_0 : T = 0$ vs. $H_1 : T = 1$). If the null is rejected, one proceeds by testing the null of a single threshold against two thresholds ($H_0 : T = 1$ vs. $H_1 : T = 2$). The second column computes the respective bootstrapped p-value, and the last two columns tabulate the point estimates (plus confidence intervals) of the threshold value(s), γ. In case more than one threshold is found, the refinement values are provided.

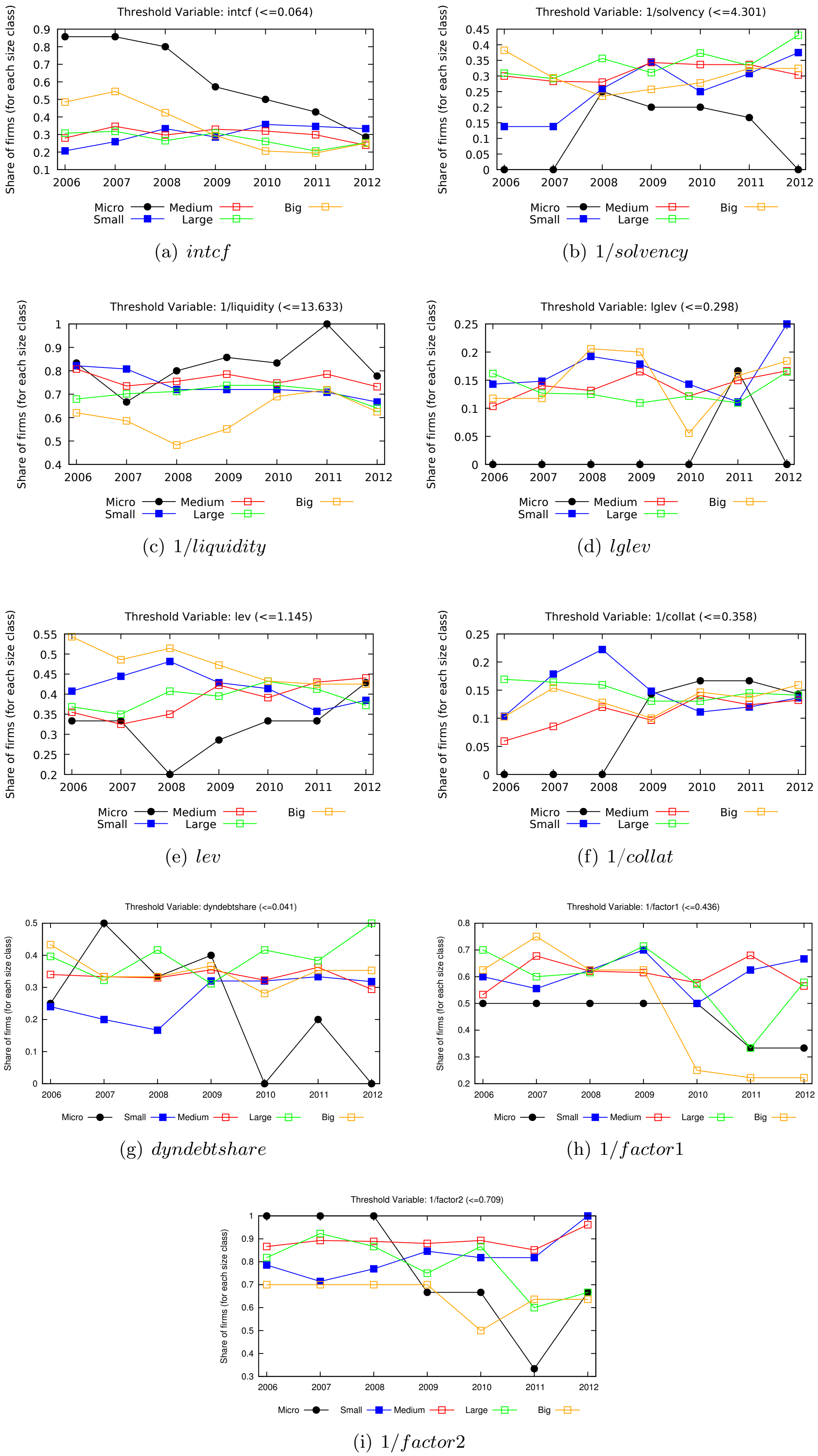
For three specifications evidence of regime-dependence is found. The respective threshold variables are the inverse solvency measure ($1/solvency$), the inverse liquidity measure ($1/liquidity$) and the dynamic debt share ($dyndebtshare$). For $1/solvency$ we find evidence for two thresholds and a single threshold for the both $dyndebtshare$ and $1/liquidity$, respectively.

The estimated threshold values for the $1/solvency$ measure are close to each other, having values of $\gamma_1 = 4.187$ and $\gamma_2 = 4.301$, respectively. The thresholds are significant at the 1% level. The empirical median value of $1/solvency$ is about 7.5 for micro firms and close to six for the remaining companies (see Figure 2.4(b)). This indicates that the estimated thresholds classify firms with rather low, medium, and high levels of $1/solvency$. In order to analyze the firms-specific regime-dependence in more detail, we plot the share of each firm size type falling below a certain threshold over time (see Figure 2.6).

Threshold Variable D **:**	**p-value**	γ_1	γ_2
intcf			
$H_0 : T = 0$ vs. $H_1 : T = 1$	0.691	0.064	
		(-0.005|0.370)	
$H_0 : T = 1$ vs. $H_1 : T = 2$	0.099	0.064	0.252
		(-0.005|0.370)	(0.054|0.254)
1/solvency			
$H_0 : T = 0$ vs. $H_1 : T = 1$	0.008	4.187	
		(4.030|4.187)	
$H_0 : T = 1$ vs. $H_1 : T = 2$	0.001	4.187	4.301
		(4.030|4.187)	(4.301|4.314)
1/liquidity			
$H_0 : T = 0$ vs. $H_1 : T = 1$	0.066	13.633	
		(11.494|17.177)	
$H_0 : T = 1$ vs. $H_1 : T = 2$	0.195	13.633	0.627
		(11.494|17.177)	(0.466|61.691)
lglev			
$H_0 : T = 0$ vs. $H_1 : T = 1$	0.293	0.298	
		(0.252|1.937)	
$H_0 : T = 1$ vs. $H_1 : T = 2$	0.074	0.298	1.824
		(0.252|1.937)	(0.621|1.937)
lev			
$H_0 : T = 0$ vs. $H_1 : T = 1$	0.175	1.145	
		(0.670|1.893)	
$H_0 : T = 1$ vs. $H_1 : T = 2$	0.054	1.145	2.843
		(0.670|1.893)	(0.670|3.246)
1/collat			
$H_0 : T = 0$ vs. $H_1 : T = 1$	0.171	0.358	
		(0.349|0.402)	
$H_0 : T = 1$ vs. $H_1 : T = 2$	0.043	0.358	0.317
		(0.349|0.402)	(0.280|0.946)
dyndebtshare			
$H_0 : T = 0$ vs. $H_1 : T = 1$	0.078	0.041	
		(0.041|0.045)	
$H_0 : T = 1$ vs. $H_1 : T = 2$	0.238	0.041	0.129
		(0.041|0.045)	(0.014|0.131)
1/factor1			
$H_0 : T = 0$ vs. $H_1 : T = 1$	0.536	0.436	
		(-3.117|2.385)	
$H_0 : T = 1$ vs. $H_1 : T = 2$	0.041	0.436	0.468
		(-3.117|2.385)	(0.468|0.468)
1/factor2			
$H_0 : T = 0$ vs. $H_1 : T = 1$	0.861	0.709	
		(-4.782|3.096)	
$H_0 : T = 1$ vs. $H_1 : T = 2$	0.000	0.709	0.766
		(-4.782|3.096)	(0.749|0.769)

NOTE: The test results for multiple thresholds are provided. $T0$ vs. $T1$ and $T1$ vs. $T2$ refer to the null hypotheses of a linear model against a single threshold model (2 regimes) and a single threshold against a double threshold model. We provide the bootstrapped p-values based on 999 replications. γ_1 and γ_2 denote the estimated threshold values (in square brackets the 95 pct. CIs are provided). For the test on two thresholds, the refinement estimates are reported. The number of quantiles checked is 300.

Table 2.1: Threshold Test Results. Sample: 2006 – 2012.



(a) *intcf* (b) $1/solvency$ (c) $1/liquidity$ (d) *lglev* (e) *lev* (f) $1/collat$ (g) *dyndebtshare* (h) $1/factor1$ (i) $1/factor2$

FIGURE 2.6: Share of firms (for each size class separately) falling below an estimated threshold over time. Sample: 2006–2012.

In Figure 2.6(b) we plot the share of firms characterized by $1/solvency$ values lower than the threshold separating the medium from the low-solvency firms ($1/solvency \leq 4.301$). As one can see, until 2007 all of the micro firms fell into the low-solvency regime. However, since 2008 the share of micro firms falling either into the medium- or high-solvency regime has had increased to about 20% before decreasing again in 2012. Overall we find that the share of firms fulfilling the $1/solvency \leq 4.301$ condition is remarkable similar across the remaining firm types. On average about 30% to 40% of all SMEs, big and large companies operate within the medium- or high-solvency regime. These observations suggests that the probability to fall into a financially sound regime is lower for micro firms in comparison to larger companies. Furthermore, small firms have caught up in terms of solvency and stabilized their balance-sheets after 2007. These developments could be a consequence of increased lending standards after the GFC: It may be the case that potential lenders demanded stronger signals of creditworthiness such that smaller firms had to increase their levels of solvency. In general, the repercussions of the GFC on the solvency situation of firms seems to be modest, and the correlation between the probability to stay in a specific regime and firm size is rather weak, at least for SMEs and larger companies.

According to the threshold variable $1/liquidity$ firms can be separated into two groups at the threshold value $\gamma = 13.633$. About 60% of all big firms operate in the high-liquidity regime fulfilling the condition $1/liquiidity \leq 13.633$ (see Figure 2.6(c)). The fraction is slightly higher for the remaining firms and ranges between 70% and 85%. Again, there is only weak evidence that firm size matters for the probability to stay in the high-liquidity regime. The GFC has not been accompanied by a substantial change in the relative shares over time. Only for big firms we observe that the fraction decreased by about 10 percentage points in 2008 before recovering again in the following year. In total, this may suggest that the repercussions of the crisis on liquidity holdings were only modest for firms in Germany. Lastly, it may be surprising that the share of big firms holding high-levels of liquidity is low in comparison to other firms. However, holding high levels of liquidity does not necessarily reflect financial soundness. It may also be the outcome of restricted investment opportunities and/or be the result of tight lending standards demanded by potential creditors to reflect a firm's creditworthiness.

For the dynamic debt share we find a single significant threshold at $\gamma_1 = 0.041$ separating lowly indebted from highly indebted companies. The median value of *dyndebtshare* is close to 0.05 for SMEs, large and big firms, and about 0.07 for micro firms (see Figure 2.4(g)). According to the data, about 35% to 45% of all medium-sized, large and big companies operate in the low-debt regime, as depicted by Figure 2.6(g). Between 2006 and 2008 only 20% of all small companies were located in the low-debt regime, but the fraction has increased to 30% since 2009. The corresponding share of micro firms fluctuates between 25% and 40% between 2006 and 2009 before it has substantially decreased. This may indicate that SMEs, large and big firms were able to compensate the adverse effects of GFC much better in comparison to micro firms. Micro firms had to increase their debt share massively such that many firms switched out of the low-debt regime.

Overall, it is hard to find clear evidence that firm size is an appropriate criteria for a firm's financial regime, as identified by means of estimated thresholds. This is in line with the findings of Martinez-Carrascal and Ferrando (2008) who also do not find evidence that firm size matters for the degree of financial restrictions firms face. However, an exception may be micro firms for which we find a high fraction of companies holding high levels of liquidity (probably reflecting tight lending standards applied), a lower share of firms holding high levels of solvency and low debt shares. Nonetheless, the results should be seen with caution as the number of micro firms in our sample is relatively low with only about 10 cross-sectional units.

Regime-dependent coefficient estimates We proceed with the estimation of the investment-to-cash-flow nexus. The benchmark specification is a linear model with no threshold effects. This specification corresponds to the case mainly applied in the literature. The respective linear coefficient estimate of cash flow is denoted by β^{cf}_{Lin} and reported in Table 2.2. For all nine specifications we find positive and significant (at the 1% level) point estimates ranging from 0.128 to 0.441. The marginal effect of cash flow is positive as expected under capital markets imperfections. However, it should be noted that the estimates are biased and inefficient in case the true model follows a threshold process.

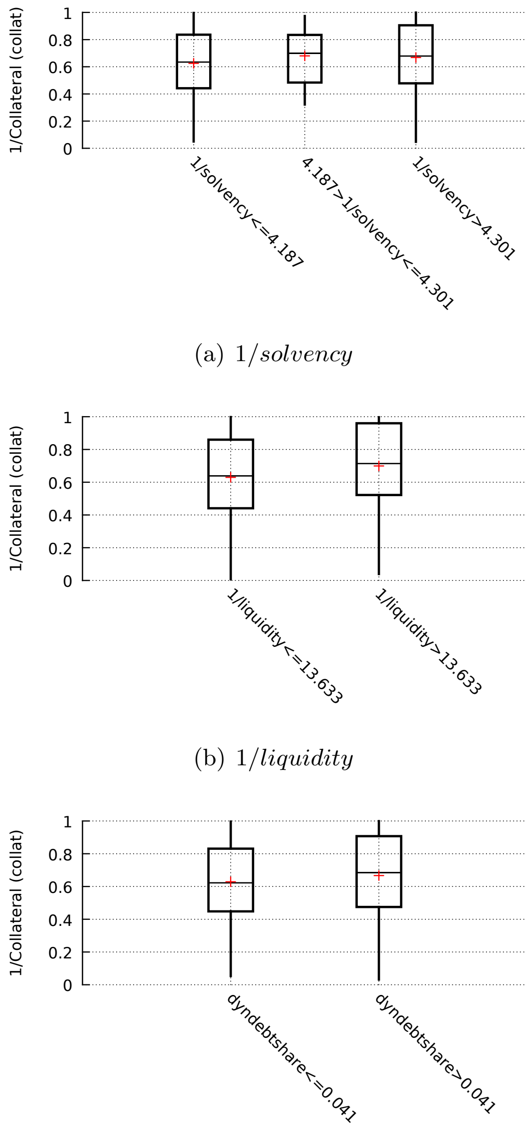
In the following, the regime-dependent coefficient estimates are reported only for the three specifications for which significant threshold effects were found. The regime-dependent coefficients are denoted by β^{cf}_{Low}, β^{cf}_{Middle} and β^{cf}_{High}, respectively, and are reported in Table 2.2. The abbreviations refer to the regime-dependent marginal effect of cash flow on fixed investments for firms with low, medium and high values of the respective threshold variable. The regimes are separated by the estimated threshold value γ, as reported before.

The regime-dependent β-coefficients substantially deviate from the point estimates obtained from the linear benchmark model. For firms with high pre-period solvency levels ($1/solvency < 4.187$), we find a marginal effect of $\beta^{cf}_{Low} = 0.155$ (significant at the 1% level). Hence, every unit of cash flow results in a 0.155 increase in investments. This effect is close to the linear benchmark coefficient, and suggests that the degree of financial constraints is modest for firms falling into this financial regime. For firms with medium levels of solvency, $4.187 \geq 1/solvency < 4.303$, the point estimate is found being much higher with $\beta^{cf}_{Middle} = 0.665$ (significant at the 1% level). This is quite remarkable as the marginal effect for firms above the upper threshold of $1/solvency \geq 4.303$ is lower with $\beta^{cf}_{High} = 0.262$ and again significant at the 1% level. Still, the latter effect is almost twice as high as for firms operating in the least restrictive regime. It should be remembered that about 60% to 70% of all SMEs and larger firms in Germany operate inside the low-solvency regime and thus face tight financial restrictions. The share of micro firms in this regime was found being even higher. This depicts the macroeconomic relevance of financial constraints for firm financing in Germany.

These results indicate a non-linear relationship between the level of *solvency* and the strength of the cash-flow-investment nexus. This seemingly counter-intuitive result may be explained as follows: A low level of *solvency* does not necessarily go hand in hand with high default risk if existing debt is secured by sufficient collateral. In Figure 2.7(a) the level of collateral holdings across firms for each of the three estimated regimes is displayed. The median value of the inverse of collateral are lowest for firms operating in the first regime being about 0.6. For firms in the highest regime the median is slightly higher with 0.65 while it is about 0.7 for firms in the middle regime which face the tightest constraints as estimated. Thus, the tight financial restrictions firms in the middle regime face, potentially result from relatively low levels of collateral available to secure their stock of debt. This indicates that creditors consciously prefer to secure their credits by collateral, and hence collateral comprises additional key information for a firm's financial constraints.

Before discussing the results for liquidity and the dynamic debt share it should be noted again that our balance sheet items may capture (totally) different information of a firm's performance, and hence are not necessarily directly comparable with each other and may even yield different results.

For highly liquid companies for which $1/liquidity \leq 13.633$ the regime-dependent coefficient estimate of cash flow is low being $\beta^{cf}_{Low} = 0.083$ and significant at the 5% level. In contrast, for firms operating in the identified financially problematic regime ($1/liquidity > 13.633$) the marginal cash flow effect is about twice that high being $\beta^{cf}_{Medium} = 0.208$ (significant at the 1% level). As shown before, about 20% to 40% of all firms operate in the low-liquidity regime and thus face intense financial constraints. Again we find that firms in the least restrictive financial regime are associated with rather high levels of collateral for which we find a median value of $1/liquidity = 0.6$, as depicted by Figure 2.7(b). Firms in the constrained regime hold less collateral as the median value of $1/collat$ is about 0.7.



(a) $1/solvency$

(b) $1/liquidity$

(c) $dyndebtshare$

FIGURE 2.7: Collateral holdings of firms according to different threshold variables associated regimes. Sample: 2006–2012.

Highly creditworthy firms are the ones for which $dyndebtshare \leq 0.041$. For these firms the marginal cash flow effect is significant at the 1% level but rather low with a value of about $\beta^{cf}_{Low} = 0.182$. For firms operating in the high-debt regime ($0.041 > dyndebtshare$) the marginal cash flow effect is substantially higher with $\beta^{cf}_{Middle} = 0.304$ and again significant at the 1% level. In total, about 70% of all SMEs and bigger firms fall inside the high-debt regime, and the fraction is much higher for micro firms. Thus, the majority of German firms faces severe financial restrictions. In line with the results for the other two threshold variables, we find that the median of the inverse of collateral for the least restricted companies is about 0.6 but 0.7 for the firms in the restricted regime (see Figure 2.7(c)).

Threshold Variable D**:**	$intcf_{t-1}$	$1/solvency_{t-1}$	$1/liquidity_{t-1}$	$lglev_{t-1}$	lev_{t-1}	$1/collat_{t-1}$	$dyndebtshare_{t-1}$	$1/factor1_{t-1}$	$1/factor2_{t-1}$
Linear benchmark coefficients									
β^{cf}_{Lin}	0.217***	0.193***	0.128***	0.182***	0.172***	0.173***	0.235***	0.441***	0.409***
	(0.055)	(0.045)	(0.045)	(0.048)	(0.048)	(0.047)	(0.057)	(0.160)	(0.129)
SSE	11.003	11.839	11.200	12.519	12.999	12.314	10.970	3.024	2.279
Regime-dependent coefficient estimates									
β^{cf}_{Low}		0.155***	0.083**				0.182***		
		(0.044)	(0.039)				(0.059)		
β^{cf}_{Middle}		0.665***	0.208***				0.304***		
		(0.103)	(0.046)				(0.055)		
β^{cf}_{High}		0.262***							
		(0.051)							
SSE		11.336	10.994				10.779		
T	6	6	6	6	6	6	6	6	6
N	234	245	220	251	268	257	214	60	67

NOTE: The β^{cf}_{Lin} coefficient is based on the corresponding linear FE panel model. The threshold variables *intcf*, *solvency*, *liquidity*, *lglev*, *lev*, *collat* *dyndebtshare*, *factor*1 and *factor*2 refer to the interest coverage ratio, cash-flow-to-debt ratio, cash-to-short-term-debt ratio, long-term-debt-to-equity ratio, total-debt-to-equity ratio, collateral, dynamic debt share, and two extracted principal components, respectively. In case more than one significant threshold is significant at least at the 10 pct. level, the refinement coefficients are reported. $***$, $**$ and $*$ indicate significance at the 1 pct., 5 pct. and 10 pct. level. White standard errors are given in parentheses.

TABLE 2.2: Coefficient Estimates of the Linear Benchmark Model and Threshold Model. Sample: 2006 – 2012.

In a nutshell, there is evidence for capital market imperfections following the methodology proposed by Fazzari and Athey (1987) and Fazzari et al. (1988). For all nine model specifications we find a positive linear effect of cash flow on the accumulation rate. The marginal effects are ranging from 0.128 to 0.441, and are economically meaningful. Furthermore, there is evidence for nonlinear threshold effects suggesting that cash flow plays a less relevant role for financially solid firms in comparison to restricted companies. Interestingly, there is limited evidence that firm size is an appropriate characteristics to discriminate between firms. Balance sheet indicators seem to be more appropriate to group firms as they contain better information on a firm's financial status. Lastly, there is evidence that the probability to fall into a financially constrained regime is higher for micro firms. One can observe that around 2008/9 a considerable share of micro firms switched from a solid financial status to a fragile one, while this is not observed for SMEs and larger firms. Hence, this indicates that micro firms in Germany were hit hardest by the recent economic downturn.

Regime-independent coefficient estimates Lastly, we briefly present the estimation results of the regime-independent coefficients which are provided in Table 2.3. For most specifications we find a negative effect of the number of workers (in logs) on capital accumulation. Growth of real sales revenue is not statistically significant in any of the models. Real return on investment seems to be positively but concavely related to capital accumulation. The effect of the depreciation rate, d, is always positive, but there is also evidence for a concave relationship between d and the investment rate. This is in line with the findings of the Bundesbank showing that deduction is a major source of internal funding for firms (Bundesbank, 2012). The great financial crisis is accompanied by a significant positive level shift in the investment rate. Additionally, the interaction term $gfc * w$ indicates that the effect of the GFC on capital accumulation increases in firm size measured by the (log) number of workers. Hence, larger firms were better able to cope with the repercussions of the economic crisis in comparison to smaller firms. Furthermore, firm-level investment is contemporaneously and pro-cyclically related to the output gap, gdp.

Threshold Variable D:	$intcf_{t-1}$	$1/solvency_{t-1}$	$1/liquidity_{t-1}$	$lglev_{t-1}$	lev_{t-1}	$1/collat_{t-1}$	$dyndebtshare_{t-1}$	$1/factor1_{t-1}$	$1/factor2_{t-1}$
$const$	-0.002	-0.002	-0.002	-0.002	-0.001	-0.002	-0.002	-0.003	-0.003
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.006)	(0.005)
w_{t-1}	-0.111^{**}	-0.088^{**}	-0.094^{**}	-0.113^{**}	-0.102^{**}	-0.108^{**}	-0.104^{**}	-0.062	-0.085
	(0.044)	(0.044)	(0.044)	(0.043)	(0.041)	(0.042)	(0.051)	(0.055)	(0.056)
gt_{t-1}	0.007	-0.001	0.017	-0.009	-0.000	0.019	0.017	-0.026	0.027
	(0.024)	(0.023)	(0.023)	(0.023)	(0.022)	(0.020)	(0.024)	(0.043)	(0.034)
roi_{t-1}	0.439^{*}	1.026^{***}	0.362	0.426^{*}	0.370^{*}	0.512^{**}	0.710^{***}	0.033	0.097
	(0.244)	(0.240)	(0.238)	(0.225)	(0.220)	(0.201)	(0.260)	(0.442)	(0.392)
roi^2_{t-1}	-3.020^{***}	-3.447^{***}	-0.636	-2.770^{**}	-2.061^{*}	-2.764^{***}	-3.402^{***}	-2.658	-4.385^{**}
	(1.039)	(1.095)	(1.246)	(1.069)	(1.067)	(0.947)	(1.284)	(2.562)	(2.197)
d_t	6.946^{***}	9.472^{***}	9.075^{***}	9.670^{***}	8.181^{***}	8.856^{***}	8.546^{***}	24.206^{***}	15.257^{***}
	(2.181)	(2.258)	(2.244)	(2.151)	(1.888)	(1.983)	(2.319)	(4.753)	(2.829)
d^2_t	-10.443	-23.493	-25.304	-24.241	-12.971	-26.735^{*}	-17.881	-153.150^{***}	-79.653^{***}
	(16.428)	(17.356)	(17.769)	(16.747)	(14.588)	(15.434)	(17.790)	(37.595)	(19.574)
gfc	0.024^{**}	0.035^{***}	0.026^{**}	0.023^{**}	0.021^{**}	0.025^{***}	0.025^{**}	-0.013	0.004
	(0.010)	(0.010)	(0.010)	(0.010)	(0.009)	(0.009)	(0.011)	(0.020)	(0.016)
$gfc_t * w_t$	0.053^{**}	0.076^{***}	0.022	0.043^{**}	0.047^{**}	0.044^{**}	0.052^{**}	0.108^{**}	0.140^{***}
	(0.021)	(0.021)	(0.021)	(0.019)	(0.018)	(0.018)	(0.022)	(0.050)	(0.035)
gdp_t	0.005^{***}	0.005^{***}	0.003^{**}	0.003^{**}	0.004^{***}	0.004^{***}	0.004^{**}	0.003	0.004
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)	(0.003)	(0.002)
D_{t-1}	0.071	0.006	-0.000	-0.006	-0.005	-0.215	-0.501	0.001	0.005
	(0.084)	(0.005)	(0.000)	(0.018)	(0.016)	(0.198)	(0.353)	(0.004)	(0.005)
D^2_{t-1}	-0.233^{*}	-0.000	0.000	0.002	-0.002	-0.039	3.816^{**}	0.000	0.002^{**}
	(0.125)	(0.000)	(0.000)	(0.004)	(0.002)	(0.160)	(1.839)	(0.001)	(0.001)
T	6	6	6	6	6	6	6	6	6
N	234	245	220	251	268	257	214	60	67

NOTE: w, gt, roi, d, gfc, gdp and D refer to the the number of workers (in logs), growth of real sales revenues, real rate of return, depreciation rate, a dummy taking unit for for 2008 and the following years and otherwise zero, the output gap and the threshold variable, respectively. $***$, $**$ and $*$ indicate significance at the 1 pct., 5 pct. and 10 pct. level. White standard errors are given in parentheses.

TABLE 2.3: Coefficient Estimates of the Regime-independent Variables. Sample: 2006 – 2012.

However, most interestingly there is only weak evidence for a relationship between capital accumulation and the lagged level of the respective threshold variable. Only for the interest coverage ratio (*intcf*), the dynamic debt share (*dyndebtshare*) and the second common factor (*factor*2) a significant (at least at the 10% level) effect is found. The level of the interest coverage ratio is negatively related to the investment rate while the two other effects are positive. This mirrors the dual character of debt, as argued before. Overall, this result highlights an additional channel through which financial conditions may affect realized investments: The status of the balance-sheet not only has indirect effects on investments by providing signals of creditworthiness but may also affect the accumulation rate by e.g. restricting the amount of available internal funds. However, to be a valid finding this potential channel needs to be analyzed in more detail in future research.

2.4.6 A word of caution

A critical point in estimating reduced-form fixed-investment functions concerns the issue of controlling for demand effects. One issue refers to the question whether Tobin's q or growth in sale revenues fully capture demand effects. If this identification issue remains unsolved, it is unclear whether the positive cash flow effect stems from a shift on the demand side or whether it has its causes in increased capital market imperfections emerging from the supply side. Hence, for identification one needs to make sure that the control variables fully capture shifts in demand in order to interpret the marginal effect of cash flow as reflecting supply side factors.

In their, unfortunately, less known paper Fazzari and Petersen (1993) have suggested an extension of their initially proposed estimation approach. The authors emphasize the dual role of working capital as a *use of funds* as well as a *source of liquidity.*[22] The authors start their argument by computing the correlation between working capital and fixed-investment. As working capital behaves pro-cyclically and is positively correlated with sales and profits, the inclusion of working capital into the fixed-investment function should result in a positive effect on fixed-investment. However, this only holds true if working capital as a use of funds does not compete with fixed-investment under a binding financial constraint. Thus, for firms facing imperfect capital markets, the marginal effect of working capital is expected to be negative.

Secondly, Fazzari and Petersen claim that the standard reduced-form fixed-investment model underestimates the full effect of capital market imperfections. They argue that the coefficients estimated only reflect an "*...average 'short-run' impact of cash flow shocks,*

[22] Working capital is defined as the difference between short-term assets comprising accounts receivable, inventories and cash, minus the sum of accounts payable plus short-term debt.

after the firm engages in optimal investment smoothing" (Fazzari and Petersen, 1993, p. 329). In order to fully capture financing constraints one has to control for endogenous changes in working capital as a source of fund mitigating cash flow shocks. If one does not control for working capital in the fixed-investment function, one cannot rule out that e.g. negative cash flow shocks are compensated by the liquidity working-capital provides (especially cash holdings). If a firm holds a large stock of working capital, the negative cash flow shock may be compensated. However, the same shock will have a much larger impact on investment if the stock of working capital is small and does not allow to smooth investment plans. Under this argumentation, the previously reported results, due to the non-consideration of working capital in our investment function, may only capture the very short-run cash-flow-to-fixed-investment sensitivity but not the long-run effects. In Fazzari and Petersen's study the marginal effect of cash flow on fixed-investment is found being indeed three to four times higher after considering working-capital as an additional regressor.

Unfortunately, the DAFNE dataset includes a high number of missing observations for working capital. However, we estimated linear benchmark models including the contemporaneous effect of working capital as an additional regressor. Overall its point estimate was found being significant and positive. Surprisingly, the effect on the cash flow sensitivity was rather negligible. These results are not reported here as the number of observations is too small to be sufficiently reliable. This short paragraph is added to outline remaining limitation of our own work and of others on measuring financial investment constraints.

Another aspect concerns the substitution effect. The financing instruments a firm can choose, include among others equity, bank loans, debt securities, inter-company loans, trade credit facilities or informal loans. Thus, firms are to some degree flexible in their financing strategies. However, it should be kept in mind that this flexibility is rather limited for typically informationally opaque SMEs. On the aggregate level there is evidence that in some Euro area countries corporations have replaced bank loans with market-based funding instruments such as equity and debt securities, trade credit as well as intra-sectoral financing between firms (ECB, 2013, p. 21ff.).[23] A strong substitution channel may mitigate the relevance of financial frictions stemming from bank credits. However, to control for substitution effects is demanding as an appropriate model requires a multivariate or instrumental variable set-up in order to control for endogeneity issues.

[23] See also Casey and O'Toole (2013) for empirical evidence on the use of alternative sources of finance by European SMEs during the financial crisis.

Lastly one should mention the potential repercussions of the recent financial crisis on the estimation results. It might be the case that the relationships between the variables have changed as a result of deeper structural changes due to the GFC. In this article we have dealt with this issue by including a simple shift dummy which accounts for possible changes in the conditional mean of the accumulation rate, as well as an interaction term between the shift dummy and the (log) number of workers. The latter regressor controls for differences in the repercussions of the GFC depending on firm size. This may be justified for two reasons: First, the article is about the relationship between realized firm investment, cash flow and balance sheet aspects. Thus, the GFC, captured in the data, may even provide information on rare events which helps us to identify specific regimes. Second, as the time span covered is rather small, it is difficult to detect parameter changes due to breaks over time using the econometric model applied. Nevertheless, the question of how the GFC might have impacted on the relationships between investment, cash flow and balance sheet measures is definitely of importance but should be addressed in another paper using a longer time span.

2.5 Policy Implications and Summary

This article has shown that a firm's financial situation matters. In particular, it has linked firms' balance-sheet positions to fixed capital accumulation. The paper contributes to the literature on financial investment constraints which has gained renewed interest during the recent financial crisis (IMF, 2015). The results from the estimation of investment functions reveal a significant and positive effect of cash flow on fixed-investment. This confirms major previous findings in the literature. Additionally, there is evidence that the cash-flow-investment nexus is regime-dependent as the marginal effect of cash flow on capital accumulation is lower for financially solid firms in comparison to fragile ones. The differences in the magnitude are substantial for some specifications. Neglecting those nonlinearities results in biased coefficient estimates and underrates the relevance of financial constraints firms face.

In contrast to standard contentions, we find only limited evidence that firm size is a relevant variable to discriminate between financially constrained and unconstrained companies. It is argued that balance sheet indicators are more appropriate to separate firms accordingly. The only exception are micro firms for which the probability to fall into a financial constrained regime is found being higher in comparison to other size classes. During the recent financial crisis period, a considerable share of micro firms switched from a solid financial state to a fragile one. This suggests that micro firms were hit hardest by the recent downturn. Our results clearly stress that a symmetric macro-wide shock such as the recent financial crisis may have asymmetric repercussions across heterogeneous firms.

Our findings help to explain the persistence of low investment growth in Germany over the past decade. There is direct evidence that stresses the role of financial frictions in restricting the availability of credit to firms (Hall, 2011; Stock and Watson, 2012). This channel may also explain the long-lasting weak labor market development in Germany at the beginning of the 2000s, as restricted access to credit may result in persistent insufficient aggregate demand and forces firms to purge excess labor. Chodorow-Reich (2013) has recently studied the link between the health of a firm's lenders and a firm's employment outcomes, and finds an economically important relationship.

As statistical numbers indicate, German firms were on average less indebted (according to standard balance-sheet measures) compared to firms e.g. in Italy, Spain, Greece or Portugal before the GFC. Thus, the share of firms falling into the financially fragile regime is rather low in Germany. However, this may be different for economies in the periphery, and helps to explain why the "deleveraging-aggregate demand" channel recently emphasized by Mian and Sufi (2010) is less prevalent in Germany in comparison to other crisis countries. As firms and households face high debt burdens and restricted access to external finance, they are forced to de-leverage which has severe negative repercussions on aggregate demand (Biggs et al., 2009; Keen, 2010; Eggertsson and Krugman, 2012; Mian et al., 2013). These links also help to point out why the downturn accelerated in 2008 much stronger in these southern European economies in comparison to Germany. Furthermore, it also provides an explanation of why the negative economic repercussions of the GFC were rather limited in Germany in the period after 2008.

Finally, the finding that the financial regime a firm operates in does not depend on firm size may highlight the working of relationship-banking in Germany. The literature suggests that relationship-banking still plays a prominent role in Germany (Memmel et al., 2008). SMEs typically hold long-term relationships with a single or a small number of banks which are mostly public non-profit maximizing institutions. Relationship-lending can be a meaningful institutional device to mitigate the impact of unforeseen events and/or asymmetric information problems on credit lending (Gobbi and Sette, 2012). A bank-based system with widespread relationship-banking characteristics may explain, why for German SMEs the degree of financial constraintness in terms of access to external funds is rather low over the business cycle. Unfortunately, data constraints limit further investigation on this issue but future research should put a focus on whether relationship-banking aspects help to resolve the weak correlation between firm size and the degree of financial frictions in Germany.

The implications for economic policy can be briefly summarized as follows: Stimulating aggregate demand may foster firm-level investments, but is most likely not sufficient. According to the results, corporate indebtedness impedes investment, and thus economic policy must find instruments to deal with excessive debt and non-performing loans. Furthermore, policies should be aimed at improving the access to capital at lower costs.

Chapter 3

A Microfounded Model of Money Demand Under Uncertainty, and its Empirical Validation Using Cointegration and Rolling-Window Dynamic Multiplier Analysis.

This chapter is based on Größl and Tarassow (2015).

3.1 Introduction

The rise of monetarism and New Classical Economics in the 1970s and 1980s fueled an ongoing debate about the stability of money demand and its prominent role for the effectiveness of monetary policy (Barnett et al., 1992). In the course of the 1990s the attention shifted away from money as a guide for monetary policy to interest rates. However, in the aftermath of the financial crisis, interest in private actors' liquidity preference has regained academic interest. One line of argument points to quantitative easing policies exercised by central banks leading to growth rates of money which are seen as incompatible with real growth rates thus raising concerns about future inflation. A second line of argument emphasizes the risk of protracted periods of secular stagnation for the world economy (Eggertsson and Mehrotra, 2014) with a high preference for liquidity as a major cause (Bossone, 2014). Both concerns suggest that theoretical as well as empirical research on the determinants of money demand should be resumed. However, different from the debate of the 1970s and 1980s which had a focus on the issue of a stable relationship between money demand and income, now fears of future inflation due to excessive monetary growth directs the attention to whether and how expected inflation as well as its volatility affect money holdings in the non-bank sector. A negative correlation between both variables and money demand implies that the non-bank sector wants to rid itself from high money holdings thus boosting purchases of goods and assets, and accompanied with that, prices. On the other hand, worries about secular stagnation also advocate an interest in how risks might affect actors' liquidity preference. The most prominent fear in this regard is that people do not believe in inflation but are instead afraid of lasting deflationary forces. In this case, a negative correlation between desired money holdings and expected inflation, too, would aggravate the situation whereas a negative correlation between deflationary risks and money demand could act as a stabilizer. Finally, as a consequence of recent financial regulations, central banks will play a more active role in the process of financial supervision. This extension of authority has not gone uncriticized for reasons which point to a possible conflict of interest between financial and price stability. In this respect the demand for money, too, gains importance, where this time reactions to higher financial risk as compared to inflationary risk gain importance. All these arguments suggest that forecasts of monetary demand will play a pivotal role for both the assessment of the future macroeconomic development as well as for the effectiveness of monetary policy.

There is indeed an increasing number of publications examining the impact of diverse risks on money demand. Overwhelmingly, these studies are empirical basing their estimations on either plausibility or on Euler equations. With our paper we aim to contribute to this line of research. In accordance with these last-mentioned studies, we base our estimations on a comprehensive theoretical framework built on intertemporally optimizing households. Contrary to the literature, however, we do not content ourselves with the Euler equations but rather propose a complete solution of the optimization problem taking the intertemporal budget constraint into account. As one main difference between models using the Euler equation as a monetary demand function and our approach, we do not only consider substitution effects but in addition possibly countervailing income effects. As a second difference, in our approach expectations about future income and not only current consumption determine households' money holdings. Finally, we consider different types of liquid assets which bear the major characteristics of money, by taking interest-bearing bank deposits into account. Unlike most empirical applications we estimate both the long-run money demand relationship as well as its short-run dynamics. Additionally, we study the potential time-varying dynamics during the recent financial crisis.

The remainder of the paper is composed of a theoretical and an empirical part. Each part starts with a brief literature review which helps to clarify the commonalities as well as differences of our approach compared to the state of the art. In the theoretical part we develop a macroeconomic model of money demand using an OLG framework distinguishing between a long-run and short-run perspective. Our analysis is partial in the sense that we do not set up a complete macroeconomic model but concentrate on the demand for alternative assets. The empirical part comprises the solid testing on cointegration and the estimation of error-correction models. The model dynamics are studies by means of (recursive) dynamic multiplier analysis.

3.2 Theory

3.2.1 Literature review

The examination of risk variables as components of the money demand function directs the attention to money as a store of value. That non-interest bearing cash holdings serve to protect investors from capital market risk was emphasized by J.M. Keynes and formally elaborated by James Tobin within a static portfolio framework (Tobin, 1956). On the other hand, a reduction of portfolio risk can be achieved by holding interest-bearing assets provided that they are considered as riskless (Ingersoll, 1987). And indeed, due to numerous financial innovations the supply of interest-bearing assets promising their holders safety, has increased over the years. Hence a further argument is needed to legitimate cash as a store-of-value. In this respect cash as immediate liquidity gained importance, which came to be incorporated into microeconomic models of optimizing behavior either by assigning direct utility to money (based on Patinkin (1965)) or by assuming transaction costs of transforming assets into immediate liquidity (Saving, 1971; McCallum and Goodfriend, 1987). That both approaches are equivalent in terms of their results for optimal cash holdings, was shown for example by Feenstra (1986). Overwhelmingly, in these approaches money is defined as cash thus legitimating its status as immediate liquidity. However, taking into account that due to improved payment technologies, costs of liquidating a broad range of assets have been reduced to a rather negligible quantity, central banks nowadays resort to broad aggregates of money as indicators of the effectiveness of their policies as well as of macroeconomic liquidity preferences. Arguably, this, too, has not gone criticized for reasons which doubt that the components of either monetary aggregate should be considered as perfect substitutes (Barnett et al. (1992) for a review). On the other hand, already the existence of just a few distinct monetary aggregates acknowledges that private actors hold different types of riskless assets reaching from cash to interest-bearing deposits simultaneously, which requires explanation. Macroeconomic theory so far has not taken up this issue (with an exception of Bossone, 2014).

In DSGE models which have come to serve as the workhorse model for monetary policy, cash yields direct utility thus legitimating positive cash holdings even in the presence of a riskless but interest-bearing security of indeterminate maturity. Since this class of models generally exclude the derivation of explicit solutions, log-linearization around the steady state is chosen, which leads to percentage deviations of optimal cash holdings as a function of both deviations of current consumption from steady state values and the riskless nominal rate of interest (Walsh, 2003, as one example). Moreover, due to the application of a Taylor expansion of first order, risk variables are excluded from the analysis.

It is finally worth noting at this point that typically intertemporal macroeconomic models do not offer complete solutions for household optimization problems taking the intertemporal budget constraint into account, but derive all types of behavioral functions directly from the Euler equations. This implies that the relationship between money demand and its explanatory variables reflects substitution effects thus telling only half of the story. This procedure is also followed in Choi and Oh (2003), who derive a money demand function from a general equilibrium model focusing on the impact of output as well as monetary uncertainty which has its origins in information deficiencies concerning the money supply process. By assuming that both output and the supply of money are log-normally distributed, they are able to consider risk by including variances and covariances as components of optimal cash holdings. Furthermore they do not need to resort to log-linearization procedures around some equilibrium in order to derive explicit optimality conditions. Money demand here, too, depends on current consumption but furthermore both output shock variances and monetary shock variances play a role though the direction of impact is ambiguous. The authors explain this ambiguity by the coincidence of a substitution and precautionary effect. For example higher monetary uncertainty motivates households to reduce money balances (substitution effect). On the other hand, the authors argue that higher uncertainty as such also motivates higher savings. This last argument is true but its formal derivation requires a complete solution of the household's optimization problem thus resorting to the intertemporal budget constraint. Such a complete solution is missing in the paper and for that reason any ambiguous reaction of money demand to higher monetary uncertainty calls for a different explanation. Rather, the two countervailing effects point to the assumed utility function which departs from the commonly assumed (weak) separability of consumption and money but sees them as complements. Hence if consumption increases due to higher monetary uncertainty, this raises the marginal utility of money thus suggesting higher money holdings, too. Bossone (2014) departs from the standard general equilibrium macroeconomic model by explicitly considering different degrees of liquidity as a distinguishing feature of assets leading to different utilities assigned to them. Of relevance for his results are interactions between rational expectations and market sentiments. Pessimistic market sentiments may be such that households' preferences are directed towards "ultra liquid" assets thus raising money at the expense of expenditures on consumption goods.

3.2.2 The theoretical model

We analyze the role of money holdings in an OLG setting. The economy is inhabited by a young and an old generation. Combined with the assumption of finite life, this allows us to avoid problems following from an infinite series of future incomes when integrating the intertemporal budget constraint into the derivation of a complete solution of the household optimization problem. The young generation lives two periods and plans its optimal time path of consumption when young. The old generation finances consumption by the liquidation of accumulated wealth. It dies at the end of the second period without leaving any bequests. The macroeconomic framework models a stationary economy with uncertainty concerning the real rate of return of assets. We depart from the standard DSGE model by assuming that each young household maximizes the certainty equivalent. This enables us to give capital market risk as well as inflationary risk an explicit representation, even after we have linearized around the steady state.

Since we will compute an explicit formulation for the money demand function by using linearization techniques around the steady state, we start with a characterization of the long-run equilibrium and its consequences for optimal money holdings as well as optimal consumption and asset holdings.

3.2.2.1 Money demand in the long-run

Household sector In each period a young generation is born. For simplicity we normalize the size of the cohort to one. When young, the household maximizes its lifetime welfare, where we take the underlying utility functions to be of the CRRA type. Utility is derived from consumption when young and old as well as from holding money when young. In this respect we distinguish between interest-bearing time-deposits and non-interest-bearing cash holdings. Both types of money yield direct utility though at a different degree, depending on their different liquidity services.

Welfare maximization is subject to period budget constraints. We assume that the young household receives an exogenous labor income when young and has to pay a lump-sum tax. Net income is used to consume and to save for the old age when consumption has to be exclusively financed out of accumulated wealth. There are no bequests and hence the young household's initial wealth is zero. The household can use its savings for the accumulation of interest-bearing and interest-free cash holdings as well as for the purchase of an interest-bearing asset which serves to finance the given capital stock in the economy. By buying this asset the household acquires ownership rights in firms. When old the household liquidates its wealth in order to finance consumption. The old generation has to pay a lump-sum tax, too.

In accordance with the major bulk of macroeconomic DSGE models, we assume that the steady state is characterized by the absence of uncertainty but not necessarily by the absence of inflation. In the absence of uncertainty the young household maximizes the following lifetime welfare function which is assumed to be strictly concave in all its components:

$$U = u\left(C_t^y\right) + \beta u\left(C_{t+1}^o\right) + v\left(\frac{M1_t^{yn}}{P_t}\right) + \gamma\left(\frac{T_t^{yn}}{P_t}\right) \rightarrow \max \tag{3.1}$$

subject to the following period budget constraints:

$$C_t^y + \frac{M1_t^y}{P_t} + \frac{T_t^y}{P_t} + A_t^y = Y_t^y - \Theta_t^y \tag{3.2}$$

$$C_{t+1}^o = A_t^y\left(1 + r_{t+1}\right) + \frac{M1_t^{yn}}{P_t}\frac{P_t}{P_{t+1}} + \frac{T_t^{yn}}{P_t}\frac{P_t}{P_{t+1}}\left(1 + i_{t+1}\right) - \Theta_{t+1}^o \tag{3.3}$$

where $M1_t^{yn}$ ($M1_t^y$)denotes nominal (real) interest-free money holdings and T_t^{yn} (T_t^y) nominal (real) time deposits, Y_t^y denotes real (labor) income accruing to the young household, C_t^y $\left(C_{t+1}^o\right)$ denotes real consumption by the young (old) household, Θ_t^y $\left(\Theta_{t+1}^o\right)$ real lump-sum taxes paid by the young and old generation, respectively, β denotes the subjective discount factor and A_t^y the real value of shares which is related to the capital stock K_t through the real share price (average Tobin's q):

$$A_t^y = K_t^y \frac{P_{kt}}{P_t} \equiv K_t^y q_t \tag{3.4}$$

$q = \frac{P_k}{P}$ represents the relative price of the capital stock which is constant over time if shares offer a protection against inflation which we will assume throughout the paper. In the steady state q is always equal to one. However, since we abstract from investment, this will also be true outside the steady state:

$$q_t = 1 \tag{3.5}$$

In order to facilitate computations outside the steady state, we use the following approximation:

$$\frac{P_t}{P_{t+1}} \approx 1 - \pi_{t+1} \tag{3.6}$$

with π representing the rate of inflation. In doing so we assume that π^2 is close to zero.

Summarizing equations (3.2) and (3.3), we obtain the intertemporal budget constraint:

$$C_t^y + \frac{C_{t+1}^o}{1+r_{t+1}} = Y_t^y - M1_t^y\left(r_{t+1}+\pi_{t+1}\right) - T_t^y\left(r_{t+1}+\pi_{t+1}-i_{t+1}\right) - \Theta_t^y - \frac{\Theta_{t+1}^o}{1+r_{t+1}} \tag{3.7}$$

Note that $M1_t^y$ and T_t^y represent real values. In what follows we will treat real money holdings as the household's control variable. In order to obtain the optimality conditions, we maximize the Lagrangian:

$$\begin{aligned}\mathfrak{L} \;=\; & u\left(C_t^y\right) + \beta u\left(C_{t+1}^o\right) + v\left(M1_t^y\right) + \gamma\left(T_t^y\right) - \\ & \lambda\left[C_t^y + \frac{C_{t+1}^o}{1+r_{t+1}} - \left(Y_t^y - M1_t^y\frac{\left(r_{t+1}+\pi_{t+1}\right)}{1+r_{t+1}} - T_t^y\frac{\left(r_{t+1}+\pi_{t+1}-i_{t+1}\right)}{1+r_{t+1}} - \Theta_t^y - \frac{\Theta_{t+1}^o}{1+r_{t+1}}\right)\right]\end{aligned} \tag{3.8}$$

As first-order conditions we get:

$$u'\left(C_t^y\right) = \lambda \tag{3.9}$$

$$\beta u'\left(C_{t+1}^o\right) = \frac{\lambda}{1+r_{t+1}} \tag{3.10}$$

$$v'\left(M1_t^y\right) = \lambda\left(\frac{r_{t+1}+\pi_{t+1}}{1+r_{t+1}}\right) \tag{3.11}$$

$$\gamma'\left(T_t^y\right) = \lambda\left(\frac{r_{t+1}+\pi_{t+1}-i_{t+1}}{1+r_{t+1}}\right) \tag{3.12}$$

As is well known the optimal ratio of present and future consumption is determined by the ratio between the rate of the time preference and the real interest rate according to equation (3.13):

$$u'\left(C_t^y\right) = \beta\left(1 + r_{t+1}\right) u'\left(C_{t+1}^o\right) \tag{3.13}$$

Note that in the overlapping generation case the steady state does not require the identity of the real interest rate and the rate of time preference of the young generation.

As the optimal ratio between interest-free money holdings and current consumption we obtain:

$$v'\left(M1_t^y\right) = u'\left(C_t^y\right)\left(\frac{r_{t+1} + \pi_{t+1}}{1 + r_{t+1}}\right) \tag{3.14}$$

In order to interpret this optimality condition, assume that the household increases $M1_t^y$ by somewhat. This reduces the amount that alternatively can be channeled into capital, which also implies that the amount of capital interest income foregone goes down thus reducing the opportunity cost of current consumption and rendering higher money holdings less disadvantageous. This explains why an increase of the gross real interest rate on capital, $(1 + r)$ increases the optimal ratio of interest-free money holdings and current consumption. On the other hand $M1$ does not yield interest, rather a positive rate of inflation reduces the purchasing power of a given nominal amount. In addition, a higher amount of interest-free cash holdings leads to real opportunity cost explained by a lower amount of capital which the household is able to purchase. The expression $\frac{r_{t+1}+\pi_{t+1}}{1+r_{t+1}}$ represents total opportunity cost of interest-free money holdings.

The optimal ratio between time deposits and current consumption

$$\gamma'\left(T_t^y\right) = u'\left(C_t^y\right)\left(\frac{r_{t+1} + \pi_{t+1} - i_{t+1}}{1 + r_{t+1}}\right) \tag{3.15}$$

can be explained in a likewise manner with the difference that time deposits yield a nominal interest rate which reduces its opportunity cost correspondingly.

(3.14) and (3.15) taken together, informs us about the optimal ratio between interest-free and interest-bearing money holdings:

$$v'\left(M1_t^y\right) = \gamma'\left(T_t^y\right)\left(\frac{r_{t+1} + \pi_{t+1}}{r_{t+1} + \pi_{t+1} - i_{t+1}}\right) \tag{3.16}$$

Note that in the presence of a direct utility of time deposits, the real interest rate on capital and time deposits are allowed to deviate in the steady state. We observe the following: in the presence of a positive interest rate on time deposits, the household is only willing to hold interest-free money if its marginal utility exceeds that of time deposits. Hence for the following we will always assume that $v'\left(M1_t^y\right) > \gamma'\left(T_t^y\right)$ for all amounts of $M1_t^y, T_t^y$.

A complete solution of the household's optimization problem requires the assumption of an explicit form of the utility function. For illustrative purposes we take household utility to be logarithmic:

$$U = \log C_t^y + \beta \log C_{t+1}^o + \zeta \log M_t^y + \kappa \log T_t^y \rightarrow \max \tag{3.17}$$

where $\zeta > 0$ $(\kappa > 0)$ can be interpreted as a relative weight of interest-free (interest-bearing) money holdings hence $\zeta\,(\kappa) \in (0, 1)$.

Solving the optimality problem by using (3.17) yields as the optimal ratio between current and future consumption:

$$C_{t+1}^o = \beta\,(1 + r_{t+1})\,C_t^y \tag{3.18}$$

and between money holdings and current consumption:

$$M1_t^y = \zeta \left(\frac{1 + r_{t+1}}{r_{t+1} + \pi_{t+1}} \right) C_t^y \tag{3.19}$$

$$T_t^y = \kappa \left(\frac{1 + r_{t+1}}{r_{t+1} + \pi_{t+1 - }i_{t+1}} \right) C_t^y \tag{3.20}$$

Substituting (3.18), (3.19) and (3.20) into the intertemporal budget constraint, delivers the following optimal amounts of consumption (present and future), interest-free money holdings as well as interest-bearing money holdings:

$$C_t^y = \frac{Y_t^y - \Theta_t^y - \frac{\Theta_{t+1}^o}{1+r_{t+1}}}{1 + \beta + \zeta + \kappa} \tag{3.21}$$

$$C_{t+1}^o = \beta\,(1 + r_{t+1}) \left(\frac{Y_t^y - \Theta_t^y - \frac{\Theta_{t+1}^o}{1+r_{t+1}}}{1 + \beta + \zeta + \kappa} \right) \tag{3.22}$$

$$M1_t^y = \zeta \left(\frac{1 + r_{t+1}}{r_{t+1} + \pi_{t+1}} \right) \left(\frac{Y_t^y - \Theta_t^y - \frac{\Theta_{t+1}^o}{1+r_{t+1}}}{1 + \beta + \zeta + \kappa} \right) \tag{3.23}$$

$$T_t^y = \kappa \left(\frac{1 + r_{t+1}}{r_{t+1} + \pi_{t+1 - }i_{t+1}} \right) \left(\frac{Y_t^y - \Theta_t^y - \frac{\Theta_{t+1}^o}{1+r_{t+1}}}{1 + \beta + \zeta + \kappa} \right) \tag{3.24}$$

We observe that under the assumption of logarithmic utility neither present nor future consumption respond to variations of the interest rate on time deposits. The same applies to interest-free money holdings. In contrast time deposits are positively correlated with their "own" interest rate. Time deposits and interest-free money holdings are negatively correlated with the real interest rate on capital.

Production sector We choose a rudimentary framework for production. In particular, we assume that in the long-run production is at its full-employment level and constant over time. The technology is characterized by a Cobb Douglas production function with constant returns to scale:

$$Y_t = K_t^{\zeta} N_t^{1-\zeta} \tag{3.25}$$

Assuming furthermore that the input of labor is exogenous, too, the capital stock has to adjust appropriately. In order to realize this, firms offer shares to young households amounting to

$$K_t = Y_t^{(1/\zeta)} N_t^{(\zeta/(1-\zeta))} \tag{3.26}$$

The public sector and the banking sector The banking sector in our model is rudimentary, too. First, we do not distinguish between commercial banks and the central bank. Second, the central bank and the government are consolidated into a homogeneous sector being responsible for price stability.

The government finances a deficit by increasing its supply of narrow money and by offering time deposits to young households. The government budget constraint hence is defined as:

$$G_t + T_{t-1}^y (1 + i_t - \pi_t) + M1_{t-1}^y (1 - \pi_t) - \Theta_t^y - \Theta_t^o = M1_t^s + T_t^s \tag{3.27}$$

3.2.2.2 Long-run macroeconomic equilibrium

In a long-run macroeconomic equilibrium all components of real wealth as well as all rates of return on assets and the rate of inflation remain constant over time. This stationary economy is represented by a simultaneous equilibrium in the following four markets: aggregate commodity market, capital market, the market for time deposits and the market for cash. Capital market equilibrium requires that young households wish to hold the amount of capital which is necessary to realize the exogenous amount of production. This implies the assumption that old households sell their capital stock directly to firms which in their turn finance these transactions by selling capital to young households. Due to Walras' law one of the four market is redundant which we have chosen to be the aggregate commodity market. Equilibrium in the markets for capital, time deposits as well as for cash then serve to determine the real rate of return on capital, the real interest rate on time deposits as well as the rate of inflation.

Capital market equilibrium is characterized by the equality of capital desired by young households and by the amount of capital which is necessary to realize the full employment output level:

$$K_t = K_t^y \tag{3.28}$$

where the supply of capital is given by equation (3.26) and the demand for capital follows from the households' first period budget constraint taking the optimality conditions for time deposits and cash into account. The remaining markets concern the supply and demand for money. The old generation liquidates its time deposits and runs down cash balances in order to finance consumption. Note that we deviate from cash-in-advance-approaches by focusing on the store-of-value function which implies that transactions by the old generation do not show up on the supply side. Hence the supply side of both time deposits and cash is exclusively represented by decisions made in the consolidated government-banking sector. If the government wants to realize a specific desired (constant) rate of inflation, it can always do so by fixing the supply of time deposits and cash appropriately. In this case, either government expenditures and/or taxes will have to be adjusted in order to meet the budget constraint. We assume that this is the case. Equilibrium in the market for time deposits and cash then reads as:

$$T_t^s = T_t^y \tag{3.29}$$

$$M1_t^s = M_t^y \tag{3.30}$$

3.2.2.3 Household optimization outside the steady state

Outside the steady state the young representative household plans under uncertainty about the future real rate of return on capital and the future rate of inflation Maximizing welfare now requires that the household builds expectations and evaluates possible expectation errors. In the standard intertemporal macro-model this is commonly modeled by a Bernoulli utility function according to which a risk-averse agent maximizes the expected utility of uncertain consumption instead of the utility of expected consumption. However, maximizing expected utility typically does not lead to explicit or linear optimal solutions. The usually applied linearization procedure rests on the application of a Taylor series of first order to the optimality conditions, which has the drawback that risk parameters drop out. One way to include risk parameters into the optimality conditions would be to use a second-order Taylor approximation. Assuming all random variables to be distributed normally, this would give a complete description of risk. A less challenging approach in this case, which we have decided to follow, consists of approximating expecting utility directly by a second-order Taylor series thus achieving the certainty equivalent (Groessl and Fritsche, 2007). Using CRRA utility functions then still does not provide us with explicit solutions for optimal consumption, asset and money holdings. However, now using a Tylor approximation of first order around their steady state values allows us to give risk parameters an explicit representation.

Optimization The young household then maximizes the following objective function:

$$U = u\left(C_t^y\right) + \beta u\left(CE_{t+1}\right) + v\left(\frac{M_t^{ny}}{P_t}\right) + \gamma\left(\frac{T_t^{ny}}{P_t}\right) \rightarrow \max \tag{3.31}$$

where CE_{t+1} denotes the certainty equivalent. As already mentioned, the certainty equivalent is based on the assumption that both the real rate of return on capital and the rate of inflation are normally distributed. It then combines expected consumption with its variance, where the link is established by the Arrow Pratt measure of absolute risk aversion. In the case of CRRA utility the absolute measure of risk aversion is not a constant but rather correlates negatively with expected consumption meaning that the household becomes less risk-averse if its expected consumption goes up. The certainty equivalent is thus given by

$$CE_{t+1} = E_t C_{t+1}^o - \frac{\alpha}{2E_t C_{t+1}^o} Var\left[C_{t+1}^o\right] \tag{3.32}$$

where α stands for the relative degree of risk aversion which is constant for CRRA utility functions, and $E_t C_{t+1}^o$ represents expected household consumption when old with $Var\left[C_{t+1}^o\right]$ as its variance.

The young household maximizes its lifetime welfare (3.31) subject to the period budget constraints. For the first period budget constraint we obtain:

$$A_t^y + \frac{T_t^{ny}}{P_t} + \frac{M_t^{ny}}{P_t} + C_t^y = Y_t^y - \Theta_t^y \tag{3.33}$$

$$A_t^y = K_t \frac{P_{kt}}{P_t} \equiv K_t q_t \tag{3.34}$$

Outside the steady state, too, we will not take investment activities into account implying

$$q_t = 1 \tag{3.35}$$

Uncertainty prevails both with respect to future inflation as well as with respect to the future level of the real rate of return on capital. This implies for expected consumption when old:

$$E_t C_{t+1}^o = M1_t^y\left(1 - E_t \pi_{t+1}\right) + T_t^y\left(1 + i_{t+1} - E_t \pi_{t+1}\right) + K_t^y\left(1 + E_t r_{t+1}\right) - \Theta_{t+1}^o \tag{3.36}$$

where $E_t r_{t+1}$ represents the expected real interest rate on capital and i_{t+1} the safe nominal interest rate on time deposits. In order to facilitate the algebra, we have again approximated the term $\frac{P_t}{E_t P_{t+1}} = \frac{1}{1+E_t \pi_{t+1}}$ by $1 - E_t \pi_{t+1}$ implying that $(E_t \pi_{t+1})^2$ is assumed to be a negligible quantity. We continue to assume that the household takes *real* and not nominal money holdings as its decision variable, which implies that we can substitute $\frac{M1_t^{ny}}{P_t} \left(\frac{T_t^{ny}}{P_t}\right)$ by $M1_t^y \left(T_t^y\right)$ in the utility function. Substituting (3.32), (3.33) and (3.34) and (3.35) into (3.36), we obtain

$$\begin{aligned} E_t C_{t+1}^o &= \left(Y_t^y - C_t^y - \Theta_t^y\right)\left(1 + E_t r_{t+1}\right) - M1_t^y \left(E_t r_{t+1} + E_t \pi_{t+1}\right) \\ &\quad -T_t^y \left(E_t r_{t+1} + E_t \pi_{t+1} - i_t\right) - \Theta_{t+1}^o \end{aligned} \tag{3.37}$$

The variance of old age consumption is then given by

$$\begin{aligned} Var\left[C_{t+1}^o\right] &= E\left[\left(C_{t+1}^o - E_t C_{t+1}^o\right)^2\right] \\ &= \left(Y_t^y - C_t^y - M1_t^y - T_t^y - \Theta_t^y\right)^2 \sigma_{r_t}^2 + \left(M1_t^y + T_t^y\right)^2 \sigma_{\pi_t}^2 \\ &\quad -2\left(Y_t^y - C_t^y - M1_t^y - T_t^y - \Theta_t^y\right)\left(M1_t^y + T_t^y\right)\sigma_{r\pi_t} \end{aligned} \tag{3.38}$$

where

$$\sigma_{r_t}^2 \equiv Var\left[r_{t+1}\right] = E\left[\left(r_{t+1} - E_t r_{t+1}\right)^2\right] \tag{3.39}$$

$$\sigma_{\pi_t}^2 \equiv Var\left[\pi_{t+1}\right] = E\left[\left(\pi_{t+1} - E_t \pi_{t+1}\right)^2\right] \tag{3.40}$$

$$\sigma_{r\pi_t} \equiv Cov\left[r_{t+1}, \pi_{t+1}\right] = E\left[\left(r_{t+1} - E_t r_{t+1}\right)\left(\pi_{t+1} - E_t \pi_{t+1}\right)\right] \tag{3.41}$$

We observe that an increase of consumption risk lowers household utility. The degree to which this happens depends on the size of the measure of absolute risk aversion. Given CRRA this is in turn negatively correlated with the expected level of old age consumption.

To simplify notations we define broad money

$$M2 \equiv M1 + T \tag{3.42}$$

In order to derive optimality conditions we form the Lagrangian:

$$\begin{aligned} \mathfrak{L} &= u\left(C_t^y\right) + \beta u\left(CE_{t+1}\right) + v\left(M_t^y\right) + \gamma\left(T_t^y\right) + \\ &\quad \lambda[E_t C_{t+1}^o - \left(Y_t^y - C_t^y - \Theta_t^y\right)\left(1 + E_t r_{t+1}\right) + M1_t^y \left(E_t r_{t+1} + E_t \pi_{t+1}\right) \\ &\quad +T_t^y \left(E_t r_{t+1} + E_t \pi_{t+1} - i_{t+1}\right)] \end{aligned} \tag{3.43}$$

where CE_{t+1} is given by

$$\begin{aligned} CE_{t+1} &= E_t C^o_{t+1} \\ &- \frac{\alpha}{2E_t C^o_{t+1}} \left[\begin{array}{c} \left(Y^y_t - C^y_t - M1^y_t - T^y_t - \Theta^y_t\right)^2 \sigma^2_{r_t} + \left(M2^y_t\right)^2 \sigma^2_{\pi_t} - \\ 2\left(Y^y_t - C^y_t - M1^y_t - T^y_t - \Theta^y_t\right)\left(M2^y_t\right)\sigma_{r_t\pi_t} \end{array} \right] \end{aligned} \tag{3.44}$$

Computing the first derivative of the Lagrangian (3.43) with respect to current consumption we get:

$$\frac{\partial \mathfrak{L}}{\partial C^y_t} = U'\left(C^y_t\right) + \beta U'\left(CE_{t+1}\right) \frac{\alpha}{E_t C^0_{t+1}} \left[K^y_t \sigma^2_{r_t} - M2^y_t \sigma_{\pi_t r_t}\right] - \lambda\left(1 + E_t r_{t+1}\right) = 0 \tag{3.45}$$

where

$$K^y_t = Y^y_t - \Theta^y_t - C^y_t - M2^y_t \tag{3.46}$$

We observe that the optimal size of present consumption does not only depend on its immediate utility and the opportunity cost measured by $\lambda\left(1 + E_t r_{t+1}\right)$ but is also determined by future consumption risk. If the household decides to spend more on current consumption out of a given income this implies lower purchases of capital and hence lower capital market risk. For the same reason it affects the impact of the covariance between cash holdings and equity. The covariance between r and π expresses how positive (negative) deviations of the real rate of return on capital and the rate of inflation from their averages are correlated. If both rates are positively correlated, this is equivalent to a negative correlation between the real interest rate on capital and the real rate of return on cash holdings. Such a negative correlation reduces consumption risk. In our writing this is the meaning of $\sigma_{\pi r} > 0.$. The opposite is true for a negative correlation between r and π.

The first derivative of the Lagrangian with respect to expected future old age consumption delivers:

$$\frac{\partial \mathfrak{L}}{\partial E_t C^o_{t+1}} = \beta U'\left(CE_{t+1}\right) + \beta U'\left(CE_{t+1}\right) \frac{\alpha}{2\left(E_t C^0_{t+1}\right)^2} Var\left[C^o_{t+1}\right] = \lambda \tag{3.47}$$

An increase in future expected consumption increases the certainty equivalent both by increasing the utility of consumption and by lowering the Arrow Pratt measure of absolute risk aversion.

The first derivative of the Lagrangian with respect to $M1_t^y$ leads to:

$$\begin{aligned} \frac{\partial \mathfrak{L}}{\partial M1_t^y} &= \gamma'\left(M1_t^y\right) \\ &\quad + \beta U'\left(CE_{t+1}\right) \frac{\alpha}{E_t C_{t+1}^0} \left[K_t^y \sigma_{r_t}^2 - M2_t^y \sigma_{\pi_t}^2 + \left(K_t^y - M2_t^y\right) \sigma_{\pi_t r_t}\right] \\ &- \lambda\left(E_t r_{t+1} + E_t \pi_{t+1}\right) \\ &= 0 \end{aligned} \tag{3.48}$$

where $M2_t^y = M1_t^y + T_t^y$.

In the optimum, an increase in welfare due to higher cash holdings equals its opportunity cost. An increase in cash holdings leads to higher welfare due to the assumption that cash yields direct utility. Higher cash holdings, however, also have ambiguous effects on the certainty equivalent. On the one hand, a higher level of cash holdings increases inflationary risk. On the other hand, capital risk declines since higher cash holdings lower the accumulation of capital. The impact of the covariance between the real rate of return on capital and inflation does now not only depend on the covariance between the two variables. In addition it plays a role whether the capital stock exceeds money holdings, whether they are equal in size or whether the capital stock is smaller than money holdings. Note that if both have the same size, then the covariance has no impact at all.

The first derivative of the Lagrangian with respect to T_t^y leads to:

$$\begin{aligned} \frac{\partial \mathfrak{L}}{\partial T_t^y} &= \upsilon'\left(T_t^y\right) \\ &+ \beta U'\left(CE_{t+1}\right) \frac{\alpha}{E_t C_{t+1}^0} \left[K_t^y \sigma_{rt}^2 - M2_t^y \sigma_{\pi t}^2 + \left(K_t^y - M2_t^y\right) \sigma_{\pi rt}\right] \\ &- \lambda\left(E_t r_{t+1} + E_t \pi_{t+1} - i_{t+1}\right) \\ &= 0 \end{aligned} \tag{3.49}$$

Higher time deposits have the same effect on future consumption risk as higher cash holdings. However, the opportunity cost of holding time deposits are lower compared to cash holdings.

Combining (3.45) and (3.47), we get an expression for the optimal ratio between current and future consumption:

$$\begin{aligned} &\left[\begin{array}{c} U'\left(C_t^y\right) + \\ \beta U'\left(CE_{t+1}\right) \frac{\alpha}{E_t C_{t+1}^0} \left(K_t^y \sigma_{rt}^2 - M2_t^y \sigma_{\pi rt}^2\right) \end{array}\right] \\ &= \beta U'\left(CE_{t+1}\right)\left(1 + E_t r_{t+1}\right) + \beta U'\left(CE_{t+1}\right) \frac{\alpha\left(1 + E_t r_{t+1}\right)}{\left(2 E_t C_{t+1}^0\right)^2} Var\left[C_{t+1}^o\right] \end{aligned} \tag{3.50}$$

Combining (3.45) and (3.49) delivers the optimal ratio between cash holdings and present consumption:

$$\gamma'\left(M1_t^y\right)+\beta U'\left(CE_{t+1}\right)\frac{\alpha}{E_tC_{t+1}^0}\left[K_t^y\sigma_{rt}^2-M2_t^y\sigma_{\pi t}^2+\left(K_t^y-M2_t^y\right)\sigma_{\pi rt}\right] \tag{3.51}$$
$$=\left(\frac{1+E_t\left(r_{t+1}\right)+E_t\pi_{t+1}}{1+E_t\left(r_{t+1}\right)}\right)\left(U'\left(C_t^y\right)+\beta U'\left(CE_{t+1}\right)\frac{\alpha}{E_tC_{t+1}^0}\left[K_t^y\sigma_{rt}^2-M2_t^y\sigma_{\pi rt}\right]\right)$$

Combining (3.45) and (3.50) delivers the optimal ratio between time deposits and present consumption:

$$v'\left(T_t\right)+\beta U'\left(CE_{t+1}\right)\frac{\alpha}{E_tC_{t+1}^0}\left[\overline{K}^y\sigma_{rt}^2-\overline{M2}^y\sigma_{\pi t}^2+\left(\overline{K}^y-\overline{M2}^y\right)\sigma_{\pi rt}\right] \tag{3.52}$$
$$=\frac{E_tr_{t+1}+E_t\pi_{t+1}-i_{t+1}}{1+E_t\left(r_{t+1}\right)}\left(U'\left(C_t^y\right)+\beta U'\left(CE_{t+1}\right)\frac{\alpha}{E_tC_{t+1}^0}\left[K_t^y\sigma_{rt}^2-M2_t^y\sigma_{\pi rt}\right]\right)$$

Note that these optimal ratios do not only depend on a comparison between rates of return and marginal utilities but also on a comparison between reactions of consumption risk.

Linearization We symbolize percentage deviations of a variable x from its steady state value by $\widehat{x}_t$. Linearizing (3.50) around its steady state value yields:

$$E_t\widehat{c}_{t+1}^o = \widehat{c}_t^y+\frac{E_t\widehat{r}_{t+1}}{\alpha\left(1+\overline{r}\right)}+\left(\frac{\overline{K}^y}{\overline{C}^o}\right)\left[\frac{\left(\frac{\overline{K}^y}{\overline{C}^o}\right)(1+\alpha)(1+\overline{r})-2}{1+\overline{r}}\right]\sigma_{rt}^2 \tag{3.53}$$
$$+\frac{1+\alpha}{1+\overline{r}}\left(\frac{\overline{M2}^y}{\overline{C}^o}\right)^2\sigma_{\pi t}^2-\left(\frac{\overline{M2}^y}{\overline{C}^o}\right)\left[\frac{\left(\frac{\overline{K}^y}{\overline{C}^o}\right)\left(1+\alpha\right)\left(1+\overline{r}\right)-1}{\left(1+\overline{r}_{t+1}\right)}\right]\sigma_{\pi rt}$$

Equation (3.50) describes how deviations of expected future consumption from its steady state value are related to deviations of current consumption from the steady state. An excess of deviations of future expected consumption over current consumption from their steady state values is positively correlated with the real rate of return on capital, but also with inflation risk. Underlying the last effect is the result that due to a higher expected future consumption, the household becomes less risk-averse implying that the marginal disutility of the variance of future consumption goes down. By contrast the impact of capital market risk is ambiguous: On the one hand we observe the same effect as in the case of inflation risk. On the other hand a higher capital market risk, too, increases the marginal utility of present consumption. Which effect dominates, depends on whether $\left(\overline{K}^y\right)\left(1+\alpha\right)\left(1+\overline{r}\right)-2\overline{C}^o \gtreqless 0$. The impact of $\sigma_{\pi rt}>0$ remains ambiguous no. This ambiguity holds irrespective of how the rate of inflation and the real rate of return on capital are correlated.

Linearizing (3.51) around its steady state value leads to:

$$\begin{aligned}\widehat{m1}_t^y &= \frac{\alpha}{\eta}\widehat{c}_t^y - \frac{1-\overline{\pi}}{\eta\left(1+\overline{r}\right)\left(\overline{r}+\overline{\pi}\right)}E_t\widehat{r}_{t+1} - \frac{E_t\widehat{\pi}_{t+1}}{\eta\left(\overline{r}+\overline{\pi}\right)} + \\ &\frac{\alpha}{\eta}\left(\frac{\overline{K}^y}{\overline{C}^o}\right)\left(\frac{1-\overline{\pi}}{\left(1+\overline{r}\right)\left(\overline{r}+\overline{\pi}\right)}\right)\sigma_{rt}^2 - \\ &\frac{\alpha}{\eta}\left(\frac{\overline{M2}^y}{\overline{C}^o}\right)\frac{\sigma_{\pi t}^2}{\left(\overline{r}+\overline{\pi}\right)} + \\ &\frac{\alpha}{\eta}\left[\frac{\left(1+\overline{r}\right)\left(\frac{\overline{K}^y}{\overline{C}^o}\right)+\frac{\overline{M2}^y}{\overline{C}^o}\left(1+\overline{\pi}\right)}{\left(1+\overline{r}\right)\left(\overline{r}+\overline{\pi}\right)}\right]\sigma_{r\pi}\end{aligned} \tag{3.54}$$

where

$$\eta \equiv -\frac{\gamma''\left(M1^y\right)}{\gamma'\left(M1^y\right)}M1^y \tag{3.55}$$

An excess of deviations of the demand for narrow money from the steady state over deviations of current consumption from the steady state is negatively correlated with the real interest rate on capital, the expected rate of inflation and inflation risk. A positive correlation results for capital market risk and a positive covariance $\sigma_{r\pi}$.

Linearizing (3.52) around its steady state value delivers:

$$\begin{aligned}\widehat{t}_t^y &= \frac{\alpha}{\mu}\widehat{c}_t^y - \frac{1-\overline{\pi}}{\eta\left(1+\overline{r}\right)\left(\overline{r}+\overline{\pi}-\overline{i}\right)}E_t\widehat{r}_{t+1} - \frac{E_t\widehat{\pi}_{t+1}}{\mu\left(\overline{r}+\overline{\pi}-\overline{i}\right)} \\ &+\frac{\widehat{i}_{t+1}}{\mu\left(\overline{r}+\overline{\pi}-\overline{i}\right)} + \\ &\frac{\alpha}{\mu}\left(\frac{\overline{K}^y}{\overline{C}^o}\right)\left(\frac{1-\overline{\pi}}{\left(1+\overline{r}\right)\left(\overline{r}+\overline{\pi}+\overline{i}\right)}\right)\sigma_{rt}^2 - \\ &\frac{\alpha}{\mu}\left(\frac{\overline{M2}^y}{\overline{C}^o}\right)\frac{\sigma_{\pi t}^2}{\left(\overline{r}+\overline{\pi}-\overline{i}\right)} + \\ &\frac{\alpha}{\mu}\left[\frac{\left(1+\overline{r}\right)\left(\frac{\overline{K}^y}{\overline{C}^o}\right)+\frac{\overline{M2}^y}{\overline{C}^o}\left(1+\overline{\pi}\right)}{\left(1+\overline{r}\right)\left(\overline{r}+\overline{\pi}-\overline{i}\right)}\right]\sigma_{\pi rt}\end{aligned} \tag{3.56}$$

and

$$\mu \equiv -\frac{\gamma''\left(T^y\right)}{\gamma'\left(T^y\right)}T^y \tag{3.57}$$

$\widehat{t}_t^y$ is positively correlated with its own rate. For the remaining variables we obtain the same results as for cash, at least qualitatively.

In order to obtain a complete solution of the optimization problem, we have to linearize the intertemporal budget constraint around its steady state value. In doing so we assume that lump-sum taxes always retain their steady state value. After linearizing around its steady state value the intertemporal budget constraint reads as follows:

$$\begin{aligned} \overline{C}^o E_t \widehat{c}^o_{t+1} + (1+\overline{r})\,\overline{C}^y \widehat{c}^y_t &= \overline{Y}^y (1+\overline{r})\,\widehat{y}^y_t - (\overline{r}+\overline{\pi})\,\overline{M}1^y \widehat{m}1^y_t - \\ &\quad \left(\overline{r}+\overline{\pi}-\overline{i}\right)\overline{T}^y \widehat{t}^y_t + \Big(\underbrace{\overline{Y}^y - \overline{C}^y - \overline{M}1 - \overline{T}^y}_{\overline{K}^y}\Big) E_t \widehat{r}_{t+1} + \\ &\quad \overline{T}^y \widehat{i}_{t+1} - \Bigg(\underbrace{\overline{T}^y + \overline{M}1}_{\overline{M}2^y}\Bigg) E_t \widehat{\pi}_{t+1} \end{aligned} \tag{3.58}$$

The right-hand side reveals percentage deviations of lifetime resources from their steady state values. Lifetime resources are higher if labor income as well as the expected real interest rate and the nominal interest rate on deposits exceed their long-run equilibrium value. Life time resources are lower if the expected rate of inflation is higher than its steady state value. If for example deviations of the expected real interest rate from the long-run equilibrium increase, this allows to consume more both in the present and in the future.[1] We also recognize that the expected rate of inflation has a stronger effect on present and future consumption than the nominal interest rate on deposits because expected inflation does not only determine the real interest rate on deposits but also the real rate of return on interest-free cash.

We now use the linearized intertemporal budget constraint in order to obtain complete solutions to the household optimization problem. In doing so we start with young age consumption. Given old age consumption and furthermore given the levels of deposits and cash, young age consumption is entirely determined by the behavior of lifetime resources which also implies that changes in the (expected) rates of return on assets and expected inflation affect current consumption exclusively through income effects. This explains why given the assumptions we have just made, current consumption correlates positively with the rates of return on assets and negatively with the expected rate of inflation. However, neither old age consumption nor the size of deposits and cash are given quantities but are endogenously determined by the optimality conditions. For the sake of clarity we proceed in steps and start with a discussion how the optimal ratio of

[1]For the following we suppress the fact that the linearized model represents deviations from the steady state. Note that we do so in order to simplify the argument only. Implicitly our interpretation of results refer to deviations from the steady state.

current and future consumption affects $\widehat{c}_t^y$. Inserting equation (53) into (3.58) yields:

$$\begin{aligned}\left(\overline{C}^o + (1+\overline{r})\,\overline{C}^y\right)\widehat{c}_t^y \;=\;& \overline{Y}^y\,(1+\overline{r})\,\widehat{y}_t^y - \\ & (\overline{r}+\overline{\pi})\,\overline{M}1^y\widehat{m}1_t^y - \left(\overline{r}+\overline{\pi}-\overline{i}\right)\overline{T}^y\widehat{t}_t^y + \\ & \left(\overline{K}^y - \frac{\overline{C}^o}{\alpha\,(1+\overline{r})}\right)E_t\widehat{r}_{t+1} + \\ & \overline{T}^y\widehat{i}_{t+1} - \Big(\underbrace{\overline{T}^y + \overline{M}1^y}_{\overline{M}2^y}\Big)E_t\widehat{\pi}_{t+1} - \\ & \overline{K}^y\left[\frac{\frac{\overline{K}^y}{\overline{C}^o}\,(1+\alpha)\,(1+\overline{r})-2}{(1+\overline{r})}\right]\sigma_{rt}^2 - \\ & \overline{C}^o\left(\frac{\overline{M}2^y}{\overline{C}^o}\right)^2\left(\frac{1+\alpha}{1+\overline{r}}\right)\sigma_{\pi t}^2 + \\ & \overline{M}2^y\left[\frac{\frac{\overline{K}^y}{\overline{C}^o}\,(1+\alpha)\,(1+\overline{r})-1}{(1+\overline{r})}\right]\sigma_{\pi rt}\end{aligned} \qquad (3.59)$$

Obviously now the impact of the expected real interest rate depends on the relative strength of the substitution effect compared to the income effect. Note also that since the optimal ratio of current and future consumption remains unaffected if expected inflation changes, current consumption continues to be unambiguously negatively correlated with $E_t\widehat{\pi}_{t+1}$. Furthermore now risk parameters, too, have to be taken into account. We have seen from equation (47) that a higher level of expected future consumption increases the certainty equivalent by lowering the absolute Arrow Pratt measure of risk aversion. The magnitude of this effect depends positively on the size of consumption risk. This in turn explains why expected future consumption will be expanded at the cost of current consumption if inflationary risk becomes more severe. Since therefore inflationary risk and old age consumption are positively correlated due to the Arrow Pratt measure of absolute risk aversion, a negative correlation with current consumption will follow. Ambiguity prevails with respect to capital market risk. A higher current consumption increases the certainty equivalent through a lower variance of future consumption due to lower savings in the form of capital. On the other hand, a higher level of future consumption increases the certainty equivalent as a consequence of a lower Arrow Pratt measure of risk aversion. Ambiguity, too, holds with respect to $\sigma_{\pi rt}$.

We now extend our analysis by inserting equation (54) into (3.58) thus taking the optimal ratio of current consumption and cash holdings into account as explained by equation

(54). This changes equation (3.59) as follows:

$$
\begin{aligned}
\left(\overline{C}^{o} + (1+\overline{r})\,\overline{C}^{y} + (\overline{r}+\overline{\pi})\,\overline{M1}^{y}\frac{\alpha}{\eta}\right)\widehat{c}_t^{y} \quad = \\
\overline{Y}^{y}(1+\overline{r})\,\widehat{y}_t^{y} - \left(\overline{r}+\overline{\pi}-\overline{i}\right)\overline{T}^{y}\widehat{t}_t^{y} + \\
\left(\overline{K}^{y} - \frac{\overline{C}^{o}}{\alpha(1+\overline{r})} + \frac{(1-\overline{\pi})\,\overline{M1}^{y}}{\eta(1+\overline{r})}\right)E_t\widehat{r}_{t+1} + \overline{T}^{y}\widehat{i}_{t+1} - \\
\left(\underbrace{\overline{T}^{y} + \overline{M1}^{y}}_{\overline{M2}^{y}} - \frac{\overline{M1}^{y}}{\eta}\right)E_t\widehat{\pi}_{t+1} - \\
\left[\overline{K}^{y}\left(\frac{\frac{\overline{K}^{y}}{\overline{C}^{o}}(1+\alpha)(1+\overline{r})-2}{(1+\overline{r})}\right) + \frac{\alpha}{\eta}\left(\frac{\overline{K}^{y}}{\overline{C}^{o}}\right)\frac{\overline{M1}^{y}(1-\overline{\pi})}{(1+\overline{r})}\right]\sigma_{rt}^{2} - \\
\left[\overline{C}^{o}\left(\frac{\overline{M2}^{y}}{\overline{C}^{o}}\right)^{2}\left(\frac{1+\alpha}{1+\overline{r}}\right) - \frac{\alpha}{\eta}\left(\frac{\overline{M2}^{y}}{\overline{C}^{o}}\right)\overline{M1}^{y}\right]\sigma_{\pi t}^{2} + \\
\left[\overline{M2}^{y}\left(\frac{\frac{\overline{K}^{y}}{\overline{C}^{o}}(1+\alpha)(1+\overline{r})-1}{(1+\overline{r})}\right) - \frac{\alpha}{\eta}\overline{M1}^{y}\frac{\left(\frac{\overline{K}^{y}}{\overline{C}^{o}}\right)(1+\overline{r}) + \left(\frac{\overline{M2}^{y}}{\overline{C}^{o}}\right)(1+\overline{\pi})}{(1+\overline{r})}\right]\sigma_{\pi rt}
\end{aligned}
\tag{3.60}
$$

Obviously, the optimal ratio of cash holdings and current consumption strengthens the income effect of changing expected real interest rates on capital because higher real interest rates on capital lower optimal cash holdings compared to current consumption. On the other hand, a higher rate of expected inflation lowers optimal cash holdings in relation to current consumption, and this substitution effect introduces ambiguity into the correlation between current consumption and expected inflation. By contrast, higher capital market risk implies a higher level of cash holdings compared to current consumption. This strengthens a negative correlation between current consumption and capital market risk. A higher inflationary risk lowers optimal cash holdings in relation to current consumption thus introducing ambiguity with respect to the direction of correlation between inflationary risk and current consumption. Ambiguity, too, can still be observed with respect to the covariance of the real interest rate on capital and inflation, where a negative correlation gains strength.

The final step consists of introducing the optimal ratio of deposits and current consumption into (3.60). A complete solution of current consumption can then be represented by

$$\widehat{c}_t^y = \frac{1}{\Sigma}\left(\Psi_1\widehat{y}_t^y + \Psi_2 E_t\widehat{r}_{t+1} + \Psi_3\widehat{i}_{t+1} + \Psi_4 E_t\widehat{\pi}_{t+1} + \Psi_5\sigma_{rt}^2 + \Psi_6\sigma_{\pi t}^2 + \Psi_7\sigma_{\pi rt}\right) \quad (3.61)$$

$$\Sigma = \left(\overline{C}^o + (1+\overline{r})\,\overline{C}^y + (\overline{r}+\overline{\pi})\,\overline{M}1^y\frac{\alpha}{\eta} + \left(\overline{r}+\overline{\pi}-\overline{i}\right)\overline{T}^y\frac{\alpha}{\mu}\right) \quad (3.62)$$

$$\Psi_1 = \overline{Y}^y(1+\overline{r}) > 0 \quad (3.63)$$

$$\Psi_2 = \left(\overline{K}^y - \frac{\overline{C}^o}{\alpha(1+\overline{r})} + \frac{(1-\overline{\pi})\,\overline{M}1^y}{\eta(1+\overline{r})} + \frac{(1-\overline{\pi})\,\overline{T}^y}{\mu(1+\overline{r})}\right) \gtreqless 0 \quad (3.64)$$

$$\Psi_3 = \overline{T}^y - \frac{\overline{T}^y}{\mu} < 0 \text{ if } \mu < 1 \quad (3.65)$$

$$\Psi_4 = \left(-\underbrace{\left(\overline{T}^y + \overline{M}1^y\right)}_{\overline{M}2^y} + \frac{\overline{M}1^y}{\eta} + \frac{\overline{T}^y}{\mu}\right) > 0 \text{ if } \mu < 1, \eta < 1 \quad (3.66)$$

$$\Psi_5 = -\overline{K}^y\left(\frac{\frac{\overline{K}^y}{\overline{C}^o}(1+\alpha)(1+\overline{r}) - 2}{(1+\overline{r})}\right) - \frac{\alpha}{\eta}\left(\frac{\overline{K}^y}{\overline{C}^o}\right)\frac{\overline{M}1^y(1-\overline{\pi})}{(1+\overline{r})} - \quad (3.67)$$
$$\frac{\alpha}{\mu}\left(\frac{\overline{K}^y}{\overline{C}^o}\right)\frac{\overline{T}^y(1-\overline{\pi})}{(1+\overline{r})} \lesseqgtr 0$$

$$\Psi_6 = -\overline{C}^o\left(\frac{\overline{M}2^y}{\overline{C}^o}\right)^2\left(\frac{1+\alpha}{1+\overline{r}}\right) + \frac{\alpha}{\eta}\left(\frac{\overline{M}2^y}{\overline{C}^o}\right)\overline{M}1^y + \frac{\alpha}{\mu}\left(\frac{\overline{M}2^y}{\overline{C}^o}\right)\overline{T}^y \gtreqless 0 \quad (3.68)$$

$$\Psi_7 = \overline{M}2^y\left(\frac{\frac{\overline{K}^y}{\overline{C}^o}(1+\alpha)(1+\overline{r}) - 1}{(1+\overline{r})}\right) - \quad (3.69)$$
$$\frac{\alpha}{\eta}\overline{M}1^y\frac{\left(\frac{\overline{K}^y}{\overline{C}^o}\right)(1+\overline{r}) + \left(\frac{\overline{M}2^y}{\overline{C}^o}\right)(1+\overline{\pi})}{(1+\overline{r})} -$$
$$\frac{\alpha}{\mu}\overline{T}^y\frac{\left(\frac{\overline{K}^y}{\overline{C}^o}\right)(1+\overline{r}) + \left(\frac{\overline{M}2^y}{\overline{C}^o}\right)(1+\overline{\pi})}{(1+\overline{r})}$$

We observe that by integrating the optimal relationship between deposits and current consumption into (3.60), the positive income effect of changing real interest rates on capital for current consumption will be strengthened further. We also note that now a higher rate of expected inflation will lead to a higher level of current consumption, given that μ and η are smaller than one. A negative correlation between current consumption and capital market risk attains a higher probability. Furthermore, a higher level of current consumption due to higher inflationary risk now has an even greater chance. With caution we may furthermore conclude that if the rate of inflation and the real interest rate on capital are positively correlated, then a higher covariance between the two variables will lead to a lower level of current consumption. Finally, we observe that now current consumption and the nominal interest rate on deposits are negatively correlated for $\mu < 1$ and hence the substitution effect dominates.

3.2.3 Implications for money demand

For the following analysis we take cash and deposits together to obtain broad money according to

$$M2_t^y = M1_t^y + T_t^y \tag{3.70}$$

or in percentage deviations from the steady state:

$$\hat{m}2_t^y = \frac{\overline{M}1^y}{\overline{M}2^y}\hat{m}1^y + \frac{\overline{T}^y}{\overline{M}2^y}\hat{t}_t^y \tag{3.71}$$

where $m1_t^y$ and t_t^y are given by equations (54) and (56). Of importance for the following analysis between direct effects (substitution effects) of changing rates of return and risk parameters and indirect effects due to the impact of these same variables on current consumption.

As a straightforward result we obtain that due to its dependence on current consumption, money demand correlates positively with (labor) income according to:

$$\begin{aligned}
\frac{\partial \hat{m}2_t^y}{\partial \hat{y}_t} &= \left(\frac{\alpha}{\eta}\left(\frac{\overline{M}1^y}{\overline{M}2^y}\right) + \left(\frac{\overline{M}1^y}{\overline{M}2^y}\right)\frac{\alpha}{\mu}\right)\frac{\partial \hat{c}_t^y}{\partial \hat{y}_t} \\
&= \left(\frac{\alpha}{\eta}\left(\frac{\overline{M}1^y}{\overline{M}2^y}\right) + \left(\frac{\overline{T}^y}{\overline{M}2^y}\right)\frac{\alpha}{\mu}\right)\frac{\Psi_1}{\Sigma}
\end{aligned}$$

$$\left(\frac{\alpha}{\eta}\left(\frac{\overline{M}1^y}{\overline{M}2^y}\right) + \left(\frac{\overline{T}^y}{\overline{M}2^y}\right)\frac{\alpha}{\mu}\right) \equiv \Delta$$

Taking equations (54) and (55) together, the reaction of broad money to changes of the expected real interest rate on capital is as follows:

$$\begin{aligned}
\frac{\partial \hat{m}2_t^y}{\partial E_t\hat{r}_{t+1}} &= \Delta\frac{\Psi_2}{\Sigma} - \frac{1-\pi}{\eta(1+\overline{r})(\overline{r}+\overline{\pi})}\left(\frac{\overline{M}1^y}{\overline{M}2^y}\right) - \\
&\quad \frac{1-\pi}{\eta(1+\overline{r})(\overline{r}+\overline{\pi}-\overline{i})}\left(\frac{\overline{T}^y}{\overline{M}2^y}\right)
\end{aligned} \tag{3.72}$$

Ambiguity exists because do not know whether current consumption will increase or fall due to a higher expected real interest rate on capital. The interesting point is that the direction of this correlation itself is affected by money demand where in this case only the unambiguous substitution effect is relevant.

An increase in the nominal interest rate on deposits leads to a higher demand for money provided that the impact of consumption on money is smaller than the impact of deposits:

$$\frac{\partial \hat{m}2_t^y}{\partial \hat{i}_{t+1}} = \Delta \frac{\Psi_3}{\Sigma} + \frac{\frac{\overline{T}^y}{\overline{M2}^y}}{\mu(\overline{r} + \overline{\pi} - \overline{i})}$$

A change in expected inflation changes money demand as follows:

$$\frac{\partial \hat{m}2_t^y}{\partial E_t \hat{\pi}_{t+1}} = \Delta \frac{\Psi_4}{\Sigma} - \frac{\frac{\overline{M1}^y}{\overline{M2}^y}}{\eta(\overline{r} + \overline{\pi})} - \frac{\frac{\overline{T}^y}{\overline{M2}^y}}{\mu(\overline{r} + \overline{\pi} - \overline{i})}$$

Since current consumption and expected inflation are positively correlated for $\eta < 1$ and $\mu < 1$, the net effect is again ambiguous.

Turning to capital market risk, we observe that given current consumption, a higher capital market risk leads to a lower level of money demand. Taking into account, however, that we cannot rule out a negative correlation between current consumption and capital market risk, we are again unable to indicate clear effects.

$$\begin{aligned}\frac{\partial \hat{m}2_t^y}{\partial \sigma_{rt}^2} &= \Delta \frac{\Psi_5}{\Sigma} + \frac{\alpha}{\eta}\left(\frac{\overline{M1}^y}{\overline{M2}^y}\right)\left(\frac{\overline{K}^y}{\overline{C}^o}\right)\left(\frac{1-\overline{\pi}}{\eta(1+\overline{r})(\overline{r}+\overline{\pi})}\right) + \\ &\left(\frac{\overline{T}^y}{\overline{M2}^y}\right)\left(\frac{\overline{K}^y}{\overline{C}^o}\right)\left(\frac{1-\overline{\pi}}{\mu(1+\overline{r})(\overline{r}+\overline{\pi}-\overline{i})}\right)\end{aligned}$$

Again we face the situation that the direct effects of higher capital market risk promote a fall in current consumption which in its turn feeds back to a lower level of money demand. Qualitatively, the same applies to effects of inflationary risk:

$$\frac{\partial \hat{m}2_t^y}{\partial \sigma_{\pi t}^2} = \Delta \frac{\Psi_6}{\Sigma} - \frac{\frac{\alpha}{\eta}\frac{\overline{M1}^y}{\overline{M2}^y}\frac{\overline{M2}^y}{\overline{C}^o}}{(\overline{r} + \overline{\pi})} - \frac{\frac{\alpha}{\mu}\frac{\overline{T}^y}{\overline{M2}^y}\frac{\overline{M2}^y}{\overline{C}^o}}{(\overline{r} + \overline{\pi} - \overline{i})}$$

According to the direct effects of higher inflationary risks, money demand goes down. However, these direct effects lead to a higher level of current consumption which again leads to a higher level of money demand. How a correlation between the real interest rate on capital and the rate of inflation affects money demand is explained by the following equation:

$$\begin{aligned}\frac{\partial \hat{m}2_t^y}{\partial \sigma_{r\pi t}^2} &= \Delta \frac{\Psi_7}{\Sigma} + \frac{\alpha}{\eta}\left(\frac{\overline{M1}^y}{\overline{M2}^y}\right)\left[\frac{(1+\overline{r})\left(\frac{\overline{K}^y}{\overline{C}^o}\right) + \left(\frac{\overline{M2}^y}{\overline{C}^o}\right)(1+\overline{\pi})}{(1+\overline{r})(\overline{r}+\overline{\pi})}\right] + \\ &\frac{\alpha}{\mu}\left(\frac{\overline{T}^y}{\overline{M2}^y}\right)\left[\frac{(1+\overline{r})\left(\frac{\overline{K}^y}{\overline{C}^o}\right) + \left(\frac{\overline{M2}^y}{\overline{C}^o}\right)(1+\overline{\pi})}{(1+\overline{r})(\overline{r}+\overline{\pi}-\overline{i})}\right]\end{aligned} \tag{3.73}$$

Given current consumption, money demand is positively correlated with a positive covariance of inflation and the real interest rate on capital. These reaction contributes to a negative correlation of current consumption with a positive covariance $\sigma_{r\pi}$, which again acts as a countervailing effect on money demand. In summary we may say that the dependency of money demand on consumption explains ambiguity in the behavior of money demand. If money demand reacts strongly to changes of consumption, then it becomes possible that for example higher inflationary risks will even increase households' willingness to increase their money holdings.

3.3 The empirical section

3.3.1 Literature review on money demand under capital market and inflation risks

The existing empirical literature on money demand is rich but almost all of these studies formulate *ad hoc* models based on story-telling or plausibility. Given the large number of research articles, we will review only empirical papers explicitly considering economic risks/uncertainty on money demand. Furthermore, solely empirical studies referring to the North American or EMU area will be reviewed.[2]

As uncertainty has a latent nature it can be measured only indirectly. The concrete measure depends on the aspects one wants to evaluate. The focus can be either on the microeconomic or macroeconomic level. In this paper we put the accent on macroeconomic aspects with regard to price inflation risk and capital market risk. Recently, the IMF has emphasized the relevance of uncertainty measures as major macroeconomic stress factors (IMF, 2012, 49). Economic theory suggests that macroeconomic as well as policy uncertainty may affect the economy's demand side through its impact on household consumption or firm investment. Additionally, there are various supply side channels through which economic uncertainty may have repercussions on the economy (Bloom, 2009; Bloom et al., 2013).[3] In this subsection, we will highlight the findings of the existing empirical literature on the relationship between risk factors and money demand behavior on the aggregate.

Carpenter and Lange (2003) estimate a risk-augmented money demand relationship for the U.S. economy. They add a volatility index of the equity market into a standard equilibrium money demand relationship. According to their results a positive change in

[2]For recent and more detailed literature surveys on empirical money demand studies see Belke and Czudaj (2010) as well as Setzer and Wolff (2009). For an overview using Panel data see also Dobnik (2011) and Kumar et al. (2013).

[3]For empirical evaluations see for instance IMF (2012, 49 pp.).

equity risk leads to higher demand for M2 in the long-run. It is argued that risky assets are substituted for safe alternatives such as cash.

Choi and Oh (2003) stress the importance of uncertainty about output and monetary policy for money demand decisions. The authors derive a general equilibrium model showing that output uncertainty and monetary uncertainty, among other explanatory variables, affect U.S. money demand significantly. They apply a bi-variate rolling window VAR model including the growth rates of real GNP and M1 money measure, respectively, to extract the time-varying innovations of both series. As a result, Choi and Oh find that output uncertainty has a negative effect while monetary uncertainty (interpreted as an unexpected shift in monetary policy) positively affects money demand in their sample.

Based on data for the Canadian economy, Atta-Mensah (2004) constructs an economic uncertainty index. The author fits GARCH models to a vector of variables, namely the stock market index, the long-term yield of the bond market, the 90-day commercial paper rate, the US-CAN exchange rate and real GDP in order to compile a single index capturing economic uncertainty which enters the short-term dynamics of an error-correction model. The results indicate that a positive change in economic uncertainty is accompanied by an increase in the demand for M1 but a reduction in M2. Atta-Mensah concludes that increasing economic uncertainty "*...reduces agent's appetites for risky assets (guaranteed investment certificates and money market mutual funds). In addition, uncertainty surrounding the production and supply of goods and services in periods of increased economic uncertainty induces agents to increase their level of money holding for precautionary reasons. Furthermore, in periods of economic uncertainty, real assets, such as houses and precious metals, are more attractive than nominal assets.*" (Atta-Mensah, 2004, 10).

In their study on the Euro area, Bruggeman et al. (2003) examine the effects of stock market volatility on M3 money demand. In a first step, a leverage GARCH model is specified in order to construct a risk series. The estimated (conditional) volatility measure is added to a VECM as a weakly exogenous variable in the second step. However, the authors do not find a significant effect of stock market volatility on money demand. Nevertheless, they admit that this might be due to the selected sample which does not cover pronounced periods of stock market volatility (Bruggeman et al., 2003, 35).

Greiber and Lemke (2005) conduct some research on both the Euro area as well the U.S. economy. Among the standard set of regressors two economic uncertainty measures are estimated in a first step using an unobserved component model consisting of six variables. These variables comprise the correlation between stock and bond returns, a stock market loss measure, a stock market volatility measure, a measure on stock market returns as well as a consumer and industry-sector confidence measure, respectively. For the Euro area, the authors find that a standard money demand relationship augmented by the estimated $I(1)$ uncertainty factor, which is interpreted as a liquidity preference indicator, helps to re-establish a stable cointegrating relationship. Furthermore, the second but stationary factor, mainly reflecting idiosyncratic consumer and industry sentiments, improves the short-run fit of the model substantially. The application of this estimation strategy to the U.S. economy reveals for both monetary aggregates M2M and MZM that the inclusion of uncertainty factors improves the statistical fit of the model.

In an application to the Euro area Carstensen (2006) argues that the observed overshoot of M3 at the end of 2001 can partly be explained by a decline in equity returns as well as increased stock market volatility. The inclusion of these two additional factors re-establishes the standard long-run money demand relationship. The respective stock market volatility measure is estimated by a leverage GARCH model based on daily returns of the nominal stock price index.[4]

The role of inflation uncertainty on money demand was examined by Higgins and Majin (2009) for both M1 and M2 U.S. money measures. In order to quantify latent inflation uncertainty, the authors fit a conventional backward-looking Phillips curve model with GARCH errors to derive the conditional variance of inflation. The authors find that increased inflation uncertainty has negative impacts on the demand for M1 as concerns about higher expected inflation put low-interest bearing assets under stress. This triggers a substitution away from M1 to higher-interest bearing components of M2. Furthermore, M1 includes long-term assets which agents may want to substitute for money market instruments in order to reduce the risk associated with long-term assets. This is confirmed by the results as higher inflation uncertainty is positively correlated with M2 holdings.

De Bondt (2009) studies the effects of equity risk and macroeconomic uncertainty on M3 money demand for the Euro area. The results suggest that equity markets play a significant role for money demand dynamics. The demand for M3 is found to be negatively related to the expected risk-adjusted real rate of equity return. This is in line with previous findings that there exists a substitution effect away from equity markets during turbulent times on these markets. Additionally, the author finds that precautionary motives, stemming from the labor market, also have a significant effect on money demand holding.

The work by Seitz and von Landesberger (2010) is a recent synthesis of previous work done by De Bondt (2009) on the relevance of precautionary motives as well as the studies conducted by Greiber and Lemke (2005) and Carstensen (2006) on the effect of stock and bond market risks on money demand. Seitz and Landesberger find for the Euro

[4]Further recent studies examining the relevance of stock prices for money demand in the Euro area are written by Dreger and Wolters (2009, 2010) and Nautz and Rondorf (2011).

area that financial market uncertainty is positively correlated with the demand for M3 through the substitution channel which is in line with former studies.

Lastly, Cronin et al. (2011) apply a slightly different econometric framework using U.S. data. Instead of estimating long-run relationships, a multivariate GARCH framework is applied. This allows one to analyze the causality between money demand growth and macroeconomic as well as monetary uncertainty. In contrast to Choi and Oh (2003), who employ M1 as their money measure, it is found that a positive change in macroeconomic uncertainty leads to an increase in the demand for M2. Furthermore, Cronin et al.'s measure of monetary uncertainty does not cause changes in money demand. Rather the causality runs the other way around: monetary uncertainty may be caused by (excessive) money growth.

Overall, there is strong evidence that capital market risk as well as inflation risk are economically meaningful in explaining money demand behavior. Our own empirical application and the estimation results are provided in the next section. Following most studies, we also apply the cointegrating method. However, we also study the short-run dynamics as well as potential time-variation of the money demand relationship.

3.3.2 The modeling strategy

The starting point for the empirical analysis is given by the linearized money demand function stated in deviations from an empirically latent steady-state, as stated in eq. (3.71). The linearized money demand (for M2) function can be stated implicitly as follows[5]

$$\widehat{m_t} = f(\widehat{y}_t, E_t(\widehat{r}_{t+1}), \widehat{i}_{t+1}, E_t(\widehat{\pi}_{t+1}), \sigma^2_{rt}, \sigma^2_{\pi t}, \sigma_{\pi rt}) \tag{3.74}$$

where *hat* denotes deviations from steady state, E is the expectations operator and t refers to the time subscript. Thus, money demand m_t is a function of current income (y_t), the one-period ahead own rate of M2 (i_{t+1}), the expected real rate of return on stocks ($E_t(r_{t+1})$), expected inflation ($E_t(\pi_{t+1})$), the current variance of the real rate of return (σ^2_{rt}), the current variance of inflation ($\sigma^2_{\pi t}$) as well as the current covariance between the real rate of return and inflation ($\sigma^2_{\pi rt}$).

Combining theory and evidence poses a major issue. Under specific conditions, dynamic models (e.g. DSGE) translate into highly restricted VAR models which do not fit empirical data well (see e.g. Juselius and Franchi, 2007). Different methods to deal with this issue were suggested in the literature (see for an overview about modeling techniques Garratt et al. (2012)). However, Kapetanios et al. (2007) and Hoover et al. (2008) have

[5] Note that we have re-stated the expression in eq. (3.71) in terms of current income, as this expression is used in the following empirical application.

stressed that regardless of the method used to combine theory and evidence, the empirical model selected needs to take into account cointegrating relationships once some shocks have permanent effects. Thus, it may not be appropriate to pre-filter any of the variables with the intention to remove its permanent component, as the model will not be able to track the levels of the data, which is important for forecasting. Furthermore, measuring deviations from some *ad hoc* trend[6], e.g. by means of any univariate filter, introduces some severe estimation bias and makes it complicated to conduct inference from the long-run properties of the model (Garratt et al., 2012, 29 p.).

We take this critical perspective into consideration and specify an econometric model which differs from the theoretical approach derived in eq. (3.71), in order to reconcile theory and evidence. To be specific, we exploit the information of the levels of the variables by estimating a long-run relationship between the series. This is in contrast to the frequently applied approach of directly using deviations from some pre-determined steady-state. Since we are not interested in the size of the structural parameter values but rather in their algebraic signs, this does not pose further theoretical issues. We follow the argumentation of Pesaran and Smith (2011) stating that it is preferable to include long-run relations and to leave the short-run dynamics less restricted in order to estimate the steady-state. Furthermore, the majority of empirical approaches to money demand apply the cointegration and error-correction modeling technique. This allows us to compare our results directly with former studies. Lastly, within this modeling framework, we can distinguish between long-run and short-run dynamics of various variables in a consistent way in order to study numerous aspects of the model. However, it should be noted that the majority of empirical studies focuses solely on the long-run properties as the main concern is about the long-run stability of the money demand relationship. Nevertheless, for the conduct of monetary policy it is particularly important to analyze the short- to medium-run response of money demand to specific shocks as well (Ball, 2012).

In this study we stick to the single-equation cointegrating framework for various reasons. First, the theoretical model outlined is a partial model analyzing solely the determinants and dynamics of the money demand behavior. We do not analyze a completely closed macroeconomic system at this stage. Secondly, as shown by Pesaran and Shin (1998) and Pesaran et al. (2001) the ARDL model framework provides super-consistent estimates of the long-run parameters even in the presence of endogeneity. Hence, for estimating the money demand long-run relationship consistently, a system framework, which is much

[6]The *ad hoc* feature refers to the fact that such trend-extracting methods do not allow for series-dependent characteristics that guarantee consistency with the data. For instance, for the well-known Hodrick-Prescott filter, a (smoothing) λ-value of 100 is recommended for annual data. This value, however, has no sound theoretical justification, and the optimal smoothing parameter may depend on additional time-series characteristics. Model-based frameworks provide more precise estimates of cyclical and trend components. See e.g. Garratt et al. (2012, ch. 10) for more arguments in this.

more sensitive to (mis-)specification issues, is not necessarily required. Of course, this does not rule out the use of the VECM framework *per se*. Thirdly, the ARDL single-equation framework allows for the mixture of both $I(1)$ as well as $I(0)$ variables in the long-run relationship. The VECM framework is less flexible with respect to this problem. Overall, there are good reasons to test our theoretical model using the frequently-used single-equation approach.

3.3.3 Construction of variables

The detailed definition of variables and its data sources are provided in the Data Appendix. Most of the variables in our dataset cover observations from the 1960s to the end of 2014. However, the empirical analysis is restricted to the period 1978q1 to 2013q4 as for some variables no observations are available earlier.[7]

As we are interested in the money demand behavior of U.S. households, we decided to use the M2 definition as the starting point. The focus on households requires the appropriate adjustment of the original M2 time series by subtracting the sum of firm sector money demand (consisting of time deposits, savings deposits and mutual fund shares of corporates). The resulting series is expected to reflect $M2$ money holdings of the household sector. We again refer to the Data Appendix for more details. The nominal variable is deflated by the GDP deflator, P, $m_t = log(M_t/P_t)$.

The log of real households' disposable income is denoted by $y_t = \log(Y_t)$, and taken as the income measure. Expected inflation is approximated by the median of expected relative price changes over the next 12 months of households based on survey data, π^e_t. The own rate of M2 is denoted by i_t. Expected real stock market returns are measured by current real stock market returns, r_t, which is a convention in the literature. As the original real stock market return series is characterized by excess volatility reflecting short-term sentiments and speculation driving the underlying process, we decided to get rid of excess volatility by calculating the moving-average over three months. The co-variance between current price inflation (again based on the GDP deflator) and real stock market returns, $\sigma_{\pi r_t}$, is estimated by means of a rolling-window bi-variate VAR.[8]

In order to control for other sources of macroeconomic risk, we add two measures of capturing different types of risk. First, the time series measure of macroeconomic uncertainty proposed by Jurado et al. (2015) is considered.[9] They define macroeconomic

[7]We have also used an extended sample ending in 2014q4. However, the results indicate substantial parameter changes in the long-run relationship which leads to implausible parameter estimations.

[8]The window size is 20 quarters. For each iteration the estimated co-variance is stacked into a vector in order to construct the co-variances time-series. We also tried a window-size of 32 quarters but the results remain qualitatively unchanged.

[9]The data series is obtained from `http://www.econ.nyu.edu/user/ludvigsons`.

uncertainty as "...uncertainty that may be observed in many economic indicators at the same time, across firms, sectors, markets, and geographic regions. And we are interested in the extent to which this macroeconomic uncertainty is associated with fluctuations in aggregate real activity and financial markets." (2015, 1212). The common component across many indicators is derived from a dynamic factor model. In the following the series is denoted $econunc_t$. The second index is the so called economic policy uncertainty measure, and accounts for economic policy risks. Here, we consider the widely-used *Economic Policy Uncertainty index* compiled by Baker et al. (2013) [10] The series is denoted by $polunc_t$.[11]

Our inflation risk measure takes the literature on constructing uncertainty measures seriously. The method applied for the construction of inflation risk starts from the general observation that inflation follows a unit root process. Stock and Watson (2007) formulate an univariate unobserved component model with stochastic volatility (UCSV henceforth), and show that it provides reasonable forecasting properties for inflation. The variances of the permanent and transitory disturbances evolve randomly over time. An alternative approach to quantify inflation risk was proposed by Andrade et al. (2012) and is coined the inflation-at-risk measure using survey-based density forecasts. Their inflation risk index illustrates a more general framework since it allows for potential asymmetry of inflation risks evolving over time.[12]

The setup of the UCSV model is as follows: It is assumed that the series of interest, x_t, can be decomposed into a permanent and transitory component with time-varying volatility. Allowing for time-variations is based on the empirical fact that parameter shifts in the estimated variances of the components have occurred over time for the U.S. economy (Stock and Watson, 2007). The dynamics of inflation closely follow an integrated moving-average process which can be re-written as an unobserved component model. It is assumed that x_t is driven by a stochastic trend, τ_t, with serially uncorrelated innovations η_t. The stochastic trend is driven by another white noise innovation ϵ_t:

$$x_t = \tau_t + \eta_t \tag{3.75}$$

$$\tau_t = \tau_{t-1} + \epsilon_t \; . \tag{3.76}$$

Both innovations η_t and ϵ_t are *i.i.d* normally distributed. Furthermore, the logarithms of the variances of both the transitory part, $\sigma^2_{\eta,t}$ ($\eta_t \sim N(0, \sigma^2_{\eta,t})$), as well as permanent

[10] The historical time series is available from `http://www.policyuncertainty.com/us_monthly.html`.

[11] It should be noted that the two series indeed account for different aspects of economic risk, as the contemporaneous correlation between the series is only 0.07 for the sample 1978q1 to 2013q4.

[12] Another alternative but maybe less sophisticated approach was employed by Higgins and Majin (2009) who estimate Phillips-curves with (G)ARCH errors. The conditional heteroskedasticity series is used as a proxy for inflation risk. However, the constructed risk series is transitory by construction, and no trend-risk component is estimated.

part, $\sigma^2_{\epsilon,t}$ ($\epsilon_t \sim N(0, \sigma^2_{\epsilon,t})$), evolve as separate random-walks according to:

$$log\ \sigma^2_{\eta,t} = log\ \sigma^2_{\eta,t-1} + \nu_{\eta,t} \tag{3.77}$$

$$log\ \sigma^2_{\epsilon,t} = log\ \sigma^2_{\epsilon,t-1} + \nu_{\epsilon,t}\ . \tag{3.78}$$

The innovations to the variances, $\nu_t = (\nu_{\eta,t}, \nu_{\epsilon,t})'$, are *i.i.d.* $N(0, \gamma I_2)$ and orthogonal to each other. The parameter γ controls the smoothness of the stochastic volatilities $\sigma^2_{*,t}$. Thus, this approach models heteroskedasticity in inflation explicitly and might be preferred e.g. to standard (S)VAR models based on the (eventually) restrictive assumption of homoskedasticity, as argued by Chua et al. (2011). The model is estimated using the Gibbs sampling approach.[13] The studies by Wright (2011) and Dovern et al. (2012) have applied this model to inflation series before. Grimme et al. (2011, 7) interpret the permanent component as a measure of inflation uncertainty, whereas the transitory part may reflect some type of short-run risk measure. We fit the UCSV(0.2) model to our quarterly inflation expectation time series, π^e_t, for the sample from 1978q1 to 2013q4 using a prior for the initial condition of $\gamma = 0.2$.[14] The estimated time-varying standard deviation of the permanent component is plotted in Figure 3.1(g), and discussed in more detail below.

As a measure of stock market risk the stock market premium, as e.g. suggested by Fama and French (1988), is used. It should be noted that in our theoretical model, risk is based on actor's aversion against the volatility of rates of return, which is measured by the variance of stock market returns, while the stock market premium additionally takes the strength of risk aversion into account. Hence, changes in the stock market premium may be the result of capital market risk and/or changes in the risk attitudes. This should be considered when interpreting the empirical results. The stock market premium, $\sigma^2_{r_t}$, is given by the ratio of the dividend yield on the S&P 500 stock price index, $divy_t = 100\frac{Dividends_t}{SP500_{t-4}}$, over the yield on 10-year U.S. Treasury notes, $GS10$:

$$\sigma^2_{r_t} = log(\frac{1 + divy_t}{1 + GS10_t})\ . \tag{3.79}$$

Recall that the expected partial effect of stock market risk on money demand is ambiguous: Most likely an increase in stock market risk reduces current consumption and hence money demand. However, the countervailing portfolio shift effect is positive such that the total impact is not definite.

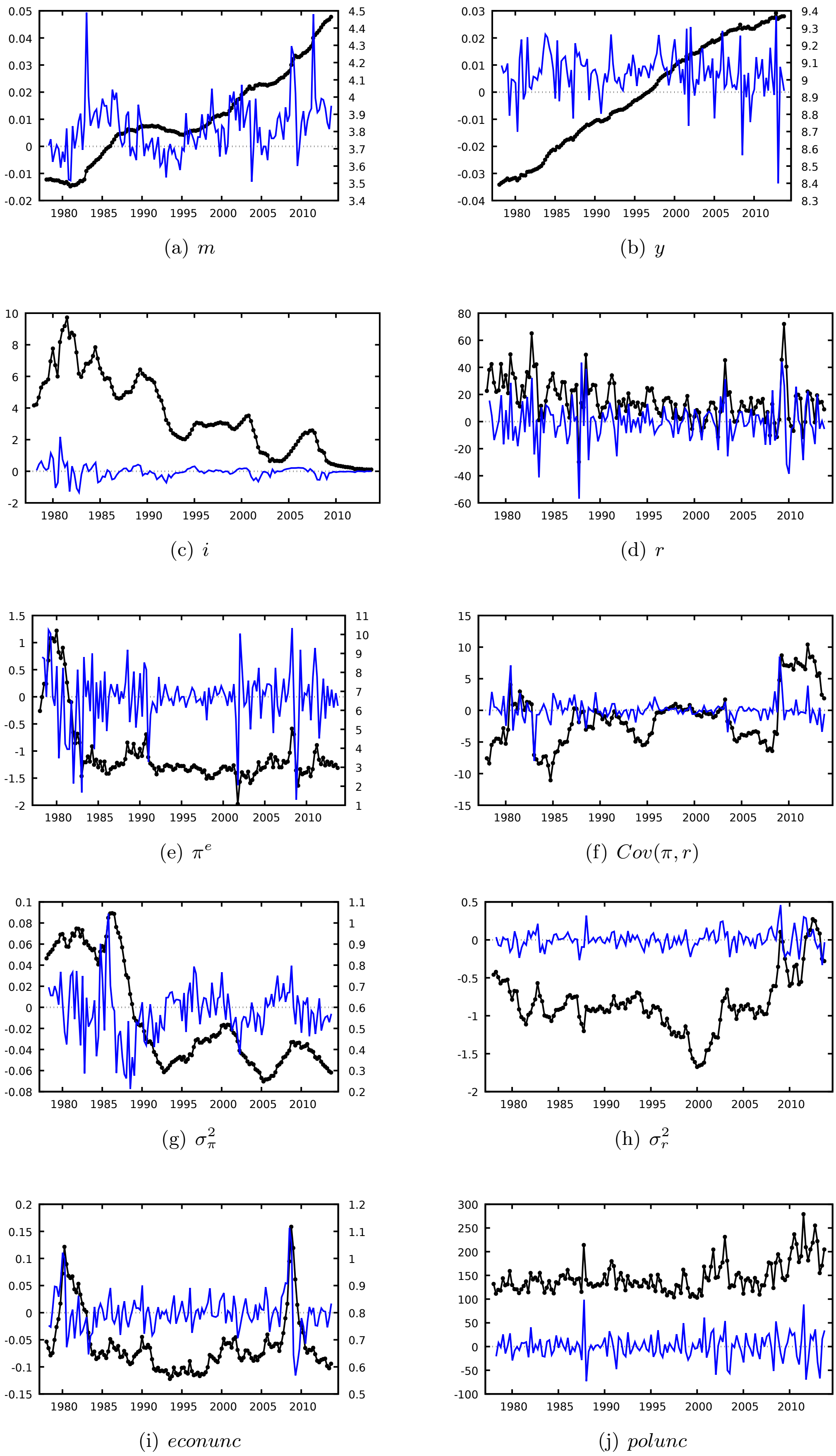
[13] We thank Peter Summers for providing his `gretl` code to us.

[14] This prior was also used by Stock and Watson (2007) for GDP inflation. We found that the results were robust against different prior values. We also applied the model to monthly data, but the results do not differ substantially, which is in line with the findings by Stock and Watson (2007).

3.3.4 Visual inspection of the time-series and initial correlation analysis

All time series are depicted in Figure 3.1. As expected, both the monetary aggregate m and the income measure y are upward trending over time (see Figures 3.1(a) and 3.1(b)). Additionally, the own rate of M2, i, (see Figure 3.1(c)) has shown a declining trend since the 1980s and reached the zero line as a result of unconventional monetary policy since 2012. Real stock market returns r are characterized by high variance and high-frequency fluctuations, as depicted in Figure 3.1(d). Real returns were temporarily negative during the bust of the New Economy bubble and also for about five quarters between 2008 and 2009 as a result of the recent great financial crisis (GFC, henceforth). Expected inflation shows a remarkable stability over time, with a few exceptional changes in the early 1980s, during the Iraq-war, the beginning of 2002/3 and during 2008/9 (see Figure 3.1(e)). However, overall there is no tendency of a fundamentally changed trend in inflation perceptions. Inflation risk, σ_π^2, as depicted in Figure 3.1(g), had been stable on a rather high level between 1978 and 1987 before its level has shifted downwards during of the Great Moderation period. Since then, the risk level has remained stable accompanied by modest cyclical fluctuations. The Clinton era boom years, the New Economy bubble and the surge in oil prices since the early 2000s were accompanied by a mild increase in inflation risk. The recent temporary increase in expected inflation is accompanied by a temporary but mild increase in the permanent component of inflation risk. However, the recent level of inflation risk is still low in historical comparison in the U.S. The risk associated with capital markets, σ_r^2, has been rather stable between 1978 and 2004 with a temporary decline between 1996 and 2000 (see Figure 3.1(h)). However, the bust of the New Economy bubble led to an increase in capital market risk. In historical comparison, the GFC has led to a sharp positive level-shift in capital market risk since 2008, reflecting the high risk associated with capital market investments.

Interestingly, the macroeconomic uncertainty index (*econunc*) shows two spikes: first during the second oil crisis in the early 1980s and another one between 2008 and 2010 (see Figure 3.1(i)). The impact of the U.S. financial market crisis in the late 1980s as well as the bust of the New Economy in 2001 have had mild impacts on macroeconomic uncertainty. Different to the *econunc* measure, the economic policy uncertainty measure, *polunc*, has successively risen as a result of the GFC (see Figure 3.1(j)) and remains on a historically high plateau. Lastly, the covariance between inflation and real stock market returns, $\sigma_{\pi r}$, is slightly negative for most of the sample. The time series shows sharp negative downturns in 1978 and 1985. However, since 2009 the covariance has turned strongly positive (see Figure 3.1(f)).



(a) m (b) y

(c) i (d) r

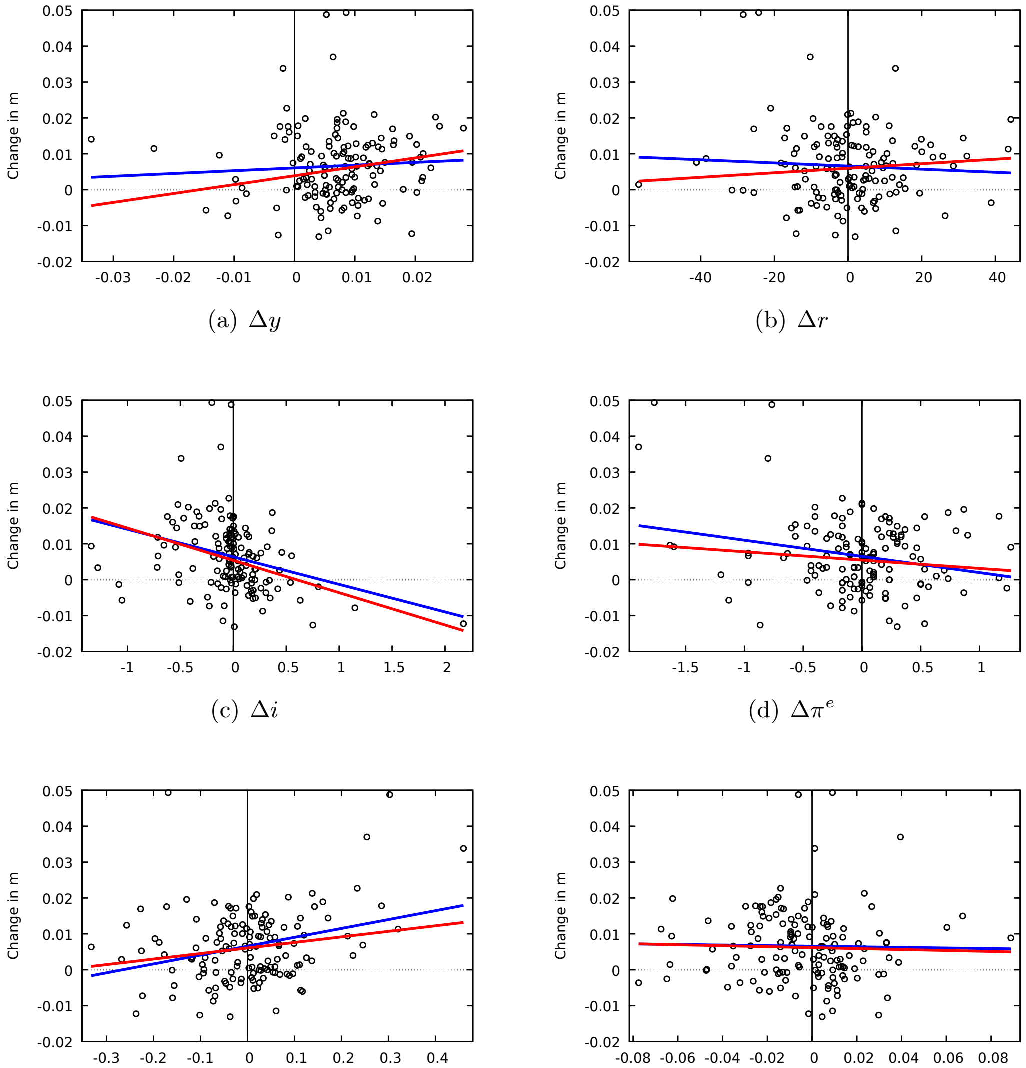
(e) π^e (f) $Cov(\pi, r)$

(g) σ_π^2 (h) σ_r^2

(i) *econunc* (j) *polunc*

FIGURE 3.1: Time series plots of the level variables (point-lines) and its corresponding first differences. If a second y-axis is given, it refers to the level variable. Sample: 1978q1 – 2013q4.

In Figure 3.2 we depict the contemporaneous correlation between the change in money stock, Δm_t, and the first difference of the variables of interest. The unconditional correlation analysis reveals a positive link between money demand and income changes (see Figure 3.2(a)) as expected.



(a) Δy (b) Δr

(c) Δi (d) $\Delta \pi^e$

(e) $\Delta \sigma_r^2$ (f) $\Delta \sigma_\pi^2$

FIGURE 3.2: Scatter plot between the log-change in money demand (m) and the first difference of the respective variable. The blue (red) line depicts the OLS (LAD) fitted line. Sample: 1978q1 – 2013q4.

In contrast to the OLS estimator, which reveals a slightly negative correlation between Δm and changes in the real rate of returns, the least-absolute deviations estimator (LAD)[15] suggests a positive correlation 3.2(b). Theoretically, it was shown that the total effect is ambiguous and depends on the response of current consumption on changes in the expected real return on capital as well as a substitution effect, as described in Section

[15] The LAD estimator is resistant to outliers as it gives equal emphasizes to all observations.

3.2.3. If the substitution effect is sufficiently strong, however, the total effect is most likely negative.

Furthermore, we find a negative unconditional correlation between changes in the own rate of M2 and changes in money holdings (see Figure 3.2(c)). This rather counter-intuitive result is also contained as a possibility in the theoretical model where the direct effect points to a positive correlation between the demand for M2 and the own rate whereas the indirect effect, which is represented by the reaction of per capita consumption, indicates the opposite, as described in Section 3.2.3.

The link between changes in expected inflation and the growth of money demand is negative, as displayed in Figure 3.2(d). According to the theoretical model, the total effect is again ambiguous but most likely current consumption responds positively to an increase in expected inflation.

Changes in money demand and inflation risk are not unconditionally correlated at all, as depicted in Figure 3.2(f). It seems that the indirect positive effect on current consumption just compensates the direct negative impact on money demand. Lastly, we find a positive unconditional correlation between the change in money holdings and changes in stock market risk (see Figure 3.2(e)).

3.3.5 Unit root properties

In this sub-section the univariate time-series properties of the variables of interest are briefly analyzed. Instead of following the classical cointegration approach by initially testing each time series for (non-)stationarity before estimating the long-run relationship, we follow the error-correction modeling (ECM henceforth) procedure. Putting the focus on the direct estimation of the ARDL or ECM has several advantages. First, it should be recalled that unit root tests can suffer from inflated Type I error rates when data are cointegrated (Reed, 2014). Secondly, the residual-based Engel-Granger (Engle and Granger, 1987) two-step estimation strategy involves additional uncertainty as all variables have to be tested for unit roots before the long-run equilibrium is also tested for stationarity. The single-step ECM-based or ARDL bounds test on cointegration involves less uncertainty and the power as well as size of the associated cointegration tests is higher as it uses available information more efficiently (Kremers et al., 1992). Additionally, the bounds test approach on cointegration also allows for a mixture of $I(1)$ and $I(0)$ series in the long-run relationship. Lastly, standard unit root tests also suffer from non-normality and structural breaks (Perron, 1989). However, instead of applying unit-root tests allowing for parameter changes, we prefer to estimate the ARDL model of interest and apply a test on parameter stability afterwards.

In order to check for the statistical properties of the separate time series, we run the ADF-GLS (Elliott et al., 1996) as well as the KPSS (Kwiatkowski et al., 1992) unit-root tests for our sample ranging from 1978q1 to 2013q4.[16] The results for both the ADF-GLS and KPSS test are provided in Tables B.1 and B.2 in the Appendix.

The null of a unit-root cannot be rejected for m, y, i, σ_r^2 and σ_π^2 at standard significance levels and lag lengths tested. This finding is confirmed by the KPSS test according to which the null of stationarity can be fairly rejected at least at the 5% level for these series.

The ADF-GLS test and KPSS tests suggest some conflicting results for the real stock market return series (r), expected inflation (π^e), the covariance measure ($\sigma_{\pi r}$) as well as for the macroeconomic uncertainty (*econunc*) and economic policy uncertainty (*polunc*) series. Thus, the tests do not present clear-cut results. However, we proceed by assuming that inflation follows a random-walk which is a generally acknowledged finding (Stock and Watson, 2005). The visual inspection of the covariance series as well as both uncertainty measures rather suggests stationary processes accompanied either by level-shifts or temporary outliers resulting in non-normality.[17] Both properties affect the power and size of standard unit-root tests, as shown by Perron (1989) and others. Similar ambiguities remain w.r.t. the stock market return series. However, the good news is that the cointegration bounds test proposed by Pesaran et al. allows one to remain open with regard to the stationarity assumptions as will be explained below.

3.3.6 Econometric long-run specification and testing, and dynamic multipliers

We proceed with the determination and estimation of possible long-run relationships. The following five long-run model specifications are tested, where Z denotes a 1 by k time series vector:

1. $Z_{1t} = [m_t \; y_t \; i_t \; r_t]'$
2. $Z_{2t} = [m_t \; y_t \; i_t \; r_t \; \pi_t^e]'$
3. $Z_{3t} = [m_t \; y_t \; i_t \; r_t \; \pi_t^e \; \sigma_{r_t}^2]'$
4. $Z_{4t} = [m_t \; y_t \; i_t \; r_t \; \pi_t^e \; \sigma_{\pi_t}^2]'$
5. $Z_{5t} = [m_t \; y_t \; i_t \; r_t \; \pi_t^e \; \sigma_{r_t}^2 \; \sigma_{\pi_t}^2]'$.

[16] All computation in this paper is done by the open-source econometric package `gretl` (Cottrell and Lucchetti, 2013).

[17] The stationarity assumption of the covariance is a sound assumption as the correlation between two series is bounded between -1 and 1.

The benchmark Model 1 includes among the dependent money series the standard set of explanatory variables namely an income measure (y) and an opportunity cost measure comprising the own rate of M2 (i) and the stock market real rate of return (r).[18] Step-by-step, inflation expectations (π^e) and the two risk variables σ_π^2 and σ_r^2 are added to the remaining four specifications. We estimate these different specifications in order to check whether the baseline long-run money demand relationship fits the data or not. If this is not the case other explanatory variables are required to eventually restore a plausible and stable long-run relationship which explains the data sufficiently well.

It may be surprising that both risk variables enter the long-run relationship, even though they are not included in the deterministic steady-state of the theoretical model obtained after a first-order Taylor expansion. In our empirical analysis we follow the argumentation of Pesaran and Smith, and allow for the "use of long-run cointegrating relations where they exist" (Pesaran and Smith, 2011, 13). As already shown in the literature review, there is overwhelming evidence that financial as well as risk variables help to re-establish a long-run money demand relationship. Thus, the inclusion of both inflation risk and capital market risk allows us to test empirically the hypothesis that both risk factors affect the households' money demand behavior.

The co-variance between inflation and stock market returns ($\sigma_{\pi r}$) is taken to be I(0), and enters the model as an unrestricted exogenous, as described below. The same assumption is made for the macroeconomic uncertainty (*econunc*) and the economic policy uncertainty (*polunc*) measures.

Bounds testing approach to the analysis of long-run relations Classical cointegration methods require all the underlying variables to follow integrated stochastic processes of the same order. The unit-root pre-testing introduces additional uncertainty into the estimation process. Recently, Pesaran, Shin and Smith (2001) (PSS henceforth) have suggested a bounds testing methodology which allows the long-run modeling of mixed $I(1)$ and $I(0)$ processes. A brief introduction into the model and estimation strategy follows.

For illustrative purposes, an unrestricted error correction model with a single regressor, x_t, and an intercept term is assumed. The conditional error-correction model (ECM)

$$\Delta y_t = \delta + \rho y_{t-1} + \theta x_{t-1} + \sum_{j=1}^{p-1} \gamma_j \Delta y_{t-j} + \sum_{j=0}^{q-1} \phi_j \Delta x_{t-j} + u_t \qquad t = 1, ..., T \tag{3.80}$$

[18]We also ran specifications using the cumulative sum of r instead of the rate itself, as the stationarity properties of r are ambiguous. Qualitatively, the results remain unchanged, irrespective of the chosen sample.

can be derived from an underlying ARDL(p,q) model which can be estimated consistently by OLS.

The parameters δ, ρ, θ, γ and ϕ denote the intercept, speed of adjustment towards the long-run attractor, the effect of the lagged level of the exogenous $I(1)$ variable and the short-run effects of the endogenous as well exogenous series, respectively. Additional $I(0)$ series and deterministic variables can be added without causing further issues for estimation and inference. The lag-order of the ARDL(p,q) model can be determined by means of information criteria and specification tests such that the residuals fulfill the standard assumptions. We follow the argumentation by Hassler and Wolters (2006) and also consider the contemporaneous Δx_t as a regressor, as it was found that the conditional ECM outperforms the unconditional ECM as long as Δx_t does not respond to past equilibrium deviations.[19]

The null hypothesis of no long-run relationship (with a restricted intercept) is stated as $H_0^{PSS}: \rho = \theta = \delta = 0$ and can be tested by using a Wald test for which the asymptotic distribution of the test statistics is non-standard under the null hypothesis irrespective of whether the regressors are $I(0)$, $I(1)$ or mutually cointegrated. Instead of exact critical values for an arbitrary mix of $I(0)$ and $I(1)$ variables, Pesaran et al. (2001) provide two sets of critical values: one which assumes that all regressors are $I(1)$, and the other one assuming that all series are $I(0)$. If the computed test-statistics falls below the $I(0)$ bound, one can conclude that the variables are $I(0)$, and hence no long-run relationship is possible. If the statistics exceeds the $I(1)$ bound a long-run relationship between the variables exists. The test is inconclusive if the statistics falls inside the bounds, and some knowledge about the order of integration of the underlying variables will be needed. To improve the power and size of the PSS test under potential heteroskedasticity, we apply a bootstrap version of the PSS test. Furthermore, it was just recently shown by Cavaliere et al. (2014) in a multivariate framework that in the presence of heteroskedasticity in the innovations process, the wild bootstrap approach significantly outperforms the i.i.d. bootstrap analogue. We expect that this also holds in the univariate context. In the Appendix in Section B.5 the corresponding bootstrap algorithm is described. Additionally, we report the results of the standard residual-based Engle-Granger test of cointegration using asymptotic critical values, instead.[20]

In case the null hypothesis of no long-run relationship can be rejected, the long-run coefficient is given by the non-linear estimate of $\widehat{\beta} = -\frac{\widehat{\theta}}{\widehat{\rho}}$ where 'hat' refers to the OLS estimate. Inference on $\widehat{\beta}$ can be conducted by means of the Delta method, as described in

[19] This assumption is frequently made in empirical applications such as the one by Shin et al. (2014).

[20] As a cross-check one could apply the test suggested by Banerjee et al. (1998) testing the null $\rho = 0$ of no cointegration against the alternative $\rho < 0$, for which Pesaran et al. (2001) also provide critical values. However, it is expected that the bootstrap PSS test clearly outperforms this test using asymptotic critical values.

Pesaran and Shin (1998), or, as conducted in this study, by means of bootstrap methods (Efron and Tibshirani, 1993, ch. 5).

Recall that the conditional specification of the ARDL model provides super-consistent estimates of the long-run parameters even in the presence of endogeneity issues. However, this is not the case for the short-run parameters which are contaminated by the contemporaneous correlations (Pesaran and Shin, 1998).

Dynamic multipliers The cumulative dynamic multiplier effects of x_t on y_t can be evaluated as follows:

$$m_h = \sum_{j=0}^{h} \frac{\partial y_{t+j}}{\partial x_t} \ , \ h = 0, 1, 2, ... \tag{3.81}$$

Notice that, by construction, and $h \to \infty$, $m_h \to \beta$, where β is the long-run coefficient.

Additionally to the $I(1)$ variable we add both contemporaneous and lagged values of the $I(0)$ regressors $Cov_{(\pi_t, r_t)}$, $econunc_t$ and $polunc_t$ up to order $q-1$. The co-variance measure enters the model due to theoretical reasons whereas the uncertainty measures account for other sources of risk different from inflation risk and capital market risk. In order to determine the optimal lag length of the ARDL model, we apply a type of general-to-specific modeling approach as well as automatic outlier detection, as described in detail in the Appendix in Section B.4. Given the small sample size, we provide the bootstrap estimation results of the error-correction adjustment term $\widehat{\rho}$, the long-run coefficients $\widehat{\beta(.)}$ jointly with bootstrap standard errors and the R^2. A battery of standard specification tests on serial correlation, heteroskedasticity, functional form and parameter stability are performed on the final specification estimated.

3.3.7 Estimation results

Table 3.1 provides the estimation and test results of all five models. The bootstrap PSS cointegration test indicates only for Models 3 and 5 (significant at the 10% level) an existing long-run relationship between the variables. These results are in contrast to the residual-based Engle-Granger test (using asymptotic 5% critical values) according to which for none of the specifications a cointegration relationship does exist.

None of the models suffers from remaining autocorrelation. Furthermore, we do not find any evidence of remaining issues with heteroskedasticity or residual non-normality problems, and Ramsey's RESET test does not indicate any issues with the functional form. The QLR test on parameter stability is performed to three categories of variables:

(A) Estimation Results

	Model 1	Model 2	Model 3	Model 4	Model 5
ρ	-0.015^{*}	-0.019^{**}	-0.070^{***}	-0.015^{*}	-0.060^{***}
	(0.008)	(0.009)	(0.018)	(0.008)	(0.019)
$\beta(y)$	2.445	1.491	0.865^{***}	3.260	1.208^{***}
	(4.246)	(2.166)	(0.105)	(6.983)	(0.223)
$\beta(r)$	-0.004	0.004	-0.002	-0.002	-0.003^{*}
	(0.023)	(0.021)	(0.002)	(0.036)	(0.002)
$\beta(i)$	0.187	0.121	0.041^{***}	0.079	0.025^{**}
	(0.432)	(0.240)	(0.012)	(0.292)	(0.012)
$\beta(\pi^e)$		-0.165	-0.041^{**}	-0.168	-0.030
		(0.432)	(0.016)	(0.665)	(0.018)
$\beta(\sigma_r^2)$			0.187^{***}		0.268^{***}
			(0.042)		(0.055)
$\beta(\sigma_\pi^2)$				2.888	0.578^{**}
				(11.041)	(0.257)
R^2	0.735	0.787	0.822	0.825	0.819
	(0.656/0.796)	(0.730/0.837)	(0.769/0.869)	(0.767/0.874)	(0.768/0.870)

(B) Diagnostic Statistics

	Model 1	Model 2	Model 3	Model 4	Model 5
$F_{SC(1)}$	0.802	0.497	0.811	0.708	0.852
	(0.063)	(0.465)	(0.058)	(0.141)	(0.035)
$F_{SC(4)}$	0.832	0.157	0.139	0.096	0.536
	(0.366)	(1.694)	(1.780)	(2.031)	(0.788)
χ^2_H	0.098	0.333	0.484	0.537	0.284
	(65.527)	(64.160)	(68.818)	(66.263)	(60.503)
χ^2_N	0.197	0.175	0.235	0.142	0.372
	(3.250)	(3.490)	(2.896)	(3.902)	(1.980)
F_{FF}	0.648	0.322	0.271	0.503	0.453
	(0.436)	(1.144)	(1.324)	(0.692)	(0.798)
QLR	0.066	0.019	0.129	0.014	0.028
	(44.056)	(48.970)	(39.661)	(50.130)	(47.494)
$QLR_{I(1)}$	0.005	0.009	0.035	0.036	0.011
	(24.292)	(24.836)	(22.907)	(22.798)	(27.983)
$QLR_{I(0)}$	0.083	0.048	0.311	0.014	0.031
	(41.675)	(45.395)	(35.059)	(50.130)	(44.488)
F^b_{PSS}	0.441	0.470	0.070	0.619	0.059
EG	0.414	0.347	-2.000	0.026	-1.955
EG_{5pct}	-3.741	-4.096	-4.415	-4.415	-4.707

Note: ρ and β denote the bootstrapped mean value of the error-correction coefficient and the long-run coefficients, respectively. The bootstrap standard error are reported in rounded parentheses. $***$, $**$ and $*$ denote the 1pct., 5 pct. and 10 pct. rejection probabilities. For R^2 the bootstrapped 95pct. intervals are provided. All results are based on 999 stable bootstrap iterations. The optimal lag length of the ARDL(p,q) model as well as potential impulse dummmies are determined by an automatic algorithm as described in Section B.4 in the Appendix. $F_{SC(1)}$, $F_{SC(4)}$, χ^2_H, χ^2_N and F_{FF} denote the p-values for the tests of no serial correlation of order 1 or 4 (respectively), White's test of homoskedasticity, the Doornik-Hansen test of residual normality and Ramsey's RESET test of the correct functional form. The Quandt likelihood ratio test, QLR, tests for a structural break at an unknown point in time, with 15pct. trimming. QLR, $QLR_{I(1)}$ and $QLR_{I(0)}$ are tests on joint parameter stability of all regressors, only of the I(1) and I(0) regressors, respectively. For these tests the p-values are provided and the test statistics are reported in rounded parentheses below. F^b_{PSS} refers to the bootstrap version of the Pesaran et al. (2001) F-test on cointegration (bootstrapped p-values are reported) while EG denotes the test statistics of the Engle-Granger residual based cointegration test. EG_{5pct} is the corresponding 5 pct. critical value. The restricted intercept with no trend case is considered.

Table 3.1: Estimation results of the money demand relationship. Sample: 1978q1 to 2013q4.

A) join test on all regressors, B) joint test on $I(1)$ regressors, and C) jointly on all $I(0)$ regressors.[21] The null of joint stability of all parameters can be rejected at least at the 5% level for specifications 2, 4 and 5. Performing the test on the $I(1)$ level regressors results in clear rejection of parameter stability (at least at the 5% level) for all specifications. Interestingly, with respect to the $I(0)$ variables the null of parameter stability can only be rejected (at the 5% level) for Models 2, 4 and 5. Overall, the results indicate some significant parameter changes over time.

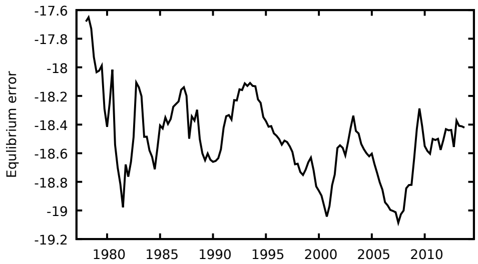
A visual inspection of the long-run equilibrium errors reveals a mixed picture (see Figure 3.3). For Models 1 to 3 one can observe a permanent downward level-shift in the long-run equilibrium errors at the beginning of the 1980s. This level shift disappears after the inclusion of inflation risk into Models 4 and 5 (see Figures 3.3(d) and 3.3(e)). Overall, the long-run errors of the preferred specification Model 5 show a low persistence. However, one can observe a temporary decline in the errors during the 1980s as well as a slight negative trend in the time series between the mid-1990s and 2000. Furthermore, the impact of the GFC is visible as a negative spike in 2009. Overall, the long-run equilibrium error of Model 5 looks much more stationary compared to the baseline specification.

Given that structural breaks may result in biased parameter estimates, we decided to re-estimate the specifications using a smaller sample ending in 2008q3; just before the GFC started. The estimation results are provided in Table B.3 in the Appendix. We find evidence for some differences in the estimated parameters. For instance, the error-correction coefficient (ρ) is smaller for the full sample in comparison to the restricted sample: For Model 5 the corresponding ρ-coefficient is about -0.06 for the sample ending in 2013q4 but -0.12 for the sample ending in 2008q3. Furthermore, a comparison of the long-run income elasticity of money demand reveals some differences for specifications 1, 2 and 4. Fort specification 5 we find an income elasticity of about 1.2 for the full sample in comparison to 0.997 for the restricted sample which indicates only minor differences.

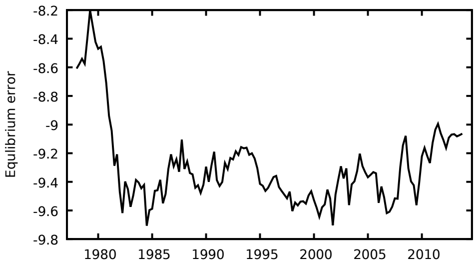
As the QLR-test searches recursively for potential breaks only in the inner 70% of the sample, parameter changes at the sample beginning and end (including the recent GFC period), are not detected. To circumvent this problem, we will compute the rolling-window multipliers for the period between 1998 and 2013.[22] The results support the view that parameter changes have occurred during this period for some of the variables as will be shown in more detail below.

[21] The likelihood ratio test for a break, maximized over all possible break dates in the inner 70% of the full sample 1978q1–2013q4.

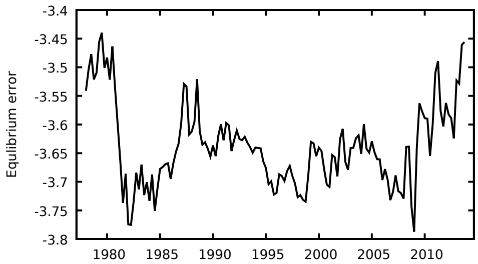
[22] An alternative approach allowing for end-of-sample stability testing was recently proposed by Andrews (2003).



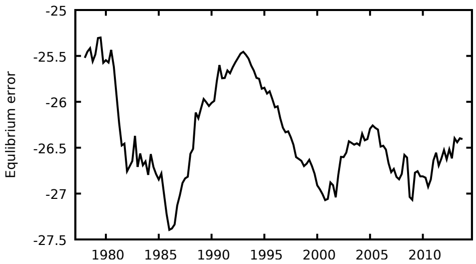
(a) Model 1



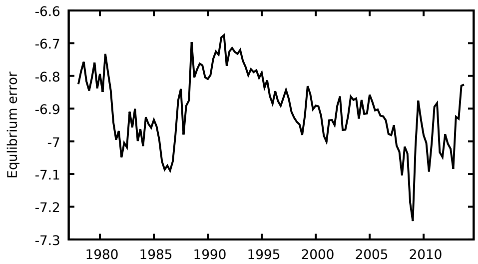
(b) Model 2



(c) Model 3



(d) Model 4



(e) Model 5

NOTE: The optimal lag length of the ARDL(p,q) model as well as potentially required impulse dummies are determined by an automatic algorithm, as described in Section B.4 in the Appendix. The long-run equilibrium error is computed using bootstrap mean values of the long-run coefficients.

FIGURE 3.3: Long-run equilibrium error of money demand. Sample: 1978q1 – 2013q4.

Lastly, it should be mentioned that we also worked with a restricted sample starting in 1985q1 in order to avoid the inclusion of the very turbulent periods in the early 1980s. In total, the results reported do not change. However, restricting the sample to start in the mid-1980s does not seem to be a reasonable choice as we are actually interested in explicitly considering periods of high inflation risk and capital market risk.

Long-run effects The long-run estimation results are reported in Table 3.1. The bootstrap mean value of the long-run income elasticity of money demand is severely upward biased for Models 1, 2 and 4. We find a long-run elasticity of $\beta(y) = 2.445$ for Model 1, $\beta(y) = 1.491$ for Model 2, and $\beta(y) = 3.260$ for Model 4. Most importantly, the coefficients are not significantly different from zero using bootstrap standard errors. However, the consideration of capital market risk in Model 3 and additionally inflation risk in Model 5 results in a significant (at the 1% level) and close to unity long-run income elasticity of money demand (for Model 4 $\beta(y) = 0.865$ and Model 5 $\beta(y) = 1.208$). This suggests that the separate consideration of capital market risk or the joint account of both risk variables in the cointegrating space helps to restore a plausible and widely-acknowledged assumption that there is a (probably one-to-one) long-run relationship between money demand and income. An income elasticity of money demand above unity is often interpreted as proxying omitted wealth effects (Coenen and Vega, 2001), and hence not implausible.

Overall, Model 5 is the favorable specification on which we focus in the following, as the specification includes both risk factors.

The point estimate of the long-run impact of real stock market return is significant at the 10% level and negative for Model 5. A 10 percentage-point increase in stock market returns is associated with a 3% reduction in money demand in the long-run as households shift their portfolio away from low-interest bearing money holdings to stocks. This means that the unambiguous substitution effect dominates. Based on the restricted sample ending in 2008q3, we find for Model 5 no significant long-run effect, as reported in Table B.3 in the Appendix.

The results reveal evidence for a significant (at the 5% level) and positive long-run effect of a change in the own rate. Long-run Money demand holdings increase by about 2.5% as a result of a one percentage point increase in the own rate. Almost the same long-run effect is obtained for the restricted sample ending in 2008q3 for which we find a semi-elasticity of 2.2%. Theoretically, the total effect is ambiguous. However, the empirical finding indicates the dominance of the direct positive substitution effect of deposits on money holdings.

For the full sample, we do not find a significant long-run effect of expected inflation money demand. This implies that the positive effect of higher expected inflation on current consumption (and hence money demand) just equals the direct negative impact on the demand for money. However, based on Model 3 the impact of expected inflation on money demand is negative and significant (at the 5% level). Hence, the joint consideration of stock market as well as inflation risk in the long-run relationship in Model 5, cancels out the long-run effect of expected inflation. The picture is slightly different for the restricted sample ending in 2008q3 where the point estimate is negative and significant at the 5% level. Here we find for Models 2 to 5 a significant (at least at the 5% level) negative effect of expected inflation. As will be shown below in the rolling-window dynamic multiplier exercise, the effect of expected inflation crucially depends on the sample period considered.

According to the estimation results, households shift their portfolio towards safer assets away from risky stocks in response to higher perceived or actual stock market risks. The long-run effect of a change in the stock market premium on money demand is positive and significant at the 1% level. A 0.1 percentage point increase in σ_r^2 is accompanied by a long-run increase in money demand of about 2.7%. Interestingly, this long-run effect disappears if the sample ends in 2008q3. Furthermore, the point estimate is much lower for the sample not covering the recent GFC period. This suggest that the long-run responsiveness of households to stock market risk has recently increased due to the crisis episode in the U.S. economy. Overall, the full sample findings confirm the results of Cook and Choi who find a positive long-run relationship between stock market risk and the demand for M2, and who argue that the "...relative risk effect dominates the relative return effect" (Cook and Choi, 2007, 15).

Even though our findings (based on the full sample) rather indicate that U.S. households do not react to changes in inflation expectations in the long-run, there is stark evidence that they respond to inflation risk. For the full sample, the long-run effect is significant at the 5% level, and a 0.1 unit increase in inflation risk results in a 5.8% increase in money demand in the long-run. This effect remains positive and significant for the restricted sample ending in 2008q3, even though the long-run effect is found being slightly smaller being 3.3%. The positive effect can be explained by a relatively strong positive response of current consumption to an increase in inflationary risk which outperforms the direct negative substitution effect. It should be noted that the result is in line with previous findings by Higgins and Majin (2009).[23]

Overall, we find strong support for the inclusion of both risk factors into the long-run relationship. First, their inclusion helps to restore a plausible economic long-run money demand relationship, indicating that inflation risk as well as capital market risk variables are crucial factors in explaining the economic behavior of U.S. households over the period considered. Secondly, the respective long-run coefficients of both risk factors are statistically significant using the sample covering the recent financial crisis episode. This finding is in stark contrast to the standard and frequent assumption that the steady-state is characterized by full certainty *per definition* which rules out that higher moments of shocks may have a permanent effect.

Dynamic multipliers In Figure 3.4 the dynamic multipliers of money demand are depicted. Still, the estimation results are based on Model 5, even though almost identical results are obtained using Model 3. The dynamics reveal find that a positive unit change

[23]It should be mentioned that we also used different inflation series such as CPI and core inflation for estimating the inflation risk series using the UC-SV model. However, the results stay robust against alternative inflation rates applied.

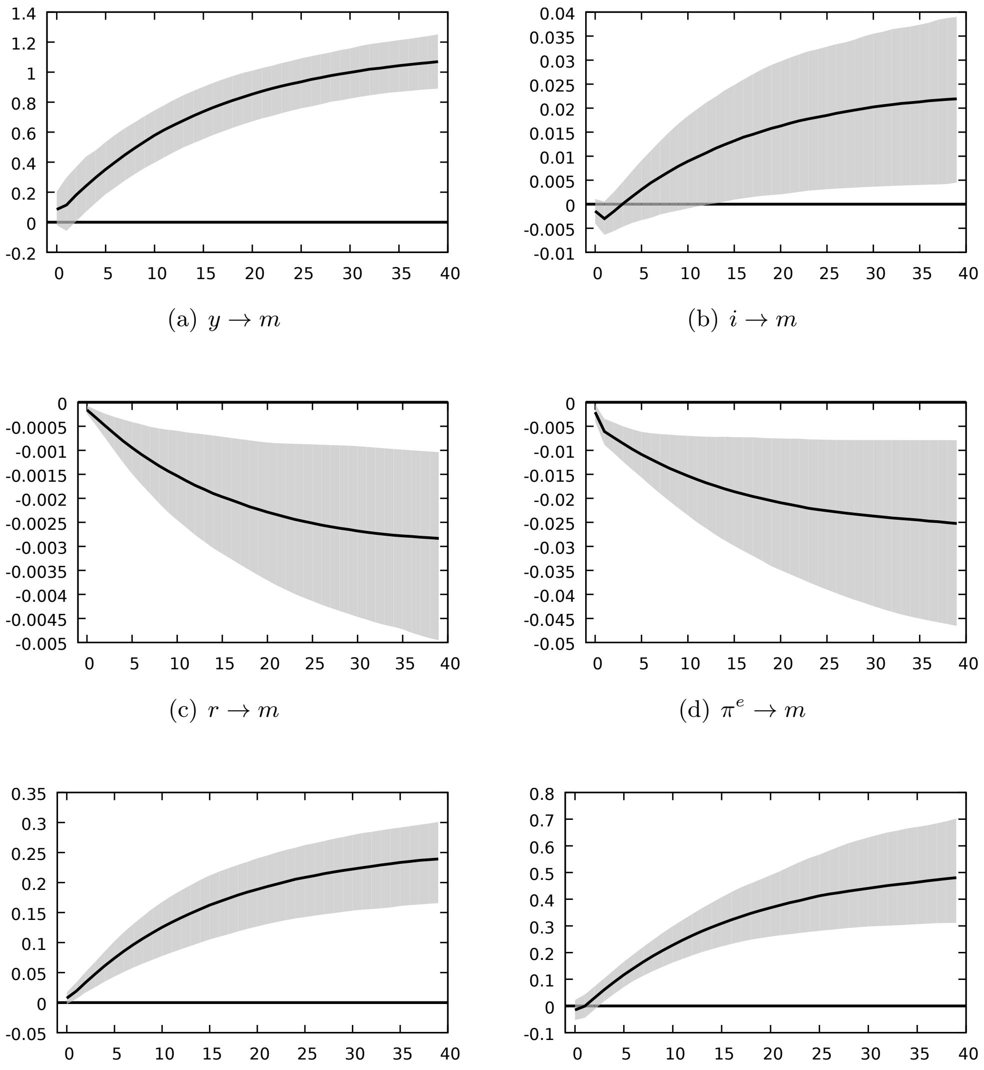
in income leads to a significant increase in the demand for money after a mild two quarter lag and lasts permanently. The effect is significant over the entire horizon (see Figure 3.4(a)), and remains valid even if the sample ends in 2008q3, as shown in Figure B.1(a) in the Appendix.

U.S. households shift their portfolio immediately towards higher-interest-bearing assets away from money after a positive change in real stock market returns (see Figure 3.4(c)). This effect is significantly negative and lasts permanently. For the pre-GFC period we find a totally changed picture (see Figure B.1(c)): The point estimate is positive and significant. However, as shown in Table B.3 the long-run effect is not significantly different from zero.

A positive change in the own rate has a significant positive effect after about two to three years, as displayed in Figure 3.4(b). The effect lasts permanently. Again, the dynamics do not change qualitatively for the pre-GFC period with the only difference that the effect is found being significant already after five quarters, as depicted in Figure B.1(b) in the Appendix.

Irrespective of the selected sample end, we do find evidence for an impact of expected inflation on money demand holdings in the short and medium term. The point estimate is negative over the entire horizon of forty quarters, as displayed in Figure 3.4(d). Similar holds for the restricted sample (see Figure B.1(d)). However, it should be recalled that the long-run effect is only significant for the restricted sample ending in 2008q3 but not for the full sample. U.S. households do not only respond to changes in stock market risk in the long-run but also in the short- and medium-term, as depicted in Figure 3.4(e). We find an immediate increase in money demand in response to a positive change in this type of risk. However, the dynamics change fundamentally using the restricted sample ending in 2008q3: the dynamic multiplier is only temporarily significant in the third quarter after a change in stock market risk (see Figure B.1(e)). This strengthens the argument that the capital market risk has become a crucial determinant of money demand during the GFC episode which was accompanied by an increase in capital market risk.

The adjustment dynamics for a positive change in inflation risk are displayed in Figure 3.4(f). U.S. households respond to an increase in inflation risk by increasing their safe money holdings after a mild lag of two to four quarters. The effect stays positive over the entire horizon which can be explained by an increase in households' current consumption expenditures. Hence, the positive effect is stronger compared to the countervailing negative substitution effect. The dynamics for the pre-crisis period are very similar, as depicted in Figure B.1(f) in the Appendix.



(a) $y \rightarrow m$ (b) $i \rightarrow m$

(c) $r \rightarrow m$ (d) $\pi^e \rightarrow m$

(e) $\sigma_r^2 \rightarrow m$ (f) $\sigma_\pi^2 \rightarrow m$

NOTE: The optimal lag length of the ARDL(p,q) model as well as potentially required impulse dummies are determined by an automatic algorithm, as described in Section B.4 in the Appendix. The 90% Efron percentiles are based on a wild bootstrap method using 999 iterations.

FIGURE 3.4: Dynamic multipliers of money demand with 90% non-parametrically bootstrapped confidence intervals (Efron percentiles) based on Model 5 after general-to-specific model reduction. Sample: 1978q1 – 2013q4.

Rolling-window dynamics In Figure 3.5 the rolling-window dynamic multipliers of money demand are depicted. The purpose of this exercise is to study eventual parameter-variations over time and to control for time-varying conditional heteroskedasticity. Given that our sample covers turbulent times such as the second oil price crisis, the late banking crisis in the 1980s, the New Economy Boom and Bust as well as the current recent financial crisis, structural shifts are likely to have occurred. The lag length of the ARDL(p,q) model is set to the full sample equivalent, as determined in the previous step.[24] Potential

[24] We also allowed for the determination of the optimal lag length at each iteration, but the results remain unchanged.

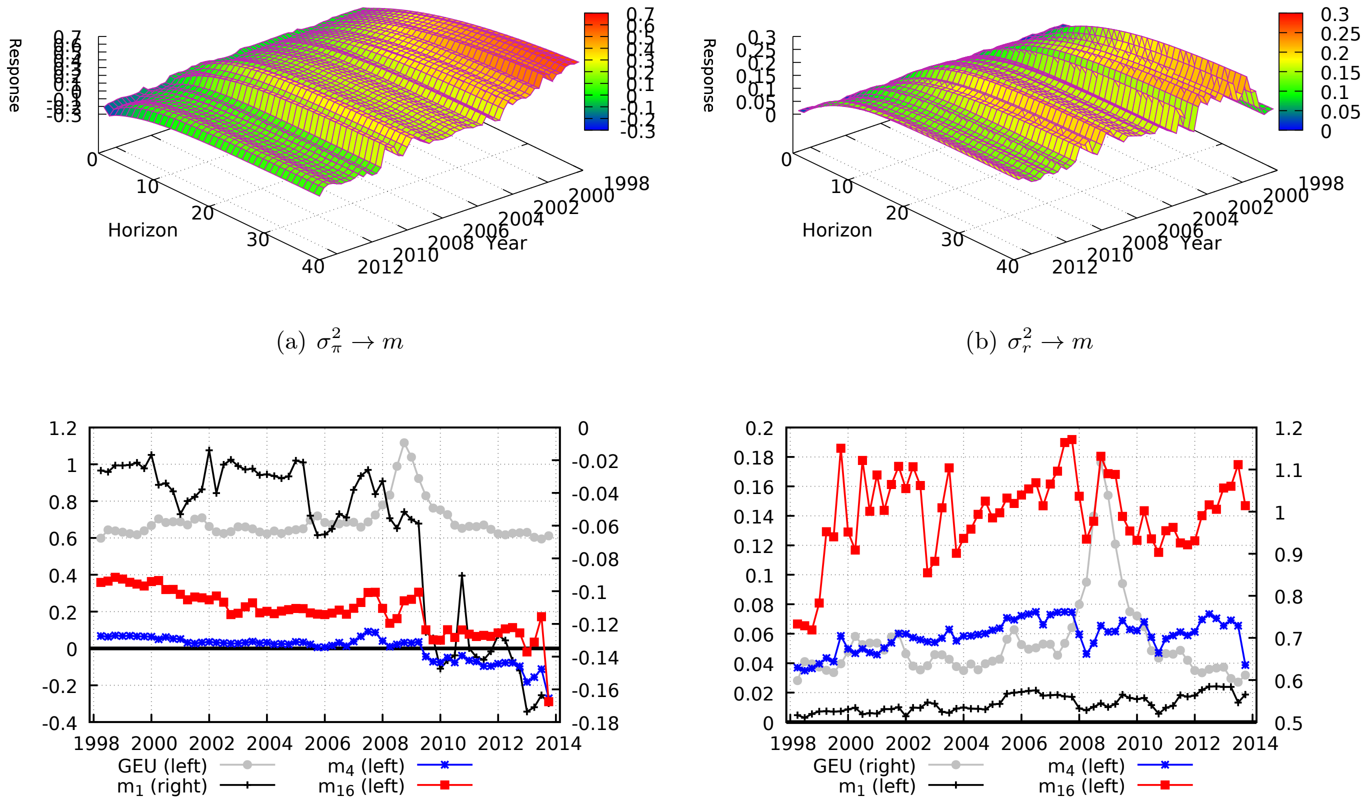
outliers are again automatically detected at each iteration. The window-size is fixed to eighty quarters to ensure sufficient degrees of freedom. Again the reported results are based on Model 5.

Figures 3.5(a) and 3.5(c) depict the dynamic multipliers of inflation risk over time.[25] The impact multiplier ($m_1^{\sigma_\pi^2}$) is found to be fairly stable between 1998 and 2008 with a mean level of about -0.04. The 4th-quarter multiplier also behaves stable between 1998 and 2013 but is close to zero. The medium-term 16th-quarter multiplier is about 0.3 until 2009 before it decreases to 0.1 in the following.[26] The downward shift in the impact as well as the 16th-quarter multipliers just coincide with a spike in the macroeconomic uncertainty measure in 2009. The associated increase (in absolute terms) in the impact multiplier from about -0.04 to -0.14 indicates that U.S. households' money demand holdings have become more sensitive to inflation risk during this period which is also accompanied by the reduction of the Federal Funds rate close to zero. Furthermore, in mid-2008 the FED initiated its program of unconventional monetary policy accompanied by quantitative easing and forward-guidance which led to some temporary increase in expected inflation (see again Figure 3.1(e)) and some further increase in inflation risk.

It is interesting to see that the qualitative properties of the stock market risk effect on money demand have remained stable throughout the time period considered. It can be observed that the magnitude of the impact multiplier is about $m_1^{\sigma_r^2} = 0.01$ between 1998 and 2013 (see 3.5(b) and 3.5(d)). Also the 4th-quarter multiplier effect stays constantly around $m_4^{\sigma_r^2} = 0.06$ and no tendencies of breaks are visible. However, the medium-term multiplier after sixteen quarters shows some strong cyclical dependency over time. Additionally, its point estimate has increased at the end of 1999 from about 0.06 to about 0.16 has started to fluctuate around this level. Lastly, one can observe that the GFC led to a temporary decline in the mean value of the $m_{16}^{\sigma_r^2}$ multiplier between 2009 and 2012 before it has bounced back to its pre-crisis level. Nevertheless, the observed shifts in the point estimates are rather modest, indicating parameter constancy.

[25]The date reported on the x-axis refers to the sample end of the specific window.

[26]However, since no formal tests are applied at this stage, no decisive conclusion can be made whether the parameter changes over time are statistically significant or not.



(a) $\sigma_\pi^2 \to m$

(b) $\sigma_r^2 \to m$

(c) $\sigma_\pi^2 \to m$

(d) $\sigma_r^2 \to m$

Note: The impact multiplier (m_1), the effect after four (m_4) and sixteen periods (m_{16}) are reported, respectively. *GEU* refers to general economic uncertainty (*econunc*). The window size is 80 quarters. The optimal lag length of the ARDL(p,q) model as well as potentially required impulse dummies are determined by an automatic algorithm, as described in Section B.4 in the Appendix.

Figure 3.5: Rolling-window dynamic multipliers based on model 5. Sample: 1978q1 – 2013q4.

In the Appendix we also depict the rolling-window dynamic multipliers for the remaining variables. In Figure B.2(a) and B.2(c) the time-varying multiplier effects of an income change are depicted. The impact multiplier has increased between 1998 and 2004 from about zero to 0.2. Since then, the effect is found being stable. A very similar development can be observed for the fourth-quarter multiplier effect. No substantial disruptions are visible for the medium-term multiplier after sixteen quarters which is about 0.85 over the entire period considered. It is interesting to see that the GFC, the monetary policy programs initiated and the increase in macroeconomic uncertainty did not have any impact on the income elasticity of money demand.

Based on the full sample estimations, we found a positive but delayed dynamic multiplier effect of an increase in the own rate on money demand. The rolling-window exercise indicates changes in the dynamic relationship between the own rate of M2 and money demand: The multiplier effects are fairly stable between 1998 and 2002 prior to a lasting reduction in the point estimate of the absolute value of the impact multiplier from about zero to -0.01 and for the 16th-quarter effects from about 0.03 to 0.01 until 2008 (see Figures B.2(b) and B.2(d)). Since 2009 the impact multiplier has declined (in absolute terms) to around zero. A similar tendency can be observed for the medium-term effect after sixteen quarters. Thus, both periods the New Economy bust as well as the period after 2008 were accompanied by a reduction in the responsiveness of money demand to changes in the own rate in the U.S. economy. This may not be that surprising given that the nominal own rate of M2 declined to almost zero as a result of the conducted zero-lower bound policy strategy.

The responsiveness of households to changes in real stock market returns, r, has experienced some changes between 1998 and 2013, as depicted in Figures B.3(a) and B.3(c)). While the impact multiplier stays stable just below zero during this episode, one can observe some declining tendency in the 4th-quarter multiplier since 2008 from about -0.0005 to -0.001. For the medium-term multiplier after sixteen quarters one can see a first decline between 2000 and 2002 before the effect stabilizes at a rather low level (in absolute terms) between 2003 and 2008. However, since the end of 2008–again just coinciding with the spike in macroeconomic uncertainty–the multiplier effect has more than doubled (in absolute terms) from -0.0015 to about -0.0035 at the end of 2013. It remains hard to say what exactly has triggered those changed responsiveness of money demand to real stock market returns. A potential cause may have been the increase in the relative yields of stocks over deposits as a result of the low-interest environment accompanied by a strong stock market development.

The time-varying effects of expected inflation on money demand are depicted in Figures B.3(b) and B.3(d). As shown before, the short- and long-run multipliers are negative and statistically different from zero using the full sample. The rolling-window exercise indicates severe instability in the multiplier effects between the entire period considered. During both episodes between 2000 and 2002 as well as 2008 and 2009 the 4th- and 16th-quarter dynamic multipliers turned negative. The dynamics of the multiplier effects indicate the responsiveness of money demand on expected inflation is counter-cyclical: During upswings the correlation is positive but turn negative during recession periods.

3.4 Concluding remarks

We investigated the demand for narrow as well as broad money both within a theoretical as well as empirical framework. In doing so our primary focus was directed to the impact of inflationary and stock market risks. In our theoretical analysis we distinguished between a deterministic stationary state implying the absence of uncertainty and hence risks and deviations from this long-run equilibrium marked by information deficiencies with respect to inflation and the real rate of return on capital. Two differences compared to standard DSGE models stand out: First, risk parameters enter the household's objective function directly which is a due consequence of using the certainty equivalent instead of expected utility. This procedure enabled us to give risk parameters an explicit representation in the Euler equations even after linearization around the steady state. Second, demand for money in our model is the result of a complete solution to the household optimization problem taking the intertemporal budget constraint into account. This implies that the impact of rates of return as well as risk parameters on money demand do not only depend on substitution effects but also on income effects. Most notably both effects proved to be countervailing leading to ambiguous results concerning the role of higher inflationary as well as stock market risks. In particular we were not able to rule out a higher demand for cash and deposits due to higher inflationary risks, which has to be expected whenever money demand reacts strongly to changes in consumption.

We used a single-equation error-correction model to test the underlying theoretical model of money demand under uncertainty. Some of the estimation results are in contrast to theoretical assumptions made in our model. For instance, both inflation risk and stock market risk significantly enter the long-run money demand relationship (using quarterly data between 1978q1 and 2013q4) implying that the empirical steady-state is not characterized by a fixed-point with full certainty as higher moments of shocks play a role. This questions the frequent theoretical assumption that the (deterministic) steady-state incorporates no information about the stochastic nature of the economic environment. There is a growing literature introducing the concept of a *risky steady state* which is associated with our findings (see e.g. Coeurdacier et al. (2011); De Groot

(2013)). Future theoretical research should consider this perspective if it wants to build more realistic models which are closer in line with empirical evidence.

The dynamics show that U.S. households increase their demand for safe assets when confronted by an increase in either inflation risk or stock market risk. The recursive empirical analysis reveals evidence for non-constancy of structural parameters which also questions a frequent assumption of fixed preferences. The rolling-window dynamic multiplier analysis allows us to compare similarities and differences in both the short- and long-run relations. Particularly, we find a general decline in the impact multiplier effect of inflation risk on money demand since the late 1998s accompanied by an acceleration in this trend since 2008. Similar holds, correspondingly, for the long-run effect. The sensitivity of money demand to stock market risk has been rather stable since 2000 even though it the long-run multiplier is associated with some cyclical variation over time. Furthermore, the dynamic effects of both the own rate of M2 and expected inflation are found being time-varying. The changes in these effects coincide with the start of unconventional monetary policy in the U.S. in 2008. Lastly, we find that the negative long-run responsiveness of money holdings to real stock market returns has become stronger in absolute terms since mid-2009. Interestingly, most of the parameter shifts coincide with the height of economic policy uncertainty as well as macroeconomic uncertainty in the U.S., as approximated by the now widely-used measures of Baker et al. (2013) and Jurado et al. (2015), respectively. In line with the evidence found by Bloom (2009, 2013) that uncertainty matters for business cycle fluctuations, our results indicate another channel through which uncertainty may affect macroeconomic developments.

With respect to the analysis of the long-run relationship, this econometric approach provides a valid framework as the long-run coefficients are still super-consistent even in the presence of endogeneity issues. However, in a general-equilibrium context feedback-relationships between the variables may arise. Thus, for future work a system modeling framework should be applied.

As the cost of investing in stocks and bonds has declined and households hold broader sets of monetary assets, it can be argued that money holdings may have become more sensitive to financial as well as inflation risk (Cook and Choi, 2007). Assuming that the money-growth-to-inflation nexus remains relevant, an inflation-targeting central bank needs to monitor financial and inflation risk to future inflation. Future research also needs to take into account the interaction between financial and inflation risk developments as well as money demand. Our results provide another argument for the inclusion of financial stability measures into a central bank's objective function, as the stabilization of financial markets can be seen an additional pillar for ensuring price stability (Cronin et al., 2011).

Chapter 4

A Macroeconometric Assessment of Minsky's Financial Instability Hypothesis.

This chapter is based on a fully revised version of Greenwood-Nimmo and Tarassow (2013).

4.1 Introduction

Economic history has been characterised by booms and busts in the asset markets which seem neither predictable nor avoidable *ex ante*.[1] A crude but representative generalisation is that as rising speculative profits fuel an increasingly bullish economic outlook, investors undertake progressively more risky positions until confidence in the sustainability of asset prices eventually fails and the bubble collapses. Subsequently, many commentators are left wondering how so many investors, seasoned and novice alike, were swept up in an *ex-post* unsustainable clamour to realise speculative gains based largely on market euphoria.

The historical inability of market participants to prevent the growth and subsequent collapse of bubbles has been well documented. This has led to a lively debate within the academic literature as to whether the central bank should (and indeed could) formulate monetary policy to intervene in financial markets (e.g. Cecchetti et al., 2000; Nickell, 2005; Posen, 2006; Roubini, 2006). Surprisingly, however, references to the Financial Instability Hypothesis (FIH) proposed by Minsky (1982) are largely absent from this literature despite its relevance. The FIH suggests that by pursuing active monetary policy, the central bank may actually *precipitate* financial crises. The link between monetary policy and financial fragility arises because by changing the interest rate in accordance with its policy objectives, the central bank is also changing the cash-commitments of leveraged firms.

This paper seeks to test this mechanism at the macro level in the US. We first derive a simple four-equation macroeconomic model embedding many of the aspects central to the FIH. This framework is then used to define the long-run relations in a vector error correction model (VECM) by placing appropriate restrictions on the equilibrium vectors spanning the cointegrating space. The results support Minsky's key proposition that an interest rate shock will drive a wedge between the cash-inflows of firms and their debt-servicing commitments. In this way, a monetary tightening will indeed be associated with increasing financial fragility.

This mechanism is intimately linked with the credit channel literature, which emphasises that transaction costs, information asymmetries between borrowers and lenders and risk

[1]We are grateful to Al Campbell, Jagjit Chadha, Sheila Dow, Giuseppe Fontana, Ulrich Fritsche, Ingrid Größl, Anne Mayhew, Viet Nguyen, Robert Prasch, Massimo Ricottilli, Malcolm Sawyer, Yongcheol Shin, Ron Smith, Till Van Treeck, Éric Tymoigne and participants at the 5^{th} International Conference on Developments in Economic Theory and Policy (Universidad del Pais Vasco, 2008), the Macroeconomic and Financial Linkages Conference (Cambridge, 2008), the 3^{rd} ICAPE conference (UMass Amherst, 2011) and the 18^{th} FMM conference (Berlin, 2014) for helpful comments that profoundly shaped the development of this paper. Any remaining errors or omissions are strictly our own.

aversion against insolvency may collectively generate financial frictions in imperfect capital markets (Bernanke and Gertler, 1995; Greenwald and Stiglitz, 1990). A monetary tightening is likely to reduce loan supply and thereby initiate a flight-to-quality effect which will constrain the borrowing power of smaller and more informationally opaque firms (Gertler and Gilchrist, 1994; Kashyap and Stein, 1997). In addition, contractionary monetary policy may be expected to reduce both aggregate demand and aggregate profits, thereby undermining the net worth of the representative borrower and increasing the probability of default – the combined effect will therefore feed back into an increased external financing premium (Bernanke and Gertler, 1995; Bernanke et al., 1996). A further strand of the literature is concerned with credit rationing phenomena (Stiglitz and Weiss, 1981; Greenwald and Stiglitz, 1990). Thus, this literature posits that both the cost of credit and the conditions governing its supply should move in accordance with monetary policy decisions, with the result that the contractionary influence of a monetary tightening will be concentrated among informationally opaque firms with lower net worth (Berger and Udell, 1998).

From a Minskyan perspective, the effects of a monetary tightening are not felt only at the idiosyncratic level but also at the systemic level, because by raising the interest rate, the central bank weakens the balance sheets of all firms and creates a generalised shift toward greater fragility in the distribution of firms' financing structures. We conclude, therefore, that the central bank should generally strive to enhance the predictability of interest rate adjustments conditional on the state of the economy in order to avoid creating unexpected shocks which may undermine the financial stability of leveraged firms. Furthermore, by introducing a macro-prudential policy framework including countercyclical capital requirements on financial institutions as recommended under the Basel III framework, the central bank may ensure that the precautionary reserves of financial institutions are at their strongest when asset prices are inflated.

This paper proceeds in 4.6 sections. In Section 4.2, we selectively review the literature on Minskyan modelling and derive our small macroeconomic model. Section 4.3 introduces the dataset, while our estimation results are presented and discussed in detail in Section 4.4. Section 4.5 discusses the controversy surrounding the role of asset prices in the formulation of monetary policy and proposes the use of macro-prudential policy as a means of moderating the threat of asset market cycles. Section 4.6 concludes, while details of the dataset and its construction may be found in the Data Appendix.

4.2 The Financial Instability Hypothesis

In a series of articles, Hyman Minsky (1976, 1982, 1986a,b) developed a sophisticated theory of financial fragility, the essence of which is neatly summarised by Erturk (2006, p. 3) as follows:

> [O]ptimistic expectations about the future create a margin, reflected in higher asset prices, which makes it possible for borrowers to access finance in the present. In other words, the capitalized expected future earnings work as the collateral against which firms can borrow in financial markets or from banks. But, the value of long-lived assets cannot be assessed on any firm basis as they are highly sensitive to the degree of confidence markets have about certain states of the world coming to pass in the future. This means that any sustained shortfall in economic performance in relation to the level of expectations that are already capitalized in asset prices is susceptible to engendering the view that asset prices are excessive. Once the view that asset prices are excessive takes hold in financial markets, higher asset prices cease to be a stimulant and turn into a drag on the economy. Initially debt-led, the economy becomes debt-burdened.

At the very core of the FIH is the concept of financial fragility, which Minsky discusses in relation to a trinity of financing strategies: hedge, speculative and Ponzi financing (c.f. Minsky, 1986a, pp. 335-341). Sordi and Vercelli (2006) define these with reference to the current and intertemporal financial ratios, k_{it} and k^*_{it}:

$$k_{it} = \frac{e_{it}}{y_{it}} \qquad \text{and} \qquad k^*_{it} = \frac{\sum\limits_{n=0}^{h} \left\{ (1+\rho)^{-n} \, e^*_{it+n} \right\}}{\sum\limits_{n=0}^{h} \left\{ (1+\rho)^{-n} \, y^*_{it+n} \right\}}$$

where e_{it} represents cash-outflows, y_{it} denotes cash-inflows, an asterisk signifies an expected value, ρ is the discount rate and the subscripts i and t identify firms and time periods, respectively. For any horizon, h, a firm is hedge financing if $k_{it} < 1$ and $k^*_{it} < 1$ for $t \leq h$. It is engaged in speculative financing if, for $s < h$, $k_{it} > 1$ for $t \in [1, ..., s]$ but $k^*_{it} < 1$ for $t \in [1, .., h]$. Finally, it is Ponzi-financing if $k_{it} > 1$ for $1 \leq t \leq h - 1$ and $k^*_{it} > 1$ for $1 \leq t \leq h$. It should be clear that hedge financing is the most robust strategy when faced with unanticipated shocks while Ponzi financing is highly risky.

In this context, Minsky emphasises the destabilising effects of interest rate policy and the conditions under which credit may be obtained. In an uncertain world, agents faced with long-lived and irreversible investment decisions engage in forward planning based on optimal forecasts of future conditions which, owing to this very uncertainty, must be heavily conditioned on recent historic experience. An element of this decision is the choice of financing structure. Under the assumption that that the equity base remains approximately constant (which is plausible under imperfect capital markets), an *ex ante* unforeseeable increase in the interest rate after such plans haven been enacted is likely to cause a general shift rightwards through the hedge-speculative-Ponzi spectrum, associated with increasing financial fragility at an aggregate level.[2]

A simple Minskyan boom-bust cycle is presented in Figure 4.1. In the initial recovery phase, the investment decisions of firms are based upon their tentative forecasts. As expectations grow increasingly optimistic and the previous bust is forgotten, an investment boom ensues. Minsky assumes that the investment boom is largely debt-funded and that it is associated with a rising share of profits in national income. The rising profit-share leads workers to bargain for nominal wage increases to maintain the wage-share. The resulting wage inflation is passed through to the general price level as a result of mark-up pricing. In accordance with its inflation-targeting mandate (*de facto* in the case of the Federal Reserve), the central bank raises the short-term nominal interest rate. This is passed through to the lending rate (perhaps incompletely or with some overshooting), raising firms' cash-outflows and increasing aggregate financial fragility. Alongside the events described thus far, financial institutions have been loosening their credit criteria and reducing their margins of safety in response to the euphoric sentiment in financial markets (we will revisit this contention shortly).[3] This leaves them particularly vulnerable to the increasing incidence of default associated with the increase in financial fragility among their borrowers. Given the difficulties faced by firms and financial institutions alike, confidence in the boom will eventually fail and the bust phase will ensue. If one assumes that memories are short and/or selective, then the cycle is free to start over.

This stylised schematic representation summarises the key elements of a Minskyan cycle as it was originally conceptualised. However, one must not neglect the array of relevant institutional changes that have occurred gradually over the course of multiple decades and a number of such cycles. Firstly, the strong and direct linkage between wage inflation and price-level inflation has been weakened since the late 1970s but a tight link between the two nevertheless remains due to the widespread practice of negotiating wage settlements in relation either to the realised or forecast rate of inflation and the large portion of many firms' costs which is accounted for by their staffing costs (Druant et al., 2009). Furthermore, the process of weakening credit standards and thinning safety margins

[2] Minsky (1982, pp. 66-8) provides a thorough discussion of the transition between financing structures.

[3] Minsky's notion of euphoria is essentially a generalised shift towards increasingly optimistic expectations.

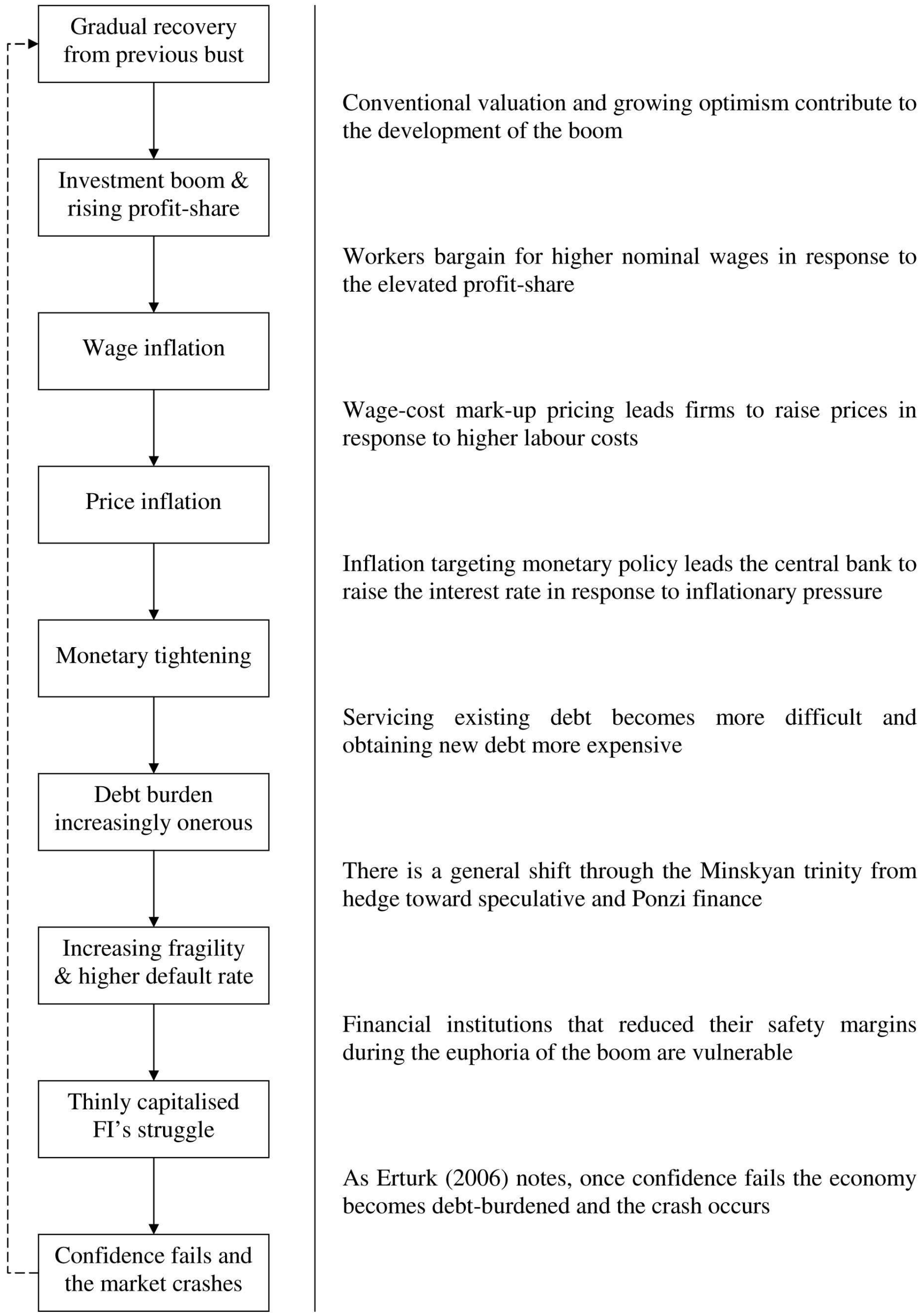


FIGURE 4.1: A schematic representation of the Minksyan boom-bust cycle

was particularly acute in the boom that preceded the recent crisis (Dell'Ariccia et al., 2008). Indeed, the widespread and rapid financial innovation that characterised much of the Great Moderation period may have introduced a tendency toward falling credit standards which has not been confined only to the euphoric phase of the cycle, thereby generating a general trend toward increasingly fragile financing arrangements.

Figure 4.1 does not directly address the linkage between the short-term interest rate administered by the central bank and the longer-term rates relevant for firms' financing decisions. As discussed in Greenwood-Nimmo et al. (2013), the pass-through from short-term to longer-term rates is generally complex, exhibiting various frictions and asymmetries. Longer-term interest rates combine a discount rate[4] and an external financing premium which varies with perceived credit worthiness: it was variations in the latter which played a particularly significant role in the early stages of the Global Financial Crisis. In general, the end of the euphoric stage is likely to be associated with a significant rise in the external financing premium demanded by lenders, exacerbating the effect of any rate rise enacted by the central bank in response to inflationary pressures. Moreover, in such a setting, Greenwood-Nimmo et al. show that expansionary rate cuts intended to bolster the economy will generally not be passed on to borrowers strongly or rapidly, constraining the central bank's ability to stimulate the economy via conventional expansionary policy.

Finally, while there is a natural tendency toward increasing financial fragility in a Minskyan system, this does not mean that stabilisation policy is ineffective. Minsky (1986a) stresses the role of active stabilisation policies in preventing financial crises, crediting the increasing importance of transfer payments since World War II with the relative stability enjoyed by the US until recently. He argues that when confidence starts to fail, the scale of any contraction is reduced as increased government spending (whether a result of automatic stabilisers or discretionary policy) supports the profitability of businesses, helping them to meet their debt-servicing obligations. This view provides direct support for the use of fiscal stimuli during recessions. In this paper, we will further argue in favour of a judicious combination of conventional monetary policy and countercyclical capital requirements.

4.2.1 A small Minskyan model

While various authors have developed chaotic systems in the Minskyan tradition and a good deal of research effort has been devoted to simulation exercises (e.g. Hannsgen, 2005), direct empirical scrutiny of the FIH at the macro level is largely absent from the

[4] For our purposes this can be thought of as the risk-adjusted opportunity cost of internal finance.

literature[5]. This paper attempts to address this lacuna by developing and estimating a simple macroeconomic model with many of the salient features of a Minskyan economy. The model owes an intellectual debt to Lavoie's (1986) early contribution, extending his work in a number of directions. The model may be represented by a system of four equations: an aggregate demand function, an interest rate rule, an investment function and a pair of combined price- and wage-inflation equations.[6]

Aggregate demand Aggregate demand is modelled following (4.1) where y_t denotes real output, r_t denotes the base rate, Δp_t is the logarithmic approximation to the rate of inflation (hence $r_t - \Delta p_t$ is the real interest rate), i_t is real gross investment, y_t^* represents real potential output and $t = 0, 1, 2, \ldots, T-1$ is a deterministic time trend.

$$y_t = b_{10} + b_{11}t + \phi_{11}\left(r_t - \Delta p_t\right) + \phi_{12}i_t + \phi_{13}y_t^* + \xi_{1,t} \tag{4.1}$$

Imposing $\phi_{13} = 1$ allows one to interpret (4.1) in terms of the output gap rather than aggregate demand *per se*. In this form, the equation represents an IS curve and it is this form which is employed in estimation below.

The monetary policy reaction function The central bank is assumed to follow a Taylor-type interest rate rule represented by (4.2), where Δp^* denotes the desired rate of inflation and r^* the natural rate of interest.

$$r_t = \widetilde{b}_{20} + b_{21}t + \varphi_{21}r^* + \varphi_{22}\Delta p_t + \varphi_{23}\left(\Delta p_t - \Delta p^*\right) + \varphi_{24}\left(y_t - y^*\right) + \xi_{2,t} \tag{4.2}$$

Following the approach commonly adopted in the empirical Taylor rule literature, r^* and Δp^* are assumed constant over the period under study. The constancy of these terms allows one to re-write (4.2) as:

$$r_t = b_{20} + b_{21}t + \phi_{21}\Delta p_t + \phi_{22}\left(y_t - y^*\right) + \xi_{2,t} \tag{4.3}$$

where $b_{20} = \widetilde{b}_{20} + \varphi_{21}r^* - \varphi_{23}\Delta p^*$, $\phi_{21} = \varphi_{22} + \varphi_{23}$ and $\phi_{22} = \varphi_{24}$. The empirical tractability achieved in this way comes at the expense of the ability to distinguish the constituents of the composite parameters b_{20} and ϕ_{21} without the imposition of further identifying restrictions. The magnitudes of these quantities are not, however, of interest

[5]Fazzari (1999) notes that there is, however, a wealth of indirect evidence to be found in the micro-founded financial economics literature. Further indirect evidence can be derived from the voluminous literature on the external financing premium.

[6]Note that all variables are expressed as natural logarithms in the following equations.

in themselves in the current context. Lastly, note that when $\phi_{22} = 0$ then the central bank acts as a pure inflation targeter (Christiano and Gust, 1999).

The investment function At the core of the model is a theory of investment behaviour based on that of Godley and Lavoie (2001) which, in turn, draws on Ndikumana (1999). The investment function is specified as follows[7]:

$$i_t = b_{30} + b_{31}t + \phi_{31}f_t + \phi_{32}\left(r_{l,t} - \Delta p_t\right)l_t + \phi_{33}q_t + \phi_{34}\left(y_t - y^*\right) + \xi_{3,t} \tag{4.4}$$

where f_t denotes real internal funds (which proxies real cash-flow), $r_{l,t}$ the rate of interest on bank-lending, l_t the real stock of outstanding corporate debt (and hence $\left(r_{l,t} - \Delta p_t\right)l_t$ denotes the inflation-adjusted cost of servicing real debt) and q_t is Tobin's (1969) average q.[8] This specification exhibits a number of interesting features. Firstly, monetary policy affects investment in at least two ways. A direct effect arises through the change in the cost of borrowing associated with a change in the base rate. A further indirect effect operates through the impact of a change in the base rate on the balance sheets of firms brought about by the associated change in the opportunity cost of retained earnings.

Secondly, the inclusion of Tobin's q provides a mechanism whereby market sentiment can affect the investment decision. During a financial boom, the market value of equity increases relative to the replacement cost of capital. In such a situation, the acquisition of second-hand capital assets (takeovers) becomes relatively less attractive than the purchase of new capital, which may be expected to stimulate non-financial investment. Furthermore, if one assumes that changes in q are driven predominantly by asset prices, then it may be viewed as a proxy for market sentiment. Increasing optimism among market participants will drive asset prices up, increasing q. Such bull markets typically reflect favourable conditions in the broader economy and also provide companies with easier access to investment funds, particularly if they are listed. In conjunction with the first point, it is clear that the broad credit channel of monetary transmission operates within the model.[9]

[7]This formulation exhibits two principal differences to that of Godley and Lavoie. Firstly, in order to achieve an homogeneous $I(1)$ specification, internal funds and the debt-servicing cost are deflated by the price level as opposed to being normalised by capital. Secondly, the independent variables in the Godley-Lavoie specification are lagged but they are treated contemporaneously here to provide richer contemporaneous interaction; of course the vector autoregressive framework will naturally capture lagged effects as well.

[8]Note that it is not average q which is typically of interest but marginal q, which is unobservable. However, Hayashi (1982) demonstrates that the two quantities are equal when various conditions relating to the installation function, the nature of competition and the constancy of returns-to-scale are met.

[9]Although the investment function does not explicitly include expectations, Godley and Lavoie contend that they are incorporated implicitly in the debt-service term. They argue that any increase in the indebtedness of firms will reduce investment as higher debt in the present period reduces expected future profits.

Price and wage inflation The model is completed by two equations characterising price and wage inflation. Minsky and Ferri (1984, pp. 491-2) propose the following relationship:

$$p_t = \gamma_1 \left(\frac{w_t}{\bar{z}_t} \right) + \gamma_2 p_t^e \tag{4.5}$$

$$w_t = \delta_1 \left(\boldsymbol{x}_t, p_t \right) + \delta_2 p_t^e \tag{4.6}$$

where w_t is the nominal wage, $\bar{z}$ is average labour productivity, p_t^e is the expected price level, $\boldsymbol{x}_t$ is a vector of real factors influencing the wage-setting process and Greek letters are positive parameters. Following this approach, a general form of the price- and wage-inflation equations may be written as:

$$\Delta p_t = \widetilde{b}_{40} + \widetilde{b}_{41} t + \varphi_{41} \left(\Delta w_t - \Delta z_t \right) + \varphi_{42} \left(y_t - y^* \right) + \varphi_{43} \Delta p_t^e + \widetilde{\xi}_{4,t} \tag{4.7}$$

$$\Delta w_t - \Delta z_t = \widetilde{b}_{50} + \widetilde{b}_{51} t + \varphi_{51} \Delta p_t + \varphi_{52} \left(y_t - y^* \right) + \varphi_{53} \Delta p_t^e + \widetilde{\xi}_{5,t} \tag{4.8}$$

For generality, equation (4.7) follows Gordon (1985) in including the output gap as a measure of demand pressure – we will return to this issue shortly. The coefficient φ_{41} represents the markup of prices over productivity-adjusted wages. Equation (4.8) represents the process of wage bargaining in which the labour force demands increases in the productivity-adjusted wage rate commensurate with price-level inflation to mitigate downward pressure on the real wage. $\widetilde{\xi}_{4,t}$ and $\widetilde{\xi}_{5,t}$ are stationary mean-zero error processes. Inflation expectations are not, however, readily observable and an uncontroversial proxy remains elusive. In order to overcome this issue, Δp^e is substituted out of the model by combining (4.7) and (4.8), yielding:

$$\Delta p_t = b_{40} + b_{41} t + \phi_{41} \left(\Delta w_t - \Delta z_t \right) + \phi_{42} \left(y_t - y^* \right) + \xi_{4,t} \tag{4.9}$$

where:

$$b_{40} = \Psi \left[\widetilde{b}_{40} - \frac{\varphi_{43} \widetilde{b}_{50}}{\varphi_{53}} \right] \;\; ; \;\; b_{41} = \Psi \left[\widetilde{b}_{41} - \frac{\varphi_{43} \widetilde{b}_{51}}{\varphi_{53}} \right] \;\; ; \;\; \phi_{41} = \Psi \left[\varphi_{41} + \frac{\varphi_{43}}{\varphi_{53}} \right] \;\; ;$$

$$\phi_{42} = \Psi \left[\varphi_{42} - \frac{\varphi_{43} \varphi_{52}}{\varphi_{53}} \right] \text{ and } \xi_{4,t} = \Psi \left[\widetilde{\xi}_{4,t} - \frac{\varphi_{43}}{\varphi_{53}} \widetilde{\xi}_{5,t} \right],$$

where $\Psi = \frac{\varphi_{53}}{\varphi_{53} + \varphi_{43} \varphi_{51}}$. If $\phi_{41} = 1$ then wage costs are fully passed through to prices in the long-run while if $\phi_{42} = 0$ then inflation is modelled as a pure cost-push phenomenon in the long-run in line with Minsky and Ferri's specification. Our initial experimentation with the dataset revealed that both of these restrictions are supported by the data. The finding that demand pull factors are not significant drivers of inflation *in the long-run* is perhaps not surprising given that net excesses or deficiencies of demand should be confined to the short-run in an economy which is free to reallocate resources in response to stimuli over a suitably long time-frame.

The long-run structure Economic theory suggests the existence of the four long-run relationships (4.1), (4.3), (4.4) and (4.9). These may be imposed as the over-identified long-run structure in a Vector Error Correction Model (VECM). Garratt, Lee, Pesaran and Shin (2006, GLPS) advance a long-run structural modelling approach which provides for the inclusion of weakly exogenous $I(1)$ variables. This feature may be useful in the current context as it is theoretically appealing to model potential output as weakly exogenous (c.f. GLPS, Assenmacher-Wesche and Pesaran, 2009).

Consider partitioning the m vector of variables comprising the system, $\mathbf{z}_t$, into the m_y and m_x vectors $\boldsymbol{y}_t$ and $\boldsymbol{x}_t$ of endogenous and exogenous variables (respectively). Given the general structural VECM of the form:

$$\boldsymbol{A}\Delta\boldsymbol{z}_t = \widetilde{\boldsymbol{a}} + \widetilde{\boldsymbol{b}}t + \widetilde{\boldsymbol{\Pi}}\boldsymbol{z}_{t-1} + \sum_{i=1}^{p-1}\widetilde{\boldsymbol{\Gamma}}_i\boldsymbol{\Delta z}_{t-i} + \boldsymbol{\epsilon}_t \tag{4.10}$$

GLPS observe that one may write:

$$\begin{pmatrix} \boldsymbol{A}_{yy} & \boldsymbol{A}_{yx} \\ \mathbf{0} & \boldsymbol{A}_{xx} \end{pmatrix} \begin{pmatrix} \Delta\boldsymbol{y}_t \\ \Delta\boldsymbol{x}_t \end{pmatrix} = \widetilde{\boldsymbol{a}} + \widetilde{\boldsymbol{b}}t + \widetilde{\boldsymbol{\Pi}} \begin{pmatrix} \boldsymbol{y}_{t-1} \\ \boldsymbol{x}_{t-1} \end{pmatrix} + \sum_{i=1}^{p-1}\widetilde{\boldsymbol{\Gamma}}_i \begin{pmatrix} \Delta\boldsymbol{y}_{t-i} \\ \Delta\boldsymbol{x}_{t-i} \end{pmatrix} + \begin{pmatrix} \epsilon_{yt} \\ \epsilon_{xt} \end{pmatrix} \tag{4.11}$$

where:

$$\widetilde{\boldsymbol{\Pi}} = \begin{pmatrix} \widetilde{\boldsymbol{\Pi}}_y \\ \mathbf{0} \end{pmatrix} = \begin{pmatrix} \widetilde{\boldsymbol{\alpha}}_y \\ \mathbf{0} \end{pmatrix} \boldsymbol{\beta}'$$

and $\mathbf{0}$ denotes a null matrix. The $m_y \times m_y$ and $m_y \times m_x$ matrices $\boldsymbol{A}_{yy}$ and $\boldsymbol{A}_{yx}$ represent the contemporaneous effects of the endogenous and exogenous variables (respectively) on the endogenous variables. The $m_x \times m_y$ null matrix in the lower triangle of $\boldsymbol{A}$ obtains from the exogeneity of $\boldsymbol{x}_t$ and indicates that there can be no contemporaneous impacts of the variables in $\boldsymbol{y}_t$ on those in $\boldsymbol{x}_t$.

The matrix $\widetilde{\boldsymbol{\Pi}}$ defines how the long-run errors $\boldsymbol{\xi}_t$ feed back onto the system. The $m_y \times m$ submatrix $\widetilde{\boldsymbol{\Pi}}_y$ characterises how these errors feed back onto the endogenous variables while the restriction that the lower $m_x \times m$ submatrix of $\widetilde{\boldsymbol{\Pi}}$ is a null matrix ensures that the long-run errors do not feed back onto the variables in $\boldsymbol{x}_t$. The null matrices in $\boldsymbol{A}$ and $\widetilde{\boldsymbol{\Pi}}$ together ensure the exogeneity of the variables in $\boldsymbol{x}_t$. Noting the definition of the long-run reduced form errors, $\boldsymbol{\xi}_t = \boldsymbol{\beta}'\boldsymbol{z}_{t-1}$, and recalling that the vector $\boldsymbol{z}_t$ contains both endogenous and exogenous variables, it follows that the exogenous variables are long-run forcing for the system and can influence the endogenous magnitudes in the long-run.

Under the assumption of weak exogeneity in which the structural errors from the first m_y and the remaining m_x equations are joint-normally distributed such that $\boldsymbol{\epsilon}_{yt} = \boldsymbol{\Omega}_{yx}\boldsymbol{\Omega}_{xx}^{-1}\boldsymbol{\epsilon}_{xt} + \boldsymbol{\eta}_{yt}$ where $\boldsymbol{\Omega} = \begin{pmatrix} \boldsymbol{\Omega}_{yy} & \boldsymbol{\Omega}_{yx} \\ \boldsymbol{\Omega}_{xy} & \boldsymbol{\Omega}_{xx} \end{pmatrix}$, GLPS decompose equation 4.11 into the following two equations:

$$\boldsymbol{A}_{yy}\Delta\boldsymbol{y}_t + \boldsymbol{A}_{yx}^{*}\Delta\boldsymbol{x}_t = \widetilde{\boldsymbol{a}}_y^{*} + \widetilde{\boldsymbol{b}}_y^{*}t - \widetilde{\boldsymbol{\Pi}}_y\boldsymbol{z}_{t-1} + \sum_{i=1}^{p-1}\widetilde{\boldsymbol{\Gamma}}_{yi}^{*}\Delta\boldsymbol{z}_{t-i} + \boldsymbol{\eta}_{yt} \tag{4.12}$$

$$\boldsymbol{A}_{xx}\Delta\boldsymbol{x}_t = \widetilde{\boldsymbol{a}}_x + \widetilde{\boldsymbol{b}}_x t - \widetilde{\boldsymbol{\Pi}}_{xx}\boldsymbol{x}_{t-1} + \sum_{i=1}^{p-1}\widetilde{\boldsymbol{\Gamma}}_{xi}\Delta\boldsymbol{z}_{t-i} + \boldsymbol{\epsilon}_{xt} \tag{4.13}$$

where $\widetilde{\boldsymbol{a}}_y^{*} = \widetilde{\boldsymbol{a}}_y - \boldsymbol{\Omega}_{yx}\boldsymbol{\Omega}_{xx}^{-1}\widetilde{\boldsymbol{a}}_x$, $\widetilde{\boldsymbol{b}}_y^{*} = \widetilde{\boldsymbol{b}}_y - \boldsymbol{\Omega}_{yx}\boldsymbol{\Omega}_{xx}^{-1}\widetilde{\boldsymbol{b}}_x$, $\widetilde{\boldsymbol{\Gamma}}_{yi}^{*} = \widetilde{\boldsymbol{\Gamma}}_{yi} - \boldsymbol{\Omega}_{yx}\boldsymbol{\Omega}_{xx}^{-1}\widetilde{\boldsymbol{\Gamma}}_{xi}$, $\boldsymbol{A}_{yx}^{*} = \boldsymbol{A}_{yx} - \boldsymbol{\Omega}_{yx}\boldsymbol{\Omega}_{xx}^{-1}\boldsymbol{A}_{xx}$ and where the vectors $\widetilde{\boldsymbol{a}}$ and $\widetilde{\boldsymbol{b}}$ and the matrix $\widetilde{\boldsymbol{\Gamma}}_{yi}$ are partitioned into endogenous and exogenous sub-vectors and sub-matrices denoted by the subscripts y and x, respectively. Based on their decomposition of equation 4.11 into the conditional VECM for $\Delta\boldsymbol{y}_t$ (equation 4.12) and the marginal VAR for $\Delta\boldsymbol{x}_t$ (equation 4.13), GLPS write the full system as:

$$\boldsymbol{A}^{*}\Delta\boldsymbol{z}_t = \widetilde{\boldsymbol{a}}^{*} + \widetilde{\boldsymbol{b}}^{*}t - \widetilde{\boldsymbol{\Pi}}\boldsymbol{z}_{t-1} + \sum_{i=1}^{p-1}\widetilde{\boldsymbol{\Gamma}}_i^{*}\Delta\boldsymbol{z}_{t-i} + \boldsymbol{\epsilon}_t^{*} \tag{4.14}$$

denoting:

$$\boldsymbol{A}^{*} = \begin{pmatrix} \boldsymbol{A}_{yy} & \boldsymbol{A}_{yx}^{*} \\ \boldsymbol{0} & \boldsymbol{A}_{xx} \end{pmatrix}, \ \widetilde{\boldsymbol{\Pi}} = \begin{pmatrix} \widetilde{\boldsymbol{\Pi}}_{yy} & \widetilde{\boldsymbol{\Pi}}_{yx} \\ \boldsymbol{0} & \widetilde{\boldsymbol{\Pi}}_{xx} \end{pmatrix}, \ \widetilde{\boldsymbol{a}}^{*} = \begin{pmatrix} \widetilde{\boldsymbol{a}}_y^{*} \\ \widetilde{\boldsymbol{a}}_x \end{pmatrix}$$

$$\widetilde{\boldsymbol{b}}^{*} = \begin{pmatrix} \widetilde{\boldsymbol{b}}_y^{*} \\ \widetilde{\boldsymbol{b}}_x \end{pmatrix}, \ \widetilde{\boldsymbol{\Gamma}}_i^{*} = \begin{pmatrix} \widetilde{\boldsymbol{\Gamma}}_{yi}^{*} \\ \widetilde{\boldsymbol{\Gamma}}_{xi} \end{pmatrix} \text{ and } \boldsymbol{\epsilon}_t^{*} = \begin{pmatrix} \boldsymbol{\eta}_{yt} \\ \boldsymbol{\epsilon}_{xt} \end{pmatrix}.$$

The reduced form of the system is achieved in the usual way by pre-multiplying all terms by $\boldsymbol{A}^{*-1}$. Identification, estimation and testing then proceed in the usual manner.

Formal structural modelling is not considered here due to the dependence of the results on various strong modelling assumptions and on a limited number of deep parameters (GLPS make a similar point). Rather, orthogonalisation is achieved via Cholesky factorisation, thereby imposing a Wold-causal ordering on the variables. For this reason, the variables in $\boldsymbol{z}_t = (\boldsymbol{x}_t|\boldsymbol{y}_t)'$ are ordered as follows:

$$\boldsymbol{z}_t = (p_t^o, y_t^*, q_t, \Delta w_t - \Delta z_t, \Delta p_t, r_t, d_t, f_t, i_t, y_t)'$$

where p_t^o is the price of crude oil and $d_t = (r_{l,t} - \Delta p_t)\, l_t$. The oil price is included to account for the effects of the OPEC oil shocks, the Gulf wars and the recent turbulence in global oil markets.

The proposed ordering reflects the sequence of economic decisions. The variables p_t^o and y_t^* are placed first as they are treated as weakly exogenous $I(1)$ forcing variables. q_t is the first of the endogenous variables, followed by Δw_t and Δp_t. This ordering reflects the Minskyan view of the inflationary process. The inflationary pressure leads the central bank to raise the interest rate, r_t. The rate change will affect both the debt-servicing cost (d_t) and internal funds(f_t), which will then influence the investment decision (i_t) and output (y_t).

The four long-run relationships may be written in terms of the long-run deviations from equilibrium as follows:

$$\boldsymbol{\xi} = \boldsymbol{\beta}_{ov}' \boldsymbol{z}_{t-1} - \boldsymbol{b}_0 - \boldsymbol{b}_1 t$$

where $\boldsymbol{b}_0 = (b_{10}, b_{20}, b_{30}, b_{40})'$, $\boldsymbol{b}_1 = (b_{11}, b_{21}, b_{31}, b_{41})'$, and $\boldsymbol{\beta}_{ov}$ is the over-identified cointegrating matrix:

$$\boldsymbol{\beta}_{ov}' = \begin{pmatrix} 0 & 1 & 0 & 0 & -\phi_{11} & \phi_{11} & 0 & 0 & \phi_{12} & -1 \\ 0 & -\phi_{22} & 0 & 0 & \phi_{21} & -1 & 0 & 0 & 0 & \phi_{22} \\ 0 & -\phi_{34} & \phi_{33} & 0 & 0 & 0 & \phi_{32} & \phi_{31} & -1 & \phi_{34} \\ 0 & -\phi_{42} & 0 & \phi_{41} & -1 & 0 & 0 & 0 & 0 & \phi_{42} \end{pmatrix}$$

Thus far, very little has been said about the nature of the deterministic time trends included in the long-run relationships and captured by the vector $\boldsymbol{b}_1$. Allowing for the presence of deterministic trends in the long-run provides a general framework that can accommodate the possibility that b_3 may be non-zero as a result of economic growth. Equally, it is possible that the variables in the model may co-trend. These hypotheses can be easily investigated empirically.

4.3 The dataset

The dataset consists of 95 quarterly observations for the US economy between 1985Q1 and 2008Q3 on the following variables: the real price of crude oil (p_t^o); potential output

(y^*_t)[10]; Tobin's average q (q_t); productivity-adjusted wage inflation ($\Delta w_t - \Delta z_t$); consumer price inflation (Δp_t); the Federal funds rate (r_t); the real debt-service cost (d_t); corporate non-financial internal funds (f_t); real gross corporate non-financial investment (i_t); and real GDP (y_t). All variables are logged prior to estimation, and are depicted in the Appendix in Section C.3. Full details of the data sources and manipulations as well as our approach to computing potential output are recorded in the Data Appendix Section C.1 and the following sections in the Appendix.

We choose to end our sample before the switch to unconventional monetary policy in the US. The Global Financial Crisis saw drastic initial cuts in short-term nominal interest rates in the US, after which they have remained constant proximate to the zero lower bound and a combination of quantitative easing and forward guidance has emerged as the preferred policy. Consequently, it is generally acknowledged that no systematic relationship between the interest rate, inflation and output gap can be discerned in this period (Hofmann and Bogdanova, 2012). Bearing in mind that a key element of the FIH is the contention that manipulation of the interest rate may exacerbate financial fragility it would be inappropriate to estimate our model over the crisis period when no such manipulation has occurred. Rather, we will focus on the period leading up to the crisis, during which financial fragility built up and interest rate manipulation played a key role in macroeconomic management.

4.4 Estimation of the model

The order of the VAR model is determined in the normal manner using model selection criteria.[11] AIC favours the inclusion of two lags while SIC selects just one. Given this ambiguity we select the VAR(2) specification in the expectation of achieving a richer dynamic structure. Based on the simulated critical values tabulated by Harbo et al. (1998), small-sample adjusted trace statistics of Johansen indicate four cointegrating relationships (see the Appendix in Section C.2 for full results).

The derivation of the long-run structure above admits a number of modelling choices relating to the reaction function of the central bank, the nature of the inflationary process etc. The structure that receives the greatest support from the data is that in which the central bank does not respond to the output gap in the long-run and where inflation is

[10] We compute potential output using the production function approach in a similar manner to the Bank of Japan (2003). This approach has the advantage that it avoids the controversy surrounding estimation of the NAIRU which is inherently unobservable (c.f. Staiger et al., 1997). For the details see the Appendix on page 173

[11] The results are recorded in the Technical Annex which is available online. The figures reported result from the estimation of an unrestricted VAR model comprising y_t, r_t, Δp_t, $\Delta w_t - \Delta z_t$, i_t, f_t, d_t and q_t, as well as the exogenous variables y^*_t and p^o_t.

modelled as a cost-push phenomenon in the long-run where wage inflation changes are fully passed through to price level inflation. We also find that investment does not enter the IS curve in the long-run, although it will exert a short-run influence through the model dynamics. Finally, the inclusion of the oil price in both the IS curve and the monetary policy rule is found to improve the performance of the model. This is not surprising as it is well known that the oil price conveys a great deal of information about the global business cycle and that oil shocks can exert a lasting influence on productivity and potentially also on exchange rates, a point stressed by GLPS. Furthermore, it is widely believed that the monetary policy response to oil shocks differs from that prescribed by standard New Keynesian models, with recent research by Natal (2012) indicating that the central bank directly responds to oil price innovations, just as it does in our model.

For the reader's convenience and in the interest of clarity, the estimated long-run relations are:

$$y_t = b_{10} + \phi_{11}(r_t - \Delta p_t) + \phi_{13} y_t^* + \phi_{14} p_t^o + \xi_{1,t}\ , \quad \phi_{13} = 1 \tag{4.15}$$

$$r_t = b_{20} + \phi_{21}\Delta p_t + \phi_{22} p_t^o + \xi_{2,t} \tag{4.16}$$

$$i_t = b_{30} + \phi_{31} f_t + \phi_{32} d_t + \phi_{33} q_t + \phi_{34}(y_t - y_t^*) + \xi_{3,t} \tag{4.17}$$

$$\Delta p_t = b_{40} + \phi_{41}(\Delta w_t - \Delta z_t) + \xi_{4,t}\ , \quad \phi_{41} = 1 \tag{4.18}$$

while the over-identified long-run matrix $\boldsymbol{\beta}'_{ov}$ is estimated as follows:

$$\begin{pmatrix} -0.050 & 1.000 & 0.000 & 0.000 & 5.766 & -5.766 & 0.000 & 0.000 & 0.000 & -1.000 \\ -0.002 & 0.000 & 0.000 & 0.000 & 3.331 & -1.000 & 0.000 & 0.000 & 0.000 & 0.000 \\ 0.000 & -0.196 & 0.269 & 0.000 & 0.000 & 0.000 & -0.011 & 0.812 & -1.000 & 0.196 \\ 0.000 & 0.000 & 0.000 & 1.000 & -1.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \end{pmatrix}.$$

Finally, empirical testing provides little support for the inclusion of deterministic trends in either (4.1), (4.3), (4.4) or (4.9). Hence, $\boldsymbol{b}_1 = (0.000\ \ 0.000\ \ 0.000\ \ 0.000)'$.

Estimation of this over-identified structure involves the imposition of 36 restrictions on $\boldsymbol{\beta}$, representing $36 - 4^2 = 20$ over-identifying restrictions. The resulting likelihood ratio of 85.460 indicates that the over-identified structure is firmly rejected at the 10% level where the asymptotic critical value is 31.41. However, the poor performance of the LR test in small samples is well documented (c.f. GLPS, p. 140). Therefore, we employ non-parametric bootstrapping with 1999 iterations which results in a mean likelihood ratio of 51.667, and yields critical values of 70.540 (10%), 76.073 (5%), 81.860 (2.5%) and 90.023 (1%), thereby providing support for our over-identified structure. Furthermore, we verify the stability of the system by analysing the persistence profiles (available in the

Technical Annex), which show that a systemwide shock exerts only a *temporary* effect, after which the system returns to its equilibrium state (Lee and Pesaran, 1993).

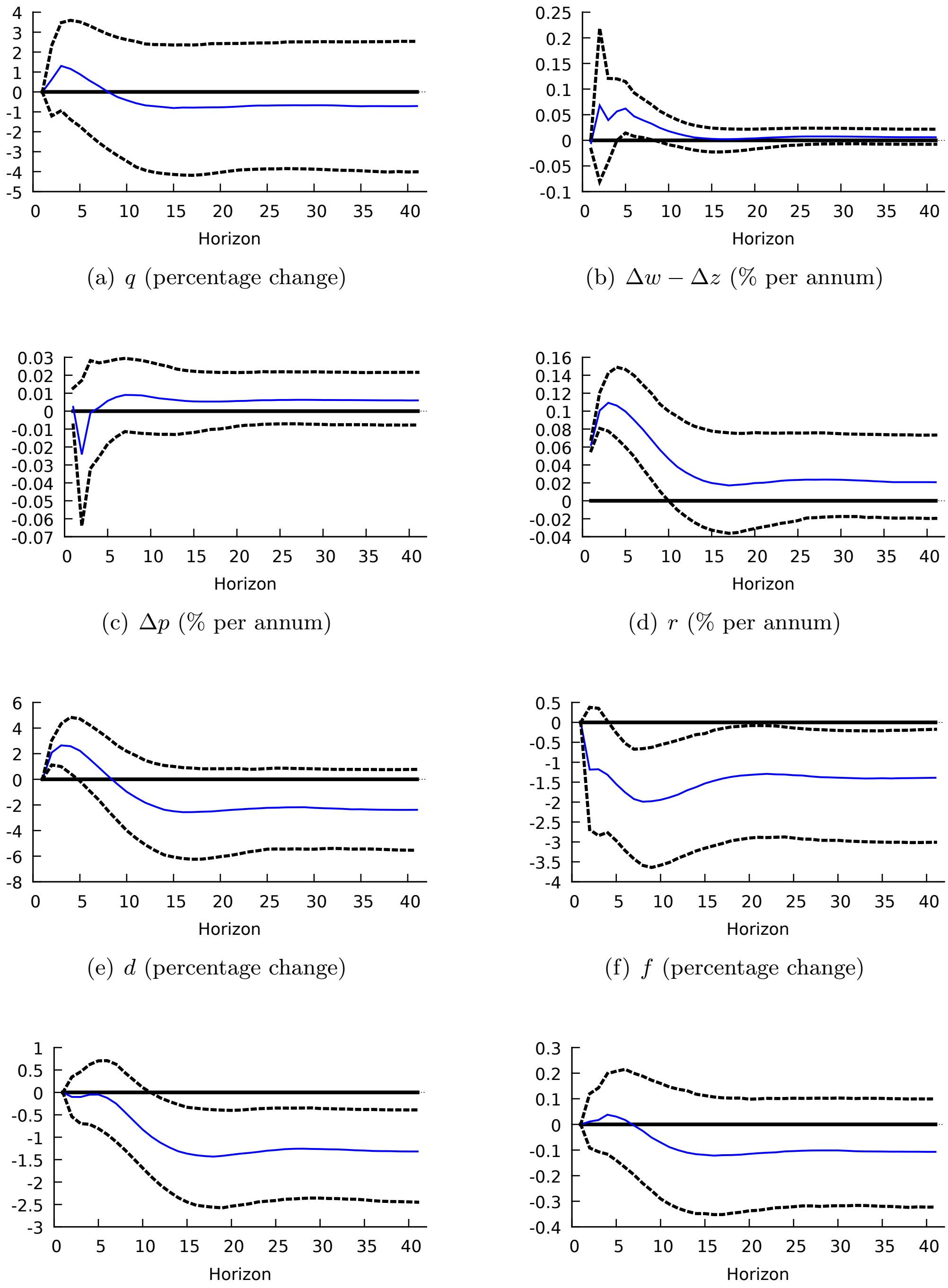
4.4.1 Dynamic analysis

A positive interest rate shock The principal concern of this paper is testing the central proposition of the FIH that the central bank may exacerbate financial fragility by pursuing anti-inflationary monetary policy. To this end, Figure 4.2 plots the orthogonalised impulse response functions (OIRFs) following a one standard deviation positive interest rate shock. The figures include bootstrapped 90% confidence intervals as an indication of statistical significance.[12] Recall that OIRFs have a structural interpretation conditional on the ordering of the variables in the system (more accurately a Wold-causal interpretation) and that shocks to non-stationary variables can have permanent effects in cointegrating systems, so the OIRFs need not asymptote to zero as the horizon increases. We also report orthogonalised forecast error variance decompositions (OFEVDs) in Figure 4.3. The OFEVDs show the percentage of the h-step-ahead forecast error variance (FEV) for each variable in the system attributable to each other variable. As such, they provide valuable supplementary information about the interlinkages among the variables in the model.

The OIRFs provide strong evidence that a positive interest rate shock is associated with an immediate increase in the real cost of debt servicing. This finding is strongly consistent with the recent results of Drehmann and Juselius (2012) who show that changes in the central bank's short-term interest rate are transmitted to the real economy by changes in debt service costs in Europe. The observed increase is significant for approximately four quarters before it dies out. After a short delay, the policy shock is also associated with a lasting reduction in firms' internal funds and investment demand in a manner broadly consistent with the balance sheet effects stressed by the credit channel literature. Similarly, the OFEVD for debt-service cost reported in Figure 4.3(e) indicates that approximately 60% of the FEV is explained by interest rate innovations in the short-run and that this proportion falls but nevertheless remains non-neglible in the long-run. By contrast, the OFEVD for firms' internal funds (Figure 4.3(f)) indicates a relatively small role for interest rates, with the large majority of the FEV being attributable to internal funds themselves in the short-run and q in the long-run.

These results are consistent with the FIH. Recall the definitions of the current and intertemporal financial ratios offered by Sordi and Vercelli (2006) and discussed in Section 4.2. It is clear that the combination of increasing cash-outflows and falling cash-inflows

[12] These intervals are based on the non-parametric method allowing for parameter uncertainty with 1999 bootstrap iterations.



(a) q (percentage change)

(b) $\Delta w - \Delta z$ (% per annum)

(c) Δp (% per annum)

(d) r (% per annum)

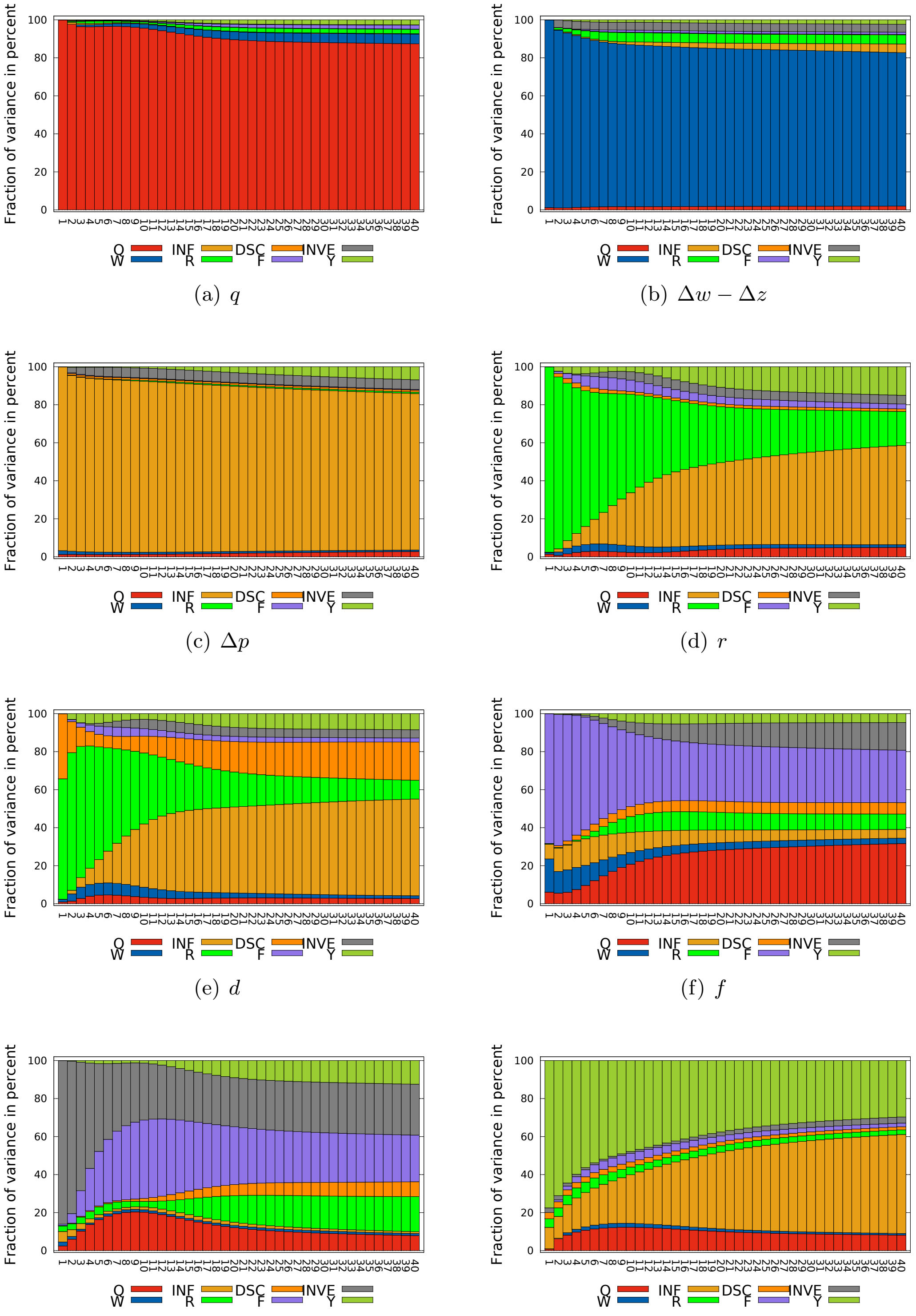
(e) d (percentage change)

(f) f (percentage change)

(g) i (percentage change)

(h) y (percentage change)

FIGURE 4.2: OIRF of a positive shock to the interest rate on all variables with 90% bootstrapped confidence intervals (bootstrapped median value)



(a) q (b) $\Delta w - \Delta z$

(c) Δp (d) r

(e) d (f) f

(g) i (h) y

FIGURE 4.3: FEVD of all variables, in %. q, $\Delta w - \Delta z$, Δp, r, d, f, i and y refer to Tobin's q, the rate of wage inflation, price inflation, the interest rate, debt-servicing costs, cash flow, investment demand and aggregate output

will cause k_t to increase for the representative firm. Moreover, as agents' expectations are revised in light of the new higher interest rate, it follows that k_t^* will also increase. At the aggregate level, this will be reflected by a general shift through the hedge-speculative-Ponzi spectrum and by the prevalence of increasingly fragile financing arrangements.

Interestingly, we find that the interest rate innovation exerts no statistically significant effect on either Tobin's q or real output, although it does depress real investment with a moderate lag. The resilience of the stock market and real output is likely to be linked, and is related to the results obtained by Angeloni et al. (2003). The authors estimate a VAR model for the US economy for the period 1984 to 2001 and find that, while private investment responds negatively to a monetary policy shock, neither private consumption nor aggregate demand show any significant response. Similarly, Boivin et al. (2010) find that an unexpected federal funds rate shock has no significant effect on real GDP based on their estimation of a factor augmented VAR as well as a simple three-equation VAR model for the US economy for the period 1984 to 2008.

Finally, we observe a very mild and short-lived positive reaction of productivity-adjusted wage inflation to the shock. This is consistent with the observation that labour productivity is highly procyclical while wages show a high degree of persistence and are downwardly sticky. Therefore, the positive response may result from a combination of falling productivity and relatively stable wage payments. By contrast, we observe no significant effect on price-level inflation based on the GDP deflator, a result which is again consistent with the findings of Boivin et al. and which links to the growing debate over the relative importance of good policy as opposed to good luck during the Great Moderation.

A positive inflation shock In order to assess the implications of the long-run cost-push inflationary process specified above, Figure 4.4 presents OIRFs for all variables in response to a positive inflation shock. Such a scenario may result from changes in inflation expectations or from an adverse supply shock, for example. The shock has significant effects on both price inflation and wage inflation (in the latter case only in the long-run), debt-servicing costs, the interest rate and aggregate output, but not on the remaining variables in the system.

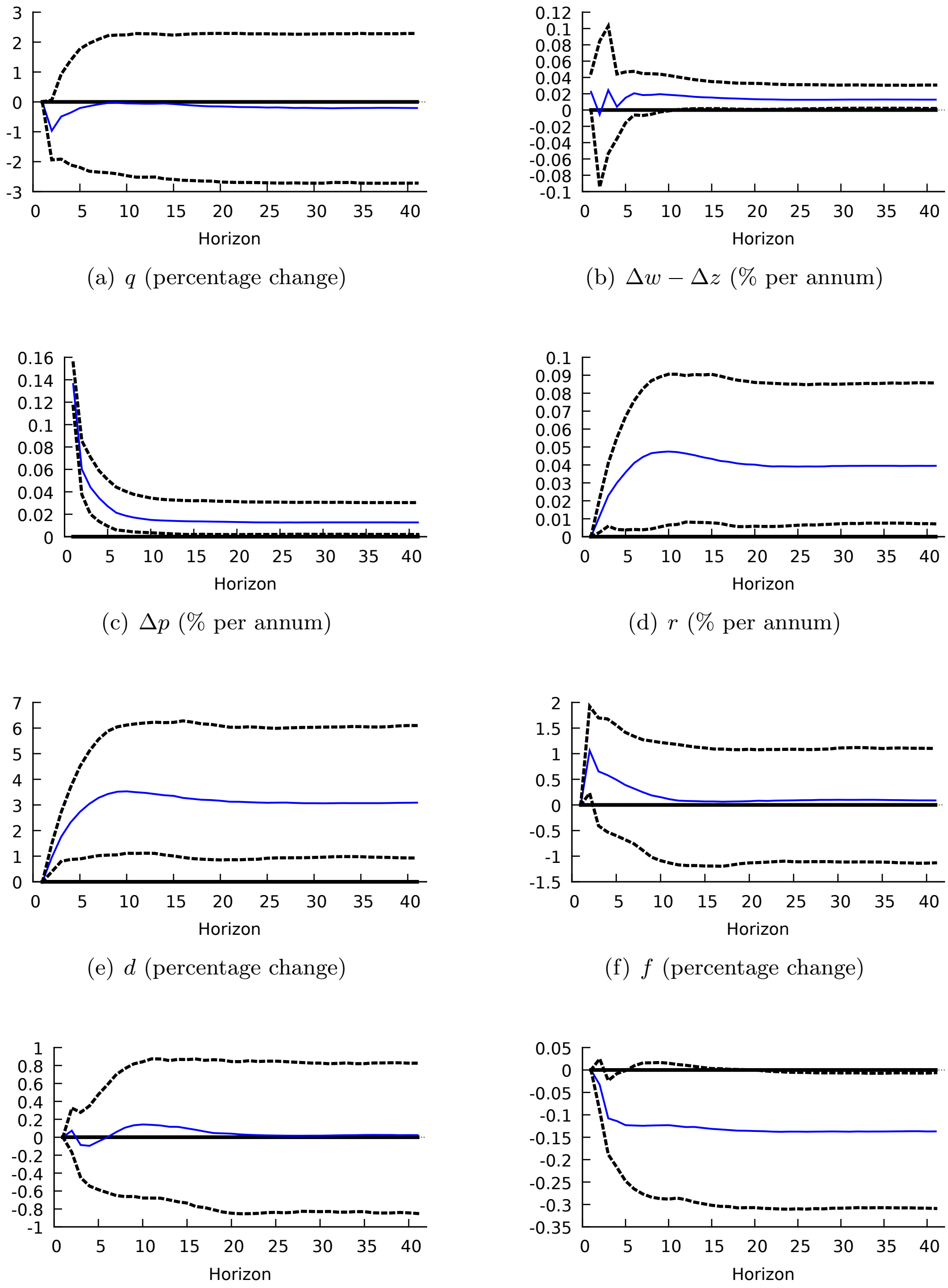
The two most important results are the positive responses of the nominal interest rate and the cost of debt-servicing to the inflation shock. The former reflects the systematic operation of anti-inflationary monetary policy during the sample period given the well documented *de facto* inflation targeting mandate of the Federal Reserve. This is also reflected in the FEVDs reported in Figure 4.3(d) which show that inflation innovations explain approximately 50% of the total FEV for the interest rate in the long-run. This is a very large proportion when one considers that the majority of the interest rate FEV is accounted for by the interest rate itself, a result which is strongly consistent with the well established literature on inertial monetary policymaking.

Our finding that the shock exerts a profound and persistent positive effect on the real cost of debt-servicing is very interesting and is certainly consistent with the remarkable increase in business borrowing over our sample period given that inflation remained low and stable for the majority of this time (i.e. low inflation rates were associated with low interest rates and rapid growth of the debt stock). The observed positive response is likely to be driven by different forces in the short-run as opposed to the long-run. In the short-run, the inflationary erosion of the loan principal may encourage firms to take on more debt.[13] Such behaviour is consistent with opportunism on the part of firms which act to exploit the benefits that a high inflation environment affords borrowers. In the longer-term, as a result of inflation-targeting monetary policy, the real interest rate faced by borrowers increases. This can be readily seen in the OIRFs as the long-run response of inflation to the shock is smaller than that of the nominal interest rate. In the longer-term, firms are therefore faced with higher ongoing costs of servicing their debts. The interpretation of the remaining OIRFs is generally straightforward. The inflationary shock is associated with mild wage inflation in the long-run, in keeping with the nature of wage settlements and wage indexation in modern economies. Meanwhile, the shock exerts a contractionary influence on economic activity in the long-run reflecting the contractionary increases in both the nominal and real rates of interest triggered by the inflationary pressure.

'Irrational Exuberance' Finally, the model can be used to investigate the nature of so-called *irrational exuberance* (Greenspan, 1996). Figure 4.5 presents OIRFs of all variables to a positive shock to Tobin's q, reflecting the inflation of equity prices relative to the replacement cost of capital assets. Firstly, it is important to note the significant increase in both realised output and real investment which last for between nine and twelve quarters. From a Minskyan perspective, this reflects a generally euphoric market sentiment associated with robust demand and minimal financing constraints. The importance of innovations to Tobin's q in explaining the variance in private investments and aggregate output is also clearly reflected in Figures 4.3(g) and 4.3(h).

Given the expansionary nature of the shock, it is not surprising to note that it exerts a significant positive effect on the interest rate. Importantly, however, the shock has no noticeable effect on the rate of inflation; indeed, the FEVDs reported in Figure 4.3(c) suggest that variations in Tobin's q contribute a negligible proportion of the FEV for the

[13] The reasoning is as follows: if Δp_t increases by more than r_t, then for $(r_t - \Delta p_t)\, l_t$ to remain constant, l_t must increase.



(a) q (percentage change)

(b) $\Delta w - \Delta z$ (% per annum)

(c) Δp (% per annum)

(d) r (% per annum)

(e) d (percentage change)

(f) f (percentage change)

(g) i (percentage change)

(h) y (percentage change)

FIGURE 4.4: OIRF of a positive shock to inflation on all variables with 90% bootstrapped confidence intervals (bootstrapped median value)

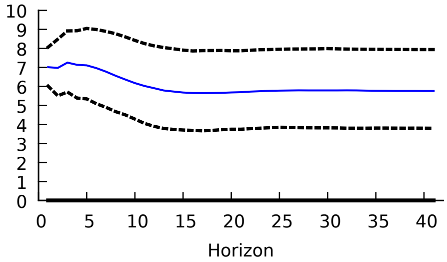
inflation equation. Interestingly, it is also the case that q does not contribute significantly to the interest rate FEV (Figure 4.3(d)). As noted above, however, the shock exerts a powerful influence on both real output and real investment, both of which do contribute significantly to the interest rate FEV. This suggests that the effect of Tobin's q on the interest rate may come about indirectly. These findings are intimately linked with the extensive literature on the optimal monetary policy response to the stock market. Recall that a central bank pursuing a pure inflation targeting strategy would *not* respond to a stock market shock unless it was reflected in a change in its targeted inflation index – here, that is not the case. By contrast, it follows that a central bank whose reaction function includes an output term such as the rate of output growth or the output gap may raise rates in this case as the shock exerts a non-negligible expansionary influence on economic activity. Hence, there may be good reasons for the inclusion of the output gap in monetary policy rules if one believes that interest rates should indirectly respond to conditions in the asset markets.

Figures 4.5(f) and 4.3(f) reveal a strong negative response of internal funds to the Tobin's q shock, a finding which seems counter-intuitive at the first glance. However, careful consideration of the definition of the internal funds employed here offers a plausible explanation. Internal funds are defined as profits after corporate income tax plus capital consumption allowance minus net dividends. Therefore, a negative response of f may arise if dividend payouts increase more strongly than profit income in response to an asset price shock. Such a procyclical effect of dividend payouts is in line with recent findings by Covas and Haan (2011) who study the cyclical behavior of debt and equity finance of US firms. Firms are inclined to increase dividend payouts as they do not face such restrictive conditions when accessing external capital as their net worth position improves as well.

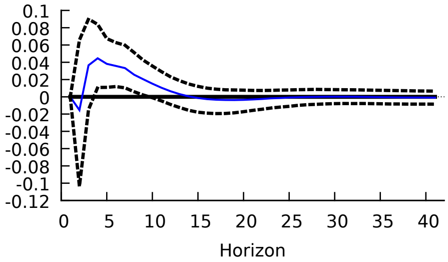
4.5 Implications for monetary policy

Our analysis highlights the close linkage between speculative excesses and financial fragility, thereby furnishing an *a priori* case for policies aimed at curbing financial cycles. While Schwartz (2002, p. 23) stresses that the central bank "is not the arbiter of the correct level of asset prices", it has become clear through recent events that financial markets are unlikely to deliver stability in the absence of policy or regulatory intervention. The underlying issue is not the desirability of avoiding boom-bust cycles but rather the issue of how to achieve this end.

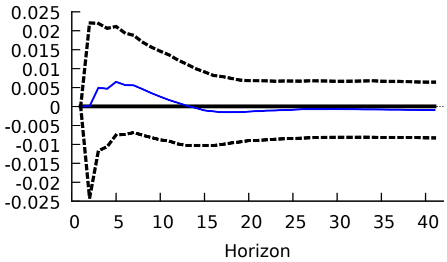
The dominant view prior to the GFC was that the short-term interest rate should not be used to prick nascent bubbles. In support of this view, it was widely asserted that



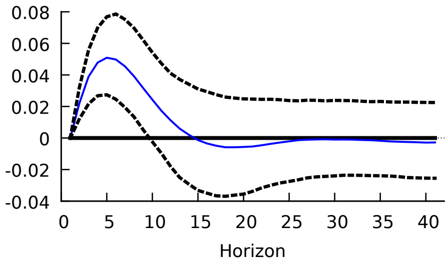
(a) q (percentage change)



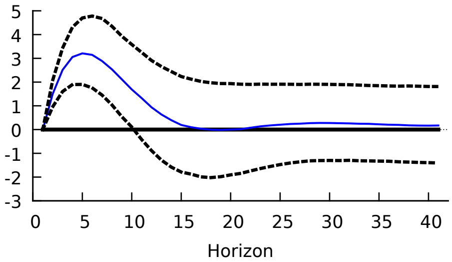
(b) $\Delta w - \Delta z$ (% per annum)



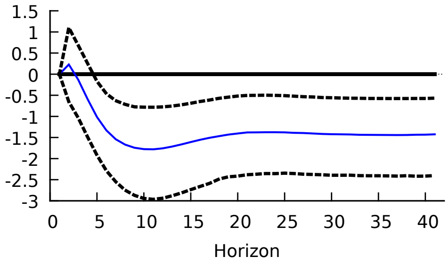
(c) Δp (% per annum)



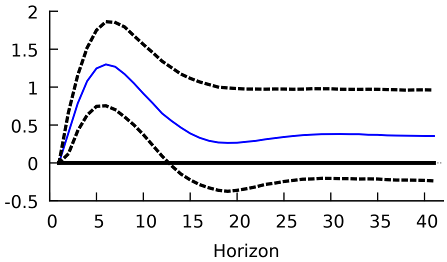
(d) r (% per annum)



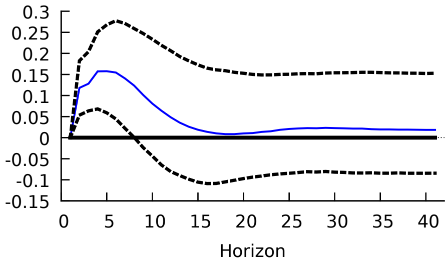
(e) d (percentage change)



(f) f (percentage change)



(g) i (percentage change)



(h) y (percentage change)

FIGURE 4.5: OIRF of a positive shock to Tobin's q on all variables with 90% bootstrapped confidence intervals (bootstrapped median value)

bubbles have proven notoriously hard to identify *ex ante* (Gurkaynak, 2008) and that the cost-benefit analysis of pricking a bubble via a rate hike would typically be unfavourable due to the collateral damage inflicted on non-bubble sectors (Nickell, 2005; Posen, 2006). Instead, it was believed that monetary policy should strive to stabilise the price level which would yield commensurate gains in financial stability (Schwartz, 1998)[14] and that, in the event of a bubble, policy should aim to "mitigate the fallout when it occurs and, hopefully, ease the transition to the next expansion" (Greenspan, 2002).

While this was the majority view, it was not universal. Roubini (2006) argued that asset market indicators should enter the objective function directly while Goodhart (2001) proposed that the targeted measure of inflation entering the policy rule should include various asset prices, appropriately weighted. However, our model cautions against the use of the interest rate to influence the trajectory of asset prices because interest rate changes alter firms' cash commitments and may thereby exacerbate the frailty of firms' financing arrangements (a related point is made by Korinek and Simsek, 2014). Furthermore, in the words of the former and current Fed Chairmen Bernanke (2006) and Yellen (2014), the interest rate is a 'blunt tool' incapable of addressing individual overheated markets. Nonetheless, the repeated emergence of bubbles during the Great Moderation – notable as a prolonged period of price stability – suggests that the mechanism described by Schwartz (1998) is insufficient to deliver financial stability. We therefore advocate the management of asset cycles without recourse to the interest rate.

In the era of unconventional monetary policy, it is clear that the central bank possesses alternative policy instruments that may be used to smooth asset cycles in a targeted fashion. In the aftermath of the GFC, unconventional policy measures including quantitative easing and forward guidance have proven highly effective in restoring confidence in financial institutions and markets (Bernanke, 2012). Similarly, the opening of longer-term credit facilities in order to restore liquidity and reduce interest rate spreads in response to the crisis is consistent with Minsky's (1986a, p. 354) advocacy of the accommodative use of the discount window.

Looking to the future – and anticipating the next boom – macro-prudential policies aimed at limiting excessive credit growth and restraining asset price inflation are once again set to play a key role in mitigating the emergence of systemic risk (Elliott et al., 2013; **?**). Macro-prudential policies to curtail excessive credit creation and to maintain the creditworthiness of borrowers may be directed at either lenders, borrowers or both. On the lenders' side, Schwartz (2002) provides an early contribution outlining the role of capital

[14] Schwartz argues that instability of the price level (particularly disinflation) may cause financial instability. She stresses that it may exacerbate informational asymmetries and introduce greater uncertainty in the lending process, particularly as it hampers attempts to accurately evaluate the expected returns to debt-funded investment projects.

requirements, stressing that the use of quantity constraints to curtail unsafe lending in excessively bullish markets directly protects the portfolios of financial institutions from large corrections in the value of collateral assets. Such countercyclical capital requirements underpin the Basel III framework. Meanwhile, on the borrowers' side, capping the loan-to-value ratio can strengthen borrowers' incentives to manage funds responsibly by increasing their own stake in debt-funded projects and also reduces bank losses in the event of default. Similarly, capping the debt-to-income ratio may prevent the emergence of Ponzi financing.

Crucially, policymakers can set capital requirements and caps on borrower's key ratios that differ across markets or categories of borrower. In contrast to interest rate policy, macro-prudential policy represents a sharp and precise instrument which can accurately target an overheated market to prevent the inflation of a bubble without imposing unnecessary costs on other sectors. For example, the Bank of Canada has recently imposed such limits on mortgage lending and has succeeded in constraining credit growth and house price inflation (Krznar and Morsink, 2014).

By judicious use of such measures, policymakers can maintain financial stability while leaving conventional monetary policy largely free to focus on price stability and full employment. However, an important caveat arises due to the linkage between interest rate innovations and financial fragility. When adjusting the interest rate, policymakers should strive to avoid generating large *unexpected shocks* which may precipitate a deterioration in the soundness of the financial system. In some cases, this may constrain their ability to pursue anti-inflationary interest rate policy. However, if agents are well informed about the state of the economy and the objectives of the central bank then they will be better able to forecast and plan for policy innovations that may impact upon their financial stability, lessening the degree to which interest rate changes may endanger their solvency. Hence, as stressed by **?**, the transparency of policy decision-making and the clarity of central bank communications will play a key role.

4.6 Concluding remarks

This paper has developed a small macroeconomic model embodying many of the key attributes of the Minskyan Financial Instability Hypothesis. The model is composed of a simple IS curve, an inflation-targeting interest rate rule, an investment function inspired by that of Godley and Lavoie (2001), and a mark-up pricing rule. This theoretical framework was then imposed as the over-identifying long-run structure in a VECM.

The results suggest that the manipulation of the interest rate by the central bank in order to achieve an inflation target may contribute to the financial fragility of leveraged firms. Raising the interest rate reduces firms' internal funds while increasing their debt-burden, thereby undermining their ability to service existing debt. Furthermore, the results indicate that price level inflation may not capture conditions in the financial markets, an observation which is consistent with the combination of low and stable price level inflation and high levels of asset price inflation experienced by many developed countries during the Great Moderation. This suggests that if monetary policymakers respond solely to fluctuations in the rate of price level inflation, they will not react to the inflation of nascent asset market bubbles. By contrast, our results suggest that where policymakers also respond to the output gap then they will indirectly respond to asset market conditions as well. Our results therefore highlight an important practical distinction between a pure inflation targeting mandate and a dual mandate.

Our findings raise the difficult issue of how policymakers can approach the smoothing of asset cycles and the management of nascent bubbles. We conclude that the central bank must acknowledge that conditions in financial markets may impose constraints on its freedom to pursue anti-inflationary interest rate policy and that it must remain mindful of its fundamental responsibility to maintain financial stability. Furthermore, by employing macro-prudential policies including countercyclical capital requirements, the central bank would gain the ability to target overheated markets in a manner that would strengthen the balance sheets of financial institutions while simultaneously reducing the speculative excesses that are among the main drivers of financial fragility. By pursuing this combined approach, uncertainty in credit markets may be reduced and the monetary authority would gain the power to achieve multiple goals in a manner consistent with the targets-and-instruments approach originated by Tinbergen (1952).

Appendix A

Appendix to Chapter 2

A.1 Data description

The list of industrial sectors considered is provided in Table A.1 below.

Industrial sectors included
Mining and quarrying
Manufacturing
Electricity, gas, steam and air conditioning supply
Water supply, sewerage, waste management and remediation act
Construction
Wholesale and retail trade; repair; repair of motor vehicles and motorcycles
Transportation and storage
Accommodation and food service activities
Information and communication

Table A.1: Overview of industries considered in the dataset

Variable definition and sources All data are taken from the Creditreform DAFNE database, as long as not differently stated.

Investment to capital stock ratio, $ik_{i,t} = \frac{\Delta K_{i,t}}{K_{i,t-1}} = \frac{I_{i,t}}{K_{i,t-1}}$, is the ratio of the change in tangible fixed assets over tangible fixed assets of the previous period. Tangible fixed assets consists of land, property, plant and equipment.

Cash flow over tangible fixed assets, $cf_{i,t} = \frac{Cf_{i,t}}{K_{,t-1}}$, is the ratio of profits after taxes and interest over tangible fixed assets of the previous period.

Depreciation on fixed assets over tangible fixed assets, $d_{i,t} = \frac{D_{i,t}}{K_{,t-1}}$. The depreciation on fixed assets had to be imputed due to missing values for all units calculating it alternatively by: depreciation on total assets weighted by the ratio of tangible fixed assets to total assets. This approach closely follows Engel and Middendorf (2009).

Real return on investment $roi_{i,t}$ is the nominal return on investment minus GDP inflation rate (AMECO: PVGD).

Growth of real sales revenue, $gt_{i,t}$, where nominal sales revenue is deflated by GDP price level (AMECO: PVGD).

Log of the number of workers per firm, $w_{i,t}$.

Total liabilities to total equity ratio, $lev_{i,t}$.

Total liabilities minus short-term liabilities (maturity up to one year) to total equity ratio, $lglev_{i,t}$.

Interest coverage ratio, $intcf_{i,t}$, equals interest expenditures minus interest income to cash flow ratio, $intcf_{i,t} = \frac{Int_{i,t}}{Cf_{,t}}$

Solvency measures the cash flow to total liability ratio, $solvency_{i,t}$.

Collateral equals the sum of total inventory stock, tangible assets plus cash available at hand or at bank, over total tangible assets, $collat_{i,t}$.

Liquidity is the ratio of cash at hand over short-term debt, $liquidity_{i,t}$.

GDP output gap, gdp_t, (AMECO: AVGDGP).

Great Financial Crisis, gfc_t, is dummy variable which takes unity for observations $T \geq 2008$, otherwise zero.

Screening procedure The following screening procedure has been applied to the data to avoid excessive outliers or further implausible values.

- Drop observations with negative values for the following variables: w, lev, $lglev$, $liquidity$, $collat$ and $dyndebtshare$.
- Drop observations for which $w \leq 0$.
- Drop observations of the 5% and 95% percentiles of the following variable: ik, $intcf$, $solvency$, $liquidity$, $lglev$, lev, $collat$, $dyndebtshare$, $factor1$ and $factor2$.
- Drop observations of the 97.5% percentiles of the following variable: w, roi.
- Drop observations of the 95% percentiles of the following variable: cf, d.
- Drop observations of the 2.5% and 97.5% percentiles of the following variable: gt.

A.2 Tables

Component	**Eigenvalue**	**Proportion**	**Cumulative**
1	2.952	0.422	0.422
2	1.327	0.190	0.611
3	0.961	0.137	0.749
4	0.745	0.107	0.855
5	0.531	0.076	0.931
6	0.318	0.045	0.976
7	0.166	0.024	1.000

Component loading	**PC1**	**PC2**	**PC3**	**PC4**	**PC5**	**PC6**	**PC7**
lev	0.472	0.230	-0.412	0.130	-0.149	-0.007	0.718
lglev	0.404	0.419	-0.466	0.018	0.055	0.086	-0.658
intcf	0.405	-0.255	0.276	-0.041	-0.809	-0.060	-0.187
collat	-0.029	0.588	0.508	0.620	-0.051	-0.093	-0.002
solvency	-0.470	0.121	-0.245	0.136	-0.423	0.711	0.024
liquidity	-0.185	0.587	0.142	-0.723	-0.205	-0.161	0.102
dyndebtshare	0.440	0.019	0.446	-0.236	0.312	0.670	0.074

NOTE: Eigenanalysis of the correlation matrix. The variables *lev*, *lglev*, *intcf*, *collat*, *solvency*, *liquidity* and *dyndebtshare* refer to leverage, long-term leverage, interest-coverage ratio, collateral, solvency, liquidity and the dynamic debt share.

TABLE A.2: Principal components analysis. Sample: 2006–2012.

A.3 A simple model with monitoring costs

The introduction of the following model is mainly based on Romer (2011, ch. 9.9) and Townsend's (1979) *costly state verification* approach to asymmetric information. A representative risk-neutral firm (a standard assumption in the literature) has the opportunity to invest in a project. The investment requires one unit of resources, but the firm's wealth W is less than unity, $0 < W < 1$. The firm must obtain $1 - W$ units of outside finance to realize the project. Each outside investor possesses more wealth than $1 - W$, to make sure that each project is financed by a single investor ruling out further complications. The success of a project is uniformly distributed on the support $[0, 2\gamma]$ and may differ in the expected value, $\gamma > 0$, across firms. The investor must bear some of the project's risk as the firm's wealth is completely invested. Hence, the payment to the investor cannot exceed the actual outcome (limited liability case).

The firm can invest its wealth at a risk-free rate r. Thus, the risk-neutral firm will only invest if the expected net return of the project is greater than the return on the risk-free asset:

$$\underbrace{\gamma - E[\text{payments to investor}]}_{\text{net return}} > (1 + r)W \; .$$

The outside investor is risk-neutral, and faces a competitive market. He can also invest at the risk-free rate. This implies that in equilibrium the investor's expected return on any investment must be r. It is assumed that the *ex post* project outcome is only observed by the firm without additional costs. The investor, however, must pay a positive cost $0 < c < \gamma$ to observe output which is less than expected output γ. This framework is known as costly state verification.

Under asymmetric information the form of the contract can be described as follows. For the given assumptions of a risk-neutral investor operating on a competitive market, the expected payment to the outside investor must equal the receipts on an alternative risk-free asset plus the expected verification costs. The latter will be determined later:

$$E[\text{payments to investor}] = (1 + r)(1 - W) + E[\text{verification costs}] \; .$$

Thus, the firm's expected income is given by the difference between expected output and expected payments to the investor:

$$\gamma - E[\text{payments to investor}] \; .$$

The optimal contract minimizes the verification costs, while providing the outside investor with the required rate of return, r. The payment function of the optimal contract is a debt contract. If actual output exceeds some level D (which is derived below), the firm pays D to the investor and keeps the surplus. If actual output is lower than D, the investor does pay the verification costs and takes all of output. The investor's required rate of return must equal the expected payments by the firm minus the expected verification costs which must equal the return on a risk-free asset:

$$E[\text{payment to investors}] - E[\text{verification costs}] = (1+r)(1-W) \ .$$

The equilibrium value of D provides the investor with the required rate of return. Before the equilibrium value is determined, it is shown how the investor's net receipts vary with the value of D. In the first case we suppose that D is less than the projects maximum outcome, 2γ. The actual outcome can either be higher than D or lower. The probability that actual outcome exceeds D is $(2\gamma - D)/(2\gamma)$, in which case the investor does not verify the output and receives D. If output is lower than D, the investor wants to verify the actual outcome which occurs with probability $D/(2\gamma)$. The average output, conditional on this case, is $D/2$ for a given uniform distribution. If D exceeds 2γ, output is always less than D, which implies that the investor always pays verification costs and receives total output. In this case the expected payment is γ minus verification costs c.

This can be summarized as follows and gives an overview of the investor's expected receipts minus verification costs, $R(D)$:

$$R(D) = \begin{cases} \frac{2\gamma - D}{2\gamma} D + \frac{D}{2\gamma}\left(\frac{D}{2} - c\right) & \text{if } D \leq 2\gamma \\ \gamma - c & \text{if } D > 2\gamma \ . \end{cases} \tag{A.1}$$

The return increases in D only up to a certain point. Taking the first derivative with respect to D one obtains for $D \leq 2\gamma$

$$\frac{dR}{dD} = 1 - \frac{c}{2\gamma} - \frac{D}{2\gamma} = 2\gamma - c - D \tag{A.2}$$

which shows that the investor's expected net revenue, R, increases in D until $D = 2\gamma - c$. A further increase in D lowers the expected net revenue as the net amount is less than $2\gamma - c$. Thus, in case output is larger than $2\gamma - c$ the investor is better of if he accepts a payment of $2\gamma - c$ without verification in comparison to a situation where the investor would demand $D > 2\gamma - c$. In this latter case he needs to pay verification costs which reduces the net amount received.

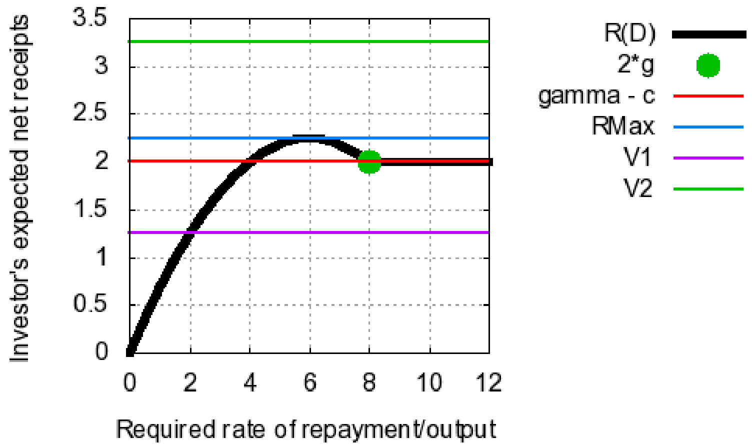


FIGURE A.1: The investor's expected revenues net of verification costs for $\gamma = 4$ and $c = 2$

In order to determine the maximum of the expected net revenues, replace D in eq. (A.1) by $D = 2\gamma - c$. The maximum is given by $R^{MAX} \equiv (\frac{2\gamma - c}{2\gamma})^2\gamma$ and equals expected output if $c = 0$. However, for positive verification costs, $c > 0$, expected revenues decrease by c. For $D = 2\gamma$ expected revenues become $\gamma - c$, as the investor pays verification costs and takes total output.

The $R(D)$ function for specific values of γ and c is provided in Figure A.1. The plot illustrates two possible values of the investor's required net receipts, $(1 + r)(1 - W)$. In case the net receipts are less than $\gamma - c$, e.g. equal to $V1$, there is a unique value of D that yields the investor's required net revenues. For instance, for $V1$ the equilibrium value of D is given by $D = 2$.

This simple model also incorporates a kind of *credit rationing* situation: If the required net revenues exceed R^{MAX}, e.g. $V2$, no value of D exists which satisfies the necessary conditions of the investor. The investor is not willing to lend to the firm at any interest rate (Romer, 2011, p. 441).

Solving $R(D) = (1 + r)(1 - W)$ for D yields the equilibrium value, D^*, which equates the investor's net receipts and the return on a risk-free asset:

$$D^* = 2\gamma - c - \sqrt{(2\gamma - c)^2 - 4\gamma(1 + r)(1 - W)} \quad \text{(A.3)}$$

for $(1 + r)(1 - W) \leq R^{MAX}$.

Finally, one needs to determine under which conditions the firm is willing to undertake the project. One of the two necessary conditions is that expected output minus expected payments to the investor including expected verification costs, A, need to be larger than the return on a safe asset. The calculation requires that we first determine expected verification costs.

The investor only pays verification costs when actual output is less than D^*, which occurs with probability $D^*/(2\gamma)$. Given the formula for D^* by eq. (A.3) and after some rearrangement, we obtain the determination of *expected agency costs*:

$$A = \frac{D^*}{2\gamma}c = \left[\frac{2\gamma - c}{2\gamma} - \sqrt{\left(\frac{2\gamma - c}{2\gamma}\right)^2 - \frac{(1+r)(1-W)}{\gamma}}\right] c \; . \tag{A.4}$$

The first derivatives are given by:

$$A = A(c, r, W, \gamma) \; , \qquad A_c > 0, \qquad A_r > 0, \qquad A_W < 0, \qquad A_\gamma < 0 \; . \tag{A.5}$$

Expected agency costs are positively related to c and r, and negatively to the firm's wealth level, W, as well as the expected output, γ. Thus, the firm's expected receipts are given by the left-hand side of the following expression:

$$\gamma - (1+r)(1-W) - A(c, r, W, \gamma) > (1+r)W \; . \tag{A.6}$$

The firm will only undertake the investment if its net receipt are larger than the return on a safe asset. Furthermore, $(1+r)(1-W) \leq R^{MAX}$ needs to be fulfilled.

The partial derivatives of agency costs in eq. (A.5) as well as condition (A.6) have several important implications on firm investment. We have shown that asymmetric information makes external finance more costly. Under symmetric information the project will be realized if $\gamma > 1 + r$, but if agency costs occur, expected output has to exceed the return on the safe asset plus agency costs, $\gamma > 1 + r + A(c, r, W, \gamma)$. Thus, conditional on the safe interest rate agency costs will reduce investment by restricting the maximum credit supply.

Variations in the business cycle not only affect investment demand through its impact on future profitability, as they do in the standard model of perfect financial markets. Changes in actual output reduce the firm's internal finance (a proxy for wealth) which this has immediate effects on agency costs. A negative wealth shock to a firm means less collateral available which raises the firm's default probability and increases agency costs, leading to reduced investment, even if expected profitability (the distribution of γ) remains unchanged.

Monetary policy changes not only affect investment through its effect on the user cost of capital[1], but have an additional impact on agency costs. An increase in the risk free rate r raises the firm's payments to the investor, $(1 + r)(1 - W)$ and thus reduces the firm's surplus (available cash flow). This has a positive effect on its default probability implying higher agency costs. Similar to the wealth effect on agency costs, interest rate shocks may be amplified and become effective through more than one channel. This amplification mechanism was already described by Bernanke and Gertler (1989).

With perfect capital markets, investment depends solely on γ. However, if imperfections on the capital market are prevalent, investment additionally depends on wealth W. As wealth and expected output are heterogeneously distributed across firms, this may already imply a lower level of aggregate investment.

Another important implication refers to the role of the financial system itself. Agency costs arise due to asymmetric information of all kinds and as a result of market inefficiencies. Differently designed financial markets and creditor-debtor relationships may affect agency costs. For instance, asymmetric information may be lower if market transparency, legal standards and information flows could be enhanced. An additional aspect may refer to the polar designs of financial markets known as 'arm's-length-lending' vs. 'relationship-lending' financial systems.

[1] An increase in the user cost of capital means for the first-order condition of the profit-maximizing competitive firm to hold, that the capital stock has to decrease to make sure that the marginal revenue product equals the user cost of capital (Romer, 2011, p. 406).

A.4 A model with a risk-averse lender and credit rationing

The agents' planning horizon is a single period. A commercial bank grants loans to private companies. By assumption, loans are extended at the beginning of each period and have to be repaid at the very beginning of the next period. Credit is granted to finance a project for which (gross) cash flow is a random variable. The outcome of the investment project is defined as a random variable with realizations falling into the interval $[\underline{y}, \bar{y}]$ and probability distribution function $F(y) = \int f(y)dy$ with $F(\underline{y}) = 0$ and $F(\bar{y}) = 1$. The probability distribution function can also be named the *payback function*.[2] Both the creditor and the borrower posses full knowledge about the probability distribution of the project outcome, which rules out information information asymmetry.

In the literature information asymmetry is usually taken as a necessary assumption for the pledge of collateral, C, by the lender. And indeed, provided that the lender is risk-neutral then he should not have an interest in collateral provided hen can rule out opportunistic behavior by the borrower. In our case, however, the lender is risk-averse. We assume a partial collaterilization of his claim in order to get at least partial risk insurance.

Accounting for partial collateral, the creditor faces the following possible realizations of gross profits, R, from granting the loan K

$$R = \begin{cases} K(1+k) & \text{if } y \geq \hat{y} = K(1+k) - C \\ y + C & \text{if } y < \hat{y} \end{cases} \tag{A.7}$$

where k is the yield on a risk-free alternative and $\hat{y}$ refers to the amount of cash flow plus collateral sufficient enough to cover the lender's debt claim. Hence, the creditor will be exposed to a loss if $y + C < K(1+k)$, and losses $\tilde{L}$, too, will be a random variable with realizations falling into the interval $[0, \bar{L}]$ where $\bar{L} = \hat{y} - (\underline{y} + C)$.

The expected net return of the lender is given by the agreed refinancing costs under no default less the amount of the expected loss. The expected loss is described by the probability that the actual loan repayment is lower than the amount agreed upon minus collateral

$$E(R) = K(1 + i_K) - \int_{\underline{y}}^{\hat{y}} F(y)d(y) - K(1+k) \tag{A.8}$$

[2]This function depicts the probability that the creditor will earn at maximum the amount y. For instance, $F[K(1+k)]$ equals the probability that the project outcome y is just sufficient to cover the refinancing costs consisting of the loan volume K and the yield of a risk-free investment alternative k. Thus, the payback function provides the *actual* probabilities of a loss L up to the amount $\bar{L} = K(1+k) - (\underline{y} + C)$ (Fischer, 1986, p. 177).

where i_K denotes the lending rate, the integral describes the loss probability and $\hat{y} = K(1+i_K) - C$ is the amount of cash flow plus partial collateral sufficient to cover the lender's debt claim.

A risk-averse lender does not rule out any risk *per se* but is only willing to tolerate expected losses up to a specific level, even if the borrower offers to compensate the increasing risk by paying higher interest rates and in spite of partial collaterilization. Formally, this is reflected by an additional restriction which enters the credit supply decision and which expresses the lender's risk-aversion (see Größl-Gschwendtner et al. (1995)).

A polar case occurs if the lender does not tolerate any loss, $\bar{L} = L^{max} = 0$. In this case the credit supply limit equals the discounted minimum project outcome (expected to be certain):

$$L = K(1+k) - (\underline{y} + C) = 0 \tag{A.9}$$

$$\Rightarrow \bar{K} = \frac{\underline{y} + C}{1+k} \; . \tag{A.10}$$

The credit ceiling is positively related to $\underline{y}$ and value of collateral, but negatively to the opportunity cost k. By substituting $\bar{K}$ from eq. (A.10) into eq. (A.8) for K, the lender's expected net return under the *no-loss-tolerated* case becomes:

$$E(R)_{min} = (\underline{y} + C)\frac{(1+i_K)}{(1+k)} - \int_{\underline{y}}^{\tilde{y}} F(y)d(y) - (\underline{y} + C) \; . \tag{A.11}$$

The expected net return increases if the lender tolerates at least some credit loss (Größl-Gschwendtner, 1993, p. 124). Assume that the lender accepts losses up to $\bar{L} > 0$. In this case, the credit limit is the discounted sum of the project's minimum outcome plus collateral and the tolerated loss L:

$$K(1+k) = \underline{y} + C + \bar{L} \tag{A.12}$$

$$\Leftrightarrow \bar{K} = \frac{\underline{y} + C + \bar{L}}{1+k} \tag{A.13}$$

The maximum tolerated loss is given by:

$$L^{max} = K(1+k) - (\underline{y} + C) \tag{A.14}$$

but will only be realized as long as the actual project's outcome is lower than the minimum expected outcome plus partial collateral, $y < (\underline{y} + C)$.

Using credit risk evaluation techniques, a lender can estimate the (objective) probability distribution of losses. The degree of risk-aversion can be identified by the relationship between the amount of loss the lender tolerates and its associated probabilities of occurrences. While the payback function depicts the actual (objective) probability of expected losses up to $L^* = K(1+k) - (\underline{y}+C)$, the *risk frontier* depicts the tolerated (subjective) probability of losses up to L^*. In equilibrium tolerated and actual probability of losses equalize, and determine the amount of loss the lender is willing to accept. This in turn determines the credit volume the lender is willing to supply.

The risk-frontier can be expressed as:

$$w(L^*) = w(L - L^*) \qquad \text{with } L^* \leq \bar{L} \tag{A.15}$$

and has the following properties: First, increasing losses are only accepted for decreasing probabilities of occurrence, $w(L^*)$. The slope of this function depends on the lender's possibility to compensate losses by other businesses and on the (subjectively) expected minimum outcome, $\underline{y}$. This is depicted by the $w(L^*)$ schedule in Figure A.2 which can be convex as well as concave (Größl-Gschwendtner et al., 1995, 52). The risk-frontier implies that the creditor tolerates (infinitesimal) small amounts of loss, L^*, with a certain probability $\bar{w}$ which could be below unity.[3] However, a risk-averse creditor only accepts higher losses if its associated probability of occurrence, w, decreases. Thus, there is a threshold $L^* \geq \bar{L}$ beyond which he does not accept any loss such that $w(L^* \geq \bar{L}) = 0$. Excluding this extreme degree of risk-aversion does still imply that the creditor is only willing to bear losses up to some maximum amount $L^* \leq \bar{L}$. Correspondingly, as long as the actual (objective) probability of occurrence of the loss L^*, $F(L^*)$, is below the tolerated probability of this amount, $w(L^*)$, (all points left to point A) the creditor is willing to lend the associated amount of loan.

In equilibrium (point A), the risk-frontier, $w(L^*)$, and the payback function, $F(y)$, intersect and determine the maximum tolerated loss L^{max}. For given values of the opportunity cost k as well as $\bar{w}$, the minimum subjectively assumed safe project outcome $\underline{y}$, partial collateral C, and the shape of the repayment function $F(y)$, the maximum credit supply, K^{max}, can be determined for a specific L^{max} (see eq. A.13). This makes the loan supply maximum a function of a vector of parameters

$$K^{max} = K^{max}(k, \bar{w}, \underline{y}, C, \alpha) \tag{A.16}$$

[3]We define $\bar{w}$ as the tolerated probability of occurrence at which no loss is accepted anymore by the creditor.

where α refers to the ability of the lender to compensate losses by other businesses. The expected partial effects have the following signs $k' < 0$, $\bar{w}' > 0$, $\underline{y}' > 0$, $C' > 0$ and $\alpha' > 0$.

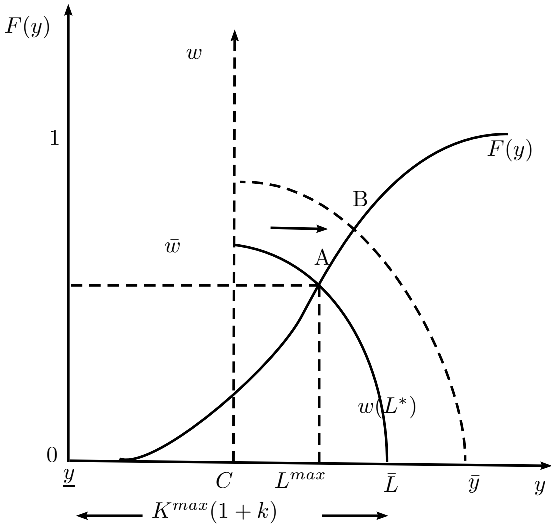


FIGURE A.2: Risk-frontier and payback function.

There are good reasons to assume that the lender's subjective risk tolerance as well as the value of collateral move pro-cyclically. Thus, tranquil periods tending towards a boom phase may increase the lender's risk tolerance causing a shift from hedge to speculative or even Ponzi lending schemes (Minsky, 1975). Such a shift may affect the shape of the $w(L^*)$-function or move it outwards, as depicted by the dashed risk-frontier schedule in Figure A.2. An improvement in the lender's business optimism results in higher tolerated losses for a given probability of occurrence. This shifts the new credit market equilibrium rightwards from A to B, and results in an increase in the maximum loan supply.

Note that a credit limit is not a sufficient condition for credit rationing. If credit demand exceeds credit supply for a given lending rate, the lender could react to this excess demand by an increase in the lending rate, which reduces demand if it is interest elastic. A necessary condition for credit rationing must ensure that the lending rate does not react to excess demand (Größl-Gschwendtner, 1993, p. 126). Groessl-Gschwendtner (1993) and Größl-Gschwendtner et al. (1995) have adopted a framework used in the banking literature to derive a lending rate which is related to the loan volume. It is assumed that the lender is able to set the price of its product on a monopolistic market. The price of credit, the lending rate, is equal to its costs plus a risk premium a risk-averse lender demands. The risk premium is determined by the borrower's expected default risk and associated costs.

The standard literature typically assumes a lender who maximizes his expected return (risk neutral case). This type of lender demands a higher risk premium for the compensation of higher default risk, which implies that there is actually no upper credit supply limit. The lender uses the interest rate to discriminate between borrowers. However, this only holds true if a bank lends to a large number of borrowers who face independent idiosyncratic shocks (correlated idiosyncratic risks as well as system-wide shocks are ruled out). In this case, the law of large numbers applies to the lender's portfolio, and the maximization of expected return may be a reasonable objective.[4] But there are strong theoretical and practical reasons why banks are not acting in a risk-neutral manner. For instance, from the corporate finance literature it is well-known that external funds are more expensive than internal ones. Thus, a firm which is actually risk-neutral but keeps this fact in mind, may behave like a risk-averse firm as it has an incentive to minimize random fluctuations of internally generated funds in order to avoid the need to rely on external finance (Froot et al., 1993). Froot and Stein (1998) have applied this argument of *endogenous risk-aversion* to the decision making process of banks. Furthermore, Pausch and Welzel (2002) show how capital adequacy regulations force banks to take into account the risk of their balance-sheet. These regulations enforce banks to hold more capital the higher the bank's exposure to risk, which is associated with higher costs for the bank. Thus, banks have to care about their risk levels as well. In this environment, returns below the expected value may trigger increasing costs for the bank, making it plausible to consider cases when the actual project outcome is below its expected value. Hence, it is feasible to assume that a risk-averse lender will only accept losses up to a specific threshold. We will show that this not only leads to a credit supply limit K^{max} but also establishes an upper interest rate ceiling.

The bank's credit proposal is based on the following decision making process: The credit risk evaluation determines a specific payback function, and thus for a given risk frontier the maximum loan supply. The loss probability which is tolerated at maximum determines the maximum lending rate, as shown below. The maximum of the lending rate consists of the following components

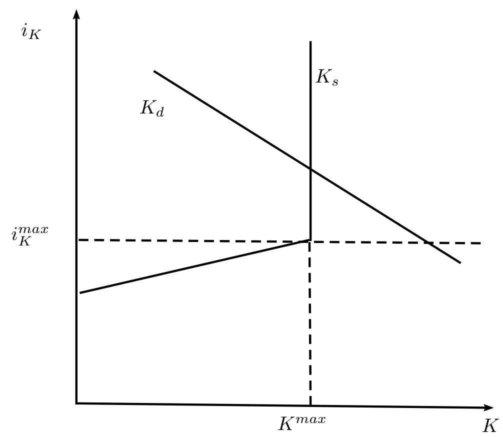
$$i_K^{max} = m + i + \gamma[F(K^{max}(1+k))] \tag{A.17}$$

where m is a mark-up. Furthermore, it is plausible to assume that k equals an opportunity cost measure such as a risk-free rate i (Größl-Gschwendtner, 1993, p. 128). The introduction of a risk-premium makes the lending rate a function of the loan volume, which is implicitly stated by γ. The risk-premium increases in loss probability. Thus,

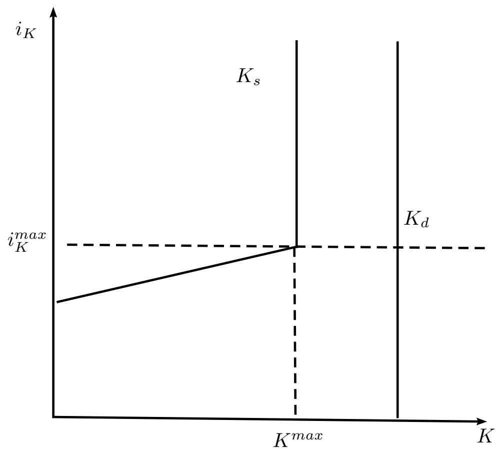
[4] This issue is also related to the research on contagion and network effects at the systemic level. For instance, Battiston et al. (2012) have shown that individual risk diversification may have ambiguous effect at systemic level. Network structures and heterogeneity of levels of financial robustness across agents have important repercussions on system-wide effects of idiosyncratic shocks.

for given parameters m, i and the maximum loan supply, this conception determines a maximum lending rate. Thus, the model involves a rigid credit supply as well as lending rate rigidity. Next, we describe the function γ in more detail, and discuss the situations under which credit rationing occurs.

Figure A.3 depicts the credit demand (K_d) and credit supply (K_s) schedules in the loan-interest space. Credit supply is positively related to the lending rate up to a threshold. Below this threshold increasing credit supply is associated with higher probabilities of credit default. Hence, the lender will extend credit supply only at the cost of higher risk-premium to compensate for higher potential losses. However, risk-aversion against default implies that the lender only accepts losses up to L^{max}, and is not willing to tolerate higher ones beyond this threshold–irrespective of the interest rate the borrower offers to pay. Thus, the credit supply schedule has a positively slope up to K^{max} but becomes vertical beyond this point.



(a) Partial credit rationing



(b) Credit rationing

FIGURE A.3: Credit demand and credit supply schedules

In figure A.3(a) credit demand is interest elastic, and exceeds supply at the maximum lending rate i_K^{max}. As the borrower is willing to pay an interest above i_K^{max} at K^{max}, credit rationing only occurs if the bank has no incentive to increase the lending rate above i_K^{max}.[5] Within this setting of an interest elastic credit demand schedule, credit rationing only occurs under the condition that the lending rate does not react to excess demand.

[5]Market competition might provide a rationale for this assumption. An individual bank cannot be sure how competitors will react to excess demand for credit. If the bank increases the lending rate but others do not, potential clients will move to other banks. Furthermore, a borrower may also try to obtain external funds from capital markets, instead. This may also explain constant mark-ups (Größl-Gschwendtner, 1993, p. 129).

The right panel (Figure A.3(b)) depicts a case in which credit demand is fully interest inelastic. Credit demand exceeds credit supply at any interest rate. The borrower faces credit rationing and only receives credit of the amount K^{max}.

Overall, a credit supply limit, as derived here, always results in credit rationing if the demand for credit is interest inelastic and exceeds credit supply. If demand is interest-elastic further assumptions are required to explain why the lending rate is rigid and does not react to excess demand.

Appendix B

Appendix to Chapter 3

B.1 Data description

All, except two series, were collected from the Federal Reserve Economic Data Service. The variables are defined as follows:

Real money demand, m_t, is the difference between M2 money stock (FRB: M2, SA) and the sum of demand for money by the firm sector which consists of the sum of time and saving deposits held by nonfinancial corporate business (FRB: NCBTSDQ027S, SA) and nonfinancial noncorporate business (FRB: NNBTTDQ027S, SA) as well as money market mutual fund shares of both the nonfinancial corporate business (FRB: NCBMASQ027S, SA) and nonfinancial noncorporate business (FRB: NNBMFTQ027S, SA). The resulting nominal series is deflated by the GDP price deflator (FRB: GDPDEF, SA) and logged.

Real disposable income, y_t, is the log of real disposable income (FRB: DPIC96, SA).

The own rate, i_t, refers to the own rate of M2 (FRB: M2OWN, NSA) converted from monthly to quarterly frequency.

The real stock market rate of return, r_t, is the 3-period moving average of the real rate of return of the S&P 500 Stock Price Index plus dividends on S&P 500 (both data are available at: http://www.econ.yale.edu/~shiller/data/ie_data.xls). Inflation rate is based on the GDP price deflator (FRB: GDPDEF, SA). The series is expressed at an annual rate and converted from monthly to quarterly frequency.

Expected price level inflation, π_t^e, is the University of Michigan Inflation Expectation (FRED: MICH, NSA).

For the construction of the covariance series, $Cov(\pi_t, r)$, we use the log-difference of the GDP price deflator (FRB: GDPDEF, SA) to approximate inflation and the real stock market rate of return, r_t.

The Economic Policy Uncertainty measure, $polunc_t$, is constructed by Baker et al. (2013), and can be downloaded from http://www.policyuncertainty.com/media/US_Policy_Uncertainty_Data.xlsx. The series is converted from monthly to quarterly frequency.

The macroeconomic uncertainty measure, $econunc_t$, is constructed by Jurado et al. (2015), and available from http://www.econ.nyu.edu/user/ludvigsons/MacroUncertainty_update.zip. The series is converted from monthly to quarterly frequency.

B.2 Tables

Variable	Lag=1	Lag=2	Lag=3	Lag=4
(i) For the levels (test statistics)				
m	-0.590	-0.723	-1.072	-1.373
y	-0.671	-0.893	-1.164	-1.190
i	-2.156	-1.786	-2.220	-2.216
r	-7.246	-9.172	-5.168	-5.120
π^e	-2.132	-1.927	-2.275	-3.015
σ_r^2	-2.045	-1.614	-1.669	-1.532
σ_π^2	-1.539	-1.781	-2.415	-2.573
$Cov(\pi, r)$	-2.749	-2.790	-3.062	-3.047
$polunc$	-5.379	-3.730	-3.039	-2.505
$econunc$	-3.393	-2.718	-3.050	-3.149
(ii) For the first differences (p-values)				
Δm	0.000	0.000	0.003	0.013
Δy	0.000	0.000	0.000	0.000
Δi	0.000	0.000	0.000	0.000
Δr	0.000	0.000	0.002	0.045
$\Delta \pi^e$	0.000	0.008	0.081	0.075
$\Delta \sigma_r^2$	0.000	0.000	0.000	0.000
$\Delta \sigma_\pi^2$	0.000	0.005	0.014	0.010
$\Delta Cov(\pi, r)$	0.000	0.000	0.000	0.000
$\Delta polunc$	0.000	0.000	0.000	0.007
$\Delta econunc$	0.000	0.000	0.000	0.000

NOTE: When applied to the first differences, augmented Dickey-Fuller using the GLS procedure suggested by Elliott et al. (1996) (ADF-GLS) test statistics with an intercept and p lagged first differences of dependent variable, while when applied to levels, ADF-GLS statistics are computed using regression with an intercept, a linear time trend and p lagged first differences of dependent variable. The relevant 1%, 5% and 10% critical values for the ADF-test on the levels are -3.46, -2.93 and -2.64, respectively and are taken from Elliott et al. (1996, Table 1). For the first differences the p-values are provided. The calculation is based on MacKinnon (1996).

TABLE B.1: ADF-GLS unit root test results. Sample: 1978q1 – 2013q4.

Variable	Lag=1	Lag=2	Lag=3	Lag=4
(i) For the levels				
m	0.871	0.589	0.449	0.365
y	0.757	0.517	0.397	0.325
i	0.245	0.172	0.136	0.114
r	0.227	0.203	0.214	0.225
π^e	0.878	0.602	0.462	0.379
σ_r^2	1.061	0.731	0.566	0.467
σ_π^2	0.978	0.658	0.499	0.404
$Cov(\pi, r)$	0.282	0.197	0.154	0.129
$polunc$	0.534	0.427	0.359	0.309
$econunc$	0.724	0.500	0.389	0.324
(ii) For the first differences				
Δm	0.821	0.667	0.571	0.501
Δy	0.342	0.330	0.312	0.302
Δi	0.135	0.127	0.119	0.112
Δr	0.008	0.008	0.014	0.018
$\Delta \pi^e$	0.070	0.077	0.075	0.069
$\Delta \sigma_r^2$	0.145	0.145	0.148	0.153
$\Delta \sigma_\pi^2$	0.183	0.149	0.125	0.108
$\Delta Cov(\pi, r)$	0.040	0.040	0.039	0.039
$\Delta polunc$	0.017	0.027	0.037	0.046
$\Delta econunc$	0.047	0.042	0.040	0.039

NOTE: KPSS represents the test suggested by Kwiatkowski et al. (1992) (KPSS). In first difference equations, KPSS test statistics are obtained including only an intercept and p lagged first differences of dependent variable, while when applied to levels, KPSS statistics are computed using regression with an intercept, a linear time trend and p lagged first differences of dependent variable. The relevant 1%, 5% and 10% critical values for the KPSS test on the levels are 0.216, 0.148 and 0.120, respectively. The relevant 1%, 5% and 10% critical values for the KPSS test on the first differences are 0.735, 0.465 and 0.349, respectively. All critical values are provided by Sephton (1995).

TABLE B.2: KPSS unit root test results. Sample: 1978q1 – 2013q4.

(A) Estimation Results

	Model 1	Model 2	Model 3	Model 4	Model 5
ρ	-0.072^{***}	-0.081^{***}	-0.075^{***}	-0.111^{***}	-0.120^{***}
	(0.017)	(0.018)	(0.023)	(0.024)	(0.028)
$\beta(y)$	0.881^{***}	0.766^{***}	0.693^{***}	1.006^{***}	0.997^{***}
	(0.097)	(0.097)	(0.149)	(0.114)	(0.110)
$\beta(r)$	-0.000	0.003	0.002	0.004^{***}	0.002
	(0.001)	(0.002)	(0.003)	(0.001)	(0.002)
$\beta(i)$	0.035^{***}	0.027^{**}	0.021	0.019^{**}	0.022^{***}
	(0.011)	(0.010)	(0.023)	(0.008)	(0.008)
$\beta(\pi^e)$		-0.047^{***}	-0.051^{*}	-0.027^{**}	-0.025^{**}
		(0.015)	(0.028)	(0.013)	(0.012)
$\beta(\sigma_r^2)$			-0.065		0.033
			(0.157)		(0.060)
$\beta(\sigma_\pi^2)$				0.307^{***}	0.328^{***}
				(0.091)	(0.086)
R^2	0.741	0.826	0.839	0.867	0.895
	(0.665/0.812)	(0.765/0.878)	(0.786/0.887)	(0.823/0.905)	(0.858/0.927)

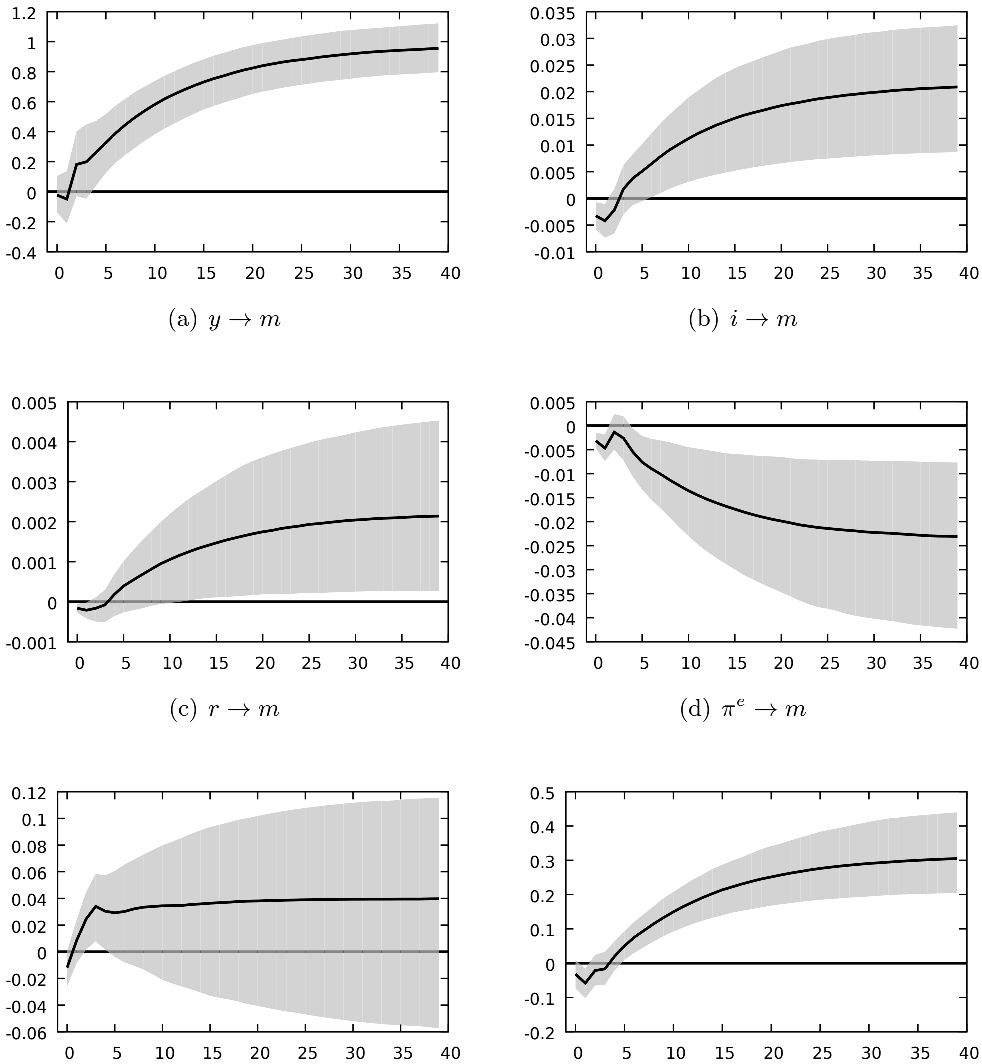
(B) Diagnostic Statistics

	Model 1	Model 2	Model 3	Model 4	Model 5
$F_{SC(1)}$	0.041	0.449	0.295	0.438	0.437
	(4.286)	(0.578)	(1.111)	(0.608)	(0.611)
$F_{SC(4)}$	0.087	0.656	0.567	0.127	0.013
	(2.099)	(0.611)	(0.741)	(1.860)	(3.442)
χ_H^2	0.235	0.602	0.736	0.435	0.303
	(45.019)	(55.583)	(59.341)	(85.465)	(100.555)
χ_N^2	0.529	0.308	0.363	0.132	0.589
	(1.274)	(2.355)	(2.028)	(4.045)	(1.059)
F_{FF}	0.865	0.737	0.913	0.024	0.046
	(0.146)	(0.306)	(0.091)	(3.909)	(3.234)
QLR	0.000	0.594	0.155	0.050	0.007
	(62.118)	(26.734)	(36.146)	(41.196)	(48.559)
$QLR_{I(1)}$	0.000	0.033	0.011	0.009	0.010
	(35.154)	(21.184)	(26.216)	(26.817)	(28.464)
$QLR_{I(0)}$	0.001	0.669	0.102	0.067	0.050
	(45.664)	(25.660)	(38.083)	(40.009)	(41.207)
F_{PSS}^b	0.455	0.577	0.082	0.965	0.098
EG	-1.544	-1.234	-2.029	-1.230	-2.032
EG_{5pct}	-3.741	-4.096	-4.415	-4.415	-4.707

Note: ρ and β denote the bootstrapped mean value of the error-correction coefficient and the long-run coefficients, respectively. The bootstrap standard error are reported in rounded parentheses. $***$, $**$ and $*$ denote the 1pct., 5 pct. and 10 pct. rejection probabilities. For R^2 the bootstrapped 95pct. intervals are provided. All results are based on 999 stable bootstrap iterations. The optimal lag length of the ARDL(p,q) model as well as potential impulse dummmies are determined by an automatic algorithm as described in Section B.4 in the Appendix. $F_{SC(1)}$, $F_{SC(4)}$, χ_H^2, χ_N^2 and F_{FF} denote the p-values for the tests of no serial correlation of order 1 or 4 (respectively), White's test of homoskedasticity, the Doornik-Hansen test of residual normality and Ramsey's RESET test of the correct functional form. The Quandt likelihood ratio test, QLR, tests for a structural break at an unknown point in time, with 15pct. trimming. QLR, $QLR_{I(1)}$ and $QLR_{I(0)}$ are tests on joint parameter stability of all regressors, only of the I(1) and I(0) regressors, respectively. For these tests the p-values are provided and the test statistics are reported in rounded parentheses below. F_{PSS}^b refers to the bootstrap version of the Pesaran et al. (2001) F-test on cointegration (bootstrapped p-values are reported) while EG denotes the test statistics of the Engle-Granger residual based cointegration test. EG_{5pct} is the corresponding 5 pct. critical value. The restricted intercept with no trend case is considered.

Table B.3: Estimation results of the money demand relationship. Sample: 1978q1 to 2008q3.

B.3 Figures



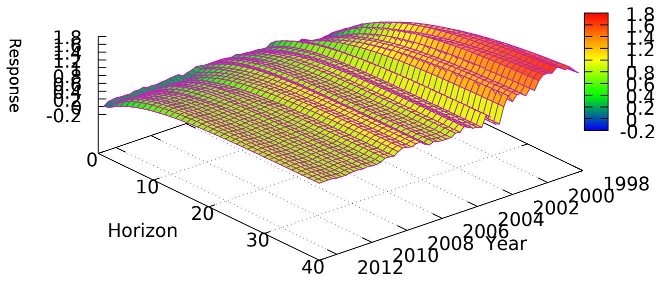
(a) $y \to m$ (b) $i \to m$

(c) $r \to m$ (d) $\pi^e \to m$

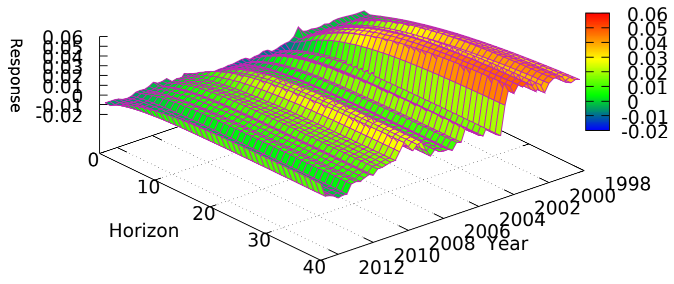
(e) $\sigma_r^2 \to m$ (f) $\sigma_\pi^2 \to m$

NOTE: The optimal lag length of the ARDL(p,q) model as well as potentially required impulse dummies are determined by an automatic algorithm, as described in Section B.4 in the Appendix. The 90% Efron percentiles are based on a wild bootstrap method using 1999 iterations.

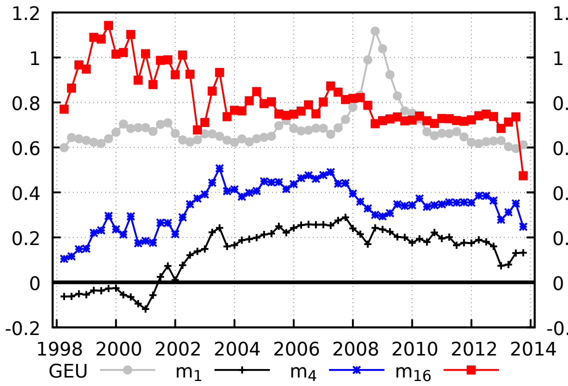
FIGURE B.1: Dynamic multipliers of money demand with 90% non-parametrically bootstrapped confidence intervals (Efron percentiles) based on Model 5 after general-to-specific model reduction. Sample: 1978q1 – 2008q3.



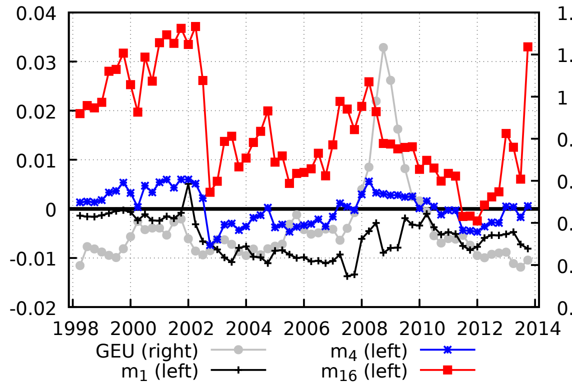
(a) $y \rightarrow m$



(b) $i \rightarrow m$



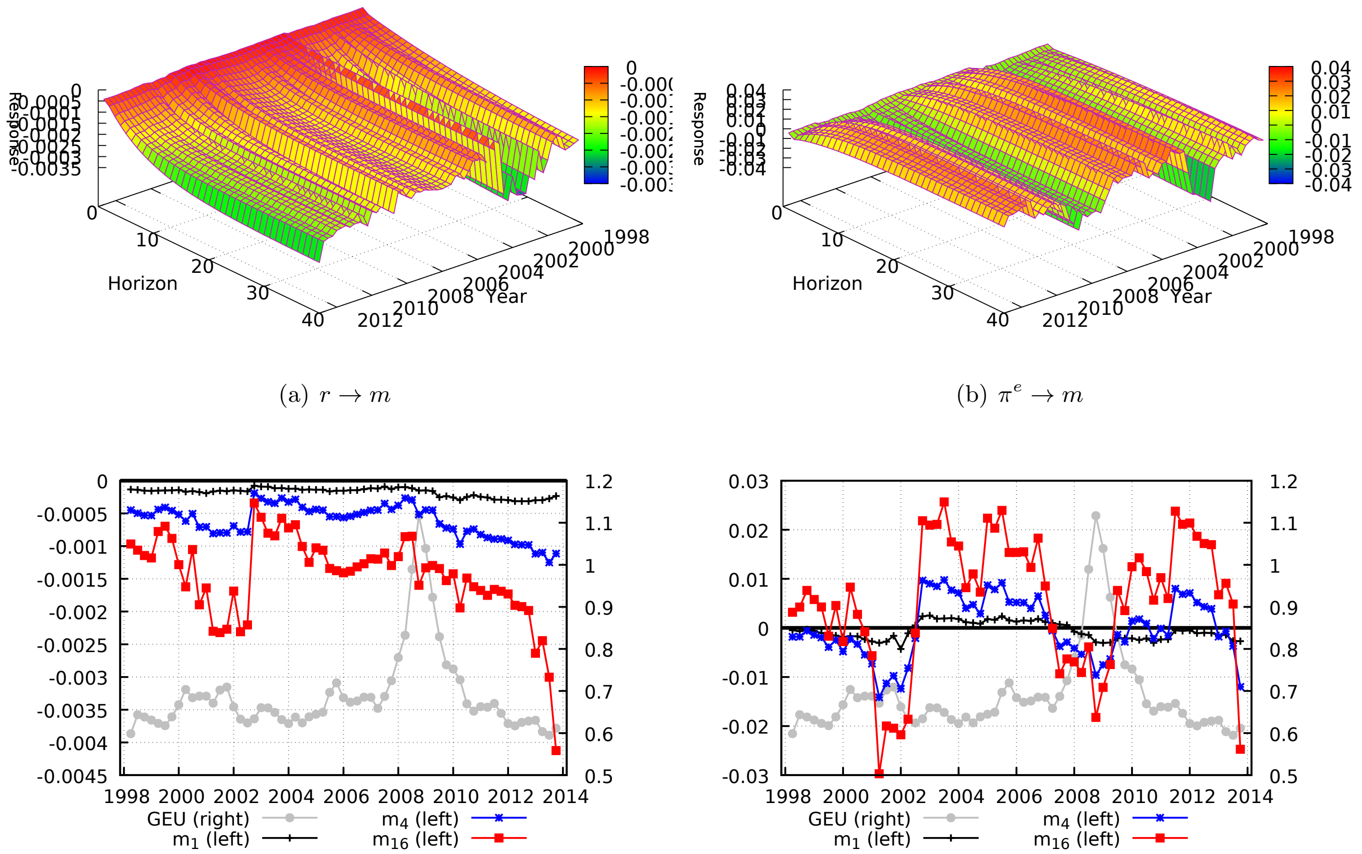
(c) $y \rightarrow m$



(d) $i \rightarrow m$

Note: The impact multiplier (m_1), the effect after four (m_4) and sixteen periods (m_{16}) are reported, respectively. *GEU* refers to general economic uncertainty (*econunc*). The window size is 80 quarters. The optimal lag length of the ARDL(p,q) model as well as potentially required impulse dummies are determined by an automatic algorithm, as described in Section B.4 in the Appendix.

Figure B.2: Rolling-window dynamic multipliers based on model 5. Sample: 1978q1 – 2013q4.



(a) $r \rightarrow m$

(b) $\pi^e \rightarrow m$

(c) $r \rightarrow m$

(d) $\pi^e \rightarrow m$

NOTE: The impact multiplier (m_1), the effect after four (m_4) and sixteen periods (m_{16}) are reported, respectively. *GEU* refers to general economic uncertainty (*econunc*). The window size is 80 quarters. The optimal lag length of the ARDL(p,q) model as well as potentially required impulse dummies are determined by an automatic algorithm, as described in Section B.4 in the Appendix.

FIGURE B.3: Rolling-window dynamic multipliers based on model 5. Sample: 1978q1 – 2013q4.

B.4 Notes on the general-to-specific algorithm and outlier detection procedure

The following algorithm is applied to determine the lag order of the ARDL(p,q) model as well as the need for impulse dummy variables:

1. Estimate the ARDL(p,q) and set the lag length to $p = q = k$ where k is an integer value and $k = 1..4$. The BIC information criteria is used to select the lag length which minimizes the BIC criteria. The maximum lag order tested is $k = 4$. The optimal lag order is denoted by ARDL(p^*,q^*).

2. Store the residuals $\widehat{u}$ of the estimated ARDL(p^*,q^*) model. Create impulse dummies taking unit for observations for which $\widehat{u}_t >= 2\sigma(\widehat{u})$, otherwise zero, where $\sigma(\widehat{u})$ refers to the estimated standard deviation.

3. Re-estimate the ARDL(p^*,q^*) model including all dummy variables determined in the step before. Sequentially eliminate the dummy variables with a p-value greater 0.1, until all remaining dummy variables have a p-value not greater than 0.1.

B.5 Notes on PSS wild bootstrap test on cointegration

The bootstrap estimator of the cointegration relationship, denoted $\widehat{PSS}_b$ in what follows, iterates over the following steps:

1. Estimate model B.1 under null hypothesis $H_0 : \rho = \theta = 0$ using OLS yielding the estimates $\widehat{\gamma}_1^r, ..., \widehat{\gamma}_{p-1}^r$ and $\widehat{\phi}_1^r, ..., \widehat{\phi}_{p-1}^r$ together with the corresponding residuals $\widehat{u}_t$:

$$\Delta y_t = \rho y_{t-1} + \theta x_{t-1} + \sum_{j=1}^{p-1} \gamma_j \Delta y_{t-j} + \sum_{j=1}^{q-1} \phi_j \Delta x_{t-j} + u_t \qquad t = 1, ..., T \tag{B.1}$$

   where the initial values, $y_{1-p}, ..., y_0$ and $x_{1-q}, ..., x_0$, are taken to be fixed in the statistical analysis.

2. Construct the bootstrap sample, $\{y_t^*\}$, recursively from the first step with the T bootstrap errors u_t^*, generated using the re-centered residuals, $\widehat{u}_t^c := \widehat{u}_t - T^{-1}\sum_{i=1}^T \widehat{u}_t$, for the wild bootstrap, where for each $t = 1, ..., T$, $u_t^* := \widehat{u}_t^c w_t$, where w_t, $t = 1, ..., T$, is an i.i.d. $N(0, 1)$ sequence.

3. Using the bootstrap sample, $\{y_t^*\}$, estimate model B.1 under the alternative $H_1 : \rho \neq \theta \neq 0$ using OLS. Check that the error-correction term $\rho <= 0.0001$ and

that stability is ensured. If the condition is fulfilled, proceed with the next step, otherwise go back to step 2 and draw from another set of residuals.

4. Using the bootstrap sample, $\{y_t^*\}$, compute the bootstrap PSS test statistics, $\widehat{PSS}_b$.

5. Repeat steps 1 to 4 B times.

6. The bootstrap p-value is computed as $F^b_{PSS} = \#\{\widehat{PSS}_b \geq \widehat{PSS}\}/B$ where $\widehat{PSS}$ is the observed value of the statistics.

B.6 `gretl` macros

All `gretl` code[1] used in the paper is available upon request. The results presented in the paper are based on `gretl` version `1.10.0 cvs`. See the file `readme.txt` included in the zip archive for further details.

To recreate the results in the paper run the main file `MAIN.inp`. This program performs the following steps:

- Load the gretl-type data file `DATASET_1978q1_2013q4.gdt`.
- Call `gretl_urtest.inp` to conduct the ADF-GLS and KPSS unit root test, and compile the Latex-tables.
- Call `ARDL.inp`. This file comprises the whole setup for the following ARDL model estimations, cointegration test analysis, dynamic multiplier computation, and rolling-window dynamic multiplier computation. The required sub-procedures are included in the file named `PROCEDURES.inp` and automatically called. All Latex-tables and figures are compiled automatically.

[1]See Cottrell and Lucchetti (2013) for the more information on the open-source econometric software package `gretl`.

Appendix C

Appendix to Chapter 4

C.1 Data description

The following sources were consulted in collecting the data: the Federal Reserve Board of Governors (FRB); the National Income and Product Accounts (NIPA); the Flow of Funds Accounts Release Z1 (FoF); the Bureau of Labor Statistics (BLS); and the Federal Reserve Economic Data Service (FRED). The variables are defined as follows:

Realised output, y_t, is the log of real GDP (NIPA: GDP Table 1.1.6 row 1, SA) converted into index form with base year 2000.

The base rate, r_t, is the Federal funds rate (FRB: H15/H15/RIFSPFF_N.M) converted from monthly to quarterly frequency and logged. To maintain the annual rate characteristics of the series, the following log-transformation is employed: $r_t = \frac{1}{4} ln\left(1 + \frac{R_t}{100}\right)$.

Price level inflation, Δp_t, is computed as the log-difference of the GDP deflator (NIPA: GDP Table 1.1.4 row 1), again expressed as an annual rate.

Real cash flow, f_t, is proxied by internal funds, defined as the book value of US internal funds of the nonfinancial corporate sector (FoF: FA106000135.Q, SA), deflated by the GDP deflator. The series is indexed and logged.

Tobin's q is the ratio of the market value of corporate equity (FoF: FL103164103.Q, adjusted using Census X12) to the linearly interpolated net corporate total fixed capital stock (NIPA: Fixed Assets Table 6.1). The series is indexed and logged.

Real investment, i_t, is corporate non-financial gross fixed capital investment (FRB: Z1/Z1/
FA105019005.Q, SA) deflated by the GDP deflator, indexed and logged.

The real debt-service cost, d_t, is defined as the product of the real prime loan rate and the deflated stock of outstanding corporate credit market liabilities excluding equities (FoF: FL384104005.Q, SA). The real prime lending rate is constructed as the prime loans rate (FRB: H15/H15/RIFSPBLP_N.M) minus the rate of inflation (monthly data is converted to quarterly frequency). The series is then indexed and logged.

Productivity-adjusted wage inflation, $\Delta w_t - \Delta z_t$ is the logarithmic approximation computed as 400 times the difference between the first difference of the log of hourly compensation (BLS: PRS88003103, SA) and the log of hourly output (BLS: PRS88003093, SA) for the non-financial corporate sector. The resulting series is logged and expressed as an annual rate.

The price of crude oil, p_t^o, is the West Texas Intermediate spot oil price (FRED: OIL-PRICE, NSA, X12) converted from monthly to quarterly frequency, indexed and logged.

C.2 Tables

Variable	ADF-GLS(1)	ADF-GLS(2)	ADF-GLS(3)	ADF-GLS(4)
(i) For the levels (test statistics)				
p_t^o	-0.89	-1.35	-0.98	-1.31
y_t^*	-0.79	-1.95	-2.07	-2.41
q_t	-1.09	-1.25	-1.25	-1.51
w_t	-6.39	-3.49	-3.64	-3.01
Δp_t	-3.33	-2.27	-1.86	-1.59
r_t	-1.70	-2.77	-2.62	-2.84
d_t	-1.49	-3.24	-3.59	-3.78
f_t	-3.01	-2.99	-2.61	-3.15
i_t	-1.07	-1.66	-2.18	-2.78
y_t	-0.59	-1.01	-1.79	-1.44
(ii) For the first differences (*p-values*)				
Δp_t^o	0.00	0.00	0.00	0.00
Δy_t^*	0.00	0.01	0.02	0.02
Δq_t	0.00	0.00	0.00	0.05
$\Delta(\Delta w_t - \Delta z)$	0.00	0.00	0.00	0.07
$\Delta(\Delta p_t)$	0.00	0.00	0.31	0.28
Δr_t	0.18	0.01	0.02	0.00
Δd_t	0.00	0.00	0.05	0.00
Δf_t	0.00	0.00	0.00	0.00
Δi_t	0.00	0.00	0.09	0.00
Δy_t	0.00	0.00	0.22	0.46

Note: When applied to the first differences, augmented Dickey-Fuller using the GLS procedure suggested by Elliott et al. (1996) (ADF-GLS) test statistics with an intercept and p lagged first differences of dependent variable, while when applied to levels, ADF-GLS statistics are computed using regression with an intercept, a linear time trend and p lagged first differences of dependent variable. The relevant 5% and 10% critical values for the ADF-test on the levels are -3.03 and -2.74, respectively and are taken from Elliott et al. (1996, Table 1). For the first differences the p-values are provided. The calculation is based on MacKinnon (1996).

TABLE C.1: Augmented Dickey-Fuller unit Root tests using the GLS procedure Sample: 1985q1 – 2008q3.

Variable	KPSS(1)	KPSS(2)	KPSS(3)	KPSS(4)
(i) For the levels				
p_t^o	0.83	0.59	0.47	0.39
y_t^*	0.96	0.65	0.49	0.40
q_t	0.74	0.51	0.40	0.33
$\Delta w_t - \Delta z$	0.12	0.11	0.10	0.09
Δp_t	0.52	0.40	0.32	0.27
r_t	0.17	0.12	0.09	0.08
d_t	0.17	0.12	0.09	0.08
f_t	0.18	0.13	0.11	0.09
i_t	0.36	0.24	0.19	0.15
y_t	0.39	0.27	0.21	0.17
(ii) For the first differences				
Δp_t^o	0.37	0.37	0.35	0.36
Δy_t^*	0.26	0.20	0.17	0.14
Δq_t	0.31	0.30	0.28	0.29
$\Delta(\Delta w_t - \Delta z)$	0.02	0.04	0.03	0.05
$\Delta(\Delta p_t)$	0.02	0.04	0.05	0.05
Δr_t	0.08	0.07	0.06	0.05
Δd_t	0.08	0.06	0.05	0.05
Δf_t	0.04	0.05	0.05	0.06
Δi_t	0.23	0.18	0.15	0.13
Δy_t	0.36	0.29	0.26	0.24

Note: KPSS represents the test suggested by Kwiatkowski et al. (1992) (KPSS). In first difference equations, KPSS test statistics are obtained including only an intercept and p lagged first differences of dependent variable, while when applied to levels, KPSS statistics are computed using regression with an intercept, a linear time trend and p lagged first differences of dependent variable. The relevant 5% and 10% critical values for the KPSS test on the levels are 0.148 and 0.120, respectively. The relevant 5% and 10% critical values for the KPSS test on the first differences are 0.466 and 0.349, respectively. All critical values are provided by Sephton (1995).

Table C.2: KPSS unit root tests. Sample: 1985q1 – 2008q3.

Variable	Mean	Min.	Max.	Var.	Skew.	Kurt
Δp_t^o	0.015	-0.535	0.380	0.017	-0.718	2.972
Δy_t^*	0.007	0.003	0.011	0.000	-0.651	1.081
Δq_t	0.008	-0.291	0.145	0.006	-1.083	2.146
$\Delta(\Delta w_t - \Delta z)$	-0.000	-0.038	0.025	0.000	-0.213	1.051
$\Delta(\Delta p_t)$	0.000	-0.006	0.007	0.000	0.128	1.300
Δr_t	-0.000	-0.003	0.002	0.000	-0.592	0.246
Δd_t	0.003	-0.229	0.142	0.005	-0.813	1.298
Δf_t	0.005	-0.301	0.158	0.004	-1.245	4.570
Δi_t	0.006	-0.080	0.061	0.001	-0.570	1.084
Δy_t	0.007	-0.009	0.019	0.000	-0.472	0.968

Note: Min., Max., Var., Skew. and Kurt. denote the sample maximum, minimum variance, skewness and kurtosis values, respectively.

Table C.3: Descriptive statistics. Sample: 1985q1 – 2008q3.

Lags	LL	AIC	SIC	p(LR)
5	2805.0	-51.8	-42.5	0.0000
4	2712.3	-51.2	-43.6	0.0001
3	2650.5	-51.2	-45.5	0.0059
2	2602.5	-51.7	-47.5	0.0000
1	2533.5	-51.5	-49.1	

Note: LL denotes the log-likelihood, AIC the Akaike Information Criterion, SIC the Schwarz Information Criterion and p(LR) the p-value of the likelihood ratio test.

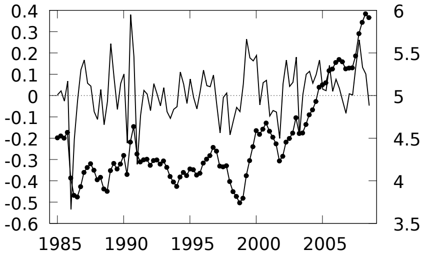
Table C.4: Selection of the VAR lag length. Sample: 1985q1 – 2008q3.

Rank	Eigenvalue	Trace statistic	p-value (asymp.)	p-value (adj.)
0	0.663	341.5	0.000	0.000
1	0.559	239.3	0.000	0.000
2	0.366	162.1	0.003	0.018
3	0.302	119.2	0.014	0.042
4	0.281	85.3	0.030	0.059
5	0.233	54.3	0.088	0.125
6	0.188	29.2	0.212	0.247
7	0.097	9.6	0.499	0.520

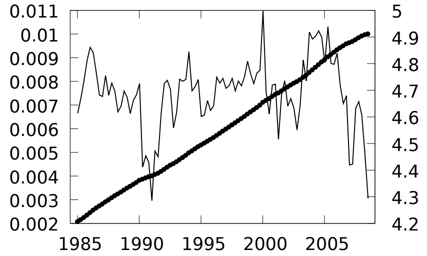
NOTE: This table reports results for the Johansen trace statistic for the VAR(2) model under Case IV (unrestricted constant and restricted trend) conditional on the I(1) variables p_t^o and y_t^* which are restricted to the cointegrating space. p-values are computed via Doornik's gamma approximation. Both asymptotic and sample-size adjusted p-values are shown.

TABLE C.5: Selection of the cointegrating rank of the system. Sample: 1985q1 – 2008q3.

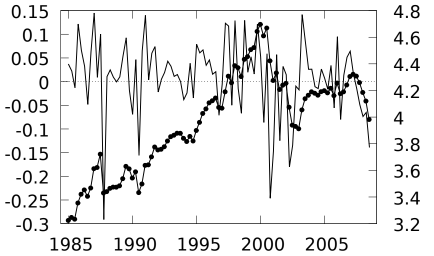
C.3 Figures



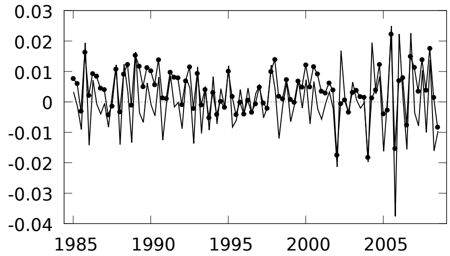
(a) p_t^o



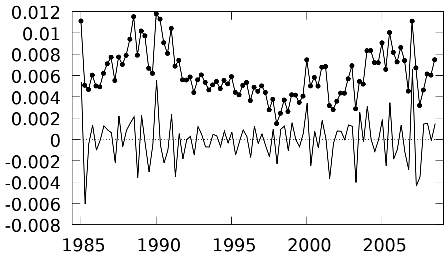
(b) y^*



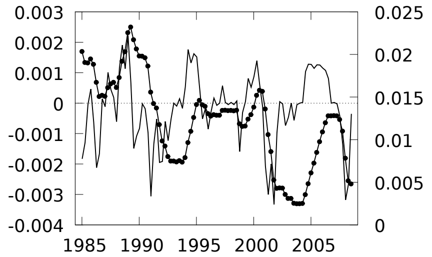
(c) q



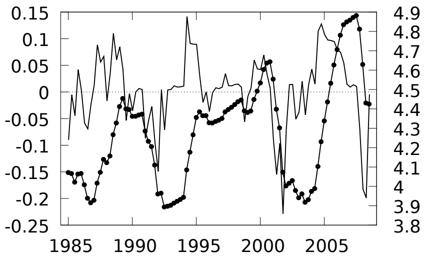
(d) $\Delta w - \Delta z$



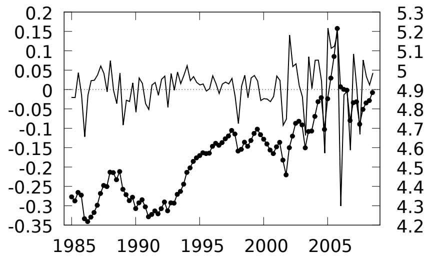
(e) Δp



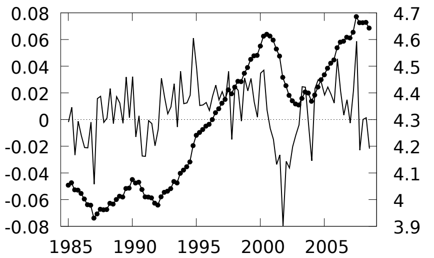
(f) r



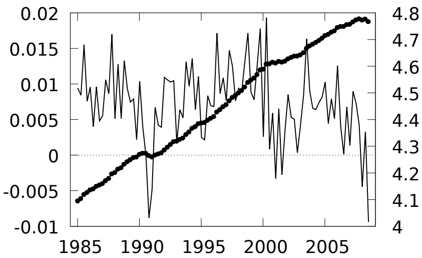
(g) d



(h) f

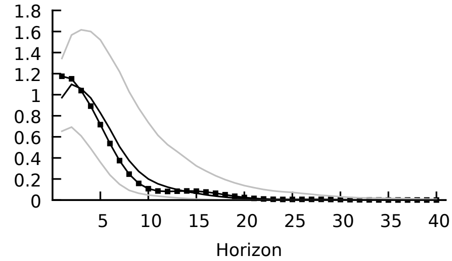


(i) i

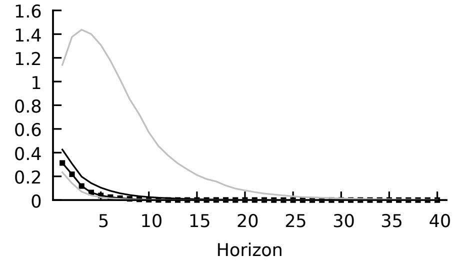


(j) y

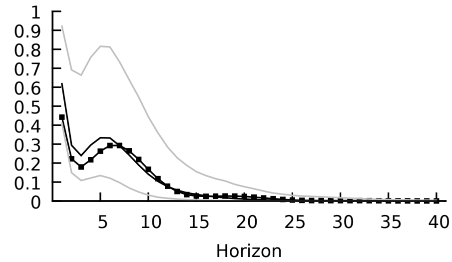
FIGURE C.1: Time series plots of the level variables (points) and its corresponding first difference (right y-axis if a second one on the left is given). Sample: 1985q1 – 2008q3.



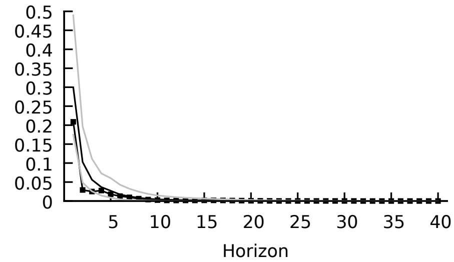
(a) Aggregate demand relationship



(b) Monetary policy reaction function



(c) Investment function



(d) Price and wage inflation

FIGURE C.2: Persistence profiles of the effect of a system-wide shock to the cointegrating relations with 90% bootstrapped confidence intervals (black line: bootstrapped median)

C.4 The estimation of potential output

We compute potential output using the production function approach. This is generally considered preferable to the use of atheoretical estimates of trend output derived from statistical detrending as it makes use of available information about installed production technologies and factors of production. We adopt the 'benchmark output gap' approach used by the Bank of Japan (2003) in which potential output is defined as that level of output that would be achieved if all factors of production were utilised to the fullest possible extent, regardless of the inflationary consequences. By construction, this will always result in a negative output gap. This approach has the advantage that it avoids the controversy surrounding estimation of the NAIRU which is inherently unobservable (c.f. Staiger et al., 1997). Our computation is based on a linearly homogeneous transcendental logarithmic (translog) production function which is estimated by maximum likelihood simultaneously with the associated cost share functions to avoid the bias issues raised by Kim (1992).[1]

The transcendental logarithmic (translog) specification is written as:

$$\begin{aligned} ln\left(Y_t\right) &= ln\left(A_0\right) + \alpha_L ln\left(L_t\right) + \alpha_K ln\left(K_t\right) + \frac{1}{2}\beta_{LL}\left\{ln\left(L_t\right)\right\}^2 + \frac{1}{2}\beta_{KK}\left\{ln\left(K_t\right)\right\}^2 \\ &+ \beta_{LK} ln\left(L_t\right) ln\left(K_t\right) + \beta_{tL} ln\left(L_t\right) t + \beta_{tK} ln\left(K_t\right) t + \alpha_t t + \beta_{tt} t^2 + \epsilon_t \end{aligned} \tag{C.1}$$

where Y_t, L_t and K_t denote output, labour input and capital input in non-logged form. In order to achieve a tractable specification, linear homogeneity is imposed by setting $\alpha_L + \alpha_K = 1$, $\beta_{LK} = \beta_{KL}$, $\beta_{LL} = \beta_{KK}$, $2\beta_{LL} = -\beta_{LK}$ and $\beta_{tL} = -\beta_{tK}$. Substituting these restrictions into (C.1) yields:

$$\begin{aligned} ln\left(Y_t\right) &= ln\left(A_0\right) + \alpha_L ln\left(L_t\right) + \left(1-\alpha_L\right) ln\left(K_t\right) + \frac{1}{2}\beta_{LL}\left\{ln\left(L_t\right)\right\}^2 + \frac{1}{2}\beta_{LL}\left\{ln\left(K_t\right)\right\}^2 \\ &- 2\beta_{LL} ln\left(L_t\right) ln\left(K_t\right) + \beta_{tL} ln\left(L_t\right) t - \beta_{tL} ln\left(K_t\right) t + \alpha_t t + \beta_{tt} t^2 + \epsilon_t \end{aligned} \tag{C.2}$$

It is well established that OLS estimation of (C.2) is biased (see, for example, Kim, 1992). To overcome this problem, maximum likelihood estimation is employed in the

[1] As a robustness check we also estimate potential output using a log-linearised constant returns-to-scale Cobb-Douglas function and find that the results are very similar.

simultaneous estimation of equation C.2 and the associated cost-share equations, which Kim defines as:

$$S_L = \frac{\delta ln(Y)/\delta ln(L)}{\delta ln(Y)/\delta ln(L)+\delta ln(Y)/\delta ln(K)}$$
$$S_K = \frac{\delta ln(Y)/\delta ln(K)}{\delta ln(Y)/\delta ln(L)+\delta ln(Y)/\delta ln(K)} = 1 - S_L$$

where S_L and S_K denote the cost shares of labour and capital, respectively, and sum to unity by construction. Under the assumption that S_L and S_K are logistic-normally distributed, one may log-linearise as follows:

$$ln(S_L) = \frac{\delta ln(Y)}{\delta ln(L)} - \left[\frac{\delta ln(Y)}{\delta ln(L)} + \frac{\delta ln(Y)}{\delta ln(K)}\right]$$

$$ln(S_K) = \frac{\delta ln(Y)}{\delta ln(K)} - \left[\frac{\delta ln(Y)}{\delta ln(L)} + \frac{\delta ln(Y)}{\delta ln(K)}\right]$$

from which it is straightforward to obtain:

$$ln\left[\frac{S_L}{S_K}\right] = ln\left[\frac{\alpha_L + \beta_{LL}ln(L) - 2\beta_{LL}ln(K) + \beta_{tL}t}{\alpha_K + \beta_{LL}ln(K) - 2\beta_{LL}ln(L) - \beta_{tL}t}\right] + e_t \tag{C.3}$$

where $e_t \sim N\left(0, \sigma_e^2\right)$ is an idiosyncratic error process. In order to estimate potential output from (C.2) and (C.3), parameter estimates are first obtained using realised data, and these are then used in conjunction with estimates of potential capital and labour inputs to impute the level of output consistent with full factor utilisation.

Data Used in the computation of potential output

Realised output, Y_t, is quarterly GDP data in chained 2000 dollars (NIPA: GDP Table 1.1.6 row 1, SA).

The realised labour input, L_t, is equal to the product of civilian employment (BLS: LNS12000000, SA) and hours worked (regular hours (BLS: CES0500000007, SA) plus overtime in the manufacturing sector (BLS: CES3000000009, SA)). Quarterly employment data is generated from monthly data.

Potential labour input, L_t^*, is equal to the civilian labour force (BLS: LNS11000000, SA) multiplied by the maximum legal working hours before overtime (assumed to be 40 per week here) plus the trend overtime hours calculated by HP filtering ($\lambda = 1600$).

The utilised capital input, K_t, is the product of total net capital stock (private and governmental – NIPA: Fixed Asset Table 1.1, row 2) and the utilisation rate (FRB: G17/CAPUTL/CAPUTL.B50001.S.Q). Quarterly capital stock data is computed by linear interpolation. The series is deflated by the GDP deflator.

The potential capital input, K_t^*, is equal to the deflated total net capital stock.

Technical progress, t, is a simple cumulative sum process, $t = 0, 1, 2, ..., T - 1$.

The labour cost-share, S_L, is defined as the sum of employee compensation (NIPA: GDP Tables 6.2A-D, row 1), employer social security contributions (NIPA: GDP Tables 6.10B-D, row 1) and pension and insurance contributions (NIPA: GDP Tables 6.11A-D, row 1). All series are deflated by the GDP deflator. The labour share is computed as labour cost/(labour + capital cost).

The capital cost-share, S_K, is equal to the deflated total net capital stock multiplied by the real loan rate plus deflated depreciation (NIPA: Fixed Asset Table 1.3, row 2). The capital share is computed as capital cost/(labour + capital cost). Note that S_L and S_K sum to unity by construction.

Finally, note that the NIPA data used in the computation of potential output was at annual frequency and was therefore linearly interpolated to generate quarterly series. Note also that the value taken by potential output in the base year is not 100. Rather, it is indexed relative to the level of potential output in the base year to maintain the negative sign of the output gap.

C.5 gretl macros

All *Gretl* code[2] used in the paper is available online at www.greenwoodeconomics.com. The results presented in the paper are based on version 1.9.92cvs of the program. See the file readme.txt included in the zip archive with the programs for further details.

To recreate the results in the paper run the main file cvarx.inp. This program performs the following steps:

- Load the dataset.cvs file.
- Call gretl_variable_plots.inp to plot the time series and its first differences.
- Call gretl_urtest.inp which calls the sub-procedure varmodtest_v06.inp to compute the descriptive statistics and conduct the ADF-GLS as well as KPSS unit root tests.
- Run VAR lag length and Johanson cointegration tests.
- Set up and estimate the unrestricted CVARX and restricted CVARX.
- Call gretl_diagnostics.inp and run some model specification tests.
- Call oirf_fevd.inp to compute the OFEVDs and compile the corresponding figures (using the sub-procedure function_barplot_stacked.inp).
- Load various functions to run the bootstrap over-identification LR test.
- Computes persistence profiles and OIRFs.

[2]See Cottrell and Lucchetti (2013) for the more information on the open-source econometric software package *gretl*.

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Declarations

Selbstdeklaration

Die Eigenleistung von Artur Tarassow der präsentierten Arbeit in Kapitel 2 liegt bei 100%.

Kapitel 3 basiert auf der gemeinsamen Arbeit Größl and Tarassow (2015). Ingrid Größl ist vollständig verantwortlich für die Konzeption der theoretischen Fragestellung und die Herleitung des theoretischen Modells. Artur Tarassow ist zu 100% für den empirischen Teil verantwortlich. Dies umfasst den Literaturüberblick über die publizierten empirischen Arbeiten, die Wahl und Diskussion der methodischen Vorgehensweise sowie des empirischen Analyserahmens, die Datenbeschaffung, die Implementation des nötigen Programmcodes in die Software `gretl`, die Schätzung, Evaluation und Interpretation der ökonometrischen Modelle.
Eigenleistung für Kapitel 3:

- Konzept/Planung: 50%
- Durchführung: 50%
- Manuskripterstellung: 50%

Kapitel 4 basiert auf der gemeinsamen Arbeit mit Matthew Greenwood-Nimmo (Greenwood-Nimmo and Tarassow, 2013). Während Greenwood-Nimmo für die Idee, Konzeption, Wahl und Beschreibung der ökonometrischen Methodik zuständig ist, ist Tarassow für die Implementierung des VECMX Modells in `gretl` verantwortlich. Tarassow ist darüber hinaus zuständig für die Aktualisierung des erforderlichen Datensatzes, die Schätzung und Inferenz des Modells. Das Sub-Kapitel mit dem Titel *Implications for monetary policy* resultiert aus gemeinsamer Arbeit beider Autoren.
Eigenleistung für Kapitel 4:

- Konzept/Planung: 40%
- Durchführung: 60%
- Manuskripterstellung: 50%

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Eidesstattliche Versicherung

Hiermit erkläre ich, Artur Tarassow, an Eides statt, dass ich die Dissertation mit dem Titel *Renewed Macroeconomic Interest in the Role of Money and Finance. Essays on Financial Constraints, Financial Fragility and Money Demand Under Uncertainty* selbständig und ohne fremde Hilfe verfasst habe. Andere als die von mir angegebenen Quellen und Hilfsmittel habe ich nicht benutzt. Die den herangezogenen Werken wörtlich oder sinngemäß entnommenen Stellen sind als solche gekennzeichnet. Es wurde keine kommerzielle Promotionsberatung in Anspruch genommen. Ich habe mich anderweitig noch keiner Doktorprüfung unterzogen oder um Zulassung zu einer solchen beworben. Diese Dissertation hat noch keiner Fachvertreterin, keinem Fachvertreter und keinem Prüfungsausschuss einer anderen Hochschule vorgelegen; sie wurde nicht schon einmal in einem früheren Promotionsverfahren angenommen oder als ungenügend beurteilt.

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* Gemäß § 6 Abs. 4 der Promotionsordnung der Fakultät Wirtschafts- und Sozialwissenschaften der Universität Hamburg vom 24. August 2010.