# Essays in Liquidity, Monetary Policy, and the Commodity Market

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A Thesis submitted for the degree of

**Doctor of Philosophy in Finance**

**Essex Business School**

**University of Essex**

September 2022

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# Acknowledgments

I would like to express my sincere gratitude to my supervisors Chiara Banti and Neil Kellard for their continuous guidance and support throughout this journey.

I offer my special thanks to Radu Manac and Roxana Baltaru for their encouragements and valuable discussions. I should also thank Alexandros Kontonikas and Simon Price for insightful comments and suggestions. Furthermore, I gratefully acknowledge the financial support from the South East Network for Social Sciences (SeNSS).

I am very grateful to my family and friends for their unwavering support and belief in me.

# Declarations

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I declare that the first paper included in the main body of the thesis, 'Prime Money Market Funds Regulation, Global Liquidity, and the Crude Oil Market', is co-authored with my PhD supervisors, Chiara Banti and Neil Kellard, and published in the Journal of International Money and Finance.

# Abstract

This thesis presents three studies related to liquidity, monetary policy, and the commodity market. The first paper is an empirical study of the effect of the 2016 US Prime Money Market Funds (PMMFs) regulation on the crude oil market. This reform increased short-term dollar borrowing costs and due to its debt expansion, the oil sector became particularly susceptible to disruptions in the global funding market. Building on the global crude oil market SVAR model of Kilian and Murphy (2014), we find that tighter PMMFs funding conditions have a negative effect on the real price of crude oil and a positive effect on oil production, driven primarily by a fall in certificates of deposits issued by global banks.

The second paper provides an empirical investigation into a novel directional liquidity-based transmission channel to explain the heterogeneity in the response of commodity futures prices to changes in the monetary policy stance. Using an event-study analysis with a high-frequency instrumental variable estimator, we find a reduction in trading activity following surprise increases in the policy rate. Further, we find that more traded commodities are also more exposed to monetary policy surprises, suggesting a significant role for trading activity in the transmission of monetary policy shocks to commodity markets.

Finally, the third paper explores the international bank-lending transmission channel of unconventional monetary policy to the Brent crude oil futures market. Employing a hybrid model, combining the traditional VAR framework with a policy surprise high-frequency identification approach, we document that perceived expansionary monetary policies reduce the trading volume and the returns of Brent futures via international bank local claims on emerging Asia. Further, perceived contractionary policies also reduce trading activity in Brent futures market, while evading the proposed international bank-lending channel.

# Acronyms

**AEs** Advanced economies.

**CDs** Certificated of deposits.

**CPs** Commercial papers.

**EMEs** Emerging market economies.

**FFFR** The (daily imputed) 30-day federal funds futures rate.

**FOMC** Federal Open Market Committee.

**GFC** Global Financial Crisis of 2007–2008.

**HFIV** High-frequency instrumental variable.

**KM (2014)** Killian and Murphy (2014).

**LSAPs** Large-scale asset purchases.

**NEER** US nominal effective exchange rate.

**PMMFs** Prime money market funds.

**UMP** Unconventional monetary policy.

# Introduction

## Background to the study

Commodity price dynamics have been the subject of international policy debate during the last decades due to their role in shaping the dynamics of global economic activity (Harvey et al., 2017; Ge and Tang, 2020). Movements in commodity prices have often coincided with shifts in global monetary conditions (Anzuini, Lombardi and Pagano, 2012). Specifically, monetary policy decisions, a well-known driver of global monetary conditions, and commodity prices are interlinked (Filardo et al., 2018). Monetary policy decisions drive aggregate demand and subsequently commodity prices, while commodity price volatility influences price stability and hence monetary policy decisions. This relationship can stabilise and de-stabilise the economy under certain conditions.

Since Frankel (1984), global monetary conditions and interest rates have attracted a growing interest as potential driving factors of commodity price movements. This has led to a growing literature devoted to examining the relationship between monetary policy and commodity prices. For example, Anzuini, Lombardi and Pagano (2012) show that expansionary monetary policy shocks drive up the broad commodity price index and all its components, while Mallick and Sousa (2013) document that a monetary policy contraction in the Euro area leads to a quick fall in the commodity price index and a small decline in monetary liquidity, as measured by the growth rate of broad money.

This literature has identified several transmission mechanisms of monetary policy to the commodity market related to macroeconomic fundamentals (Barsky and Kilian, 2001, 2004; Rosa, 2011; Glick and Leduc, 2012). Since 2004, investable commodities have been experiencing an "asset class" effect thought to be driven by institutional investors. The pioneering work of Barberis and Shleifer (2003), followed by Barberis, Shleifer, and Wurgler (2005) and Boyer (2011) define this “asset class” effect as the excessive co-movement of assets belonging to the same index, and attribute this effect to the presence of institutional investors. Focusing on the commodity market, Tang and Xiong (2012) find that since 2004, index commodities have started to behave increasingly different from that of non-indexed commodities, with the former becoming more correlated with oil, an important index constituent, and the equity market. Moreover, commodities included in investable commodity indices such as S&P-GSCI and DJ-AIG have seen a higher exposure to common shocks, driven by investor interest, rather than macroeconomic fundamentals. Building on this work, Basak and Pavlova (2016) show that, in the presence of institutional investors, shocks to the fundamentals of index commodities are transmitted to all other commodity prices.

Given that the US dollar is the foremost funding and investment currency in the international monetary and financial system, the resilience of global economic and financial activity is conditional on the continuous flow of US dollar funding (CGFS, 2020). The extant literature has identified monetary policy actions in the US to be linked to credit cycles through global bank lending to recipient economies, denominated predominantly in US dollars (Avdjiev and Takats, 2014; Bräuning and Ivashina, 2020). The propagation of gross capital flows, particularly through the banking sector, has been widely debated in the literature (Lane and Pels, 2011; Forbes and Warnock, 2012; Obstfeld, 2012a, 2012b; Shin, 2012; Rey, 2015). Bruno and Shin (2015) argue that capital flows transmitted through the international banking system represent a substantial proportion of the total capital flows and propose a model which captures cross-border bank lending in US dollars.

The importance of the bank lending transmission channel of monetary policy to international financial markets is broadened by recent changes in the structure of US dollar funding intermediation process and, in particular, by the presence of non-bank financial intermediaries (Disyatat, 2011, and Schnabel, 2021). Since the Global Financial Crisis of 2007-2008 (GFC), intermediation in advanced economies has moved away from the traditional deposit-based funding towards international debt securities (Turner, 2014; Aldasoro and Ehlers, 2018;

Avdjiev et al, 2020). While global banks have diminished their loan and debt security positions, non-banks have increased their dominance in driving global liquidity (Shin, 2014; Aldasoro and Ehlers, 2018; CGFS, 2020). The notion of global liquidity has been associated in policy discussions with permissive credit conditions in financial centres resulting in capital flows to other parts of the world (BIS, 2011). This recent change in the composition of global liquidity has been referred to as the "second phase of global liquidity" (Shin, 2014; Avdjiev et al., 2020). The shift in international financial intermediation implies that global funding conditions have become more sensitive to developments in bond markets, and more connected to US monetary policy as a key driver of global liquidity conditions.

Despite recent changes in the structure of the intermediation process enhancing the relevance of this channel, the role of unconventional monetary policy (UMP) in the ability of banks to provide liquidity to the economy and, in particular, to the commodity market, is less clear. The transmission of monetary policy via lending supply may be impaired by the presence of capital and funding constraints for banks, driven by either regulatory or market pressure (Bernanke, Lown and Friedman, 1991; Van den Heuvel, 2002). From a non-bank finance perspective, the rise of non-bank financial institutions (NBFI) created new risks for the conduct of monetary policy. The increased risk-taking of NBFI, highlighted by significant duration, liquidity, and credit risks exposure on their balance sheets, can generate liquidity mismatches which affect the ability of NBFI to absorb losses in a downturn. In turn, this can give rise to systemic risk and the impairment of monetary policy transmission mechanism (Schnabel, 2021). In addition, the growing role of non-financial corporations (NFCs) as "financial intermediaries" could reduce the effectiveness of macro-prudential policies (Korniyenko and Loukoianova, 2015).

Empirical literature on monetary policy and liquidity creation documents positive spillover effects via capital flows on other economies (Korniyenko and Loukoianova, 2015; Anaya, Hachula and Offermanns, 2017). Korniyenko and Loukoianova (2015) find a positive relationship between UMP in the S4 (US, UK, Euro area, and Japan), global liquidity and monetary conditions, measured by global NFC deposit growth, banks' cross-border flows, and the issuance of securities. In a similar fashion, Anaya, Hachula and Offermanns (2017) find that an expansionary UMP shock, associated with an exogenous innovation to the Federal Reserve' balance sheet, significantly increases portfolio outflows from the US. In response, the growth of real output and real equity returns increase, and the real exchange rate appreciates. In addition, empirical studies within this strand of research identifies heterogeneity in the response of financial and macroeconomic variables to monetary policy (Korniyenko and Loukoianova, 2015; Chen et al. 2016). Korniyenko and Loukoianova (2015) stress that the impact on global liquidity, monetary conditions, and bank balance sheets from individual UMP programmes varies based on the nature of each program, the initial macro-economic conditions, and the policy response of individual countries.

A large body of literature has examined the response of macroeconomic variables and the stance of monetary policy to changes in commodity prices, with a particular focus on oil price dynamics (Barsky and Kilian, 2004; Kilian, 2008, 2014). However, relatively less attention has been paid to the impact of monetary conditions on commodity prices. Empirical studies within this strand of literature have covered various of commodity markets, with the oil market receiving particular attention (Kilian and Vega, 2011; Rosa, 2014; Scrimgeour, 2015; Hammoudeh, Nguyen, and Sousa, 2015; Basistha and Kurov, 2015). Having yet to reach a consensus on the response of the oil price to shifts in the policy rate, this line of research provides evidence of significant heterogeneity in the response of commodity prices to monetary policy. Scholars have assigned this heterogeneity to the factors related to the specific commodity market, such as weather conditions, storability, easiness of supply, the strength of demand for commodity inventories, and to overreaction due to speculation (Hammoudeh, Nguyen, and Sousa, 2015).

The effect of global liquidity on commodity prices has been explored by relatively few studies and primarily in terms of a co-integrated relationship (Belke, Bordon and Hendricks, 2010; Belke, Bordon and Volz, 2013; Beckmann, Belke and Czudaj, 2014). These studies document a positive long-term relationship between global liquidity, proxied through global aggregates of broad money, and the Commodity Research Bureau (CRB) commodity price index. The effect on the oil market is less clear. Ratti and Vespignani (2013) show that unanticipated increases in the liquidity of BRIC countries lead to significant and persistent increases in real oil prices, global oil production and global real aggregate demand, while Anzuini, Lombardi and Pagano (2012) find that global liquidity results in a sharp, but temporary increase in the price of oil.

### Objectives and contribution of the thesis

This thesis presents three studies examining the effects of liquidity and monetary policy on the commodity market. The first study explores the effect of global liquidity movements on the crude oil spot market. The second study adopts a microstructure perspective in investigating a novel directional liquidity-based transmission channel of monetary policy to the commodity futures market. The third paper provides evidence on the nature of the UMP transmission mechanism to the Brent crude oil futures market.

At the macro level, the first objective of the thesis is to explore the effects of US dollar funding strains brought about by the 2016 Prime Money Market Funds (PMMFs) regulation on the crude oil spot market. In this respect, the paper proposes two channels through which disruptions in the short-term funding of PMMFs can be transmitted to oil companies which borrow in US dollars: an indirect channel through cross-border bank flows based on the model of Bruno and Shin (2015) and a direct channel through PMMFs. The latter channel postulates that disruptions in the short-term wholesale funding, driven by the reform, affect oil companies which borrow directly from PMMFs.

The first study brings original contributions to the extant literature on global liquidity and the crude oil market (Belke, Bordon and Hendricks, 2010; Anzuini, Lombardi and Pagano, 2012; Ratti and Vespignani, 2013), by showing that strains on US dollar funding coming from PMMFs, a crucial source of short-term funding, are transmitted to the crude oil market via cross-border bank flows. Specifically, the study documents that global liquidity matters both for the price and the global production of crude oil.

Secondly, the study contributes to this strand of literature by using a novel measure capturing the short-term component of private global liquidity, namely the investment holdings of US PMMFs by global issuance and by instrument.

In doing so, the paper accounts for the post-GFC shift in US dollar funding intermediation. Specifically, intermediation in advanced economies has shifted away from the traditional deposit-based funding towards international debt securities (Turner, 2014; Aldasoro and Ehlers, 2018; Avdjiev et al, 2020). This implies that monetary aggregates, generally employed in related empirical studies to measure global liquidity, have become less suited to capture shifts in liquidity (IMF, 2013). Thirdly, our study is novel with respect to the literature since it explores the transmission of global liquidity disruptions to the crude oil market, channelled through the activity of oil companies rather than the activity of financial investors and commodity consumers.

In view of the importance of oil price dynamics to modern economy and environmental policies, the first study is relevant for current global economic conditions as it documents that unstable short-term money markets funds affect the crude oil market. Lastly, given the persistent vulnerabilities faced by PMMFs, this study is relevant to the global economic outlook as well as to policymakers. In particular, deteriorating global dollar funding conditions during the peak of the Covid-19 crisis, triggered by severe conditions in the PMMFs industry, are a further reminder of the high dependency of global banks and corporations on the short-term unsecured funding of PMMFs. The findings of our first study support the role of central bank swap lines, central banks' international reserve holdings, central banks' backstop liquidity via asset purchases and special lending facilities, and the monitoring of US dollar funding fragility, in reducing the adverse effects of US dollar funding constraints on the US dollar cross-border bank flows (Eren, Schrimpf, and Sushko, 2020a; IMF, 2021).

At a micro level, the objective of the thesis is to provide empirical evidence of a novel directional liquidity-based transmission channel of monetary policy based on the theory of trade of Lagos and Zhang (2020), to the commodity futures market. The second study of the thesis seeks to explain the heterogeneity in the response of commodity futures prices to changes in the stance of monetary policy, identified in related literature (Scrimgeour, 2015; Hammoudeh, Nguyen, and Sousa, 2015), through this novel directional channel associated with the financialization of the commodity market.

Scholars within the literature on monetary policy and commodity prices have attributed this heterogeneity to the factors related to the particular commodity market such as weather conditions, storability, easiness of supply, the strength of demand for commodity inventories, and to overreaction due to speculation. The extant literature proposes several monetary policy transmission mechanisms to commodity markets centred on macroeconomic fundamentals (i.e., inventory channel, supply channel, demand channel (Barsky and Kilian; 2001, Frankel, 2006; Frankel and Rose, 2010; Rosa, 2011; Gospodinov and Jamali, 2018). This second study brings original contribution to this line of research by investigating a new microstructure channel based on the opportunity cost of holding money arising from the process of financialization of commodities and the observation that trading volume varies across commodity futures. Hence, the paper hypothesizes that surprise increases in the nominal rate reduce the trading volume of commodity futures regardless of whether the increase is associated with an increase in the expected inflation, and that more heavily traded commodities are relatively more exposed to changes in the policy rate. Results confirm our hypotheses.

Secondly, whereas related literature is silent on the asymmetric response of commodity futures prices to policy announcements, our study makes a clear distinction between the type of Federal Open Market Committee (FOMC) policy action (restrictive versus expansive) by employing two interactive dummy variables, based on actual changes in the federal funds target rate. Thirdly, focusing on a sample of individual commodity futures, rather than on an aggregate commodity index or a particular commodity market, as it has been generally studied in the literature, enables us to identify not only the new transmission channel, but also the commodity futures which are most sensitive to changes in the policy rate as well as the direction of their responses.

This evidence is informative to policy makers as it provides insight into how monetary policy operates in the commodity futures market. In particular, given that disruptions in the commodity market can spillover to other financial markets, and to the macroeconomy, our findings are relevant for maintaining financial and price stability, and for the effective implementation of monetary policy. In this respect, our study suggests that policy makers should carefully consider monitoring liquidity creation in the financial system (i.e., credit availability and flow of capital) to control price stability in the commodity market, and the pronounced effect monetary policy has on particular commodities.

The third objective of the thesis is to provide empirical evidence on the nature of the transmission of UMP to the crude oil market. The third study seeks to explain how trading activity in the Brent crude oil futures market is influenced by international bank lending to emerging market economies (EMEs). Three main considerations motivate us to explore this topic. First, UMP operations to which the Federal Reserve turned to since the beginning of the Great Recession of 2007-2008, are considered a source of adverse spill overs to other economies, and in particular to EMEs. Second, driven by the growing interconnectedness in financial markets and deepening of cross-border integration, spillovers of monetary policy on international financial markets occur through international bank linkages. Third, during the last decade, the energy market has been the centre of policy debate for its exceptional volatility and for its role in shaping the modern economy and environmental policies. Given that commodity futures are effectively used for hedging purposes by non-financial corporations concentrated in commodity-based industries such as the oil industry, we expect UMP operations to be channelled onto the Brent crude oil futures market via international bank lending to EMEs.

Our study brings important contributions to the nascent but growing literature on UMP and the commodity market (Glick and Leduc, 2012; Rosa, 2014; Hammoudeh, Nguyen, and Sousa, 2015, Apergis, Chatziantoniou and Cooray, 2020) by being the first to investigate the international bank-lending channel of UMP to the Brent crude oil futures market. Our findings show that trading activity in Brent futures market is affected by perceived expansionary monetary policies through international bank local claims on Asia EMEs, while perceived contractionary monetary policies evade the bank lending channel. Instead, at the micro level, contractionary policies are transmitted to the Brent futures market through the financial liquidity channel.

The scarce related literature adopting a macroeconomic empirical framework (Hammoudeh, Nguyen, and Sousa, 2015; Apergis, Chatziantoniou and Cooray, 2020) has employed UMP proxies measured at monthly frequency, namely, the growth rate of central bank reserves and the short-term shadow rate. This third paper adds to this strand of literature by adopting a more credible approach to the identification of monetary policy shocks, well suited to analysing policy at the zero lower bound. Specifically, this study uses a hybrid model which combines the traditional VAR with a high-frequency identification (HFI) of monetary policy. In doing so, the empirical analysis amends concerns surrounding endogeneity as well as simultaneity. Besides, related empirical studies using a macroeconomic framework are silent on the asymmetric response of commodity futures prices to policy announcements related to LSAPs. We bring important considerations to this line of research by accounting for the direction of policy surprises.

### Structure of the thesis

This thesis presents an empirical investigation of liquidity, monetary policy, and the commodity market. The next three chapters, each presenting a paper, are followed by concluding remarks, which present the conclusions of the thesis and potential avenues for future research.

The first chapter presents the first paper which is an empirical study of the effect of the 2016 Prime Money Market Funds regulation on the crude oil price in the spot market. Modelling the global crude oil market using the pioneering SVAR model of Kilian and Murphy (2014) (KM, henceforth), to which we add our funding variable, PMMFs investment holdings by global issuance, the paper finds compelling evidence of a lagged negative effect of tighter funding conditions, driven by the reform, on the real crude oil spot price, and of a lagged positive effect on oil production. Turning to the source of the dollar funding shock, we augment the SVAR model of KM (2014) by introducing certificates of deposit (CDs), which represent the highest proportion of the investment instruments held by PMMFs during our sample period 2011:2 to 2021:10. CDs also constitute the most important unsecured wholesale funding for banks. The paper finds the effect of the PMMFs funding disruption on the crude oil market to be driven by a fall in the CDs. The estimation of the augmented SVAR models relies on a Uhlig's (2005) pure-sign restriction identification approach of structural shocks. The responses of PMMFs and

CDs, respectively, to a negative PMMFs funding shock are restricted to be negative for three months, starting in the impact period. This additional information allows for a fine distinction between funding shocks generated by the reform of interest and funding shocks driven by other factors. Furthermore, this restriction is relaxed to assess the general impact of funding shocks on the crude oil market. Results are very similar. Finally, the paper employs the US nominal effective exchange rate (NEER) to account for an appreciation in the value of the dollar against other major currencies driven by thinner dollar supply from US PMMFs and finds that the NEER acts as a complementary transmission channel for the negative funding shock to the real price of oil.

The second chapter, which presents the second paper, provides a thorough empirical investigation into a novel directional liquidity-based transmission channel of monetary policy to the commodity futures market. The analysis begins with an estimation of the reaction of the trading volume of 19 commodity futures that comprise the S&P GSCI to monetary policy surprises (i.e., target surprises) on the days of FOMC announcements. In this respect, the paper employs an event-study analysis with a high-frequency instrumental variable estimator and documents that the trading volume of the sample of commodity futures declines following target surprise increases. Further, exploiting the cross-sectional variation in trading volume that exists across commodity futures, the study then employs an event-study regression of individual commodity future returns on changes in the policy rate, an interaction term between the change in the policy rate and the average trading volume of individual commodity futures, and several controls. In this second exercise, interactive dummy variables based upon actual changes in the federal funds target rate are used to explore the asymmetric response of commodity futures prices to the stance of monetary policy. The study shows that the returns of commodity futures are negatively (positively) affected by target surprise increases, associated with contractionary (expansionary) FOMC policy actions. In addition, the analysis provides supporting evidence that the magnitude of the effect of policy surprises is stronger for more heavily traded commodity futures.

The third chapter presenting the third paper provides a thorough empirical analysis of the nature of the transmission mechanism of UMP to the Brent crude oil futures market. At the macro level, the paper explores the international bank-lending channel of UMP. In this respect, a hybrid model combining the traditional VAR framework with a high-frequency identification approach of monetary policy surprises is employed. The surprise content of FOMC announcements related to UMP operations (interpreted as asset purchase surprises) is determined using daily changes in the 10-year government bond yield bracketing FOMC announcements. Policy surprises are then included in the VAR model as an exogenous variable. At the micro level, the paper studies whether the financial liquidity-transmission channel based on the theory of trade of Lagos and Zhang (2020) is operative in the Brent futures market at the zero-lower bound, by focusing on both the return and the trading volume of Brent crude oil futures. Our empirical analysis makes a clear distinction between positive and negative surprises to account for potential asymmetries in the response of Brent futures to UMP operations. Our results show that a perceived expansionary monetary policy affects trading activity via international bank local claims on emerging Asia, while perceived contractionary monetary policies bypass the bank-lending channel. This latter finding supports the financial liquidity-transmission channel of Lagos and Zhang (2020).

# Chapter 1

# Prime Money Market Funds Regulation, Global Liquidity, and the Crude Oil Market

## 1.1 Introduction

US Prime Money Market Funds, hereafter PMMFs, are a primary funding source of short-term liquidity, offering financial institutions and non-financial corporations access to wholesale funding.[1] PMMFs play a vital role in global dollar funding provision and represent an important source of US dollar funding for non-US borrowers, especially during crisis episodes such as the 2007-2009 Global Financial Crisis (GFC), the Eurozone crisis and the recent global outbreak of Covid-19, which has made them the centre of the current international policy debate (see IMF, 2021).

In 2016, a set of regulatory reforms for PMMFs were introduced to address the vulnerabilities which emerged during the GFC, according to which PMMFs were required to adopt a floating net asset value structure, liquidity fees and redemption gates in the event of a large increase in outflows (SEC, 2014).[2] This regulatory reform represented an important shift in the intermediation of wholesale bank funding as it led to higher short-term dollar borrowing costs in a number of ways (BIS, 2016). Firstly, the subsequent portfolio shifts of PMMFs resulted in significantly wider Libor-OIS spreads (BIS, 2016). Secondly, the rising market share of prime funds belonging to top fund families, triggered by the reform, indicates that smaller-sized prime funds were more likely to exit or convert to government or treasury funds. This resulted in a rise in the

[1]PMMFs are unsecured MMFs which invest in a combination of public *(repos)* and private sector obligations (e.g. certificates of deposit *(CDs)*, commercial paper *(CPs)* and asset-backed commercial papers *(ABCP)*).

[2]Government MMFs, which are secured money market funds investing solely in government securities or repos, were not subject to the new regulation.

market power of the remaining funds, which were able to charge a higher price to banks with less elastic demand and weaker bargaining power (Aldasoro, Ehlers and Eren, 2019).

We propose two channels through which disruptions in the short-term funding of PMMFs can be transmitted to companies which borrow in US dollars: an indirect channel through cross-border bank flows and a direct channel through PMMFs (see Figure 1.1). The cross-border bank lending model of Bruno and Shin (2015a) suggests that global banks lend in US dollars to regional banks, which in turn lend to local borrowers (non-financial corporations). This cross-border lending is funded by global banks by raising US dollars in the major financial centers. US PMMFs are an important source of this funding (see Hanson, Scharfstein, and Sunderam, 2015; Aldasoro, Ehlers and Eren, 2019; Aldasoro, Eren and Huang, 2021).[3] More specifically, certificates of deposits (CDs) held by PMMFs became the most important unsecured wholesale funding source for banks following the GFC and a barometer for bank funding conditions (Eren, Schrimpf and Sushko, 2020b). Thus, short-term funding strains from PMMFs, particularly in the CDs market, will generate spillover effects to oil companies, which borrow in US dollars from banks via the cross-border bank lending channel.

Alternatively, disruptions in the short-term wholesale funding brought about by the US PMMFs reform can affect companies which borrow directly from PMMFs. The expansion of debt in the oil sector in the post-GFC period makes oil companies particularly susceptible to sudden disruptions in the global funding market. Post-GFC, oil companies have borrowed heavily in US dollars from both banks and in the bond markets, with the issuance of debt securities far outpacing the overall issuance of other commodity sectors (see Domanski et al., 2015 for further details).[4] Commercial papers (CPs) represent the primary financing source used to balance short-term funding liquidity requirements by major oil companies, accounting for roughly 6.2 percent to 25.5 percent of total debt as of the end of 2020.[5] As noted in Eren, Schrimpf and Sushko (2020a,b), PMMFs are major global providers of short-term dollar funding to non-financial corporates. As of the beginning of 2020, PMMFs held a total

[3] PMMFs are estimated to provide roughly 35 percent of the short-term, wholesale dollar funding to global financial institutions (Hanson, Scharfstein and Sunderam, 2015). US and offshore PMMFs accounted for around 12 percent of the on-balance sheet funding for non-US banks at end of 2019 (Aldasoro, Eren and Huang, 2021).

[4] In particular, bonds outstanding in oil and gas sector increased from 455 billion US dollars in 2006 to 1.4 trillion US dollars in 2014, while syndicated loans increased from 600 billion US dollars in 2006 to an estimated 1.6 trillion US dollars in 2014. Debt issued by oil and other energy firms stands at 15 percent of both investment grade and high-yield major US debt indices, which represents a 5 percent increase in five years (see Domanski et al., 2015).

[5] These percentages were computed using information contained in the 2020 annual reports of Chevron, Exxon Mobil, BP, and Royal Dutch Shell.

amount of 255,545 dollars (in millions) of CPs.

Motivated by the effects of the 2016 US PMMFs regulation on global dollar funding conditions, the post-crisis debt expansion of the oil sector and the importance of oil price dynamics on the modern economy and environmental policies, we study the impact of this regulation on the crude oil price in the spot market. We model the global crude oil market using the pioneering SVAR model of Kilian and Murphy (2014), hereafter KM (2014), and refer to this model as our baseline model throughout the paper. We use monthly data for the four global crude oil market variables of KM (2014), namely, global crude oil production, global real economic activity, global crude oil inventories and the real price of crude oil, to which we add our funding variable, PMMFs investment holdings by global issuance.[6] We augment the SVAR model of KM (2014) by introducing CDs as an investment instrument held by PMMFs.[7] We thus aim to measure how the crude oil spot price is impacted according to the source of the dollar funding shock.

The US nominal effective exchange rate (NEER) is employed in our modelling approach of the exchange rate transmission channel of funding shocks, to account for an appreciation in the value of the dollar against other major currencies driven by thinner dollar supply from US PMMFs. Fluctuations in the value of the dollar affect the price of crude oil via oil supply, oil demand or cross-border bank lending. In particular, an appreciation of the US dollar (i.e., an increase in the US NEER) is associated with deleveraging of global banks and a reduction in cross-border dollar bank lending (Miranda-Agrippino and Rey, 2020). The value of the dollar is thus an indicator of global credit conditions, with an appreciation of the dollar constituting a tightening of global financial conditions (see Bruno and Shin, 2015a; Shin, 2016, for further discussion). We also include the consumer price index and VIX, as control variables for the feedback effects between inflation, risk appetite and uncertainty, and the price of crude oil (Belke, Bordon and Volz, 2013; Beckmann, Belke and Czudaj, 2014; Cheng, Kirilenko and Xiong, 2015). The structural shocks are identified using Uhlig's (2005) pure-sign restriction approach. Sign restrictions have become increasingly popular in the recent literature on oil markets (Baumeister and Peersman, 2013a, 2013b; Kilian and Murphy, 2012, 2014).

Our results empirically confirm our main hypothesis that tighter dollar funding conditions driven by the 2016 regulatory reform for US PMMFs affect

[6]Global real economic activity is measured by the dry cargo shipping rate index as developed in Kilian (2009). A further discussion on the advantages of this index compared to measures of global real GDP or global industrial production is presented in Kilian and Zhou (2018).

[7]For completeness, we also consider the effect of *repos*, *other repos*, *CPs*, *ABCP* and other instruments held by PMMFs on the crude oil market. The estimation results are available upon request.

the crude oil market. We also provide more general evidence of the impact of shifts in PMMFs funding conditions on the oil market. Hence, we capture not only the major disruptions from the introduction of the 2016 regulatory reforms, but also other relatively minor funding shocks. Specifically, we find compelling evidence of a lagged negative effect of tighter funding conditions on the real crude oil spot price, proxied through the US refiners' acquisition cost for imported crude oil, and of a lagged positive effect on oil production. These results are robust to measuring the real price of oil using the WTI spot price and the Brent spot price as well as to the inclusion of VIX. Notably, these findings hinge on the validity a number of identifying assumptions such as an immediate reduction in real activity and PMMFs, following a negative funding shock.

Further, we find that the effect of the PMMFs funding disruption on the crude oil market is driven by a fall in the CDs, which constitute the most important unsecured wholesale funding for banks. Thus, we argue that the US dollar funding disruption triggered by the PMMFs reform is transmitted indirectly from PMMFs to the crude oil market, through cross-border bank flows. Lastly, we find that the US nominal effective exchange rate acts as a complementary transmission channel for the negative funding shock to the real price of oil. We argue that an appreciation of the US dollar caused by a shortage of US dollars supplied by US PMMFs could decrease oil demand, as oil imports become more expensive in local currencies for non-US countries (De Schryder and Peersman, 2015). Alternatively, this US dollar appreciation could reduce the cross-border lending of non-US banks, thus affecting cross-border bank flows and generating a spillover effect to companies such as oil producers, which borrow in US dollars from non-US banks (Bruno and Shin, 2015a; Avdjiev et al., 2019; IMF, 2019).

The main contribution of this paper to the extant literature, is that we are, to the best of our knowledge, the first to show that strains on US dollar funding from PMMFs, a vital source of short-term funding, affect the crude oil market. More specifically, we show that global liquidity matters for the price and the global production of crude oil. Secondly, the existing literature on global liquidity and commodity spot prices uses global aggregates of broad money as a proxy for global liquidity, which have become less suited to capture the post-GFC shift in US dollar funding intermediation, referred to as the "second phase of global liquidity". We account for this "second phase of global liquidity" by using a novel measure capturing the short-term component of private global liquidity, namely the investment holdings of US PMMFs by global issuance and by instrument (Belke, Bordon and Hendricks, 2010; Anzuini, Lombardi and Pagano, 2012; Ratti and Vespignani, 2013, among others).

In view of the importance of the US PMMFs, our findings are relevant for current global economic conditions as they show that unstable short-term money markets funds affect the crude oil market. We add to the literature by investigating the effect of global liquidity movements on crude oil prices, channelled through the activity of oil companies rather than the activity of financial investors and commodity consumers, which has been the focus of the recent studies on the oil market (Belke, Bordon and Hendricks, 2010; Anzuini, Lombardi and Pagano, 2012; Ratti and Vespignani, 2013; Beckmann, Belke and Czudaj, 2014, among others). Lastly, this study is relevant to the global economic outlook due to the persistent vulnerabilities faced by PMMFs, which are a major concern for regulators. Deteriorating global dollar funding conditions during the peak of the Covid-19 crisis, triggered by severe conditions in the PMMFs industry, is a further reminder of the high reliance of global banks and corporations on the short-term unsecured funding of PMMFs.[8]

The rest of the paper is organized as follows. Section 1.2 reviews the related literature. Section 1.3 sets out the methodology. In Section 1.4, we describe the data and provide some preliminary analysis. Section 1.5 discusses the empirical results. In Section 1.6, we introduce some robustness checks. Finally, Section 1.7 concludes.

## 1.2 Literature Review

### 1.2.1 Global liquidity

Global liquidity, defined as the overall ease of financing in international financial markets, is a central subject of international policy debates and identified as one of the main factors behind the accumulation of financial vulnerabilities in the global financial system in the pre-GFC period (Borio, McCauley and McGuire, 2011; CGFS, 2011; IMF, 2013a; Cohen, Domanski and Shin, 2017). Following the GFC, commodity producers have increasingly tapped international bond markets, with the oil and other energy companies far outpacing the overall issuance of other commodity sectors (see Domanski et al., 2015). Yet, literature on the relationship between global liquidity and commodity spot prices, particularly the crude oil spot prices, is still quite sparse.

Relatively few studies have investigated the impact of global liquidity on commodity spot prices and, when doing so, mainly in terms of a cointegrated relationship (see Belke, Bordon and Hendricks, 2010; Belke, Bordon and Volz,

[8]PMMFs experienced severe disruptions during mid-March of 2020 as investors switched from core unsecured funding markets to secured funding markets and Government MMFs. PMMFs suffered outflows which led to a shortage of funding for banks and corporations and a significant shortening of funding maturities. This episode exposed the persistent susceptibility of PMMFs to rapid redemptions, despite the efforts of the 2016 US PMMFs regulation to address the structural weaknesses which surfaced during the GFC (see IMF, 2021; Avalos and Xia, 2021).

2013; Beckmann, Belke and Czudaj, 2014). These studies find evidence of a positive long-term relationship between global liquidity, proxied through global aggregates of broad money, and the CRB commodity price index.[9] With a particular focus on the oil market, Ratti and Vespignani (2013) show that unanticipated increases in the liquidity of BRIC countries, measured by M2, lead to significant and persistent increases in real oil prices, global oil production and global real aggregate demand. In contrast, Anzuini, Lombardi and Pagano (2012) find that global liquidity, proxied through M2, leads to a sharp, but temporary increase in the price of oil which lasts until month ten.

The empirical studies mentioned above have used global aggregates of broad money as a proxy for global liquidity. However, intermediation in advanced economies has moved away from the traditional deposit-based funding towards international debt securities (Turner, 2014; Aldasoro and Ehlers, 2018; Avdjiev et al, 2020). This recent change in the composition of global liquidity has been referred to as the "second phase of global liquidity" (Shin, 2014; Avdjiev et al., 2020). The shift in international financial intermediation implies that global funding conditions have become more sensitive to developments in bond markets, and more connected to US monetary policy as a key driver of global liquidity conditions.[10] Therefore, monetary aggregates, which have been traditionally used to capture global liquidity, have become less suited to capture movements in liquidity (IMF, 2013a).

Credit aggregates have been recently proposed as an alternative measurement of global private liquidity (CGFS, 2011; Domanski, Fender and McGuire, 2011; Bruno and Shin, 2015a).[11] International credit has continued to expand in recent years from 33 percent of global GDP in 2015 to 38 percent in 2018 (Aldasoro and Ehlers, 2018). This growth has been driven primarily by the issuance of international debt securities, rather than bank loans (Turner, 2014; Avdjiev et al, 2020). Empirical literature on global liquidity, proxied through credit aggregates, and commodity prices is sparse. Abdel-Latif and El-Gamal (2020) use a GVAR model consisting of Middle East countries and the BIS series for credit from all sectors to the private non-financial sector as a measure of global financial liquidity, and find a temporary decline in oil prices in response

[9] The CRB spot index consists of energy (39 percent), softs/tropicals (21 percent), grains/livestock (20 percent), and industrial/precious metals (20 percent).

[10] An extensive literature investigates the effect of US monetary policy on oil prices, having yet to reach a consensus. Rosa (2014) and Basistha and Kurov (2015) find that an unexpected cut in the Fed funds rate increases the oil futures price during the intraday event window following the announcement. Hammoudeh, Nguyen and Sousa (2015) find that an increase in policy interest rates leads to a persistent reduction in energy prices. In contrast, Kilian and Vega (2011), Chatrath, Miao, and Ramchander (2012), Chan and Gray (2017) and Scrimgeour (2015) do not find a statistically significant relationship between US interest rates and oil prices.

[11] Most global liquidity today is privately created through cross-border operations by both bank and non-bank financial institutions (BIS, 2011). Total credit is defined by the BIS as the sum of bank loans to non-banks and debt securities issuance by non-banks.

to a negative shock in global financial liquidity.

We argue that our main funding measure, PMMFs investment holdings by global issuance, is a suitable proxy for global liquidity for the following reasons. Firstly, it captures international debt securities characterized by short maturities and minimal credit risk, which are the main driver of the "second phase of global liquidity". Secondly, it is a quantity-based measure of global private liquidity as it captures both bank and non-bank credit in both advanced and emerging market economies. This provides an identification of liquidity creation by the private sector and can help track global liquidity cycles (CGFC, 2011). Moreover, our proxy takes the US dollar currency denomination perspective. Since the GFC, the US dollar has increased its dominance as the prime international funding currency (Maggiori, Neiman and Schreger, 2018). Lastly, the use of PMMFs investment holdings by instrument, allows us to differentiate between short-term debt issuance by banks and non-banks.[12]

### 1.2.2 PMMFs as short-term US dollar credit providers

US dollar funding intermediation has faced major structural changes since the GFC. While global banks have diminished their loan and debt security positions, non-banks have increased their dominance in driving global liquidity (Shin, 2014; Aldasoro and Ehlers, 2018; CGFS, 2020).[13] Several studies have investigated the role of PMMFs in the provision of short-term US dollar funding (Hanson, Scharfstein, and Sunderam, 2015; Parlatore, 2016; Aldasoro, Ehlers and Eren, 2019; Eren, Schrimpf and Sushko, 2020a,b, among others). Hanson, Scharfstein, and Sunderam (2015) argue that the dominance of PMMFs as providers of short-term funding for global financial institutions has remained stable since prior to the GFC.[14] They estimate that PMMFs provide roughly 35 percent of short-term, wholesale dollar funding to large global financial institutions. *CDs* represent the highest proportion of PMMFs investment holdings (an average of 18 percent) during our sample period 2011:2-2021:10 (see Figure 1.1A in the Appendix).

Few studies have highlighted the importance of PMMFs as funding providers

[12] *CPs* are commonly issued by both banks and non-financial corporations, while *CDs* are only issued by banks.

[13] This shift been driven by several factors such as new regulatory reforms, the recovery and recapitalisation of weak banks, and changing business models of intermediaries in many jurisdictions. Furthermore, the sustained performance of the US and several emerging market economies (EMEs) in the past few years and their elevated interest rates compared to advanced economies has led to a shift in global portfolios towards US securities and US dollar cross-border lending into EMEs (CGFS, 2020).

[14] PMMFs have reduced their funding to US banks following the GFC, but this decrease was reversed by an increase in funding for non-US banks (largely European banks). However, the funding for European banks declined during the Eurozone crisis, which was offset by an increase in funding to Japanese and Australian banks (Hanson, Scharfstein, and Sunderam, 2015).

to global banks. For instance, Aldasoro, Ehlers and Eren (2019) investigate the interactions between global banks and PMMFs, arguing that PMMFs from which non-US global banks obtain a significant amount of dollar funding are not perfectly competitive, with a few top funds serving the funding needs of global banks. Aldasoro, Ehlers and Eren (2019) find that PMMFs charged a higher price to banks with weaker bargaining positions such as Japanese banks following the 2016 PMMF reform. Eren, Schrimpf and Sushko (2020b) propose that during the recent Covid-19 crisis, redemptions from US PMMFs resulted in a loss of funding for global banks and to a significant shortening of funding maturities, which in turn affected bank funding costs such as the LIBOR-OIS spread.

The anticipation of the 2016 regulatory reforms led to a reduction in the size of PMMFs of almost 75 percent and a decline in the total assets of PMMFs of more than 1 trillion US dollars, over the period October 2015 to October 2016 (BIS, 2016). As a result, the amount of credit provided by these funds to financial institutions across the world fell by around 130 billion US dollars, which amounted to no less than a 70 percent contraction in short-term dollar funding obtained from PMMFs (BIS, 2016). This funding contraction was particularly evident for banks in Canada, France and Japan, with the latter two countries being two of the five major creditor countries, alongside Germany, UK and US.[15] Thus, we argue that this newly implemented regulation could have broader implications for funding markets.

### 1.2.3 Determinants of historical oil price fluctuations

In recent years, a vast literature on the determinants of oil price fluctuations has emerged. At first, major fluctuations in the price of oil were associated with disruptions in the flow of global oil production led by exogenous political events such as wars and changing conditions in the OPEC member countries (Hamilton, 2003). The research on the determinants of historical oil price fluctuations has evolved to show that disruptions in oil supply are not as important as initially thought and has found that most major movements in the price of oil since 1973 can be explained to a great extent by fluctuations in the demand for crude oil associated with global economic activity (Barsky and Kilian 2002, 2004; Kilian 2009; Kilian and Murphy 2012, 2014; Bodenstein, Guerrieri, and Kilian 2012; Lippi and Nobili, 2012; Baumeister and Peersman, 2013a, 2013b; Kilian and Hicks, 2013; Kilian and Lee, 2014).

Research has shown that fluctuations in the price of oil may reflect changes in expectations about future shortages in the oil market, which affect future demand for above-the-ground inventories of crude oil (Adelman, 1993; Pindyck,

[15]These five creditor countries account for 55 percent of the global cross-border credit (see Aldasoro and Ehlers, 2018).

2004; Kilian, 2009; Alquist and Kilian, 2010). Historically, higher demand for oil inventories has been observed during geopolitical tensions in the Middle East, low spare capacity in oil production, and strong expected global economic growth (Baumeister and Kilian, 2016). Thus, the existing literature identifies oil supply shocks, oil demand shocks and speculative demand shocks as major causes of fluctuations in the price of oil.

However, despite the developments made in recent years in understanding historical oil price fluctuations, such movements still surprise economists, policymakers, consumers, and financial market participants as the oil price determinants remain difficult to predict in practice, as discussed in Baumeister and Kilian (2016). For example, global economic activity, a key determinant of the price of oil, can be predicted at best at short term horizons and even under these circumstances the prediction remains imprecise. A second difficulty in predicting oil price fluctuations relates to disruptions in global oil production caused by political events in oil-production countries, which can be relatively difficult to anticipate. Moreover, changes in inventory demand, another key determinant of oil prices, depend on continuously evolving expectations about future oil supply influenced by uncertainty about geopolitical or economic crises. Lastly, the accuracy of predicting fluctuations in the price of oil can be subject to how expectations are formed.[16]

We add to this strand of literature which identifies oil supply shocks, oil demand shocks and speculative demand shocks as key determinants of crude oil price movements, by showing that tighter short-term funding conditions driven by PMMFs affect crude oil production and subsequently the crude oil spot price.

## 1.3 Methodology

### 1.3.1 The transmission channel of funding shocks to the crude oil market

We propose two channels through which US dollar funding shocks stemming from deteriorating US dollar credit conditions in the US PMMFs industry can be transmitted to oil companies: an indirect channel through cross-border bank flows and a direct channel through PMMFs. These two transmission channels of funding shocks from US PMMFs to oil companies are depicted in Figure 1.1 and discussed in the following two subsections.

[16]The literature discusses four alternative measure of oil price expectations (e.g. economists' oil price expectations, policymakers' oil price expectations, financial market oil price expectations and consumers' oil price expectations). A detailed discussion of the limitations of these four measures of oil price expectations can be found in Baumeister and Kilian (2016).

#### 1.3.1.1 Cross-border bank flows

The notion of global liquidity has been associated in policy discussions with permissive credit conditions in financial centres resulting in capital flows to other parts of the world (BIS, 2011). The propagation of gross capital flows, particularly through the banking sector, has been widely debated in the literature (see Lane and Pels, 2012; Forbes and Warnock, 2012; Obstfeld, 2012a, 2012b; Shin, 2012; and Rey, 2015, among others). For instance, Bruno and Shin (2015) document that capital flows transmitted through the international banking system represent a substantial proportion of the total capital flows and propose a model which captures the cross-border bank lending in US dollars (see Figure 1.1). According to this model, regional banks borrow in US dollars from global banks to lend to local borrowers, which are typically non-financial corporates. Global banks fund their cross-border lending to regional banks by raising US dollars in the major financial centres. PMMFs are a vital source of dollar funding. The US dollar is the foremost funding and investment currency in the international monetary and financial system and its broad international usage suggests that the resilience of global economic and financial activity is conditional on the continuous flow of US dollar funding (CGFS, 2020).

Global cross-border bank credit flows are dominated by a small number of very large cross-border linkages, with the US being one of the five major creditor economies alongside France, Germany, Japan and the United Kingdom, together accounting for 70 percent of the credit volume of the largest bilateral country-level links (Aldasoro and Ehlers, 2018).[17] Hence, in the light of the importance of the US financial system and the US dollar in the provision of global cross-border bank credit, we argue that deteriorating dollar funding conditions in the US, particularly for the US PMMFs, can reduce global bank cross-border flows. The rationale behind this transmission channel is that a broad US dollar appreciation increases the credit risk of global banks with globally diversified dollar-loan portfolios, thereby reducing their cross-border lending capacity for any given level of economic capital (see Bruno and Shin, 2015; Avdjiev et al., 2019). This induced financial strain on the recipient economy's banking system will generate a spillover effect to companies such as oil producers, that borrow in US dollars from non-US banks (IMF, 2019).

#### 1.3.1.2 Prime Money Market Funds

Hanson, Scharfstein, and Sunderam (2015) reported that of the 50 largest nongovernment issuers of money market instruments held by PMMFs only

[17] Roughly 2.4 percent of all bilateral cross-border bank linkages were larger than 50 billion US dollars as of 2018. However, they represent two thirds of the global cross-border bank credit volumes (Aldasoro and Ehlers, 2018).

two are non-financial firms. Although PMMFs are a major funding source for financial institutions, they remain a significant provider of short-term US dollar funding to non-financial corporations. Thus, we propose that funding constrains in the US PMMFs industry can be transmitted directly to companies such as oil firms that borrow heavily in US dollars. This channel is depicted in Figure 1.1.

### 1.3.2 Modelling the global crude oil market

There has been extensive debate in the academic literature on the modelling of the global market for crude oil. A traditional approach in the literature has been to estimate the exogenous variation in the crude oil production in OPEC countries and to relate this variation to changes in the crude oil prices (Hamilton, 2003; Kilian, 2008a). Building on this work, Kilian (2009) attributes the variation in oil price which cannot be explained by shifts in crude oil supply, to shocks to the global demand for industrial commodities driven by fluctuations in the global business cycle, and to higher precautionary crude oil demand associated with expectations about the availability of future oil supplies. The theoretical and empirical work of Hamilton (2009) and Alquist and Kilian (2010) further examines the role of expectations on the dynamics of oil prices, proposing that shifts in expectations of forward-looking traders are reflected in changes in the real oil price and changes in oil inventories. The rationale is that, given that crude oil is storable and assuming that the price elasticity of demand is different from zero, any expectation of a shortfall of future oil supply relative to future oil demand not already captured by flow demand and flow supply shocks causes an increase in the demand for above-ground oil inventories and hence in the real price of oil.[18] KM (2014) later refer to shifts in demand for above-ground oil inventories arising from increased uncertainty about future demand or supply conditions as a speculative demand shock in the spot market of crude oil.[19]

KM (2014) were the first to introduce a structural vector autoregressive (SVAR) model of the global oil market that explicitly accounts for speculative demand and allows for forward-looking behavior in oil markets. This model, presented in (1.1), has become one of the leading models for the analysis of the oil market and is employed as our baseline model throughout the rest of

[18]The flow demand shock captures unexpected fluctuations in the global business cycle, while the flow supply shock refers to supply disruptions related to exogenous political events in oil-producing countries, unexpected politically-driven supply decisions by OPEC as well as to other shocks to the supply of crude oil.

[19]The speculative demand shock is associated with shifts in the demand for above-ground oil inventories driven by speculation.

the paper.

$$B_0 y_t = \alpha + \sum_{n=1}^{N} B_n y_{t-n} + \epsilon_t \qquad (1.1)$$

where $y_t = [RealActivity_t, OilProduction_t, OilInventories_t, RealCrudeOil SpotPrice_t]'$, $\epsilon_t$ is a vector of orthogonal structural innovations, *Real crude oil spot price* refers to the real spot price of crude oil, *Oil inventories* represents global crude oil inventories, *Oil production* is global crude oil production and *Real activity* is a measure of global real economic activity.

#### 1.3.2.1 The global crude oil market model of KM (2014): an estimation

We estimate the baseline model of KM (2014) presented in (1.1) using Kilian's updated and corrected index for global real economic activity, for our sample period 2011:2-2021:10. The choice of the beginning and ending of this sample period is motivated by data availability of our funding variables, *PMMFs* and *CDs*.[20] We estimate this model by identifying structural shocks using Uhlig's (2005) pure-sign restriction approach. The sign restrictions are reported in Table 1.1.

#### 1.3.2.2 Funding shocks and the global crude oil market

To evaluate the impact of the funding shock induced by the US PMMFs reform on the real crude oil spot price, we extend the global crude oil market model of KM (2014) by introducing PMMFs investment holdings by global issuance, *PMMFs*, as our funding measure. The augmented model (1.1) now has $y_t = [PMMFs_t, RealActivity_t, OilProduction_t, OilInventories_t, RealCrudeOil SpotPrice_t]'$, where *PMMFs* represents the US PMMFs investment holdings. The model uses 1 lag, determined by AIC information criteria. The sign restrictions are reported in Table 1.2 (Panel A) and discussed in the next subsection.

In the next step, we alter $y_t$ by introducing the *CDs* as an alternative to the aggregate PMMFs investment holdings by global issuance to capture the direct channel. We then introduce the nominal effective exchange rate of the US dollar (*NEER*) to the baseline model to identify the exchange rate channel. The sign restrictions used to construct the impulse response estimates are reported in Table 1.2 (Panel B). Lastly, we further analyze the transmission channel of our funding shock of interest on the real crude

[20]For completeness, we estimate the baseline model of KM (2014) for the sample periods 1973:3-2009:8 and 1973:3-2021:10. The estimation results are qualitatively similar and are available upon request. The nature of the corrections to the global real economic activity index is discussed in Kilian (2019).

oil spot price by augmenting the baseline model, with the following control variables: *CPI*, the consumer price index for the US and *VIX* as our measure of investor risk appetite. The augmented model (1.1) now has $y_t = [PMMFs_t, VIX_t, CPI_t, NEER_t, RealActivity_t, OilProduction_t, Oil Inventories_t, RealCrudeOilSpotPrice_t]'$. The model uses 1 lag, once again determined by AIC information criteria.

### 1.3.3 SVAR Identification

Structural interpretations of VAR models require identifying assumptions motivated by economic theory or institutional knowledge. Several approaches to the identification of structural shocks within the framework of a reduced-form VAR model have been advanced in the literature (e.g. short-run restrictions, long-run restrictions, sign restrictions, heteroskedasticity). While the first oil market VAR models were based on exclusion restrictions imposed on the impact multiplier matrix (see Kilian, 2009), increasing scepticism towards traditional identification by short-run exclusion restrictions has subsequently led to the development of an alternative approach in which structural shocks are identified by restricting the sign of the responses of the variables used in the model to structural shocks.[21]

Sign-identified VAR models have become increasingly popular in the more recent literature on oil markets (see Baumeister and Peersman, 2013a, 2013b; Kilian and Murphy, 2012, 2014). In line with this literature, we use sign restrictions to identify structural shocks and to construct impulse response estimates. We employ Uhlig's (2005) pure sign-restriction rejection method as a complementary approach to the KM (2014) set of identifying assumptions.[22] This is a standard method employed in the literature to identify structural shocks. The key difference between KM's (2014) set of identifying assumptions and Uhlig's (2005) approach is that the latter does not allow bounds on the price elasticity of oil supply and oil demand. The use of Uhlig's (2005) approach rather than KM's (2014) set of identifying assumptions is motivated by the latter being essential to distinguish between speculative demand, oil demand and oil supply shocks. Hence, KM (2014) assumptions are not effective in the identification of our funding shock of interest.

[21] Unless a convincing rationale for a particular recursive ordering exists, the resulting VAR impulse responses are economically meaningless (Kilian and Lutkepohl, 2017).

[22] KM (2014) set of identifying assumptions relies on a combination of sign restrictions, bounds on the implied price elasticities of oil demand and oil supply, and dynamic sign restrictions, to distinguish between speculative demand, oil demand and oil supply shocks.

#### 1.3.3.1 A discussion of the sign restrictions used in the extended models

This subsection discusses the sign restrictions used in our extended models of the KM (2014) SVAR framework. First, we introduce the sign restrictions imposed to identify the negative funding shock driven by the US PMMFs reform. We argue that this negative funding shock is associated with an immediate reduction in *Real Activity* and *PMMFs* (Table 1.2, Panel A). A sharp reduction in the credit availability associated with a negative shock to credit supply results in a decline in aggregate economic activity (Friedman et al., 1993). We also impose the additional restriction that the response of *PMMFs* to a negative PMMFs funding shock must be negative for three months, starting in the impact period. This restriction is based on our identification of a 3-month structural break in the percentage changes of *PMMFs*, which coincides with the implementation of the US PMMFs reform (see Figure 1.2). This additional information allows us to make a fine distinction between funding shocks generated by our reform of interest and funding shocks driven by other factors. Furthermore, we relax this restriction to assess the general impact of funding shocks on oil market.[23]

Furthermore, we argue that a negative funding shock results in an increase in the *NEER*, a decrease in *CPI* and an increase in *VIX* (Table 1.2).[24] The positive response of the *NEER* to a negative funding shock is motivated by the reduction in US dollar supply from market-based intermediaries, which has resulted in elevated indicators of dollar funding costs following the announcement of the 2016 reform (Avdjiev, Eren and McGuire, 2020). As documented by Avdjiev, Eren and McGuire (2020), dollar exchange rate and dollar funding costs tend to move together. Secondly, we follow the theoretical prediction that an appreciation of domestic currency tends to raise the price levels by making imports cheaper and attribute a negative response of *CPI* to a negative funding shock. We leave the responses of *Real crude oil spot price*, *Oil production* and *Oil inventories* to the negative funding shock unrestricted as these are our variables of interest in terms of outcome.

Next, we introduce the additional sign restrictions used to identify a negative oil supply shocks, a positive oil demand shock and a speculative oil demand shock for our extended models. We impose a positive response of *CPI* to a negative oil supply shocks, a positive oil demand shock and a speculative oil demand shock (Table 1.2). These sign restrictions are motivated by KM (2014), who document an increase in the price of oil as a result of negative oil supply

[23] Results are very similar (see Figures 1.2A to 1.9A in the Appendix).

[24] The US NEER is a measure of the value of the dollar against a weighted average of several foreign currencies. An increase in NEER corresponds to an appreciation of the dollar against the weighted basket of foreign currencies.

shocks, positive oil demand shocks and speculative oil demand shocks and by Chen (2009), who find that oil price shocks pass partially through to inflation.

## 1.4 Data

### 1.4.1 Description of the data

The main data set analysed in this paper comprises of monthly data for four global crude oil market variables, global crude oil production *(Oil production)*, global real economic activity *(Real activity)*, global crude oil inventories *(Oil inventories)* and the real spot price of crude oil *(Real crude oil spot price)*, two macroeconomic variables, consumer price index *(CPI)*, nominal effective exchange rate *(NEER)*, and two funding variables, PMMFs investment holdings by global issuance *(PMMFs)* and by instrument *(CDs)* and *VIX*. The sample period is 2011:2-2021:10.[25] This particular sample period is chosen due to limited data availability for our funding variables, *PMMFs* and *CDs*. Each of the variables mentioned is described in the following subsections.

#### 1.4.1.1 Global crude oil market

We measure changes in global real activity by employing the dry cargo shipping rate index developed in Kilian (2009). This business cycle index, stationary by construction, is designed to capture changes in the global use of industrial commodities. Global crude oil production data is collected from the *Monthly Energy Review of the Energy Information Administration (EIA)* and includes lease condensates but excludes natural gas plant liquids (KM, 2014). We proxy the global crude oil inventories through the US crude oil inventories, scaled by the ratio of OECD petroleum stocks over US petroleum stocks, as discussed in Hamilton (2009) and KM (2014). Data on US crude oil inventories, OECD petroleum stocks and US petroleum stocks is collected from EIA.

Our focus on quantifying speculation in the spot market through the use of above-ground oil inventories is based on the standard assumption of arbitrage linking the oil futures market and the spot market for crude oil. Particularly, as the price of crude oil in the futures market is driven up by financial speculation, arbitrage ensures that traders of crude oil respond by purchasing inventories in the spot market (Alquist and Kilian, 2010). As noted in Alquist and Kilian (2010), the absence of speculation in the spot market also rules out speculation in oil futures markets. Further, shifts in precautionary demand coincide with an accumulation of oil inventories, as has been observed in the period leading up to the 1973 oil price shock.

[25] We use the sample period 1973:3-2009:8 to replicate KM's (2014) model and sample period 1973:3-2021:10 and 2011:2-2021:10 to verify the robustness of the results of KM (2014) to an extended time-frame. Results are qualitatively similar and are available upon request.

We follow KM (2014) in defining the real price of oil as the US refiners' acquisition cost for imported crude oil, deflated by the US CPI.[26] Data on US refiners' acquisition cost is collected from EIA.[27] Kilian and Murphy (2014) note that the refiners' acquisition cost for imported crude oil is likely to be a better proxy for the price of oil in global markets, than the US price of domestic crude oil, which was regulated during the 1970s and early 1980s. Due to non-stationarity, we express the *Real crude oil spot price* in percentage changes for the sample period 2011:2-2021:10 (see Table 1.2A in the Appendix).

#### 1.4.1.2 PMMFs investment holdings

The SVAR models in the tradition of Kilian (2009) and KM (2014) face the potential limitation of not being able to differentiate between shocks originating in different geographical regions of the world or to recognise the difference between the underlying drivers of these shocks. Yet, these structural VAR models are able to capture average responses to these shocks.[28] We overcome this limitation by employing two funding variables, the US PMMFs investment holdings by global issuance *(PMMFs)* and US PMMFs investment holdings by instrument *(CDs)*, as reported by the Federal Reserve. These two quantity-based measures of global private liquidity are able to capture PMMFs funding disruptions originating in the US. Moreover, the latter variable allows us to differentiate between the source of the funding shock and capture the indirect channel of transmission of funding shocks on oil market via cross-border bank flows.[29]

The inclusion of *CDs* held by PMMFs is motivated by their growing importance as a source of unsecured wholesale funding for banks following the GFC. During the GFC, PMMFs adjusted the risk of their investment mix by shifted their portfolios from riskier *CPs* to safer *CDs*. This resulted in PMMFs holding a larger share of non-US banks as issuers of *CDs* than of *CPs* (Baba, McCauley, and Ramaswamy, 2009). *CDs* became the most important unsecured wholesale funding source for banks, being thus regarded a barometer for bank funding conditions (Eren, Schrimpf and Sushko, 2020b).[30]

[26]We employ Brent and WTI oil prices as alternative oil price indicators in the robustness section.

[27]We report the details of sources, construction and data sample availability of the variables included in the analysis in Table 1.1A in the Appendix.

[28]DSGE models have the ability to make such distinctions and to provide more detailed answers about the transmission of oil price shocks. However, this comes at the cost of full specification of the microeconomic structure of the model, which involves making ad hoc assumptions (Kilian, 2014).

[29]We use an alternative measure for global liquidity, the *VIX*, in the robustness test section.

[30]Non-US banks lacking access to insured retail dollar deposits are particularly dependent on *CDs* funding to finance dollar assets (Eren, Schrimpf and Sushko, 2020b).

#### 1.4.1.3 US dollar exchange rate, inflation and uncertainty

A number of empirical studies confirm the importance of the US nominal effective exchange rate in explaining variations in the crude oil prices in both the short run (Amano and Van Norden, 1998; Sadorsky, 2000) and the long run (Zhang et al., 2008; Akram, 2009; Fratzscher, Schneider and Van Robays, 2014). The price of crude oil is denominated in US dollar in the World markets, with the US dollar increasing its dominance as the prime foreign currency for international funding. Thus, following the theoretical and empirical predictions of the studies documenting that an appreciation of the US dollar exchange rate decreases the price of crude oil via oil supply, oil demand, financial markets channels or via the law of one price for tradeable commodities, we employ the *NEER* as an explanatory variable in our refined model.[31]

We are further expanding the work of KM (2014) by controlling for a macroeconomic variable, *CPI*, and for global risk aversion, *VIX*. In line with the literature investigating the effect of global liquidity on commodity prices, we include the *CPI* as measure of inflation (see Belke, Bordon and Volz, 2013; Beckmann, Belke and Czudaj, 2014; to name a few).[32] We also follow Cheng, Kirilenko and Xiong (2015) in controlling for the strong real effect of risk appetite and uncertainty on crude oil prices by employing the stock option prices-based measure of implied volatility, the *VIX*. Cheng, Kirilenko and Xiong (2015) show that high financial uncertainty, proxied by the *VIX*, reverses the flows from financial investors into commodity markets, thereby depressing oil prices.

### 1.4.2 Preliminary analysis of the variables

Table 1.3 (Panel a) reports the descriptive statistics of PMMFs investment holdings by global issuance, *PMMFs*. *PMMFs* account for an average amount of investment holdings of nearly 1.29 million US dollars. The average monthly percentage change is 0.43 percent, with a standard deviation of 5 percent, suggesting a large variation in the investment holdings of *PMMFs*. The evolution of *PMMFs*, measured in percentage changes, during the sample period 2011:2-2021:10 is depicted in Figure 1.2. Figure 1.2 shows a low variation of 2 percent during the sample period 2011:2 - 2015:6 and of 1 percent during the sample period 2017:1 - 2021:10. The greatest variation is exhibited from 2015:6 to 2017:1 (9 percent), period which coincides with the implementation of the US PMMFs regulation.

Table 1.3 (Panel b) displays the descriptive statistics of PMMFs investment

[31] We refer the reader to the work of Beckmann, Czudaj and Arora (2020) for a review of the existing theoretical and empirical research on the relationship between oil prices and exchange rates.

[32] Description and sources of the data are given in Table 1.1A in the Appendix.

holdings by instrument, *CDs*, measured in percentage changes. The average monthly percentage change of *CDs* stands at roughly 0.9 percent, while the standard deviation of *CDs* is 7 percent. The evolution of *CDs*, *CPs* and *PMMFs* measured in percentage changes is presented in Figure 1.3. We note that the three funding measures experience the greatest decline over the period 2016:7 – 2016:9, which coincides with the implementation of the US PMMFs regulation. The second substantial decline is seen in March 2020 during COVID-19 market disruption. Noteworthy, in both periods, *CDs* see a more pronounced decline as compared to *CPs*.

Table 1.3 (Panel c) reports descriptive statistics of the *Real crude oil spot price*. *Real crude oil spot price* has an average monthly percentage change of 0.3 percent and experiences a strong variation of 10.9 percent over the sample period. The variation in the percentage changes in *Real crude oil spot price* and *PMMFs* throughout our sample period is depicted in Figure 1.2. The figure points towards a negative relationship between *Real crude oil spot price* and *PMMFs* during the period 2016-2017.[33]

The correlation matrix reported in Table 1.4 depicts the correlation coefficients among the variables included in our SVAR model. As expected, we find that the *Real crude oil spot price* is negatively correlated with the *Oil production*, with *Real activity*, and with *NEER* with a correlation coefficient of -32 percent, -16 percent, -38 percent respectively. We also note a strong negative correlation of -20 percent between *VIX* and the *Real crude oil spot price* and a strong positive correlation of 52 percent between *CPI* and the *Real crude oil spot price*. *Oil production* is negatively correlated with the *Oil inventories*, with a low coefficient of -15 percent. We identify a positive correlation of around 16 percent between *VIX* and *PMMFs*.

## 1.5 Empirical Results

### 1.5.1 The global crude oil market model of KM's (2014)

This section discusses the empirical results for our estimation of KM's (2014) model for the sample period 2011:2-2021:10. The results are presented in Figure 1.4. Overall, our empirical results confirm the findings of KM (2014). In particular, a negative flow supply shock is associated with a persistent drop in *Oil production* and *Real activity* (Figure 1.4, Panel 1). *Real crude oil spot price* sees a persistant rise 6 months from the impact, while *Oil inventories* see a temporary fall (Figure 1.4, Panel 1). A positive flow demand shock, in contrast, is associated with an immediate and persistent jump in the *Real*

[33] The correlation coefficient for the period 2016:1 – 2017:1, for the variables *PMMFs* and *Real crude oil price*, is -0.17 (17 percent).

*activity* (Figure 1.4, Panel 2). *Real crude oil spot price* sees a small and temporary increase on impact, followed by a temporary fall from month 6 to month 15, while *Oil production* increases immediately and temporarily. *Oil inventories* do not see a statistically significant response (Figure 1.4, Panel 2). A positive speculative demand shock is associated with a persistent increase in *Oil inventories* and *Oil production* (Figure 1.4, Panel 3). *Real crude oil spot price* increases until month 3, before declining gradually, while *Real activity* sees a small and persistant drop on impact (Figure 1.4, Panel 3).

Yet, our results differ from the findings of KM (2014) in two ways. Firstly, we note a persistent positive response of *Oil production* to a speculative demand shock, while KM (2014) report a small negative response. While this result is in contrast with the findings of KM (2014), it is in line with the KM (2014) prediction that a positive speculative demand shock on impact stimulates *Oil production.* Secondly, we provide evidence of a small temporary (3 months) increase in *Real crude oil spot price* in response to a positive speculative demand, results which contrasts with KM (2014) finding of an immediate jump in *Real crude oil spot price*, which persists up to 10 months from the impact. These slight differences can be explained given the different sample periods.[34]

### 1.5.2 Funding shocks of PMMFs and the price of crude oil

We augment the model of KM (2014) by our main funding variable, *PMMFs*. Structural impulse response estimates to a negative one-standard deviation shock in *PMMFs* are depicted in Figure 1.5. Figure 1.5 indicates that a negative funding shock is associated with a lagged temporary decline in the *Real crude oil spot price* and a lagged and temporary increase in *Oil production.*

*Real crude oil spot price* temporary decreases 20 months following the negative funding shock, while *Oil production* raises 8 months following the funding shock. It peaks after 12 months and declines to its pre-shock levels after 23 months. The impulse response estimates of *Real activity* and *PMMFs* are negative on impact, as imposed through our sign restriction identification approach. However, the decline in *Real activity* and *PMMFs* is persistent until month 19 and 10, respectively. Thus, these results indicate that the response of our global crude oil market variables to negative funding shocks is persistent.

Our empirical results confirm the theoretical predictions of Domanski et al. (2015) who argue that, in response to higher short-term dollar funding costs, oil producers seek to increase their output levels to raise short-term cash flow. Sustaining the continuity of short-term cash flows is needed for oil producers

[34] It should be noted that when we estimate the KM model using their sample period (i.e., 1973:3-2009:8) we find analogous results to them, when using their set of identifying restrictions. For the extended sample period (i.e., 1973:3–2021:10), we find a positive response of oil production to a speculative demand shock, when using the KM (2014) set of identifying restrictions, result which is in line with our findings for the sample period 2011:2-2021:10.

to meet obligations and to avoid supressing market demand in the long run. The 6-months lagged response of oil production to a negative funding shock is line with the general consensus in the literature that even in the presence of spare capacity, the response of oil production within the month to price fluctuations is close to zero, if not effectively zero, due to the costs incurred by changing oil production (Kilian, 2009).[35]

Considering these findings, we then proceed to analyse the effect of the negative funding shock, proxied through *CDs*, on the *Real crude oil spot price*. The response estimates are presented in Figure 1.6. The results indicate that the *Real crude oil spot price* is negatively affected by a fall in *CDs*. Furthermore, we notice that a decline in *CDs* causes an increase in *Oil production* and *Oil inventories*. This result highlights the role of cross-border bank flows in the transmission of the funding disruptions generated by the 2016 US PMMFs reform to the crude oil market.

When we relax the 3-month sign-restriction, we find very similar results of a negative response of the oil price and a positive response of oil production to funding shocks. Thus, we document that funding shocks have a general significant impact on oil markets.[36]

#### 1.5.2.1 Discussion

Several arguments can be advanced to explain the lagged negative impulse response of real crude oil spot price to our negative funding shock of interest. Firstly, an increase in oil production levels will temporarily decrease real crude oil spot price and will increase oil inventories (KM, 2014). Secondly, an appreciation of the dollar could suppress oil demand in the long-term, as oil imports become more expensive in local currencies for non-US countries (De Schryder and Peersman, 2015). As a result of lower demand, the real crude oil spot price will temporarily decrease and oil inventories will temporarily increase (KM, 2014). Lastly, real crude oil spot price could temporarily decrease due to oil producers hedging their future production by selling futures contracts. Current and future sales of oil will create downward pressures on real crude oil spot price (Domanski et al., 2015). Hence, our negative funding shock of interest can lead to a lagged decline in real crude oil spot price via its effect on oil production, oil demand or on the hedging demand of oil producers.

[35] Revenues for 43 US oil companies increased from a low of roughly 25 dollars per barrel of oil equivalent in 2016, to over 45 dollars per barrel of oil by the end of 2017, together with the ratio of cash flows generated from operating activities to capital expenditures (EIA, 2019). Noteworthy, oil companies with higher production levels had higher ratios of cash from operations to capital expenditures (EIA, 2019). Net oil export revenues for OPEC also increased in 2017 and 2018 after reaching a low in 2016 of under 500 billion dollars (see Figure 2A in the Appendix.

[36] Results are qualitatively similar when the 3-months sign restriction imposed on *PMMFs* and *CDs* is relaxed. These results are available upon request.

### 1.5.3 Funding shocks of PMMFs, the price of crude oil, and the dollar exchange rate channel

We further analyze the impact of our funding shock of interest on the real crude oil spot price by introducing the *NEER* to the augmented model (1.1). The results are presented in Figure 1.7. Figure 1.7 indicates that our negative funding shock of interest leads to a persistent decline in the *Real crude oil spot price*, and a persistant increase in *Oil inventories*, *Oil production*, *NEER*. As expected, the *Real activity* and *PMMFs* see a decline in response to a negative funding shock. The reduction in *Real Activity* is persistent throughout the observed period, while the reduction in *PMMFs* is mostly reversed within 10 months. Noteworthy, the decline in the *Real crude oil spot price* becomes persistant when *NEER* is introduced to the augmented model (1.1).[37]

This result indicates that the *NEER* could be a complementary transmission channel of funding shocks to the *Real crude oil spot price.* The rationale behind the transmission of our funding shock of interest to the *Real crude oil spot price* is that the 2016 reform has raised the dollar funding costs, driving the US *NEER* higher. A higher US dollar exchange rate negatively affects real price of oil through its effect on oil supply, oil demand and financial markets (Breitenfellner and Cuaresma, 2008).

We then proceed to introduce the *CPI* and *VIX*, alongside the *NEER*, to the augmented model (1.1).[38] The impulse response estimates are depicted in Figure 1.8. Figure 1.8 indicates that our negative funding shock of interest is associated with a temporary decline in the *Real crude oil spot price*, from month 16 to month 44, and a temporary increase in *Oil production*, from month 10 to month 34.[39] This result further emphasizes the role of the *NEER* in the transmission of funding shocks to the real price of oil and is in line with the predictions of Yousefi and Wirijanto (2004) and Fratzscher, Schneider and Robays (2014), discussed in Beckmann, Czudaj and Arora (2020), which indicate that in the case of a partial or full-exchange rate pass-through, foreign oil producers could increase the oil production or reduce the oil price, if there is an appreciation in the US dollar.

[37]Results are qualitatively similar when the 3-months sign restriction imposed on *PMMFs* is relaxed. These results are available upon request.

[38]For completeness, we introduce the *CPI* to augmented model (1.1) for the period 2011:2–2021:10 and find no statistically significant effect of the negative funding shock on the *Real crude oil spot price.* The estimation results are available upon request.

[39]Results are very similar when the 3-months sign restriction imposed on *PMMFs* is relaxed. These results are available upon request.

## 1.6 Robustness tests

### 1.6.1 Alternative measures of the price of crude oil

We further analyse the impact of the funding shock driven by the US PMMFs reform on crude oil prices by proxying the real price of oil through the *Brent crude oil spot price* and the *WTI crude oil spot price.* The impulse response estimates are presented in Figure 1.9 and Figure 1.10, respectively. The results are in line with our findings from the augmented model, which introduces to the global crude oil market model of KM (2014) our funding variable *PMMFs* and measures the real crude oil price as the US refiners' acquisition cost for imported crude oil, deflated by the US CPI.

More specifically, we find that the negative funding shock increases *Oil production* 8 months from the impact and decreases the real *Brent Crude Oil spot price* and the real *WTI Crude Oil spot price* 19 months from the impact.[40]

### 1.6.2 VIX as an alternative measure of global liquidity

We further analyze the impact of our funding shock of interest on the *Real crude oil spot price* by introducing *VIX* to the augmented model (1.1). *VIX* is a widely used price-based measure of global private liquidity, capturing investor risk perception and tolerance, while US PMMFs is a quantity-based measure of global private liquidity, which captures short-term debt securities as a component of international credit (see Cesa-Bianchi, Cespedes, and Rebucci, 2015; Cerutti, Claessens and Ratnovski, 2017). The results are presented in Figure 1.11.

The response of the *Real crude oil spot price* to our funding shock of interest is lagged, negative and persistent. While the timing of the response of the *Real crude oil spot price* remains unchanged with the introduction of *VIX*, its magnitude changes from temporary to persistent. This result confirms the negative effect of tighter dollar funding conditions driven by the 2016 US PMMFs regulatory reform on the *Real crude oil spot price* as well as the validity of our main proxy for global liquidity, *PMMFs*.[41]

### 1.6.3 CPs as an alternative measure of PMMFs investment holdings by instrument

We investigate the direct link between *PMMFs* and the oil companies by introducing *CPs* as our funding variable (i.e., an alternative to the aggregate PMMFs investment holdings by global issuance) to the baseline model (1.1) for

[40]Results are qualitatively similar when the 3-months sign restriction imposed on *PMMFs* is relaxed. These results are available upon request.

[41]Results are qualitatively similar when the 3-months sign restriction imposed on *PMMFs* is relaxed. These results are available upon request.

the period 2011:2 – 2021:10. As previously noted, *CPs* represent the primary short-term funding source of oil companies and thus allows us to capture the impact of funding shocks on the oil market via the direct channel of direct oil company borrowings. The impulse response estimates are presented in Figure 1.12. The response of *Oil inventories* and *Real crude oil price* is not statistically significant for the period 2011:2 – 2021:10. *Oil production* sees a lagged and positive response, however, low in magnitude. The responses of *Real activity* and *CPs* are negative on impact, as imposed through our identification approach. These results indicate that funding shocks are not transmitted directly from *PMMFs* to oil companies, through *CPs* and reinforce our finding of a cross-border bank transmission channel of funding shocks from *PMMFs* to the oil market via *CDs*.[42]

## 1.7 Conclusion

PMMFs represent a vital source of US dollar funding for non-US borrowers, especially during crisis episodes. In 2016, a set of regulatory reforms for US PMMFs were introduced to address the susceptibilities which emerged during the GFC, which led to higher short-term dollar borrowing costs. The expansion of debt in the oil sector in the post-GFC period at a faster pace compared to other commodity sectors, makes oil companies particularly vulnerable to this sudden disruption in the short-term dollar funding market.

Using the global crude oil market SVAR model of KM (2014), we show that tighter short-term dollar funding conditions driven by the 2016 US PMMFs reform affect the crude oil market. More specifically, we find compelling evidence of a lagged negative effect of tighter funding conditions on the real crude oil spot price, and of a lagged positive effect on oil production and oil inventories. We suggest that the positive response of the oil production to tighter short-term dollar funding conditions can be explained by oil companies increasing output levels to raise short-term cash flows, which will enable them to remain liquid and meet dividend payments or to stabilize the purchasing power value of their export revenues in dollars. Moreover, we argue that disruptions in PMMFs funding provision can lead to a lagged decline in real crude oil spot price via its effect on oil production, oil demand or on the hedging demand of oil producers.

Importantly, we find that the effect of the PMMFs funding disruption on the crude oil market is driven by a fall in CDs, which constitute the most important unsecured wholesale funding for global banks. Hence, the US dollar funding disruption triggered by the PMMFs reform is transmitted indirectly

[42]Results are very similar when the 3-months sign restriction imposed on *CPs* is relaxed. These results are available upon request.

from PMMFs to the crude oil market, through cross-border bank flows. Further, we show that if our negative funding shock of interest results in an US dollar appreciation, the US nominal effective exchange rate acts as a transmission channel of US short-term dollar funding shocks to the real crude oil spot price, through a fall in oil demand or a reduction in the cross-border lending of non-US banks.

As we find cross-border bank lending to be a key driver of US PMMFs funding shocks to the crude oil market, our findings stress the importance of a number of mechanisms recently discussed in literature in mitigating the adverse effects of US dollar funding constraints on the US dollar cross-border bank flows, namely, central bank swap lines, central banks' international reserve holdings, central banks' backstop liquidity vis asset purchases and special lending facilities, and the monitoring of the US dollar funding fragility. Firstly, dollar swap lines allow central banks to obtain dollar funding liquidity from the Federal Reserve to meet underlying demand from banks in their jurisdictions for a fixed period of time at a pre-specified interest rate. These injections of liquidity flow across borders and show up in the form of a rise in cross-border interbank claims, which help to stabilise global dollar funding liquidity conditions. Secondly, by identifying a fall in the CDs to be a primary driver of the PMMFs funding disruption, our findings support the purchase of CDs via special lending facilities by central banks. Thirdly, stronger global financial safety nets such as the international reserves of central banks, largely denominated in US dollars, can play a stabilizing role in the event of stress in US funding markets such as PMMFs, by providing US dollar funding liquidity to the non-US financial system.

Moreover, we support the strong need for monitoring the US dollar funding fragility of recipient banks and for strengthening currency-specific liquidity risk frameworks, stress tests, emergency funding strategies and resolution planning (IMF, 2019). Lastly, in the light of the persistent disruptions of the US PMMFs during the GFC, the European debt crisis, the disruptions following the 2016 US PMMFs reform and the Covid-19 outbreak, by showing that PMMFs funding shocks affect the crude oil market, our findings highlight the need for reassessing the resilience of the US PMMFs sector and support the call for a global approach to monitoring these markets (Eren, Schrimpf, and Sushko, 2020a; IMF, 2021).

We propose the following avenue for future research. Given the growing interconnectedness between banks and non-financial institutions and the structural vulnerabilities in the NBFI sector, exposed by the COVID-19 market turmoil, it would be interesting to explore how funding liquidity shocks are transmitted between non-bank financial institutions (NBFI), and subsequently to the bank sector and the oil market (see Aldasoro, Huang and Kemp, 2020, for a discussion on cross-border links between banks and non-bank financial institutions). A first step in this direction would be to investigate how systematic differences in the balance sheet structure of banks and non-banks affect the funding liquidity transmission across the financial sector. The substantially different regulatory frameworks of NBFI as compared to banks, and their limited access to central bank liquidity facilities pose financial stability risks and call for an effective global monitoring exercise on non-bank financial intermediation.

**Table 1.1: Sign restrictions for the KM (2014) baseline model**

| Panel A. Impact sign restrictions for the KM (2014) baseline model | | | |
|---|---|---|---|
| | Negative flow supply shock | Flow demand shock | Speculative demand shock |
| Oil production | - | + | + |
| Real activity | - | + | - |
| Real crude oil spot price | + | + | + |
| Oil inventories | | | + |

| Panel B. Dynamic sign restrictions to a flow supply shock KM (2014) baseline model | | | |
|---|---|---|---|
| | Oil production | Real activity | Real crude oil spot price |
| Negative flow supply shock | - | - | + |

*Notes:* All structural shocks have been normalized to imply an increase in the real price of oil. Missing entries mean that no sign restriction is imposed. The responses of oil production and global real activity to an unanticipated flow supply disruption are negative for the first 12 months, while the response of the real price of oil is positive for the first 12 months starting in the impact period.

**Table 1.2: Impact sign restriction for the extension of KM (2014) baseline model, 2011:2 – 2021:10**

| Panel A. | | | |
|---|---|---|---|
| | Negative flow supply shock | Flow demand shock | Speculative demand shock |
| Oil production | - | + | + |
| Real activity | - | + | - |
| Real crude oil spot price | + | + | + |
| Oil inventories | | | + |

| Panel B. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Real crude oil spot price | Oil production | Real activity | Oil inventories | VIX | NEER | CPI | PMMFs |
| Negative funding shock | | | - | | + | + | - | - |

*Notes:* We impose the additional restriction that the response of PMMFs variable to a negative funding shock must be negative for three months starting in the impact period.

**Table 1.3: Descriptive statistics of PMMFs investment holdings and real crude oil spot price**

**a. PMMFs investment holdings by global issuance (PMMFs)**

| *Levels (include units in US dollars)* | |
|---|---|
| Mean | 1,290,133 |
| Median | 1,412,814 |
| St dev | 456,387 |
| Max | 1,851,013 |
| Min | 545,284 |
| *Percentage changes* | |
| Mean | -0.43 |
| Median | 0.16 |
| St dev | 4.96 |
| Max | 11.61 |
| Min | -28.92 |

**b. PMMFs investment holdings by instrument (CDs)**

| *Percentage changes* | |
|---|---|
| Mean | -0.90 |
| Median | -0.03 |
| St dev | 7.07 |
| Max | 15.75 |
| Min | -46.51 |

**c. Real crude oil spot price**

| *Percentage changes* | |
|---|---|
| Mean | 0.33 |
| Median | 1.03 |
| St dev | 10.87 |
| Max | 59.32 |
| Min | -40.87 |

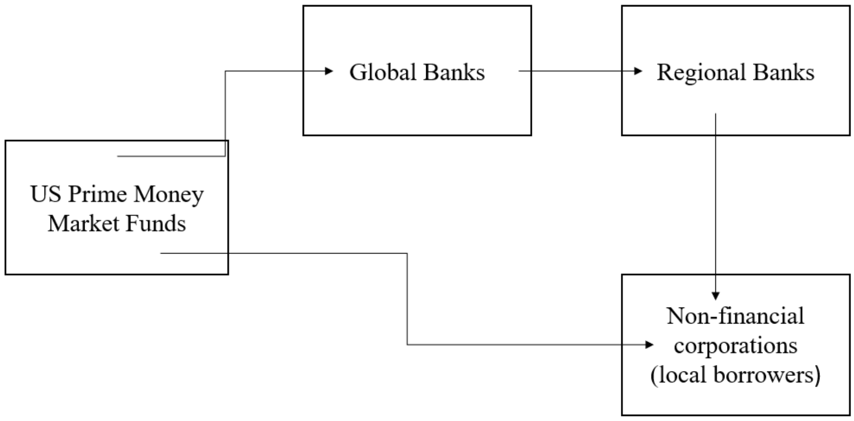
*Notes:* Descriptive statistics are reported for the PMMFs investment holdings by global issuance *(PMMFs)* in Panel a and by instrument in Panel b *(CDs)*. Panel c reports the descriptive statistics of monthly percentage changes in the *Real crude oil spot price*. The sample is 2011:2 - 2021:10.

**Table 1.4: Correlation matrix of the variables involved in the analysis**

| | Oil Inventories | Oil production | Real activity | PMMFs | Real crude oil spot price | CPI | VIX |
|---|---|---|---|---|---|---|---|
| Oil production | -0.15*** | | | | | | |
| Real activity | 0.09 | -0.14 | | | | | |
| PMMFs | 0.08 | -0.13 | 0.02 | | | | |
| Real crude oil spot price | -0.08 | -0.32* | -0.16*** | 0.03 | | | |
| CPI | -0.06 | -0.07 | -0.12 | -0.01 | 0.52* | | |
| VIX | -0.05 | 0.04 | 0.01 | -0.16** | -0.20* | -0.05 | |
| NEER | 0.09 | 0.10 | 0.05 | -0.09 | -0.38* | -0.12 | 0.09 |

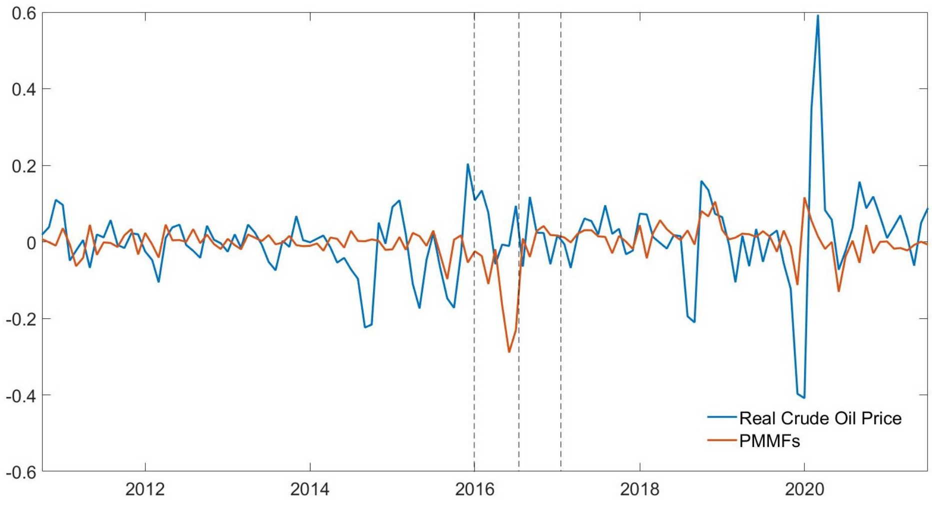
*Notes:* The correlation matrix reports the correlation coefficients between the variables, measured in percentage changes. *** indicates significance at 5 percent,** indicates significance at 5 percent and * indicates significance at 1 percent.

**Figure 1.1: Transmission channels of funding shocks from US PMMFs to non-financial corporations**



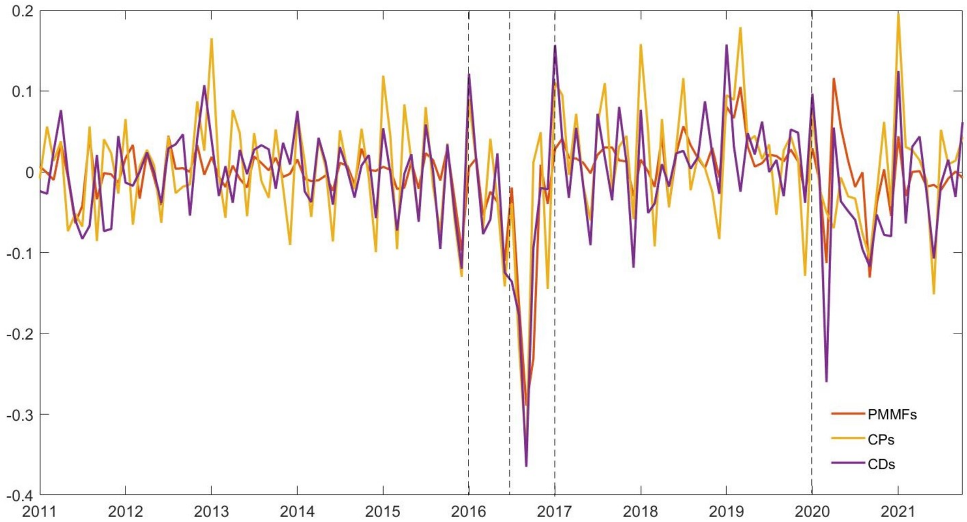

*Notes:* Two channels through which disruptions in the short-term funding of PMMFs can be transmitted to companies which borrow in US dollars: an indirect channel through cross-border bank flows, discussed in Bruno and Shin (2015), and a direct channel through PMMFs.

**Figure 1.2: Percentages changes in PMMFs and the Real crude oil spot price**



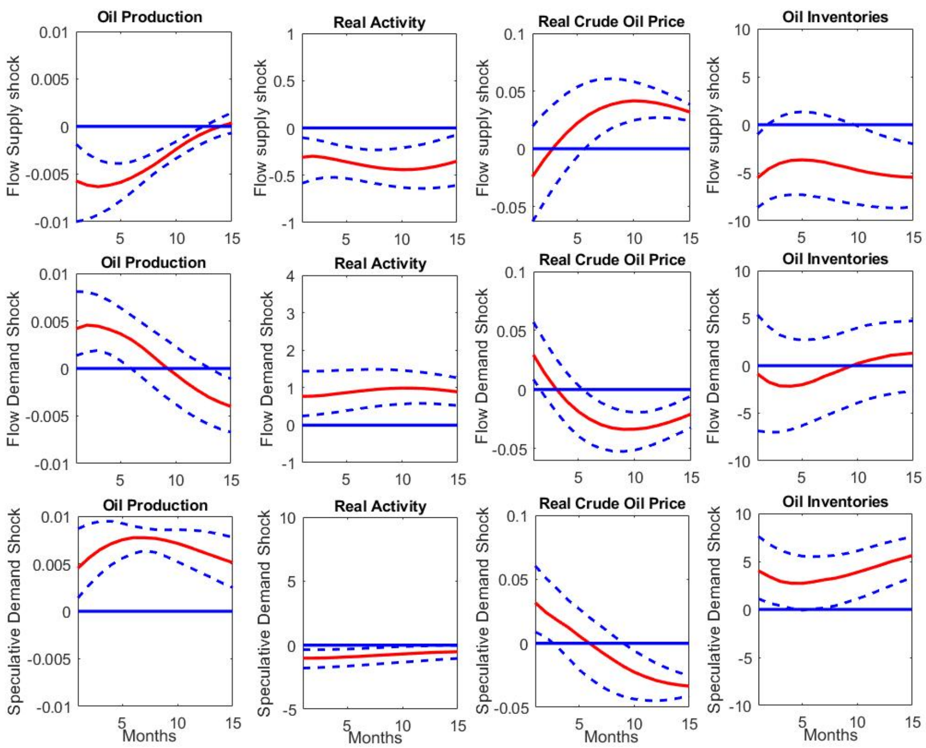

*Notes:* The evolution of *PMMFs* and the *Real crude oil spot price*, measured in percentage changes, over the sample period 2011:2 - 2021:10. The dotted lines represent the period associated with the introduction of the 2016 PMMFs reform.

**Figure 1.3: PMMFs Investment Holdings by Instrument (CDs, CPs) and by global issuance (PMMFs)**



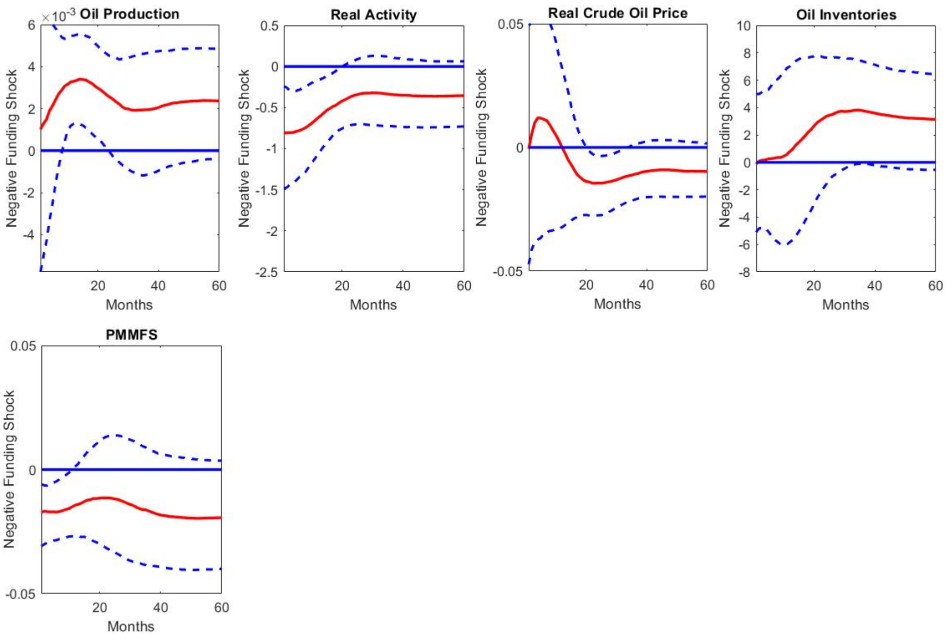

*Notes:* The evolution of *CDs*, *CPs* and *PMMFs* measured in percentage changes, over the sample period 2011:2 - 2021:10. The dotted lines represent the periods associated with the introduction of the 2016 PMMFs reform and the COVID-19 market turmoil.

**Figure 1.4: Structural impulse responses identified using Uhlig's (2005) method, 2011:2–2021:10. KM (2014) baseline model replication**



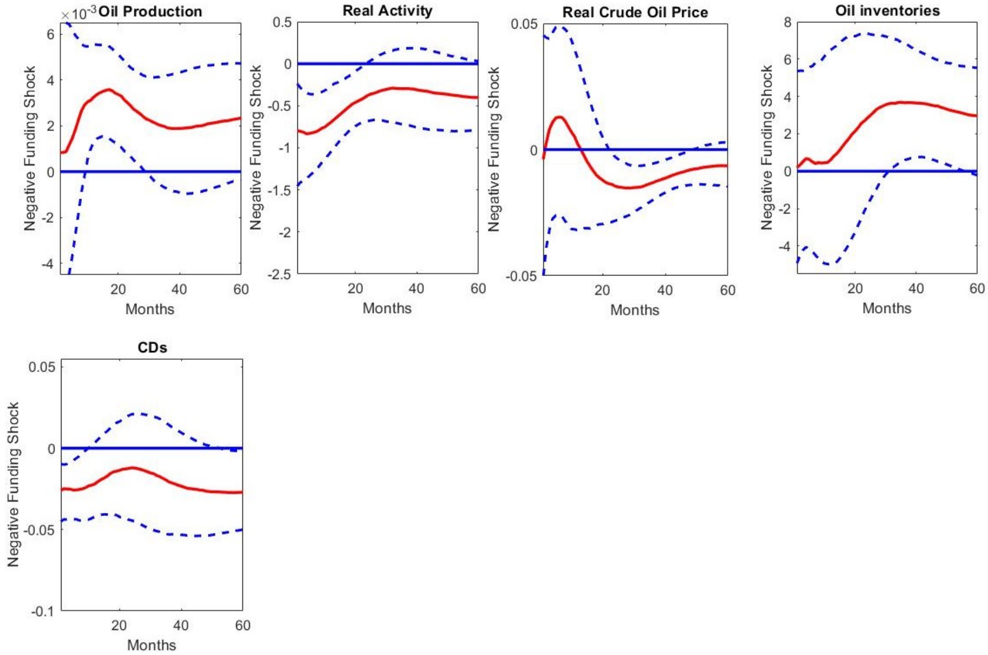

*Notes:* Solid lines indicate the impulse response estimates for the model to a one-standard deviation shock in flow demand, flow supply and speculative demand. Structural shocks are identified using Uhlig's (2005) pure-sign restriction rejection method. Impulse response curves are generated based on Bayesian inference which accommodates sign restrictions in the VAR model. Dashed lines indicate the corresponding pointwise 68 percent posterior error bands. Error bands are calculated using all the draws which have been kept. *Oil Inventories* refer to cumulative changes in oil inventories. *Oil production*, *Real crude oil spot price*, *Real Activity* and *PMMFs* are measured in cumulative percentage changes. The model is estimated using 1 lags, according to AIC criteria.

**Figure 1.5: Structural impulse responses to funding shocks, Uhlig's (2005) identification, 2011:2–2021:10**



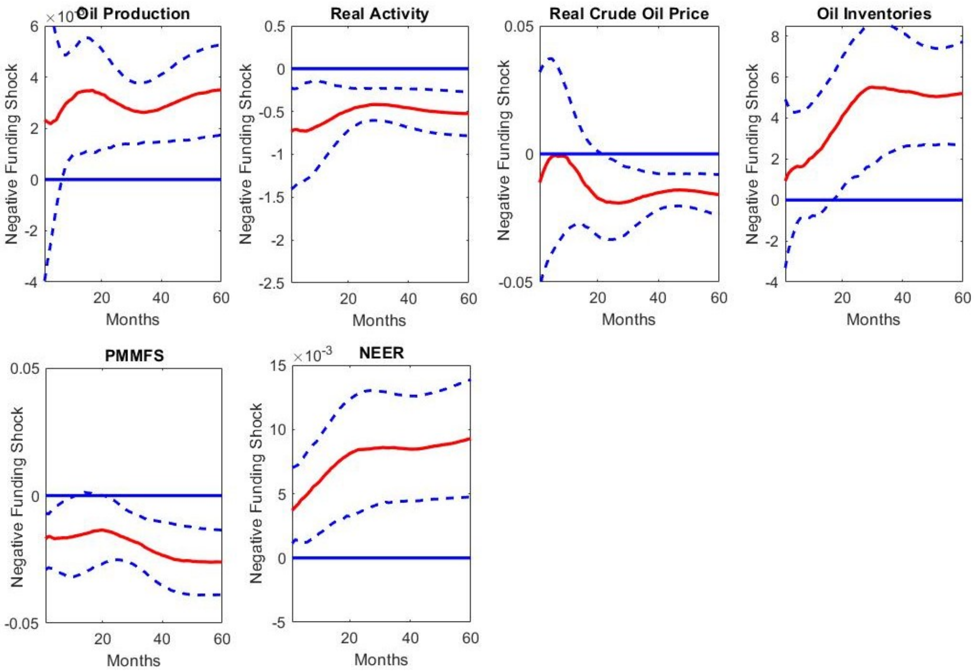

*Notes:* Solid lines indicate the impulse response estimates for the model to a one-standard deviation shock in PMMFs funding.

**Figure 1.6: Structural impulse responses to funding shocks using CDs, 2011:2–2021:10**



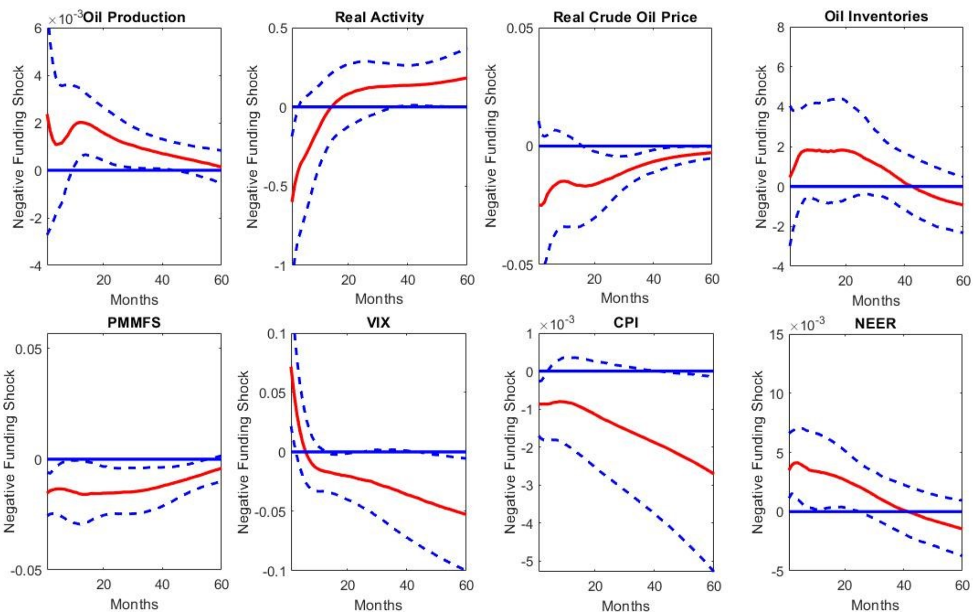

*Notes:* Solid lines indicate the impulse response estimates for the model to a one-standard deviation shock in CDs funding.

**Figure 1.7: Structural impulse responses to negative funding shocks, 2011:2–2021:10. Further analysis: the NEER channel**



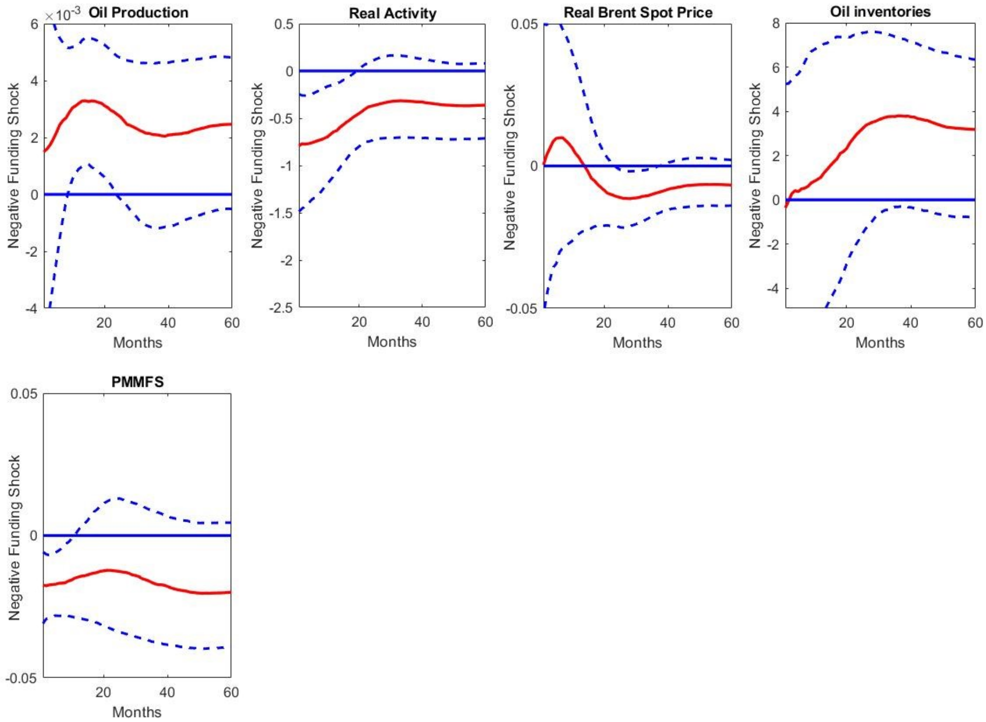

*Notes:* Solid lines indicate the impulse response estimates for the model to a one-standard deviation shock in PMMFs funding. *NEER* is measured in cumulative percentage changes. The *Real crude oil spot price* is measured in logs and presented in decimals.

**Figure 1.8: Structural impulse responses to negative funding shocks, 2011:2–2021:10. Further analysis**



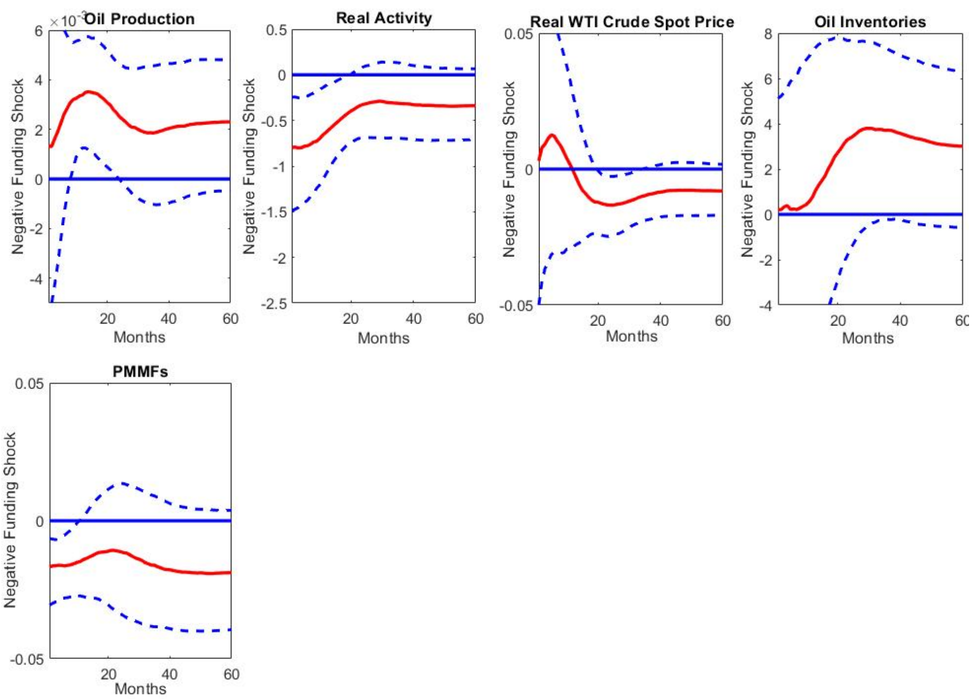

*Notes:* Solid lines indicate the impulse response estimates for the model to a one-standard deviation shock in PMMFs funding. *CPI* and *VIX* are measured in cumulative percentage changes. The *Real crude oil spot price* is measured in logs and presented in decimals.

**Figure 1.9: Structural impulse responses to funding shocks using Brent spot price, 2011:2–2021:10**



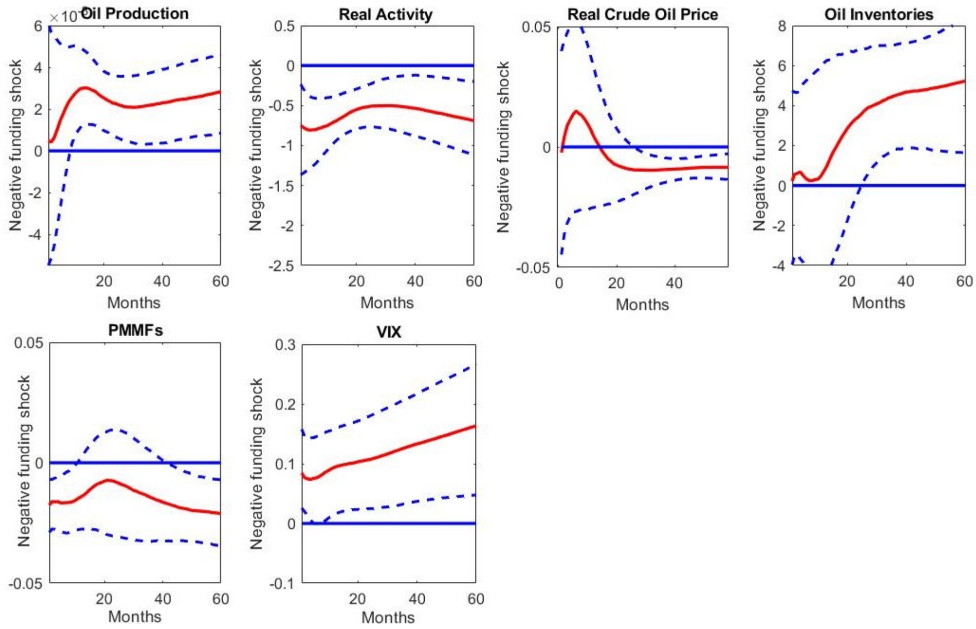

*Notes:* Solid lines indicate the impulse response estimates for the model to a one-standard deviation shock in PMMFs funding.

**Figure 1.10: Structural impulse responses to funding shocks using WTI spot price, 2011:2–2021:10**



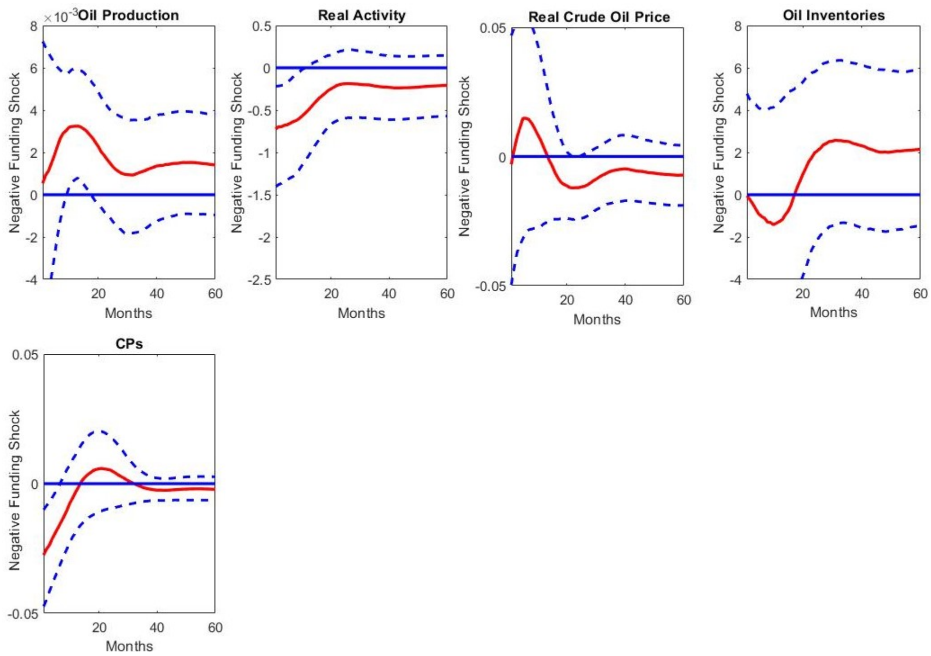

*Notes:* Solid lines indicate the impulse response estimates for the model to a one-standard deviation shock in PMMFs funding.

**Figure 1.11: Structural impulse responses to negative funding shocks, 2011:2–2021:10. Further analysis: the VIX channel**



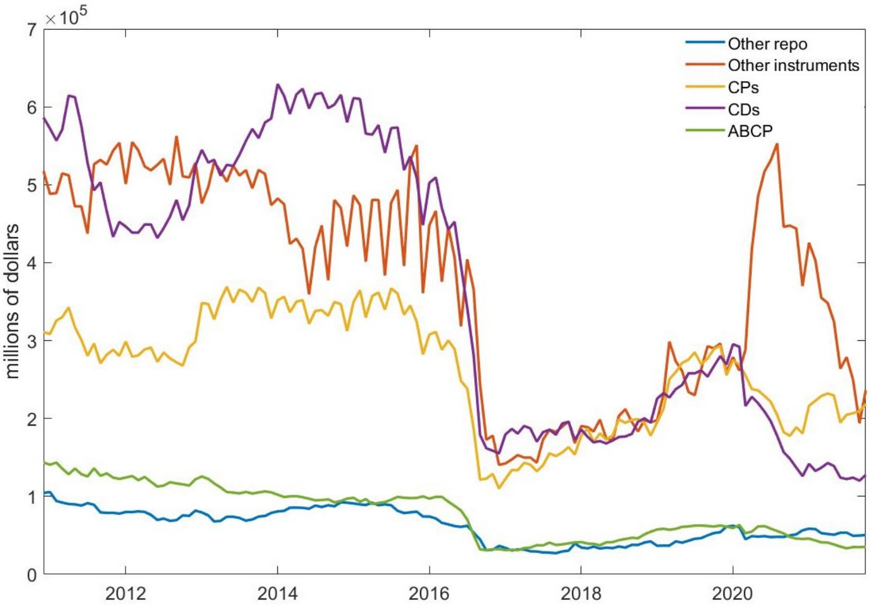

*Notes:* Solid lines indicate the impulse response estimates for the model to a one-standard deviation shock in PMMFs funding.

**Figure 1.12: Structural impulse responses to funding shocks using CPs, 2011:2–2021:10**



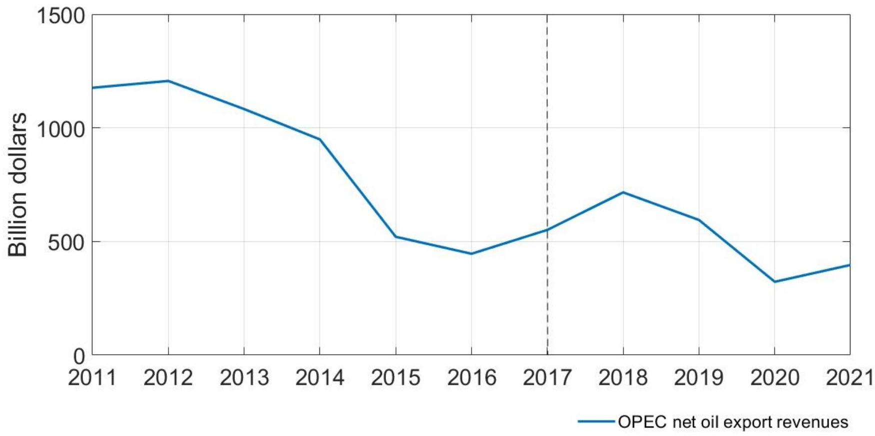

*Notes:* Solid lines indicate the impulse response estimates for the model to a one-standard deviation shock in *CPs* funding.

**Figure 1.1A: PMMFs Investment Holdings by Instrument, 2011-2020**




*Source:* Board of Governors of the Federal Reserve System. *CPs* stand for commercial papers, *CDs* for certificates of deposit, and *ABCP* for asset-backed commercial paper.

**Figure 1.2A: OPEC net oil export revenues, 2011-2021**




*Source:* U.S. Energy Information Administration, derived from data published in the October 2020 *Short-Term Energy Outlook*, OPEC stands for the Organization of the Petroleum Exporting Countries.

## Appendix 1A.

### Table 1.1A: Description of the variables included in the analysis

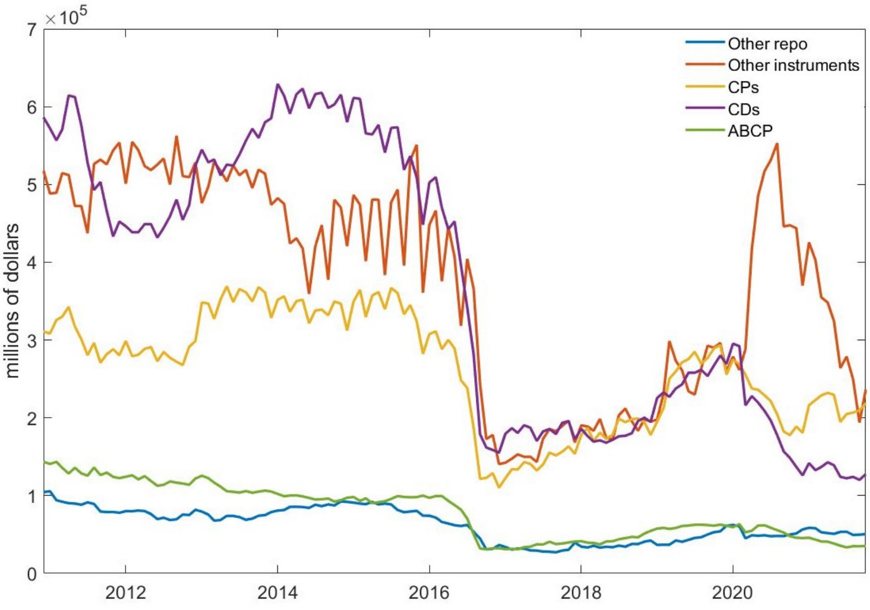
| Variable | Source | Construction | Measurement |
|---|---|---|---|
| PMMFs | Federal Reserve | | percentage changes |
| CDs | Federal Reserve | | percentage changes |
| CPs | Federal Reserve | | percentage changes |
| CPI | BIS | | percentage changes |
| Real Activity | Kilian (2009) index | Dry cargo shipping rate index | percentage changes |
| Oil production | EIA | | percentage changes |
| Real crude oil spot price | EIA | US refiners' acquisition cost for imported crude oil deflated by US CPI | natural logarithm |
| Oil inventories | EIA | US crude oil inventories, scaled by the ratio of OECD petroleum stocks over US petroleum stocks | percentage changes |
| NEER | BIS | | percentage changes |
| VIX | CBOE | | percentage changes |
| BRENT spot price | EIA | deflated by US CPI | natural logarithm |
| WTI spot price | EIA | deflated by US CPI | natural logarithm |

**Table 1.2A: Unit root tests of the variables involved in the analysis, 2011-2021**

| | **t-stat** |
|---|---|
| **Real Economic Activity** | -2.15 |
| **Global Crude Oil Inventories** | -1.95 |
| **Global Crude Oil Production** | -2.23 |
| **PMMFs** | -1.42 |
| **Crude Oil Spot Price** | -1.52 |
| **NEER** | -1.59 |
| **CPI** | 0.40 |

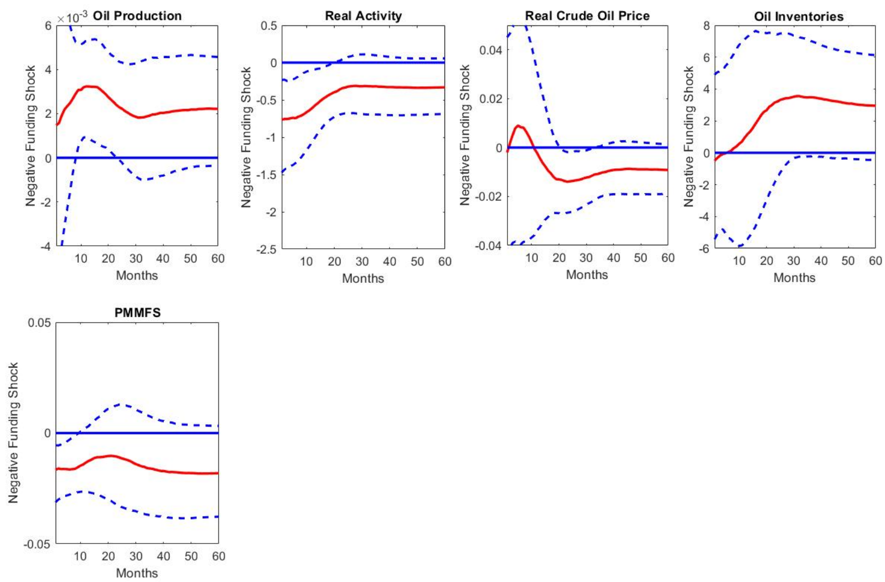
*Notes:* The table reports the t-statistics of the unit root ADF test. According to SIC, we use 12 lags. Variables are measured in levels. Sample period: 2011:2 – 2021:10.

**Figure 1.1A: PMMFs Investment Holdings by Instrument, 2011-2020**



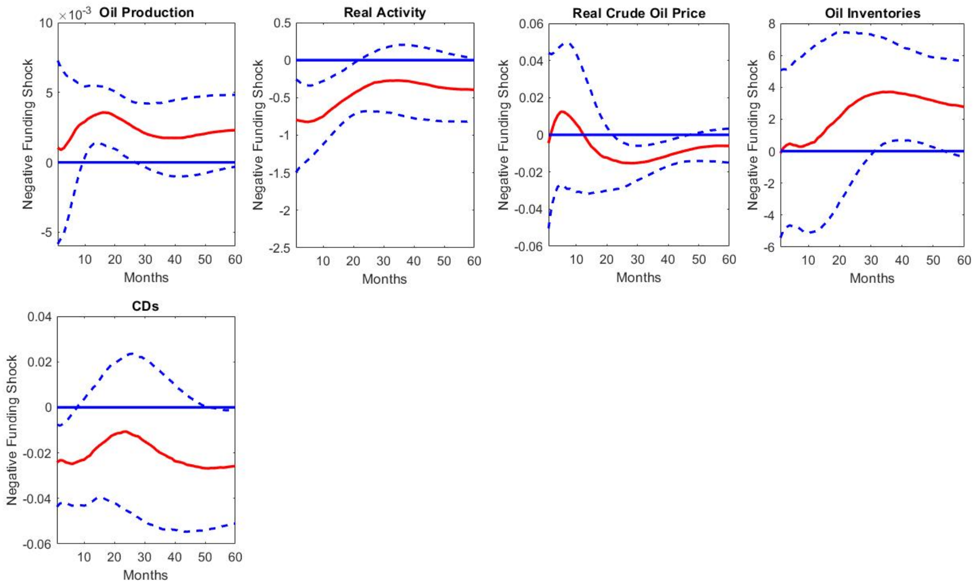

*Source:* Board of Governors of the Federal Reserve System. *CPs* stand for commercial papers, *CDs* for certificates of deposit, and *ABCP* for asset-backed commercial paper.

**Figure 1.2A: Structural impulse responses to funding shocks, Uhlig's (2005) identification, 2011:2–2021:10**



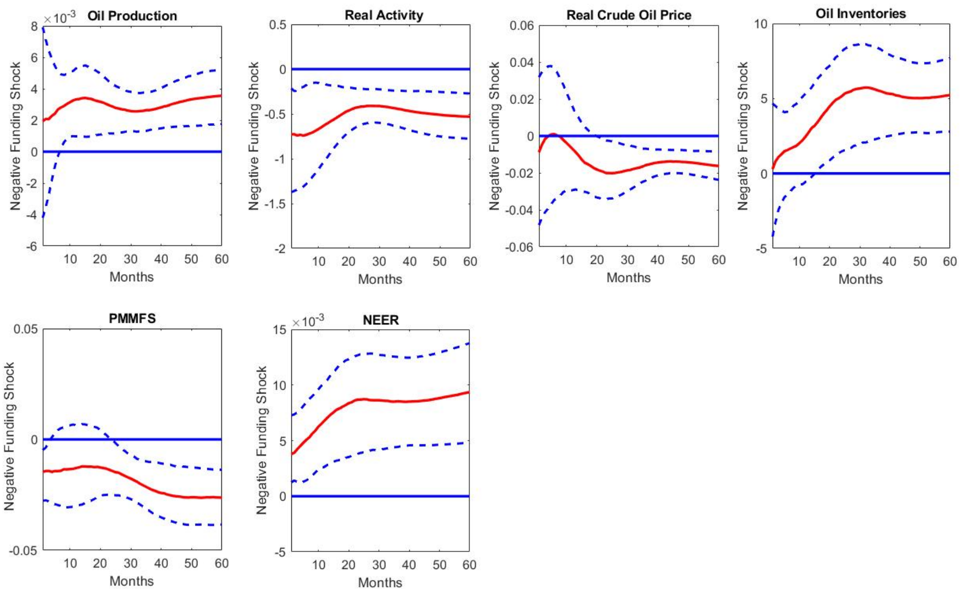

*Source:* Solid lines indicate the impulse response estimates for the model to a one-standard deviation shock in PMMFs funding.

**Figure 1.3A: Structural impulse responses to funding shocks using CDs, 2011:2–2021:10**



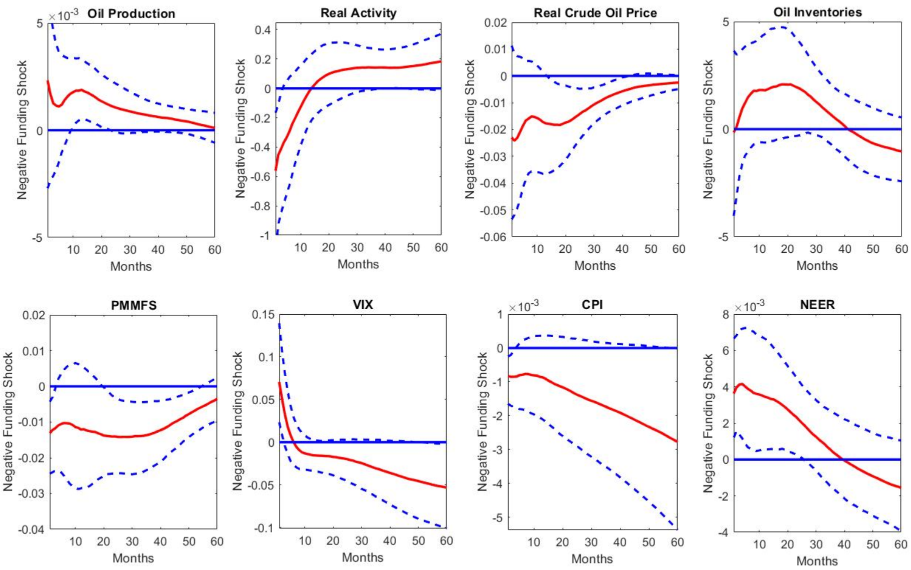

*Source:* Solid lines indicate the impulse response estimates for the model to a one-standard deviation shock in CDs funding.

**Figure 1.4A: Structural impulse responses to negative funding shocks, 2011:2–2021:10. Further analysis: the NEER channel**



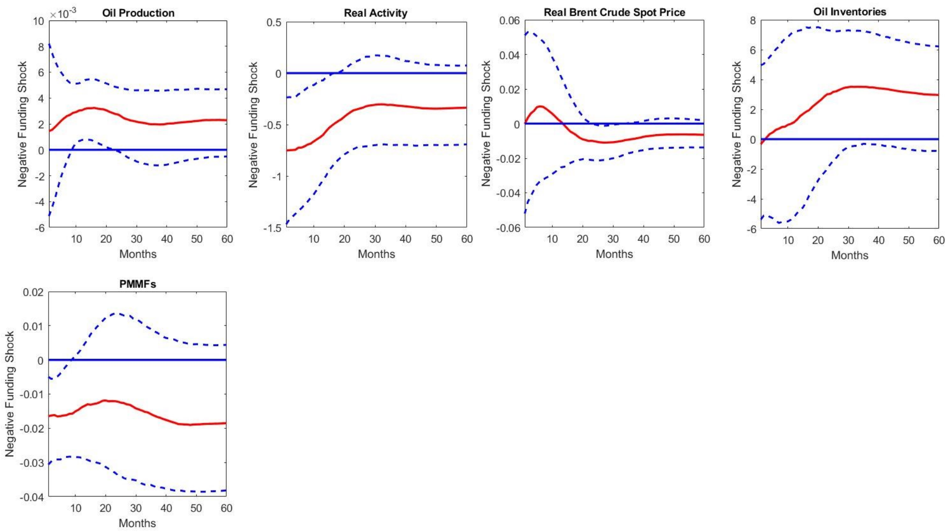

*Source:* Solid lines indicate the impulse response estimates for the model to a one-standard deviation shock in PMMFs funding. NEER is measured in cumulative percentage changes. The Real crude oil spot price is measured in logs and presented in decimals.

**Figure 1.5A: Structural impulse responses to negative funding shocks, 2011:2–2021:10. Further analysis**



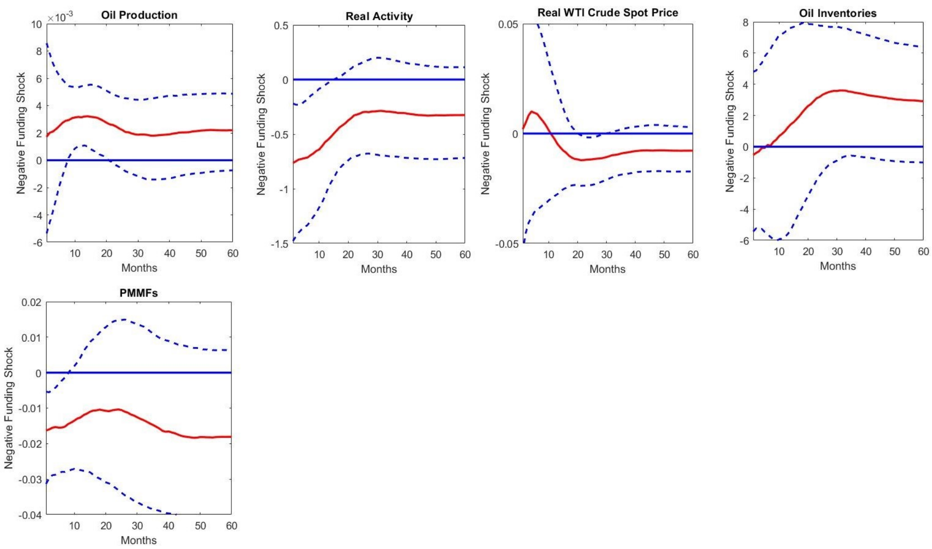

*Source:* Solid lines indicate the impulse response estimates for the model to a one-standard deviation shock in PMMFs funding. CPI and VIX are measured in cumulative percentage changes. The Real crude oil spot price is measured in logs and presented in decimals.

**Figure 1.6A: Structural impulse responses to funding shocks using Brent spot price, 2011:2–2021:10**



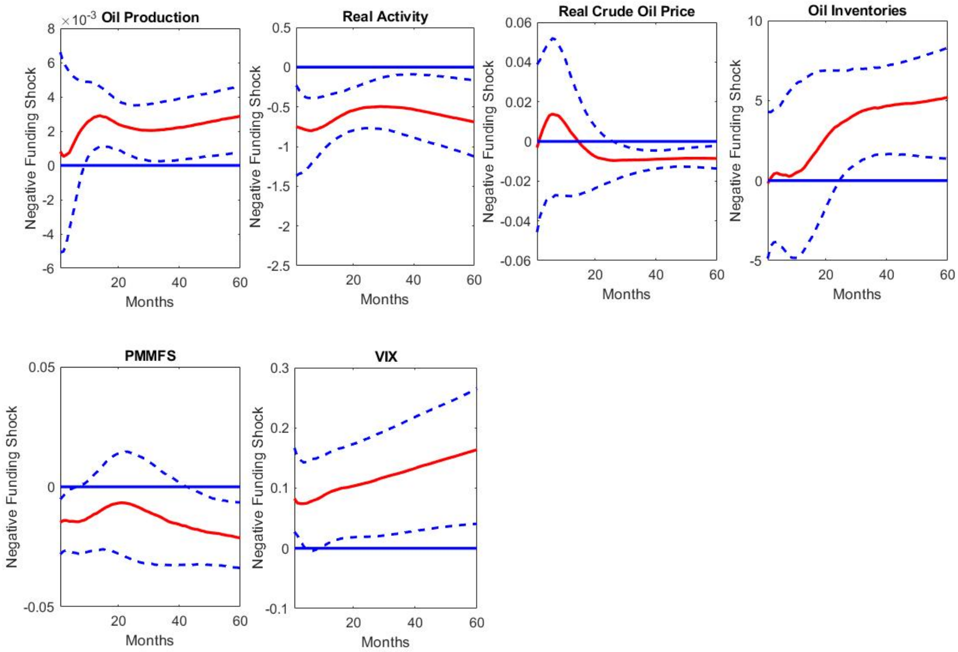

*Source:* Solid lines indicate the impulse response estimates for the model to a one-standard deviation shock in PMMFs funding.

**Figure 1.7A: Structural impulse responses to funding shocks using WTI spot price, 2011:2–2021:10**



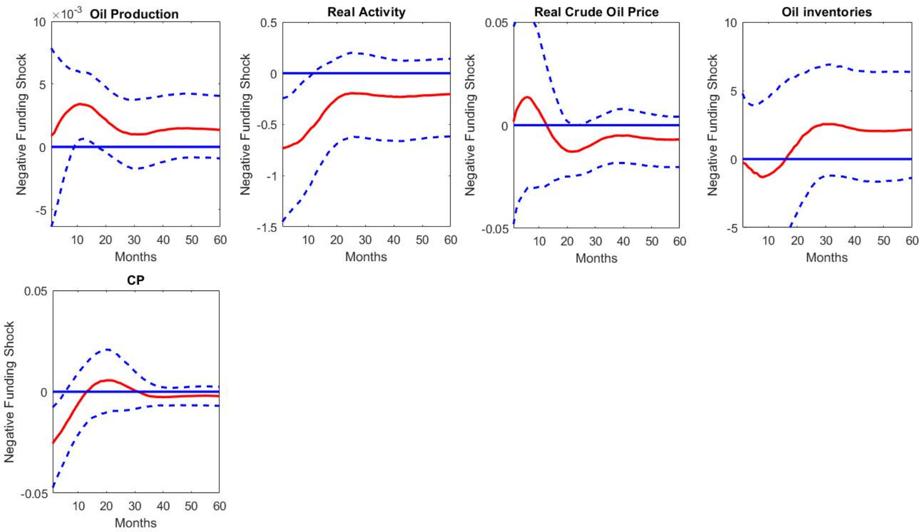

*Source:* Solid lines indicate the impulse response estimates for the model to a one-standard deviation shock in PMMFs funding.

**Figure 1.8A: Structural impulse responses to negative funding shocks, 2011:2–2021:10. Further analysis: the VIX channel**




*Source:* Solid lines indicate the impulse response estimates for the model to a one-standard deviation shock in PMMFs funding.

**Figure 1.9A: Structural impulse responses to funding shocks using CPs, 2011:2–2021:10**




*Source:* Solid lines indicate the impulse response estimates for the model to a one-standard deviation shock in CPs funding.

# Chapter 2

# Liquidity, Monetary Policy and the Commodity Futures Market

## 2.1 Introduction

This paper provides empirical evidence of a novel directional liquidity-based transmission channel of monetary policy to the commodity futures market. Commodity price dynamics have been a major source of concern for policy-makers during the last decades given their crucial role in shaping the dynamics of global economic activity (Harvey et al., 2017; Ge and Tang, 2020). Variations in commodity prices have often coincided with shifts in global monetary conditions (Anzuini, Lombardi and Pagano, 2012). Specifically, monetary policy decisions, a known driver of global monetary conditions, and commodity prices are linked in two ways (Filardo et al., 2018). Monetary policy decisions impact aggregate demand and, as a result, commodity prices, while commodity price changes influence price stability and hence monetary policy decisions. This relationship can both stabilise and de-stabilise the economy under certain conditions. For instance, monetary policy can become pro-cyclical if the nature of commodity price drivers is systematically misdiagnosed and spillover effects are overlooked (Filardo et al., 2018).

A large body of literature has examined the response of macroeconomic variables and the stance of monetary policy to changes in commodity prices, with a particular focus on oil price dynamics (Barsky and Kilian, 2004; Natal, 2012; Kilian, 2008, 2014; Jo, 2014; Kilian and Vigfusson, 2017; Kilian and Zhou, 2022). However, relatively less attention has been paid to the impact of monetary conditions on commodity prices. Empirical studies within this strand of literature have covered various commodity markets, with the oil market receiving most attention (Kilian and Vega, 2011; Rosa, 2014; Scrimgeour, 2015; Hammoudeh, Nguyen, and Sousa, 2015; Basistha and Kurov, 2015). Having yet to reach a consensus on the response of the oil prices to changing interest rates, this literature provides evidence of significant heterogeneity in the response of commodity prices to monetary policy. Scholars have attributed this heterogeneity to different factors affecting a particular commodity such as weather conditions, storability, easiness of supply, the strength of demand for commodity inventories, and any overreaction due to speculation (Hammoudeh, Nguyen, and Sousa, 2015).

To explain this heterogeneity, we provide empirical evidence of a novel liquidity transmission channel of monetary policy to the commodity futures market, based on the direction of the policy action. First, we contribute to the literature by showing that policy (target) surprises affect the trading volume of commodity futures. Second, we find that the magnitude of the effect of target surprises on the returns of commodity futures is stronger for more heavily traded commodity futures. Third, the existing literature on the commodity market and the related empirical framework advanced by Lagos and Zhang (2020) to explore the turnover liquidity-based transmission of monetary policy to the stock market does not account for asymmetries linked to the type of policy action taken by the Federal Open Market Committee (FOMC).[1] In this respect, we employ dummy variables based upon actual changes in the federal funds target rate. We add to this literature by showing that the direction of the target change matters to the transmission of monetary policy to the commodity market. Lastly, we conduct our empirical analysis on individual commodity futures, rather than an aggregate commodity index, as explored in related literature (Anzuini, Lombardi and Pagano, 2012; Mallick and Sousa, 2013). Crucially, this enables us to investigate which commodity futures are most sensitive, according to their dollar trading volume, to policy changes.

Whereas the extant literature on the commodity market explores several monetary policy transmission mechanisms centred on macroeconomic fundamentals, adopting a microstructure perspective, we provide a detailed and fragmented insight into capital allocation in secondary markets. Secondary market efficiency depends on the allocation of capital to investors which are best suited to use it at any point in time (i.e., high valuation investors in a policy tightening scenario).

In our approach, we follow the theoretical framework of Lagos and Zhang (2020), which formalizes a new mechanism: asset prices and conventional

[1]Since Keynes (1936), economists have seen asymmetries as an important aspect of the transmission mechanism of monetary policy to the macroeconomy and the financial markets. Asymmetries in the response of the stock market to monetary policy, related to economic conditions, the direction of the surprise, the size of the policy or the nature of the actual target rate change, have been explored by a growing body of empirical work (Lobo, 2000; Bernanke and Kuttner, 2005; Basistha and Kurov, 2008; Kurov, 2010).

measures of financial liquidity (i.e., trading volume) are determined by the (real) quantity of money and the characteristics of the market in which the asset trades (i.e., the degree of market power of dealers and the ease with which investors find counterparties). Specifically, changes in the monetary policy stance influence the opportunity cost of holding the nominal assets used routinely to settle financial transactions (i.e., money balances). Accordingly, changes in the opportunity cost of holding money affect the equilibrium real balances. Precisely, if the opportunity cost of holding money is positive, the highest valuation investors no longer choose to hold enough real money, becoming budget constrained in the next valuation period. As high-valuation investors are no longer able to absorb the whole asset supply traded in the commodity futures market, some assets remain in the hands of investors with relatively low valuations. This in turn distort the asset allocation in the market where the asset is traded and depress the real price of the asset.

Based upon this theoretical framework, Lagos and Zhang (2020) provide original empirical evidence of a new turnover liquidity-based transmission mechanism through which monetary policy affects the stock market. We investigate whether this transmission mechanism is operative in the commodity futures market by identifying a new directional liquidity transmission channel of monetary policy, related to the financialization of the commodity market, rather than to macroeconomic fundamentals, as it has been explored in the literature so far, and to the direction of the policy action. The financialization of the commodity market, which is argued to have begun in 2004 saw an unprecedented inflow of institutional funds into the commodity futures market. Given that trading volume, which we employ as our measure of financial liquidity, varies across commodity futures, and monetary policy is transmitted to commodity prices via the opportunity cost of holding money, we expect more heavily traded commodities to be relatively more exposed to changes in the monetary policy stance.[2] Further, the extant literature finds a larger effect of monetary policy tightening on credit and asset prices than monetary policy easing (Gambacorta and Rossi, 2010; Angrist, Jordà, and Kuersteiner, 2013; Tenreyro and Thwaites, 2016). Thus, building on the empirical framework advanced by Lagos and Zhang (2020), we provide evidence of asymmetries in the effects of target rate announcements on the commodity market.

The commodity futures market shares several characteristics with the stock market and other financial assets with respect to the objectives and trading strategies of financial investors as well as the platforms on which they are traded. For instance, investable commodities have been experiencing an "asset

[2]According to the theoretical framework of Lagos and Zhang (2020), an increase in turnover liquidity led by a decline in money supply, real interest rates or an increase in dealer market power, will manifest itself through an increase in trading volume.

class" effect since 2004, thought to be driven by institutional investors.[3] The pioneering work of Barberis and Shleifer (2003), followed by Barberis, Shleifer, and Wurgler (2005) and Boyer (2011), document an "asset class" effect, defined as the excessive co-movement of assets belonging to the same index, and attribute this effect to the presence of institutional investors. Tang and Xiong (2012) study this asset class effect on the commodity market and find that, after 2004, the behaviour of index commodities has become increasingly different from that of non-indexed commodities, with the former becoming more correlated with oil, an important index constituent, and the equity market. They also find a higher exposure of commodities included in investable commodity indices such as S&P-GSCI and DJ-AIG to common shocks, driven by investor interest, rather than macroeconomic fundamentals. Building on this work, Basak and Pavlova (2016) show that, in the presence of institutional investors, shocks to the fundamentals of index commodities are transmitted to the prices of all other commodities. Moreover, they find that the volatilities and correlations of all commodity futures returns rise in the presence of such investors, with those of index commodities increasing by more.

Despite these similarities, clear distinctions exist between these markets. The most relevant distinction for our empirical analysis is the contract specification of commodity futures. Each futures contract specifies the quantity of the product delivered for a single contract, known as the contract size. Given that commodity futures are based on different types of underlying physical assets, each contract differs in size. These differences in the size of the contract can result in inaccurate inferences about the magnitude of the effects of changes in monetary policy stance on the returns of commodity futures with different liquidity. This limitation is addressed by our financial liquidity measure (i.e., dollar trading volume).[4]

To assess this novel directional liquidity-based mechanism, we first conduct an event-study analysis, consisting of estimating the reaction of the trading volume of individual commodity futures to monetary policy surprises (i.e. target

[3]Following the collapse of the equity market in the 2000, the discovery of a negative correlation between the returns of commodities and the returns of stocks by Gorton and Rouwenhorst (2006) and Erb and Harvey (2006) has triggered an unprecedented inflow of institutional funds into the commodity futures market (i.e., the holdings of institutional investors have increased from \$15 billion in 2003 to over \$200 billion in 2008 according to The Commodity Futures Trading Commission (CFTC) (2008) staff report). This inflow is estimated to have emerged around 2004 and is referred in the literature as the financialization of commodities (Irwin and Sanders, 2011; Tang and Xiong, 2012; Hamilton and Wu, 2014; Boons, De Roon, and Szymanowska, 2014). The emerging literature on the financialization of commodities has argued that commodity futures have been since viewed by financial institutions and wealthy investors seeking diversifications opportunities as a new asset class (Büyükşahin and Robe, 2014; Singleton, 2014).

[4]Following Marshall, Nguyen and Visaltanachoti (2012), dollar volume is computed by multiplying the number of contracts traded by the contract size and the settlement price, measured in dollars.

surprises) on the days of FOMC announcements. We use daily data for a sample of 19 commodity futures that comprise the S&P Goldman Sachs Commodity Index (S&P GSCI).[5] Following Lagos and Zhang (2020), we consider a version of the event-study estimator that relies on an instrumental variable identification strategy which uses, intra-day, high-frequency tick-by-tick interest rate data (the HFIV estimator). Next, we inspect the liquidity-based transmission channel of monetary policy by exploiting the cross-sectional variation in trading volume that exists across commodity futures. We run a fixed effects panel model of individual commodity future returns on changes in the policy rate, an interaction term between the change in the policy rate and the average trading volume of individual commodity futures, and several controls. In this second exercise, our paper poses the question concerning asymmetries, defined as the possibility of the response of commodity futures prices to monetary policy, to depend on the direction of the FOMC policy action. In the spirit of Bernanke and Kuttner (2005), interactive dummy variables based on changes in the federal funds target rate are employed to investigate this empirical question.[6]

Our results can be summarized as follows. Firstly, we find that target surprise increases, proxied through the 3-months Eurodollar rate, reduce the trading volume of 16 individual commodity futures. Secondly, exploiting the cross-sectional variation in the trading volume of our sample of commodity futures, we find that the magnitude of the negative (positive) effect of target surprises associated with contractionary (expansionary) FOMC announcement days, on the returns of commodity futures, is larger for commodity futures with higher trading volume. Further, we note that these effects are stronger for policy tightening actions than policy easing. Our findings are robust to several alternative specifications (i.e., a 1-week estimation window and an alternative proxy for the nominal policy rate, namely, surprise changes in the (daily imputed) 30-day federal funds futures rate (FFFR, hereafter) in a very narrow 30-minute window around the time of the FOMC announcement).

Our empirical findings provide important new perspectives into how monetary policy operates in the commodity futures market. Considering that the effect of monetary policy interventions on commodity prices can spillover to other financial markets, and to the macroeconomy, these results are informative to policymakers for maintaining financial and price stability, and for the effective implementation of monetary policy. In addition, our findings are of interest to investors for formulating effective investment and risk management decisions, and to commodity producers for designing hedging strategies against volatile

[5]Motivated by the work of Tang and Xiong (2012) and Basak and Pavlova (2016), we focus on the behaviour of index commodities.

[6]The difference between the federal funds target rate and the target surprise is that the former is not market determined, but administered by the Federal Reserve.

commodity prices (Rigobon and Sack, 2004).[7] Noteworthy for commodity producers, the ease of capital reallocation on secondary markets also affects investment in primary markets (Geromichalos, et al. 2021).

The outline of the rest of the paper is the following. Section 2.2 reviews the related literature and introduces hypotheses development. In Section 2.3, we describe the data and provide some preliminary analysis. Section 2.4 sets out the methodology. Section 2.5 discusses the empirical results. In Section 2.6, we introduce some robustness checks. Section 2.7 sets the further analysis. Finally, Section 2.8 concludes.

## 2.2 Literature Review and Hypotheses Development

This paper draws from the literature exploring the impact of monetary policy on the commodity market.

### 2.2.1 The response of aggregate commodity prices to monetary policy

Since Frankel (1984), global monetary conditions and interest rates have attracted a growing interest as potential driving factors of the price of commodities. This has led to a growing literature devoted to the assessment of the relationship between monetary policy and commodity prices. The mechanisms through which monetary policy affects the commodity market identified in the extant literature are based on macroeconomic fundamentals (Barsky and Kilian, 2001, 2004; Rosa, 2011; Glick and Leduc, 2012). Anzuini, Lombardi and Pagano (2012) investigate the empirical relationship between monetary policy in the US, proxied by the federal funds rate, and commodity prices, by means of a standard VAR system. They find that expansionary monetary policy shocks drive up the broad commodity price index and all its components. A similar result is highlighted by Mallick and Sousa (2013), who by means of a Bayesian SVAR, show that a monetary policy contraction in the Euro area leads to a quick fall in the commodity price index and produces a small decline in monetary liquidity, as measured by the growth rate of broad money.

A number of studies empirical studies within this strand of literature have covered a variety of commodity markets, with the oil market receiving particular attention. While the literature has yet to reach a consensus on the response of the price of oil to changing interest rates, there is ample evidence of significant heterogeneity in the response of other commodity prices to monetary policy. We discuss this literature in the following two subsections.

[7] Basak and Pavlova (2016) find that in the presence of institutional investors, shocks to the fundamentals of index commodities are transmitted to the price of all other commodities.

#### 2.2.1.1 The response of energy commodities to monetary policy

Several studies argue that expansionary monetary policy leads to an increase in energy commodity prices (Barsky and Kilian, 2001, 2004; Frankel, 2008; Taylor, 2009; Basistha and Kurov, 2015). For example, building on the seminal work of Frankel (1986), Barsky and Kilian (2001, 2004) show that monetary policy stance is a good predictor of commodity prices. In particular, Barsky and Kilian (2001) suggest that the oil price increase of the 1970s could have been caused, at least in part, by anticipated inflation brought on by expansionary monetary policy. The impact of monetary policy on the price of oil is further investigated by Taylor (2009), who finds that the reduction in interest rates by the Federal Reserve was responsible for accelerating the rise in oil prices during the early stages of the Global Financial Crisis (GFC). An explanation for this effect is provided by Frankel (2008), who argues that the very rapid decline in short-term interest rates in the first quarter of 2008 fuelled speculation in the commodity market, with negative real interest rates encouraging investments in physical commodities. More recently, Basistha and Kurov (2015) find that a hypothetical and unexpected cut in the fed funds target rate (defined as target surprise) increases the price of crude oil, gasoline and heating oil futures during the intra day event window following the announcement.[8] While Basistha and Kurov (2016) focus solely on whether path surprises affect energy prices, we extend the analysis to other commodity sectors, and explore a liquidity-based transmission mechanism of policy surprises.

The literature on the response of the energy market to contractionary monetary policy finds a decline in energy prices (Rosa, 2014; Apergis, Chatziantoniou and Cooray, 2020). For example, using a similar empirical approach to Basistha and Kurov (2015), Rosa (2014) finds that a hypothetical unanticipated hike in the federal funds target rate (target surprise) is associated with a decline in the price of light crude oil and heating oil futures during a 1-hour window around the FOMC press release.[9] Using non-parametric tests, Rosa (2014) also show that the releases of the FOMC statement induce a significantly higher price volatility and higher trading volumes for crude oil futures compared to non-event days. Taking an EGARCH-X modelling approach, Apergis, Chatziantoniou and Cooray (2020) find that a monetary policy contraction has a negative effect on the returns of oil and natural gas.

[8]The target surprises for all meetings are computed in the event window from 10 minutes before to 20 minutes after the announcement time. The target surprises are computed from fed funds futures prices as in Kuttner (2001). Kuttner (2001) shows that the unexpected change in the current federal funds target rate can be computed by scaling the futures price change to account for the timing of the announcement within a month. Basistha and Kurov (2015) also find that the unexpected changes in the fed funds target rate that occur at unscheduled FOMC meetings tend to have a larger immediate effect on energy futures prices than the policy decisions made at scheduled FOMC meetings.

[9]Target surprises are computed from fed funds futures prices as in Kuttner (2001).

The literature has yet to reach a consensus on the persistence of the effects of monetary policy on the energy market. For instance, Basistha and Kurov (2015) find that the accumulated responses of energy prices to monetary shocks over a period of several days after scheduled and unscheduled FOMC meetings are not statistically significant, while Hammoudeh, Nguyen, and Sousa (2015) find that an increase in policy interest rates leads to a persistent reduction in the price of energy.

Few studies find no evidence that energy prices are affected by monetary policy (Kilian and Vega, 2011; Chatrath, Miao, and Ramchander, 2012; Chan and Gray, 2017). Specifically, using daily as well as monthly data, Killian and Vega (2011) show that energy prices are predetermined with respect to macroeconomic news. Building on the methodological work of Kilian and Vega (2011), Chatrath, Miao, and Ramchander (2012) and later, Chan and Gray (2017), find that scheduled macroeconomic announcements do not impact energy futures prices. Employing a heteroscedasticity-based identification approach with high-frequency data, Scrimgeour (2015) find that oil prices tend not to be affected by increases in interest rates.

#### 2.2.1.2 The heterogeneous response of other commodities to monetary policy

The literature finds evidence of significant heterogeneity in the response of other commodity futures prices to increases in the policy rate (see Scrimgeour, 2015; Hammoudeh, Nguyen, and Sousa, 2015). Using a heteroskedasticity-based identification approach, Scrimgeour (2015) provide evidence of heterogeneity in the negative response of commodity prices to an increase in interest rates. For example, they show that metal commodity prices tend to respond more than agricultural commodities to a raise in the interest rates. The heterogenous response of commodity prices to changes in interest rates is supported by Hammoudeh, Nguyen, and Sousa (2015), who by means of a SVAR, find that an increase in policy interest rates leads to a positive and persistent rise in highly volatile food prices, a fall in the prices of beverages and a persistent reduction in the prices of metals.[10]

### 2.2.2 Transmission channels of monetary policy to the commodity market

The extant literature proposes several transmission channels through which monetary policy may affect the real price of commodities (Barsky and Kilian;

[10]Focusing on stock market liquidity, Chung, Elder and Kim (2013) find that liquidity declines more when the information content of the announcement (i.e., the surprise component of the policy target) is larger.

2001, Frankel, 2006; Frankel and Rose, 2010; Rosa, 2011; Gospodinov and Jamali, 2018). We summarize the proposed channels as follows:

1. *Inventory channel:* low interest rates reduce the opportunity cost of carrying physical inventories, which increases the demand for commodities and induces higher commodity prices (Frankel, 2006; Frankel and Rose, 2010; Gospodinov and Jamali, 2018).

2. *Supply channel:* interest rates affect the inter-temporal incentive to extract exhaustible commodities. For instance, lower rates decrease the cost of holding inventories in the ground and create an incentive to strategically delay the extraction of exhaustible commodities (see Hotelling, 1931, for the formal model and Frankel, 2006, for further discussion). This will increase the market price of commodities, as it occurred during the period 2002-2004. An increase in real interest rates will have the opposite effect, increasing the cost of carrying inventories and lowering the price of commodities, similar to the early 1980s.

3. *Financial channel:* lower interest rates reduce the cost of speculative positions in the commodity market, putting upward pressure on futures prices and, by arbitrage, on spot prices (Frankel, 2006; Frankel and Rose, 2010; Gospodinov and Jamali, 2018).

4. *Exchange rate channel:* expansionary monetary policy by the Federal Reserve reduces the spot value of the U.S. dollar and the relative price of commodities for holders of other currencies (Rosa, 2011; Glick and Leduc, 2012).

5. *Demand channel:* expansionary monetary policy improves expectations of higher inflation and stronger economic growth, which increases demand for all goods, including commodities (Barsky and Kilian, 2001, 2004). This channel is closely related to the risk-transmission channel discussed in Borio and Zhu (2012), defined as the impact of changes in policy rates on risk perceptions and risk tolerance and hence on the degree of risk in the portfolios and on asset pricing. Precisely, changes in interest rates and central bank's open market operations influence risk-taking, by shifting perceptions of risk, and risk tolerance.

Our paper contributes to this line of research by investigating a new microstructure channel based on the opportunity cost of money arising from the process of financialization of commodities, the observation that trading volume varies across commodity futures, and the direction of policy action.

### 2.2.3 Hypothesis development

The theory of opportunity cost of money developed in Lagos and Zhang (2020), on which our proposed monetary policy transmission channel is based, postulates that an increase in the growth rate of money supply (and therefore the expected inflation rate) or the real interest rate, causes equilibrium real money balances to decline. The direct effect of expected inflation on the real value of money is larger than the indirect effect on the price of equity. Hence, investors are no longer indifferent between carrying cash or equity, they prefer equity. In other words, an investor that was marginal under the lower inflation rate shifts his portfolio away from money towards equity in an attempt to avoid inflation tax, making money balances scarcer.

This theory has important asset price implications. Specifically, the real price of equity in a monetary equilibrium is in part determined by the option available to low-valuation investors to resell the equity to high-valuation investors. However, if the opportunity cost of holding money is positive, the highest valuation investors become budget constrained in the next valuation period, as they no longer choose to hold enough real money. Since high-valuation investors are no longer able to absorb the whole asset supply traded in the commodity futures market, some assets remain in the hands of low-valuation investors. As a result, the asset allocation in the commodity futures market is distorted and the resalability of commodity futures is reduced. This implies that trading volume, which measures the trading activity in the market, is determined by the (real) quantity of money, the real interest rate, and the details of the microstructure where the asset trades (e.g., the degree of market power of dealers and the ease with which investors find counterparties). Notably, a lower resale value option for the asset is reflected in a depressed real asset price. Henceforth, we hypothesize that an increase in the nominal interest rate will manifest itself through a reduction in trading volume, and subsequently, in the returns of commodity futures.

*Hypothesis 1: Surprise increases in the nominal rate reduce the trading volume and the returns of commodity futures.*

Since the real asset price is determined, in part, by the expected value of the asset resale option, and hence the trading volume of the asset, we hypothesize that the magnitude of the effect of a change in the nominal interest rate on the returns of commodity futures is larger for commodity futures with higher trading volume.

*Hypothesis 2: The magnitude of the change in the returns of commodity futures induced by a change in policy rate depends on the trading volume of the commodity futures and it is larger for commodity futures with higher trading volume.*

Our paper contributes to this line of research by investigating a new microstructure channel based on the opportunity cost of money arising from the process of financialization of commodities and the observation that trading volume varies across commodity futures.

#### 2.2.3.1 A two-period model for exchange-traded commodity futures

We translate Lagos and Zhang's (2020) theory of trade in financial over-the-counter (OTC) markets into an exchange-traded space for the commodity futures market by proposing a two-period model with three agents: hedgers (or commercial participants), speculators (or non-commercial participants), and commodity index investors, and two financial instruments: cash and commodity futures contracts.

Hedgers are the producers and consumers of the physical commodities, and they are part of both the commodity futures markets and the underlying physical markets for the commodities. Speculators and commodity index investors are financial participants in the commodity futures market. Speculators and commodity index investors differ with respect to their trading approach. Particularly, speculators trade actively in the commodity futures markets, while commodity index investors are long-term investors who passively hold commodity futures positions in their portfolio as part of their overall asset allocation strategy (Greely and Currie, 2008). Commodity indices are long-only investment vehicles, which establish a stable supply of passive buyers (commodity index investors) to balance the commercial selling (hedgers). Hence, index investors supply a pool of stable, passive, unleveraged capital to bear the commodity price risk that commercial participants want to hedge. For this liquidity provision, hedgers pay a premium which can be observed in the relative underperformance of long commodity positions and outperformance of short commodity positions (Kang, Rouwenhorst and Tang, 2020).

Trading is organised at follows. At the beginning of the first period each agent is endowed with a portfolio of commodity futures contracts and cash. All financial instruments are perfectly recognizable, cannot be foraged and can be traded in the second period. All agents can trade commodity futures and cash over a central exchange, backed by a clearing house. Hedgers make their production decisions in the first period, positioning themselves as net short in the commodity futures market, while speculators who demand short-term liquidity, step in to fill the unmet hedging demand. Index investors hold long only positions, balancing the surplus of commercial short positions relative to commercial long positions.

Following Lagos and Zhang (2020), our proposed model assumes that an increase in the nominal rate is associated with an increase in the money growth rate. Hence, an increase in the nominal interest rate between the end of the first period and the beginning of the second period, results in speculators becoming budget constrained in the next valuation period, as they no longer choose to hold enough cash balances. Given budget constraints, speculators are not able to meet hedging demand, causing the asset allocation in the commodity futures market to be distorted, and the re-saleability of commodity futures contracts to decline.

## 2.3 Data

### 2.3.1 Description of the data

The main sample period proposed in this analysis commences in November 2000 and ends in December 2008.[11] The beginning of the sample period is motivated by data limitations for our chosen sample of commodity futures contracts. We follow the extant literature on conventional monetary policy and the commodity market in choosing December 2008 as the end of the sample period (Anzuini, Lombardi and Pagano, 2012; Mallick and Sousa, 2013; Hammoudeh, Nguyen, and Sousa, 2015; Basistha and Kurov, 2015 and Scrimgeour, 2015). The sample ends in the final stages of the GFC, December 2008, after which the federal funds target rate has remained near zero and the FOMC began its unconventional monetary policy operations.[12] Following this period, the literature has argued that changes in asset prices that followed the FOMC announcements are likely to be driven by news about unconventional monetary policy operations (i.e., quantitative easing) (Basistha and Kurov, 2015). The time period we investigate is therefore characterized by monetary policy operating through changes in the federal funds target rate.

This sample period includes a total of 82 scheduled FOMC policy announcement dates. Seventy FOMC policy announcement dates are kept for the high-frequency estimation approach. The FOMC holds 8 regularly scheduled meetings each year to decide the monetary policy stance. Since 1994, the decisions of scheduled meetings have been announced to the public at roughly 2 PM Eastern Time (ET) on the announcement day. The statement notes

[11] We use the data provided by Lagos and Zhang (2020) for our sample period. In building the dataset comprising of FOMC announcement dates, Lagos and Zhang (2020) discard two dates: 9/13/2001 and 9/17/2001 (the two atypical FOMC announcements in the immediate aftermath of 9/11/2001). For the estimation procedure requiring the high-frequency instrumental variable estimator (HFIV estimator), we follow Lagos and Zhang (2020) in using data from Gorodnichenko and Weber (2016). In line with Lagos and Zhang (2020), we discard observations for commodity futures with the return and trading volume in the top and bottom one percentile. We thank Lagos and Zhang (2020) for making this data available.

[12] The federal funds target rate is the interest rate on overnight loans of reserves between banks.

the change in the federal funds target rate, an explanation for the decision taken and a brief summary of the FOMC view on the current and future economic conditions. While the federal funds target rate was volatile from 1987 to 2006, it reached the zero-lower bound in December 2008 (Smales and Apergis, 2017).[13] Commodity futures are traded on a number of exchanges such as the Chicago Mercantile Exchange (CME) (livestock), Intercontinental Exchange (ICE) US and Chicago Board of Trade (CBOT) (agricultural), ICE Europe and New York Mercantile Exchange (NYMEX) (energy). The daily settlement time for commodity futures contracts tratded on these primary exchanges ranges from 2 PM to 3.30 PM ET. Considering these closing trading hours, the effect of the 2 PM ET FOMC policy announcement on the closing price of commodity futures is captured by the proposed model.

#### 2.3.1.1 Monetary policy proxies

In line with the previous literature, we use the 3-month Eurodollar futures contract due to mature after the FOMC policy announcement as a proxy for the policy (nominal interest) rate.[14] One of the advantages of using the futures rate to proxy the policy rate is that its movement on FOMC policy announcement dates reflects only policy surprises and does not reflect anticipated policy changes. As noted in Kuttner (2001) and Gürkaynak, Sack, and Swanson (2007), federal funds futures rates are high-quality, continuous measures of market expectations for the federal funds rate. Specifically, daily changes in the current-month futures rate reflect revisions to the market's expectations for the federal funds rate over the remainder of the month. Notably, Krueger and Kuttner (1996) show that forecast errors of the federal funds rate, based on the futures price, are not significantly correlated with other variables known when the contract was priced.

Failing to measure the surprise component of the announcement will result in underestimating the impact of monetary policy on the financial market (IMF, 2013). The value of using the surprise component of policy announcement, rather than the anticipated component, to assess the response of asset prices to monetary policy, has been first discussed in Kuttner (2001) and has since been standard in the literature. Specifically, expected changes in the policy rate will be priced into financial assets prior to the announcement. Hence, asset price movements in response to policy rate changes are solely determined by the surprise component of monetary policy.

[13]During our sample period, the FOMC has had two chairs: Alan Greenspan (Aug 1987 to Jan 2006) and Ben Bernanke (Feb 2006 to Jan 2014).

[14]The 3-months Eurodollar futures contract is produced by the Chicago Mercantile Exchange Group (CME Group) and supplied by DataStream. We thank Lagos and Zhang (2020) for supplying the data on the 3-months Eurodollar futures contract.

#### 2.3.1.2 Commodity futures contracts

Following Marshall, Nguyen and Visaltanachoti (2012), we study 19 commodities that comprise the S&P GSCI.[15] The dataset includes daily settlement prices and daily number of contracts traded for 19 commodity futures contracts obtained from DataStream International. Our motivation in using commodity futures data stems from the reliance of policymakers on quotes from commodity futures markets to derive forecasts of the prices of key commodities, as noted in Bernanke (2008). Additionally, commodity futures have received the most coverage in the media and are used in the construction of major commodity indices, as discussed in Marshall, Nguyen and Visaltanachoti (2012).

Our sample consists of six energy commodities *(WTI, Brent crude oil, RBOB gasoline, heating oil, gasoil, and natural gas)*, eight agricultural commodities *(wheat, red winter wheat, corn, soybeans, cotton, sugar, coffee,* and *cocoa)*, three livestock commodities *(live cattle, feeder cattle,* and *lean hogs)*, one industrial metal *(copper)*, and two precious metals *(gold* and *silver)*.[16] Our motivation for choosing this sample comes from the aforementioned commodity markets having relatively large trading volumes and providing a broad cross-section of commodity futures contracts. As commodities trade on multiple exchanges, we use data from the primary exchange based on the work of Marshall, Nguyen and Visaltanachoti (2012) and the information provided by S&P GSCI. A detailed description of our dataset can be found in Table 2.1A and Table 2.2A in the Appendix.

The returns of commodity futures are computed as log changes of the settlement prices of the nearest contract up to one month before maturity; we then roll to the second-nearest contract.

#### 2.3.1.3 Trading volume as a measure of financial liquidity for commodity futures

The vast academic literature on market microstructure employs various measures reflecting different dimensions of liquidity.[17] We employ trading volume as a measure of financial liquidity for our sample of commodity futures. This choice is dictated by the conceptual underpinnings of the liquidity-transmission mechanism proposed by Lagos and Zhang (2020). The theory advanced by Lagos and Zhang (2020) explores the transmission of monetary policy to financial markets, by focusing on how changes in the real quantity of money affects the

[15] Commodities qualify for inclusion in the S&P GSCI on the basis of liquidity.

[16] We exclude three industrial metal commodities *(aluminium, lead and nickel)* due to lack of availability of trade size.

[17] Existing measures of liquidity can be categorized as follows: trading activity measures (i.e., trading volume, turnover, average trade size), transaction costs measures (i.e., bid-ask spread, price impact) and liquidity supply measures (i.e., dealer inventory, order book depth).

efficient allocation of assets among investors.

Trading volume is a commonly used measure of market liquidity as it reflects the ability of the market to reallocate assets across investors (Brennan and Subrahmanyam, 1995; Datar, Naik and Radcliffe, 1998; Chordia, Subrahmanyam and Anshuman, 2001; Chordia, Roll and Subrahmanyam, 2001). Specifically, Sarr and Lybek (2002) determine that trading volume is a good estimator of market depth, i.e., the existence of numerous trades and market participants. Relevant studies such as Stoll (1978), Glosten and Harris (1988) and Chordia, Roll and Subrahmanyam (2001) suggest a strong relationship between trading volume, the bid-ask spread and market liquidity, whereas Brennan, Chordia and Subrahmanyam (1998) argue for trading volume being a better liquidity proxy than the bid-ask spread, with a higher traded volume reflecting an increase in liquidity. Conversely, Johnson (2008) finds trading volume not to be related to price impact measures of liquidity, but rather to the variance of liquidity, or liquidity risk.

The construction of the trading volume as a proxy of financial liquidity in the commodity market follows Marshall, Nguyen and Visaltanachoti (2012). We convert the number of commodity futures contracts traded to a dollar volume variable by multiplying the number of contracts traded by the contract size and then multiplying this by the settlement price. We then take the natural logarithm of the resulting number, as follows:

$$T_t = ln(NrContractsTraded_t * ContractSize_t * SettlementPrice_t) \quad (2.1)$$

### 2.3.2 Preliminary analysis of the variables

As discussed in the previous section, we use the daily change in the CME Group 3-month Eurodollar future on the day of the FOMC announcement ($\Delta i_t$) to capture the target surprise component of the true change in the policy rate. Descriptive statistics for this proxy are presented in Table 2.1. The first column shows the daily change in the 3-month Eurodollar futures rate on the day of the FOMC announcement, whereas the second column reports the daily change in our proxy on all trading days during the sample period November 2000 to December 2008. $\Delta i_t$ has a mean of -1.63 bps and a standard deviation of 7.95 bps on the day of the FOMC announcement, and a mean of -0.18 bps and standard deviation of 4.98 bps on all trading days, implying a higher volatility on the days of FOMC announcements than on the rest of the days, and a higher magnitude of the reductions in this proxy on the FOMC announcement days as compared to other days.

The descriptive statistics for the returns of individual commodity futures, measured in log changes, are reported in Table 2.2. The standard deviation of the returns of individual commodity futures on FOMC announcement days is higher than the standard deviation of the returns of individual commodity futures associated with all trading days during the sample period November 2000 to December 2008 for 10 commodity futures. This implies that commodity futures returns are more volatile on the days of monetary policy announcements than on the rest of the days, which is consistent with policy actions inducing some reaction in the futures market.

The correlation matrix reported in Table 2.3 shows the correlation coefficients among our variables of interest, namely our proxy for the surprise component of the policy rate (target surprise), the trading volume and the returns of our commodity futures. As expected, the correlation between the target surprise and the returns of our sample of commodity futures $s$ is significant and negative at -10%.

The historical change (in basis points) in the FOMC's target federal funds rate is reported in Table 2.4.[18] We observe that out of our full sample of 82 FOMC announcement days, 17 represent contractionary monetary policy actions, 23 expansionary monetary policy actions, while the rest of the sample accounts for neutral policy changes.[19] The increases in the target federal funds rate stood at 25 bps, while the reductions ranged from 25 bps to 100 bps.[20] This data is used to construct two binary dummy variables (i.e., $D_{EasingAction}$ and $D_{TighteningAction}$) representing the type of FOMC policy action (see Bernanke and Kuttner, 2005). The dummy variable representing an easing policy action is equal to one on the FOMC announcement-day if the Federal Reserve decreased the target rate (expansive monetary policy), and zero otherwise. Conversely, the dummy variable representing a tightening policy action is equal to one on the FOMC announcement-day if the Federal Reserve increased the target rate (restrictive monetary policy), and zero otherwise.

The descriptive statistics for the trading volume of individual commodity futures is reported in Table 2.5. Energy commodities *(gasoline, WTI, natural gas, Brent crude oil* and *heating oil)* are the most liquid, with a mean trading volume ranging from 1.58 to 8.36 (in billions). These findings are in line with Marshall, Nguyen and Visaltanachoti (2012), who using mean trade sizes for the sample period April 2008 to August 2009, find that *WTI, Brent crude oil,* and *gasoil* are the most liquid. Industrial commodities *(copper)*, metal commodities *(gold* and *silver)* and livestock commodities *(cattle feeder)* are the most illiquid, with a mean trading volume ranging from 0.02 to 0.06 (in billions). The last row in Table 2.5 shows that the average mean and median

[18]This data is published by the Board of Governors of the Federal Reserve System.

[19]We include policy announcements associated with neutral changes in the policy rate, as they reflect market based policy surprises as much as an actual change.

[20]Out of the 23 expansionary monetary policy actions, 10 accounted for 25 bps, 10 for 50 bps, 2 for 75 bps and 1 for 100 bps.

trading volume across all commodities are 1.19 and 0.69 (in billions).

## 2.4 Methodology

We follow Lagos and Zhang (2020) in using disaggregate and aggregate announcement-day effects to explore the proposed directional liquidity-based transmission of monetary policy to the commodity futures market. In doing so, we first test whether an increase in the nominal rate reduces the liquidity of commodity futures (as measured by their dollar trading volume). Employing aggregate announcement-day effects, we explore whether this effect is transmitted to the price of individual commodity futures, and whether the strength of the mechanism increases with the liquidity of the asset.

### 2.4.1 Dis-aggregate announcement-day effects

Event-study analysis represents a popular approach in the empirical literature to estimate the impact of monetary policy on asset prices. To test whether an increase in the nominal rate reduces the liquidity of individual commodity futures, we estimate the reaction of individual commodity futures to monetary policy surprises on a subsample of trading days consisting exclusively of the days of FOMC announcements as follows:

$$\Delta T_t = \beta_0 + \beta_1 \Delta i_t + \epsilon_t \tag{2.2}$$

where $T_t$ represents the daily trading volume for individual commodity futures. $i_t$ denotes the day $t$ "policy rate" expressed in percentage terms, and define $\Delta i_t$= $i_t$- $i_{t-1}$, $\varepsilon_t$ is an exogenous shock to the asset trading volume.[21] The estimator $\beta_1$ is the high-frequency instrumental variable estimator (the HFIV estimator), which is estimated using a two-stage least squares (2SLS) approach.

The HFIV estimator is a version of the event-study estimator that relies on an instrumental variable identification strategy which uses intra day high-frequency tick-by-tick interest rate data. The HFIV focuses on unexpected changes in the proxy for the policy rate (FFFR) in a very narrow 30-minute window around the time of the FOMC announcement. Thus, the HFIV estimator addresses the concern that a number of other variables (i.e., news about economic outlook) are likely to have an impact on both the policy rate and asset prices, and that the policy rate may itself respond to market conditions on policy announcement days (simultaneity bias). This makes the HFIV estimator superior to the event-study estimator and the heteroscedasticity-based estimator

[21] In the context of monetary policy, this approach was originally used by Cook and Hahn (1989) and and has since been employed in the literature, see Thorbecke (1997), Cochrane and Piazzesi (2002), Kuttner (2001), and Bernanke and Kuttner (2005).

used in the literature.

### 2.4.2 Dis-aggregate announcement-day effects: cross-sectional analysis

We then investigate the liquidity-based transmission mechanism of monetary policy to the commodity futures market by exploiting the cross-sectional variation in trading volume that exists across commodity futures. The theory proposed by Lagos and Zhang (2020) implies that the magnitude of the change in the asset return induced by a change in the policy rate will depend on the liquidity of the financial asset (e.g., as measured by the turnover rate of the stock in Lagos and Zhang, 2020). To test this prediction, we run a fixed effects panel model of individual commodity future returns on changes in the policy rate, an interaction term between the change in the policy rate and the average trading volume of the individual commodity future, and several controls, as follows:

$$R_{s,t} = \beta_0 + \beta_1 \Delta i_t + \beta_2 T_{s,t-1} + \beta_3 \bar{T}_{s,t-1} * \bar{\Delta i}_t + \beta_4 (\Delta i_t)^2 + \beta_5 (T_{s,t-1})^2 + D_s + \epsilon_{s,t} \tag{2.3}$$

where $R_{s,t}$ is the individual commodity futures $s$ return, $\Delta i_t$ denotes the monetary policy shock on policy announcement day $t$ (measured by the change between day $t$ and day *t-1* in the 3-month Eurodollar futures contract with nearest expiration after the day $t$ FOMC policy announcement). $T_{s,t-1}$ is the trading volume of the individual commodity futures $s$ during the trading day prior to the day of the policy announcement (day $t$), $D_s$ is the commodity futures cross-section fixed effects, and $\varepsilon_{s,t}$ is the error term corresponding to the commodity futures $s$, on policy announcement day $t$. The commodity futures fixed effects control for the effects that permanent commodity futures characteristics not included explicitly in the regression may have on individual commodity futures returns. White cross-section t-statistics are used to account for heteroscedasticity in the residuals.

We include the interaction term $\bar{T}_{s,t-1}$*$\bar{\Delta i}_t$ , where $\bar{T}_{s,t-1}$= $T_{s,t-1}$-$T$, $\bar{\Delta i}_t$=$\Delta i_t$-$\Delta i$ and $\Delta i$ and $T$ are cross-sectional averages of $\Delta i_t$ and $T_{s,t-1}$. The interaction term estimates how the effect of target surprise changes on individual commodity futures returns varies across commodity futures with different trading volumes. This allows us to test whether policy rate changes affect individual commodity returns through the proposed liquidity-based channel. Hence, the coefficient of interest is $\beta_3$, which helps us evaluate whether increases (reductions) in the policy rate cause larger reductions (increases) in returns of commodity futures with larger trading volume. The quadratic terms $(\Delta i_t)^2$ and $(T_{s,t-1})^2$ are included to account for non-linearity.

In the next step, we explore the cross-sectional variation in trading volume that exists across commodity futures by accounting for the type of action taken by the FOMC and its effect on the returns of commodity futures. We augment the baseline model by introducing two dummy variables, $D_{EasingAction}$ and $D_{TighteningAction}$, representing the easing and tightening actions of the FOMC. We interact the two dummy variables, in turn, with the monetary policy shock, $\Delta i_t$, the trading volume of individual commodity futures during the day prior to the announcement day, $T_{s,t-1}$, and the interaction term $\bar{T}_{s,t-1} * \bar{\Delta i_t}$, as follows:

$$R_{s,t} = \beta_0 + \beta_1 \Delta i_t + \beta_2 T_{s,t-1} + \beta_3 \bar{T}_{s,t-1} * \bar{\Delta i_t} + \beta_4 \Delta i_t * D_{EasingAction} + \\ + \beta_5 T_{s,t-1} * D_{EasingAction} + \beta_6 \bar{T}_{s,t-1} * \bar{\Delta i_t} * D_{EasingAction} + \beta_7 (\Delta i_t)^2 + \beta_8 (T^S_{t-1})^2 + \\ + D_s + \epsilon_{st} \quad (2.4)$$

$$R_{s,t} = \beta_0 + \beta_1 \Delta i_t + \beta_2 T_{s,t-1} + \beta_3 \bar{T}_{s,t-1} * \bar{\Delta i_t} + \beta_4 \Delta i_t * D_{TighteningAction} + \\ + \beta_5 T_{s,t-1} * D_{TighteningAction} + \beta_6 \bar{T}_{s,t-1} * \bar{\Delta i_t} * D_{TighteningAction} + \beta_7 (\Delta i_t)^2 + \\ + \beta_8 (T_{s,t-1})^2 + D_s + \epsilon_{st} \quad (2.5)$$

## 2.5 Empirical Results

In this section we present the empirical responses of the individual trading volume of commodity futures, and of the returns of commodity futures to monetary policy, accounting for the type of policy action.

### 2.5.1 Empirical response of the trading volume to monetary policy

Using the HFIV estimator, we explore the effect of monetary policy, proxied through the 3-months Eurodollar futures rate, on the trading volume of individual commodity futures. We find that target surprise increases reduce the trading volume of individual commodity futures. Table 2.6 reports the estimated announcement-day effects of target surprise on the trading volume of individual commodities. According to the HFIV estimator, a 100 bps increase in the policy rate decreases the trading volume of 16 individual commodity futures by a minimum of 0.39 for *cattle* and a maximum of 0.81 for *wheat composite*. These results are in line with our first hypothesis.

### 2.5.2 Empirical response of the individual commodity futures returns to monetary policy by the type of FOMC action – a cross-sectional analysis

We exploit the cross-sectional variation in trading volume that exists across commodity futures using an event-study regression of individual commodity futures returns on the policy rate, an interaction terms between the change in the policy rate and individual daily trading volumes and several controls.

Table 2.7 presents the estimated announcement-day effects of target surprises, proxied through the 3-months Eurodollar futures rate and associated with tightening policy actions, on the returns of individual commodity futures. The average trading volume is measured in a 1-day window prior to the day of the policy announcement. The negative and statistically significant coefficients of the interaction term $\bar{T}_{s,t} * \bar{\Delta i}_t * D_{TighteningAction}$, from specifications (IV) and (V) in equation (2.3), indicate that the magnitude of the negative effect of target surprise changes associated with tightening FOMC policy decisions, on the returns of individual commodity futures is larger for commodity futures with higher trading volume. These results are in line with our second hypothesis.

Table 2.8 presents the results for expansionary policy actions on the returns of individual commodity futures. The positive and statistically significant coefficients of the interaction term $\bar{T}_{s,t} * \bar{\Delta i}_t * D_{EasingAction}$, from specifications (IV) and (V) in equation (2.3), indicate that the magnitude of the positive effect of target surprise changes associated with expansionary FOMC policy decisions, on the returns of individual commodity futures is larger for commodity futures with higher trading volume.[22]

Further, we note that the estimates are stronger for tightening policy actions than for easing. Our results are in line with the extant literature on the asymmetric effects of monetary policy, which finds that the effect of a monetary policy tightening on credit and asset prices is larger than the effect of a monetary policy easing (Gambacorta and Rossi, 2010; Angrist, Jordà, and Kuersteiner, 2013; Tenreyro and Thwaites, 2016, among others). In particular, Gambacorta and Rossi (2010) notes that the response of loan demand to changes in monetary policy may be asymmetrical due to a differential effect on investment decisions and self-financing. These asymmetric effects are in line with the 'pushing on the string' view of monetary policy attributed to John Maynard Keynes (De Long and Summers, 1993; Karras, 1996). This view argues that existing asymmetric aggregate demand movements depend on the sign of the monetary impulse, and when the economy is weak, the Fed's ability to stimulate real economic activity through monetary policy is much more limited.

[22] Expansionary FOMC policy decisions refer to an increase in the federal fund target rate.

Exploring the monetary policy effect on the dynamics of switching between bull and bear markets, Chen (2007) argues that a tightening monetary policy shock depresses asset returns by lowering the probability of staying in the bull-market regime, and increasing the probability of shifting to a bear-market regime. As financial constraints are more likely to bind in bear markets, their results emphasize the role of financial constraints in the asymmetric transmission of monetary policy

Our results can be summarized as follows. Surprise increases in the policy rate reduces the trading volume of 16 commodity futures. The second hypothesis implied by the theory of trade advanced by Lagos and Zhang's (2020) is confirmed when we account for the type of FOMC policy action. Specifically, the strength of the negative (positive) effect of contractionary (expansionary) FOMC policy actions, represented by actual increases (decreases) in the federal funds target rate, is larger for commodity futures with higher trading volume. These results imply that the mechanism through which policy rate changes are transmitted to the price of commodities is a change in the financial liquidity of individual commodity futures, as measured by the trading volume, with the strength of the mechanism depending on the liquidity of the asset, and the direction of policy action. Henceforth, we show that the liquidity-based transmission channel proposed by Lagos and Zhang (2020) is not confined to the stock market and also holds for the commodity futures market.

## 2.6 Further analysis

Following Gürkaynak, Sack, and Swanson (2005), we take into consideration the multi-dimensional effects of monetary policy by focusing on the unexpected changes in forward guidance. While the target surprise captures surprise changes to the current federal funds target rate (surprise in the policy action), the path surprise reflects the surprise component in the policy communication.[23] Specifically, the path surprise captures the news about the future direction of the policy rate (also defined in the literature as forward guidance) and Federal Reserve's view of future economic conditions. Moreover, the path surprise includes the timing of policy decisions, which reflects the surprises that have an effect on rates beyond the current month. The path surprise is thus constructed from a rotation of the first two principal components across a set of future surprises around scheduled FOMC meetings.[24]

[23] Given that FOMC started to release policy statements after the meeting in February 1994, path surprises started having economic significance in the post-1994 period.

[24] We would like to thank Gürkaynak, Lee and Karasou Can (2019) for making the data publicly available (http://refet.bilkent.edu.tr/research.html). Their calculation follows Gürkaynak, Sack and Swanson (2005) and has been since used in the literature (Paul, 2020). Data includes the current-month and three-month-ahead federal funds futures contracts (with a scale factor to account for the timing of FOMC meetings within the month) and the two-,

Our results show that the liquidity channel explored in this paper does not operate through the path factor of monetary policy (i.e. news about future path of monetary policy and/or Fed's view of future economic conditions), but through the direction of the changes in the current federal funds target rate.[25] These findings are in line with the scarce literature on monetary policy, proxied by the path surprise, and the commodity market, which finds positive and statistically significant estimates solely for gasoline (Basistha and Kurov, 2015).[26]

## 2.7 Robustness tests

This section checks the robustness of the results to several alternative specifications: a high-frequency proxy for the policy rate and a 1-week estimation window for the average trading volume.

### 2.7.1 High-frequency proxy for policy rate

We further analyse the validity of our results using a high-frequency measure of the unexpected change in the nominal policy rate in a narrow 30-minute time window around the FOMC announcement. We re-estimate the baseline model and the augmented models in (2.4) and (2.5), using $\Delta FF_t$ as a proxy for the policy rate. $\Delta FF_t$ is the daily imputed change in the 30-day FFFR from the level it has 10 minutes before the FOMC announcement and the level 20 minutes after the FOMC announcement, as outlined in (2.6).[27] $i_{t,m}$ denotes the daily imputed 30-day fed funds futures rate on minute $m$ of day $t$, $D$ is the number of days in the month of the announcement and $d$ is the day of the announcement. The scaling factor $\frac{D}{D-d}$ accounts for the timing of the FOMC announcement within a month.

$$\Delta FF_t = \frac{D}{D-d}(i_{t,m_t+20} - i_{t,m_t-10}) \tag{2.6}$$

We find that the response of the returns of commodity futures to contractionary policy actions remains consistent to using the aforementioned proxy for the nominal policy rate. Table 2.9 reports the estimated announcement-day

three-, and four-quarter-ahead Eurodollar futures contracts.

[25] The path surprise estimation results are available upon request.

[26] The literature finds that international stock markets respond solely to target surprises (Hausman and Wongswan, 2011).

[27] Federal funds futures are widely used in computing high-frequency market-based monetary policy surprises. The surprise component (target surprise) refers to the difference between expected and announced federal funds target rates at the current FOMC meeting. This proxy for the policy rate is the target surprise employed in Rosa (2014) and Basistha and Kurov (2015). We thank Lagos and Zhang (2020) for supplying the data on the tick-by-tick nominal interest rate implied by 30-day federal funds futures, which is also employed in the construction of the HFIV estimator.

effects of contractionary policy actions on the returns of individual commodity futures, when average trading volume is measured in the 1-day window prior to the day of the policy announcement. The results confirm that the magnitude of the negative effect of target surprises on contractionary announcement days, on the returns of commodity futures, is larger for commodity futures with higher trading volume. Table 2.10 reports the estimated announcement-day effects of expansionary policy actions on the returns of individual commodity futures, when average trading volume is measured in a 1-day window prior to the day of the policy announcement. We find no statistically significant evidence of a monetary policy effect on the returns of commodity futures, which varies across futures contracts with different trading volumes.

### 2.7.2 An alternative estimation window for the average trading volume of commodity futures

We further analyse the impact of the monetary policy shock on the returns of individual commodity futures by re-estimating the baseline model and the augmented models in (2.4) and (2.5), using the average trading volume of the individual commodity future $s$ over all the trading days during the 1-week prior to the day of the policy announcement, as follows:

$$R_{s,t} = \beta_0 + \beta_1 \Delta i_t + \beta_2 T_{s,t-7} + \beta_3 \bar{T}_{s,t-7} * \bar{\Delta i_t} + \beta_4 \Delta i_t * D_{EasingAction} + \\ + \beta_5 T_{s,t-7} * D_{EasingAction} + \beta_6 \bar{T}_{s,t-7} * \bar{\Delta i_t} * D_{EasingAction} + \beta_7 (\Delta i_t)^2 + \beta_8 (T_{s,t-7})^2 + \\ + D_s + \epsilon_{st} \quad (2.7)$$

$$R_{s,t} = \beta_0 + \beta_1 \Delta i_t + \beta_2 T_{s,t-7} + \beta_3 \bar{T}_{s,t-7} * \bar{\Delta i_t} + \beta_4 \Delta i_t * D_{TighteningAction} + \\ + \beta_5 T_{s,t-7} * D_{TighteningAction} + \beta_6 \bar{T}_{s,t-7} * \bar{\Delta i_t} * D_{TighteningAction} + \beta_7 (\Delta i_t)^2 + \\ + \beta_8 (T_{s,t-7})^2 + D_s + \epsilon_{st} \quad (2.8)$$

The estimates of the announcement-day effects of contractionary monetary policy, proxied through the 3-month Eurodollar futures rate, on the returns of individual commodity futures are reported in Table 2.11. The results confirm that the magnitude of the effects of contractionary announcements, on the returns of commodity futures remains larger for commodity futures with higher trading volume, when trading volume is measured in the 1-week window prior to the policy announcement day. Specifically, Table 2.12 indicates that the magnitude of the positive effect of target surprises proxied through the 3-month Eurodollar futures rate and associated with expansionary policy actions, on the returns of commodity futures, is larger for commodity futures with higher trading volume. The average trading volume is measured in a 1-week window.

We then investigate whether the effects of monetary policy, proxied through high-frequency changes in the FFFR around the time of the FOMC announcement, change when we use the 1-week estimation window for the average trading volume of commodity futures. We find that our results remain consistent. Table 2.13 reports the announcement-day effects of target surprises, proxied through high-frequency FFFR changes, and associated with tightening policy actions, on the returns of commodity futures. The average trading volume is measured in the 1-week window prior to the policy announcement day. We find that the results remain consistent with changing the measurement window for the trading volume of commodity futures. Table 2.14 reports the announcement-day effects of target surprises, proxied through high-frequency FFFR changes, and associated with expansionary policy actions, on the returns of commodity futures. The average trading volume is measured in the 1-week window prior to the policy announcement day. The results become statistically significant when using this extended measurement window for the trading volume of commodity futures.

## 2.8 Conclusion

Commodity price dynamics have been a major source of concern for policymakers during the last couple of years for their crucial role in shaping the dynamics of global economic activity. The extant literature on monetary policy and commodity futures price dynamics has provided evidence of significant heterogeneity in the response of commodity prices to monetary policy channelled via macroeconomic fundamentals. Taking a microstructure approach, our paper explores the heterogeneity in the transmission of monetary policy to the commodity futures market through a novel directional liquidity-based transmission mechanism based on the theory of trade in financial markets developed in Lagos and Zhang (2020). The theory formalizes a new mechanism: a reduction in trading volume induced by an increase in the opportunity cost of holding the nominal assets used routinely to settle financial transactions depresses real asset prices. Specifically, we argue that monetary policy affects the price of commodities through changes in the growth rate of money supply, which in turn disrupts the commodity market asset allocation. Thus, our paper provides a novel insight into how monetary policy operates in the commodity market and highlights the way in which monetary policy is linked to financial and commodity price stability.

We assess this channel by estimating the effects of monetary policy announcements on the trading volume of a sample of 19 individual commodity futures contracts using event-study analysis. Employing a HFIV estimator, we document that policy target surprises affect the trading volume of our sample of commodity futures. Moreover, exploiting the cross-sectional variation in the trading volume of our sample of commodity futures, we find that the magnitude of the negative (positive) effect of target surprise associated with tightening (expansionary) FOMC policy announcement days, on the returns of commodity futures, is larger for commodity futures with higher trading volume. These results hold to several robustness checks.

We make three contributions to the related literature on monetary policy and the commodity market. First, to our knowledge, we are the first to provide evidence of a directional liquidity-based transmission mechanism of monetary policy to the commodity futures market. Through our empirical exercises, we show that financial liquidity plays a crucial role in how commodity prices are affected by monetary policy. Second, the empirical framework of Lagos and Zhang (2020) on the transmission of monetary policy to the stock market and the related literature on commodity market is silent on the asymmetric response to policy announcements. In the spirit of Bernanke and Kuttner (2005), our paper distinguishes between the type of FOMC policy action (restrictive versus expansive) by employing two interactive dummy variables, based on actual changes in the federal funds target rate.

Our paper is relevant to the current global economic conditions as the Federal Reserve begins the fastest tightening of monetary policy since 1980s to address high levels of inflation led by the recent geopolitical shocks. With respect to policy implications, our findings emphasize the need for policymakers and market participants to consider the policy stance asymmetry in the liquidity-based transmission of monetary policy to the commodity futures market. Further, our findings suggest that policymakers should consider monitoring liquidity creation in the financial system (i.e., credit availability and flow of capital) to control price stability in the commodity market going forward. Moreover, it is nonetheless important for authorities to consider the pronounced effect of monetary policy on certain commodity markets. For instance, monetary policy can be implemented indirectly by policymakers through interventions in certain financial markets.[28] One way to support the effective implementation of monetary policy, revealed by this paper, is to promote the direct liquidity of commodity futures (i.e., by taking measures to reduce transaction costs that agents must incur).

Alternatively, given that market liquidity emerges from an intricate process involving different market participants, and the ability of traders to provide market liquidity relies on their availability of funding, policymakers should carefully consider monitoring funding liquidity risk in commodity futures market, and making use of liquidity and credit facilities to improve funding

[28]In the US, the Fed intervened in the federal funds market and the market for treasury securities.

liquidity for commodity futures market players (O'Hara and Zhou, 2021).[29] An improvement in the liquidity of commodity futures markets subsequently assists the implementation and transmission of monetary policy to the economy.

[29]Following Drehmann and Nikolaou (2013), we define funding liquidity as the ability to settle obligations with immediacy. For a discussion on link between market liquidity, funding liquidity and funding liquidity risk, we refer the reader to the work of Brunnermeier and Pedersen (2008) and Drehmann and Nikolaou (2013), respectively. During the COVID-19 crisis, the Fed responded to strained liquidity conditions in the corporate bond markets by providing term funding to primary dealers through the Primary Dealer Credit Facility (PDCF) and the Secondary Market Corporate Credit Facility (SMCCF) (O'Hara and Zhou, 2021).

**Table 2.1: Descriptive statistics for the proxies for the policy rate employed in the analysis**

| | $\Delta i_t$ (announcement days) | $\Delta i_t$ (all trading days) |
|---|---|---|
| **Mean** | 1.63 | -0.18 |
| **Median** | 0.00 | 0.00 |
| **Maximum** | 14.00 | 49.00 |
| **Minimum** | 44.00 | -51.00 |
| **St. Dev** | 9.04 | 4.98 |
| **Obs** | 70 | 2436 |

*Notes:* Descriptive statistics are reported for the proxies for the unexpected component of the change in the true policy rate, i.e., the effective federal funds rate. The first column shows the daily change in the 3-month Eurodollar futures rate on the day of the FOMC announcement. The second column reports the daily change in the 3-month Eurodollar futures rate on all trading days during the sample period November 2000 to December 2008. The descriptive statistics for the proxies for the policy rate are expressed in basis points.

**Table 2.2: Descriptive statistics for the returns of individual commodity futures**

| | Mean | Median | Obs | Mean | Median | Obs |
|---|---|---|---|---|---|---|
| | (announcement days) | | | (all trading days) | | |
| **CBoT Corn** | 36.35 | 23.22 | 82 | 3.28 | 0.00 | 2044 |
| **CBoT Hard Red Winter Wheat** | 9.66 | 3.86 | 82 | 3.51 | 0.00 | 2037 |
| **CBoT Wheat Composite** | 26.97 | 22.99 | 82 | 4.26 | 0.00 | 2044 |
| **CBoT Soybean** | 26.08 | 36.52 | 82 | 3.54 | 12.60 | 2044 |
| **CME Cattle(Feeder)** | -4.08 | 6.44 | 82 | 0.30 | 2.81 | 2042 |
| **CME Lean Hogs** | -12.27 | -30.57 | 82 | 0.54 | 3.65 | 2043 |
| **CME Live Cattle** | 3.38 | 4.3 | 82 | 0.76 | 0.00 | 2045 |
| **COMEX Copper** | 18.52 | 5.58 | 82 | 2.58 | 4.22 | 2033 |
| **COMEX Gold** | 3.96 | 4.2 | 82 | 5.94 | 7.15 | 2029 |
| **COMEX Silver** | -1.4 | 4.82 | 82 | 4.35 | 16.23 | 2023 |
| **ICE Europe Brent Crude** | -19.58 | -34.35 | 82 | 1.61 | 10.69 | 2069 |
| **ICE Europe Low Sulphur Gasoil** | -12.98 | 0.00 | 82 | 1.58 | 0.00 | 2069 |
| **ICE-US Cocoa** | 4.2 | 0.00 | 82 | 6.65 | 6.32 | 2023 |
| **ICE-US Coffee** | 28.02 | 14.44 | 82 | 2.23 | 0.00 | 2024 |
| **ICE-US Cotton** | -24.13 | -8.47 | 82 | -1.38 | -1.41 | 2029 |
| **Heating Oil** | -7.54 | -13.3 | 82 | 1.42 | 0.00 | 2031 |
| **NYMEX Henry Hub Natural Gas** | 45.74 | 38.02 | 82 | -0.33 | -1.62 | 2031 |
| **WTI** | -2.6 | -30.44 | 82 | 1.21 | 10.65 | 2030 |
| **NYMEX RBOB Gasoline** | 32.63 | 46.74 | 34 | -7.70 | 12.12 | 815 |

*Notes:* Descriptive statistics for daily the returns of individual commodity futures are presented in basis points. Daily returns are measured in log changes. The first three columns are associated with FOMC announcement days, while the last three columns are associated with all trading days during the sample period November 2000 to December 2008.

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**Table 2.3: Correlation matrix for our main variables of interest**

| | $\Delta i_t$ | $R_{s,t}$ |
|---|---|---|
| $R_{s,t}$ | **-0.10*** ** | |
| | (-3.47) | |
| $T_{s,t-1}$ | 0.01 | 0.03 |
| | (0.25) | (0.94) |

*Notes:* The average daily trading volume of individual commodity futures $S$ is measured in a 1-day window prior to the day of the policy announcement. t-statistics are reported in parenthesis. ***, **, * indicate significance at 1 percent, 5 percent and 10 percent respectively. Number of observations: 1215.

**Table 2.4: Historical change (basis points) in FOMC's target federal funds rate**

| Date | Increase | Decrease |
|---|---|---|
| 03 January 2001 | | 50 |
| 31 January 2001 | | 50 |
| 20 March 2001 | | 50 |
| 18 April 2001 | | 50 |
| 15 May 2001 | | 50 |
| 27 June 2001 | | 25 |
| 21 August 2001 | | 25 |
| 02 October 2001 | | 25 |
| 06 November 2001 | | 25 |
| 11 December 2001 | | 25 |
| 06 November 2002 | | 50 |
| 25 June 2003 | | 25 |
| 30 June 2004 | 25 | |
| 10 August 2004 | 25 | |
| 21 September 2004 | 25 | |
| 10 November 2004 | 25 | |
| 14 December 2004 | 25 | |
| 02 February 2005 | 25 | |
| 22 March 2005 | 25 | |
| 03 May 2005 | 25 | |
| 30 June 2005 | 25 | |
| 09 August 2005 | 25 | |
| 20 September 2005 | 25 | |
| 01 November 2005 | 25 | |
| 13 December 2005 | 25 | |
| 31 January 2006 | 25 | |
| 28 March 2006 | 25 | |
| 10 May 2006 | 25 | |
| 29 June 2006 | 25 | |
| 18 September 2007 | | 50 |
| 31 October 2007 | | 25 |
| 11 December 2007 | | 25 |
| 30 January 2008 | | 50 |
| 18 March 2008 | | 75 |
| 30 April 2008 | | 25 |
| 07 October 2008 | | 50 |
| 29 October 2008 | | 50 |
| 16 December 2008 | | 75-100 |

*Notes:* This data is published by the Board of Governors of the Federal Reserve System, Open Market Operations Archive. Sample period: November 2000 to December 2008.

**Table 2.5: Descriptive statistics for the trading volume of individual commodity futures**

| | Mean | Median | Max | Min | Std. Dev. | Skew | Kurt | Obs |
|---|---|---|---|---|---|---|---|---|
| **CBoT Corn** | 0.83 | 0.45 | 9.59 | 0.00 | 1.05 | 2.66 | 12.79 | 2046 |
| **CBoT Hard Red Winter Wheat** | 0.13 | 0.10 | 1.22 | 0.00 | 0.13 | 1.92 | 8.46 | 2039 |
| **CBoT Wheat Composite** | 0.49 | 0.27 | 7.34 | 0.00 | 0.67 | 3.02 | 16.85 | 2046 |
| **CBoT Soybean** | 1.27 | 0.77 | 18.40 | 0.00 | 1.62 | 3.12 | 18.68 | 2046 |
| **CME Cattle(Feeder)** | 0.06 | 0.04 | 0.36 | 0.00 | 0.04 | 1.57 | 6.62 | 2044 |
| **CME Lean Hogs** | 0.15 | 0.11 | 0.95 | 0.00 | 0.12 | 1.81 | 7.12 | 2045 |
| **CME Live Cattle** | 0.21 | 0.14 | 1.59 | 0.00 | 0.24 | 2.11 | 7.99 | 2047 |
| **COMEX Copper** | 0.03 | 0.02 | 0.56 | 0.00 | 0.05 | 5.57 | 44.99 | 2035 |
| **COMEX Gold** | 0.06 | 0.00 | 8.47 | 0.00 | 0.39 | 13.13 | 210.54 | 2031 |
| **COMEX Silver** | 0.02 | 0.00 | 2.25 | 0.00 | 0.12 | 11.11 | 148.38 | 2025 |
| **ICE Europe Brent Crude** | 3.47 | 1.74 | 19.90 | 0.13 | 3.61 | 1.67 | 5.43 | 2071 |
| **ICE Europe Low Sulphur Gasoil** | 1.06 | 0.57 | 6.61 | 0.00 | 1.06 | 1.66 | 5.76 | 2071 |
| **ICE-US Cocoa** | 0.07 | 0.05 | 0.53 | 0.00 | 0.08 | 1.77 | 7.37 | 2025 |
| **ICE-US Coffee** | 0.22 | 0.12 | 1.81 | 0.00 | 0.26 | 1.48 | 5.51 | 2026 |
| **ICE-US Cotton** | 0.16 | 0.10 | 1.43 | 0.00 | 0.20 | 1.98 | 8.49 | 2031 |
| **Heating Oil** | 1.58 | 1.19 | 9.08 | 0.00 | 1.30 | 1.81 | 6.93 | 2033 |
| **NYMEX Henry Hub Natural Gas** | 2.82 | 2.19 | 19.10 | 0.00 | 2.12 | 2.47 | 11.47 | 2033 |
| **WTI** | 8.36 | 4.15 | 70.50 | 0.00 | 9.87 | 2.11 | 7.51 | 2032 |
| **NYMEX RBOB Gasoline** | 1.69 | 1.07 | 11.50 | 0.00 | 1.82 | 0.97 | 3.38 | 816 |
| **19 commodity futures** | 1.19 | 0.69 | | | | | | |

*Notes:* Descriptive statistics for the daily trading volume of individual commodity futures associated with all trading days are presented in basis points. Daily trading volume is computed by multiplying the number of contracts traded by the contract size and then multiplying this by the settlement price. Sample period: November 2000 to December 2008.

**Table 2.6: Policy announcement-day response of individual commodity futures trading volume**

| | HFIV-BASED | |
|---|---|---|
| **CBoT Corn** | **-0.51**** | (-2.38) |
| **CBoT Hard Red Winter Wheat** | **-0.42**** | (-2.24) |
| **CBoT Wheat Composite** | **-0.81***** | (-3.83) |
| **CBoT Soybean** | **-0.65***** | (-3.39) |
| **CME Cattle(Feeder)** | **-0.39**** | (-2.05) |
| **CME Lean Hogs** | **-0.43**** | (-2.06) |
| **CME Live Cattle** | **-0.46**** | (-2.23) |
| **COMEX Copper** | **-0.37**** | (-2.06) |
| **COMEX Gold** | -0.21 | (-0.95) |
| **COMEX Silver** | -0.01 | (-0.04) |
| **ICE Europe Brent Crude** | **-0.5**** | (-2.13) |
| **ICE Europe Low Sulphur Gasoil** | **-0.47**** | (-2.09) |
| **ICE-US Cocoa** | **-0.57***** | (-3.42) |
| **ICE-US Coffee** | **-0.38*** | (-1.76) |
| **ICE-US Cotton** | **-0.45**** | (-2.23) |
| **Heating Oil** | **-0.48**** | (-2.08) |
| **NYMEX Henry Hub Natural Gas** | **-0.48**** | (-2.01) |
| **WTI** | **-0.51**** | (-2.07) |
| **NYMEX RBOB Gasoline** | -0.16 | (-0.29) |

*Notes:* t-statistics are reported in parenthesis. ***, **, * indicate significance at 1 percent, 5 percent and 10 percent, respectively.

**Table 2.7: Tightening policy announcement-day effects on the returns of individual commodity futures: a 1-day window trading volume and Eurodollar futures rate proxy estimation**

| | **(I)** | **(II)** | **(III)** | **(IV)** | **(V)** |
|---|---|---|---|---|---|
| $\Delta i_t$ | -2.64 | -2.64 | -3.11 | -2.76 | -3.28 |
| | (-1.28) | (-1.29) | (-1.26) | (-1.23) | (-1.19) |
| $T_{s,t}$ | -2206.71 | -2318.97 | -36193.96 | -3942.62 | -45456.27 |
| | (-0.44) | (-0.47) | (-0.78) | (-0.76) | (-1.03) |
| $\bar{T}_{s,t}$ * $\bar{\Delta i_t}$ | | 319.60 | 325.42 | 428.79 | 421.42 |
| | | (0.91) | (0.97) | (1.19) | (1.23) |
| $D_{TighteningAction}$ | | | | **-269.44*** ** | **-285.30*** ** |
| | | | | (-2.36) | (-2.50) |
| $\Delta i_t$ * $D_{TighteningAction}$ | | | | 1.01 | 2.02 |
| | | | | (0.35) | (0.48) |
| $T_{s,t}$ * $D_{TighteningAction}$ | | | | **15655.22*** ** | **16376.78*** ** |
| | | | | (2.36) | (2.48) |
| $\bar{T}_{s,t}$ * $\bar{\Delta i_t}$ * $D_{TighteningAction}$ | | | | **-3123.00*** | **-3093.67*** |
| | | | | (-1.74) | (-1.71) |
| $(\Delta i_t)^2$ | | | -0.06 | | -0.06 |
| | | | (-0.60) | | (-0.55) |
| $(T_{s,t})^2$ | | | 1012384.06 | | 1235343.01 |
| | | | (0.69) | | (0.88) |
| $D_S$ | yes | yes | yes | yes | yes |
| *Obs* | 1430.00 | 1430.00 | 1430.00 | 1429.00 | 1429.00 |
| $R^2$ | 0.02 | 0.02 | 0.02 | 0.03 | 0.03 |

*Notes:* Both the interest rate and the daily returns of commodity futures are expressed in basis points. Trading volume is measured at daily frequency and is expressed in thousands. Each column reports the coefficients from a separate pooled OLS regression. White cross-section t-statistics have been used to account for heteroscedasticity in the residuals. t-statistics are reported in parenthesis. ***, **, * indicate significance at 1 percent, 5 percent and 10 percent, respectively. Sample period: November 2000 to December 2008.

**Table 2.8: Expansionary policy announcement-day effects on the returns of individual commodity futures: a 1-day window trading volume and Eurodollar futures rate proxy estimation**

| | **(I)** | **(II)** | **(III)** | **(IV)** | **(V)** |
|---|---|---|---|---|---|
| $\Delta i_t$ | -2.64 | -2.64 | -3.11 | **-7.13**** | **-6.92**** |
| | (-1.28) | (-1.29) | (-1.26) | (-2.10) | (-1.99) |
| $T_{s,t}$ | -2206.71 | -2318.97 | -36193.96 | -3637.82 | -30494.60 |
| | (-0.44) | (-0.47) | (-0.78) | (-0.70) | (-0.67) |
| $\bar{T}_{s,t} * \bar{\Delta i}_t$ | | 319.60 | 325.42 | -309.25 | -320.32 |
| | | (0.91) | (0.97) | (-0.53) | (-0.58) |
| $D_{EasingAction}$ | | | | -92.98 | -85.67 |
| | | | | (-0.88) | (-0.80) |
| $\Delta i_t * D_{EasingAction}$ | | | | **7.44**** | 6.90 |
| | | | | (2.00) | (1.46) |
| $T_{s,t} * D_{EasingAction}$ | | | | 7585.36 | 7307.28 |
| | | | | (0.64) | (0.69) |
| $\bar{T}_{s,t} * \bar{\Delta i}_t * D_{EasingAction}$ | | | | **1152.75*** | **1148.17*** |
| | | | | (1.70) | (1.79) |
| $(\Delta i_t)^2$ | | | -0.06 | | -0.02 |
| | | | (-0.60) | | (-0.25) |
| $(T_{s,t})^2$ | | | 1012384.06 | | 805266.68 |
| *Obs* | 1430.00 | 1430.00 | 1430.00 | 1430.00 | 1430.00 |
| $D_S$ | yes | yes | yes | yes | yes |
| $R^2$ | 0.02 | 0.02 | 0.02 | 0.04 | 0.05 |

*Notes:* Both the interest rate and the daily returns of commodity futures are expressed in basis points. Trading volume is measured at daily frequency and is expressed in thousands. Each column reports the coefficients from a separate pooled OLS regression. White cross-section t-statistics have been used to account for heteroscedasticity in the residuals. t-statistics are reported in parenthesis. ***, **, * indicate significance at 1 percent, 5 percent and 10 percent, respectively. Sample period: November 2000 to December 2008.

**Table 2.9: Tightening policy announcement-day effects on the returns of individual commodity futures: a 1-day window trading volume and FFFR proxy estimation**

| | (I) | (II) | (III) | (IV) | (V) |
|---|---|---|---|---|---|
| $\Delta FF_t$ | -0.68 | -0.60 | -2.11 | -0.59 | -2.11 |
| | (-0.67) | (-0.58) | (-0.62) | (-0.56) | (-0.61)) |
| $T_{s,t}$ | -267.73 | -609.65 | -60150.15 | -2274.74 | **-69098.09*** |
| | (-0.06) | (-0.14) | (-1.45) | (-0.46) | (-1.66) |
| $\bar{T}_{s,t} * \overline{\Delta FF_t}$ | | 427.94 | 449.69 | 462.38 | 485.15 |
| | | (1.14) | (1.24) | (1.25) | (1.37) |
| $D_{TighteningAction}$ | | | | **-564.78*** | **-599.65*** |
| | | | | (-3.29) | (-3.37) |
| $\Delta FF_t * D_{TighteningAction}$ | | | | 1.47 | 2.84 |
| | | | | (0.14) | (0.25) |
| $T_{s,t} * D_{TighteningAction}$ | | | | **30417.57*** | **32184.76*** |
| | | | | (3.16) | (3.24) |
| $\bar{T}_{s,t} * \overline{\Delta FF_t} * D_{TighteningAction}$ | | | | **-15518.17*** | **-16027.40*** |
| | | | | (-3.71) | (-3.74) |
| $(\Delta FF_t)^2$ | | | -0.05 | | -0.05 |
| | | | (-0.58) | | (-0.56) |
| $(T_{s,t})^2$ | | | 1775912.08 | | 1988167.23 |
| | | | (1.39) | | (1.56) |
| $D_S$ | yes | yes | yes | yes | yes |
| *Obs* | 1215.00 | 1215.00 | 1215.00 | 1215.00 | 1215.00 |
| $R^2$ | 0.02 | 0.02 | 0.02 | 0.03 | 0.04 |

*Notes:* Both the interest rate and the daily returns of commodity futures are expressed in basis points. Trading volume is measured at daily frequency and is expressed in thousands. Each column reports the coefficients from a separate pooled OLS regression. White cross-section t-statistics have been used to account for heteroscedasticity in the residuals. t-statistics are reported in parenthesis. ***, **, * indicate significance at 1 percent, 5 percent and 10 percent, respectively. Sample period: November 2000 to December 2008.

**Table 2.10: Expansionary policy announcement-day effects on the returns of individual commodity futures: a 1-day window trading volume and FFFR proxy estimation**

| | (I) | (II) | (III) | (IV) | (V) |
|---|---|---|---|---|---|
| $\Delta FF_t$ | -0.68 | -0.60 | -2.11 | -9.45 | -9.33 |
| | (-0.67) | (-0.58) | (-0.62) | (-1.08) | (-1.05) |
| $T_{s,t}$ | -267.73 | -609.65 | -60150.15 | -1469.44 | -59655.82 |
| | (-0.06) | (-0.14) | (-1.45) | (-0.27) | (-1.59) |
| $\bar{T}_{s,t} * \overline{\Delta FF_t}$ | | 427.94 | 449.69 | -181.50 | -262.14 |
| | | (1.14) | (1.24) | (-0.16) | (-0.24) |
| $D_{EasingAction}$ | | | | -61.34 | -46.59 |
| | | | | (-0.47) | (-0.36) |
| $\Delta FF_t * D_{EasingAction}$ | | | | 10.25 | 9.25 |
| | | | | (1.17) | (0.99) |
| $T_{s,t} * D_{EasingAction}$ | | | | 5312.60 | 4613.20 |
| | | | | (0.65) | (0.58) |
| $\bar{T}_{s,t} * \overline{\Delta FF_t} * D_{EasingAction}$ | | | | 851.80 | 950.78 |
| | | | | (0.70) | (0.81) |
| $(\Delta FF_t)^2$ | | | -0.05 | | -0.03 |
| | | | (-0.58) | | (-0.33) |
| $(T_{s,t})^2$ | | | 1775912.08 | | 1752421.41 |
| | | | (1.39) | | (1.50) |
| $D_S$ | yes | yes | yes | yes | yes |
| *Obs* | 1502 | 1502 | 1502 | 1501 | 1501 |
| $R^2$ | 0.02 | 0.02 | 0.02 | 0.04 | 0.04 |

*Notes:* Both the interest rate and the daily returns of commodity futures are expressed in basis points. Trading volume is measured at daily frequency and is expressed in thousands. Each column reports the coefficients from a separate pooled OLS regression. White cross-section t-statistics have been used to account for heteroscedasticity in the residuals. t-statistics are reported in parenthesis. ***, **, * indicate significance at 1 percent, 5 percent and 10 percent, respectively. Sample period: November 2000 to December 2008.

**Table 2.11: Tightening policy announcement-day effects on the returns of individual commodity futures: a 1-week window trading volume and Eurodollar futures rate proxy estimation**

| | (I) | (II) | (III) | (IV) | (V) |
|---|---|---|---|---|---|
| $\Delta i_t$ | -2.76 | -2.76 | -3.06 | **-7.13**** | **-7.04**** |
| | (-1.37) | (-1.36) | (-1.25) | (-2.19) | (-2.09) |
| $T_{s,t}$ | 120.99 | 94.26 | -9350.18 | -1483.10 | -7964.12 |
| | (0.02) | (0.015) | (-0.57) | (-0.24) | (-0.49) |
| $\bar{T}_{s,t} * \bar{\Delta i_t}$ | | 98.96 | 101.92 | -456.70 | **-460.23*** |
| | | (0.39) | (0.43) | (-1.66) | (-1.70) |
| $D_{TighteningAction}$ | | | | -29.05 | -27.54 |
| | | | | (-0.87) | (-0.81) |
| $\Delta i_t * D_{TighteningAction}$ | | | | **7.23**** | 7.03 |
| | | | | (2.00) | (1.55) |
| $T_{s,t} * D_{TighteningAction}$ | | | | 5836.42 | 5785.72 |
| | | | | (1.41) | (1.39) |
| $\bar{T}_{s,t} * \bar{\Delta i_t} * D_{TighteningAction}$ | | | | **-965.71***** | **-959.18***** |
| | | | | (2.69) | (2.71) |
| $(\Delta i_t)^2$ | | | -0.05 | | -0.01 |
| | | | (-0.47) | | (-0.09) |
| $(T_{s,t})^2$ | | | 402284.60 | | 276548.90 |
| | | | (0.46) | | (0.32) |
| $D_S$ | yes | yes | yes | yes | yes |
| *Obs* | 1502 | 1502 | 1502 | 1501 | 1501 |
| $R^2$ | 0.02 | 0.02 | 0.02 | 0.04 | 0.04 |

*Notes:* Both the interest rate and the daily returns of commodity futures are expressed in basis points. Trading volume is measured at daily frequency and is expressed in thousands. Each column reports the coefficients from a separate pooled OLS regression. White cross-section t-statistics have been used to account for heteroscedasticity in the residuals. t-statistics are reported in parenthesis. ***, **, * indicate significance at 1 percent, 5 percent and 10 percent, respectively. Sample period: November 2000 to December 2008.

**Table 2.12: Expansionary policy announcement-day effects on the returns of individual commodity futures: a 1-week window trading volume and Eurodollar futures rate proxy estimation**

| | **(I)** | **(II)** | **(III)** | **(IV)** | **(V)** |
|---|---|---|---|---|---|
| $\Delta i_t$ | -2.76 | -2.76 | -3.1 | **-7.06**** | **-6.92**** |
| | (-1.37) | (-1.36) | (-1.27) | (-2.17) | (-2.08) |
| $T_{s,t}$ | 120.99 | 93.45 | -29449 | -2972.33 | -17827.2 |
| | (0.02) | (0.01) | (-0.57) | (-0.47) | (-0.35) |
| $\bar{T}_{s,t}$ * $\bar{\Delta i_t}$ | | 65.09 | 75.84 | -706.07 | -710.37 |
| | | (0.14) | (0.18) | (-1.43) | (-1.47) |
| $D_{EasingAction}$ | | | | **-218.75*** | -214.96 |
| | | | | (-1.96) | (-1.90) |
| $\Delta i_t$ * $D_{EasingAction}$ | | | | **7.04*** | 6.72 |
| | | | | (1.96) | (1.5) |
| $T_{s,t}$ * $D_{EasingAction}$ | | | | **14245.11**** | **14111.34*** |
| | | | | (1.99)* | (1.93) |
| $\bar{T}_{s,t}$ * $\bar{\Delta i_t}$ * $D_{EasingAction}$ | | | | **1520.72**** | **1512.89**** |
| | | | | (2.41) | (2.45) |
| $(\Delta i_t)^2$ | | | -0.05 | | -0.01 |
| | | | (-0.48) | | (-0.16) |
| $(T_{s,t})^2$ | | | 867315.6 | | 437910.9 |
| | | | (0.53) | | (0.27) |
| $D_S$ | yes | yes | yes | yes | yes |
| *Obs* | 1502 | 1502 | 1502 | 1502 | 1502 |
| $R^2$ | 0.02 | 0.02 | 0.02 | 0.05 | 0.05 |

*Notes:* Both the interest rate and the daily returns of commodity futures are expressed in basis points. Trading volume is measured at daily frequency and is expressed in thousands. Each column reports the coefficients from a separate pooled OLS regression. White cross-section t-statistics have been used to account for heteroscedasticity in the residuals. t-statistics are reported in parenthesis. ***, **, * indicate significance at 1 percent, 5 percent and 10 percent, respectively. Sample period: November 2000 to December 2008.

**Table 2.13: Tightening policy announcement-day effects on the returns of individual commodity futures: a 1-week window trading volume and FFFR proxy estimation**

| | **(I)** | **(II)** | **(III)** | **(IV)** | **(V)** |
|---|---|---|---|---|---|
| $\Delta FF_t$ | -0.73 | -0.68 | -2.39 | -0.67 | -2.411 |
| | (-0.71) | (-0.61) | (-0.69) | (-0.58) | (-0.69) |
| $T_{s,t}$ | 2278.78 | 2236.33 | -51760.25 | 1326.56 | -53866.84 |
| | -0.37 | -0.37 | (-1.19) | (0.20) | (-1.25) |
| $\bar{T}_{s,t}$ * $\overline{\Delta FF_t}$ | | 168.12 | 163.88 | 187.36 | 181.57 |
| | | (0.49) | (0.52) | (0.54) | (0.57) |
| $D_{TighteningAction}$ | | | | **-496.04*** ** | **-505.07*** ** |
| | | | | (-2.97) | (-2.96) |
| $\Delta FF_t$ * $D_{TighteningAction}$ | | | | -2.71 | -1.18 |
| | | | | (-0.20) | (-0.09) |
| $T_{s,t}$ * $D_{TighteningAction}$ | | | | **26647.37*** ** | **27040.08*** ** |
| | | | | (2.81) | (2.80) |
| $\bar{T}_{s,t}$ * $\overline{\Delta FF_t}$ * $D_{TighteningAction}$ | | | | **-12571.40*** ** | **-12615.39*** ** |
| | | | | (-3.52) | (-3.49) |
| $(\Delta FF_t)^2$ | | | -0.06 | | -0.06 |
| | | | (-0.69) | | (-0.69) |
| $(T_{s,t})^2$ | | | 1578005.08 | | 1612044.63 |
| | | | (1.15) | | (1.19) |
| $D_S$ | yes | yes | yes | yes | yes |
| *Obs* | 1502.00 | 1502.00 | 1502.00 | 1502.00 | 1502.00 |
| $R^2$ | 0.02 | 0.02 | 0.02 | 0.04 | 0.05 |

*Notes:* Both the interest rate and the daily returns of commodity futures are expressed in basis points. Trading volume is measured at daily frequency and is expressed in thousands. Each column reports the coefficients from a separate pooled OLS regression. White cross-section t-statistics have been used to account for heteroscedasticity in the residuals. t-statistics are reported in parenthesis. ***, **, * indicate significance at 1 percent, 5 percent and 10 percent, respectively. Sample period: November 2000 to December 2008.

**Table 2.14: Expansionary policy announcement-day effects on the returns of individual commodity futures: a 1-week window trading volume and FFFR proxy estimation**

| | (I) | (II) | (III) | (IV) | (V) |
|---|---|---|---|---|---|
| $\Delta FF_t$ | -0.73 | -0.68 | -2.39 | -9.49 | -9.37 |
| | (-0.71) | (-0.61) | (-0.69) | (-1.08) | (-1.06) |
| $T_{s,t}$ | 2278.78 | 2236.33 | -51760.25 | 1265.03 | -45553.51 |
| | (0.37) | (0.37) | (-1.19) | (0.20) | (-1.20) |
| $\bar{T}_{s,t}$ * $\overline{\Delta FF_t}$ | | 168.12 | 163.88 | -1230.15 | -1219.32 |
| | | (0.49) | (0.52) | (-1.19) | (-1.18)) |
| $D_{EasingAction}$ | | | | -161.42 | -148.75 |
| | | | | (-1.14) | (-1.06) |
| $\Delta FF_t$ * $D_{EasingAction}$ | | | | 10.25 | 8.97 |
| | | | | (1.16) | (0.97) |
| $T_{s,t}$ * $D_{EasingAction}$ | | | | 10750.71 | 10206.00 |
| | | | | (1.20) | (1.16) |
| $\bar{T}_{s,t}$ * $\overline{\Delta FF_t}$ * $D_{EasingAction}$ | | | | **1890.87*** | **1850.98*** |
| | | | | (1.70) | (1.68) |
| $(\Delta FF_t)^2$ | | | -0.06 | | -0.04 |
| | | | (-0.69) | | (-0.51) |
| $(T_{s,t})^2$ | | | 1578005.08 | | 1376903.46 |
| | | | (1.15) | | (1.17) |
| $D_S$ | yes | yes | yes | yes | yes |
| *Obs* | 1282.00 | 1282.00 | 1282.00 | 1282.00 | 1282.00 |
| $R^2$ | 0.02 | 0.02 | 0.02 | 0.04 | 0.04 |

*Notes:* Both the interest rate and the daily returns of commodity futures are expressed in basis points. Trading volume is measured at daily frequency and is expressed in thousands. Each column reports the coefficients from a separate pooled OLS regression. White cross-section t-statistics have been used to account for heteroscedasticity in the residuals. t-statistics are reported in parenthesis. ***, **, * indicate significance at 1 percent, 5 percent and 10 percent, respectively. Sample period: November 2000 to December 2008.

## Appendix 2A.

**Table 2.1A: Description of the monetary policy proxies included in the analysis**

| Variables | Source | Frequency |
|---|---|---|
| 3-months Eurodollar futures rate | DataStream | Daily |
| tick-by-tick nominal interest rate implied by 30-day federal funds futures | Lagos and Zhang (2020) | Intraday |

**Table 2.2A: Description of commodity futures included in the analysis**

| **Panel A: Agricultural commodities** | |
|---|---|
| Wheat | CBoT |
| Red wheat | CBoT |
| Corn | CBoT |
| Soybean | CBoT |
| Cotton | ICE-US |
| Sugar | ICE-US |
| Coffee | ICE-US |
| Cocoa | ICE-US |
| **Panel B: Energy commodities** | |
| Brent | ICE Europe |
| Gasoil | ICE Europe |
| WTI | NYMEX |
| Gasoline | NYMEX |
| Heating oil | NYMEX |
| Natural Gas | NYMEX |
| **Panel C: Livestock commodities** | |
| Live cattle | CME |
| Feeder cattle | CME |
| Lean hogs | CME |
| **Panel D: Industrial Metal commodities** | |
| Copper | COMEX |
| **Panel E: Precious Metal commodities** | |
| Gold | COMEX |
| Silver | COMEX |

# Chapter 3

# Unconventional Monetary Policy and the Brent Futures Market: a Bank-Lending Channel

## 3.1 Introduction

This paper provides evidence on the nature of the unconventional monetary policy (UMP) transmission mechanism to the Brent crude oil market. In particular, we uncover how US UMP operations influence international bank claims on emerging market economies (EMEs), that in turn affect trading activity in the Brent futures market. In the wake of the Global Financial Crisis of 2007-2008 (GFC), policy rates reached the zero lower bound (ZLB) and the Federal Reserve, among other central banks, turned to UMP operations such as large-scale asset purchases (LSAPs) of mortgage-backed securities and debt issued by Fannie Mae, Freddie Mac, and Ginnie Mae, in addition to the purchase of longer-term Treasury securities, and forward guidance, with the goal of containing immediate risks and stabilizing the global economy. Yet, these operations were a source of adverse spillovers to other economies. In particular, several EMEs view US LSAPs to be responsible for excessive flows of capital to their economies, which contributed to raising asset prices and exchange rate appreciation pressures (Ahmed and Zlate, 2014; Chen et al, 2016).[1] Considering the economic significance of global banks' US dollar lending to EMEs relative to advanced economies (AEs), UMP actions in the

[1]US monetary policy spillovers led to the overheating the economies of Brazil and China in 2010 and 2011 (i.e, China's output growth and inflation exceeded 9% and 5%, respectively) (Chen et al, 2016). In this respect, Chen et al (2016) argue that US UMP measures have a greater impact on Latin America and Asia EMEs.

US play a key role as a "push factor" for credit cycles in EMEs (Bräuning and Ivashina, 2020).

Spillovers of UMP on financial markets can occur through several transmission channels. For example, UMP may convey information about the future path of the policy rate. The expectation by market participants the Federal Reserve is committing to a period of low policy rates, reduces long-term interest rates by lowering the expectations component of bond yields *(policy signalling channel).* Further, the purchase of Treasury securities shrinks the overall supply of assets accessible to financial market participants, lowering their yields, and encourages investors to rebalance their portfolios and move towards substitute securities, increasing their price *(portfolio rebalance channel).* UMP can also lower liquidity premium on assets purchased or eligible for purchase *(liquidity premium effects).* It is worthy to note that the theoretical conditions that underpin the transmission mechanisms of UMP described above depend on the state of the economy and the financial markets.[2]

Driven by the growing financial markets interconnectedness and deepening of cross-market integration, spillovers of monetary policy may occur through international bank linkages. The bank lending channel is expected to be particularly relevant for UMP as stimulating bank lending supply is often explicitly mentioned as the main objective of central banks (Albertazzi, Nobili, and Signoretti, 2021). In contrast to the traditional bank lending channel, the international bank lending channel of UMP operates through the flattening of the yield curve and an increase in broad money supply (Grab and Zochowski, 2017). Specifically, UMP expands the balance sheet of the central bank, lowering the interest rates across all maturities and increasing broad money supply. In this context, banks increase lending and in particular, cross-border lending. In turn, foreign banks respond by increasing their loan supply.

One of the recipients of bank credit is the non-financial corporations (NFCs) sector, which obtains credit to finance its working capital and to support its operations. In addition to NFCs (i.e., producers and consumers of commodities) having linkages with financial institutions through their financing activities, they are also connected to other industries through trade credit, supply and production chains (Dungey et al al, 2022). This makes NFCs vulnerable to systematic risk, which is managed through the use of foreign currency, interest rate and commodity derivatives. As recent sharp commodity price fluctuations led by global macroeconomic shocks affect earnings, the availability of credit, production costs and product pricing, commodity price risk becomes central to financial risk management. Large NFCs effectively use commodity futures to hedge against commodity price risk, as well as for speculative purposes often

[2]We present the primary transmission channels of UMP in Figure 3.1A in the Appendix.

disguised as hedging (Bartram, 2019).[3]

The crude oil market is of particular interest as the users of commodity derivatives, commodity producers and consumers, are concentrated in the oil industry (Bartram, 2019). Further, the post-GFC debt expansion of the oil industry far outpaced other commodity sectors (see Domanski et al., 2015 for further discussion), which indicates an excessive build-up of leverage. In the event of market stress, commodity price swings amplified by excessive leverage, can lead to large margin calls and increase the risk of default for NFCs in the oil sector. Hence, NFCs in the oil sector have a higher underlying commodity price risk exposure compared to NFCs in other industries. As UMP shifts credit supply through international bank lending, driving economic uncertainty and market liquidity, UMP also determines how NFCs in the oil industry engage in risk hedging through Brent crude oil futures. Notably, understanding the transmission channel of UMP operations to NFCs in the oil sector, and subsequently onto the Brent crude oil market, is particularly relevant for the current global economic conditions and the global economic outlook, as the price dynamics in the energy market continue to shape the world modern economy and environmental policies. In addition, energy commodities remain the subject of exceptional volatility given the scale of energy transition and geopolitical uncertainty.

To assess the proposed international bank-lending transmission channel of monetary policy empirically, our paper employs a hybrid model combining the traditional VAR framework with a high-frequency identification (HFI) approach of monetary policy surprises. In the spirit of Bernanke and Kuttner (2005) and Gertler and Karadi (2015), we rely on monetary policy surprises, constructed using daily changes in the 10-year government bond yield bracketing monetary policy announcements during the ZLB (January 2009 – October 2021), and included as an exogenous variable in the VAR model. Further, following the identification of UMP shocks advanced by Gambacorta, Hofmann and Peersman (2014), we control for a set of macroeconomic and financial variables that respond to UMP shocks, namely, industrial production index (IPI), the consumer price index (CPI), and the implied stock market volatility index (VIX). We look at EMEs by region, and in particular at emerging Central Europe, Latin America and Asia, to account for the existing variation in hedging intensity and derivative usage as well as the variation in the effect of Federal Reserve's measures across regions.

At the micro level, we explore the financial liquidity-transmission channel based on the theory of trade of Lagos and Zhang (2020) by focusing on both the return and trading volume of Brent crude oil futures. The theory implies

[3]Commodity producers, which produce and sell physical commodities, hedge via short derivative positions, while commodity consumers hedge with long derivative positions.

that tightening policy actions (i.e., QE tapering in the context of our study) affect asset prices through a change in the real quantity of money, which in turn disrupts the asset allocation among investors. Specifically, tight money increases the opportunity cost of holding money balances, increasing their scarcity, which in turn reduces the ability of financial assets to be resold. This results in a decline in asset liquidity and price. Finally, our empirical analysis makes a clear distinction between positive and negative surprises to account for potential asymmetries in the response of Brent crude oil futures to FOMC announcements related to LSAPs.

Overall, our results establish an international bank-lending transmission channel of UMP to the Brent crude oil futures market, operative through bank lending to NFCs in emerging Asia. We provide evidence that positive policy surprises (i.e., a perceived expansionary policy) are transmitted to the trading activity of the Brent futures market via local claims on Asia EMEs. In particular, an increase in local claims on Asia EMEs, led by positive policy surprises, reduces trading activity. This decline in market participation can be attributed to the fact that by boosting credit supply and reducing economic uncertainty, QE also reduces the need for corporate hedging and therefore for the use of crude oil futures. Further, we document that negative policy surprises (i.e., a perceived contractionary policy) affect trading activity directly, bypassing the bank lending channel to EMEs. Instead, a decrease in trading activity in high risk markets such as the Brent crude oil market following negative policy surprises supports the financial-liquidity transmission channel of monetary policy. This latter channel is enhanced by the uncertainty associated with FOMC announcements perceived as tight policy actions.

This paper brings original contributions to the extant literature on UMP and the commodity market (Glick and Leduc, 2012; Rosa, 2014, Hammoudeh, Nguyen, and Sousa, 2015) by being the first to investigate the transmission of UMP to the Brent crude oil futures market via the international bank-lending channel. The scarce related literature adopting a macroeconomic empirical framework (Hammoudeh, Nguyen, and Sousa, 2015; Apergis, Chatziantoniou and Cooray, 2020) measures UMP at monthly frequency using the growth rate of central bank reserves and the short-term shadow rate, respectively. Our paper contributes to this strand of literature by adopting a more credible approach to the monetary policy shocks identification, well suited to analysing policy at the ZLB: a hybrid model which combines the traditional VAR with a high-frequency identification of monetary policy. In doing so, the empirical analysis amends endogeneity as well as simultaneity concerns. Further, related empirical studies using a macroeconomic framework are silent on the asymmetric response of commodities to policy actions. We bring important considerations to this line of literature by showing that the direction of the UMP surprise matters in the transmission of UMP to the Brent futures market.

The outline of the rest of the paper is the following. Section 3.2 reviews the related literature and introduces hypotheses development. In Section 3.3, we describe the data and provide some preliminary analysis. Section 3.4 sets out the methodology. Section 3.5 discusses the empirical results. Section 3.6 sets the further analysis. Finally, Section 3.7 concludes.

## 3.2 Literature Review and Hypotheses Development

This paper draws from three strands of literature. The first relates to the effect of UMP on commodity prices, while the second and third relate to UMP and monetary conditions, and the transmission channels of UMP to commodity prices, respectively.

### 3.2.1 Unconventional monetary policy and commodity prices

The existing literature has extensively investigated the impact of UMP on various macroeconomic and financial variables (Hamilton and Wu, 2010; Baumeister and Benati, 2010; Greenwood and Vayanos, 2010; Gagnon et al., 2010, 2011; Joyce, Tong and Woods, 2011; Krishnamurthy and Vissing-Jorgensen, 2011). Nonetheless, the response of commodity markets, and in particular, the energy market, to FOMC announcements during the LBZ period, has received much less consideration in the literature. Empirical studies within this strand of literature have primarily employed an event-study methodology to study the effects of LSAPs of Treasury securities on the commodity market (Glick and Leduc, 2012; Rosa, 2014; Chebbi; 2021). These studies have yet to reach a consensus on the direction of the effect of LSAPs on the commodity price. For instance, Glick and Leduc (2012) find that the US LSAPs announcements which generally brought about expansionary financial conditions led to a decline in the S&P GSCI commodity spot prices, even as long-term interest rates fell, and the US dollar depreciated. Glick and Leduc (2012) attribute their findings to the signalling effects of LSAPs announcements about the future economic growth, which led investors to downgrade their US growth forecasts. This in turn, lowered long-term US yields, depreciated the value of the US dollar and induced a decline in commodity prices. Hence, the *policy signalling channel:* implies that the effects of LSAPs announcements depend crucially on the state of the economy as well as the investor sentiment about risk.

By contrast, Rosa (2014) finds that an unanticipated expansionary US LSAPs announcement, constructed using a multinomial indicator (i.e., a ternary dummy), is associated with an increase in the front-month WTI futures prices in a tight window around LSAPs announcements (i.e., 10-min before the LSAP announcement to 50-min after the announcement). Using non-parametric tests, Rosa (2014) also finds that trading activity tends to be lower prior to FOMC announcements, displaying the so called "calm before-the-storm" effect, and an increase in the volatility and trading volume of WTI futures prices, up to 40-min after the announcement. This finding is supported by Chebbi (2021), who measuring the LSAPs announcements using daily changes in the long-term Treasury futures rates right around the policy announcement, show that the response of commodity prices to LSAPs depends on the sign of the monetary surprise. For instance, Chebbi (2021) finds that LSAPs shocks associated with an expansionary monetary policy stance, typically coupled with lower Treasury yields, lead to a significant rise in the price of precious metals, while negative LSAPs surprises were accompanied by a fall in the price of precious metals. Noteworthy, the magnitude of these effects is lower than the one following positive monetary surprises.

The literature adopting a macroeconomic empirical framework to study the effect of UMP on the commodity market is rather scarce (Hammoudeh, Nguyen and Sousa, 2015; Apergis, Chatziantoniou and Cooray, 2020). Empirical studies within this strand of literature provide supportive evidence of a negative relationship between UMP and commodity futures prices. For example, by means of a SVAR, Hammoudeh, Nguyen and Sousa (2015) show that a positive shock in the growth rate of central bank reserves (i.e., equivalent to an expansionary UMP shock as a by-product of quantitative easing) leads to an increase of 0.5% in the aggregate commodity price index (S&P GSCI). This effect becomes stronger after 12 months and is persistent at a 20-month horizon. In a similar fashion, Apergis, Chatziantoniou and Cooray, 2020 (2020) employ an EGARCH-X framework and find that monetary policy contractions under UMP, proxied by the short-term shadow rate, have a negative impact on the returns of energy, metal and precious metal commodities.[4]

We add to this literature by employing a hybrid model which combines the traditional VAR with a high-frequency identification (HFI) of monetary policy. In doing so, the empirical analysis amends concerns surrounding endogeneity as well as simultaneity. Further, it is able to capture the surprise components on unconventional monetary policy announcements. Besides, related empirical studies using a macroeconomic framework are silent on the asymmetric response of commodity futures prices to policy announcements related to LSAPs. We bring important considerations to this line of research by accounting for the direction of policy surprises.

[4] A key indicator of US UMP is the short-term shadow rate developed by Krippner (2015).

### 3.2.2 Unconventional monetary policy and monetary conditions

Close to our empirical approach is the extant literature on UMP and liquidity creation (Korniyenko and Loukoianova, 2015; Chen et al., 2016; Anaya, Hachula and Offermanns, 2017). Korniyenko and Loukoianova (2015) find a positive relationship between UMP in the S4 (US, UK, Euro area, and Japan), global liquidity and monetary conditions, measured by global NFCs deposit growth, banks' cross-border flows, and the issuance of securities (particularly in foreign currency).[5] Employing a global VAR approach, Anaya, Hachula and Offermanns (2017) analyse the role of capital flows as a channel of transmission of US monetary policy shocks and find that an expansionary UMP shock, associated with an exogenous innovation to the Federal Reserve' balance sheet, significantly increases portfolio outflows from the US for almost two quarters. In response to the UMP shock, the growth of real output and real equity returns increase, and the real exchange rate appreciates.

The heterogeneity in the response of financial and macroeconomic variables to UMP is highlighted in Korniyenko and Loukoianova (2015) and Chen et al. (2016). Korniyenko and Loukoianova (2015) stress that the impact on global liquidity, monetary conditions and bank balance sheets from individual UMP programmes, differs depending on the nature of each program, the initial macro-economic conditions and the policy response of individual countries. Chen et al. (2016) investigate the domestic and cross-border effects (both real and financial) of the Federal Reserve's UMP using a GVECM, and find that the effects of Federal Reserves' measures, which lower the US corporate spread, vary significantly across regions and individual economies.

#### 3.2.2.1 Unconventional monetary policy, capital flows, and EMEs

Related literature has identified a direct link between US monetary policy and EMEs credit cycles, explained by global bank lending to firms in EMEs, which is denominated predominantly in US dollars (Avdjiev and Takáts, 2014; Bräuning and Ivashina, 2020).[6] Empirical studies within this strand of literature find a positive spillover effects of US UMP on EMEs via capital flows (Ahmed and Zlate, 2014; Lavigne, Sarker and Vasishtha, 2014).

[5] Korniyenko and Loukoianova (2015) focus on several QE programs such as LSAP (i.e., US treasuries, mortgage-backed securities (MBS), and securities of government sponsored enterprises (GSE)), the QE strategy implemented by the Bank of England; the assets purchase program of the Bank of Japan; and the ECB's government bond purchases (phases one and two), the ECB's three-year long-term refinancing operation (LTRO), and the ECB's securities market program (SMP).

[6] We refer the reader to McCauley, McGuire and Sushko (2015) for a discussion on the effect of US monetary policy on global dollar credit, and to Takáts and Temesvary (2020) for a discussion on the role of currency denomination in the transmission of international monetary policy.

The spillover effects of US UMP have been found to be stronger for EMEs than for AEs. Bräuning and Ivashina (2020) estimate that borrowers in EMEs see a 32-percentage-point greater increase in the volume of loans issued by foreign banks than do borrowers in AEs over a US monetary policy easing cycle, with riskier EMEs experiencing a stronger spillover effect. Lavigne, Sarker and Vasishtha (2014) argue that, in the period following the GFC, spillover effects of QE have been amplified due to differences in macroeconomic and financial conditions between EMEs and AEs. For instance, Bräuning and Ivashina (2020) show that the proportion of foreign claims of global banks on EMEs is twice as large as the proportion of foreign claims of global banks on AEs. Moreover, Bräuning and Ivashina (2020) stress that the relative importance of bank cross-border claims for AEs has followed a decreasing trend from 2005 to 2015, while EMEs have seen an increase.[7]

### 3.2.3 Transmission channels of unconventional monetary policy to commodity prices

The extant literature proposes several transmission channels through which UMP may affect asset prices (Krishnamurthy and Vissing-Jorgensen, 2011; Glick and Leduc, 2012; Rosa, 2014; Fratzscher, Lo Duca and Straub, 2016).[8] We briefly review the proposed channels as follows:

*Portfolio rebalance channel:* The purchase of Treasury securities by the Federal Reserve, decreases the overall quantity of assets accessible to investors, causing their associated yields to decline. Lower yields deter investors from holding such assets and encourage them to move towards substitute securities (such as commodities), thus increasing their price (Krishnamurthy and Vissing-Jorgensen, 2011; Joyce, Tong and Woods, 2011; Glick and Leduc, 2012; Rosa, 2014).

*Policy signalling channel:* LSAPs announcements issued by the Federal Reserve provide signalling effects about the underlying state of the economy and the response of the Federal Reserve to forthcoming developments. Hence, the signalling effect is able to move asset prices in either direction: announcements that indicate deteriorating economic and financial conditions lead market participants to increase their demand for Treasuries, as safe-haven investments, lowering their yields. This in turn reduces the demand of other financial assets such as commodity futures, lowering their price. Conversely, better economic conditions than expected would increase the demand for other financial assets (i.e., commodity futures) and subsequently increase their price.

[7] The total volume of foreign bank claims on AEs increased from 12 billion dollars in 2005 to 25 trillion dollars in 2008 and declined gradually to 16 trillion dollars in 2016, while claims on EMEs increased more than threefold throughout the entire sample, from 2 dollars trillion in 2005 to 7 dollars trillion in 2016 (Bräuning and Ivashina, 2020).

[8] Noteworthy, these channels are not mutually exclusive.

In addition, LSAPs announcements could provide signalling effects about the Federal Reserves future path of short-term interest rates. In particular, expectations of lower future short-term interest rates lower long-term interest rates (Krishnamurthy and Vissing-Jorgensen, 2011; Bauer and Rudebusch, 2014).

*Liquidity premium effects:* Asset purchases programmes provide market liquidity by encouraging market trading. In response, asset prices increase through lower liquidity premium (Joyce, Tong and Woods, 2011; Glick and Leduc, 2012).

### 3.2.4 Hypotheses development

The paper sets itself to investigate whether the international bank-lending transmission channel of monetary policy is operative in the Brent crude oil futures market, at the macro level, and whether the liquidity-based transmission mechanism identified in Lagos and Zhang (2020) is operative at the micro level.[9]

The growing interconnectedness in financial markets and deepening of cross-market integration, driven by increased cross-border financial exposure, led to spillovers of monetary policy shocks on international financial markets via international bank linkages, and in particular, the international bank lending channel of monetary policy (Cetorelli and Goldberg, 2011; Kalemli-Ozcan, Papaioannou, Perri, 2013; Gräb, and Żochowski, 2017; Temesvary, Ongena and Owen, 2018; Morais et al., 2019). The international bank lending channel of UMP operates differently compared to the conventional bank lending channel and, particularly, through the flattening of the yield curve and an increase in broad money supply. The bank lending channel postulates that asset purchases expand the central bank reserves. In turn, higher reserves and/or deposits shift loan supply, indirectly increasing broad money supply and broad money holdings of institutional investors (Gräb, and Żochowski, 2017). Considering that the proportion of foreign claims of global banks on EMEs is larger than on AEs, we expect a stronger response from EMEs to UMP operations.

The bank lending channel is expected to be particularly relevant for UMP operations as stimulating bank lending supply is often explicitly mentioned as the main objective of central banks (Albertazzi, Nobili, and Signoretti, 2021). The importance of this channel is broadened by the presence of non-bank financial intermediaries (NBFI), which play a key role in the transmission mechanism (Disyatat, 2011, and Schnabel, 2021). From a non-bank finance perspective, the rise of NBFI generated new risks for the conduct of monetary policy. The increased risk-taking of NBFI, unveiled by substantial duration,

[9] We refer the reader to Gräb and Żochowski (2017) for a further discussion on the international bank lending channel of UMP, and to Lagos and Zhang (2020) for a detailed discussion on the liquidity-based transmission channel for the period prior to the GFC.

liquidity, and credit risks exposure on their balance sheets, can give rise to liquidity mismatches which affect the ability of NBFI to absorb losses in a downturn. In turn, this can lead to systemic risk and the impairment of the monetary policy transmission mechanism (Schnabel, 2021). In addition, the expanding role of NFCs as de facto "financial intermediaries" could reduce the effectiveness of macroprudential policies (Korniyenko and Loukoianova, 2015).[10]

Most large NFCs use commodity future derivatives to reduce commodity price risk exposures, as well as for speculative proposes possibly disguised as hedging (Bartram, 2019). Greater perceived financial distress by NFCs leads to more hedging (Mo, Suvankulov, and Griffiths, 2021). However, QE stimulates credit supply, mitigates policy and economic uncertainty, and improves market liquidity by lowering risks to dealers, which implies that the need to engage in risk management through the use of commodity future derivatives diminishes. Given that the usage of commodity futures is concentrated in the oil industry (Bartram, 2019), we expect that an expansion in bank lending to NFCs in EMEs would affect trading activity in the Brent crude oil futures market, in particular, by reducing the need to hedge. Henceforth, we hypothesize that UMP is channelled onto the Brent crude oil futures market via the bank lending to EMEs.

*Hypothesis 1: An increase in central bank reserves and/or deposits created through asset purchases shifts bank loan supply in EMEs, which in turn affects trading activity in the Brent crude oil futures market, by reducing the need to hedge commodity price risk exposures.*

Despite recent changes in the structure of the intermediation process enhancing the relevance of this channel, the role of UMP in the ability of banks to provide liquidity to the economy, and in particular to the commodity market, is less clear. The transmission of monetary policy via lending supply may be hampered by the presence of capital and funding constraints for banks, which could stem from either regulatory or market pressure (Bernanke, Lown and Friedman, 1991; Van den Heuvel, 2002).

The liquidity-based transmission channel of Lagos and Zhang (2020) postulates that an increase in the growth rate of money supply or the real interest rate, reduces the equilibrium real money balances. Moreover, the direct effect of expected inflation on the real value of money is stronger than the indirect effect on the equity price. As a result, investors marginal under the lower

[10]Shin and Zhao (2013) note that the behaviour of non-financial firms in China and India is similar to that of financial intermediaries. In particular, the extent of financial intermediation of NFCs co-moves with global indicators of credit availability (Shin and Zhao, 2013). Moreover, NFCs have engaged heavily in cross-border inter-company investment in the form of portfolio investment and have increased their holdings of liquid financial assets, while decreasing investment in tangible non-financial assets (Fano and Trovato, 2013; Tebrake and O'Hagan, 2017).

inflation rate shifts their portfolio away from money towards equity to avoid inflation tax, making money balances scarcer. The real price of equity in a monetary equilibrium is partially determined by the option available to low-valuation investors to resell the equity to high-valuation investors. Yet, if the opportunity cost of holding money is positive, high-valuation investors become budget constrained in the next valuation period, as they now choose to hold less real money. This makes high-valuation investors unable to absorb the whole supply of traded risky assets, including Brent crude oil futures and as a result, some assets will be priced by low-valuation investors. Hence, the asset allocation in the Brent crude oil futures market becomes distorted and the ability of Brent futures to be resold is reduced. This implies that trading volume, which measures trading activity in the market, is determined by the (real) quantity of money, the real interest rate, and the characteristics of the market in which the asset trades (e.g., the degree of market power of dealers and the ease with which investors find counterparties). We hypothesize that a contraction in the broad money supply lowers the financial liquidity of Brent crude oil futures.

*Hypothesis 2: QE tapering leads to a contraction in the broad money supply, which lowers the financial liquidity and the price of Brent crude oil futures.*

## 3.3 Data

### 3.3.1 Description of the data

The sample period commences in January 2009 and ends in October 2021. We follow the extant literature in choosing this date for the beginning of our sample period, as it relates to the final stages of GFC, after which the federal funds target rate has remained near zero and the FOMC began its UMP operations (Gagnon et al, 2010; Krishnamurthy and Vissing-Jorgensen, 2011; Kapoor and Peia, 2021). During this period, changes in asset prices that followed the FOMC announcements are likely to be driven by news about UMP operations (Basistha and Kurov, 2015). We give details on the sources and the construction of the variables employed in the analysis in Table 3.1A in the Appendix.

The two main types of UMP pursued by the Federal Reserve following the GFC include altering the size and composition of central banks' balance sheets (i.e., LSAP) and/or issuing announcements about the future path of short-term interest rates (i.e., forward guidance). To determine the surprise content of FOMC announcements related to UMP operations, we employ the change in the 10-year government bond yield. Following Rogers, Scotti and Wright (2018), we interpret these policy surprises as asset purchase surprises.

#### 3.3.1.1 Monetary policy surprise construction

The surprise component of UMP is constructed from daily changes in the returns of the 10-year bond futures contracts, divided by the duration of the cheapest-to-deliver security in the futures basket.[11] Our choice of maturity is motivated by several studies which have focused on daily changes in the 10-year government bond yields to proxy UMP (Kapetanios et al., 2012; Guidolin, Orlov, and Pedio, 2017; Chebbi, 2018). We follow Gertler and Karadi (2015) in converting these daily futures' surprises on FOMC days into monthly average surprises before proceeding to the monthly VAR estimations. In the spirit of Romer and Romer (2004) and Barakchian and Crowe (2013), we account for the fact that the day of the FOMC meetings can vary over the month, and that monetary surprises occurring at the end of the month are expected to have a smaller influence, by following three steps. First, we cumulate all FOMC day surprises within a month. Second, we take monthly averages of these series. Third, we obtain monthly average surprises by computing the first differences of these series.

#### 3.3.1.2 Monetary policy surprise frequency

The reliability of a high-frequency (intra-day) measurement of the unexpected component of monetary policy surprises at intra-day frequency has been questioned by several empirical studies, which conclude that monetary policy surprises can be measured well using daily data (Gürkaynak, Sack, and Swanson, 2005; Gagnon et al., 2011; Hanson and Stein, 2015; Chebbi, 2018). Specifically, Gagnon et al. (2011) argue that, given the novelty of the LSAPs and the investor sentiment about the various channels through which they operate, the market absorbs news from UMP announcements more slowly than from conventional monetary policy shocks (such as from shocks to the federal funds target rate). Similarly, Hanson and Stein (2015) note that the effect of monetary announcements might not be instantaneous, particularly for long term yields. In light of these considerations, we follow Inoue and Rossi (2019) in collecting daily zero-coupon yields (mnemonics "SVENY") from Gürkayna, Sack and Wright (2007). As noted previously, we include yields at 10-year maturity. The daily frequency is dictated by data availability for this series and allows for a more precise identification of UMP.[12]

[11]Glick and Leduc (2012) identify this UMP proxy as the long-term path surprise.

[12]While one might be interested in investigating the identification of monetary policy at a higher frequency, Gürkayna, Sack and Wright (2007) show that daily data are sufficient for extracting monetary policy shocks using a high-frequency identification if the sample is limited to post-1995 data, which is the case of our paper.

#### 3.3.1.3 Global liquidity indicators

Building on Bridges and Thomas (2012), we model global liquidity jointly with commodity future prices and global economic activity in a VAR framework.[13] We employ data on global liquidity indicators estimated and supplied by the Bank of International Settlements (BIS) Consolidated Banking Statistics. Motivated by the economic significance of US dollar lending by global banks to EMEs and the rise of non-bank finance in the transmission of US monetary policy, we use banks' international claims on emerging market economies (EMEs) (*Cross-border* and *local claims on Central Europe EMEs*, *Cross-border* and *local claims on Latin America EMEs*, *Cross-border* and *local claims on Asia EMEs*) as proxies for global liquidity.[14] In particular, Bartram (2019) show that large NFCs in emerging Asia and emerging Latin America are users of commodity future derivatives for corporate hedging purposes.[15] Our motivation to explore bank international claims on EMEs by region is to account for the existing variation in hedging intensity and futures derivative usage across the regions explored.

#### 3.3.1.4 Industrial Production, Uncertainty, and Inflation

Following the identification of UMP shocks advanced by Gambacorta, Hofmann and Peersman (2014), we control for a set of macroeconomic and financial variables that respond to UMP shocks and influence the price of commodities, namely, industrial production index *(IPI)* and the consumer price index *(CPI)*, and the implied stock market volatility index (*VIX)*.[16]

The inclusion of *VIX* as an indicator of financial turmoil, economic risk and uncertainty is key to disentangle exogenous innovations to central bank balance sheets from endogenous responses to financial market risk perceptions and uncertainty.[17] In addition, we follow the related literature which considers

[13] This empirical approach is motivated by the need to account for the feedback effects from commodity asset prices to global economic activity, and vice and versa.

[14] Cross-border claims are denominated in all currencies, while local claims are denominated in foreign currencies. Hence, cross-border claims refer to claims on the non-bank sector, including claims on the non-bank financial sector (NBFI) and the government sector, in addition to the private non-financial sector (PNFS), while local claims refer to bank credit to the non-financial sector (CNFS). With respect to the region, emerging Asia includes China, Hong Kong SAR, India, Indonesia, Korea, Malaysia, Singapore and Thailand, emerging Central Europe includes Czech Republic, Hungary, Poland, and emerging Latin America corresponds to Argentina, Brazil, Chile, Mexico.

[15] The commodity futures users in emerging Asia are China, India and Malaysia and the commodity futures users in emerging Latin America are Mexico (Bartram, 2019).

[16] We refer the reader to Whaley (2009) for a more detailed discussion of the *VIX* and its interpretation, and to the Bureau of Economic Analysis for further details on the construction of *IPI*.

[17] Gambacorta, Hofmann and Peersman (2014) highlight that failing to consider the endogenous reaction of central bank balance sheets to financial disruption and economic uncertainty would lead to estimation bias.

the relationship between commodity markets and uncertainty (Andreasson et al. 2016; Joëts, Mignon and Razafindrabe, 2017; Zhang and Broadstock, 2018; Apergis, Chatziantoniou and Cooray, 2020). *IPI* measures output in manufacturing, mining, and electric and gas utilities and is employed in Gambacorta, Hofmann and Peersman (2014) and Hammoudeh, Nguyen and Sousa (2015) to replace real GDP as a proxy for aggregate output. In line with the scant literature investigating the effect of UMP on commodity prices in a macroeconomic framework, we include the *CPI* to measure inflation (Hammoudeh, Nguyen and Sousa, 2015).

#### 3.3.1.5 Brent crude oil futures contracts

Our paper focuses on the energy futures market, and in particular on the *Brent crude oil*. This choice is motivated by the importance of energy price dynamics on macroeconomy and environmental policies. Specifically, energy commodities experience a greater volatility relative to other commodities and the stock market (EIA, 2018). Since the 1970s, energy price volatility has been a reoccurring source of economic disturbance. While past sharp energy price movements have stabilised rapidly, given the current climate change challenges and geopolitical uncertainty, energy prices are expected to remain elevated and to experience further spikes. These conditions could pose significant risks to both fiscal and monetary stability (Schnabel, 2022).

The dataset comprises daily settlement prices and daily number of contracts traded for Brent crude oil futures contracts obtained from DataStream International. We focus on commodity futures rather than spot data, as the former are financial derivative instruments effectively used in the management of commodity price risk exposures as well as for speculative purposes. Further, the users of commodity future derivatives are concentrated in commodity-based industries, in particular in the oil and utilities industries, more likely to face exposure to commodity price risk, and substantially more leveraged. Specifically, the oil sector has seen a debt expansion in the post-GFC period, which far outpaced other commodity industries. Hence, the underlying risk exposure of the oil sector, which we expect to be higher than the utilities sector, represents a second motivation for our focus on the Brent crude oil market.

The returns of commodity futures are computed as the log changes of the settlement prices of the nearest contract up to one month before maturity; we then roll to the second-nearest contract.

#### 3.3.1.6 Trading volume as a measure of financial liquidity for Brent crude oil futures

The market microstructure literature identifies various measures of liquidity, each encapsulating a different facet.[18] Considering the conceptual underpinnings of the liquidity-transmission mechanism based on the theory of trade of Lagos and Zhang (2020), our paper measures financial liquidity through trading volume. The theory postulates that the efficient allocation of assets among investors is affected by shifts in the real quantity of money.

Reflecting the ability of the market to reallocate assets across investors, trading volume is commonly employed as a proxy for market liquidity (Brennan and Subrahmanyam, 1995; Datar, Naik and Radcliffe, 1998; Chordia, Subrahmanyam and Anshuman, 2001; Chordia, Roll and Subrahmanyam, 2001). In particular, Sarr and Lybek (2002) document that trading volume is a good estimator of market depth. Relevant studies in the liquidity literature (Stoll, 1978; Glosten and Harris; 1988; Chordia, Roll and Subrahmanyam, 2001) argue a strong relationship between trading volume, the bid-ask spread and market liquidity, whereas Brennan, Chordia and Subrahmanyam (1998) show that trading volume is a better liquidity proxy than the bid-ask spread, with a higher traded volume reflecting an increase in liquidity.

The construction of trading volume as a measure of financial liquidity in the Brent crude oil market follows Marshall, Nguyen and Visaltanachoti (2012). The dollar trading volume is the natural logarithm of the number of Brent crude oil futures contracts traded multiplied by the contract size and the settlement price, as follows:

$$TV_t = ln(NumberOfContractsTraded_t * ContractSize_t * SettlementPrice_t) \quad (3.1)$$

### 3.3.2 Preliminary analysis of the variables

The descriptive statistics for the policy surprises embedded in UMP announcements are presented in Table 3.1. The first column reports the descriptive statistics for the policy surprise split by the surprise direction.[19] We find a slightly higher standard deviation for the positive surprise relative to the negative surprise, 29.66 basis points (bps) compared to 23.55 bps, implying a higher volatility for the positive surprise on the days of FOMC announcements.

[18] Existing measures of liquidity can be categorized as follows: trading activity measures (i.e., trading volume, turnover, average trade size), transaction costs measures (i.e., bid-ask spread, price impact) and liquidity supply measures (i.e., dealer inventory, order book depth).

[19] A negative policy surprise corresponds to an increase in long-term bond yields and a tightening monetary stance as perceived by the market, while a positive policy surprise is associated with declining long-term bond yields and a perceived expansionary monetary policy.

The means for the negative surprise, and the positive surprise stand at -6.21 bps and 7.79 bps, respectively. A higher mean for the positive surprise indicates that the magnitude of the decline in bond yields is higher than the increase.

Table 3.2 presents the descriptive statistics for the daily returns and trading volume of Brent crude oil futures. The returns have a mean of 3% and a standard deviation of 9.2%, over our sample period (2009M01 to 2021M10), indicating a relatively high volatility. The trading volume has a mean of 23.38 (in billions) and a standard deviation of 0.38 (in billions).

Descriptive statistics for the bank cross-border and local claims on EMEs are presented in Table 3.3. *Local Claims on Asia EMEs* experience the highest volatility with a standard deviation of 16.76 (percent of GDP), followed by *Local Claims on Latin America EMEs* and *Local Claims on Central Europe EMEs*, with a standard deviation of 3.92 and 3.11, respectively. *Local Claims on Asia EMEs* also present the highest mean (131.68), followed by *Local Claims on Central Europe EMEs* and *Local Claims on Latin America EMEs* with a mean of 60.24 and 49.93.

The VAR estimations are first analysed with respect to the Granger causality pairwise test. The VAR models are estimates with 1 lag respectively, according to SIC. This analysis is supportive of the presence of causation between policy surprises, international bank cross border and local claims on EMEs, and the return and trading volume of Brent crude oil. The results, which are reported in Tables 3.4 and 3.5, document some causality from negative policy surprises to Brent trading volume, cross-border and local claims on Central Europe EMEs, cross-border claims on Latin America EMEs, and local claims on Asia EMEs. However, we do not find positive policy surprises to Granger cause bank cross-border or local claims on EMEs, Brent return and trading volume. We document significant causality from local claims on Asia EMEs, cross-border and local claims on Central Europe EMEs, and cross-border claims on Latin America EMEs to Brent return and trading volume.

The correlation matrix is reported in Table 3.6. Local claims on Asia EMEs are highly negatively correlated with the trading volume of Brent crude oil, with a correlation coefficient of 41%. In contrast, there is evidence of weak negative correlation between local claims on Latin America EMEs and Brent trading volume (-14%) and weak positive correlation between cross-border claims on Asia EMEs and Brent trading volume (24%). We also find evidence of weak negative correlation between bank cross-border and local claims on Central Europe EMEs, local claims Asia EME and the return of Brent crude oil, with a correlation coefficient ranging from -16% to -24%. We notice a relatively higher negative correlation of -38% between cross-border claims on Latin America EME and Brent return. As expected, there is evidence of strong correlation between cross-border and local bank claims. These relatively high negative correlations provide supporting evidence of a link between international bank lending on Asia EMEs, Latin America EMEs and the Brent futures market, and an interesting starting point for our VAR analysis.

## 3.4 Methodology

The existing literature on UMP and the commodity market has focused primarily on LSAPs of Treasury securities within an event-study framework (Glick and Leduc, 2012; Rosa, 2014; Chebbi, 2021). Nevertheless, a range of papers (Li and Wei, 2013; Wright, 2012) have questioned the ability of event studies to effectively estimate the size of the effects for most QE and MEP announcements and their statistical and economic significance. For instance, the range of plausible effects discussed in the literature is often substantially weaker than some of the effects reported by policymakers (Bernanke, 2012).[20] Studies on UMP and the commodity market adopting a macroeconomic empirical approach are rather limited (Hammoudeh, Nguyen and Sousa, 2015, for a SVAR modelling approach with recursive identification, and Apergis, Chatziantoniou and Cooray, 2020, for an EGARCH-X framework).

The VAR framework has been extensively used as a tool to analyse the macroeconomic effects of UMP innovations, due to its ability to capture the feedback effect between asset prices and the real economy. The structural interpretation of VAR shocks can be achieved in several ways (i.e., external instruments, recursive identification, sign-restrictions, high-frequency or heteroscedasticity approaches) (Kilian and Lutkepohl, 2017). Following Bernanke and Kuttner (2005), we identify UMP shocks through policy surprises included in the VAR model as an exogenous variable. The benefit of using monetary policy surprises within a VAR framework is to amend endogeneity concerns and to capture the unexpected component of monetary policy surprises.[21]

Hence, the hybrid model employed in this paper, in a similar fashion to Gertler and Karadi (2015), combines the traditional VAR framework with a high-frequency identification (HFI) approach of monetary policy surprises. As noted in Gertler and Karadi (2015), by employing daily data, this approach addresses the simultaneity concern: within a period, policy shifts not only influence financial variables, but they may also be responding to them as well. Further, the key identifying assumption is that news about the economy on the FOMC day does not affect the policy choice, and only the information available the previous day is relevant.

[20] Event-study methodologies capture temporary effects and are not able to account for the potential lagged effects related to UMP announcements (Albertazzi, Nobili, and Signoretti, 2021).

[21] Measuring the surprise component of FOMC announcements is crucial for an unbiased identification of the size of a given shock (Glick and Leduc, 2012; IMF, 2013).

### 3.4.1 Unconventional monetary policy surprises and the Brent crude oil futures market: a VAR-X framework

Our baseline econometric model is a vector autoregression model (VAR) with a mixture of economic and financial variables, as described in (3.2).

$$B_0 y_t = \alpha + \sum_{n=1}^{N} B_n y_{t-n} + \varepsilon_t \tag{3.2}$$

where $y_t = [Return_t, VIX_t, CPI_t, IPI_t, PolicySurprise_t]$', $Return_t$ represents the return of Brent crude oil commodity futures, $VIX_t$ is the CBOE volatility index, $CPI_t$ is the consumer price index for the US, $IPI_t$ is the industrial production index for the US, $PolicySurprise_t$ is the surprise component of UMP, constructed using the 10-year US government bond yield, and $\varepsilon_t$ is a vector of orthogonal structural innovations. . The model is estimated using 1 lag, according to AIC criteria.

We test the financial liquidity transmission channel based on the theory of trade of Lagos and Zhang (2020) by replacing the returns with the dollar trading volume of Brent crude oil futures *(TV)*. The augmented model (3.3) now has $y_t = [TV_t, VIX_t, CPI_t, IPI_t, PolicySurprise_t$ ]'.

To assess the international bank lending transmission channel we introduce our global liquidity indicators, one at a time, to models (3.2) and (3.3). Specifically, we look at international bank *Cross-border claims on Central Europe EMEs*, *Local claims on Central Europe EME*, *Cross-border claims on Latin America EMEs*, *Local claims on Latin America EMEs*, *Cross-border claims on Asia EMEs*, and *Local claims on Asia EMEs.* Posing the question concerning asymmetries, defined as the possibility of the response of commodity futures prices to monetary policy to depend on the direction of the policy surprise, we also split the policy surprise by direction.

## 3.5 Empirical Results

In this section, we present the empirical responses of Brent crude oil futures return and trading volume to surprises embedded in UMP announcements via cross-border and local bank claims on EMEs.

### 3.5.1 Empirical response of the trading volume and return of Brent crude oil futures to policy surprises

We first explore the effect of policy surprises split by the direction on the trading volume and the returns of Brent crude oil futures. The results presented in Table 3.7 and Table 3.8 do not show a statistically significant response of the trading volume and returns of Brent crude oil futures to a positive or a negative policy surprise. These results indicate that the baseline model is not capturing the potential transmission channels of UMP onto the Brent futures market. We proceed to study the proposed financial liquidity and international bank lending transmission channels of monetary policy in the next section.

### 3.5.2 Empirical response of the trading volume of Brent crude oil futures to policy surprises via bank claims on EMEs

We then investigate the effect of policy surprises, by direction, on the trading volume of Brent crude oil futures via cross-border and local claims on EMEs in Central Europe, Asia, and Latin America. The results are presented in Tables 3.9 to 3.14.

Tables 3.9 and 3.10 report the estimated effects of policy surprises on Brent trading volume, via cross-border and local claims on Central Europe EMEs. We find a lagged decrease in Brent trading volume following a negative policy surprise. Brent trading volume also declines following a lagged increase in cross-border and local claims on Central Europe EMEs. However, we do not find a significant change in claims on Central Europe EMEs after either a positive or a negative policy surprise. This indicates that bank flows to Central Europe EMEs are not likely to channel UMP onto the Brent futures market.

The estimated effects of policy surprises on Brent trading volume via cross-border and local claims on Asia EMEs are described in Tables 3.11 and 3.12. We find a lagged decrease in Brent trading volume following a negative policy surprise. Brent trading volume also declines following a lagged increase in local claims on Asia EMEs, which increase in response to a positive policy surprise. However, we do not find cross-border claims on Asia EMEs to impact Brent trading volume. Moreover, our results show that cross-border claims on Asia EMEs are not affected by either a positive or negative policy surprise. These findings indicate that positive policy surprises are channelled by local claims on Asia EMEs onto the Brent futures market.

Tables 3.13 and 3.14 depict the estimated effects of policy surprises on Brent trading volume via cross-border and local claims on Latin America EMEs. We find a lagged decrease in Brent trading volume following a negative policy surprise. Brent trading volume also declines following a lagged increase in cross-border claims on Latin America EMEs. However, local claims on Latin America EMEs do not affect Brent trading volume. In addition, we find that cross-border and local claims on Latin America EMEs are not affected by either a positive or negative policy surprise. These results suggest that bank flows to Latin America EMEs are not likely to transmit UMP to the Brent futures market.

### 3.5.3 Empirical response of the return of Brent crude oil futures to policy surprises via bank claims on EMEs

Further, we study the effect of policy surprises by direction on the return of Brent crude oil via cross-border and local claims EMEs in Central Europe, Asia, and Latin America. The results are presented in Tables 3.15 to 3.20. We find that policy surprises do not affect bank cross-border and local claims on EMEs in the aforementioned regions or the return of Brent crude oil. However, we do find that Brent return declines following an increase in bank (cross-border and local claims) on Central Europe EMEs, Asia EMEs, and Latin America EMEs.

### 3.5.4 Discussion

Our results can be summarized as follows. Negative policy surprises have a lagged and negative effect on Brent trading volume, which bypasses the international bank lending channel to EMEs, while positive policy surprises are transmitted to Brent trading volume and returns via local claims on Asia EMEs. Specifically, local claims on Asia EMEs increase following a positive policy surprise. In turn, an increase in local claims on Asia EMEs leads to a lagged decline in the returns and trading volume of Brent crude oil futures.

The negative response of Brent futures trading volume to a negative policy surprise can be explained by the financial liquidity transmission channel of monetary policy based on theory of trade of Lagos and Zhang (2020), which postulates that tight money increases the opportunity cost of holding money balances, making these payment instruments scarcer. This in turn reduces asset's ability to be resold and increases its illiquidity. This channel is enhanced by the uncertainty associated with FOMC announcements perceived as tightening policy actions.[22] This is in line with the literature on uncertainty and market liquidity, which highlights the detrimental effect of uncertainty on market functioning (Easley and O'Hara, 2010; Rehse, et al., 2019). For instance, Easley and O'Hara (2010) argue that uncertainty plays an important, and distinct role in influencing the behaviour of market participants in risky markets, quelling trading and, more importantly, changing the price-setting process. Further, Gospodinov and Jamali (2018) find that uncertainty associated with negative monetary policy shocks (i.e., a decrease in the target rate by more than expected by market participants) leads to a decrease in commodity prices and excess speculative activity, while Miranda-Agrippino and Rey (2020) document that US monetary policy affects global banks' leverage, risky asset prices, and global risk aversion.

Our findings of an increase in bank lending associated with positive policy

[22]The uncertainty associated with negative target rate surprises is discussed in Gospodinov and Jamali (2018).

surprises are supported by the extant literature on US monetary policy and credit cycles (Bräuning and Ivashina, 2020). Despite an increase in international bank local claims on Asia EMEs, we notice that trading activity in Brent futures market declines. Local claims on Asia EMEs refer to international bank credit to the non-financial sector in emerging Asia.[23] These results can be explained by NFCs in emerging Asia, which are users of commodity future derivatives for hedging purposes, reducing their engagement in risk management following positive policy surprises. The diminishing incentive to hedge commodity price risk is motivated by QE boosting credit supply, mitigating economic uncertainty and improving market liquidity.

## 3.6 Further Analysis

We further explore this channel by introducing changes in international bank cross-border and local claims on AEs to our models (3.2) and (3.3). In particular, we look at *Cross-border claims on US*, *Local claims on US*, *Cross-border claims Euro Area AEs*, and *Local claims on Euro Area AEs*.[24] Results are presented in Table 3.21 to Table 3.28. Overall our results show that the international bank lending channel explored in this paper does not operate through AEs. Similar to our results presented in the previous section, we find a decline in the trading volume of Brent crude oil futures following a lagged negative policy surprise, which bypasses the bank lending channel to AEs. This finding supports the presence of a financial liquidity transmission channel at the micro level.

## 3.7 Conclusion

In the wake of the Global Financial Crisis, policy rates reached the zero lower bound and the Federal Reserve, among other central banks, turned to UMP operations with the goal of stabilizing the global economy. However, US monetary policy shifts are seen as a source of adverse spillovers to other economies, and in particular to EMEs. Driven by the growing interconnectedness in financial markets and deepening of cross-border integration, spillovers of monetary policy on international financial markets occur through international bank linkages. In light of these considerations, our paper explores the nature of the transmission of UMP to the Brent crude oil futures market, which has been the centre of exceptional volatility.

[23] The bank lending transmission channel of UMP does not operate through international bank claims on the bank sector. We do not report the results for brevity, but we make them available upon request.

[24] The countries included in Euro area AEs are Austria, Belgium, Finland, France, Germany, Ireland, Italy, Netherlands, Portugal, Spain, and Greece.

We assess the international bank-lending channel of UMP by employing a hybrid model, which combines the traditional VAR framework with a high-frequency identification approach of monetary policy surprises. Our results document that positive surprises affect trading activity via local claims on Asia EMEs, while negative policy surprises are transmitted directly, bypassing the proposed international bank-lending channel. Specifically, negative policy surprises, representing a perceived contractionary monetary policy, have a lagged, negative effect on trading activity in the Brent futures market. Positive surprises, reflecting a perceived expansionary policy action, increase local claims on Asia EMEs. In response to an increase in international bank lending to Asia EMEs, trading activity in the Brent futures market declines. The observed decline in trading activity following negative surprises can be attributed to the proposed financial liquidity transmission channel of monetary policy and to uncertainty related to UMP operations, which can induce non-participation in the Brent futures market due to its high volatility. Given that QE improves credit supply and reduced economic uncertainty, lower trading activity in the Brent futures market following positive policy surprises can be explained by NFCs engaging less in commodity price risk management.

We bring several contributions to the related literature on UMP and the commodity market. First, to the best of our knowledge, we are the first to investigate the international bank-lending channel of UMP to the Brent crude oil futures market. Second, whereas the scarce empirical studies adopting a macroeconomic empirical framework have focused on the growth rate of central bank reserves and the short-term shadow rate, measured at monthly frequency to proxy UMP, we implement a more credible approach to the identification of monetary policy shocks, well suited to analysing policy at the zero lower bound. Specifically, we determine the asset purchase surprises, using daily changes in the 10-year government bond yield bracketing FOMC announcements. We then include these surprises in a VAR model as an exogenous variable. In doing so, the empirical analysis amends not only endogeneity, but also simultaneity concerns. Lastly, related empirical studies using a macroeconomic framework are silent on the asymmetric response of commodity futures prices to policy announcements. We bring important considerations to this line of research by examining the UMP effect on the Brent futures market by accounting for the direction of policy surprise.

**Table 3.1: Descriptive statistics monetary policy surprise**

| | **Negative policy surprise** | **Positive policy surprise** |
|---|---|---|
| **Mean** | -6.21 | 7.79 |
| **Median** | 0.00 | 0.00 |
| **Max** | 0.00 | 223.48 |
| **Min** | -195.45 | 0.00 |
| **St. Dev** | 23.55 | 29.66 |
| **Obs** | 21 | 21 |

*Notes:* Descriptive statistics are reported in the first column for the surprises embedded in UMP announcements, and in the second and third column for the policy surprises distinguished by the direction of the surprise. A negative (positive) policy surprise is corresponds to a perceived tightening (easing) monetary policy. The policy surprises are expressed in basis points. Our sample period is from January 2009 to September 2021.

**Table 3.2: Descriptive statistics for Brent Crude Oil commodity futures**

| | **Mean** | **Median** | **Max** | **Min** | **St Dev** | **Obs** |
|---|---|---|---|---|---|---|
| Return | 0.003 | 0.015 | 0.229 | -0.498 | 0.092 | 153 |
| TV | 23.38 | 23.44 | 23.95 | 22.02 | 0.38 | 153 |

*Notes:* Descriptive statistics are reported for the daily returns and daily trading volume of Brent Crude Oil. The returns are measured in logs. The trading volume is measured as the natural logarithm of the number of traded, multiplied by the contract size and the settlement price. Our sample period is from January 2009 to September 2021.

**Table 3.3: Descriptive statistics for global liquidity indicators**

| | **Mean** | **Median** | **Max** | **Min** | **St Dev** | **Obs** |
|---|---|---|---|---|---|---|
| Cross-border Claims Asia EMEs | 5.00 | 5.40 | 5.90 | 3.60 | 0.75 | 153 |
| Cross-border Claims Central Europe EMEs | 10.80 | 9.73 | 17.50 | 7.50 | 2.77 | 153 |
| Cross-border claims Latin America EMEs | 7.17 | 6.83 | 9.20 | 6.20 | 0.77 | 153 |
| Local Claims Asia EMEs | 131.68 | 133.07 | 164.90 | 101.37 | 16.76 | 153 |
| Local Claims Central Europe EMEs | 60.24 | 59.73 | 67.60 | 55.20 | 3.11 | 153 |
| Local Claims Latin America EMEs | 49.93 | 51.00 | 56.30 | 40.00 | 3.92 | 153 |

*Notes:* Descriptive statistics are reported for the global liquidity indicators, which are measured at monthly frequency as a percentage of GDP. Our sample period is from January 2009 to September 2021.

**Table 3.4: Granger-causality pairwise test - policy surprise**

| | Negative Policy Surprise | Positive Policy Surprise |
|---|---|---|
| TV | **3.69*** | 0.04 |
| Return | 0.05 | 0.01 |
| Cross-border claims Central Europe EMEs | **3.41*** | 0.09 |
| Local claims Central Europe EMEs | **6.95***** | 0.00 |
| Cross-border claims Latin America EMEs | **2.97*** | 0.67 |
| Local claims Latin America EMEs | 0.38 | 0.04 |
| Cross-border claims Asia EMEs | 1.39 | 0.82 |
| Local claims Asia EMEs | **7.52***** | 2.10 |

*Notes:* The table reports F-statistics for the null of the column variables Granger causing the row variables. The returns are measured at monthly frequency in logs. The trading volume is measured at monthly frequency as the natural logarithm of the number of traded, multiplied by the contract size and the settlement price. The global liquidity indicators are measured at monthly frequency as a percentage of GDP. The VAR models are estimates with 1 lag respectively, according to SIC. * indicates significance at 10 %, ** at 5 % and *** at 1 %. Our sample period is from January 2009 to September 2021.

**Table 3.5: Granger-causality pairwise test - global liquidity indicators**

| | Cross-border claims Asia EMEs | Local claims Asia EMEs | Cross-border claims Central Europe EMEs | Local claims Central Europe EMEs | Cross-border claims Latin America EMEs | Local claims Latin America EMEs |
|---|---|---|---|---|---|---|
| TV | 0.21 | **8.95***** | **7.47***** | **4.72**** | **7.74***** | 1.79 |
| Return | 1.82 | **3.70*** | **6.16**** | 2.25 | **14.70***** | 2.06 |

*Notes:* The table reports F-statistics for the null of the column variables Granger causing the row variables. The returns are measured at monthly frequency in logs. The trading volume is measured at monthly frequency as the natural logarithm of the number of traded, multiplied by the contract size and the settlement price. The global liquidity indicators are measured at monthly frequency as a percentage of GDP. The VAR models are estimates with 1 lag respectively, according to SIC. * indicates significance at 10 %, ** at 5 % and *** at 1 %. Our sample period is from January 2009 to September 2021.

## Table 3.6: Correlation matrix

| | **Cross-border claims Asia EMEs** | **Cross-border claims Central Europe EMEs** | **Cross-border claims Latin America EMEs** | **Local claims Asia EMEs** | **Local claims Central Europe EMEs** | **Local claims Latin America EMEs** | **TV** |
|---|---|---|---|---|---|---|---|
| **Cross-border claims Central Europe EMEs** | 0.03 | | | | | | |
| **Cross-border claims Latin America EMEs** | **0.22*** ** | **0.43*** ** | | | | | |
| **Local claims Asia EMEs** | **0.16** ** | **0.48*** ** | **0.41** ** | | | | |
| **Local claims Central Europe EMEs** | -0.05 | **0.84*** ** | **0.42*** ** | **0.47*** ** | | | |
| **Local claims Latin America EMEs** | **0.22*** ** | -0.01 | **0.26*** ** | **0.17** ** | 0.04 | | |
| **TV** | **0.24*** ** | -0.06 | 0.12 | **-0.41*** ** | -0.09 | **-0.14* ** | |
| **Return** | -0.04 | **-0.24*** ** | **-0.38** ** | **-0.16** ** | **-0.19** ** | -0.06 | -0.08 |

*Notes:* The correlation matrix reports the correlation coefficients between the variables. The returns are measured at monthly frequency in logs. The trading volume is measured at monthly frequency as the natural logarithm of the number of traded, multiplied by the contract size and the settlement price. The global liquidity indicators are measured at monthly frequency as a percentage of GDP. * indicates significance at 10 %, ** at 5 % and *** at 1 %. Our sample period is from January 2009 to September 2021.

**Table 3.7: The response of Brent Crude Oil Trading Volume to UMP surprise**

| | **IPI** | **CPI** | **VIX** | **TV** |
|---|---|---|---|---|
| $IPI_{t-1}$ | **0.17*** | -0.01 | 0.36 | **1.68**** |
| | ( 1.99) | (-0.39) | ( 0.34) | ( 2.12) |
| $CPI_{t-1}$ | 0.34 | **0.48***** | 2.17 | **6.60*** |
| | ( 0.84) | ( 6.64) | ( 0.43) | ( 1.72) |
| $VIX_{t-1}$ | **-0.01*** | -0.001 | **0.80***** | **-0.10**** |
| | (-1.87) | (-0.95) | ( 14.7) | (-2.39) |
| $TV_{t-1}$ | -0.01 | **-0.002**** | -0.04 | **0.82** |
| | (-1.31) | (-2.38) | (-0.81) | ( 22.3) |
| $Constant$ | 0.14 | **0.04**** | 1.49 | **4.52***** |
| | ( 1.47) | ( 2.38) | ( 1.23) | ( 4.92) |
| $PositivePolicySurprise_t$ | -0.11 | -0.08 | 5.43 | -6.31 |
| | (-0.13) | (-0.53) | ( 0.53) | (-0.81) |
| $PositivePolicySurprise_{t-1}$ | -0.03 | -0.04 | -1.35 | -1.47 |
| | (-0.06) | (-0.49) | (-0.24) | (-0.35) |
| $NegativePolicySurprise_t$ | 0.28 | -0.03 | -5.26 | -3.53 |
| | ( 0.53) | (-0.32) | (-0.79) | (-0.69) |
| $NegativePolicySurprise_{t-1}$ | 0.16 | -0.22 | 3.42 | -12.78 |
| | ( 0.18) | (-1.49) | ( 0.33) | (-1.62) |
| $R^2$ | 0.08 | 0.28 | 0.72 | 0.86 |

*Notes: IPI* and *CPI* are measured at monthly frequency in first logarithmic differences. *VIX* is measured at monthly frequency in logs. Monthly $TV$ is measured as the natural logarithm of the number of traded, multiplied by the contract size and the settlement price. t-statistics are reported in parenthesis. ***, **, * indicate significance at 1%, 5%, and 10% respectively. Our sample period is from January 2009 to September 2021. The number of observations is 153.

**Table 3.8: The response of Brent Crude Oil Return to UMP surprise**

| | **IPI** | **CPI** | **VIX** | **Return** |
|---|---|---|---|---|
| $IPI_{t-1}$ | 0.03 | -0.02 | 0.70 | **-0.98**** |
| | ( 0.39) | (-1.64) | ( 0.64) | (-2.05) |
| $CPI_{t-1}$ | **-1.11***** | **0.28***** | 5.45 | -3.86 |
| | (-2.74) | ( 3.56) | ( 0.94) | (-1.50) |
| $VIX_{t-1}$ | -0.003 | 0.001 | **0.81***** | **0.05**** |
| | (-0.75) | ( 0.80) | ( 17.0) | ( 2.22) |
| $Return_{t-1}$ | **0.10***** | **0.01***** | -0.26 | **0.49***** |
| | ( 6.96) | ( 4.66) | (-1.24) | ( 5.34) |
| $Constant$ | 0.01 | -0.0003 | **0.53***** | **-0.13**** |
| | ( 1.07) | (-0.17) | ( 3.89) | (-2.10) |
| $PositivePolicySurprise_t$ | 0.01 | -0.07 | 4.91 | -0.79 |
| | ( 0.02) | (-0.47) | ( 0.48) | (-0.17) |
| $PositivePolicySurprise_{t-1}$ | -0.42 | -0.08 | 0.18 | -1.79 |
| | (-1.10) | (-1.07) | ( 0.03) | (-0.72) |
| $NegativePolicySurprise_t$ | 0.20 | -0.04 | -5.18 | -0.76 |
| | ( 0.43) | (-0.48) | (-0.78) | (-0.25) |
| $NegativePolicySurprise_{t-1}$ | 0.35 | -0.21 | 2.14 | -2.90 |
| | ( 0.48) | (-1.49) | ( 0.20) | (-0.63) |
| $R^2$ | 0.31 | 0.35 | 0.72 | 0.20 |

*Notes: IPI* and *CPI* are measured at monthly frequency in first logarithmic differences. *VIX* is measured at monthly frequency in logs. t-statistics are reported in parenthesis. ***, **, * indicate significance at 1%, 5%, and 10% respectively. Our sample period is from January 2009 to September 2021. The number of observations is 153.

**Table 3.9: Brent trading volume response to UMP surprise by direction - bank cross-border claims on Europe EMEs**

| | (I) | (II) | (III) | (IV) | (V) |
|---|---|---|---|---|---|
| | **IPI** | **CPI** | **VIX** | **Cross-border claims Europe EMEs** | **TV** |
| $IPI_{t-1}$ | **0.15*** | -0.01 | 0.63 | -0.08 | **1.53*** |
| | (1.80) | (-0.49) | ( 0.62) | (-0.11) | ( 1.95) |
| $CPI_{t-1}$ | 0.37 | **0.48*** ** | 1.83 | 0.56 | **6.79*** |
| | ( 0.93) | ( 6.68) | ( 0.37) | ( 0.16) | ( 1.80) |
| $VIX_{t-1}$ | -0.01 | -0.001 | **0.76*** ** | -0.06 | **-0.08*** |
| | (-1.31) | (-0.68) | ( 14.3) | (-1.64) | (-1.92) |
| $Cross-borderClaimsEuropeEMEs_{t-1}$ | **-0.02*** ** | -0.002 | **0.31*** ** | **0.68*** ** | **-0.18** ** |
| | (-3.03) | (-1.32) | ( 3.29) | ( 10.5) | (-2.44) |
| $TV_{t-1}$ | -0.004 | **-0.002** ** | -0.05 | -0.03 | **0.82*** ** |
| | (-1.18) | (-2.31) | (-1.01) | (-0.96) | ( 22.8) |
| $Constant$ | 0.12 | **0.04** ** | 1.80 | 0.88 | **4.34*** ** |
| | ( 1.26) | ( 2.28) | ( 1.53) | ( 1.09) | ( 4.80) |
| $PositivePolicySurprise_t$ | 0.11 | -0.06 | 2.53 | -10.47 | -4.65 |
| | ( 0.13) | (-0.41) | ( 0.25) | (-1.54) | (-0.60) |
| $PositivePolicySurprise_{t-1}$ | -0.10 | -0.04 | -0.34 | -0.63 | -2.05 |
| | (-0.23) | (-0.56) | (-0.06) | (-0.17) | (-0.50) |
| $NegativePolicySurprise_t$ | 0.09 | -0.05 | -2.69 | -4.12 | -5.00 |
| | ( 0.17) | (-0.47) | (-0.41) | (-0.93) | (-1.00) |
| $NegativePolicySurprise_{t-1}$ | 0.07 | -0.23 | 4.53 | -3.26 | **-13.41*** |
| | ( 0.09) | (-1.54) | ( 0.45) | (-0.47) | (-1.73) |
| $R^2$ | 0.14 | 0.28 | 0.74 | 0.46 | 0.86 |

*Notes: IPI* and *CPI* are measured at monthly frequency in first logarithmic differences. *VIX* is measured at monthly frequency in logs. The global liquidity indicator is measured in first difference of quarterly data. Monthly $TV$ is measured as the natural logarithm of the number of traded, multiplied by the contract size and the settlement price. t-statistics are reported in parenthesis. ***, **, * indicate significance at 1%, 5%, and 10% respectively. Our sample period is from January 2009 to September 2021. The number of observations is 153.

### Table 3.10: Brent trading volume response to UMP surprise by direction - bank local claims on Europe EMEs

| | (I) | (II) | (III) | (IV) | (V) |
|---|---|---|---|---|---|
| | **IPI** | **CPI** | **VIX** | **Local claims Central Europe EMEs** | **TV** |
| $IPI_{t-1}$ | **0.16*** | -0.01 | 0.55 | -0.60 | **1.60*** |
| | ( 1.91) | (-0.47) | ( 0.55) | (-0.43) | ( 2.04) |
| $CPI_{t-1}$ | 0.33 | **0.48***** | 2.51 | 6.91 | **6.46*** |
| | ( 0.81) | ( 6.65) | ( 0.52) | ( 1.03) | ( 1.70) |
| $VIX_{t-1}$ | -0.01 | -0.0004 | **0.75** | -0.10 | **-0.08**** |
| | (-1.36) | (-0.55) | ( 14.1) | (-1.42) | (-1.92) |
| $LocalClaimsCentralEuropeEMEs_{t-1}$ | **-0.01**** | **-0.001*** | **0.18***** | **0.68***** | **-0.07*** |
| | (-2.14) | (-1.68) | ( 3.78) | ( 10.4) | (-1.96) |
| $TV_{t-1}$ | -0.005 | **-0.002**** | -0.05 | -0.03 | **0.82***** |
| | (-1.19) | (-2.28) | (-1.07) | (-0.52) | ( 22.6) |
| $Constant$ | 0.12 | **0.04**** | 1.88 | 1.06 | **4.36***** |
| | ( 1.29) | ( 2.24) | ( 1.62) | ( 0.66) | ( 4.78) |
| $PositivePolicySurprise_t$ | 0.04 | -0.06 | 2.20 | -2.34 | -4.98 |
| | ( 0.05) | (-0.39) | ( 0.22) | (-0.17) | (-0.64) |
| $PositivePolicySurprise_{t-1}$ | -0.01 | -0.04 | -1.73 | -1.76 | -1.31 |
| | (-0.02) | (-0.46) | (-0.33) | (-0.24) | (-0.31) |
| $NegativePolicySurprise_t$ | 0.07 | -0.06 | -0.70 | -13.56 | -5.40 |
| | ( 0.13) | (-0.63) | (-0.10) | (-1.52) | (-1.06) |
| $NegativePolicySurprise_{t-1}$ | -0.05 | **-0.25*** | 7.92 | 15.04 | **-14.62*** |
| | (-0.06) | (-1.69) | ( 0.79) | ( 1.09) | (-1.86) |
| $R^2$ | 0.11 | 0.29 | 0.75 | 0.48 | 0.86 |

*Notes: IPI* and *CPI* are measured at monthly frequency in first logarithmic differences. *VIX* is measured at monthly frequency in logs. The global liquidity indicator is measured in first difference of quarterly data. Monthly $TV$ is measured as the natural logarithm of the number of traded, multiplied by the contract size and the settlement price. t-statistics are reported in parenthesis. ***, **, * indicate significance at 1%, 5%, and 10% respectively. Our sample period is from January 2009 to September 2021. The number of observations is 153.

**Table 3.11: Brent trading volume response to UMP surprise by direction - bank cross-border claims on Asia EMEs**

| | (I) | (II) | (III) | (IV) | (V) |
|---|---|---|---|---|---|
| | **IPI** | **CPI** | **VIX** | **Cross-border claims Asia EMEs** | **TV** |
| $IPI_{t-1}$ | **0.15*** | -0.01 | 0.42 | -0.003 | **1.62**** |
| | ( 1.86) | (-0.44) | ( 0.40) | (-0.01) | ( 2.04) |
| $CPI_{t-1}$ | 0.46 | **0.49***** | 1.63 | -0.16 | **7.11*** |
| | ( 1.12) | ( 6.66) | ( 0.32) | (-0.17) | ( 1.83) |
| $VIX_{t-1}$ | **-0.01**** | -0.001 | **0.80***** | -0.01 | **-0.10**** |
| | (-2.05) | (-1.00) | ( 14.7) | (-1.14) | (-2.46) |
| $Cross-borderClaimsAsiaEMEs_{t-1}$ | **-0.05*** | -0.004 | 0.25 | **0.63***** | -0.24 |
| | (-1.92) | (-0.69) | ( 0.71) | ( 9.60) | (-0.89) |
| $TV_{t-1}$ | -0.004 | **-0.002**** | -0.04 | -0.01 | **0.82***** |
| | (-0.99) | (-2.23) | (-0.91) | (-0.82) | ( 22.2) |
| $Constant$ | 0.12 | **0.04**** | 1.61 | 0.21 | **4.41***** |
| | ( 1.20) | ( 2.26) | ( 1.32) | ( 0.93) | ( 4.75) |
| $PositivePolicySurprise_t$ | -0.33 | -0.09 | 6.47 | -1.57 | -7.30 |
| | (-0.40) | (-0.62) | ( 0.62) | (-0.82) | (-0.92) |
| $PositivePolicySurprise_{t-1}$ | -0.09 | -0.04 | -1.04 | -0.61 | -1.77 |
| | (-0.21) | (-0.54) | (-0.18) | (-0.60) | (-0.42) |
| $NegativePolicySurprise_t$ | 0.35 | -0.03 | -5.58 | -0.60 | -3.22 |
| | ( 0.66) | (-0.27) | (-0.83) | (-0.49) | (-0.63) |
| $NegativePolicySurprise_{t-1}$ | 0.08 | -0.23 | 3.76 | -2.56 | **-13.11*** |
| | ( 0.10) | (-1.52) | ( 0.36) | (-1.34) | (-1.66) |
| $R^2$ | 0.11 | 0.28 | 0.72 | 0.45 | 0.86 |

*Notes: IPI* and *CPI* are measured at monthly frequency in first logarithmic differences. *VIX* is measured at monthly frequency in logs. The global liquidity indicator is measured in first difference of quarterly data. Monthly $TV$ is measured as the natural logarithm of the number of traded, multiplied by the contract size and the settlement price. t-statistics are reported in parenthesis. ***, **, * indicate significance at 1%, 5%, and 10% respectively. Our sample period is from January 2009 to September 2021. The number of observations is 153.

**Table 3.12: Brent trading volume response to UMP surprise by direction - bank cross-border claims on Asia EMEs**

| | (I) | (II) | (III) | (IV) | (V) |
|---|---|---|---|---|---|
| | **IPI** | **CPI** | **VIX** | **Local claims Asia EMEs** | **TV** |
| $IPI_{t-1}$ | 0.11 | -0.01 | 0.99 | -0.86 | 1.27 |
| | ( 1.37) | (-0.82) | ( 0.96) | (-0.38) | ( 1.61) |
| $CPI_{t-1}$ | 0.59 | **0.51*** ** | -0.64 | **-29.55*** ** | **8.46** ** |
| | ( 1.49) | ( 7.05) | (-0.12) | (-2.72) | ( 2.23) |
| $VIX_{t-1}$ | -0.01 | -0.0004 | 0.77 | **-0.20*** | **-0.08*** |
| | (-1.27) | (-0.53) | ( 14.4) | (-1.68) | (-1.91) |
| $LocalClaimsAsiaEMEs_{t-1}$ | **-0.01*** ** | **-0.001** ** | **0.09*** ** | **0.73*** ** | **-0.06*** ** |
| | (-3.60) | (-2.34) | ( 3.27) | ( 12.8) | (-2.83) |
| $TV_{t-1}$ | **-0.01** ** | **-0.002*** ** | -0.01 | -0.17 | **0.80*** ** |
| | (-2.11) | (-2.86) | (-0.11) | (-1.62) | ( 21.7) |
| $Constant$ | **0.21** ** | **0.05*** ** | 0.76 | **4.66*** | **5.00*** ** |
| | ( 2.17) | ( 2.82) | ( 0.64) | ( 1.78) | ( 5.48) |
| $PositivePolicySurprise_t$ | -0.39 | -0.11 | 8.60 | **50.34** ** | -8.41 |
| | (-0.48) | (-0.77) | ( 0.86) | ( 2.30) | (-1.10) |
| $PositivePolicySurprise_{t-1}$ | 0.16 | -0.02 | -3.46 | 16.37 | -0.07 |
| | ( 0.37) | (-0.21) | (-0.65) | ( 1.39) | (-0.01) |
| $NegativePolicySurprise_t$ | 0.09 | -0.05 | -3.09 | -18.41 | -4.97 |
| | ( 0.18) | (-0.56) | (-0.47) | (-1.29) | (-1.00) |
| Negative $PolicySurprise_{t-1}$ | -0.12 | **-0.25*** | 6.53 | 14.24 | **-14.84*** |
| | (-0.14) | (-1.73) | ( 0.65) | ( 0.64) | (-1.92) |
| $R^2$ | 0.16 | 0.30 | 0.74 | 0.66 | 0.87 |

*Notes: IPI* and *CPI* are measured at monthly frequency in first logarithmic differences. *VIX* is measured at monthly frequency in logs. The global liquidity indicator is measured in first difference of quarterly data. Monthly $TV$ is measured as the natural logarithm of the number of traded, multiplied by the contract size and the settlement price. t-statistics are reported in parenthesis. ***, **, * indicate significance at 1%, 5%, and 10% respectively. Our sample period is from January 2009 to September 2021. The number of observations is 153.

**Table 3.13: Brent trading volume response to UMP surprise by direction - bank cross-border claims on Asia EMEs**

| | (I) | (II) | (III) | (IV) | (V) |
|---|---|---|---|---|---|
| | IPI | CPI | VIX | Cross-border claims Latin America EMEs | TV |
| $IPI_{t-1}$ | **0.16*** | -0.01 | 0.47 | -0.22 | **1.63**** |
| | ( 1.97) | (-0.46) | ( 0.46) | (-0.35) | ( 2.08) |
| $CPI_{t-1}$ | -0.12 | **0.43***** | 7.70 | -2.67 | 4.17 |
| | (-0.29) | ( 5.75) | ( 1.52) | (-0.84) | ( 1.05) |
| $VIX_{t-1}$ | -0.01 | -0.001 | **0.77***** | **-0.06*** | **-0.09**** |
| | (-1.50) | (-0.69) | ( 14.8) | (-1.76) | (-2.17) |
| $Cross-borderClaimsLatinAmericaEMEs_{t-1}$ | **-0.03***** | **-0.003** | **0.38***** | **0.63** | **-0.17**** |
| | (-3.78) | (-2.23) | ( 3.63) | ( 9.61) | (-2.03) |
| $TV_{t-1}$ | 0.00 | **0.00*** | -0.07 | 0.02 | **0.83***** |
| | (-0.65) | (-1.95) | (-1.50) | ( 0.77) | ( 22.6) |
| $Constant$ | 0.08 | **0.03*** | **2.28*** | -0.36 | **4.17***** |
| | ( 0.81) | ( 1.96) | ( 1.93) | (-0.48) | ( 4.51) |
| $PositivePolicySurprise_t$ | -0.27 | -0.10 | 7.35 | 0.99 | -7.15 |
| | (-0.34) | (-0.66) | ( 0.74) | ( 0.16) | (-0.92) |
| $PositivePolicySurprise_{t-1}$ | -0.07 | -0.04 | -0.87 | -1.04 | -1.68 |
| | (-0.15) | (-0.55) | (-0.16) | (-0.31) | (-0.40) |
| $NegativePolicySurprise_t$ | 0.20 | -0.04 | -4.21 | -3.08 | -3.99 |
| | ( 0.38) | (-0.42) | (-0.66) | (-0.77) | (-0.79) |
| $NegativePolicySurprise_{t-1}$ | -0.10 | **-0.25*** | 6.48 | 4.38 | **-14.12*** |
| | (-0.12) | (-1.69) | ( 0.65) | ( 0.70) | (-1.81) |
| $R^2$ | 0.17 | 0.30 | 0.74 | 0.46 | 0.86 |

*Notes: IPI* and *CPI* are measured at monthly frequency in first logarithmic differences. *VIX* is measured at monthly frequency in logs. The global liquidity indicator is measured in first differences of quarterly data. Monthly $TV$ is measured as the natural logarithm of the number of traded, multiplied by the contract size and the settlement price. t-statistics are reported in parenthesis. ***, **, * indicate significance at 1%, 5%, and 10% respectively. Our sample period is from January 2009 to September 2021. The number of observations is 153.

**Table 3.14: Brent trading volume response to UMP surprise by direction - bank cross-border claims on Latin America EMEs**

| | (I) | (II) | (III) | (IV) | (V) |
|---|---|---|---|---|---|
| | **IPI** | **CPI** | **VIX** | **Local claims Latin America EMEs** | **TV** |
| $IPI_{t-1}$ | **0.16*** | 0.00 | 0.14 | -1.50 | **1.68**** |
| | ( 1.88) | (-0.20) | ( 0.13) | (-1.18) | ( 2.10) |
| $CPI_{t-1}$ | 0.51 | **0.43***** | 6.52 | 10.75 | 6.62 |
| | ( 1.16) | ( 5.51) | ( 1.22) | ( 1.64) | ( 1.60) |
| $VIX_{t-1}$ | **-0.01**** | -0.0003 | **0.76***** | 0.10 | **-0.10**** |
| | (-2.06) | (-0.43) | ( 13.8) | ( 1.52) | (-2.31) |
| $LocalClaimsLatinAmericaEMEs_{t-1}$ | 0.004 | **-0.002*** | **0.12**** | **0.71***** | 0.0004 |
| | ( 1.01) | (-1.93) | ( 2.20) | ( 10.7) | ( 0.00) |
| $TV_{t-1}$ | -0.01 | **-0.002**** | -0.04 | 0.09 | **0.82***** |
| | (-1.35) | (-2.31) | (-0.91) | ( 1.57) | ( 22.2) |
| $Constant$ | 0.15 | **0.04**** | 1.67 | **-2.43*** | **4.52***** |
| | ( 1.53) | ( 2.27) | ( 1.39) | (-1.66) | ( 4.90) |
| $PositivePolicySurprise_t$ | -0.12 | -0.08 | 5.12 | 7.04 | -6.31 |
| | (-0.14) | (-0.51) | ( 0.50) | ( 0.57) | (-0.80) |
| $PositivePolicySurprise_{t-1}$ | -0.04 | -0.03 | -1.78 | -1.21 | -1.47 |
| | (-0.09) | (-0.42) | (-0.33) | (-0.18) | (-0.35) |
| $NegativePolicySurprise_t$ | 0.29 | -0.03 | -5.02 | 1.00 | -3.53 |
| | ( 0.55) | (-0.35) | (-0.76) | ( 0.12) | (-0.69) |
| $NegativePolicySurprise_{t-1}$ | 0.15 | -0.22 | 3.19 | 10.26 | -12.78 |
| | ( 0.17) | (-1.48) | ( 0.31) | ( 0.82) | (-1.62) |
| $R^2$ | 0.09 | 0.29 | 0.73 | 0.51 | 0.86 |

*Notes: IPI* and *CPI* are measured at monthly frequency in first logarithmic differences. *VIX* is measured at monthly frequency in logs. The global liquidity indicator is measured in first difference of quarterly data. Monthly $TV$ is measured as the natural logarithm of the number of traded, multiplied by the contract size and the settlement price. t-statistics are reported in parenthesis. ***, **, * indicate significance at 1%, 5%, and 10% respectively. Our sample period is from January 2009 to September 2021. The number of observations is 153.

**Table 3.15: Brent trading volume response to UMP surprise by direction - bank cross-border claims on Latin America EMEs**

| | (I) | (II) | (III) | (IV) | (V) |
|---|---|---|---|---|---|
| | **IPI** | **CPI** | **VIX** | **Cross-border claims Central Europe EMEs** | **Return** |
| $IPI_{t-1}$ | 0.03 | -0.02 | 0.72 | -0.30 | **-1.00**** |
| | ( 0.38) | (-1.63) | ( 0.69) | (-0.42) | (-2.16) |
| $CPI_{t-1}$ | **-1.00**** | **0.29***** | 2.76 | -2.07 | -2.44 |
| | (-2.46) | (3.55) | (0.49) | (-0.53) | (-0.98) |
| $VIX_{t-1}$ | -0.002 | 0.001 | **0.79***** | -0.04 | **0.06***** |
| | (-0.47) | ( 0.84) | ( 16.7) | (-1.26) | ( 2.86) |
| $Cross-borderClaimsCentralEuropeEMEs_{t-1}$ | **-0.01*** | -0.0004 | **0.29***** | **0.70***** | **-0.15***** |
| | (-1.70) | (-0.31) | ( 3.00) | ( 10.5) | (-3.60) |
| $Return_{t-1}$ | **0.09***** | **0.01***** | -0.09 | 0.17 | **0.41***** |
| | ( 6.32) | ( 4.40) | (-0.44) | ( 1.18) | ( 4.41) |
| $Constant$ | 0.01 | 0.00 | **0.62***** | 0.11 | **-0.17**** |
| | ( 0.68) | (-0.24) | ( 4.55) | ( 1.14) | (-2.91) |
| $PositivePolicySurprise_t$ | 0.12 | -0.06 | 2.37 | -10.52 | 0.55 |
| | ( 0.16) | (-0.44) | ( 0.23) | (-1.55) | ( 0.12) |
| $PositivePolicySurprise_{t-1}$ | -0.44 | -0.08 | 0.47 | -1.01 | -1.94 |
| | (-1.14) | (-1.07) | ( 0.08) | (-0.27) | (-0.82) |
| $NegativePolicySurprise_t$ | 0.11 | -0.05 | -2.88 | -4.17 | -1.97 |
| | ( 0.22) | (-0.52) | (-0.44) | (-0.94) | (-0.69) |
| $NegativePolicySurprise_{t-1}$ | 0.29 | -0.21 | 3.51 | -3.22 | -3.63 |
| | ( 0.41) | (-1.50) | ( 0.35) | (-0.47) | (-0.82) |
| $R^2$ | 0.32 | 0.35 | 0.74 | 0.46 | 0.27 |

*Notes: IPI* and *CPI* are measured at monthly frequency in first logarithmic differences. *VIX* is measured at monthly frequency in logs. The global liquidity indicator is measured in first differences of quarterly data. t-statistics are reported in parenthesis. ***, **, * indicate significance at 1%, 5%, and 10% respectively. Our sample period is from January 2009 to September 2021. The number of observations is 153.

**Table 3.16: Brent trading volume response to UMP surprise by direction - bank cross-border claims on Latin America EMEs**

| | (I) | (II) | (III) | (IV) | (V) |
|---|---|---|---|---|---|
| | **IPI** | **CPI** | **VIX** | **Local claims Central Europe EMEs** | **Return** |
| $IPI_{t-1}$ | 0.03 | -0.02 | 0.67 | -0.59 | **-0.97**** |
| | ( 0.40) | (-1.63) | ( 0.64) | (-0.41) | (-2.08) |
| $CPI_{t-1}$ | **-1.07***** | **0.29***** | 3.53 | 6.90 | -3.08 |
| | (-2.63) | ( 3.63) | ( 0.63) | ( 0.89) | (-1.22) |
| $VIX_{t-1}$ | -0.002 | 0.001 | **0.78***** | -0.09 | **0.06***** |
| | (-0.53) | ( 0.97) | ( 16.6) | (-1.33) | ( 2.88) |
| $LocalClaimsCentralEuropeEMEs_{t-1}$ | 0.00 | 0.00 | **0.17***** | **0.68***** | **-0.07***** |
| | (-1.04) | (-0.92) | ( 3.51) | ( 10.2) | (-3.20) |
| $Return_{t-1}$ | **0.10***** | **0.01***** | -0.10 | -0.02 | **0.43***** |
| | ( 6.58) | ( 4.34) | (-0.50) | (-0.06) | ( 4.69) |
| $Constant$ | 0.01 | 0.00 | **0.64***** | 0.22 | **-0.17***** |
| | ( 0.79) | (-0.39) | ( 4.77) | ( 1.17) | (-2.87) |
| $PositivePolicySurprise_t$ | 0.08 | -0.06 | 2.01 | -2.44 | 0.39 |
| | ( 0.10) | (-0.39) | ( 0.20) | (-0.17) | ( 0.08) |
| $PositivePolicySurprise_{t-1}$ | -0.40 | -0.08 | -0.78 | -1.34 | -1.40 |
| | (-1.04) | (-1.02) | (-0.14) | (-0.18) | (-0.58) |
| $NegativePolicySurprise_t$ | 0.11 | -0.06 | -0.97 | -13.72 | -2.48 |
| | ( 0.23) | (-0.65) | (-0.14) | (-1.53) | (-0.85) |
| $NegativePolicySurprise_{t-1}$ | 0.25 | -0.23 | 6.69 | 14.40 | -4.76 |
| | ( 0.34) | (-1.60) | ( 0.67) | ( 1.04) | (-1.06) |
| $R^2$ | 0.31 | 0.35 | 0.75 | 0.48 | 0.25 |

*Notes: IPI* and *CPI* are measured at monthly frequency in first logarithmic differences. *VIX* is measured at monthly frequency in logs. The global liquidity indicator is measured in first difference of quarterly data. t-statistics are reported in parenthesis. ***, **, * indicate significance at 1%, 5%, and 10% respectively. Our sample period is from January 2009 to September 2021. The number of observations is 153.

**Table 3.17: Brent returns response to UMP surprise by direction - bank cross-border claims on Asia EMEs**

| | (I) | (II) | (III) | (IV) | (V) |
|---|---|---|---|---|---|
| | **IPI** | **CPI** | **VIX** | **Cross-border claims Asia EMEs** | **Return** |
| $IPI_{t-1}$ | 0.03 | **-0.02*** | 0.71 | -0.15 | **-1.02**** |
| | ( 0.34) | (-1.65) | ( 0.66) | (-0.78) | (-2.16) |
| $CPI_{t-1}$ | **-0.98**** | **0.29***** | 4.95 | **-1.81*** | -2.71 |
| | (-2.40) | ( 3.59) | ( 0.84) | (-1.71) | (-1.05) |
| $VIX_{t-1}$ | -0.004 | 0.0005 | **0.81***** | 0.00 | **0.04*** |
| | (-1.05) | ( 0.68) | ( 16.7) | (-0.45) | ( 1.75) |
| $Cross-borderClaimsAsiaEMEs_{t-1}$ | -0.04 | -0.003 | 0.15 | **0.64***** | **-0.34**** |
| | (-1.53) | (-0.53) | ( 0.42) | ( 10.1) | (-2.21) |
| $Return_{t-1}$ | **0.10***** | **0.01***** | -0.25 | **0.11***** | **0.47***** |
| | ( 6.74) | ( 4.54) | (-1.18) | ( 2.96) | ( 5.09) |
| $Constant$ | 0.01 | 0.00 | **0.52***** | 0.02 | -0.10 |
| | ( 1.40) | (-0.05) | ( 3.68) | ( 0.73) | (-1.57) |
| $PositivePolicySurprise_t$ | -0.14 | -0.08 | 5.52 | -1.38 | -2.20 |
| | (-0.19) | (-0.54) | ( 0.53) | (-0.74) | (-0.48) |
| $PositivePolicySurprise_{t-1}$ | -0.47 | -0.08 | 0.34 | -1.01 | -2.17 |
| | (-1.21) | (-1.10) | ( 0.06) | (-1.01) | (-0.89) |
| $NegativePolicySurprise_t$ | 0.25 | -0.04 | -5.38 | -0.72 | -0.28 |
| | ( 0.54) | (-0.44) | (-0.81) | (-0.60) | (-0.09) |
| $NegativePolicySurprise_{t-1}$ | 0.30 | -0.21 | 2.32 | -2.36 | -3.33 |
| | ( 0.42) | (-1.51) | ( 0.22) | (-1.27) | (-0.73) |
| $R^2$ | 0.32 | 0.35 | 0.72 | 0.48 | 0.23 |

*Notes: IPI* and *CPI* are measured at monthly frequency in first logarithmic differences. *VIX* is measured at monthly frequency in logs. The global liquidity indicator is measured in first difference of quarterly data. t-statistics are reported in parenthesis. ***, **, * indicate significance at 1%, 5%, and 10% respectively. Our sample period is from January 2009 to September 2021. The number of observations is 153.

**Table 3.18: Brent returns response to UMP surprise by direction - bank cross-border claims on Asia EMEs**

| | (I) | (II) | (III) | (IV) | (V) |
|---|---|---|---|---|---|
| | **IPI** | **CPI** | **VIX** | **Local Claims Asia EMEs** | **Return** |
| $IPI_{t-1}$ | 0.01 | **-0.03*** | 1.16 | -1.17 | **-1.20**** |
| | ( 0.07) | (-1.76) | ( 1.10) | (-0.50) | (-2.56) |
| $CPI_{t-1}$ | **-0.89**** | **0.30***** | 1.38 | **-36.55***** | -1.95 |
| | (-2.19) | ( 3.70) | ( 0.24) | (-2.87) | (-0.76) |
| $VIX_{t-1}$ | -0.0001 | 0.0007 | **0.77***** | -0.11 | **0.07***** |
| | (-0.03) | ( 1.06) | ( 15.9) | (-1.03) | ( 3.18) |
| $LocalClaimsAsiaEMEs_{t-1}$ | **-0.004**** | -0.0004 | **0.08***** | **0.76** | **-0.04***** |
| | (-2.40) | (-1.02) | ( 3.21) | ( 13.3) | (-3.40) |
| $Return_{t-1}$ | **0.10***** | **0.01***** | -0.14 | 0.34 | **0.44***** |
| | ( 6.54) | ( 4.40) | (-0.70) | ( 0.75) | ( 4.85) |
| $Constant$ | 0.00 | 0.00 | **0.63***** | 0.42 | **-0.18***** |
| | ( 0.48) | (-0.41) | ( 4.66) | ( 1.40) | (-2.93) |
| $PositivePolicySurprise_t$ | -0.17 | -0.08 | 8.28 | **51.22**** | -2.38 |
| | (-0.23) | (-0.58) | ( 0.83) | ( 2.32) | (-0.53) |
| $PositivePolicySurprise_{t-1}$ | -0.27 | -0.07 | -2.70 | 15.73 | -0.43 |
| | (-0.70) | (-0.89) | (-0.50) | ( 1.31) | (-0.18) |
| $NegativePolicySurprise_t$ | 0.09 | -0.05 | -3.07 | -18.36 | -1.75 |
| | ( 0.18) | (-0.59) | (-0.47) | (-1.28) | (-0.61) |
| $NegativePolicySurprise_{t-1}$ | 0.15 | -0.23 | 5.96 | 13.76 | -4.70 |
| | ( 0.20) | (-1.61) | ( 0.59) | ( 0.61) | (-1.05) |
| $R^2$ | 0.33 | 0.35 | 0.74 | 0.65 | 0.26 |

*Notes: IPI* and *CPI* are measured at monthly frequency in first logarithmic differences. *VIX* is measured at monthly frequency in logs. The global liquidity indicator is measured in first difference of quarterly data. t-statistics are reported in parenthesis. ***, **, * indicate significance at 1%, 5%, and 10% respectively. Our sample period is from January 2009 to September 2021. The number of observations is 153.

**Table 3.19: Brent trading volume response to UMP surprise by direction - bank cross-border claims on Latin America EMEs**

| | (I) | (II) | (III) | (IV) | (V) |
|---|---|---|---|---|---|
| | **IPI** | **CPI** | **VIX** | **Cross-border claims Latin America EMEs** | **Return** |
| $IPI_{t-1}$ | 0.04 | -0.02 | 0.53 | -0.34 | **-0.88*** |
| | ( 0.53) | (-1.56) | ( 0.50) | (-0.52) | (-1.95) |
| $CPI_{t-1}$ | **-1.23*** ** | **0.27*** ** | 7.55 | -3.53 | **-5.10** ** |
| | (-3.07) | ( 3.38) | ( 1.33) | (-1.01) | (-2.08) |
| $VIX_{t-1}$ | -0.003 | 0.001 | **0.81*** ** | **-0.07** ** | **0.05** ** |
| | (-0.78) | ( 0.80) | ( 17.5) | (-2.35) | ( 2.32) |
| $Cross-borderClaimsLatinAmericaEMEs_{t-1}$ | **-0.02** | -0.002 | **0.34*** ** | **0.66*** ** | **-0.20*** ** |
| | (-2.53) | (-1.48) | ( 3.15) | ( 9.73) | (-4.29) |
| $Return_{t-1}$ | **0.09*** ** | **0.01*** ** | -0.07 | 0.10 | **0.38*** ** |
| | ( 6.08) | ( 4.06) | (-0.33) | ( 0.76) | ( 4.20) |
| $Constant$ | 0.01 | 0.00 | **0.52*** ** | **0.20** ** | **-0.12** ** |
| | ( 1.13) | (-0.15) | ( 3.96) | ( 2.46) | (-2.16) |
| $PositivePolicySurprise_t$ | -0.09 | -0.08 | 6.78 | 1.33 | -1.90 |
| | (-0.13) | (-0.56) | ( 0.68) | ( 0.21) | (-0.44) |
| $PositivePolicySurprise_{t-1}$ | -0.42 | -0.08 | 0.05 | -1.65 | -1.71 |
| | (-1.10) | (-1.07) | ( 0.00) | (-0.49) | (-0.74) |
| $NegativePolicySurprise_t$ | 0.16 | -0.05 | -4.44 | -3.03 | -1.19 |
| | ( 0.34) | (-0.54) | (-0.69) | (-0.76) | (-0.42) |
| $NegativePolicySurprise_{t-1}$ | 0.19 | -0.23 | 4.96 | 5.15 | -4.57 |
| | ( 0.26) | (-1.63) | ( 0.49) | ( 0.83) | (-1.05) |
| $R^2$ | 0.34 | 0.36 | 0.74 | 0.46 | 0.29 |

*Notes: IPI* and *CPI* are measured at monthly frequency in first logarithmic differences. *VIX* is measured at monthly frequency in logs. The global liquidity indicator is measured in first difference of quarterly data. t-statistics are reported in parenthesis. ***, **, * indicate significance at 1%, 5%, and 10% respectively. Our sample period is from January 2009 to September 2021. The number of observations is 153.

**Table 3.20: Brent trading volume response to UMP surprise by direction - bank cross-border claims on Latin America EMEs**

| | (I) | (II) | (III) | (IV) | (V) |
|---|---|---|---|---|---|
| | **IPI** | **CPI** | **VIX** | **Local claims Latin America EMEs** | **Return** |
| $IPI_{t-1}$ | 0.03 | -0.02 | 0.57 | -1.61 | **-0.91**** |
| | ( 0.40) | (-1.54) | ( 0.54) | (-1.23) | (-1.96) |
| $CPI_{t-1}$ | **-1.15**** | **0.17**** | **11.71*** | 9.92 | **-7.75***** |
| | (-2.59) | ( 2.06) | ( 1.88) | ( 1.28) | (-2.85) |
| $VIX_{t-1}$ | -0.002 | **0.001*** | **0.77***** | 0.06 | **0.07***** |
| | (-0.65) | ( 1.71) | ( 15.8) | ( 0.93) | ( 3.23) |
| $LocalClaimsLatinAmericaEMEs_{t-1}$ | -0.001 | **-0.002***** | **0.14**** | **0.71***** | **-0.08***** |
| | (-0.23) | (-3.16) | ( 2.46) | ( 10.4) | (-3.51) |
| $Return_{t-1}$ | **0.10***** | **0.01***** | **-0.36*** | 0.11 | **0.56***** |
| | ( 6.86) | ( 5.32) | (-1.71) | ( 0.43) | ( 6.12) |
| $Constant$ | 0.01 | 0.00 | **0.61***** | -0.15 | **-0.18***** |
| | ( 0.98) | (-0.92) | ( 4.42) | (-0.90) | (-2.94) |
| $PositivePolicySurprise_t$ | 0.02 | -0.06 | 4.41 | 7.56 | -0.48 |
| | ( 0.02) | (-0.42) | ( 0.44) | ( 0.60) | (-0.10) |
| $PositivePolicySurprise_{t-1}$ | -0.42 | -0.08 | 0.17 | -2.59 | -1.78 |
| | (-1.09) | (-1.10) | ( 0.03) | (-0.38) | (-0.75) |
| $NegativePolicySurprise_t$ | 0.20 | -0.05 | -4.85 | 1.16 | -0.96 |
| | ( 0.42) | (-0.56) | (-0.74) | ( 0.14) | (-0.33) |
| $NegativePolicySurprise_{t-1}$ | 0.35 | -0.20 | 1.55 | 11.93 | -2.54 |
| | ( 0.48) | (-1.47) | ( 0.15) | ( 0.95) | (-0.57) |
| $R^2$ | 0.31 | 0.39 | 0.73 | 0.50 | 0.26 |

*Notes: IPI* and *CPI* are measured at monthly frequency in first logarithmic differences. *VIX* is measured at monthly frequency in logs. The global liquidity indicator is measured in first differences of quarterly data. t-statistics are reported in parenthesis. ***, **, * indicate significance at 1%, 5%, and 10% respectively. Our sample period is from January 2009 to September 2021. The number of observations is 153.

**Table 3.21: Brent trading volume response to UMP surprise by direction - bank cross-border claims on Latin America EMEs**

| | (I) | (II) | (III) | (IV) | (V) |
|---|---|---|---|---|---|
| | **IPI** | **CPI** | **VIX** | **Cross-border claims Euro AEs** | **TV** |
| $IPI_{t-1}$ | **0.15*** | -0.01 | 0.58 | -1.11 | **1.60**** |
| | (1.75) | (-0.41) | (0.55) | (-1.10) | (1.99) |
| $CPI_{t-1}$ | 0.42 | **0.48***** | 1.28 | **-9.93**** | **6.93*** |
| | (1.04) | (6.60) | (0.25) | (-2.05) | (1.79) |
| $VIX_{t-1}$ | -0.01 | 0.00 | **0.78***** | -0.05 | **-0.09**** |
| | (-1.51) | (-0.88) | (14.2) | (-0.96) | (-2.21) |
| $Cross-borderClaimsEuroAreaAEs_{t-1}$ | **-0.01*** | 0.00 | 0.10 | **0.67***** | -0.04 |
| | (-1.77) | (-0.23) | (1.56) | (10.5) | (-0.76) |
| $TV_{t-1}$ | -0.01 | **0.00**** | -0.04 | -0.04 | **0.82***** |
| | (-1.31) | (-2.37) | (-0.82) | (-0.81) | (22.3) |
| $Constant$ | 0.14 | **0.04**** | 1.55 | 1.02 | **4.50***** |
| | (1.42) | (2.37) | (1.29) | (0.88) | (4.89) |
| $PositivePolicySurprise_t$ | -0.28 | -0.08 | 7.33 | 6.01 | -7.02 |
| | (-0.34) | (-0.55) | (0.71) | (0.61) | (-0.89) |
| $PositivePolicySurprise_{t-1}$ | -0.02 | -0.04 | -1.44 | 1.49 | -1.44 |
| | (-0.04) | (-0.48) | (-0.26) | (0.28) | (-0.34) |
| $NegativePolicySurprise_t$ | 0.29 | -0.03 | -5.28 | -6.37 | -3.52 |
| | (0.54) | (-0.31) | (-0.80) | (-1.00) | (-0.69) |
| $NegativePolicySurprise_{t-1}$ | -0.01 | -0.23 | 5.25 | 3.68 | **-13.46*** |
| | (-0.01) | (-1.50) | (0.50) | (0.37) | (-1.70) |
| $R^2$ | 0.10 | 0.28 | 0.73 | 0.48 | 0.86 |

*Notes: IPI* and *CPI* are measured at monthly frequency in first logarithmic differences. *VIX* is measured at monthly frequency in logs. The global liquidity indicator is measured in first differences of quarterly data. Monthly $TV$ is measured as the natural logarithm of the number of traded, multiplied by the contract size and the settlement price. t-statistics are reported in parenthesis. ***, **, * indicate significance at 1%, 5%, and 10% respectively. Our sample period is from January 2009 to September 2021. The number of observations is 153.

**Table 3.22: Brent trading volume response to UMP surprise by direction - bank local claims on Euro AEs**

| | (I) | (II) | (III) | (IV) | (V) |
|---|---|---|---|---|---|
| | **IPI** | **CPI** | **VIX** | **Local claims Euro AEs** | **TV** |
| $IPI_{t-1}$ | **0.17**** | -0.01 | 0.71 | **-5.27***** | **1.53*** |
| | (2.04) | (-0.39) | (0.68) | (-3.27) | (1.91) |
| $CPI_{t-1}$ | 0.32 | **0.48***** | 1.04 | **-12.97*** | **7.10*** |
| | (0.79) | (6.59) | (0.20) | (-1.67) | (1.85) |
| $VIX_{t-1}$ | **-0.01*** | -0.001 | **0.75***** | 0.0001 | **-0.08*** |
| | (-1.91) | (-0.87) | (13.2) | (0.00) | (-1.82) |
| $LocalClaimsEuroAreaAEs_{t-1}$ | 0.001 | -0.00002 | **0.08**** | **0.70***** | -0.04 |
| | (0.48) | (-0.04) | (2.23) | (12.2) | (-1.28) |
| $TV_{t-1}$ | -0.005 | **-0.002**** | -0.02 | **-0.14*** | **0.81***** |
| | (-1.17) | (-2.32) | (-0.31) | (-1.80) | (21.6) |
| $Constant$ | 0.13 | **0.04**** | 1.06 | **3.17*** | **4.71***** |
| | (1.37) | (2.35) | (0.87) | (1.69) | (5.08) |
| $PositivePolicySurprise_t$ | -0.05 | -0.08 | 8.72 | 1.30 | -7.77 |
| | (-0.06) | (-0.53) | (0.85) | (0.08) | (-0.99) |
| $PositivePolicySurprise_{t-1}$ | -0.01 | -0.04 | -0.19 | -4.34 | -1.98 |
| | (-0.01) | (-0.49) | (-0.03) | (-0.51) | (-0.47) |
| $NegativePolicySurprise_t$ | 0.26 | -0.03 | -6.37 | -4.89 | -3.03 |
| | (0.49) | (-0.31) | (-0.97) | (-0.48) | (-0.60) |
| $NegativePolicySurprise_{t-1}$ | 0.18 | -0.22 | 4.79 | 4.58 | **-13.38*** |
| | (0.21) | (-1.48) | (0.47) | (0.29) | (-1.70) |
| $R^2$ | 0.09 | 0.28 | 0.73 | 0.66 | 0.86 |

*Notes: IPI* and *CPI* are measured at monthly frequency in first logarithmic differences. *VIX* is measured at monthly frequency in logs. The global liquidity indicator is measured in first differences of quarterly data. Monthly $TV$ is measured as the natural logarithm of the number of traded, multiplied by the contract size and the settlement price. t-statistics are reported in parenthesis. ***, **, * indicate significance at 1%, 5%, and 10% respectively. Our sample period is from January 2009 to September 2021. The number of observations is 153.

**Table 3.23: Brent trading volume response to UMP surprise by direction - bank cross-border claims on US**

| | (I) | (II) | (III) | (IV) | (V) |
|---|---|---|---|---|---|
| | **IPI** | **CPI** | **VIX** | **Cross-border claims US** | **TV** |
| $IPI_{t-1}$ | **0.17**** | -0.01 | 0.36 | **1.50*** | **1.68**** |
| | (2.11) | (-0.39) | (0.34) | (1.91) | (2.11) |
| $CPI_{t-1}$ | 0.56 | **0.49***** | 1.41 | **-9.98**** | **6.97*** |
| | (1.45) | (6.70) | (0.27) | (-2.62) | (1.80) |
| $VIX_{t-1}$ | **-0.01*** | -0.001 | **0.79***** | -0.06 | **-0.10**** |
| | (-1.78) | (-0.91) | (14.6) | (-1.50) | (-2.36) |
| $Cross-borderclaimsUS_{t-1}$ | **-0.03***** | -0.001 | 0.09 | **0.55***** | -0.04 |
| | (-4.09) | (-0.89) | (1.05) | (8.74) | (-0.67) |
| $TV_{t-1}$ | **-0.01*** | **-0.002**** | -0.03 | **-0.11***** | **0.81***** |
| | (-1.99) | (-2.48) | (-0.64) | (-3.02) | (21.9) |
| $Constant$ | **0.19**** | **0.04 **** | 1.32 | **2.77***** | **4.61***** |
| | (2.09) | (2.48) | (1.08) | (3.03) | (4.96) |
| $PositivePolicySurprise_t$ | -0.34 | -0.09 | 6.22 | -4.67 | -6.69 |
| | (-0.43) | (-0.60) | (0.60) | (-0.60) | (-0.85) |
| $PositivePolicySurprise_{t-1}$ | -0.19 | -0.05 | -0.80 | 0.58 | -1.74 |
| | (-0.45) | (-0.57) | (-0.14) | (0.14) | (-0.41) |
| $NegativePolicySurprise_t$ | 0.42 | -0.03 | -5.71 | 2.44 | -3.31 |
| | (0.82) | (-0.26) | (-0.85) | (0.49) | (-0.65) |
| $NegativePolicySurprise_{t-1}$ | 0.47 | -0.21 | 2.37 | -9.62 | -12.26 |
| | (0.59) | (-1.39) | (0.22) | (-1.23) | (-1.55) |
| $R^2$ | 0.18 | 0.28 | 0.72 | 0.42 | 0.86 |

*Notes: IPI* and *CPI* are measured at monthly frequency in first logarithmic differences. *VIX* is measured at monthly frequency in logs.. The global liquidity indicator is measured in first differences of quarterly data. Monthly $TV$ is measured as the natural logarithm of the number of traded, multiplied by the contract size and the settlement price. t-statistics are reported in parenthesis. ***, **, * indicate significance at 1%, 5%, and 10% respectively. Our sample period is from January 2009 to September 2021. The number of observations is 153.

**Table 3.24: Brent trading volume response to UMP surprise by direction - bank local claims on US**

| | **(I)** | **(II)** | **(III)** | **(IV)** | **(V)** |
|---|---|---|---|---|---|
| | **IPI** | **CPI** | **VIX** | **Local claims US** | **TV** |
| $IPI_{t-1}$ | **0.14*** | -0.01 | 0.46 | -1.47 | **1.53*** |
| | (1.76) | (-0.61) | (0.44) | (-1.20) | (1.94) |
| $CPI_{t-1}$ | 0.09 | **0.45***** | 3.17 | **-12.40**** | 5.01 |
| | (0.22) | (6.18) | (0.62) | (-2.08) | (1.30) |
| $VIX_{t-1}$ | **-0.01**** | -0.001 | **0.80***** | **-0.13**** | **-0.10**** |
| | (-2.14) | (-1.12) | (14.7) | (-2.05) | (-2.56) |
| $LocalClaimsUS_{t-1}$ | **-0.01***** | **-0.002**** | 0.05 | **0.68***** | **-0.08**** |
| | (-3.43) | (-2.54) | (1.06) | (11.7) | (-2.25) |
| $TV_{t-1}$ | **-0.01*** | **-0.002***** | -0.03 | -0.08 | **0.81***** |
| | (-1.80) | (-2.74) | (-0.66) | (-1.38) | (22.2) |
| $Constant$ | **0.19*** | **0.05***** | 1.32 | 2.22 | **4.79***** |
| | (1.96) | (2.74) | (1.08) | (1.56) | (5.25) |
| $PositivePolicySurprise_t$ | -0.18 | -0.09 | 5.73 | -6.18 | -6.78 |
| | (-0.23) | (-0.61) | (0.56) | (-0.51) | (-0.88) |
| $PositivePolicySurprise_{t-1}$ | -0.18 | -0.06 | -0.73 | -0.48 | -2.46 |
| | (-0.42) | (-0.76) | (-0.13) | (-0.07) | (-0.59) |
| $NegativePolicySurprise_t$ | 0.39 | -0.02 | -5.70 | 4.24 | -2.82 |
| | (0.76) | (-0.16) | (-0.85) | (0.54) | (-0.56) |
| $NegativePolicySurprise_{t-1}$ | 0.45 | -0.18 | 2.26 | -5.94 | -10.94 |
| | (0.55) | (-1.24) | (0.21) | (-0.49) | (-1.40) |
| $R^2$ | 0.15 | 0.31 | 0.72 | 0.57 | 0.86 |

*Notes: IPI* and *CPI* are measured at monthly frequency in first logarithmic differences. *VIX* is measured at monthly frequency in logs. The global liquidity indicator is measured in first differences of quarterly data. Monthly $TV$ is measured as the natural logarithm of the number of traded, multiplied by the contract size and the settlement price. t-statistics are reported in parenthesis. ***, **, * indicate significance at 1%, 5%, and 10% respectively. Our sample period is from January 2009 to September 2021. The number of observations is 153.

**Table 3.25: Brent returns response to UMP surprise by direction - bank cross-border claims on Euro AEs**

| | (I) | (II) | (III) | (IV) | (V) |
|---|---|---|---|---|---|
| | **IPI** | **CPI** | **VIX** | **Cross-border claims Euro AEs** | **Return** |
| $IPI_{t-1}$ | 0.03 | -0.02 | 0.81 | -1.18 | **-1.02**** |
| | (0.33) | (-1.57) | (0.75) | (-1.14) | (-2.11) |
| $CPI_{t-1}$ | **-1.05**** | **0.27***** | 3.91 | **-10.93*** | -3.42 |
| | (-2.55) | (3.36) | (0.66) | (-1.93) | (-1.30) |
| $VIX_{t-1}$ | -0.002 | 0.0004 | **0.80***** | -0.03 | **0.05**** |
| | (-0.60) | (0.67) | (16.5) | (-0.63) | (2.34) |
| $Cross-borderclaimsEuroAEs_{t-1}$ | -0.003 | 0.001 | 0.09 | **0.67***** | -0.03 |
| | (-0.71) | (0.64) | (1.34) | (10.3) | (-0.86) |
| $Return_{t-1}$ | **0.10***** | **0.01***** | -0.20 | 0.05 | **0.48***** |
| | (6.69) | (4.68) | (-0.97) | (0.23) | (5.07) |
| $Constant$ | 0.01 | 0.00 | **0.57***** | 0.09 | **-0.14**** |
| | (0.89) | (-0.03) | (4.09) | (0.65) | (-2.23) |
| $PositivePolicySurprise_t$ | -0.05 | -0.06 | 6.65 | 5.97 | -1.29 |
| | (-0.07) | (-0.39) | (0.64) | (0.60) | (-0.28) |
| $PositivePolicySurprise_{t-1}$ | -0.41 | -0.08 | -0.14 | 1.64 | -1.70 |
| | (-1.07) | (-1.10) | (-0.02) | (0.31) | (-0.69) |
| $NegativePolicySurprise_t$ | 0.20 | -0.04 | -5.24 | -6.50 | -0.74 |
| | (0.43) | (-0.49) | (-0.79) | (-1.02) | (-0.25) |
| $NegativePolicySurprise_{t-1}$ | 0.28 | -0.20 | 3.88 | 3.29 | -3.41 |
| | (0.39) | (-1.40) | (0.37) | (0.33) | (-0.73) |
| $R^2$ | 0.31 | 0.35 | 0.73 | 0.48 | 0.21 |

*Notes: IPI* and *CPI* are measured at monthly frequency in first logarithmic differences. *VIX* is measured at monthly frequency in logs. The global liquidity indicator is measured in first differences of quarterly data. t-statistics are reported in parenthesis. ***, **, * indicate significance at 1%, 5%, and 10% respectively. Our sample period is from January 2009 to September 2021. The number of observations is 153.

**Table 3.26: Brent returns response to UMP surprise by direction - bank local claims on Euro AEs**

| | (I) | (II) | (III) | (IV) | (V) |
|---|---|---|---|---|---|
| | **IPI** | **CPI** | **VIX** | **Local claims Euro AEs** | **Return** |
| $IPI_{t-1}$ | 0.04 | -0.02 | 1.11 | **-5.09***** | **-1.03**** |
| | (0.46) | (-1.57) | (1.04) | (-3.02) | (-2.11) |
| $CPI_{t-1}$ | **-1.12***** | **0.28***** | 4.88 | -13.04 | -3.80 |
| | (-2.75) | (3.54) | (0.86) | (-1.45) | (-1.47) |
| $VIX_{t-1}$ | -0.003 | 0.0004 | **0.75***** | 0.05 | **0.05**** |
| | (-0.87) | (0.60) | (14.1) | (0.65) | (2.24) |
| $LocalclaimsEuroAEs_{t-1}$ | 0.001 | 0.0001 | 0.09** | **0.73***** | -0.01 |
| | (0.45) | (0.22) | (2.46) | (12.7) | (-0.59) |
| $Return_{t-1}$ | **0.10***** | **0.01***** | -0.29 | -0.10 | **0.50***** |
| | (6.91) | (4.62) | (-1.41) | (-0.29) | (5.36) |
| $Constant$ | 0.01 | 0.00 | **0.71***** | -0.16 | **-0.15**** |
| | (1.15) | (-0.04) | (4.65) | (-0.67) | (-2.12) |
| $PositivePolicySurprise_t$ | 0.06 | -0.06 | 8.48 | 1.60 | -1.19 |
| | (0.08) | (-0.43) | (0.83) | (0.10) | (-0.25) |
| $PositivePolicySurprise_{t-1}$ | -0.41 | -0.08 | 1.30 | -2.32 | -1.91 |
| | (-1.05) | (-1.05) | (0.23) | (-0.27) | (-0.77) |
| $NegativePolicySurprise_t$ | 0.18 | -0.05 | -6.28 | -5.49 | -0.64 |
| | (0.39) | (-0.50) | (-0.96) | (-0.53) | (-0.21) |
| $NegativePolicySurprise_{t-1}$ | 0.37 | -0.21 | 3.92 | 2.78 | -3.10 |
| | (0.51) | (-1.47) | (0.38) | (0.17) | (-0.67) |
| $R^2$ | 0.31 | 0.35 | 0.73 | 0.65 | 0.20 |

*Notes: IPI* and *CPI* are measured at monthly frequency in first logarithmic differences. *VIX* is measured at monthly frequency in logs. The global liquidity indicator is measured in first differences of quarterly data. t-statistics are reported in parenthesis. ***, **, * indicate significance at 1%, 5%, and 10% respectively. Our sample period is from January 2009 to September 2021. The number of observations is 153.

**Table 3.27: Brent returns response to UMP surprise by direction - bank local claims on Euro AEs**

| | **(I)** | **(II)** | **(III)** | **(IV)** | **(V)** |
|---|---|---|---|---|---|
| | **IPI** | **CPI** | **VIX** | **Cross-border claims US** | **Return** |
| $IPI_{t-1}$ | 0.04 | -0.02 | 0.66 | 1.05 | **-0.98*** |
| | (0.52) | (-1.63) | (0.61) | (1.27) | (-2.03) |
| $CPI_{t-1}$ | **-0.87**** | **0.28***** | 4.42 | -15.47 | -3.68 |
| | (-2.21) | (3.49) | (0.75) | (-3.44) | (-1.40) |
| $VIX_{t-1}$ | -0.001 | 0.001 | **0.80***** | 0.00 | **0.05**** |
| | (-0.36) | (0.79) | (16.8) | (0.10) | (2.24) |
| $Cross-borderclaimsUS_{t-1}$ | **-0.02***** | 0.00003 | 0.09 | **0.59***** | -0.01 |
| | (-3.48) | (0.02) | (1.02) | (9.30) | (-0.40) |
| $Return_{t-1}$ | **0.10***** | **0.01***** | -0.23 | **0.30*** | **0.49***** |
| | (6.75) | (4.61) | (-1.11) | (1.89) | (5.24) |
| $Constant$ | 0.01 | 0.00 | **0.55***** | 0.01 | **-0.13**** |
| | (0.69) | (-0.17) | (3.98) | (0.13) | (-2.12) |
| $PositivePolicySurprise_t$ | -0.18 | -0.07 | 5.73 | -4.27 | -0.94 |
| | (-0.25) | (-0.47) | (0.56) | (-0.54) | (-0.20) |
| $PositivePolicySurprise_{t-1}$ | -0.50 | -0.08 | 0.52 | 0.55 | -1.85 |
| | (-1.35) | (-1.06) | (0.09) | (0.12) | (-0.75) |
| $NegativePolicySurprise_t$ | 0.30 | -0.04 | -5.61 | 1.73 | -0.68 |
| | (0.66) | (-0.48) | (-0.84) | (0.34) | (-0.23) |
| $NegativePolicySurprise_{t-1}$ | 0.54 | -0.21 | 1.31 | -10.94 | -2.76 |
| | (0.77) | (-1.49) | (0.12) | (-1.38) | (-0.59) |
| $R^2$ | 0.36 | 0.35 | 0.73 | 0.40 | 0.20 |

*Notes:IPI* and *CPI* are measured at monthly frequency in first logarithmic differences. *VIX* is measured at monthly frequency in logs. The global liquidity indicator is measured in first differences of quarterly data. t-statistics are reported in parenthesis. ***, **, * indicate significance at 1%, 5%, and 10% respectively. Our sample period is from January 2009 to September 2021. The number of observations is 153.

**Table 3.28: Brent returns response to UMP surprise by direction - bank local claims on Euro AEs**

| | (I) | (II) | (III) | (IV) | (V) |
|---|---|---|---|---|---|
| | **IPI** | **CPI** | **VIX** | **Local claims US** | **Return** |
| $IPI_{t-1}$ | 0.02 | **-0.03*** | 0.76 | -1.67 | **-1.04**** |
| | (0.24) | (-1.75) | (0.70) | (-1.32) | (-2.21) |
| $CPI_{t-1}$ | **-1.24***** | **0.27***** | 6.14 | **-14.90**** | **-4.54*** |
| | (-3.13) | (3.36) | (1.05) | (-2.18) | (-1.77) |
| $VIX_{t-1}$ | -0.003 | 0.001 | **0.81***** | -0.08 | **0.05**** |
| | (-0.79) | (0.79) | (17.0) | (-1.48) | (2.23) |
| $LocalClaimsUS_{t-1}$ | **-0.01***** | **-0.001*** | 0.05 | **0.69***** | **-0.05**** |
| | (-2.88) | (-1.77) | (1.03) | (12.0) | (-2.30) |
| $Return_{t-1}$ | **0.10***** | **0.01***** | -0.24 | 0.15 | **0.47***** |
| | (6.78) | (4.46) | (-1.12) | (0.62) | (5.13) |
| $Constant$ | 0.01 | 0.00 | **0.53***** | 0.26 | **-0.13**** |
| | (1.13) | (-0.16) | (3.88) | (1.60) | (-2.10) |
| $PositivePolicySurprise_t$ | -0.05 | -0.07 | 5.26 | -6.18 | -1.14 |
| | (-0.07) | (-0.53) | (0.51) | (-0.51) | (-0.25) |
| $PositivePolicySurprise_{t-1}$ | -0.51 | -0.09 | 0.61 | -0.24 | -2.21 |
| | (-1.34) | (-1.21) | (0.11) | (-0.03) | (-0.91) |
| $NegativePolicySurprise_t$ | 0.28 | -0.03 | -5.61 | 3.81 | -0.34 |
| | (0.62) | (-0.38) | (-0.84) | (0.49) | (-0.11) |
| $NegativePolicySurprise_{t-1}$ | 0.53 | -0.19 | 1.18 | -7.00 | -1.97 |
| | (0.75) | (-1.34) | (0.11) | (-0.57) | (-0.43) |
| $R^2$ | 0.35 | 0.36 | 0.73 | 0.57 | 0.23 |

*Notes: IPI* and *CPI* are measured at monthly frequency in first logarithmic differences. *VIX* is measured at monthly frequency in logs. The global liquidity indicator is measured in first differences of quarterly data. t-statistics are reported in parenthesis. ***, **, * indicate significance at 1%, 5%, and 10% respectively. Our sample period is from January 2009 to September 2021. The number of observations is 153.

## Appendix 3A.

### Table 3.1A: Description of the variables included in the analysis

| Variable | Definition | Data source |
|---|---|---|
| Settlement prices of Brent Crude Oil futures | | Eikon Reuters |
| Contracts traded of Brent Crude Oil futures | | Eikon Reuters |
| Global liquidity indicators | Cross-border claims and Local claims on AEs and EMEs | BIS |
| VIX | | CBOE |
| CPI US | | IMF |
| Industrial Production Index | economic indicator measuring real output for all facilities located in the US (manufacturing, mining, electric and gas utilities) | Federal Reserve Bank of St. Louis |
| US Treasury yields at 10-years maturity | daily zero-coupon yields (mnemonics "SVENY") | Gürkayna, Sack and Wright (2007). |

**Table 3.2A. Unconventional monetary policy FOMC announcements**

| Date | Program | Event | Description |
|---|---|---|---|
| 11/25/2008 | QE1 | FOMC statement | LSAP initially announced |
| 12/01/2008 | QE1 | Bernanke speech | suggestion of extending QE to Treasuries |
| 12/16/2008 | QE1 | FOMC statement | Target federal funds rate decreased |
| 01/28/2009 | QE1 | FOMC statement | Fed is ready to expand QE |
| 03/18/2009 | QE1 | FOMC statement | LSAP expanded |
| 08/12/2009 | QE1 | FOMC statement | Details about LSAP |
| 08/10/2010 | Q2 | FOMC statement | Fed announces plan to revinvest payments from GSE and MBS in longer-term treasuries |
| 08/27/2010 | QE2 | Bernanke speech | Talks about additional QE |
| 09/21/2010 | QE2 | FOMC statement | FOMC highlights low inflation |
| 10/12/2010 | QE2 | FOMC minutes | Additional accommodation needed |
| 10/15/2010 | QE2 | Speech (Indiana) | Fed Chairman remarks supported the market's expectation of additional Treasury purchases in the next FOMC |
| 11/03/2010 | QE2 | FOMC statement | QE2 announced |
| 08/09/2011 | Maturity Extension Program | FOMC statement | Fed announced interest rates to remain exceptionally low through mid-2013 |
| 08/26/2011 | Maturity Extension Program | Speech | Fed Chairman remarks suggested additional accommodation |
| 09/21/2011 | Maturity Extension Program | FOMC statement | Maturity Extension Program announced |
| 06/20/2012 | Maturity Extension Program | FOMC statement | Maturity Extension Program extended |
| 08/22/2012 | QE3 | FOMC minutes | Additional accommodation warranted |

**Table 3.2A. continued from previous page**

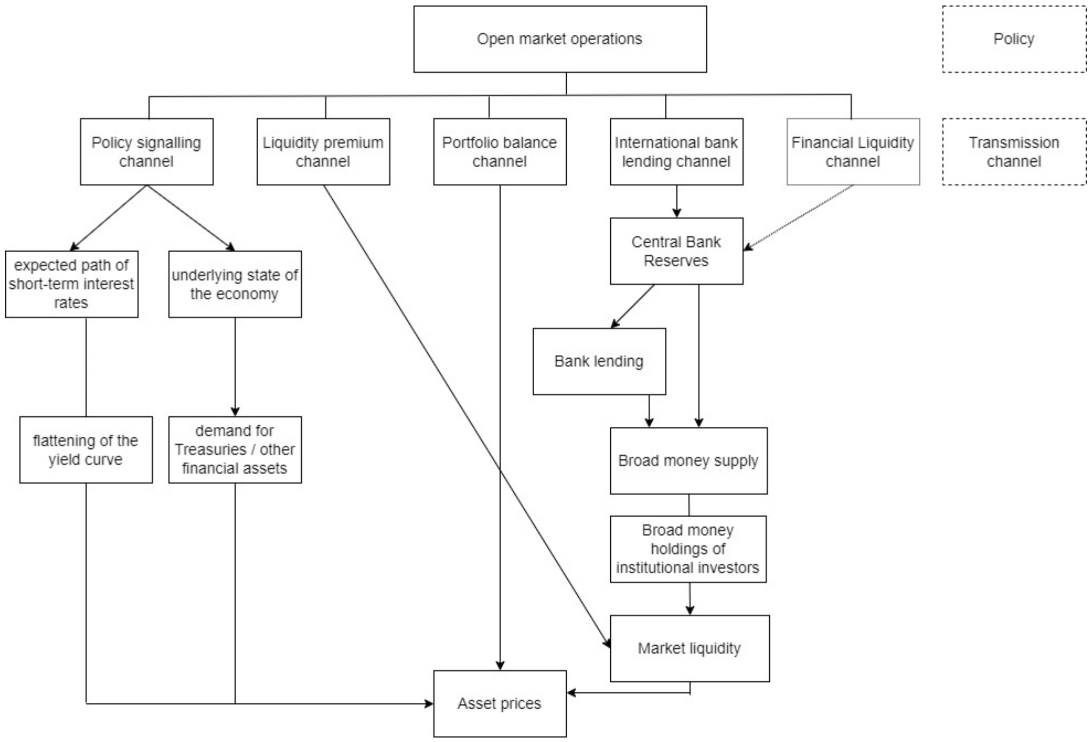
| Date | Program | Event | Description |
|---|---|---|---|
| 08/31/2012 | QE3 | Speech Jackson Hole | Fed Chairman's remarks about unconventional monetary policy tools |
| 09/13/2012 | QE3 | FOMC statement | QE3 announced |
| 12/12/2012 | QE3 | FOMC statement | QE3 expanded |
| 03/20/2013 | | FOMC statement | FOMC improved its assessment of economic and labour market conditions |
| 05/01/2013 | | FOMC statement | FOMC suggested a change in the pace of asset purchases |
| 05/22/2013 | | FOMC minutes and testimony | Fed Chairman suggests potential decrease in the pace of asset purchase |
| 06/19/2013 | | FOMC statement | FOMC assessment of economic and labour market conditions |
| 07/11/2013 | | FOMC minutes and speech | Fed Chairman suggests risks to growth and the labour market. |
| 10/30/2013 | | FOMC statement | FOMC assessment of economic and labour market conditions |
| 12/18/2013 | | FOMC statement | Fed announced a 75 billion dollar decline in the pace of asset purchases beginning in January |
| 10/29/2014 | | FOMC statement | FOMC statement announces termination of QE3 |
| 12/17/2014 | | FOMC statement | FOMC announces that it can be patient in beginning to normalize the stance of monetary policy |
| 04/18/2015 | | FOMC statement | FOMC announces that an increase in the target range for the federal funds rate remains unlikely at the April FOMC meeting |
| 06/14/2017 | | | Fed signals balance sheet normalization |
| 09/20/2017 | | | Fed states balance sheet normalization to begin in Oct |
| 11/01/2017 | | | Fed confirms balance sheet normalization is proceeding |
| 12/19/2018 | | | Fed Chair Jerome Powell statement on the balance sheet |
| 01/04/2019 | | | Powell indicates flexibility on balance sheet |

**Table 3.2A. continued from previous page**

| Date | Program | Event | Description |
|---|---|---|---|
| 01/30/2019 | | | Fed signals a more flexible approach to balance sheet normalization |
| 02/26/2019 | | | Powell says decision on balance sheet normalization to be made soon |
| 03/08/2019 | | | Powell says balance sheet endpoint likely to be higher than before the recession |
| 03/20/2019 | | | Fed announces intent to slow its balance sheet winddown and then to end it |
| 07/31/2019 | | | FOMC announces end to balance sheet winddown two months earlier than previously indicated |
| 19/11/2019 | | | FOMC reaffirms Fed's intention to conduct policy that provides for an ample supply of reserves that does not require active management |
| 03/15/2020 | QE4 | | In addition to cutting the federal funds rate to zero, the Fed also announced a new round of QE |
| 11/03/2021 | | | Fed Announces that it will Reduce Pace of Asset Purchases |

*Notes:* The FOMC announcement dates are taken from Fawley and Neely (2013), Bowman Londono and Sapriza (2015) and Swanson (2021). We obtain the dates of the remaining FOMC meetings from the Federal Reserve Board. The table consists of all FOMC announcements during the zero-bound period. The complete sample for the unconventional policy period, which includes these LSAP announcements as well as other announcements following FOMC meetings, consists of a total of 66 observations.

**Figure 3.1A: Transmission channels of unconventional monetary policy**




*Notes:* The figure portrays the primary transmission channels of US unconventional monetary policy to asset prices (policy signalling, liquidity premium, portfolio balance sheet), as well as our proposed transmission mechanisms (international bank-lending, financial-liquidity).

# Concluding remarks

During the last decades, global economic activity has been influenced by developments in the commodity market which have often coincided with shifts in global liquidity. One of the main drivers of global liquidity is monetary policy. Crucially, the relationship between monetary policy and the commodity market can both stabilise and disrupt the economy under particular conditions. The recent shift in the intermediation of international finance referred to as the "second phase of global liquidity" and its influence on this relationship has received relatively little attention. This thesis fills this gap and presents a thorough empirical investigation of liquidity and monetary policy in the commodity market.

The first study empirically examines the effect of the 2016 US PMMFs regulation on the crude oil spot market. This reform led to an increase in short-term dollar borrowing costs and the oil sector became particularly susceptible to disruptions in the global funding market due to a post-financial crisis debt expansion which far outpaced other commodity industries. The study proposes two channels through which US dollar funding shocks brought by deteriorating US dollar credit conditions in the US PMMFs industry can be transmitted to oil companies: an indirect channel through cross-border bank flows and a direct channel through PMMFs. Building on the global crude oil market SVAR model of Killian and Murphy (2014), we find that tighter PMMFs funding conditions affect the crude oil market via cross-border bank flows. Specifically, the paper documents that tighter PMMFs funding conditions generate a lagged decrease in the real price of crude oil and a lagged increase in oil production, which is driven primarily by a fall in certificates of deposits issued by global banks. In addition, the study finds supporting evidence that the US nominal effective exchange rate acts as a complementary transmission channel for the negative funding shock to the real price of oil.

The second study provides an empirical investigation into a novel liquidity-based transmission channel of monetary policy to the commodity futures market. The objective of the study is to explain the heterogeneity in the response of commodity futures price to monetary policy, identified in related literature, through a new microstructure channel based on the opportunity cost of holding money arising from the process of financialization of commodities and the observation that trading volume varies sensibly across commodity futures. First, the study finds the trading volume of individual commodity futures to decrease following target surprise increases. Second, the study shows that the mechanism through which policy rate changes are transmitted to the price of commodities is a change in the financial liquidity of individual commodity futures, as measured by the trading volume, with the strength of the mechanism depending on the liquidity of the asset. Therefore, the liquidity-based transmission channel proposed by Lagos and Zhang (2020) is not confined to the stock market and also holds for the commodity futures market.

The third study examines the nature of the transmission of UMP to the Brent crude oil futures market. At the macro level, the paper explores the international bank-lending channel of UMP via EMEs, while at the micro level, the paper investigates the financial liquidity-transmission channel of Lagos and Zhang (2020). Employing a hybrid model, which combines the traditional VAR framework with a high-frequency identification approach of monetary policy surprises, our findings document that a perceived expansionary monetary policy reduces trading activity in the Brent crude oil futures market and the returns of Brent crude oil futures via international bank local claims on Asia EMEs. Further, we find that a perceived contractionary monetary policy negatively affects trading activity in Brent futures market, bypassing the proposed international bank lending channel. This latter finding supports the financial liquidity-transmission channel of Lagos and Zhang (2020).

This thesis provides important contributions to the literature on liquidity, monetary policy, and the commodity market, illustrating the influence of US dollar funding disruptions brought by PMMFs on the crude oil spot market, within chapter one and the transmission of monetary policy via financial liquidity on the commodity futures market, within chapter two. Within chapter three, the thesis explores the international bank-lending channel of UMP to the Brent crude oil futures market. The thesis also documents the importance of our findings for policy makers and market participants, and its relevance to the current economic conditions and the global economic outlook.

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