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On shadow banking and financial frictions in DSGE modeling*

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Abstract

At the forefront of macroeconomic research on the causes of the Great Financial Crisis (GFC) was and still is the usage of dynamic stochastic general equilibrium (DSGE) models. To capture the nonlinearities of the GFC, these models were enriched with a variety of financial frictions. This paper focuses on a special subset of these frictions, the shadow banking system. We provide a structured review of the strand of literature that considers shadow banking in DSGE setups and draw particular attention to the modeling approach as well as impact of shadow banking. Our analysis allows the following conclusions: firstly, models featuring shadow banking are better able to simulate realistic movements in the business cycle that are of comparable magnitude to the GFC. Secondly, the models consider amplification channels between the financial sector and the real economy that proved to be of importance during the crisis. Thirdly, the models display a good explanatory power of financial stability measures in the light of shadow banking.

JEL-Classification: E10, E44, E32

Keywords: Shadow Banking, DSGE, Financial Frictions, Financial Intermediation, Great Financial Crisis.

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1 Introduction

At the forefront of macroeconomic research on the why and wherefore of the crisis was and still is the usage of dynamic stochastic general equilibirum (DSGE) models. These models stem from the real business cycle literature but are enriched with real and nominal frictions and are thus rich in detail in depicting the economy. The behaviour of agents is based on microeconomic foundations and to gain empirical fit, these models are often taken to the data (Smets et al. 2010). As these aspects make them applicable for reasonable business cycle analyses, these models became the state-of-the-art workhorse framework for the assessment of macroeconomic and especially monetary policy considerations and form an essential part of the policy making process of central banks (e.g. the ECB, the Fed or the Sveriges Riksbank).

However, the classes of DSGE models used for policy analysis prior to the Great Financial Crisis (GFC) did not show sufficient signs of the vulnerability of the financial system. As they placed insignificant emphasis on the role of financial markets and frictions in financial intermediation, they were neither capable of depicting the financial (subprime) crisis that hit the U.S. economy in 2007, nor were they able to predict that it might escalate into a financial crisis on an international scale. At that time, the recent generation of DSGE models was ill-suited for making adequate monetary policy and financial stability assessments (see e.g. Christiano et al. 2018 or Gertler, Kiyotaki and Prestipino 2016).

After the GFC unfolded internationally, its causes and consequences have been extensively studied. It is nowadays acknowledged that, among others, a strong nexus between the stability of financial sectors and real economic activitiy exists and that a combination of lax regulation and financial innovation precipatated the impact of shadow banking on the evolution of the GFC. These insights were gained not least because DSGE modeling rapidly turned to consider elaborated setups of financial intermediation, all sorts of unconventional monetary policy measures and macroprudential regulatory tools. This new generation of models now accounts for the nexus between financial sectors and the real economy, frictions in financial intermediation and financial distress causing crises of comparable impact to the GFC. Moreover, a growing body of literature considers heterogeneities in financial intermediation as reflected by shadow banking activities. Such considerations are especially important given the fact that non-bank financial intermediation like shadow banking has significant impacts on both monetary policy measures and financial stability tools. As postulated by the Bundesbank, if banking activities are increasingly conducted by non-bank entities outside the regular scope of central banks, implications occur for the monetary analysis on the one hand, and the proper and effective conduct of monetary policy and financial stability measures on the other (Bundesbank 2014). Hence, reasonable assessments of monetary policy and financial stability measures require DSGE setups with fully-fledged financial sectors, a nexus with the real side of the economy and shocks that can cause financial distress causing repercussions comparable to the GFC.

The objective of this paper is to give a detailed review of this new generation of DSGE models. To this end, it contributes to the literature in the following ways. To begin with, it is the first attempt to give a structured review of the literature that incorporates shadow banking activities into DSGE models. We approach the topic from the angle of the economic rationale at the heart of shadow banking. Being aware of the driving forces that motivate agents to engage in this type of intermediaton draws a clear picture of the factors influencing demand and supply and directs researchers' and policy makers' attention to more adequate and targeted modeling setups. We then give a short recap of the evolution of financial frictions and financial intermediation in DSGE modeling in order to draw attention to why these models failed to predict the GFC and what changed afterwards. Secondly, we present the latest progress of DSGE setups considering shadow banking activities and compare the findings with the economic rationales. We can identify two broader modeling emphases: one strand of the literature implements shadow banking as specialized institutions in the process of financial intermediation with comparative advantages over retail banks in managing financial capital, and the other strand focuses on the aspect of financial innovation where shadow banking acts as a supplier of securitized financial products. Hence, by considering "specialization" and "financial innovation", the DSGE literature touches on two important economic rationales at the heart of shadow banking activities. Based on this, we explain the core setup of the models, depict the structure of the financial sector and discuss the implications. Here, particular attention is drawn to the financial friction and the implementation of shadow banking.

The analysis allows some general conclusions. Firstly, the new generation of models that accounts for heterogeneity in financial intermediation constitutes a well-suited setup for analyzing financial distress that precipitates large-scale downturns in financial intermediation and real economic activitiy. These models are thus better able to simulate realistic movements in the business cycle that are of comparable magnitude to the GFC. Secondly, the considered models allow the study of amplification channels between the financial sector and the real economy that proved to be of importance during times of financial distress. Of exceptional importance are the role of leverage and liquidity and the bank capital channel. Thirdly, there remain aspects that the new generation of models do not touch on. One is the role of monetary policy and its interplay with financial regulation. As these models largely miss fully-fledged productive setups with nominal rigidities, they are unable to analyze the impact of conventional montetary policy measures. Consequently, with these new DSGE modeling attempts, researchers and policy makers are now better geared for the assessment of macroeconomic and financial stability considerations. What remains an unsolved issue, however, is the implementation of adequate modelings of conventional monetary policies. As financial stability measures and conventional monetary policy measures interact, it is of importance to analyze their interplay.

This paper is structured as follows: Section 2 gives a brief differentiation of shadow banking from traditional banking and provides some empirical evidence. Section 3 focuses on why shadow banking has become such an important part of the financial system. To this end, it considers the economic rationale and the economic consequences for financial stability measures and monetary policy. Section 4 starts with a recap of the evolution of financial intermediation in DSGE modeling and then turns towards depicting the latest progress of DSGE setups considering shadow banking. Section 5 provides a discussion of the considered models and draws implications for monetary policy and financial stability.

2 Regular banking, shadow banking and the GFC

Once shadow banking was held accountable for the bulk of maldevelopments in financial sectors during the last two decades, the debate on its reasons and consequences has been led by attempts to define and demarcate shadow banking from traditional banking.[1] In the second wave, there followed the endeavor to find adequate policy responses, regulatory mechanisms and supervisory tools in order to prevent a recurrence. These debates mainly focused on the impact of shadow banking on financial stability. We do not aim to review all these literature strands thoroughly as this has already been done by several scholars beforehand (e.g. Adrian and Ashcraft 2012). In the next subsection, we have elected to present a differentiation of shadow banking from traditional banking from the perspective of monetary policy. Three relevant properties stand out. We then briefly highlight the quantitative importance by providing empirical evidence.

2.1 A differentiation

In the course of the first wave of considerations, shadow banking was defined and explained by the use of different measurement approaches. This is, on the one hand, due to the variety of activities, financial institutions and entities involved, and, on the other, to structural differences in the economies and financial systems being considered. Two approaches stand out: (i) shadow banking can either be explained by means of the activities that are conducted (for the activity-based approach see e.g. IMF 2014), or (ii) by considering the entities that carry it out (for the entitiy-based approach see e.g. Pozsar et al. 2013).

This is, however, not the only possibility to differentiate recent subsets of shadow banking from traditional banking. Along with the former distinctions there appear to be at least three crucial properties that are relevant from the perspective of monetary policy makers while also touching on financial stability aspects.

Firstly, shadow banking in general lacked and still lacks access to federal deposit insurance systems (see e.g. Pozsar et al. 2013 or Deutsche Bundesbank 2014). Without such a fall-back position, it turned out that the system is overly exposed to runs, fire sales and losses. Secondly, shadow banking cannot resort to liquidity enhancing operations through central banks. This makes it prone to sudden liquidity fluctuations and maturity mismatches and, in combination

[1] On October 22, 2018 the Financial Stability Board (FSB) and later on the European Systemic Risk Board (ESRB 2019) replaced the term "shadow banking" with the name "non-bank financial intermediation". According to their perception, this general wording better copes with the increasing diversity of financial intermediation that exists alongside the regular banking sector (FSB 2018). As such, the new nomenclature not only captures shadow banking and its diverse substructures but all other forms and activities of non-bank financial intermediation that emerged recently, but are not shadow banking per se (e.g. crowd funding, peer-to-peer lending, FinTech credit etc.). In the subsequent paper, we will nonetheless primarly use the term "shadow banking". If this paper refers to non-bank financial intermediation, it constitutes a perfect synonym as we do not distinguish in more detail. We are only interested in the special subset of entities that emerged prior and slightly after the crisis 2007/2008. More recent subsets of non-bank intermediation are not considered here (see e.g. Käfer 2018).

with the former point, susceptible to being a systemic risk for financial stability (Deutsche Bundesbank 2014). And thirdly, its structure combined with the former points mean that it is usually not able to create new means of payments (see e.g. Deutsche Bundesbank 2014 or Unger 2016). The system only transforms and restructures existing illiquid and risky assets into marketable and higher rated securities. The exemplary process is the securitization of subprime mortgages into high-rated MBS.

How do these aspects come about? To answer this, it is useful to visualize the traditional process of credit intermediation again. Banks conduct a qualitative transformation of assets (maturity, liquidity and risk transformation), usually within a single entity and with adequate information about borrowers and savers (Noeth and Sengupta 2011). Due to the susceptibility of this business, it is intensively monitored and protected by a safety net consisting of deposit insurance schemes and access to central bank liquidity operations. Taken together, these properties assign regular banking an important stake in the economy: banks can elastically create new means of payment, i.e. supply additional money in the form of demand deposits through the origination of loans (Unger 2016).

Shadow banking can then be characterized to fit to some of these functions and properties but is lacking the ones relevant from a monetary policy perspective. Albeit in a different manner, it conducts (market-based) credit intermediation by transforming long-term assets into short-term and thus money-like liabilities. The functional similarities (Bernanke 2012) hence stem from the fact that it fulfills the core banking functions of liquidity and maturity transformation. The differences, however, emerge on the structural level. Pozsar et al. (2013) or Adrian and Ashcraft (2012) visualize that shadow banking builds on a fragmented, decentralized market-based system where structured funding techniques and specialized non-bank entities and institutions are the key players.[2]

Taken together, although both systems bear functional similarities, there are properties that set shadow banking apart from traditional banking. To get a better impression of the quantitative importance during the last few decades, we will now provide some empirical evidence.

2.2 Quantitative importance

Measures of shadow banking differ considerably across financial systems. To pin down its activtities on a global level, the macro-mapping measure of the Financial Stability Board (FSB) calculates financial assets of 21 countries and the Euro Area. According to these calculations, shadow banking assets increased from \$26 trillion in 2002 to \$62 trillion in 2007. This figure declined slightly to \$59 trillion in 2008 after the outbreak of GFC but increased

[2] The entities involved are highly specialized and comprise e.g. structured investment vehicles, special-purpose entities and other non-bank financial institutions. They are often initiated and sponsored by banks and usually placed out of their regular balance sheet operations. Funding techniques comprise asset-backed securities (ABS), mortgage-backed securities (MBS), collateralized debt obligations (CDOs), repurchase agreements (repos) or asset-backed commercial papers (CP). The resulting money-like low-risk securities are then backed by the cash-flows from multiple different assets, which have a variety of risk classes.

to $67 trillion in 2011 (FSB 2012, 2019). These measures account for roughly 25-27% of total financial assets in the considered sample and are roughly half the size of the respective traditional banking assets.

More accurate numbers are available at country level. For the U.S., a comparision of aggregate holdings of financial assets of the traditional and the shadow banking sector delivers valuable insights. We follow the approach of Adrian and Shin (2010) and calculate total financial asstes of the traditional banking sector by summing up commercial banks, savings institutions and credit unions. Total financial assets of the shadow banking sector are composed of the government-sponsored enterprises (GSEs), agency & GSE-backed mortgage pools, finance companies, security and broker dealers and ABS issuers. Figure 1 depicts the evolution of both sectors. From the beginning of the 1980's, the volume of financial assets held by shadow banking entities increased steadily, starting to outpace the stake of traditional banking around the year 1996. In 2007, just before the GFC, only 39% ($ 13 trillion) of U.S. financial assets were held by the traditional banking system, whereas the remaining 61% (roughly $19 trillion) was accounted for by the shadow banking system. Since the GFC, intermediaton by shadow banking entities decreased continuously to lower levels but picked up pace in the last three years.

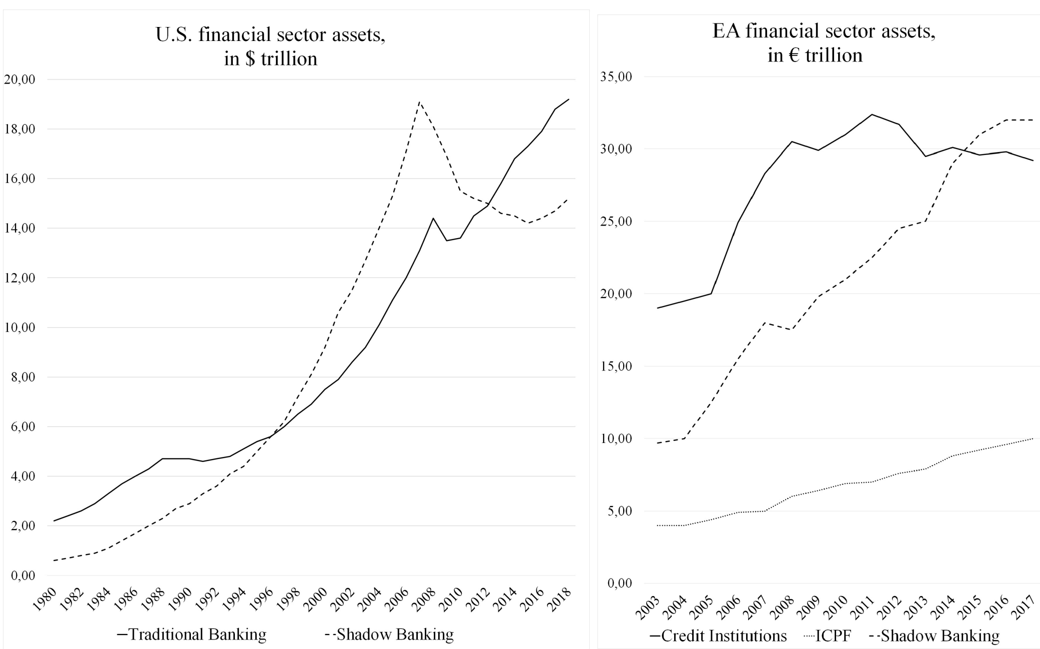

Figure 1: U.S. and EA financial sector assets, own calculations, U.S.: Fed Financial Accounts, EA: ECB Statistical Data Warehouse (broad SB measure)

How did U.S. shadow banking grew so fast during these decades? The most important stake is assigned to the evolution of structured finance, i.e. the process of securitization.

As reported by Adrian and Shin (2010), the steep increase since the 1980s can be traced back to structural changes within the U.S. financial system. It was during these years that market-based intermediaries (e.g. GSEs) became the dominant players in the market for securitizing residential mortgages. Data computed by the authors show that already by the year 1990, market-based entities outpaced banks in holding residential mortgages, intensifying to a volume of roughly $7.5 trillion held by the former compared to only $3 trillion held by the latter in 2007. As a special subset, mortgages to people below credit standards, i.e. subprime mortgages, came to be known as the main effector of the GFC. Coval, Jurek and Stafford (2009) report that between 1996 and 2006, the origination of these mortgages grew from $97 billion to $600 billion, that is 22% of all outstanding mortgages in 2006. Another example is the asset-backed commercial paper (ABCP) market. Acharya and Richardson (2009) and Acharya et al. (2013) show that ABCP became the dominant money market instrument in the U.S. prior to the GFC: its volume more than doubled from $640 billion in January 2004 to $1.3 trillion in July 2007, then even outpacing U.S. treasury bills ($940 billion).

In contrast, shadow banking activities in the Euro Area have a smaller stake in financial intermediation and rather picked up pace alongside the GFC, as reflected in total financial sector assets. As can be seen in Figure 1, at the onset of the GFC in 2007, the subset of non-bank financial entities (broad shadow banking measure: other financial institutions, investment funds and money-market funds) accounted for roughly EUR 15 trillion whereas traditional credit institutions had a stake of EUR 27 trillion. Insurance corporations and pension funds (ICPF), both not considered to be shadow entities, had a stake of roughly EUR 5 trillion. In 2015, credit institutions accounted for roughly EUR 30 trillion, ICPFs for roughly EUR 9 trillion while EUR 28 trillion was held by non-bank financial entities. Accordingly, intermediation by EA shadow banking entities doubled within a decade but still remains below the level observed in the U.S. This steady increase is mainly attributable to the subset of non-money market investment funds. Their share more than doubled in the period under conisderation, reaching roughly EUR 10 trillion in 2015.

3 Some economics of shadow banking

Why did shadow banking became such an important part of the financial system? To give reasonable answers on this question, this section begins with the rationale for agents such as commercial banks and finance companies to engage in shadow banking and proceeds with the macroeconomic consequences. Both aspects are valuable from at least two complementary considerations. On the one hand, a proper understanding of the rationale for agents to arrange credit through shadow banking channels draws a clear picture of the factors that influence supply and demand for this type of intermediation. On the other hand then, awareness and understanding of these factors can contribute to and facilitate more targeted and predictive macroeconomic research and, in turn, enable more adequate monetary and financial stability policy measures.

Besides considerations, there are, however, aspects that concern the structural setup of recent shadow banking systems. We do not aim to explain these structural aspects as this has been done several times before (see e.g. Adrian and Jones 2018). For a non-exhaustive overview, we nevertheless collected several important "structural properties" in Table 1.

Table 1: Economic characteristics of shadow banking

Economic rationale	**Financial stability implication**	**Monetary policy implication**	**Structural property**
Regulatory arbitrage	Risk transformation	Accuracy	Credit intermediation
Agency frictions and inf. asymmetry	High leverage	Effectiveness	Interconnectedness
Search for yield	Maturity transformation		Connection with banking sector
Financial innovation	Complexity		Network structure
Specialization	Interconnectedness		Market-based character
	Contagion		Missing insurance mechanisms

3.1 The economic rationale

In most of the explanatory attempts on shadow banking, the factors of motivation that contributed to its immense growth are a combination of cost avoidance through regulatory arbitrage, progress in financial innovation, specializations in the process of intermediation and misalignment problems (see e.g. Adrian, Ashcraft, Cetorelli 2013, Pozsar et al. 2013 or IMF 2014). We go through these aspects now.

Usually, shadow banking is interpreted as being an extraordinary form of **regulatory arbitrage** (see e.g. Gorton, Metrick 2010, Acharya et al. 2013, Pozsar et al. 2013 or IMF 2014). By offering a possibility to circumvent unprofitable capital and liquidity requirements, regulatory arbitrage made certain financial activities highly profitable and thereby paved the way for agents to engage in shadow banking activities. Technically, such capital and liquidity requirements are in place since financial intermediation suffers from agency frictions and misaligned incentive problems (Adrian and Jones 2018). Banks usually fail to fully internalize the costs of their risk-taking and set leverage ratios above socially optimal levels. The origins of regulatory arbitrage are then based on the fact that legal and supervisory frameworks fail to entirely capture all processes and economic relations between the economic agents involved (Fleischer 2011). Constant innovations in finance, sophisticated intermediation structures and opaque entities enable opportunities and loopholes that allow the circumvention of existing regulations with the ultimate goal of increasing profitability while shifting off risks to other parts of the financial system. Specific evidence on the hypothesis that regulatory arbitrage played a major role in shadow banking is provided by Acharya et al. (2013). The authors empirically examine the relation between commercial banks and a special subset of shadow banking entities, ABCP-conduits (asset-backed commercial paper conduits). ABCP-conduits are financial entities set up by regular banks to outsource assets and financial risk to capital markets. They are solely aimed at purchasing long-term assets from asset sellers such as the own originating bank. The conduit finances the purchase through selling short-term ABCP to investors such as money market funds. Calculations by the authors show that the volume of ABCP grew from $640 billion in January 2004 to $1.3 trillion in July 2007. They find strong arguments in favor of the regulatory arbitrage hypothesis. Such entities were more frequently used by banks that had low ratios of equity relative to assets. These banks mainly used the conduits to actively circumvent regulatory capital requirements as they enabled them to shift risky assets off their balance sheet while still investing in long-term assets and keeping regulatory capital low. Allen (2004) or Jackson (2013) report evidence that such regulatory loopholes in finance exist since the implementation of Basel I in 1988. Implemented to control and reduce bank risk-taking, the regulation unintentionally opened regulatory loopholes that encouraged banks to circumvent the measures by the use of securitized finance. These findings are supported by Acharya and Richardson (2009). They also consider misaligned regulations in Basel I+II to be crucial for regulatory arbitrage opportunities to exist. As the former authors, Acharya and Richardson trace such developments back to the lax regulation of securitization under Basel I and II. It allowed banks to barely hold regulatory capital against assets securitized through off-balance sheet entities. It thereby enabled originated loans to be shifted off the balance sheet whereas these loans would normally require to hold costly capital. Indeed, Adrian and Jones (2018) report that Basel I required zero and Basel II only little regulatory capital against exposures to ABCP-conduits or other securitization activities.

Besides cost avoidance motives through regulatory loopholes, the regulatory framework and the process of financial intermediation in itself facilitated the exploitation of frictions in the interaction between the agents involved. Commonly known from microeconomics, **agency frictions** and **informational asymmetries** are inherent in and influence the efficiency of the intermediation process. In shadow banking systems, such frictions evolve easily and exist manifold as its opaque and complex structure is susceptible to misalignments and disincentives. Accordingly, the usage and targeted exploitation of such frictions for reasons such as profit maximization might be seen as another rationale behind the existence of shadow banking. As one example, Adrian and Jones (2018) highlight that disincentives and misalignments stemming from agency frictions become significantly distinct in the process of securitzation. The complex system of intermediation combined with opaque and multilayered securitized financial instruments fuels informational frictions by obscuring the true quality of the underlying assets or loan pools. Since it converts subprime loans ("the lemons") into high-rated securities it is exemplary of informational asymmetries and agency problems between the involved players. In this respect, Ashcraft and Schuermann (2008) highlight seven frictions inherent in the process of mortgage securitization among agents. These frictions mainly stem from informational asymmetries and especially comprise adverse selection and agency frictions. This view is further supported by Coval, Jurek and Stafford (2009) who give impressive insights into the economics of structured finance. The authors pinpoint that the process of securitization obscured and underestimated the true risks of underlying loan pools, leading to vast amounts of risky assets being transformed into seemingly risk-free and high-yielding securitized products.

These frictions are to a great extent promoted by the usage of **financial innovations** in the process of credit intermediation. Although innovations in financial markets started much earlier, they picked up pace alongside the upswing in shadow banking. As such, the existence of financial innovation can be seen as a further rationale of shadow banking. It is especially structured finance that explains the large increase in financial innovation in combination with the shadow banking system. Calculations by Coval, Jurek and Stafford (2009) show that the structured finance market increased heavily in the years to prior the crisis and then significantly dropped, with \$25 billion of structured products issued quarterly in 2005, \$100 billion issued quarterly in 2007 and only \$5 billion issued in the first quarters of 2008. Coval, Jurek and Stafford (2009) and Adrian and Jones (2018) link this rapid growth, among other factors, with misalignments and disincentives in the business of rating agencies. Due to increased market demand for rated assets and a drive for expanding ratings to structured and securitized products, agencies fostered a "rating inflation" for securitized assets, thereby spurring on the securitization business and the expansion of shadow banking activities.

Closely linked to these aspects is the role of **specialization** in the process of financial intermediation (Adrian, Ashcraft and Cetorelli 2013, Pozsar et al. 2013). The decomposed intermediation structure of shadow banking usually involves entities that are highly specialized and geared to a certain function in the intermediation chain (e.g. structured investment vehicles or special-purpose entities). Although traditional banks could usually provide these services by themselves, it is the combination of economies of scale, cost avoidance through regulatory loopholes and exploitation of agency frictions that makes a seperation into different entities more efficient.

As a logical consequence of the above points follows the rationale that channeling credit through the shadow banking system serves, among others, the purpose of maximizing profits. Accordingly, the **search for yield** effect is another factor of motivation. Several authors such as Coval, Jurek and Stafford (2009) or the IMF (2014) claim that securitized products attracted investors due to their triple-A rating that combined apparently low risks with high yields. Those high yields combined with ample liquidity and relatively low market interest rates during the early 2000s spured excessive demand by investors in the US and other parts of the world. This view is further supported by Goda, Lysandrou and Stewart (2013) and Goda and Lysandrou (2014). These papers see a causal relation between the relatively low nominal long-term yields in major US bond markets in the years prior to the crisis and the exceptionally stark increase in the demand for securitized products such as CDO. According to the authors, investors were eagerly searching for high-yielding assets and triple-A rated securities that resembled triple-A rated corporate or government bonds were welcome alternatives.

3.2 The economic consequences

The macroeconomic consequences emerge on two different levels. On the one hand, channeling credit through the shadow banking system causes significant risks to financial stability, both on a country and on a global level. On the other hand, additional suppliers of liquidity alongside the regulated banking sector can potentially alter the transmission channels of monetary policy, impact on its efficiency and forecast accuracy.

3.2.1 Financial stability Implications

In a statement before the Financial Crisis Inquiry Commission in 2010, then-chairman of the Fed Ben Bernanke (2010) discussed the causes of the crisis and distinguished crisis triggers and systemic vulnerabilties. He summarized that triggers are particular events or shocks that initiate a crisis (one example are the significant losses on subprime mortgage loans) whereas vulnerabilities are the financial system's structural weaknesses, that often emerge as "products of private sector-arrangements" and enable, facilitate and propagate the triggering shocks.

In this differentiation, shadow banking clearly falls into the latter category as it evolved as a major source of vulnerabilities for the financial system. These vulnerabilities derive from the structure of shadow banking in combination with the aforementioned motivating factors (Adrian and Jones 2018). Extensive risk and maturity transformation through shadow banking entities with high levels of leverage set the stage for risks to emerge in this sector. The opqaue structure and interconnectedness with the official banking sector in combination with missing regulations and supervision then imply significant risks to the stability of the entire financial system. Adrian and Jones (2018) point out that such factors can act as stress accelerantes in times of financial downturns and facilitate a transmission of shocks. This, in turn, can initiate cascade effects between the regular and shadow banking sector and, most likely, spill over to the real economy and other parts of the global financial system. The FSB (2018) highlights the importance of such transmission effects as well. Although they identify linkages between the sectors as a means to diversify risk on the one hand, they indicate the problem of too high a level of interconnectedness that induces contagion effects across sectors and economies on the other. The latter point can cause procyclical movements in asset prices and credit supply not only in good times, but facilitate downturns as well, thereby making financial crises more likely. Where regular banking is then protected through liquidity lines and a well-developed system of regulation, shadow banking is not. In the absence of such adequate regulations, shadow banking constitutes a large risk to the stability of the financial system.

3.2.2 Monetary policy implications

Besides financial stability considerations, shadow banking bears increased significance and challenges for the proper conduct of monetary policy. In its monthly report series for March 2014 the Bundesbank identifies two central issues of importance. If banking activities are increasingly conducted by non-bank entities outside the regular scope of central banks, implications occur for the monetary analysis on the one hand, and the proper and effective conduct of monetary policy measures on the other.

As regards the former point, the Bundesbank hints at challenges that shadow banking activities constitute for the analysis and informational content of monetary and credit indicators. Such indicators play a vital role in the decision-making procedure of central banks as they are particularly important for assessing the developments of consumer prices, the real economy and hence medium term changes to price stability. Ordinarily, central banks gather such information on the basis of balance-sheet data of the regular banking sector and are thus able to compile a relatively adequate picture of financial sector activities and the price level. However, if non-bank entities in the unregulated shadow sector start to increasingly take over banking functions, the informational adequacy of balance-sheet data of the regular banking sector is distorted and may lose its representative character for financial activities and monetary developments. This in turn impairs the monetary analysis and can, at a later stage, reduce the effectiveness of monetary policy measures.

The latter point rather concers the direct transmission effects and hence the effectiveness of monetary policy measures. In light of increased shadow banking activities with the private and public sector, regular banking is constantly losing its role as primary financial intermediary between the central bank on the one hand and the non-financial sector on the other. In this regard, the Bundesbank in particular emphasizes the monetary transmission channels through which monetary policy measures such as interest rate changes are transmitted from regular banks to the real economy. Important to mention are the interest rate channel through which changes in main interest rates are transmitted to the real economy and thereby influence spending and investment, or the credit channel through which bank credit supply is influenced via interest rate changes. If, however, shadow banking entities increasingly substitute regular banking activities investors and private households start to rely on funding from alternative shadow banking sources and regular bank funding and loan origination loses ground. As a consequence, the conventional transmission channels become less important and the effectiveness of monetary policy measures weakens; monetary policy stimuli increasingly lose their stabilizing character for price developments and hence the economy.

4 Shadow banking and financial frictions in DSGE modeling

This section starts with a brief explanation of the evolution of financial frictions in monetary DSGE models as we believe this is key to understanding the workings of the models that we go through in the next oart. Based on the considerations from Section 3.1 and 3.2, we then extensively review DSGE models that feature shadow banking and illustrate their key analytical modeling blocks.

4.1 Financial frictions in DSGE modeling

The role of financial frictions in DSGE modeling can be seperated into two eras whereby the turning point is marked by the GFC.[3]

Before the crisis, DSGE modeling placed insignificant emphasis on the role of financial frictions and financial markets which is one of the reasons why these models did not foresee the global consequences of financial disturbances in the U.S. economy. At that time, a widespread opinion was that financial sectors run smoothly and are thus of less importance for business cycles. Several assumptions explain this misjudgement of which we focus on two.[4] One traces back to the work of Modigliani and Miller (1958) and postulated a separation of the macro sphere from financial aspects. In their theorem on the "irrelevance of financing structure", they proposed that given an efficient market, the external value of a firm is not affected by its financing structure, i.e. the amount of equity or net worth. By uncoupling the market value from financing aspects and capital markets, Modigliani and Miller likewise uncoupled real economic activity from financial sectors (Claessens and Kose 2017). Another assumption has been highlighted by Christiano et al. (2018) and refers to the fact that until the GFC, postwar recessions in the U.S. and Europe did not seem to be caused by frictions and disturbances in financial markets and only had small effects on business cycles. Although crises happened (e.g. the savings and loan crisis or the tech Bubble), their consequences remained local and the stake of financial markets in their development remained negligible (Christiano et al. 2018). That is why research focused on frictions other than those in financial markets.

These insights resulted in DSGE models that largely neglected financial sectors and financial frictions and rather focused on elaborated modelings of the real side of the economy to explain business cycle fluctuations. The type of frictions considered were real and nominal rigidities and usually placed in non-financial sectors. We want to sketch two important advances in the following: one is the literature on the financial accelerator mechanism and the other highlights the attempts to develop plausible model environments to generate impulse responses that were able to explain the observed fluctuations in real variables during that time (e.g. the widespread models of Smets and Wouters 2003 or Christiano et al. 2005).

As regards the financial accelerator mechanism, two approaches guided further reserach in the field of monetary DSGE modeling. The first traces back to the seminal papers of Gertler and Bernanke (1989), Carlstrom and Fuerst (1997) and Bernanke, Gertler and Gilchrist (1999). The second follows the setup developed by Kiyotaki and Moore (1997). Both strands add realism to the model world by implementing microeconomic frictions (asymmetric information stemming from principal-agent relations and enforcement problems) that result in credit market imperfections for non-financial agents (borrowers). This opens up a financial accelerator mechanism whereby small shocks are amplified and propagated throughout the economy, affecting equilibrium conditions.

[3] A detailed review on the evolution of financial frictions is extensively laid out by Quadrini (2011), Duncan and Nolan (2017) or Claessens and Kose (2017).

[4] Another assumption rests on the hypothesis of efficient capital markets by Fama (1970). For a detailed overview see Claessens and Kose (2017).

In the Bernanke/Gertler-strand, the financial accelerator essentially works through the concept of the external finance premium, which is the cost to a borrower between raising funds externally and the opportunity costs of internal funds, i.e. own cash flows (Bernanke 2007). This external finance premium is likely to be positive as lenders typically put effort into monitoring their borrowers due to the existence of asymmetric information about investment projects. These monitoring efforts are factored into the corresponding interest rate. And since lenders acknowledge that borrowers have "skin in the game", i.e. sufficient net worth or liquidity, the concept assumes an inverse relation between the premium and the financial engagement or balance sheet of borrowers. Hence, the better the financial position of borrowers in the project, the easier lenders are able to monitor them and the lower are the monitoring costs to overcome uncertainty due to informational asymmetries. This costly state verification-mechanism and the relation to the external finance premium is based on Townsend (1979). It is this nexus that creates the financial accelerator mechanims. Once a negative productivity shock starts to worsen the balance sheet positions of firms (borrowers), their external cost of finance increases as their net worth/liquidity deteriorate. The external finance premium increases, worsens their cost of funds and thus reduces investment. Hence, it is the cost of credit that is constrained here. This amplifies and propagates the initial shock over several periods. Bernanke (2007) points out that the financial accelerator mechanism is, in principle, applicable to any shock affecting borrowers balance sheet items.

The second approach to model the financial accelerator is by Kiyotaki and Moore. In this approach, asymmetric information make it difficult for lenders to fully enforce debt repayment from borrowers and that is why lenders require collateral against their outstanding funds. To show their engagement in a project, borrowers must maintain enough collateral in the form of assts. This, in turn, introduces an upper borrowing limitation based on the value and availablity of collateral. Accordingly, borrowers only receive the amount of funds they are able to collateralize with their assets as this enables lenders to take recourse to their funds in case of bankruptcy. The financial accelerator effect emerges due to the linkage of asset prices as collateral for loans. Once any shock reduces asset prices, the borrowers' collateral value decreases, reduces creditworthiness and hence access to liquidity. This, in turn, reduces investment and amplifies the initial shock over several periods (Claessens and Kose 2017). Here, it is not only the cost of credit that changes, but also the availability.

As regards the class of models using real and nominal frictions to generate impulse responses able to explain the observed fluctuations in real variables, the Smets and Wouters (2003)-model and the Christiano et al. (2005)-model evolved as a foundation for DSGE models used for monetary policy analysis. Due to space constraints, we restrict attention to the former. Smets and Wouters (2003) developed an estimated DSGE model for the euro area with a fully-fledged productive sector, stickiness in price and wage setting, and various shocks. The economy consists of households, final and intermediate good firms. Monetary policy is implemented via a standard Taylor-rule and the government runs expenditures financed via debt (bonds). Households maximize utility consisting of consumption (final goods) and leisure (drawing disutility from supplying labor). As labor is differentiated over households, they act as wage-setters and can realize a degree of market power when setting wages. This stickiness in nominal wages is based on the approach of Calvo (1983). Above, households are owners of the capital stock and rent out capital services to intermediate goods producers, which combine acquired capital and labor to an intermediate good. Monopolistic competition in the intermediate goods market allows firms to maximize profits by setting prices over marginal costs. Their price setting behaviour follows the Calvo-mechanism: firms can only reset their price once receiving a random signal, they otherwise index prices to past inflation. Final goods are produced under perfect competition using the intermediate good as input, and then sold to households. A Taylor-type reaction function for the interest-rate setting of monetary policy closes the model. Their model entails ten structural shocks (such as productivity, cost-push, monetary policy etc.) and is estimated to fit key macroeconomic variables (GDP, consumption etc.) in the Euro Area. Given these parameter estimations, they analyze the impulse responses to the shocks and their contribution to the business cycle fluctuations. As their model includes several features (sticky prices and wages, imperfect competition, capital accumulation with adjustment costs) that deliver a reasonable empirical fit, the features of the production side have become standard in recent DSGE modeling.

It was only due to the crisis that DSGE models started to consider frictions in financial intermediation as a source and amplifier for financial linkages and business cycle fluctuations. Quadrini (2011) gives valuable advice on why such frictions are to be implemented in financial intermediation except for they played a major role in the GFC. Firstly, they have a cyclical property meaning that credit flows and lending standards are highly pro-cyclical and thus reinforce shocks. Secondly, they are a channel linking financial flows to real economic activity. This is why thirdly, they cause stark amplification effects of non-financial shocks. Based on these insights, post-crisis DSGE modeling started to combine the approved features of the real side of the economy already known from e.g. Smets and Wouters (2003) or Christiano et al. (2005) with sophisticated modelings of finanical sectors, financial frictions and fitted modifications of the financial accelerator mechanism. This new class of models now accounts for elaborated financial intermedation subject to financial frictions and the possibilties of financial crises (see e.g. Schwanebeck 2018). Beyond that, they cover recent unconventional monetary policy measures (see e.g. Gertler and Karadi 2011) as well as macroprudential and regulatory tools (see e.g. De Paoli and Paustian 2017 or Poutineau and Vermandel 2017). In general, these modeling developments roughly follow two broader lines.

One strand has been mainly pushed forward by Mark Gertler, Peter Karadi and Nobuhiro Kiyotaki. These types of models feature rich financial sectors where banks are specialized intermediaries between borrowers and savers and usually act in perfect competition. Frictions in financial intermediation result from an agency problem between bankers and creditors (firms) that gives rise to endogenously determined balance sheet constraints of bankers. Once shocks hit the model, a BGG-type financial accelerator mechanism depresses financial intermediation and thereby economic activity. Noteworthy examples in this direction are Gertler and Karadi (2011), Gertler and Kiyotaki (2010, 2015), Gertler, Kiyotaki, Queralto (2012), or Dedola et al. (2013). Closely connected to this strand is the approach of Iacoviello (2005, 2015). In his seminal paper (Iacoviello 2005), he combines the BGG-financial accelerator with collateral constraints in the sense of Kiyotaki and Moore where the eligible collateral is real estate (housing). Firms (here entrepreneurs) borrow from households and the maximium amount of borrowing is dependent on the collateralizable amount of real estate (housing). In Iacoviello (2015), he extends the setup such that financial capital now flows through banks that are constrained in their ability to supply credit to entrepreneurs.

The second direction departs from the assumption of perfect competition and implements banking in a monopolisitic competitive environment. The type of frictions usually remain identical: agency problems and a BGG-financial accelerator catalyze real or financial shocks and transmit them through the economy. However, monopolistic competition now allows banks a certain degree of market power in their business environment. It assumes that although banks offer similar financial products, each is a variety with slightly different characteristics. This degree of market (pricing) power enables banks to set prices (here interest rates) above marginal costs (here interest on deposits) and generates positive lending spreads that result in (inefficient) profits. As pointed out by Andrés and Arce (2012), there is ample empirical evidence suggesting that monopolistic power in banking is a source for positive lending spreads. Among other factors, this seems to be caused by transaction and switching costs that induce a lock-in effect for customers (Gerali et al. 2010). Noteworthy examples are Gerali et al. (2010), Andrés and Arce (2012) and Poutineau and Vermandel (2015, 2017).

4.2 Shadow banking in DSGE modeling

This section reviews the existing publications in the DSGE literature that consider financial intermediation through shadow banking systems.[5] For this approach, we draw on the findings from section 3.1, and use the specified aspects there to sort the publications based on their respective method to implement shadow banking. With this approach, we are able to identify two explicit modeling emphases the literature focused on so far: shadow banking is either modeled as a form of specialization in the process of intermediation or as a manufacturer of securitized finance. Table 2 shows the segmentation. It is important to mention here that one could likewise sort along the policy problems addressed within the paper as their content emphased differs, ranging from monetary policy considerations through to financial stability and regulatory issues. We, however, sort along the special modeling characteristics of the considered setup. That is why in the subsequent sections, we illustrate the method used to implement shadow banking and only in setion 5 carve out the implications of the model for monetary policy and financial stability considerations, as described in section 3.2.

[5]Besides these publications, a number of working papers exist that we do not consider here. Mazelis (2016) studies a model with shadow banking were monetary policy is constrained by the zero lower bound, Kirchner and Schwanebeck (2017) examine unconventional monetary policy measures in the face of shadow banking, Fève et al. (2019b) study shocks to credit supply by shadow and retail banks to explain the U.S. economy during the GFC, Gebauer and Mazelis (2019) analyze the impact of tighter financial regulations for commercial banks on shadow banking.

Table 2: Modeling emphases

Specialization	Financial innovation
Gertler, Kiyotaki, Prestipino (2016)	Meeks, Nelson, Alessandri (2017)
Verona, Martins, Drumond (2013)	Nelson, Pinter, Theodoridis (2017)
	Feve, Moura, Pierrard (2019a)

4.2.1 Specialization

Section 3.1 highlighted the aspect of shadow banking being a form of specialization in the financial intermediation process. A strand of literature captures this aspect by considering shadow banks to be specialized entities with comparative advatanges in their financial activities.

The publication by **Gertler, Kiyotaki and Prestipino (GKP 2016)** focuses on this aspect of shadow banking**.** Their paper is motivated by the fact that disruptions in shadow banking markets triggered and aggravated the GFC. Their objective is to reasonably model shadow banking activities (labeled wholesale banking) and macroeconomic fragility implemented via (un)anticipated runs on the banking sector within a mainstream DSGE setup.

For that purpose, they extend the framework of Gertler and Kiyotaki (2011) and especially the model on banking instability and bank runs of Gertler and Kiyotaki (2015) to feature a rich interaction between retail and wholesale banks on the one hand, and implement the possibility of (un)anticipated bank runs on wholesale banks on the other hand. The setup is condensed to focus on financial interaction and comes without a fully fledged productive sector and nominal rigidities. The key features are as follows: households and financial intermediaries populate an economy with a nondurable and a durable good, of which the latter is capital. Agents can hold/invest in capital directly and, together with the nondurable good, use it for the production of new capital and goods. Acquiring capital, however, requires agents to borrow funds (non-financial loans) from banks and holding it is costly at the margin due to capital management costs. Here, households are supposed to posses inferior competencies and thus face higher management costs as opposed to financial intermediaries. It is this comparative advantage of financial intermediaries in managing capital/assets that motivates their existence in the model. The resulting flow of funds has financial intermediaries channeling financial capital from savers to investors, i.e. households place deposits in banks which, in turn, originate non-financial loans. Besides, intermediaries can resort to an interbank market.

In this setup, financial intermediation is modeled along the lines of Gertler/Karadi/Kiyotaki: banks maximize their bank value by accumulating retained earnings (net worth). It evolves as the difference between returns from loans and the costs for deposits; and borrowing from other banks. As long as the intermediary can earn a positive premium on its assets, it pays to make additional loans and retain any positive premium to maximize net worth until the time he has to exit. As will become apparent, the financial friction will introduce an endogeneous constraint on the borrowing ability of bankers and thereby exacerbate shocks.

The innovative feature in GKP (2016) is a heterogeneity in the banking sector. It is separated into retail and wholesale banking and the main difference arises in the way banks manage capital and are exposed to the financial friction. As regards the former point, financial intermediaries incur capital management costs whereby wholesale banks are considered to incur the lowest costs. Due to their specialization in the management of their respective assets (here capital), they are able to offer capital services at a lower cost compared to other agents. The role of shadow banks being specialized entities in the process of financial intermediation is thus crucial to the model (see section 3.1). As regards the latter point, financial frictions are implemented with the use of a moral hazard problem between banks and their creditors (households and other banks). Based on the positive premium that the banker earns when supplying credit, he might be inclined to expand lending indefinitely. The financial friction now endogenously limits the ability of both retail and wholesale banks to raise funds from creditors. It relates the borrowing capacity to the constraint that for both banks to receive funds, the going bank value V_t^j must exceed a fraction of assets that is considered to be divertable by bankers.[6]

The authors condense the friction in the following incentive constraints, where $j = r, w$ (retail and wholesale, respectively), FL are loans to firms, BF interbank funds and θ, ω, γ ($\theta, \omega, \gamma \in (0, 1)$):

$$V_t^j \geq \theta[FL + \omega BF], \text{ where } b_t^j > 0 \tag{1}$$

$$V_t^j \geq \theta[(FL + \gamma(-BF)], \text{ where } b_t^j < 0. \tag{2}$$

As the source and use of funds differ among banks, so does their exposure to the friction. Eq. (1) relates to a borrowing bank within the interbank market ($BF > 0$). It can more easily divert the fraction θFL, that is loans to firms, as compared to the fraction $\theta\omega BF$, that is assets funded with interbank funds. The reason is that GKP assume that banks posses superior qualifications in monitoring counterparties as compared to when households monitor banks they supply deposits to. Hence, assets governed by $\theta\omega$ constitute better collateral for outsiders. Eq. (2) shows the case of lending banks within the interbank market ($BF < 0$) and states that the fraction $\theta\gamma BF$, that is loans to other banks, is harder to divert as compared to the fraction θFL. Here, loans among banks are assumed to be easier to monitor for outsiders (households) since interbank lending is said to reduce idiosyncratic risk in loan origination (banks are supposed to perfectly know their counterparty). In these relations the parameters

[6] Once banks collected assets, they might be on the take instead of proceeding to maximize the bank value during the time they are active. When doing the former, banks divert a fraction of their assets to return it to their respective household and use it personally. This potential fraud induces households to be only willing to supply additional funds to banks if they see an incentive for banks to remain in business, hence to maximze V_t^j.

ω and γ are essentially important. They determine the attractiveness of interbank affairs and thereby pin down the relative size of the wholesale banking sector. Variations in ω and γ change the collateral value of interbank assets and, accordingly, their relative attractiveness to retail deposits or non-financial loans. GKP choose $\omega + \gamma > 1$, implying a situation with a plausible amount of interbank relations alongside loan origination by retail banks. Further, they focus on the scenario that has retail banks receiving deposits and, besides non-financial loans, supplying interbank loans ($BF < 0$). Wholesale banks have no access to deposits, they are dependent on funds from their sponsoring retail banks ($BF > 0$). With the help of variations to ω, the authors then try to visualize the process of securitization. Variations to ω change the collateral value of interbank borrowing and thereby the strength of the financial friction. This impacts on the leverage ratio of intermediaries and affects the lending behaviour of both retail and wholesale banks. Reducing ω increases the collateral value of interbank borrowing for wholesale banks which in turn reduces their leverage ratio and extends their non-financial lending capactiy. As more capital is channeled through wholesale banks, the economy finds itself in a more efficient steady state (wholesale banks incur the lowest capital management costs).

In this model, the financial accelerator works through the effect of the incentive constraint on the ability of financial intermediaries to supply the economy with financial capital. It is especially the existence of the wholesale sector that acts as an additional amplifier. As a shock hits the balance sheet of intermediaries, the value of their assets declines and automatically tightens/worsens the agency friction, i.e. the incentive constraint. Credit spreads rise, making finance more expensive. Wholesale banks, being higher leveraged than traditional banks, are especially hard hit and to recover, both deleverage and cut back on lending.

The content emphasis of the paper is on the interaction of financial intermediation and the consequences of (un)anticipated bank runs for financial stability. In their experiments, the authors use productivity shocks as a trigger for financial crises and assume (un)anticipated runs on wholesale banking. A run happens when sponsors of wholesale banks suddenly decide to not roll over funding lines (interbank credits). As this erodes a major source of funding for wholesale banks, they are forced to liquidate assets and start a firesale, causing a significant drop in asset prices. The starting point, however, is a negative shock to productivity that starts the well-known financial accelerator mechanism. Due to a reduction in the price of capital, it feeds through the balance sheet of both retail and wholesale banks. As their asset position worsens, the agency friction deteriorates and the collateral constraint tightens, i.e. the access to finance is impaired. Through the high level of leverage, wholesale banks worsen the effect of the initial drop in asset prices and thereby exacerbate the financial accelerator. After such a shock, the economy slowly moves bank to its steady state. What matters here is the amount of leverage held by wholesale banks. As this depends on ω, the size of wholesale banking acts as a financial amplifier. Given this, the authors then introduce two government policies: in the scenario of ex-post intervention, the central bank acts as lender of last restort while in the ex-ante intervention scenario, macroprudential policy limits the risk exposure of banks. In the former scenario, the central bank intervenes in credit markets with large scale asset purchases when the expected return on assets exceeds the cost of borrowing. GKP can show that it is the mere anticipation of intervention that weakens the impact of the crisis as it reduces the probability of runs. In the latter scenario, GKP assume leverage restrictions on wholesale banks such that an upper limit on their leverage ratio exists. Again, the policy is effective in preventing a run and thereby calms down the recessionary effects. However, as the leverage restrictions impair the ability to leverage and thereby slow down credit supply, the policy decelerates the recovery of the economy.

A second contribution that focuses on the aspect of specialization in financial intermediation is the publication by **Verona, Martins and Drumond (VMD 2013)**. The paper assesses the applicability of different DSGE model environments for analyzing business cycle fluctuations given too low and too long interest rate policies. Based on recent events, they are especially interested in whether misaligned interest rate settings in the US during the early 2000s, among other factors, facilitated a macroeconomic boom-phase that was followed by the well-konwn bust phase starting in late-2006. For their examination, the authors run different DSGE model setups. Their baseline version follows the framework of Christiano, Motto, Rostagno (2010) and includes a financial sector with the BGG-financial accelerator mechanism. For comparison, another version is missing the latter two characteristics.

The models feature the typical agents known from e.g. Smets and Wouters (2003) such as households, capital producers, intermediate and final goods firms, entrepreneurs, financial intermediaries and the government. Financial intermediaries exist because they provide the productive sector (entrepreneurs) with credit to finance investment projects. Financial frictions arise as these projects are risky though not freely observable by the bank; this bears monitoring costs. This sort of asymmetric information requires a contract that enables the bank to have recourse to its funds in case of bankruptcy of the firm. This costly state-verification causes the bank to charge an interest rate premium depending on the net worth of the firm. As such, it is countercyclical and induces the typical BGG-financial accelerator.

In the first step, the authors pinpoint the effect of banking and financial frictions in explaining boom-bust phases in economic and financial activity given anticipated and unanticipated shocks to the policy rate (technically materialized by either holding the interest rate constant with a sequence of (unexpected) shocks over several periods (unanticipated), or by announcing a policy path for several periods (anticipated)).

In a second step, the authors extend the model with a shadow banking system (labeled investment banks). In this extension, investment banks exist because entrepreneurs are now separated along two risk dimensions: one group being risky and the other being safe. Based on emprical data showing that safe firms rather resort to bond financing via investment banks, the risky ones are dependent on bank finance and the safe ones acquire funding in the form of bonds from the shadow banking system. Being safe means having sufficient net worth to be able to always repay debts and never default. The consequence is a lower interest rate on external finance. Accordingly, shadow banks exist because of their specialized competencies in supplying parts of the financial system with safe assets. A main difference is that VMD move away from the assumption of perfect competition á la Gertler/Karadi/Kiyotaki. The shadow banking system is populated by monopolisitic competitive investment banks who are suppliers of slightly differentiated financial assets (bonds) and thereby have a degree of market power. This allows them to set bond interest rates in a profit maximizing manner. The measure of market power is depicted in the elasticity of demand for financial assets (bonds) and is endogeous in that it moves with the business cycle.

Banks maximize

$$\max_{R_{t+1}^{coupon}(z)} \Pi_{t+1}^{IB}(z) = \{[1 + R_{t+1}^{coupon}(z)]BI_{t+1}^{LR,l}(z) - [1 + R_{t+1}^{e}]BI_{t+1}^{LR,l}(z)\} \tag{3}$$

subject to the (low risk) entrepreneurial demand for funds

$$BI_{t+1}^{LR,l}(z) = \left(\frac{1 + R_{t+1}^{coupon}(z)}{1 + R_{t+1}^{coupon}}\right)^{-\varepsilon_{t+1}^{coupon}} BI_{t+1}^{LR,l}. \tag{4}$$

Accordingly, investment banks set the profit-maximizing interest rate R_{t+1}^{coupon} on bonds issued to entrepreunrs above the risk free rate R_{t+1}^{e} they pay on returns to households, taking as given the entrepreneurial demand for funds. For the objective of the paper, the spread in bond finance is essential for the model dynamics. It is the difference between the bond rate and the risk free rate

$$spread_{t+1} \equiv R_{t+1}^{coupon} - R_{t+1}^{e} = \frac{1}{\varepsilon_{t+1}^{coupon} - 1}(1 + R_{t+1}^{e}) \tag{5}$$

where $\varepsilon_{t+1}^{coupon}$ is the time-varying interest rate elasticity of the demand for funds. As VMD conclude that bond spreads typically move with business cycles, the authors set up two versions whereby the reaction of $\varepsilon_{t+1}^{coupon}$ derives from different states of the economy. VMD consider that during normal times, the interest rate elasticity follows the equation $\varepsilon_{t+1}^{coupon} = \varepsilon_{t+1}^{normal} = \bar{\varepsilon} + \left(Y_t - \bar{Y}\right)$. Here, the movement of $\varepsilon_{t+1}^{normal}$ is based on the output gap $\left(Y_t - \bar{Y}\right)$ and a constant $\bar{\varepsilon}$. Deviations of current output from its potential cause changes to $\varepsilon_{t+1}^{normal}$ and force a countercyclical reaction of (5). In the second verison, that is during times of overoptimism identified through higher entrepreneurial net worth, the elasticity follows $\varepsilon_{t+1}^{coupon} = \varepsilon_{t+1}^{optimistic} = \varepsilon_{t+1}^{normal} + (1 + \varkappa_t)$ with $\varkappa_t$ being an AR(1) process of type $\varkappa_t = \rho_{\varkappa}\varkappa_{t-1} + (1 - \rho_{\varkappa})\left[\bar{\varkappa} + \alpha_2(NR_{t+1}^{LR,l} - N^{LR,l})\right]$. The elasticity $\varepsilon_{t+1}^{optimistic}$ now moves with $\varkappa_t$ reflecting optimism. Due to $\alpha_2(NR_{t+1}^{LR,l} - N^{LR,l})$ in the AR (1) process, $\varkappa_t$ is driven by its sensitivity to changes in entrepreneurial net worth (deviations from its steady-state level). Accordingly, interest rate spreads in VMD evolve endogenously, as the elasticity of the demand for funds depends on the state of the economy.

After calibrating the model to U.S. data, the authors run several experiments to analyse the model setups in terms of their applicability for explaining boom-bust phases caused by (un)anticipated interest rate regimes, during normal and overly optimistic times. Their model is able to show that setups with financial frictions, at least in their parametrization, fail to produce downturns in response to monetary policy shocks that are large enough to replicate the bust-phase starting in 2007. Once enriching the setup with a shadow banking system, the model fit changes. During normal times (the spread reacts countercyclically to the output gap), VMD find that the existence of shadow banking adds realism to the model as core macro variables such as output, investment and the price of capital react more in line with empirical findings. During optimistic times and when agents do not anticipate the policy path, VMD find that their model predicts buildups in the price of capital and excessive credit that correspond to empirical findings prior to the GFC.

4.2.2 Financial innovation (securitization)

In Section 3.1, we already identified financial innovation, especially that of securitization, to be an important rationale for the existence of shadow banking. A strand of literature is capturing this aspect by allowing shadow banks to manufacture securitized assets as collateral in the financial intermediation process.

Meeks, Nelson and Alessandri (MNA 2017) is among the most important and trend-setting paper in this model direction. The objective of their paper is to properly account for the macroeconomic implications of the interaction between shadow banking and regular banking. In particular, MNA are interested in the consequences of business cycle and financial shocks for aggregate activity and credit supply during normal and crises times in order to allow for more accurate policy advice. Central to their model is a comprehensive interaction between regular and shadow banking that is based on the process of securitization in credit provision. In principle, their model is a version of components specific to their model and components from the Gertler/Karadi/Kiyotaki-strand.

The structure of their model is as follows: households enjoy utility from consumption and are composed of workers, bankers and brokers. The model features a productive sector where firms produce final output and capital producers transform final goods into capital goods. In this environment, the former need to purchase capital for production from the latter which, in turn, intoduces the role for financial intermediaries to exist since the acquisition of physical capital requires firms to receive loans from banks. As is standard in this strand of literature, financial intermediaries maximize their bank value by accumulating net worth that evolves as the difference between returns on assets and costs for liabilities.

The innovative feature in MNA (2017) is the role of securitization in credit provision and the associated segmentation of banking into commercial banks and shadow banks (brokers). The latter exist as their specialized competencies in transforming illiquid loans into tradeable and better pledgeable assets (ABS-portfolios) adds substantial efficiency to the process of intermediation. The role of shadow banks being manufacturers of ABS in the process of financial intermediation is thus crucial to the model. The authors thereby manage to implement an important aspect of recent shadow banking systems (see Section 3.1). The economic function and the resulting flow of funds is as follows: commercial banks have a comparative advantage in originating loans to firms FL and, for that purpose, combine household deposits and net worth. Besides, they acquire portfolios of ABS m_t^c from the shadow banking system. Shadow banks, however, do not originate loans, they rather hold loan pools composed of loan bundles formerly originated by commercial banks. The acquisition is funded with net worth and manufactured ABS-portfolios m_t^b. When manufacturing portfolios of ABS, shadow banks use two securitization schemes: "risk-sharing" and "risk-taking securities". The former has its returns fed by the cash flows of the loan pools and risk is shared among both investors and shadow banks. The latter rather constitutes a fixed and noncontigent claim and is as such more comparable to bank-like debt products. According to MNA, this differentiation adds substantial realism to the model as both schemes were predominant at the onset of the GFC. As regards the leverage ratio of both intermediaries, MNA consider shadow banks to be more highly leveraged than commercial banks. The difference is caused by lower net worth of shadow banks, simply operating with higher leverage.

The financial friction in the model is the well-known agency problem in the sense of GKP (2016) and Gertler and Karadi (2011). It limits the volume of funds intermediaries are able to receive from their creditors. Accordingly, the possibility of banks to divert a fraction of assets for own purposes opens up the need of incentive comparability between their bank value and the divertable assets. The incentive constraints for commercial and shadow banks read

$$V_t^c \geq \theta_c[FL + (1 - \omega_c)m_c^t] \text{ where } [\theta_c, \omega_c] \in (0, 1), \tag{6}$$

$$V_t^b \geq \theta_b[m_t^b + n_t^b]. \tag{7}$$

Eq. (6) introduces an important feature of the model. Here, MNA consider that the process of securitization actively destroys idiosyncratic risk inherent in loans and, by pooling and tranching a variety of loans, creates a safer and thus more pledgeable asset. For creditors (households), this process guarantees a safer claim and thus a better collateral. As in GKP 2016, MNA use two diversion parameters for this relation. Loans FL are governed by θ_c only whereas ABS-portfolios m_c^t by $\theta_c \omega_c$ and as such are harder to divert. The effect is as follows: the more ABS banks hold, the more trustworthy their business appears to outsiders, the more relaxed their funding constraint (6) becomes and, accordingly, the higher their lending capacity becomes. Eq. (7) reflects these relations for shadow banks. Here, MNA capture the feature that it is not households that monitor shadow banks, but rather their sponsors, the commercial banks. MNA suppose that this fact guarantees in itself higher trust as banks have comparative advantages in monitoring their counterparties and that is why $\theta_b < \theta_c$, i.e. the divertable fraction of assets is higher for commercial as for shadow banks.

These relations then bring about the typical financial accelerator mechanism. As in GKP, it works through the effect of the incentive constraint on the ability of financial intermediaries to supply the economy with financial capital.

The content emphasis of the paper of MNA is to account for business cycle comovements between output, credit by traditional and shadow banks, and for the behaviour of the latter during a liquidity crisis. In their quantitative analysis, the exogenous disturbances that cause the crisis are twofold and target the incentive constraints (6) and (7). Firstly, (7) is hit by a positive shock to θ_b that reduces the collateral value of assets held by shadow banks. In the second scenario, a negative shock to ω_c in (6) reduces the pledgeability of shadow assets (ABS) held by commercial banks. Both scenarios depict a "securitization" crisis like the one experienced at the onset of the GFC where assets held and produced by the shadow banking system suddenly lose in value. Here, it is the impact on the incentive constraint that makes both shocks trigger a financial accelerator effect. The changes in θ_b and ω_c cause (7) and (6) to tighten as the respective assets are loosing in collateral value. Both types of bankers, interested in maximizing their bank value while confronted with tighter incentive constraints, now have to restructure their business. The effect is a contraction in securitized shadow assets (as shadow banks reduce supply) and bank loans (as commercial banks strengthen their position in ABS as they now require more of it). Since both disturbances directly hit the financial sector, financial activitiy comes to a halt, the supply of funds for the productive sector is impaired and consumption, investment and output drop significantly.

In the second step, MNA go through the possibility of official backstops by the government to moderate the effects of the securitization crisis. To this end, the government can purchase loans or securitized assets in exchange for government debt, the latter being a perfect substitute for deposits. In both instances, the government appears as an additional intermediary in markets with the benefit of being 100% creditworthy, i.e. with no financing constraints. MNA find that direct loan purchases are more effective in reducing macroeconomic volatility than interventions in shadow banking markets.

Nelson, Pinter and Theodoridis (NPT 2017) is the next publication to be considered in this subcategory. Their main contribution is to enter into the discussion of whether US interest rate decisions prior the GFC fueled misguided balance sheet expansions of commercial banks and the shadow banking system. Awareness of such opposing effects of monetary policy measures adds to the question of whether monetary policy should be used universally to lean against imbalances to achieve financial stability goals, or whether measures need to vary depending on which part of the financial system is affected.

As the point of departure, NPT (2017) estimate VAR models to control for the impact of monetary policy decisions on changes in financial sector's balance sheets. Their estimations show that during the period from 1966-2007, a tightening of monetary policy tended to reduce assets held by commercial banks. Due to the higher cost of funding, they reduced lending to the economy. In contrast, assets such as mortgage securities held by the shadow banking system increased. The authors ascribe this countercyclical impact to a circumvention strategy of commercial banks. By redirecting parts of their lending to the shadow banking system, commercial banks effectively avoided higher funding costs.

In a second step and based on the empirical findings, the authors deploy a DSGE model to replicate the empirical evidence. The structure of their model closely follows MNA (2019). Since the effects are identical to MNA (2019), we do without explanations here.

The content emphasis of the paper is on the ability of monetary policy to fully control for imbalances in the economy to achieve financial stability goals, or whether the measures need to vary depending on the part of the financial system that is affected. In their quantitative analysis, NPT run a contractionary monetary policy shock and compare the resulting impulse response functions with the perviously found empirical facts of the VAR model. Their anaylsis shows that the theoretical model comes close to the empirical data, even for a wide range of parameter values. As the increase in the monetary policy rate puts downward preasure on overall lending, it reduces asset prices and increases the funding costs for commercial banks. A financial accelerator effect sets in whereby decreasing asset prices put preasure on the balance sheet of commercial banks, who, in turn, have to reduce net worth to account for the losses. Simultaneously, commercial banks are eagerly searching for collateral in order to keep their intermediation business active and further on maximize the going bank value. Now, acquiring ABS offered by the shadow banking system helps to attentuate the downward preasure on commercial banks' balance sheet. Holding more of these assets relaxes the incentive constraint (6) and allows to extend credit. Accordingly, commercial banks increase demand for ABS and shadow banking expands.

The third publication that embeds shadow banking with the use of securitization is the paper by **Fève, Moura, Pierrard (FMP 2019a)**. The aim of their paper is to examine different forms of macroprudential regulation and their impact on financial sector stability and business cycle movements. Central to their model is an interaction between regular and shadow banking that is based on securitization in credit provision. To identify two structural model parameters, the authors use Bayesian methods and estimate the model on quarterly U.S. data for the period from 1980-2016.

The structure of their model is as follows: households' utility consists of consumption, holdings of deposits (driven by a liquidity motive) and labor supply. The latter is demanded by a representative firm and, given a standard Cobb-Douglas function, combined with capital into the final good. For renting capital for production, the firm borrows financial capital from the banking sector, what introduces the reason for financial intermediaries to exist. The banking sector is composed of traditional banks and shadow banks. The former combine deposits and net worth to hold two types of assets: loans to firms and ABS from shadow banks. Traditional banks then simply maximize profits with respect to deposits, loans and ABS. Shadow banking is modeled in an overlapping generation structure with shadow bankers living for 2 periods. FMP treat shadow banks as special-purpose vehicles created by traditional banks to outsource capital. Accordingly, the balance sheet of shadow banks comprises loans to firms funded with issued ABS. Profits evolve as the difference between income from loans and interest paid for the issuance of ABS. As FMP assume free market entry, a zero profit condition ensures a constant number of shadow banks.

From the maximization of traditional banks, they derive a crucial condition that governs the interaction between traditional and shadow banks. $\Gamma' \frac{1}{q_t l_t} + E_t \epsilon^a_{t+1} = E_t \Lambda_{t,t+1}(r^a_t - r^d_t)$ depicts the spread between ABS returns and the deposit rate and shows that the spread equals portfolio-adjustment costs Γ (limit the ability of the bank to substitute between both assets) plus $E_t \epsilon^a_{t+1}$, depicting a shadow wedge, i.e. an ABS default shock based on an AR(1) process. Hence, since there are no monitoring or regulation costs in holding ABS, its demand is solely driven by its premium over holding deposits and a default shock. With a linearized approximation of the equation, the authors can show that an increase in the return on ABS directly increases traditional banks' demand for the very same. An increase in the shadow wedge, however, increases the required return on ABS and reduces holdings of the very same.

In the model of FMP, shadow banks do not increase the efficiency of credit intermediaton by relaxing financial frictions (as in GKP or MNA), shadow banks rather act as a circumvention strategy for traditional banks as they are unregulated. Macroprudential regulation in FMP follows a capital requirement on bank capital n_t. Especially, n_t is constrained downwards by a fraction of risk-weighted assets $\bar{\eta}$ that consists of $q_t l_t$ only as abs_t are not included. The tool then gets $x_t = n_t - \bar{\eta} q_t l_t$. To circumvent the possibility that banks only hold unweighted abs_t, FMP calibrate its equilibrium return lower as that of bank loans.[7]

FMP then compare a world with fixed shadow credit to the benchmark case with active shadow banks. By means of a positve productivity shock, they find shadow banking to be an amplifier of business cycle movements. Following the shock, traditional banks want to increase lending but likewise need to increase capital at the instivation of the regulators. Due to a substitution with unregulated ABS, banks can limit the costs implied by the macroprudential tool and increase credit more strongly. The reaction of output and investment is intensified.

As their content emphasis is on regulation, they then introduce a countercyclical capital buffer following $\eta_t = \bar{\eta} + \kappa_\eta (\frac{\Delta b_t}{y_t} - \frac{\bar{\Delta} \bar{b}}{\bar{\Delta} \bar{y}})$ with Δb_t being a measure of credit growth and κ_η the sensitivity parameter. The tool now moves countercyclically with deviations of credit growth relative to output from a steady-state level. Three versions of that scheme exist: the regulator either keeps requirements constant, countercyclical on traditional loans only, or countercyclical on traditional and shadow banking loans (symbolizing Basel I, II and III, respectively). Their results show that, once unregulated, shadow banking enables regulatory cost arbitrage for traditional banks and reduces the effectiveness of macroprudential policies. If shadow and traditional banking are regulated, business cycles fluctuations can be attenuated.

5 Discussion and implications

With the occurrence of the GFC, long-neglected attention shifted to the role played by failings in regulatory frameworks and the ensuing consequences on the structure of the financial system. Due to these developments, the literature on financial intermediation in DSGE modeling has made significant progress over the last decade. The models considered in section 4.2 introduce new approaches of how to extend existing setups in order to consider heterogeneities in financial sectors where retail and shadow banks act as financial intermediaries between savers and borrowers. As the latter are usually firms in the productive sector, this new model generation is able to establish a comprehensive nexus between the financial and the real side of the economy. By introducing such interlinkages, these models are now able to bridge a gap between the observed empirics before and during the GFC on the one hand, and a lack

[7] FMP circumvent the implemention of the regulation tool due to computational challenges and use a shortcut. If a bank holds less capital than required, it is subject to a penatly cost that is proportional to th emerging capital gap. The cost function reads $\Theta_t(x_t) = -\theta_1 \ln(1 + \theta_2 x_t)$ with costs being decreasing and convex in x_t.

of sufficient DSGE modeling on financial intermediation in place at the onset of the GFC on the other. This progress allows the empirical observation that both real and financial sector shocks can cause financial distress that jeopardizes the stability of the financial system, spills over to economic activity and causes harsh and long-lasting business cycle downturns.

The models considered allow several conclusions. A first general one refers to the ability to show that once financial intermediation is extended by a shadow banking sector, the effects of both real and financial shocks hitting the economy are larger and more protracted than in comparable baseline scenarios without shadow banking sectors. Shadow banking acts as a powerful amplification mechanism. The explanatory power rests upon the implementation of frictions in financial intermediation and the resulting nexus between changes in asset prices caused by real or financial sector shocks and the balance sheet conditions of financial intermediaries. This is amplified by the fact that shadow banks are more highly leveraged than retail banking. Shocks that reduce asset prices and thereby force intermediaries to reduce net worth hit shadow banks relatively harder than retail banks. The financial friction amplifies the effect on credit (or ABS) supply of shadow banks and puts additional downward pressure on economic activity. Especially the models of MNA and GKP are well-suited setups to look back on and reappraise these occurrences. Both are rich in detail in modeling the shadow banking and the financial sector. Accordingly, the models are better able to generate business cycle movements that are comparable to the ones observed during the recent GFC.

The second general conclusion refers to the explanatory power of these models regarding considerations on financial stability and macroprudential policies, as laid down in section 3.2.1. The GFC made obvious that there is a strong nexus between the stability of the financial system and real economic activitiy. That is why in the years following the crisis, policy makers and research on financial regulation turned towards a macro perspective in banking supervision. With the regulations as laid down in the framework of Basel III, a set of new macroprudential policies has been introduced that are aimed at the stability of the financial system and its resilience during financial distress. These policies are mainly directed towards the balance sheet exposures of financial intermediaries and aim at their risk-taking, leverage restrictions and (countercyclical) capital buffers.[8] In the DSGE literature, these measures are usually covered by implementing capital requirements and analyzing their impact on macroeconomic stability. The measures are then based on a policy rule that reacts to variations in financial indicators such as credit or loan aggregates, credit and lending spreads, output growth, or any relation of these variables. Such measures have been found to work well in dampening fluctuations in bank equity/capital and other macroeconomic variables with the effect of increased financial and macroeconomic stability. The models of GKP and FMP explicitly account for financial stability in combination with shadow banking and implement macroprudential policies. GKP assume leverage restrictions on wholesale banks in the form of an upper limit on their leverage ratio. FMP introduce a countercyclical capital buffer with three versions symbolizing Basel I, II and III, respectively (see section 4.2 for closer explanations). Their results show that macroprudential policies are effective in

[8] For a literature review on macroprudential policies see Galati and Moessner (2012).

attenuating fluctuations of the business cycle and thereby foster financial stability. As pointed out by GKP, the effects of these measures stem from the fact that they weaken the financial accelerator effect. As the policies moderate the drop in net worth of financial intermediaries, they can counteract the negative effects stemming from the initial shock. A stabilization of net worth softens the financial friction and thereby dampens the contraction in credit supply by financial intermediaries. The side effect, however, comes in the form of regulatory arbitrage (if the shadow banking sector remains unregulated) and a slowdown of credit supply after a crisis whereby these policies tend to decelerate the recovery of the economy. However, what these considerations ignore is the interaction of financial stability measures with (conventional) monetary policy measures.

Besides these general conclusions, there are aspects that relate to the specific strengths and weaknesses of these models. Among the strengths are e.g. the awareness of new types of amplification channels between regular banking and the shadow banking system or modeling advances that now allow the incorporation of financial sector efficiency due to specialization and financial innovation. The weaknesses touch upon aspects that the models do not cover but that are of importance from the viewpoint of policy makers and relate to section 3.2.2 and 3.2.1.

As regards the amplification mechanisms, the bank capital channel and the role of leverage and liquidity are of exceptional significance. As outlined by Claessens and Kose (2017), balance sheet positions such as net worth are of importance for the proper conduct of credit supply through financial intermediaries. Once shocks reduce asset prices and intermediaries adjust for losses by reducing net worth, their access to funds (such as deposits) worsens and reduces their lending capacity. The source of this interaction in the models considered is the implementation of financial frictions such as agency problems and the resulting incentive constraints that bring about financial accelerator mechanisms and cause a spiral of worsening financial conditions and downward pressure on economic activity. Once asset prices deteriorate, intermediaries reduce net worth and their access to funding is impaired as their incentive constraints tighten. Given tighter incentive constraints, intermediaries cut back on lending to the real sector and investment and output drop. Another amplification channel brought to light by the GFC is the role of leverage and liquidity of financial intermediaries (Claessens and Kose (2017)). In prosperous times, high levels of leverage allow higher borrowing capacities and as such can have positive impact on economic activity. However, the downside of high leverage is that balance sheets and hence net worth of intermediaries are overly exposed to shocks that cause asset prices to fluctuate. Once disruptions in financial or economic activity cause assets to devaluate, the reaction of financial intermediaries is to cut back on lending in order to comply with leverage restrictions. This, in turn, depresses economic activity. The papers considered, especially GKP and MNA, capture this nexus. Both calibrate leverage ratios (assets to net worth) of shadow banking to be twice as high as for retail banks and the effects of shocks are amplified by the degree of leverage. Asset prices drop and the direct effect is to reduce net worth which is accompanied by a tightening of incentive constraints. Shadow banks, showing higher leverage ratios, are more exposed to this mechanism.

Besides this, these modeling advances now allow the incorporation of specialization and financial innovation. Alongside the negative impact on financial stability, specialization and financial innovation clearly comprise positive aspects in that both can increase the efficiency and extend the borrowing capacity of the financial sector. The models of GKP and MNA are able to pinpoint that these effects set in once accounting for shadow banking activities. In MNA, the shadow banking system transforms illiquid loans into tradeable assets and as such helps to manufacture economically valuable collateral that extends the lending capacity of financial intermediaries. In the model of GKP, the effect of specialization (financial innovation) is captured through changes in the agency friction (collateral constraint) between retail and shadow banks, condensed in the parameter ω. In the steady state of the model, several variables react to changes (here a reduction) in this parameter with the consequence that the overall amount of capital channeled through the shadow banking system is larger and the economy equilibrates in a more efficient steady state.

However, there remain aspects that the models considered do not cover but that are of importance from the viewpoint of policy makers. These points largely fall into the considerations made in section 3.2.2. A key argument here is that the policy measures avalibale to central banks lose in efficiency once financial intermediation is increasingly conducted by non-bank institutions such as the shadow banking system that are out of reach of central bank activities. To evaluate such interlinkages and the impact of monetary policy decisisons on real variables in DSGE setups, the crucial model condition is the presence of nominal frictions (nominal rigidities) in the price setting behaviour of firms and the presence of monopolistic competition. Once firms have a degree of market power when setting prices, prices do not change immediately when market demand changes. Since this price stickiness generates a nexus between nominal and real aggregates, monetary policy has real impacts. The most popular approach to consider stickiness in nominal prices (and wages) is the method of Calvo (1983). In this approach, prices (or wages) are set in a staggered manner as the ability to reset prices (or wages) is an exogeneous probability that is signalled randomly to a fraction of firms (or households). The remaining fraction keeps prices constant. Due to this stickiness in nominal price setting, monetary policy can use the nominal interest rate to steer the real rate and hence impact on real economic activity. In the DSGE setup, nominal rigidities require an elaborated modeling of the real side of the economy in the sense of e.g. Smets and Wouters (2003) or Christiano et al. (2005). However, several of the models considered are real business cycle models extended with financial frictions but abstract from nominal rigidities. This applies for GKP, FMP and MNA. The two former models omit to model a fully-fledged productive sector that features the typical web of firms needed to implement nominal rigidities. In the model of MNA, a more elaborated productive sector exists as the production of capital is outsourced to capital producers. However, the absence of nominal rigidities permit the study of conventional monetary policy. Given the circumstance that central banks conduct conventional tools simultaneously to unconventional measures and macroprudential tools, a proper policy analysis needs to evaluate the effects of applying such measures synchronously.

Another aspect relates to the structure of bank balance sheets in the considered models.

In the wake of the crisis, it became obvious that the capitalization of the banking sector was insufficient to account for the immense losses in asset values and the abrupt illiquidity of private borrowers. The regulatory response to these maldevelopments was the introduction of new supervisory measures as laid down in the BASEL III regulations. In contrast to BASEL II, the new regulations aim for a better resistence of the banking sector to shocks that cause a depreciation in asset values and thereby threaten the solvency of banks. The requirements comprise a more detailed segmentation of relevant supervisory equity capital into tier 1 capital (segmented into common equity tier 1 capital and additional tier 1 capital) and tier 2 capital. These new regulations intend to increase the quality of equity capital, reduce bank leverage and excessive levels of liquidity. In the models considered, the balance sheet of banks usually consists of the asset side with credit to firms (and possibly other financial intermediaries) and liabilities composed of deposits and net worth/equity. Implementations of regulatory macroprudential tools then usually take advantage of capital requirements or leverage restrictions that draw on bank net worth. However, given this rather simple structure of balance sheets, the models miss a detailed depiction of the different equity tiers of banks. This is, however, important in order to give a neat depiction of macroprudential policies in the sense of Basel III. Some recent advancements in this direction are Gertler et al. (2012) or Nelson and Pinter (2018) who allow banks to issue outside equity along with net worth.

Finally, the advancements in DSGE modeling over the last decade yielded more realistic model environments that allow elaborated analyses on the causes and consequences of financial distress and business cycle fluctuations. As these models account for the interaction between financial sectors and the real economy, they are able to track that even small financial or real shocks can precipitate a financial crisis of internatonal dimension that is followed by sharp declines in real economic activity. Given these new modeling setups, research and policy making is now better able to estimate and assess the effects of shocks and thereby implement more accurate policy measures.

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