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Abstract

This paper estimates a nonlinear Threshold-VAR to investigate if a Keynesian liquidity trap due to a speculative motive was in place in the U.S. Great Depression and the recent Great Recession. We find clear evidence in favor of a breakdown of the liquidity effect after an unexpected increase in M2 in the 1921-1940 period. This evidence, which is consistent with the Keynesian view on a liquidity trap, is shown to be state contingent. In particular, it emerges only when a speculative regime identified by high realizations of the Dow Jones index is considered. A standard linear framework is shown to be ill-suited to test the hypothesis of a Keynesian liquidity trap. An investigation performed with the same data for the period 1991-2010 confirms the presence of a liquidity trap just in the speculative regime. This last result emerges significantly only when we consider the federal funds rate as the policy instrument and we model the Divisia M2 measure of liquidity.

JEL classification: B22, C52, E52, N12, N22

Keywords: Keynesian liquidity trap, threshold VAR, monetary and financial cliometrics, Great Depression, Great Recession

1 Introduction

In his *General Theory of Employment, Interest and Money*, Keynes (1936) refers to a liquidity trap as an episode characterized by the insensitivity of nominal interest rates with respect to changes in money supply. According to Keynes, this insensitivity could be due to speculators operating in the financial markets.¹ The reasoning goes as follows. Suppose a central bank aims at lowering the short-term nominal interest rate on Government securities (a proxy for the intermediate monetary policy target) in order to lower longer terms rates and stimulate economic activities. A standard way to do it is to buy Government securities to raise their price and, therefore, decrease the corresponding interest rate. How could speculators react to this policy move? If after the policy move prices are considered "normally high" by speculators, some of them will predict future prices to be higher, and some other speculators - perhaps because of a different information set available, or a different ability to process information conditional on a given information set - will predict them to be lower. The former ones will then buy assets today to enjoy (expected) capital gains, while the latter ones will do the opposite. Depending on the relative strength of the demand vs. supply of assets, the aggregate effect of speculators' moves on asset prices (and, with an opposite sign, on interest rates) could be zero, positive, or negative, but it will not be large. Suppose instead that, after the monetary policy move, speculators believe that prices are "abnormally high". Likely, most speculators will expect future prices to be lower. Then, they will sell assets today, leading the supply of assets to largely exceed demand. As a result, prices will be driven downward, and interest rates will consequently go up. Hence, when prices are "abnormally high", an expansionary monetary policy move will most likely be counterbalanced by the infinite (or close to) money demand elasticity due to speculators' desire to sell bonds and hold cash and, as a consequence, it will be unable to drive interest rates downward.²

The reasoning presented above describes a two-regime world. In presence of "normal" prices and interest rates levels, speculators would likely form heterogeneous expectations over the future course of prices. Some agents would expect future prices to be higher, while other agents would expect them to be lower. On aggregate, these

¹In Chapter 15 of Keynes' *General Theory of Employment, Interest and Money*, titled *The psychological and business incentives to liquidity*, Keynes states: "*The speculative motive is particularly important in transmitting the effects of a change in the quantity of money ...*" (p. 196)

²"*Finally, is the question of the relation between M_2 and r ...*" (Keynes, *General Theory of Employment, Interest and Money*, Chapter 15, p. 201). Notice that here r stands for a short-term interest rate. Our empirical exercise will deal with multiple interest rates, not just the short-term one.

agents' actions will not necessarily harm the ability of the central bank to influence short- and long-term rates via liquidity impulses. Differently, in presence of "abnormally high" prices (and "abnormally low" interest rates), speculators will most likely form homogeneous expectations of falling prices in the future, and a liquidity trap will occur. Notably, this interpretation of the trap does not require interest rates to be close to zero. In fact, speculators can expect future prices to decrease even when the economy is far away from the Zero Lower Bound.³

This paper aims at econometrically testing if a Keynesian Liquidity Trap (KLT) was in place in two large scale crises, the Great Depression and the recent Great Recession. It does so by estimating a nonlinear Threshold Vector AutoRegressive (TVAR) model with U.S. data in order to discriminate between "speculative" periods, in which the U.S. stock market was over a threshold, and "normal" periods, characterized by more moderate stock market values. The huge swings occurred in the U.S. stock market (and therefore in asset prices) in these two periods are potentially informative on the possible changes and breakdowns of the money-interest rate relationship in these two crises. We use data regarding both crises to unveil empirical similarities and differences on the presence of a KLT in these two periods. Importantly, to maximize the degree of comparability of the results found for these two different historical periods, our baseline exercises focus on interest rates which are available for both crises and study the response of Baa and Aaa corporate bond yields, which are key indicators for entrepreneurs' investment decisions.

The TVAR framework is particularly suited to investigate our research question. First, it enables us to capture changes in the relationship between liquidity and interest rates which are likely to occur in an abrupt fashion in presence of variations in the underlying economic conditions (for instance, swings in asset prices). This is the reason why we prefer to use a TVAR model to an alternative framework such as the Smooth Transition VAR, which is typically employed to study variations in macroeconomic

³In *The New Palgrave Dictionary of Economics*, Eggertsson (2008) coins the following definition: "A liquidity trap is defined as a situation in which the short-term nominal interest rate is zero." This concept refers to the situation commonly known as the Zero Lower Bound. This theoretical definition focuses exclusively on a short-term interest rate, which is often considered as the policy rate. Our interest in this paper is empirical and it refers to the Federal Reserve's ability to influence a set of interest rates. From an empirical standpoint, the presence of the ZLB in our data (for instance, the December 2008-December 2010 data) is neither a necessary nor a sufficient condition for the KLT to be in place. In this sense, we share Basile et al.'s (2011) view expressed in the Introduction of their paper: "*An alternative view associated with Milton Friedman, Anna Schwartz, Karl Brunner, Allan Meltzer and a number of other writers - a list that ironically includes Keynes himself - is that a true liquidity trap requires that the entire spectrum of rates [...] must have reached low sticking points to conclude that the economy had entered a liquidity trap.*" *Finding that rates on short-term governments, or similar private assets, were near zero, in this view, is insufficient to establish a true liquidity trap.*"

relationships occurring more gradually. With respect to Markov Switching models, the TVAR enables us to focus on an observable transition variable - the Dow Jones stock market index, in our exercise - to discriminate between "normal" and "speculative" regimes. The use of an observable variable to determine the switch from a regime to another is crucial for our exercise given that we aim at establishing a connection between the KLT and the speculative regime possibly realizing on the U.S. financial markets.⁴ Finally, the TVAR enables us to endogenously estimate the threshold level in the switching variable that defines the two regimes. Given that this threshold is key to date the financial cycle in the U.S. to identify speculative times and normal periods, the possibility of having the data speak freely on the value of the threshold is obviously a plus for our empirical exercise.

Our main results are the following. First, we find clear evidence in favor of a KLT in the Great Depression sample. Our TVAR model documents a significant liquidity effect in normal times. In other words, an unanticipated increase in money supply - measured by the official M2 aggregate - is found to trigger a significantly and persistently negative response of all the interest rates we consider. Differently, after a positive money supply shock, interest rates remain still when the stock market index takes values over the estimated threshold. Importantly, the reaction of the long-term interest rates modeled in our analysis is found to be statistically different in the two regimes.

Second, and related to our first finding, we show that working with a linear model is likely to lead to misleading results if one wants to understand the relationship between liquidity and interest rates. A linear model estimated with the same data we use to estimate our TVAR framework returns evidence pointing to a standard liquidity effect. Indeed, the linear framework offers no visible sign of a liquidity trap. We show, however, that such linear model is not supported by the data. Following Altissimo and Corradi (2002), we do so by combining i) a testing procedure that allows to obtain an asymptotically valid decision rule in cases like ours in which the nuisance parameter (the threshold) is unknown and present only under the alternative hypothesis with ii) bounded-Wald and Lagrange Multiplier tests. These tests offer clear statistical support in favor of the TVAR framework. This evidence points to the need of employing a

⁴Auerbach and Gorodnichenko (2012), Mitnik and Semmler (2012), and Caggiano, Castelnuovo, Colombo, and Nodari (2015) propose a similar reasoning on the importance of using an observable variable as a transition indicator in nonlinear VAR analysis. They tackle a different research question, which is, the size of the fiscal multiplier along the U.S. business cycle. They employ a number of observable indicators of the business cycle to estimate fiscal multipliers in recessions and expansions. They document evidence of larger multipliers in recessions.

nonlinear framework to understand the relationship between money and interest rates in the periods we investigate.

Third, the breakdown in the liquidity effect and the evidence consistent with a KLT are not necessarily a by-product of our TVAR analysis. In fact, using the same data for the 1991-2010 period - a period characterized by speculative phases and the recent Great Recession - and the very same TVAR model, we find evidence in favor of muted responses of long-term nominal interest rates not only in speculative times but also in normal times. This evidence points to a breakdown of the money-interest rate relationship, at least as interpreted via the lens of a liquidity shock. However, two modeling assumptions are questionable here. First, modern empirical analysis of monetary policy shocks in the U.S. focus on the federal funds rate (as opposed to M2) as the main policy instrument used by the Federal Reserve to stimulate the economic system. A theoretical analysis supporting this choice is provided by Bernanke and Mihov (1998), while Christiano, Eichenbaum, and Evans (1999, 2005) propose empirical investigations along this line. Second, as argued by Barnett (1980), the official measure of M2 fails to account for the imperfect degree of substitution characterizing different assets featuring different returns. He proposes a measure which takes this issue into account, which he calls "Divisia money". As recently documented by Belongia and Ireland (2015a,b), the discrepancy between the official measure of money and Divisia money has become larger since the financial liberalizations implemented in the early 1980s. Hence, we also consider the Divisia M2 measure in our analysis. Conditional on these two modeling modifications, our results point to a KLT also for the Great Recession period. Similarly to the findings related to the Great Depression, the evidence in favor of the KLT is present only when a speculative regime is considered.

Our work extends those by Orphanides (2004), Hanes (2006), Landon-Lane and Rockoff (2011), and Swanson and Williams (2014), which are presented and discussed in Section 2. We anticipate here that our contribution extends theirs by considering a nonlinear multivariate model able to discriminate between normal and speculative times, a distinction which turns out to be particularly informative when searching for the presence of a KLT in the data. Moreover, we consider both the Great Depression and the Great Recession, therefore complementing the above cited contributions which deal with the former one only (the first three cited contributions), with the exception of Swanson and Williams' (2014), which deals with the Great Recession only.

The rest of the paper is organized as follows. In section 2, we discuss our contacts with the extant literature. Section 3 presents the TVAR model we use, and section 4

documents our results. Section 5 explores the played role of the federal funds rate and Divisia M2 for the identification of monetary policy shocks in the period containing observations related to the Great Recession. Section 6 documents a list of robustness checks and offers further discussions on our empirical analysis. Section 7 concludes.

2 Extant literature

Our paper joins previous contributions by Orphanides (2004), Hanes (2006), Basile, Landon-Lane, and Rockoff (2011), and Swanson and Williams (2014) on the case of a KLT in the United States. The first three studies refer to the Thirties and the Great Depression. Orphanides (2004) elaborates on a number of excerpts of the minutes of the Federal Open Market Committee (FOMC), which he combines with a visual analysis of the main macroeconomic series economists focus on to interpret monetary policy moves and their effectiveness (mainly, a number of nominal interest rates, inflation, various real activity indicators, and the stock market). Referring to a definition of KLT as ZLB, he focuses on the 1937-1938 period during which nominal interest rates were close to zero, and states that the economy was not caught in a liquidity trap, at least according to his narrative analysis of the FOMC minutes. Differently, our paper proposes a model-based analysis which considers an estimated nonlinear VAR with Great Depression and Great Recession data. With respect to Orphanides' (2004) narrative-only approach, we provide a formal test of the KLT hypothesis. Hanes (2006) calls into question the idea that a central bank loses the ability to influence interest rates through variations in reserve supply as soon as overnight rates go to zero. Focusing on the aftermath of the Great Depression, more precisely on the period running from 1934 to 1939, he argues that reserve supply could be directly related to longer-term rates when overnight rates are at zero. He explains that in this case (for a zero overnight rate) banks' demand for reserves can be defined by the role of cash as an asset free of interest-rate risk. He presents empirical evidence that when overnight rates were at the zero floor, reserve supply continued to affect longer-term interest rates in the U.S. over this period. With respect to Hanes (2006), whose analysis is based on a linear framework, our investigation tightly links the stock market to the switch from normal to speculative times, and it therefore unveils the breakdown of the liquidity-interest rate relationship which occurs when the latter regime is in place.

The papers closest to ours are probably Basile, Landon-Lane, and Rockoff (2011) and Swanson and Williams (2014). Basile et al. (2011) reexamine the debate on the

existence of a liquidity trap in the '30s by estimating a linear VAR which includes a bond yield, M2, and an indicator of general economic conditions. They find that a monetary policy shock exerts no significant impact on the Aaa and Baa bond rates. However, they find a significant response of the junk bond rate to a liquidity shock, and interpret their results against the KLT hypothesis. Our paper generalizes Basile et al.'s (2011) contribution by considering a nonlinear VAR framework which encompasses the linear VAR employed in their investigation. Following them, we also consider different interest rates with the aim of drawing robust conclusions as regards the impact of a liquidity shock. Interestingly, we find similar results to theirs with a linear version of our VAR. However, we show that a nonlinear VAR is preferred by the data, and that such nonlinear framework produces interest rate responses which are consistent with a KLT when financial markets are in a boom.⁵ Swanson and Williams (2014) employ macroeconomic announcements identified by appealing to high-frequency data to estimate the time-varying sensitivity of a large array of yields to such announcements. They do so by comparing an "unconstrained" period - 1990-2000 - to the one that is commonly labeled as ZLB-period (involving the Great Recession years and the following ones up to 2012). Yields which are equally sensitive to macroeconomic announcements in the two periods are labeled as unconstrained, i.e., not affected by the ZLB. Their main result is that the 1- and 2-year Treasury yields were unconstrained during the 2008-2010 period, a finding suggesting that, de facto, no ZLB was in place before 2010. Our results complement Swanson and Williams' (2014) analysis because we consider a nonlinear model suited to isolate periods featuring a KLT driven by speculative motives. Our results clearly point to the existence of a KLT during the Great Depression, a period which is not covered by Swanson and Williams' (2014) investigation. Our nonlinear multivariate framework delivers results consistent with Swanson and Williams' (2014) findings when non-speculative times are in place.

⁵A recent study by Basile, Landon-Lane, and Rockoff (2015) constructs a new monthly index of the yield on junk (high yield) bonds from 1910-1955, and it employs it to reexamine some of the key debates about the financial history of the interwar years. Using a linear framework, the authors find evidence against a liquidity trap in the second half of the 1930s. Basile et al.'s (2015) index is not available for the Great Recession period, something which forces us to keep it out of the current analysis for reasons pointed out in the text. However, we see the combination between a nonlinear approach like the one pursued in this paper and informative data like the index proposed by Basile et al. (2015) as a fruitful avenue for future research.

3 Data and Methodology

This section presents and discusses the data we deal with in our econometric analysis. Then, it provides a formal description of the TVAR model we use to test the hypothesis of the presence of a KLT in the context of the Great Depression and Recession.

3.1 Samples and data

Our analysis involves two large-scale financial crises. The Great Depression is studied by focusing on the commonly employed January 1921-December 1940 period. The hypothesis of a KLT in action during the recent Great Recession is investigated by working with the January 1991-December 2010 period. There are two main reasons for choosing this sample period. First, this sample features the same size as the Great Depression one. This choice is done to minimize the risk of having differences in results across crises merely driven by different sample lengths. Hence, the same number of data points in the two crises is considered. Second, Swanson and Williams (2014) find that the ZLB constraint likely started being binding in 2011. To complement the analysis by Swanson and Williams (2014), we investigate if a liquidity trap in the sense of Keynes, which does not necessarily require the presence of a binding ZLB, was in place before 2010.

The hypothesis of a KLT is tested by focusing on measures of liquidity and interest rates which are present in both recessions. This is done in order to maximize the degree of comparability of the results obtained with our TVAR model in the two investigated periods. The idea is that heterogeneous responses of the same interest rate between the two crises could hint to a different underlying transmission mechanism or, alternatively, to a breakdown of such a mechanism. Our measure of money supply is M2. As regards long-term interest rates, we use Moody's seasoned Aaa and Baa corporate bond yields. These are reference long-term yields in the U.S. financial market for prime and lower-medium grade borrowers. Given the willingness to accede to long-term loans to finance investment projects and durable consumption by entrepreneurs and households, these yields are of key-importance for the monetary policy transmission mechanism. Of course, such mechanism also features a short-term interest rate, which is typically influenced by movements in liquidity and it eventually transmits monetary policy impulses to the long-term rates. The federal funds rate has been considered the key short-term policy rate since the contribution by Bernanke and Mihov (1998). Given its availability for our Great Recession sample, we will use this rate as short-term one. Unfortunately,

the federal funds rate is available starting not earlier than July 1954. For the Great Depression, we will then use the 3-month Treasury Bill rate, which is the shortest-term policy rate available for that period. We also include in our VAR control variables such as industrial production, which we take as a proxy for real activity, and the producer price index, PPI, which is a measure of the price level. The presence of these last two variables is justified by our willingness to isolate changes in M2 which do not represent systematic policy responses to the evolution of the U.S. macroeconomic conditions.⁶ Finally, as a measure of financial activity, we use the Dow Jones index. This index is available in both periods, and it is therefore preferable to the S&P500, which is available just from the 1950 onward. The Dow Jones index is employed as a threshold variable in our TVAR to model the possibility of a nonlinear relationship between M2 and interest rates driven by a speculative motive. In particular, higher (lower) realizations of the Dow Jones index with respect to a threshold value will lead our TVAR to produce statistically insignificant (negative) responses of the interest rates we consider to an expansionary monetary policy shock.⁷ Importantly, the threshold value will be estimated together with the rest of the relevant TVAR coefficients, hence its value will be fully determined by the data. We use monthly data, which we mainly downloaded from the Federal Reserve Bank of St. Louis' website. Exceptions are the 3-month Treasury Bill rate and the M2 series for the Great Depression, and the Dow Jones index for the Great Recession. Following Ramey and Zubairy (2014), we construct the former series by merging the NBER series m13029a for the period 1920-1930, the NBER series m13029b for the period 1931-1933, and the series with mnemonic TB3MS from the Federal Reserve Bank of St. Louis's database as regard the period 1934 onwards.⁸

⁶Data availability forces us to use the PPI index instead of more conventional measures of the price level such as, for instance, the CPI index. Admittedly, the latter is probably closer to the concept of inflation which is targeted by the Federal Reserve. The producer price index for all commodities (PPI) is available starting from 1913M1. Differently, the consumer price index for all urban consumers (all times) (CPI) is available only starting from 1947M1. The correlation between the year-on-year inflation rates computed with these two price indexes in the common sample 1947M1-2015M11 is 0.80. Our online Appendix shows that the Great Recession results are robust when the CPI index and the PCE index are (alternatively) used as price indices in our vector.

⁷Notice that we identify speculative/normal times by using the stock price level (as opposed to the stock price growth rate) in order to follow Keynes' theoretical insights (according to which speculation is related to high stock prices).

⁸As pointed out above, we use the federal funds rate as a proxy for the policy stance during the Great Recession period. The correlation between the 3-month TBill rate and the federal funds rate during the period July 1954 (first available observation of the federal funds rate)-December 2010 (last observation in the Great Recession period we analyze) is 0.987. Our Appendix shows that our results are robust to the employment of the 3-month TBill rate as a proxy for the monetary policy instrument in the Great Recession sample.

As regards the M2 series for the first period we analyze, the source is Friedman and Schwartz (1963, pages 29-35). Finally, the Dow Jones index for the second period we analyze was downloaded from Datastream.

3.2 Threshold VAR model

We investigate the potential state-dependent effects of a money supply shock on selected interest rates during the two big crises we focus on by estimating the following TVAR model:

$$\mathbf{Y}_t = \begin{cases} \boldsymbol{\alpha}^H + \sum_{j=1}^k \mathbf{B}_j^H \mathbf{Y}_{t-j} + \boldsymbol{\varepsilon}_t^H & \text{if } z_{t-1} \geq z \\ \boldsymbol{\alpha}^L + \sum_{j=1}^k \mathbf{B}_j^L \mathbf{Y}_{t-j} + \boldsymbol{\varepsilon}_t^L & \text{if } z_{t-1} < z \end{cases} \quad (1)$$

where \mathbf{Y}_t is the vector of endogenous variables we model, $\boldsymbol{\alpha}^H$ and $\boldsymbol{\alpha}^L$ are vector of constants, H and L indicate - respectively - the "speculative" (related to "high" realizations of the stock price index) and "normal" (low realizations of the stock market) regimes, \mathbf{B}_j^H and \mathbf{B}_j^L , $j = 1, \dots, k$ stand for the coefficients capturing the dynamic evolution of the modeled variables in the two regimes, k stands for the number of lags of our framework, and $\boldsymbol{\varepsilon}_t^H \sim N(\mathbf{0}, \boldsymbol{\Omega}_H)$, $\boldsymbol{\varepsilon}_t^L \sim N(\mathbf{0}, \boldsymbol{\Omega}_L)$ are the regime-specific reduced form residuals. The switching variable in this TVAR framework is indicated by z_{t-1} . As pointed out above, when its value is above (below) a given threshold z , the model identifies the corresponding set of observations at time $t - 1$ as belonging to the high (low) speculative regime.⁹ This variable is assumed to be exogenous with respect to those embedded in our vector \mathbf{Y}_t . While being admittedly debatable, this assumption enable us to compute regime-specific linear impulse responses whose statistical properties are well known (for recent examples of papers working with this assumption in the context of fiscal and uncertainty shocks, see Mitnik and Semmler (2012), Auerbach and Gorodnichenko (2012), Berger and Vavra (2014), and Caggiano, Castelnuovo, and

⁹Our empirical model identifies two regimes, a regime in which stock market values are "high" and a regime in which stock market values are "low". A priori, high values of the stock market index we use (the Dow Jones) may or may not trigger a speculative behavior by agents operating in the financial markets. More importantly for our study, these two regimes may or may not feature different dynamic responses to a monetary policy shock. Our empirical model allows, but it does not necessarily require, for regime-specific impulse responses to be in place. As we will see, the data modeled here do point to different responses in these two regimes, something which is consistent with Keynes' reading on the impact of speculators' activity on a central bank's ability to influence long-term rates.

Groshenny (2014). Given that the switching variable enters the model with a lag, we believe the exogeneity assumption to be reasonable.¹⁰ The model is estimated by using the conditional least squares estimator as proposed by Tsay (1998).

Our vector of endogenous variables is the following: $\mathbf{Y}_t = [P_t, IP_t, M2_t, i_t]'$, where these variables are (in order of appearance) the producer price index, the industrial production index, M2, and a nominal interest rate. We consider a short-term interest rate, which is, the 3-month Treasury Bill rate in the Great Depression sample and the effective federal funds rate in the Great Recession sample. We also consider alternative version of the model in which the interest rate is the Baa yield, or the Aaa one.¹¹ Given that the price index, the industrial production index, and money are all trending variables, we model them in growth rates. Differently, interest rates enter the model in levels.

The variance-covariance matrix is modeled as regime-dependent. Hence, our model has the ability to estimate different on-impact reactions between the two regimes of the interest rates we model to an equally-sized money supply shock.¹² The threshold value that determines the high vs. the low speculative regime is estimated endogenously. Following Tsay (1998), it is chosen by minimizing the Akaike criterion. The identification of the threshold value is based on a trimming percentage equal to 40%. The money supply shock is identified via a Cholesky decomposition of the variance-covariance matrix $\mathbf{\Omega}$ of the residuals $\boldsymbol{\varepsilon}_t$ of the TVAR in each state (state-index dropped for brevity here). Hence, the ordering of the variables in our VAR is important for the identification of the liquidity shock. We order money supply after the price and quantity macroeconomic indicators to be consistent with the view of a money supply rule systematically moving the stock of nominal money in a contemporaneous fashion, as in Chowdhury and Schabert (2008). Differently, we do not allow for a systematic response of money to an interest rate shock in order to sharpen the identification of money supply shocks (those we aim at identifying in this paper to test for the presence of a KLT) as opposed to money demand shocks (which would call for the control of contemporaneous interest

¹⁰Of course, stock prices can very well be driven by *expectations* over future realizations of some or all the variables we model. Notice, however, that we model *realizations* (as opposed to expectations) of such variables.

¹¹For maximizing the degrees of freedom of our analysis, we focus on four-variate VARs and rotate in one interest rate at a time.

¹²Working with post-WWII U.S. data, Canova and Menz (2011) and Castelnovo (2012) show that money (demand, in their case) shocks exerted a time-varying role in shaping the U.S. business cycle and inflation. We see this evidence, and the fact that the dynamics at play in the two great crises we focus on in this paper may very well be different, as a rationale for the effects of money supply shocks to be modeled as state-dependent.

rates consistently with a standard money demand schedule). Moreover, our ordering implies that interest rates are allowed to react on impact (within a month), to a money supply shock, an assumption which seems to be plausible given that the interest rate is a "fast moving" variable, and that central banks typically react quickly to shocks affecting their goal variables.

We test for the null hypothesis of linearity versus the alternative of threshold VAR using the Bounded-Wald (BW) and the Bounded-LM (BLM) test statistics proposed by Galvão (2006). These test statistics are based on the asymptotic bounds computed by Altissimo and Corradi (2002). Following them, we use a test statistic based on asymptotic bounds equal to $(1/2 \ln(\ln T))$ and the maximum value of a Wald and LM statistic over a grid of possible values for the nuisance parameter, i.e., the threshold. A well known problem in testing for linearity vs. nonlinearity when the nuisance parameter is present only under the alternative and is not known is that the asymptotic distribution of the Wald (LM) statistic is non-standard. A strongly consistent rule, i.e., a rule such that both type I and type II errors approach zero asymptotically, is proposed by Altissimo and Corradi (2002). They propose to reject the null hypothesis of linearity whenever the value of the BW (BLM) statistic is greater than one. We will provide details on the outcome of this test in the next Section. We anticipate here that the linear model is clearly rejected in favor of our the nonlinear TVAR for both investigated periods.

4 Empirical results

This section documents the response of a range of interest rates to money supply shocks in normal vs. speculative times. Before doing so, it is informative to investigate what information one would get out of the estimation of a standard linear VAR. This exercise is conducted to highlight the marginal contribution that a nonlinear framework like the TVAR can provide us with.

4.1 Great Depression

Linear VAR. We begin the analysis of our results with the Great Depression period. The impulse response functions to a one percent money supply shock computed via a linear version of our model, along with 90% bootstrapped confidence bands, are shown in Figure 1. The on-impact response of the short-term interest rate is negative and statistically significant. This response is line with the liquidity effect predicted by a

wide variety of standard monetary policy model (see, e.g., Walsh 2010). In spite of the increase in liquidity simulated in this exercise, a somewhat puzzling negative response of industrial production realizes in the short-run, although the sign turns positive after a few months. Prices respond negatively (perhaps due to the just commented short-run response of industrial production) a few months after the shock before going back to their pre-shock level. The Aaa and Baa yields also react negatively to this liquidity shock.

According to this linear VAR, no KLT was in place during the Great Depression. But is a linear VAR the correct model to examine the effects on interest rates of a positive money supply shock in the sample at hand? To answer this question, we implement the BLM and BW tests proposed by Galvão (2006) and use the bound analysis advocated by Altissimo and Corradi (2002) to assess if the null hypothesis of a linear model is, according to these tests, rejected in favor of the alternative TVAR framework. In line with our request for the identification of the threshold value, our nonlinear tests are based on a trimming percentage equal to 40%.

Table 1 collects the figures relative to these two tests for three different models, i.e., a VAR featuring the 3-month short-term interest rate, one featuring the Aaa yield, and one modeling the Baa one. Both BLM and BW provide strong evidence against the null hypothesis of linearity. More precisely, we get the values BLM=1.177 and BW=1.219 for the model with the short-term interest rate, while we get the values BLM =2.108 (2.090) and BW= 2.387 (2.363) for the model with the Aaa (Baa) yield.¹³ According to Altissimo and Corradi (2002), values greater than one provide evidence in favor of a nonlinear, TVAR model. Consistently, we then estimate the TVAR model (1) presented in the previous section.

TVAR model: Estimation of the threshold. We then move to our two-regime framework. We are interested in identifying a "normal" regime, characterized by values of the Dow Jones index under a threshold, and a "speculative" regime, in which speculators sell their assets and hold liquidity because prices (and, therefore, the value of the Dow Jones) are "high", i.e., over a certain threshold. Once identified, these two regimes will potentially tell different stories on the role played by liquidity shocks for the conditional dynamics of the interest rates we are considering and, therefore, on the possible presence of a KLT in this historical period.

The threshold value is identified by searching for the value of our transition indicator

¹³The lag-length of each VAR is selected according to the Akaike criterion conditional on the linear framework. Our results are robust to different lag-length selections.

which minimizes the value of the Akaike (AIC) criterion of our estimated TVAR. The choice of the threshold value is performed by considering a "core" set of observations of the switching variable equal to 20% of the total sample. Consequently, each of the two regimes features at least 40% of the observations in the whole sample.¹⁴

For this period, and conditional on our baseline vector of modeled variables \mathbf{Y}_t , the AIC is minimized when the Dow Jones reaches a value of about 120, which is our selected threshold value. All observations above (below) the estimated threshold belong to what we define the high (low) speculative regime. Our estimated threshold indicates that the periods between 1925 and 1931 and between the end of 1935 and the end of 1937 are identified as speculative ones. Figure 2 depicts the so identified speculative regime periods (grey bars) along with the Dow Jones index.

TVAR model: Results. Figure 3 plots the estimated impulse response functions (point estimates, along with the 90% confidence bands) of the three interest rates we focus on to a positive (one percent) increase in money supply in the two identified regimes. The red solid line is the response in the high speculative regime, while the blue solid line represents the response in the low speculative regime (labeled as “normal times” in the Figure). The message related to these impulse responses is clear. In normal times, the response of all interest rates is negative and significant, and it is therefore in line with a standard liquidity effect in an economy in which the monetary policy impulse is effectively transmitted to the long-term rates. Vice versa, the responses associated to the speculative regime are all insignificantly different from zero. In other words, when the value of the Dow Jones index exceeds the estimated threshold, an exogenous increase in money supply is not followed by a significant response of any of the interest rates we consider. This evidence is fully consistent with the KLT mechanism discussed in the Introduction, which predicts an absence of a liquidity effect in presence of high prices today, which lead speculators to predict lower prices tomorrow and suggest them to sell their assets today, therefore contrasting the effect of an increase in liquidity by the monetary policy authorities on asset prices.

The responses displayed in Figure 3 seem to point to an economically different mechanism at work in the two regimes. But are these responses different (between regimes) also from a statistical standpoint? Table 2 reports the t-statistic for the

¹⁴We experimented with different trimming choices to isolate the observations we use for the estimation of the threshold and, conditional on it, the impulse responses to a liquidity shock in the two regimes. The choice of a two-sided 40% trimming turned out to be the one ensuring stability of our impulse responses.

difference between the estimated impulse responses in normal and speculative times.¹⁵ In particular, the Table reports the value chosen by searching for the highest value of this difference considered in absolute terms across all the horizons belonging to the two-year span we consider. Figures in bold identify differences between impulse responses in the two regimes which are statistically significant when considering a two-sided (one-sided) 10% (5%) statistical level, which is associated to a critical value equal to -1.64 . Evidence of a liquidity trap in the sense of Keynes would imply a negative and significant difference. Indeed, this is what we find for the three interest rates we consider.

All these results point to the possibility of a KLT during the Great Depression period.¹⁶

4.2 Great Recession

We now move to the second period of our interest, i.e., the 1991-2010 one, which comprises observations of the recent Great Recession. As for the previous period, we begin our analysis by estimating a linear version of our VAR model. Then, we will move to the nonlinear TVAR framework.

Linear VAR model: Results. For our baseline specification, we use the effective federal funds rate as short-term interest rate in the model. The remaining modeled variables (producer price index, industrial production index, and M2) are the same used in the Great Depression analysis. Figure 4 shows impulse response functions to a one percent money supply shock, along with 90% bootstrapped confidence bands for the linear model. The response of the effective federal funds rate is negative and (marginally) statistically significant at short horizon, again confirming a liquidity effect. Differently from the previous period, the remaining variables do not react, at least from a statistical viewpoint, to a positive money supply shock.¹⁷

¹⁵The test is based on a t-statistic for the statistical difference between regime-dependent responses, taken to be independent (as estimated on two different samples). In particular, we first compute bootstrapped standard deviations of the IRFs, for each horizon ahead. Then, the test-statistic is computed as follows: $t - stat_{t,i} = (IRF_{t,i}^L - IRF_{t,i}^H) / \sqrt{(st.dev.(IRF_{t,i}^L))^2 + (st.dev.(IRF_{t,i}^H))^2}$, where $IRF_{t,i}^r$ represents the estimated value of the impulse response at time $t = 0, \dots, 23$ for the interest rate i in regime r , $r \in \{L, H\}$.

¹⁶This finding is robust to the employment of a number of alternative interest rates available for this sample, including the commercial paper rate, the average rate on stock exchange call loans, the ninety-day money rate on stock exchange time loans. These impulse responses are not documented here because these rates are not available for the Great Recession analysis, but are available upon request.

¹⁷Indeed, this is not a new result in a sample largely contaminated by observations belonging to the "great moderation". For instance, see Boivin and Giannoni (2006) and Castelnuovo and Surico (2010).

TVAR model: Estimation of the threshold. We next turn to the TVAR specification. As before, we begin by pre-testing the null hypothesis of linearity versus the alternative hypothesis of a TVAR framework via the BLM and BW tests discussed above. Again, as shown by the figures reported in Table 1, both tests strongly reject the null hypothesis of linearity, with the BLM statistic reading 1.590 and the BW=1.699 - which is, both larger than unity - for the model featuring the federal funds rate, and BLM=1.529 (1.405) and BW=1.625 (1.478) for the framework modeling the Aaa (Baa) yield. We then estimate the threshold value that splits the sample in "speculative" and "normal" regimes. We do so by considering a filtered version of the Dow Jones stock market index in order to meet the requirement of a stationary switching variable (Tsay, 1998). Our results for this sample are then based on the Hodrick-Prescott filtered Dow Jones stock market index (with smoothing parameter λ fixed to 129,600 as suggested by Ravn and Uhlig, 2002).¹⁸ The value of the AIC criterion is minimized when the detrended Dow Jones reaches a value of about -10 , which is our selected threshold value. Figure 5 portrays the periods associated to the speculative regime as vertical gray bars. Our estimated threshold points to three main "speculative" periods, which are, the early 1990s, the 1999-2001 period, and the 2006-2008 one.

Notice that, according to our estimates, the observations of the December 2008-December 2010 period almost exclusively fall under the "normal times" regime. In this period, the ZLB was in place and it was binding as regards the federal funds rate. However, it is not clear that this ZLB period was associated to an inability by the Federal Reserve to influence longer-term rates. Swanson and Williams (2014) employ high-frequency data to estimate the sensitivity of a large array of yields to changes to the surprise components of macroeconomic announcements, and find 1- and 2-year yields to be affected by macroeconomic news (among which, monetary policy surprises) until 2010. Their interpretation for this result is that the ZLB becomes effective when the expected number of quarters for the federal funds rate to increase to 25 basis points or more is larger than five. According to Swanson and Williams (2014), when the expected duration of the ZLB is "short-enough" (five quarters or lower), the ability of the Federal Reserve to affect the term structure of interest rate

¹⁸Admittedly, filtering/detrending is a risky business, in that filters can produce spurious cycles (see Cogley (2008)) and the references cited therein). For this reason, given that the Dow Jones index does not display any clear trend in the 1921-1940 sample, we do not use the Hodrick-Prescott filter in our baseline exercise on the Great Depression. However, a robustness check conducted with the Hodrick-Prescott filtered version of the Dow Jones index for the 1921-1940 sample returns results in line with our baseline ones. Our Appendix documents the outcome of this robustness check.

is hardly affected. They also document that, after the announcement in August 2011 by the Federal Reserve to keep the funds rate near zero "at least through mid-2013" in expected terms, private sector's Blue Chip consensus expectations on the duration of the ZLB jumped up from five to seven quarters, and the ZLB became effectively binding. Interestingly, our econometric model classifies the December 2008-December 2010 period as "normal times", an empirical finding in line with Swanson and Williams' (2014). Section 6 documents that, when extending the Great Recession sample to 2016, our empirical results are line with Swanson and Williams' (2014) on the ZLB becoming binding around 2011.

TVAR model: Results. Figure 6 plots the impulse responses to a one percent increase in the growth rate of M2. First of all, the evidence in favor of a liquidity effect in normal times is scant at best. Second, no negative and significant response is found as regards the Baa and Aaa yields. In fact, while the response of the Aaa rate is statistically insignificant, the response of the Baa yield is significantly positive. Third, and in line with the results found for the Great Depression, the responses of all these rates in speculative times are found to be largely insignificant. Finally, and differently with respect to what found for the 1921-1940 sample, Table 2 points to the fact that while the responses of the short-term interest rate and the Aaa yield are statistically lower in the normal regime than in the speculative one, the response of the Baa yield is not.

Which are the drivers behind the different results we found over the two crises? The next Section discusses two possible elements that may be behind the change in our impulse responses, i.e., the policy instrument and the money measure, and it verifies their relevance in our empirical framework.

5 1991-2010 sample: The role of the federal funds rate and Divisia M2

The exercise conducted with 1991-2010 data reveals that different dynamics may be at work here with respect to those in place during the Great Depression. We discuss two elements that may be responsible for the differences in the impulse responses between the two periods we investigate.

First, since the contribution by Bernanke and Mihov (1998), the federal funds rate has consistently been considered as the main policy instrument managed by the Federal Reserve to influence the U.S. economy (see, e.g., Christiano et al. 1999, 2005). Hence,

it appears more appropriate to consider the federal funds rate as the relevant policy instrument in the 1991-2010 sample.

Second, the measure of M2 we employ in our empirical exercise, which is the official measure of M2 employed by the Federal Reserve, is constructed by considering the simple sum of monetary aggregates. Barnett (1980) shows that this definition of the stock of money may severely mismeasure the true flow of monetary services generated in a context where agents have access to different liquid assets bearing different yields and different ability to facilitate transactions, and which are therefore imperfect substitutes. He proposes an alternative monetary aggregate, called "Divisia", which tracks - under some assumptions - variations in the flow of monetary services in a more accurate manner. In particular, Belongia and Ireland (2015b) discuss how variations in the norms on banks' reserve requirements have rendered this measurement problem more acute since the early 1990s. They conduct an exercise à la Friedman and Schwarz with Divisia money for a sample running until 2013, and show that Divisia money is likely to have information content on top of the usually employed indicators of monetary policy stance. In a VAR context, Belongia and Ireland (2015a) show that the presence of Divisia monetary aggregates helps identify monetary policy shocks even when the federal funds rate is present. Hence, it seems appropriate to use Divisia M2 instead of the standard M2 measure of liquidity to test for the hypothesis of a KLT during the Great Recession.

We tackle these issues by controlling for these possible sources of misspecification of our TVAR in an incremental fashion. In particular, we first consider a shock to the federal funds rate, and then we consider such shock but in a model in which Divisia M2 replaces the standard measure of M2 in the vector. Given that the issue of interpretability of our results refers to the responses obtained with Great Recession data, in conducting our exercises we focus on the 1991-2010 sample. Given that the BW and BLM statistics indicate the rejection of the linear framework for all the cases we consider below (see figures reported in Table 1), we will only consider the nonlinear version of our VAR models from here onwards.

Federal funds rate as monetary policy instrument. We then move to the identification of an expansionary monetary policy shock by focusing on the federal funds rate. Following Christiano et al. (1999, 2005), we order "slow moving" variables like industrial production and prices before the federal funds rate, and the "fast moving" one (money and, alternatively, one of the two long-term yields we consider) after. Given the Cholesky structure of our structural TVAR, this ordering, at least as far as the

contemporaneous response of money is concerned, is consistent with the money growth rule à la McCallum (1990), which does not feature the nominal interest rate as variables liquidity responds to. Empirical evidence provided by Damette and Parent (2016a) for the Great Depression and by Chowdhury and Schabert (2008) for the post-WWII era offers support to this assumption. This triangular structure of the economy is also consistent with a money demand equation featuring the nominal interest rate as one of its drivers in the form of opportunity cost.

Figure 7 plots the responses to a 1% decrease in the federal funds rate. Two interesting findings arise. First, nonlinearities matter again here. In particular, the response of M2 is positive and significant only in normal times. In other words, there is a standard liquidity effect at work only when the stock price index is below its threshold. The responses of the Aaa and Baa rates are also insignificant. Table 2 reveals that a statistically relevant difference emerges when comparing the reactions estimated for the two regimes.¹⁹ However, while a liquidity effect arises in normal times, the response of long terms rates is negative after a few quarters but insignificant as regards the Aaa rate. Did the money-interest rates relationship breakdown during the 1991-2010 period? Before making this statement, it is important to control for the role that Barnett's (1980) measure of liquidity plays in this context.

Divisia M2. Figure 8 plots the impulse responses obtained by substituting the traditional measure of M2 with Divisia M2. The absence of a liquidity effect in speculative times and its presence in normal times are confirmed by this exercise, as well as the non-reactiveness of the long-term rates to an expansionary monetary policy shock in speculative times. Intriguingly, however, the responses of both Aaa and Baa yields are now statistically significant in normal times. This result corroborates Barnett's (1980) intuition on the need to use the correct measure of liquidity when it comes to understand money and the effects of money supply shocks, as well as Belongia and Ireland's (2015a,b) on the role that money may play in VAR analysis. This result lines up with studies in which the authors find that the substitution of the official measure of money with their Divisia counterparts may unveil a role for liquidity that official measures would not point to (Belongia (1996), Hendrickson (2014)). Finally, as documented by the figures reported in Table 2, the responses of the two long-term yields in normal times are statistically larger in normal times.

¹⁹Notice that Table 2 does not report the t-statistic of the federal funds rate. The reason is that, in this scenario and the next one, the federal funds rate is the policy variable. Hence, by construction, its on-impact response to its own shock is forced to be the same in both regimes.

Wrapping up, in a model with the federal funds rate used as the main monetary policy instrument and endowed with Divisia M2 to better control for the response of liquidity to an expansionary monetary policy shock, a KLT trap emerges in speculative times in years characterized by the Great Recession. Differently, the transmission of monetary policy shocks in normal times appears to work as predicted by textbook monetary policy models.

6 Robustness checks and further discussion

This Section is composed by two parts. The first part documents a list of robustness checks confirming our baseline results. The list of checks includes: i) the extension of the sample to 2016 to include all ZLB observations; ii) the computation of Generalized Impulse Response Functions, which take into account the endogeneity of the Dow Jones as transition indicator; iii) an exercise in which we study the possibility of asymmetric effects of monetary policy shocks; iv) an exercise in which we use the Price/Earning ratio as alternative transition indicator; v) a version of the model in which variables are modeled in levels; vi) an investigation focusing on the responses of 10-year and 30-year rates; and vii) a check on the robustness of our results to small perturbations of the threshold variable. The second part of this Section offers further discussion on our empirical model and findings.²⁰

6.1 Robustness checks

Great Recession and the ZLB. Our investigation on the Great Recession focuses on the 1991-2010 sample. It is of interest to extend the investigated period to include all the Zero Lower Bound (ZLB) phase experienced by the United States, which is, December 2008-December 2015. Figure 9 plots the regimes obtained by updating our sample until June 2016. Two results are worth noticing. First, for the common sample January 1991-December 2010, the dating of the speculative/normal times turns out to be unaffected. This result is reassuring as regards the regime dating in our baseline analysis. Second, the ZLB sample is characterized by two regimes. The first part of the ZLB sample, i.e., December 2008-December 2010, is classified as "normal times" by our model. Then, most observations fall under the "speculative" regime. When considering the first and last observations classified as speculative ones, the "specula-

²⁰We thank both referees for their questions and suggestions which led us to write this Section.

tive" regime spans the January 2011–November 2015 period. Finally, the remaining observations, i.e., those of the period December 2015–June 2016, are again classified as "normal times". The dating of the ZLB sample squares well with recent research on the ZLB and its effects on monetary policy shocks as well as historical events. Swanson and Williams (2014) estimate the time-varying sensitivity of yields to macroeconomic announcements using high-frequency data and compare that sensitivity to a benchmark period in which the zero bound is assumed not to be binding (the 1990–2000 period). They find that longer-term interest rates (in particular, 1- and 2-year ahead interest rates) remained unconstrained until late 2011, a phase in which the ZLB became binding for these rates too. Our Great Recession analysis is based on Aaa and Baa rates, which are risky, long-term rates. However, in spite of the differences in terms of methodology as well as interest rates considered, our dating of the speculative regime almost perfectly overlaps with Swanson and Williams' (2014) timing of the binding ZLB. We see this result as reassuring as regards the ability of our econometric model to discriminate between normal and speculative times. Second, our econometric framework dates the exit from the ZLB phase in December 2015. Indeed, this is the month in which Governor Janet Yellen implemented the lift-off of the federal funds rate. Hence, our model perfectly captures the timing of the lift-off. Are our baseline impulse responses robust to extending the sample to June 2016? Figure 10 reports the baseline impulse responses with corresponding 90% confidence bands along with the responses obtained by conducting the following two exercises. First, we re-estimate our baseline model and simply extend the sample to June 2016. Given that most of the ZLB sample features an effective federal funds rate close to zero, we run a second exercise and estimate a model in which we replace the federal funds rate with the shadow federal funds rate estimated by Wu and Xia (2016) and data until 2016. The shadow rate is the federal funds rate consistent with the term structure of interest rate which would have realized if the ZLB had not been in place and negative rates had been possible. This rate is often used to account for the effects of unconventional policy moves. Figure 10 shows that our baseline impulse responses are robust to extending the sample to 2016, even when accounting for the effect of unconventional policies.

GIRFs. A strong assumption entertained in our analysis is that of "absorbing" states. When we compute impulse responses, we assume that the economy cannot switch from the normal (speculative) times regime to the Speculative (Normal) times one. To the extent that an expansionary monetary policy shock hitting in normal times can lead to a stock price boom and, therefore, to trigger a speculative behavior by

financial market operators, this assumption is questionable. We then re-run our analysis by computing Generalized Impulse Response Functions (GIRFs) à la Koop, Pesaran, and Potter (1996), with the modification of considering an orthogonal structural shock, as in Kilian and Vigfusson (2011). GIRFs enable us to keep track of the evolution of the transition indicator, which is modeled as endogenous, in order to account for the impact that the shock hitting the economic system exerts to the transition indicator itself. Technically, this feature of the model makes us move from a Threshold VAR (TVAR) to a Self Exciting-Threshold VAR (SE-TVAR). The SE-TVAR model re-classifies, per each given horizon, the regime the economy finds itself in. Hence, GIRFs of a given economic regime (say, normal times) may very well end up being contaminated by the dynamics of another regime (speculative times in this example). Given that this modeling choice renders the model nonlinear also as regards the computation of the impulse responses to a monetary policy shock, such responses will depend on initial conditions, the sign of the shock, and the size of it. We then compute the impulse responses of the SE-TVAR model in speculative/normal times to an unexpected 1% increase of the money growth rate in the Great Depression sample and an unexpected 1% decrease in the federal funds rate in the Great Recession sample.²¹ It is of interest to see how different the so-computed GIRFs are with respect to impulse responses produced with conditionally-linear VARs in which the transition indicator is also modeled as endogenous but regimes are absorbing. Figures 11 and 12 show this comparison per each of the two regimes we focus on. Given that the recovery of the confidence bands with GIRFs is computationally intensive, we plot - for each regime - the point estimates of the GIRFs vs. the point estimates of the conditionally-linear responses and the corresponding confidence bands.²² While in theory GIRFs and conditionally-linear responses could be substantially different, Figures 11 and 12 show that, in our empirical exercise, they are very similar from a quantitative standpoint. We then conclude that our findings are not driven by the assumption of absorbing states we entertain in our baseline scenarios.

Asymmetric effects of monetary policy shocks. As stressed in the Introduction, our empirical analysis aims at understanding if and when monetary policy shocks can affect long-term rates. The KLT offers a reason for thinking that, a priori, these

²¹Per each initial condition, we compute 500 series of future shocks and the corresponding 500 sets of impulse responses to a monetary policy shock. Next, we compute the average across these 500 sets, which enables us to obtain initial condition-specific point estimates. Finally, we compute the regime-specific point estimate by averaging across initial conditions per each of the two regimes. A detailed presentation of the algorithm we follow to compute the GIRFs is available in our Appendix.

²²We thank an anonymous referee for this suggestion, which enabled us to substantially accelerate the computation of the empirical results for this exercise.

rates could react in normal times but not necessarily in speculative times. This is indeed what we find when estimating our empirical models. The logic of the KLT pushes us to dig deeper and analyze if asymmetric effects of monetary policy shocks are present within each one of the two regimes we analyze. In normal times, a positive shock to liquidity should lead to an increase in asset prices and a decrease in the nominal interest rate. If the increase in prices does not imply a switch to the speculative regime, policy shocks should affect longer terms rates. If an increase in prices does lead the economy to switch to the speculative regime, speculators will expect lower prices in the future, they will sell assets today, asset prices will fall, and interest rates would consequently go up, something which could offset the effects of policy shocks on long-term interest rates and make the economy fall in a liquidity trap. Differently, a policy shock in normal times leading to a reduction in liquidity would - according to the aforementioned mechanism - induce a fall in prices and an increase in interest rates. Hence, according to this theory, asymmetric effects of policy shocks could realize in normal times if an expansionary shock led asset prices to an abnormally high value. Turning to speculative times, an expansionary liquidity shock should drive asset prices up and interest rates down. But given that asset prices in speculative times are already high, speculators will form expectations of declining prices in the future, sell assets today, and offset the effects of monetary policy shocks on asset prices and interest rates. What about a contractionary liquidity shock? ²³ Such shock should lead to a decrease in asset prices and an increase in interest rates. If the decrease in prices is not large, speculators could still expect future prices to be lower. Then, they will sell assets today, and interest rates will go up even further. In this case, speculative times would feature an asymmetric effect of policy shocks, because expansionary policy shocks are predicted to have no effect on long-term rates while contractionary shocks are predicted to have it. However, if the decrease in asset prices is large and able to drive the economy to normal times, then speculators could expect future prices to be higher. In this case, they would buy assets today, and this action would (at least partly) offset the effect that monetary policy shocks have on long-term interest rates. Wrapping up, the one of asymmetric effects of monetary policy shocks in normal/speculative times is an empirical case. Unfortunately, a conditionally-linear analysis like our baseline one does not allow us to investigate asym-

²³In presence of the ZLB, a contractionary liquidity shock is an unrealistic case from an economic standpoint. However, speculative times and the ZLB do not necessarily go hand-in-hand. In fact, our empirical analysis find that the 2008-2010 period - i.e., the first years of the ZLB phase in the U.S. - was not a speculative one. For similar conclusions on the transmission of monetary policy shocks on long-term rates in this period, see Swanson and Williams (2014).

metries related to differently-signed monetary policy shocks because, by construction, the model returns symmetric responses to a - say - 1% increase/decrease in the growth rate of money. However, the computation of the GIRFs (described above) does in principle enable us to discriminate between positive and negative shocks and their effects. Following this strategy, Weise (1999) finds positive and negative monetary shocks to have nearly symmetric effects in an analysis that is not concerned with the distinction between speculative and normal times, while Balke (2000) finds that contractionary monetary policy shocks have larger effects on output than expansionary ones.²⁴ Figures 13 and 14 depict the GIRFs to a 1% increase/decrease of money supply growth and the federal funds rate for the Great Depression and the Great Recession, respectively. The Figures report the impulse responses to a contractionary liquidity shock with inverted sign, so that evidence of no asymmetric effects is obtained when the GIRFs to an expansionary and contractionary shock overlap. Figure 13 shows that no sign of asymmetric effects is found in the Great Depression no matter what the regime one considers is. Turning to the Great Recession (shown in Figure 14), mild evidence in favor of a quantitatively asymmetric response of the Baa rate in normal times is found, but the asymmetry is not statistically relevant.²⁵ Our results can be seen as consistent with a set of sub-cases of the cases described above. Another interpretation is that the mechanism in place is more complex than the one described above. Hence, our findings could serve as stylized facts modelers should refer to when writing models on the transmission mechanism of monetary policy shocks in normal and speculative times.

P/E ratio as transition indicator. Our baseline exercise is conducted by identifying speculative and normal times via the employment of the Dow Jones index. An alternative measure of overvaluation/undervaluation related to the financial market is the Price/Earning ratio (P/E henceforth). We then re-run our regressions by using

²⁴A different modeling strategy would be that of constructing monetary policy shocks and exploit the flexibility of nonlinear local-projections to discriminate between positive and negative realizations of the shocks and their effects. Riera-Crichton, Vegh, and Vuletin (2015) conduct an analysis along this line focused on the asymmetric effects of fiscal spending shocks. We do not follow this road because of the lack of a measure of monetary policy shocks for the Great Depression period.

²⁵Notice that GIRFs are able to capture asymmetric responses to differently signed shocks only to the extent that such shocks are able to force the system to switch regime. The shocks simulated in our empirical application are hardly able to force the economic system to switch regime. We then considered -/+3% shocks to money growth/the federal funds rate. The size of these shocks correspond to extreme realizations of the distribution of money growth/the federal funds rate. The results of these simulations (available upon request) turn out to deliver a very similar picture with respect to the one associated to the -1%/+1% shocks. Our results depend upon a reactivity of the Dow Jones to monetary policy shocks which is not large enough to induce asymmetry in our GIRFs.

this ratio as a transition indicator in both regimes.²⁶ For consistency with respect to our analysis conducted with the Dow Jones, we conduct an exercise with the unfiltered P/E ratio for the 1921-1940 sample, and with the Hodrick-Prescott filtered P/E ratio in the 1991-2010. However, the P/E ratio does not feature a distinct trend in the second period. Hence, we conduct another exercise in which we work with the unfiltered P/E ratio for the Great Recession sample. No matter what the treatment of the P/E ratio in the Great Recession period is, the impulse responses produced by the models involving the P/E ratio turn out to be statistically in line with our baseline ones. Our Appendix reports the impulse responses associated to these exercises.

Modeled variables: Growth rates vs. log-levels. Our baseline exercises model trending variables with growth rates, while interest rates are kept in levels. However, price and money can be cointegrated. If this is the case, working with growth rates could force our empirical models to neglect the role played by stochastic common trends. We re-estimate our models in (log-)levels to make sure that our baseline results are not driven by the omission of stochastic trends. Our Appendix documents that our findings are not driven by our choice of modeling trending variables with growth rates.

Other long-term interest rates. Our results are confirmed when using alternative long-term interest rates. In particular, our Appendix shows that the responses of the 10-year Treasury Bill rate and the 30-year fixed mortgage rate are similar to those of the Aaa and Baa yields. In normal times, the response of the 10-year Treasury Bill rate is actually borderline significant, while that of the 30-year mortgage rate is clearly negative and statistically significant. Differently, these rates do not significantly react in speculative times. Interestingly, our result point to the need of including long-term rates to better detect the effectiveness of monetary policy shocks. In fact, the Baa and Aaa yields modeled in our baseline analysis also feature a maturity longer than 10 years. In constructing the Baa and Aaa yields, Moody's tries to include bonds with remaining maturities as close as possible to 30 years, and it drops bonds if the remaining life falls below 20 years. Hence, it is not perhaps not surprising that our regressions involving the 30-year mortgage rate return similar indications to those including the Baa and the Aaa yields. Notice that this analysis is limited to the Great Recession because, to the best of our knowledge, the very same 10-year and 30-year rates are not available for the Great Depression period. For the Great Depression, we conduct an analysis by

²⁶We used Robert J. Shiller's "Cyclically Adjusted Price Earnings Ratio" available at http://www.econ.yale.edu/~shiller/data/ie_data.xls. This series is available at a monthly frequency from 1881. Hence, we can use it to analyze both our periods of interest.

focusing on a proxy of the 10-year rate, which is a mixture of the 8-year and the 12-year rate taken from the Banking and Monetary Statistics, Washington DC, 1943, Second Printing, August 1976 (Table 128). This rate confirms the substantial difference in normal vs. speculative times as regards the response of long-term rates to a monetary policy shock.

Small changes in the identified regimes. When conducting nonlinear analysis like ours, a natural question is: How robust are the results to small changes in the identified regimes? We then conduct two robustness exercises to check if perturbations to the estimated threshold, via which we identify the two regimes, lead to different results. Per each historical sample under scrutiny, we estimate the value of the threshold a) augmenting the observations used for the estimation by 20%, and b) reducing the observations used to estimate the threshold value by 20%. Our results turn out to be robust to these perturbations. The impulse responses associated to these checks are documented in our Appendix.

6.2 Further discussion

This part of the Section offers further discussion on our modeling strategies and results. In particular, we explain why we prefer to use a Cholesky identification scheme to alternatives such as sign restrictions, the narrative approach, local-projections, and high-frequency data. We also discuss the possibility of confounding speculative and normal times with financial booms and busts. Then, we defend our choice of using a stock market index as transition indicator as opposed to an interest rate. We briefly comment on why we believe that the stock market should be preferred to other markets if one wants to study speculative activities that have a large impact on the macroeconomic environment. We also comment on our choice of estimating the TVAR model using a subsample approach as opposed to a full-sample estimation, and on why we believe that our results are not driven by other possible sources of nonlinearities like financial volatility or the real business cycle. Finally, we offer a brief description on our estimated responses of prices and industrial production to monetary policy shocks.

Cholesky vs. alternative identification strategies: Sign restrictions. The assumption of a recursive economy which allows the policy instrument to contemporaneously respond to the state of the economy while affecting inflation and output with a lag is standard in the empirical macroeconomic literature (see, e.g., Christiano, Eichenbaum and Evans 1999, 2005). In the context of VAR analysis in which both money

and interest rates are present, recursive schemes have been used to identify money supply shocks (e.g., Favara and Giordani (2009)). However, an alternative based on the imposition of sign restrictions on the dynamic responses of a set of variables to one or more shocks has increasingly been used in VAR analysis to quantify the effects of macroeconomic shocks. For instance, Mountford and Uhlig (2009) identify the effects of fiscal policy shocks by imposing restrictions on the signs of the response of a taxes, fiscal spending, and a number of real activity indicators. Candelon and Lieb (2013) go a step further and use this strategy to analyze the effects of fiscal policy in good and bad times. While being a good idea in general, the identification of money supply shocks via sign restrictions presents some challenges. First, let us focus on the contemporaneous presence of money and an interest rate in the vector of variables we model. In normal times, a decrease in the short-term rate could be associated to an increase in output and inflation (as in a textbook new-Keynesian model) as well as to an increase in the quantity of money (thinking of a money-demand relationship). Hence, one could think of using these restrictions to identify a shock to the policy rate. But this set of restrictions would be exactly those one could impose to identify a liquidity (money supply) shock. In fact, such a shock could be thought of as able to increase liquidity, decrease the short-term interest rate, and induce a business cycle boom followed by a temporary inflationary phase. Therefore, in a vector like the one we focus on, sign restrictions would be unable to disentangle shocks to the policy rate and shocks to liquidity. Second, the identification of monetary policy shocks in speculative times would be challenging if pursued via sign restrictions. In presence of a KLT, interest rates should not respond to a monetary policy shock. For this prediction to be accounted for by the sign restrictions analysis, we would need to have impulse vectors featuring a zero in correspondence to the mapping between the monetary policy shock and the response of the interest rates modeled with our VAR.²⁷ Assuming a continuum of possible realizations $(-\infty, 0]$ of this cell, this would be a zero-probability event. Third, Paustian (2007) and Canova and Paustian (2011) show that sign restrictions may fail to return the true responses to a macroeconomic shock if this shock explains a too little share of the forecast error variance of the variables of interest. The identification of monetary policy shocks would

²⁷An impulse vector dictates the on-impact response of the variables modeled in a VAR analysis to a given shock. Sign restrictions can identify a set of vectors meeting the required set of signs imposed on the vector. The set of vectors is recovered by rotating matrices related to the reduced-form covariance matrix Ω of the residual, a reference typically being the one obtained via the Cholesky-factorization of the Ω matrix. Each rotation gives a novel impulse vector, and the signs of the coefficients of the impulse vector are checked to verify the admissibility of such vector in the set of those meeting the impose restrictions.

require the imposition of restrictions on the response of output. However, Altig, Christiano, Eichenbaum, and Lindé (2011) find monetary policy shocks to be responsible for only 9% of the movements of the real GDP at business cycle frequencies in the sample period 1982-2008. Justiniano and Primiceri (2008) document the time-dependence of the contribution of such shock to output growth in the post-WWII U.S. sample. They find that their largest realizations, which are estimated to occur in the mid-1970s and early-1980s, never exceed a contribution of 15% (median values) of the volatility of real GDP at business cycle frequencies. These are the reasons why, while being theoretically sound, sign restrictions may be problematic for the identification of monetary policy shocks in our analysis.

Cholesky vs. alternative identification strategies: Narrative approach, local projections, high frequency identification. A recent survey by Ramey (2016) lists a number of alternatives to Cholesky- or sign restriction-based identification of monetary policy shocks. Romer and Romer (2004) regress the federal funds rate on the Greenbook forecasts available at each FOMC meeting date and use the residuals as policy shocks. These shocks are used in a VAR context. A popular alternative is to use externally constructed shocks (in this case, monetary policy disturbances) in the context of local projections à la Jordà (2005). Local projections are a way to reduce the distortions associated to VAR analysis when the VAR is misspecified. Rather than estimating impulse responses based on nonlinear functions of the VAR parameters, local projections estimate regressions of the dependent variable (say, a nominal interest rate) at horizon $t + h$ on the dependent variable (the shock of interest) at time t and some controls. The estimated coefficient of the shock represents the impulse response of the dependent variable at time $t + h$ to a shock at time t . While being a clever procedure, the Jordà method can be meaningfully used just if an estimate of the shock of interest is available. Unfortunately, Greenbook data are available from 1967. Hence, these data does not allow us to construct a measure of liquidity shocks to analyze the Great Depression. For the very same reason, we cannot use this Greenbook data-based shocks as an instrument to implement the proxy-SVAR approach à la Stock and Watson (2012), Kliem and Kriwoluzky (2013), and Mertens and Ravn (2013a,b). Gertler and Karadi (2015) use high frequency identification methods combined with a proxy SVAR approach to investigate the effects of monetary policy shocks on macroeconomic variables. Policy shocks are surprises in federal funds future rates that occur on FOMC days. Given FOMC-related data limitation, Gertler and Karadi (2015) construct an instrument for a monetary policy shock which is available not earlier than 1979. As before, this is

something that renders the proxy-SVAR approach ill-suited for an analysis like ours which involves a sample like the one of the Great Depression. Our decision to work with a standard recursive identification scheme à la Christiano et al. (1999, 2005) is due to the reasons listed in this bullet point and in the previous one.

Speculative/normal times vs. booms/busts. The choice of the Dow Jones index in level implies that the regimes we capture are likely to encompass two distinct period within the cycle of the threshold variable. On the one hand, speculative times could be associated to stock market booms. On the other hand, normal times could go hand-in-hand with stock market busts. Are our impulse responses guided by stock market booms and busts, more than speculative/normal times? A simple way to empirically consider this hypothesis could be to estimate a four-regime model which separates the observations in the sample in four different regimes: Speculative/Booms times, Speculative/Busts times, Normal/Booms times, and Normal/Busts times. Before doing so, it is informative to check how many observations per each one of these four regimes are present in our Great Depression and Great Recession samples. To do so, we need a dating of the financial cycle. The literature proposes a number of papers dating stock market booms and busts. Bordo and Wheelock (2007) use a modified version of the Pagan and Sossounov's (2003) financial cycle-dating procedure to identify periods of rapidly rising stock market indices in ten different industrialized countries during the period 1915-2004. Working with 19th- and 20th-century U.S. data, Christiano, Ilut, Motto, and Rostagno (2010) identify financial panics via google searches (keywords: "panic of"). They define the peak associated with a particular financial panic as the year before the panic when the stock market reached a local maximum, and the trough before the peak as the year when the stock market reached a local minimum. Albuquerque, Eichenbaum, Papanikolaou, and Rebelo (2015) use a modified version of the Bry and Boschan (1971) algorithm to identify low-frequency swings in the stock market in the 1869-2008 period. Castelnuovo and Nisticò (2010) estimate a new-Keynesian model of the business cycle in which agents' expected participation to the financial markets is finite. As a consequence, swings in financial assets affect consumers' decisions. Castelnuovo and Nisticò (2010) produce an estimate of a micro-founded "stock price gap", which represents deviations of the stock market value with respect to its "natural" counterpart for the sample 1954Q2-2009Q1. Table 3 collects datings of the stock market booms according to these four papers for the two historical periods of our interest. Conditional on these datings, we compute the number of observations out of the 240 in our sample (per each of the two periods we analyze)

available in each of the following four regimes: Speculative times/Booms, Speculative times/Busts, Normal times/Booms, Normal times/Busts. The first two columns (with figures) in Table 4 indicate the number of observations for each of these four regimes. As regards the Great Depression, one of the four regimes is clearly under-represented. Depending on the classification of the stock market booms, we have just 20 observations in Normal times/Booms according to the Bordo-Wheelock (2007) classification. Moving to the Christiano et al. (2010) and Albuquerque et al. (2015) classifications, the Normal times/Busts regime is represented by just 17 and 4 observations, respectively. Hence, while in principle the idea of estimating four separate linear VARs over these four different regimes makes sense, it does not appear to be viable in practice. A similar reasoning holds as regards the Great Recession. In this case, the distribution of observations across the four regimes is more balanced. However, according to the Castelnuovo-Nisticò (2010) classification of the business cycle, just 43 observations are available to estimate the Normal times/Booms regime; according to the Christiano et al. (2010), just 51 observations are available for the Normal times/Busts regime; finally, the Albuquerque et al. (2015) classification points to 22 observations describing the Normal times/Busts regime. We believe the available information for these regimes is just insufficient to estimate a five-variate VAR model, which is our reference model for the Great Recession period. However, the information reported in Table 4 enables us to conjecture that our results are importantly driven by bear/bull phases of the stock market. The last two columns of Table 4 report, conditional on each of the two regimes we focus on in our main analysis (Speculative/Normal times), the percentage of observations in Booms/Busts in our samples. Interestingly, the speculative regime seems to be characterized by a very balanced presence of observations in booms vs. busts in both samples.²⁸ While not representing hard-evidence against the idea that the dynamics in the speculative regime could be driven by a stock market boom, these figures suggest that observations in busts importantly affect the computation of the impulse responses documented in Sections 4 and 5. Similarly, the normal time regime does not overlap with stock market busts but it is characterized by the presence of observations of both financial booms and financial busts. Wrapping up, we believe that our responses in Speculative/Normal times are computed by exploiting information coming both from bear phases and from bull phases of the stock market.

Interest rate as transition indicator. Our exercises consider transition indica-

²⁸The only exception appears to be the case of the Great Recession when the Albuquerque et al. (2015) classification is considered. This classification assigns 62% of the observations to booms.

tors whose evolution is connected with stock market values. This choice is motivated by the link made by Keynes between monetary policy moves and expected stock market realizations which are key to determine speculators' current decisions. Then, it is crucial for this analysis to consider transition indicators which are informative about speculators' expectations. Current realizations of the nominal interest rate may or may not reflect speculators' expectations about the future evolution of asset prices. Moreover, it is not clear that, say, the policy rate would be a good indicator to discriminate between "normal times" and "speculative" regimes. The level of the interest rate can be thought as "normal" by speculators because it is in line with what suggested by a Taylor rule, which links the nominal interest rate to the real natural interest rate, the inflation target, an inflation gap, and a real activity gap (say, an unemployment gap or an output gap). Notice that this rule features two possibly time-varying objects, i.e., the real natural interest rate and the inflation target. Then, the value of the "normal" interest rate level is likely to change over time, something that - in principle - may call for "speculative" times even in presence of high interest rates and "normal" times in presence of low rates. The ZLB period during the Great Recession is a good example for this discussion. If we used the federal funds rate as transition indicator for our analysis, we would classify the 2008-2010 period as "speculative". However, according to Swanson and Williams (2014), during that period monetary policy shocks were still able to influence the term structure of interest rates. Hence, this period is not a KLT period. Our choice of the transition indicator enables our empirical model to classify a phase with low realizations of the interest rate as "normal times", as in the case of the 2008-2010 period. This is the reason why we prefer to use the Dow Jones index (or, in one of our robustness checks, the P/E ratio) as transition indicator with respect to a short-term interest rate.²⁹

Speculation in the stock market vs. other markets. Speculative activities may take place in a number of different markets, e.g., commodities, currencies, derivatives, and so on. Our focus on the stock market is justified by numerous references by Keynes on the relevance of the financial market for the transmission of monetary policy impulses. This is so because the idea of Keynes is that, in speculative times,

²⁹Damette and Parent (2016b) use credit spreads between open market short term interest rates and the Federal Reserve's instrument rates as a proxy for liquidity risk. They use such spreads as transition indicators in a nonlinear multivariate analysis that investigates the freeze of the New-York open markets following the crash of October 29. They find that the Fed became aware of liquidity tensions at the very beginning of the thirties, reacted to the stress on monetary markets and, consequently, altered its monetary policy conduct. We leave the employment of these spreads in an econometric analysis like ours to future research.

agents operating on financial markets may counterbalance the effects of injections of liquidity by the central bank by selling bonds or riskier assets to buy them back in the future and enjoy capital gains out of these exchanges in financial assets. Hence, for the KLT to be in place, speculators have to massively operate on markets able to strongly influence asset prices and, consequently, interest rates, something which is more likely related to the stock market than to other markets.

Estimation of the TVAR on the 1921-2010 sample. Our analysis focuses on two different samples, i.e., 1921-1940 and 1991-2010. An alternative would be to estimate our model on the 1921-2010 sample. We prefer to follow the former way for a number of reasons. First, analyzing the Great Depression and the Great Recession separately allows us to model different observables. This is important for our analysis because, as discussed in the previous Section, the way in which money is measured is crucial to understand the effects of monetary policy shocks. In particular, while the standard M2 measure is suited for analyzing the Great Depression period, the Divisia M2 measure appears to carry superior information as regards the Great Recession. Modeling one long sample would complicate the empirical analysis if this switch in definition is relevant, as we believe it is. Second, the estimation over a long sample without admitting for any break-point would lead us to force the model to estimate the same impulse responses (per each given regime) between the two crises. Moreover, the same threshold would be naturally imposed in the estimation of the regimes.³⁰ Differently, our approach allows (without requiring) these responses to be different between the two periods we analyze conditional on a possibly different, regime-specific threshold. The estimation of a TVAR model allowing for breaks would seem to be a possibility (for a reference, see Galvão (2006)). One could also pre-impose the break dates to analyze the two periods we are interested in and distinguish them with respect to the 1941-1990 period. However, this third period would be assumed to feature no instabilities, an assumption which is unpalatable considering that our vector models the systematic response of monetary policy makers to movements in inflation and industrial production. Fernández-Villaverde, Guerrón-Quintana, and Rubio-Ramírez (2010, 2015) analyze the systematic monetary policy conduct of the Federal Reserve in the sample 1959-2007 with a DSGE model which allows for a time-varying policy response

³⁰Notice that the estimation with this long sample would still force us to transform a stock market index in a stationary transition variable. For instance, if one considers the P/E ratio, a regression of the level of such ratio over a constant and a linear trend for the sample 1921-2010 returns a significant coefficient for the trend. Regressions modeling higher order trends confirm the presence of a trending component.

to inflation. They find clear evidence in favor of variations in the aggressiveness via which different chairmen reacted to inflation fluctuations. Chairmen Martin and Volcker are associated to a tougher systematic response than the one implemented by Burns, Miller, and Greenspan. A regime conditional on the sample 1941-1990 would confound four different regimes, the Martin one, the ones by Burns and Miller, the Volcker one, and the first years of the Greenspan one. Focusing on smaller periods appear to be a superior strategy if stability is a concern. About this point, it is of interest to notice that Fernández-Villaverde, Guerrón-Quintana, and Rubio-Ramírez (2010) find a quite stable policy response to inflation in the 1991-2007 period (Greenspan’s and the first part of Bernanke’s chairmanships), which is a relevant subset of our Great Recession sample (1991-2010). Finally, in presence of breaks along the time-dimension, the relevant information for a TVAR analysis comes from period-specific observations. As a matter of fact, our sample-specific analysis minimizes the risk of confounding information coming from two (or more) different subsamples featuring different characteristics. Overall, given that we are not interested in analyzing the period between the two great crises, our strategy of focusing on two distinct periods appears to be preferable.

Stock price level- vs. financial volatility- vs. business cycle-related nonlinearities. Our claim in this paper is that monetary policy shocks may exert different effects on long-term interest rates conditional on different values (high vs. low) of stock market indices such as the Dow Jones and the P/E ratio. Notably, other analysis in the literature document a state-contingent effect of monetary policy shocks. Tenreyro and Thwaites (2015) estimate the impulse response of a variety of U.S. macro series to the monetary policy shocks identified by Romer and Romer (2004). In doing so, they allow the response of the macro series to depend on the state of the business cycle. They find evidence in favor of more powerful effects during expansions. Caggiano, Castelnuovo, and Nodari (2015) use a flexible VAR model and show that systematic monetary policy is relatively more powerful in tackling the effects of uncertainty shocks in expansions. Aastveit, Natvik, and Sola (2013) and Pellegrino (2014, 2016) estimate nonlinear models in which measures of uncertainty are employed as conditioning element to identify high/low uncertainty states. They find that monetary policy shocks exert weaker effects when uncertainty is high. Eickmeier, Metiu, and Prieto (2016) work with a regime-switching VAR and document that expansionary monetary policy shocks are less effective at stimulating output and investment in periods of high financial volatility. They interpret their empirical findings via a structural model in which a weaker financial accelerator mechanism is in place during high volatility peri-

ods because of the reduction in leverage by banks, something that decreases the ability by the central bank to improve funding conditions and credit supply. One may then wonder to what extent the speculative/normal times regimes identified in our paper coincide with the boom/bust periods or the high volatility periods experienced by the U.S. economy. We then compute the correlation between our transition indicators (the HP-filtered Dow Jones index used in our baseline analysis and the (unfiltered) P/E ratio employed in a robustness check) and - alternatively - the dating of the NBER recessions and the VIX, the last measure being a widely-used financial volatility indicator. Given that all papers cited above refer to post-WWII investigations, our computation refer to the Great Recession only. The aforementioned correlations in the 1991-2010 sample read as follows: $\rho(DJ, VIX) = -0.26$, $\rho(DJ, NBER) = -0.12$, $\rho(P/E, VIX) = 0.05$, $\rho(P/E, NBER) = -0.18$, where *DJ* stands for Dow Jones index and *NBER* identifies NBER recessions.³¹ These correlations are weak at best, and they take the negative sign in three cases out of four. In light of these figures, we believe there is little evidence of coincidence between the regimes we analyze and those already investigated by the literature. Hence, our analysis complements the investigations conducted by the authors mentioned above.

Response of prices and industrial production. Our paper focuses on the response of long-term interest rates to monetary policy shocks. For the sake of brevity, we confine the responses of prices and industrial production to monetary policy shocks in our Appendix. We offer a brief description of such responses here. During the Great Depression, an expansionary monetary policy shock leads to a temporary and significant increase in industrial production and a positive and significant response of PPI in speculative times. These responses are in line with the prediction of a number of macroeconomic models (see Walsh 2010). Differently, the response of prices in normal times is negative, although short-lived and statistically insignificant. This reaction is known in the literature as the "price puzzle" (Eichenbaum (1992)). Christiano, Eichenbaum, and Evans (2005) rationalize the price puzzle by appealing to a working capital channel which justifies the presence of a short-term interest rate in firms' marginal costs due to the fact that firms need to borrow money to pay wages before the goods market opens. Hence, a reduction in the short-term interest rate after a monetary policy shock - which is what occurs in normal times - could be a factor driving prices down. The response of output in normal times is negative and statistically significant, although

³¹The plot of the series employed to compute these correlations, not shown here for the sake of brevity, is available in our Appendix.

short-lived. As documented by Ramey (2016), these price and output puzzles are often found in VAR analysis and do not seem to depend on the way in which the econometrician identifies a monetary policy shock. Turning to the Great Recession period, we find similar responses (although not significant) of the price level and basically no significant responses of output in the two scrutinized regimes. Again, the mild-to-muted response of prices and quantities appear to be a regularity of periods heavily influenced by the Great Moderation, as documented by Ramey (2016) and Castelnuovo (2016). Overall, the responses of prices and industrial production are either in line with those predicted by standard textbook models or in line with recent empirical VAR evidence on the macroeconomic effects of monetary policy shocks. Finally, a related strand of the literature documents instabilities in the relationship between money and inflation (see Sargent and Surico (2011) and the references therein). This literature is concerned with the role that systematic monetary policy plays in affecting this relationship. Our paper complements this literature by focusing on the role of monetary policy shocks.

7 Conclusions

Keynes (1936) put forth the idea of a liquidity trap possibly driven by speculative motives. These motives may make the system depart from normal conditions in which a liquidity effect is in place, and they may freeze the response of interest rates to a money supply shock. This paper estimates a nonlinear Threshold-VAR with the aim of identifying the response of a range of interest rates to money supply shocks in normal and speculative times. We do so by considering two great crises, the Great Depression and the recent Great Recession.

Two main results stand out. First, conditional on the Great Depression period, we find that impulse responses associated to the speculative period point to insignificant reactions of all the interest rates we consider to a money supply shock. Differently, such responses are all negative and significant when the normal times state is considered. This result is consistent with a liquidity trap at work in speculative times as advocated by Keynes. Importantly, we show that a linear VAR framework, which is of course ill-suited to discriminate between normal and speculative times, would miss to provide evidence in favor of a liquidity trap. Second, we find that the transmission mechanism linking monetary policy instruments to long-term rates is likely to have changed going from the Great Depression to the Great Recession. In particular, the modeling structure employed to identify liquidity shocks with observations related to the Great Depression

turns out to produce dynamic responses that are difficult to interpret via the lens of standard textbook monetary policy models. Differently, a more modern approach focusing on prices (in particular, the federal funds rate) more than on quantities (M2) delivers much more interpretable results confirming the presence of a Keynesian liquidity trap in speculative times only. Importantly, the model delivering the most compelling results in this sense is a framework modeling Divisia M2. This suggests that a careful consideration of how to define liquidity when it comes to understanding the transmission of monetary policy shocks in recent times may be more important than what it is commonly understood.

Our paper unveils the role played by nonlinearities in the assessment of conditional correlations linking interest rates and money. Two extensions of our analysis appear to be of interest. First, our nonlinear framework does not explicitly deal with the zero lower bound as a deviation with respect to the normal monetary policy course. We see the combination of a nonlinear model suited to discriminate between different financial markets regimes and the zero lower bound as a natural step for future investigations. Another interesting modeling exercise would be to account for the battery of unconventional monetary policy measures implemented by the Federal Reserve during the Great Recession in a nonlinear context. We plan to contribute to this exciting research agenda in future times.

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<i>Period</i>	<i>Interest rate</i>	<i>BLM</i>	<i>BW</i>
Great Depression	Short-term	1.177	1.219
	Aaa	2.090	2.387
	Baa	2.108	2.363
Great Recession: M2 shock	Short-term	1.590	1.699
	Aaa	1.529	1.625
	Baa	1.405	1.478
Great Recession: FFR shock, M2	Aaa	1.487	1.574
	Baa	1.550	1.649
Great Recession: FFR shock, Divisia M2	Aaa	1.773	1.927
	Baa	1.608	1.720

Table 1: **Linear Model: Statistical Evidence.** Bounded-LM (BLM) and Bounded-Wald (BW) test statistics proposed by Galvão (2006) and based on the asymptotic bounds proposed by Altissimo and Corradi (2002). Null hypothesis: Linear model. Alternative hypothesis: TVAR framework. Null hypothesis rejected when the values of the BLM, BW tests are larger than one. Figures in bold indicate the rejection of the linear model.

<i>Period</i>	<i>Interest rate</i>	<i>t-stat</i>
Great Depression	Short-term	-3.36
	Aaa	-2.43
	Baa	-2.58
Great Recession: M2 shock	Short-term	-1.83
	Aaa	-2.01 (*)
	Baa	1.49 (*)
Great Recession: FFR shock, M2	Aaa	-1.91 (*)
	Baa	-2.15
Great Recession: FFR shock, Divisia M2	Aaa	-1.66
	Baa	-2.17

Table 2: **Differences between IRFs: Statistical Evidence.** t-stat computed as the difference between the value of the impulse response of a given interest rate at a given horizon in normal times minus the one of the impulse response in speculative times. Each value reported in the table was selected by searching for the maximum difference (in absolute value) between the two impulse responses across the considered horizons. Figures in bold identify differences between impulse responses in the two regimes which are statistically significant when considering a two-sided (one-sided) 10 percent (5 percent) statistical level. Figures associated to the "(*)" identifier refer to scenarios which feature non-statistically significant responses of the interest rates in the "normal" regime.

Authors and datings
<i>Bordo and Wheelock (2007)</i>
October 1923-September 1929
March 1935-February 1937
<i>Christiano et al. (2010)</i>
July 1921-September 1929
April 1932-June 1937
April 1994-June 2000
January 2003-March 2007
<i>Albuquerque et al. (2015)</i>
July 1919-June 1928
July 1930-June 1936
July 1940-June 1972
July 1973-June 1999
July 2001-June 2007
<i>Castelnuovo and Nisticò (2010)</i>
April 1994-June 2001
April 2006-December 2007

Table 3: **Stock Market Booms in the Literature.** Datings of the stock market booms relative to four different papers. The papers appeal to four different methodologies to date stock market booms in the United States - see the main text for details. Initial and end-points in Albuquerque et al. (2015) paper are translated from yearly to monthly frequencies by referring to six months before each year indicated as the first one of the stock market boom in the original paper as the beginning of the boom. This is done to solve the "overlapping" problem affecting the original classification, which assigns the same year to the end of a boom and to the beginning of a bust. As regards Castelnuovo and Nisticò's (2010) microfounded stock price gap, we label as "stock market booms" periods in which the estimated stock price gap takes a positive value for at least two consecutive quarters. All non-booms are classified as "busts" in our analysis.

<i>Great Depression</i>				
	Booms	Busts	<i>Booms</i> <i>reg.</i> , %	<i>Busts</i> <i>reg.</i> , %
<i>Bordo and Wheelock (2007)</i>				
Speculative	76	65	54%	46%
Normal times	20	79	20%	80%
<i>Christiano et al. (2010)</i>				
Speculative	80	61	57%	43%
Normal times	82	17	83%	17%
<i>Albuquerque et al. (2015)</i>				
Speculative	61	80	43%	57%
Normal times	95	4	96%	4%
<i>Great Recession</i>				
	Booms	Busts	<i>Booms</i> <i>reg.</i> , %	<i>Busts</i> <i>reg.</i> , %
<i>Castelnuovo and Nisticò (2010)</i>				
Speculative	65	50	57%	43%
Normal times	43	82	34%	66%
<i>Christiano et al. (2010)</i>				
Speculative	52	63	45%	55%
Normal times	74	51	59%	41%
<i>Albuquerque et al. (2015)</i>				
Speculative	71	44	62%	38%
Normal times	103	22	83%	17%

Table 4: **Speculative/Normal Times vs. Booms/Busts: Observations per Regime and Percentage of Observations Conditional on Speculative/Normal Times Regimes.** The first two columns with figures indicate the number of observations per each of these four regimes: Speculative times/Booms, Speculative times/Busts, Normal times/Booms, Normal times/Busts. The last two columns report, conditional on each of the two regimes we focus on in our analysis (Speculative/Normal times), the percentage of observations in Booms/Busts.

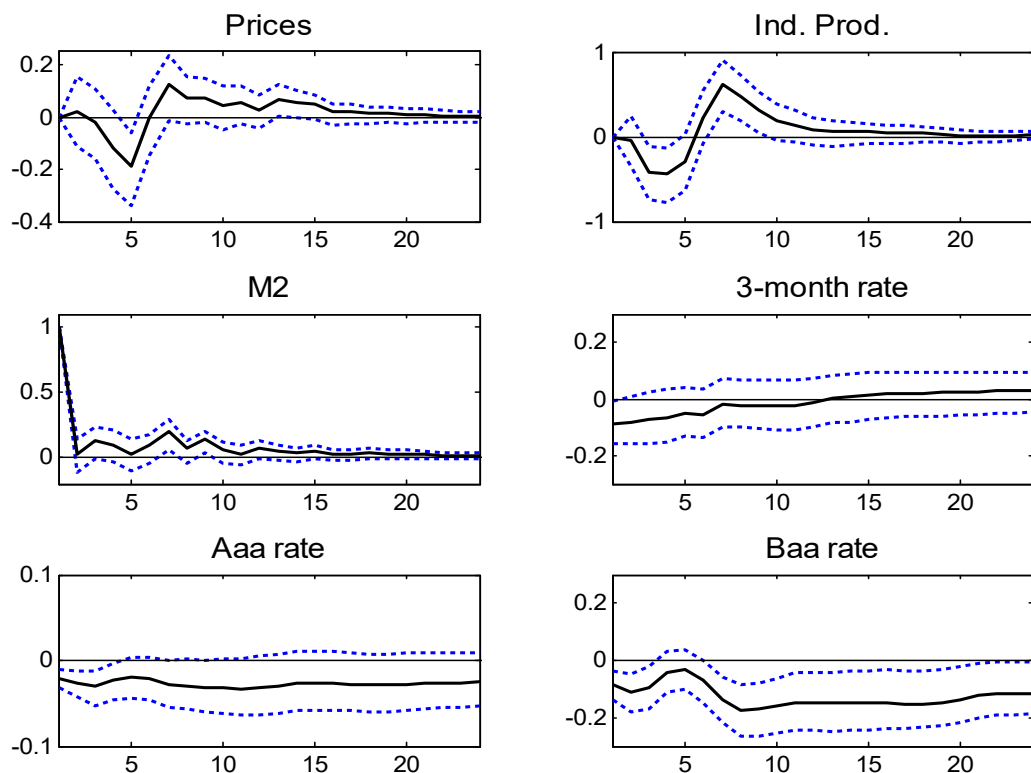


Figure 1: **Impulse Responses to a 1% Increase in Money Growth: Linear VAR, Great Depression.** Sample ranging from January 1921 to December 1940. Linear four-variate VAR estimated with variables in first differences (with the exception of the interest rates). Interest rates rotated in one at a time. Number of lags of the VAR selected according to the Akaike criterion. Points estimates (bootstrapped 90% confidence bands) identified by the black solid line (blue dotted lines). IRFs of prices, industrial production, and money refer to the VAR estimated with the 3-month interest rate.

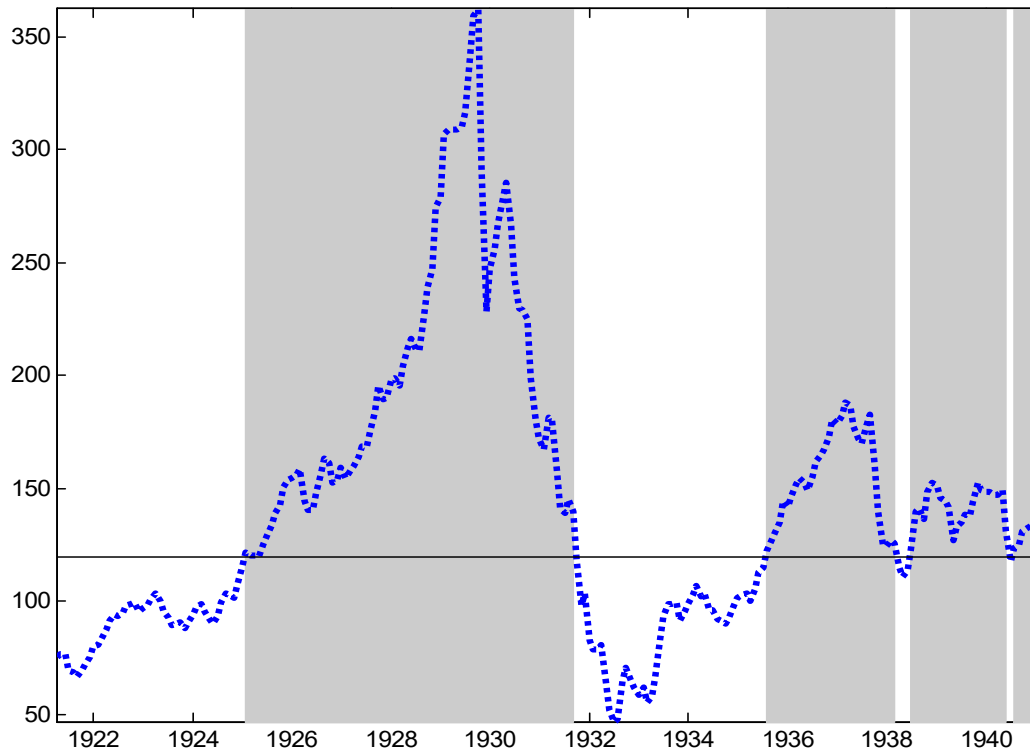


Figure 2: **Estimated Threshold, Great Depression.** Sample ranging from January 1921 to December 1940. Dow Jones index, indicated with the blue dashed line, employed as a switching variable for the identification of the "normal times" and "speculative" regimes. TVAR estimated with variables in first differences (with the exception of the 3-month rate). Number of lags of the VAR equal to 2 as indicated by the Akaike criterion. Threshold value identified by the black solid horizontal line.

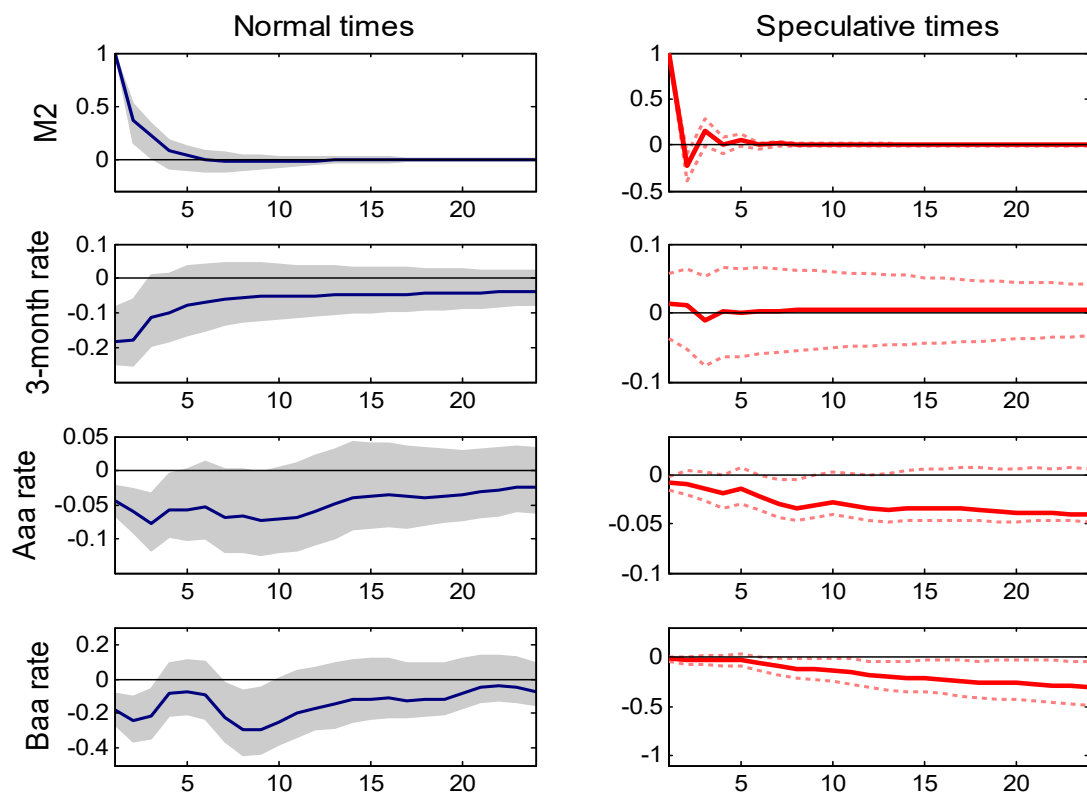


Figure 3: **State-dependent Impulse Response Functions, Great Depression.** Sample ranging from January 1921 to December 1940. Dow Jones index employed as a switching variable for the identification of the "normal times" and "speculative" regimes. TVAR estimated with variables in first differences (with the exception of the interest rates, which are rotated in the model one by one). Number of lags of the VAR selected according to the Akaike criterion. The IRF of money refers to the VAR estimated with the 3-month interest rate.

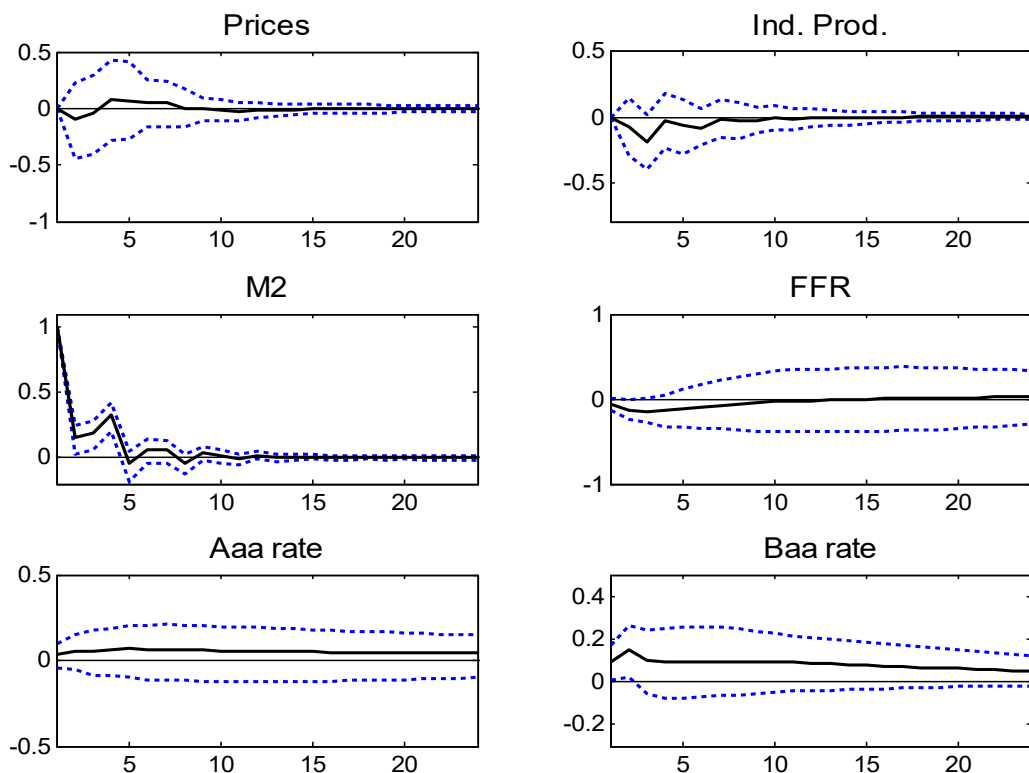


Figure 4: **Impulse Responses to a 1% Increase in Money Growth: Linear VAR, Great Recession.** Sample ranging from January 1921 to December 1940. Linear four-variate VAR estimated with variables in first differences (with the exception of the interest rates). Interest rates rotated in one at a time. Number of lags of the VAR selected according to the Akaike criterion. Points estimates (bootstrapped 90% confidence bands) identified by the black solid line (blue dotted lines). IRFs of prices, industrial production, and money refer to the VAR estimated with the federal funds rate.

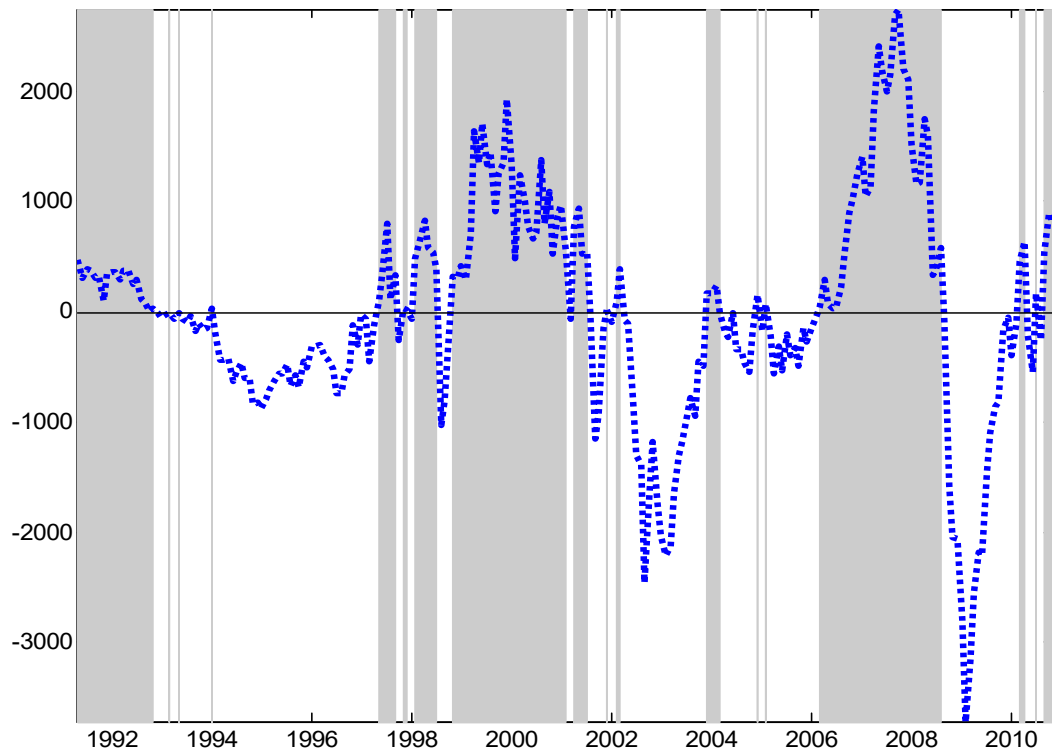


Figure 5: **Estimated Threshold, Great Recession.** Sample ranging from January 1991 to December 2010. Dow Jones index (Hodrick-Prescott filtered, smoothing weight: 129,600) employed as a switching variable for the identification of the "normal times" and "speculative" regimes. TVAR estimated with variables in first differences (with the exception of the federal funds rate). Number of lags of the VAR equal to 4 as indicated by the Akaike criterion.

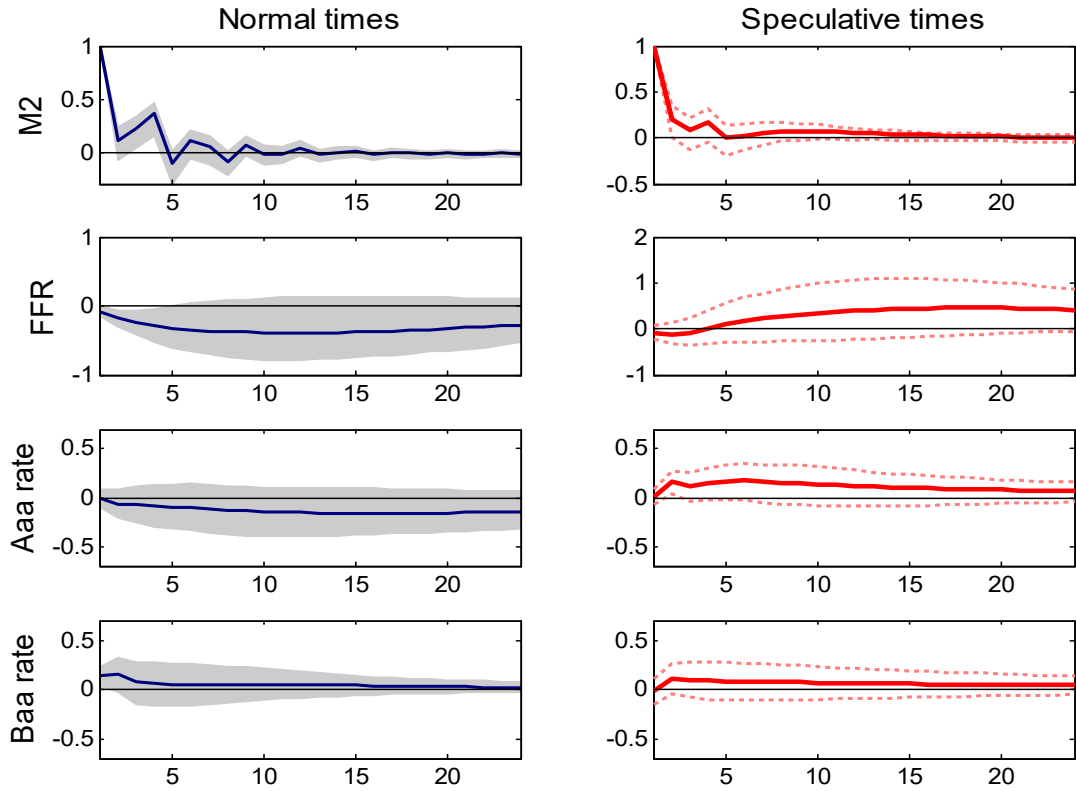


Figure 6: **State-dependent Impulse Response Functions, Great Recession.** Sample ranging from January 1991 to December 2010. Dow Jones index (Hodrick-Prescott filtered, smoothing weight: 129,600) employed as a switching variable for the identification of the "normal times" and "speculative" regimes. TVAR estimated with variables in first differences (with the exception of the commercial paper rate). Number of lags of the VAR selected according to the Akaike criterion. The IRF of money refers to the VAR estimated with the federal funds rate.

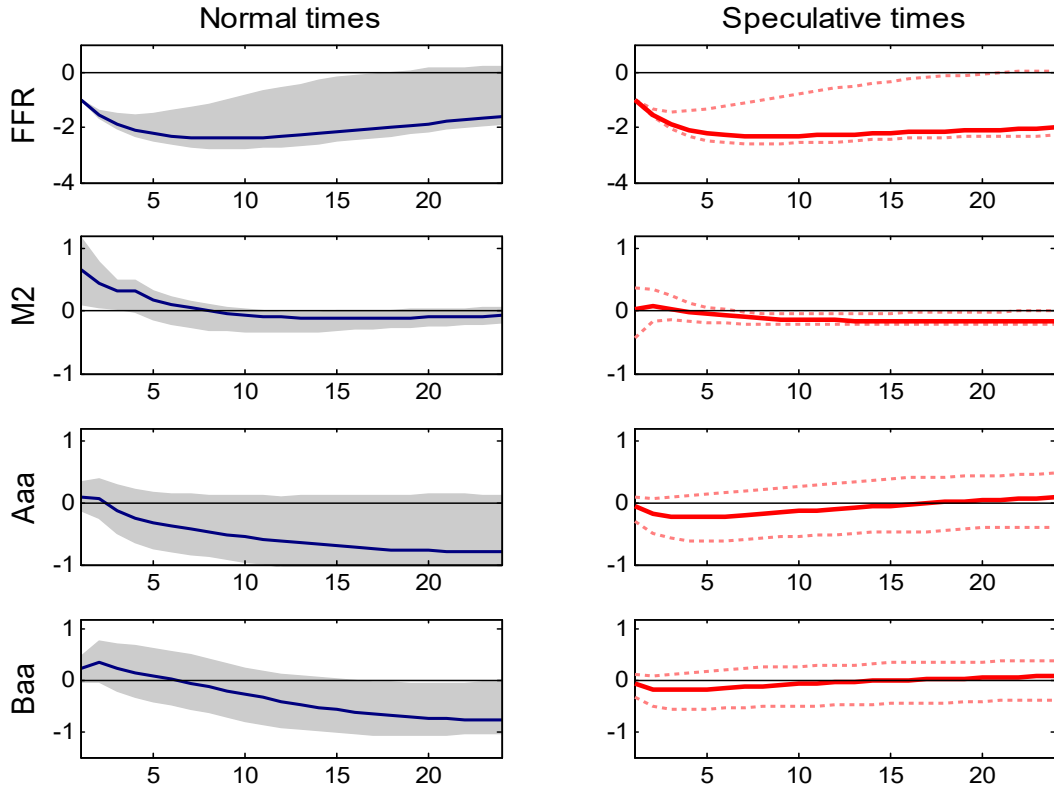


Figure 7: **State-dependent Impulse Response Functions, Great Recession: Shock to the Federal Funds Rate.** Sample ranging from January 1991 to December 2010. Dow Jones index (Hodrick-Prescott filtered, smoothing weight: 129,600) employed as a switching variable for the identification of the "normal times" and "speculative" regimes. TVAR estimated with variables in first differences (with the exception of the commercial paper rate). Number of lags of the VAR selected according to the Akaike criterion. The IRFs of the federal funds rate and money refer to the VAR estimated with the Aaa rate.

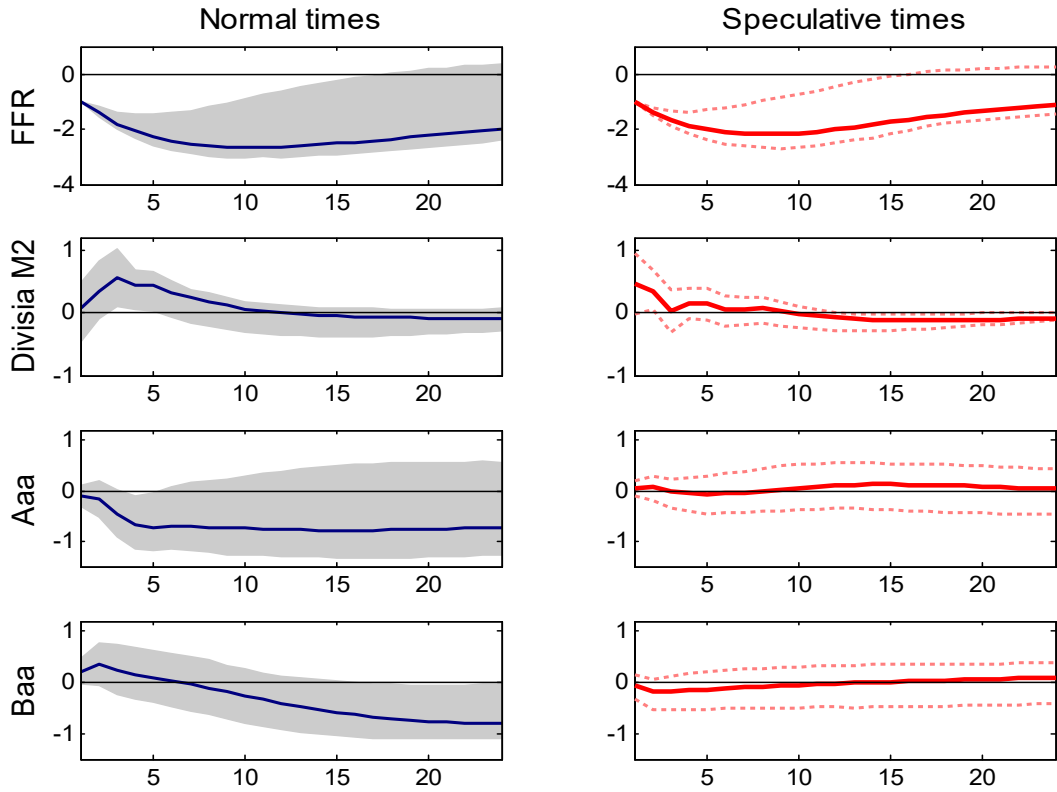


Figure 8: **State-dependent Impulse Response Functions, Great Recession: Shock to the Federal Funds Rate, Model with Divisia M2.** Sample ranging from January 1991 to December 2010. Dow Jones index (Hodrick-Prescott filtered, smoothing weight: 129,600) employed as a switching variable for the identification of the "normal times" and "speculative" regimes. TVAR estimated with variables in first differences (with the exception of the commercial paper rate). Number of lags of the VAR selected according to the Akaike criterion. The IRFs of the federal funds rate and money refer to the VAR estimated with the Aaa rate.

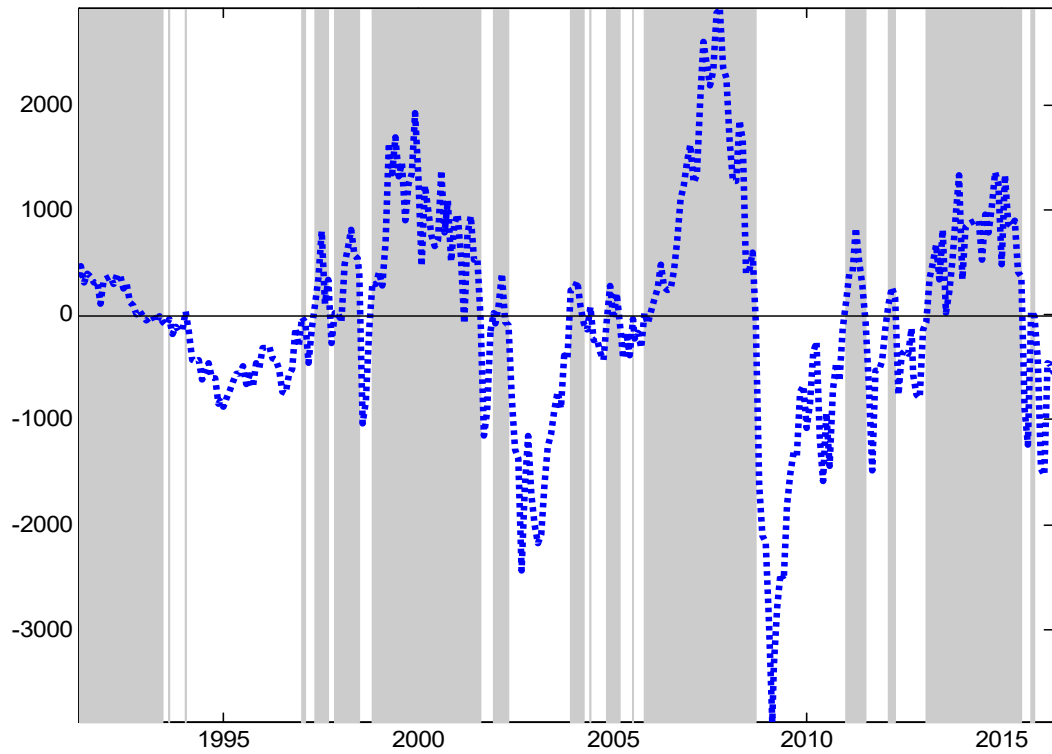


Figure 9: **Estimated Threshold, Great Recession: Sample including the ZLB period.** Sample ranging from January 1991 to June 2016. Dow Jones index (Hodrick-Prescott filtered, smoothing weight: 129,600) employed as a switching variable for the identification of the "normal times" and "speculative" regimes. TVAR estimated with variables in first differences (with the exception of the federal funds rate). Number of lags of the VAR equal to 4 as indicated by the Akaike criterion.

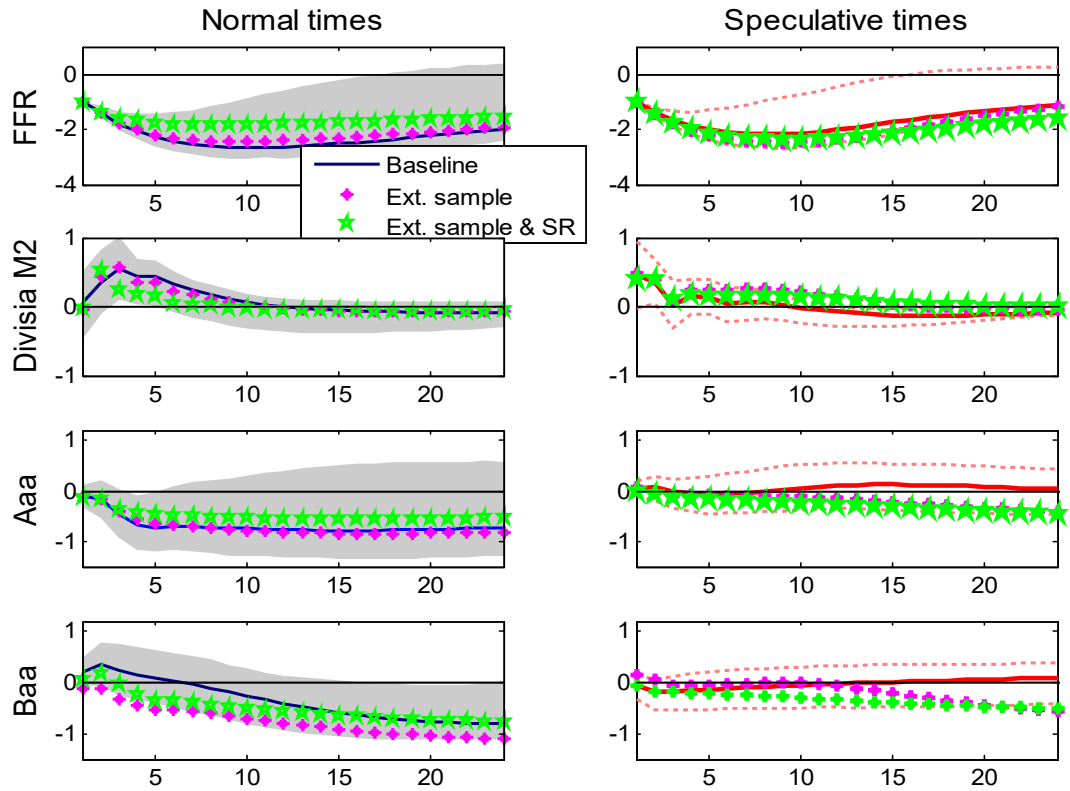


Figure 10: **State-dependent Impulse Response Functions, Great Recession - Sample Extended until June 2016: Shock to the Policy Rate, Model with Divisia M2.** Baseline model: Model estimated over the January 1991-December 2010 sample. Ext. sample model: Model estimated over the January 1991-June 2016 sample. Ext. sample & SR: Model estimated over the January 1991-June 2016 sample and featuring the shadow federal funds rate rate à la Wu and Xia (2016). Dow Jones index (Hodrick-Prescott filtered, smoothing weight: 129,600) employed as a switching variable for the identification of the "normal times" and "speculative" regimes. TVAR estimated with variables in first differences (with the exception of the commercial paper rate). Number of lags of the VAR selected according to the Akaike criterion. The IRFs of the federal funds rate and money refer to the VAR estimated with the Aaa rate.

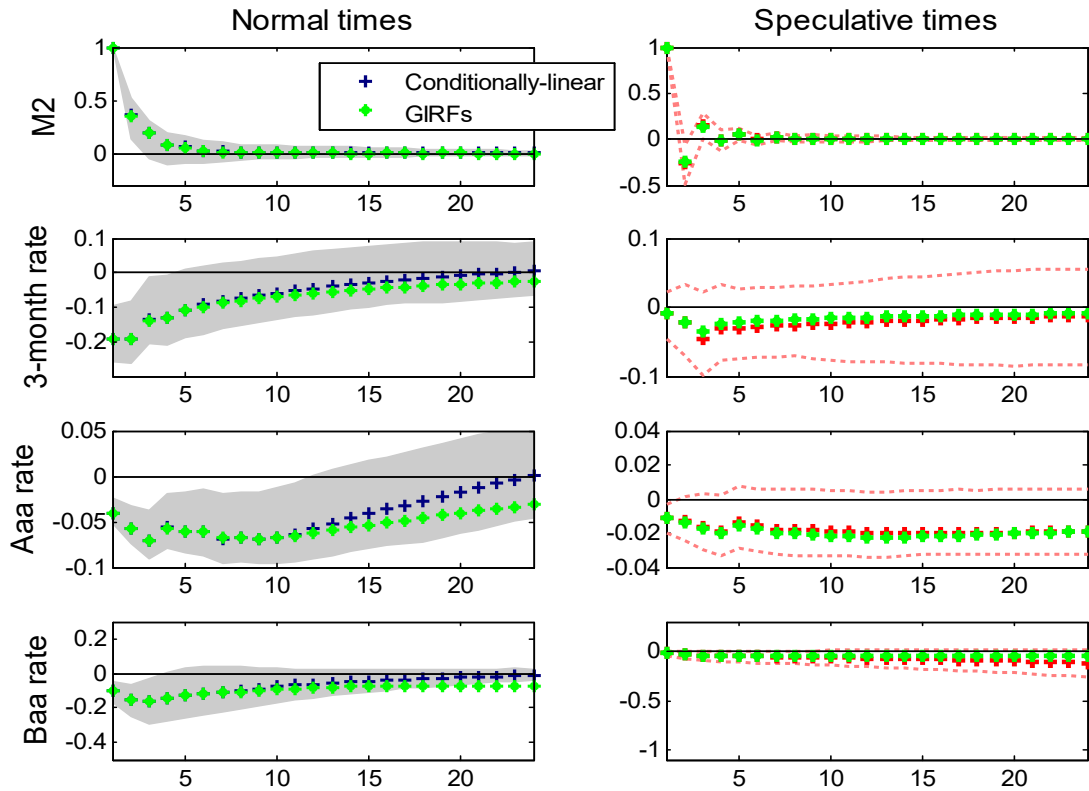


Figure 11: **State-dependent Impulse Response Functions, Great Depression: Conditionally-linear Responses vs. GIRFs.** Sample ranging from January 1921 to December 1940. Conditionally-linear: Responses estimated with a VAR modeling the Dow Jones index but that does not allow for the switch from the Normal times (Speculative) to the Speculative (Normal times) regime. TVAR estimated with variables in first differences (with the exception of the interest rates, which are rotated in the model one by one). Number of lags of the VAR selected according to the Akaike criterion. The IRF of money refers to the VAR estimated with the Aaa rate. 90% confidence bands associated to the Conditionally-linear case.

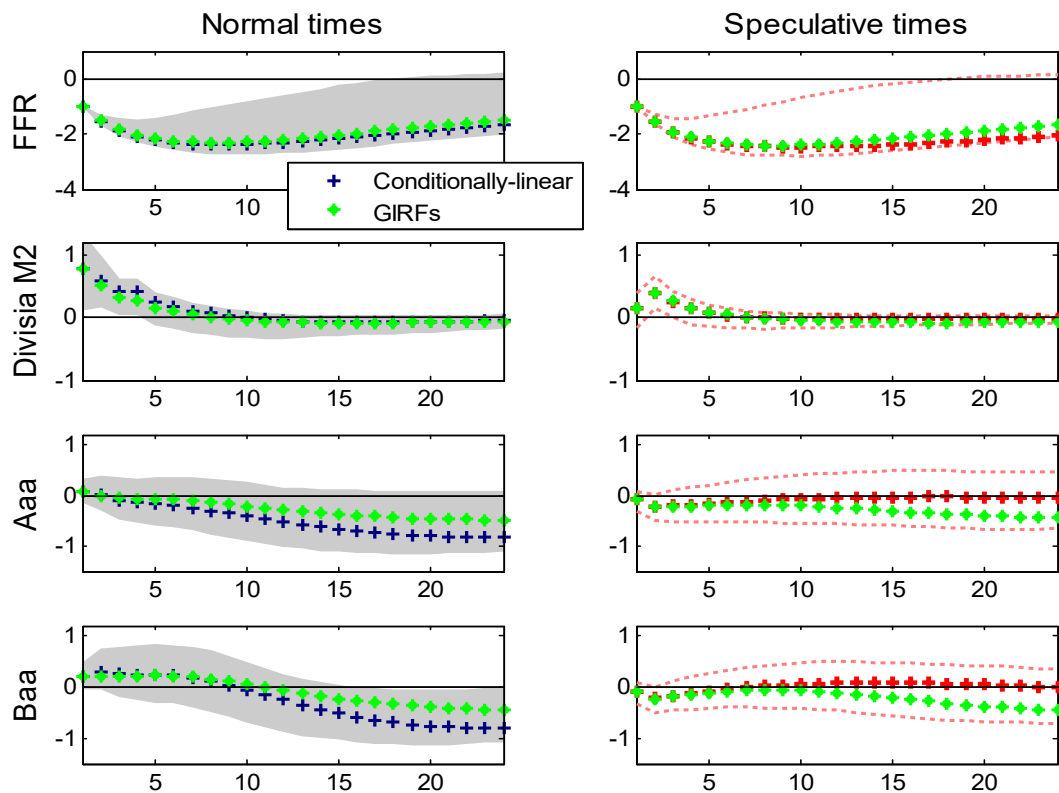


Figure 12: **State-dependent Impulse Response Functions, Great Recession: Conditionally-linear Responses vs. GIRFs.** Sample ranging from January 1991 to December 2010. Conditionally-linear: Responses estimated with a VAR modeling the (HP-filtered) Dow Jones index but that does not allow for the switch from the Normal times (Speculative) to the Speculative (Normal times) regime. TVAR estimated with variables in first differences (with the exception of the interest rates, which are rotated in the model one by one). Number of lags of the VAR selected according to the Akaike criterion. The IRF of money refers to the VAR estimated with the Aaa rate. 90% confidence bands associated to the Conditionally-linear case.

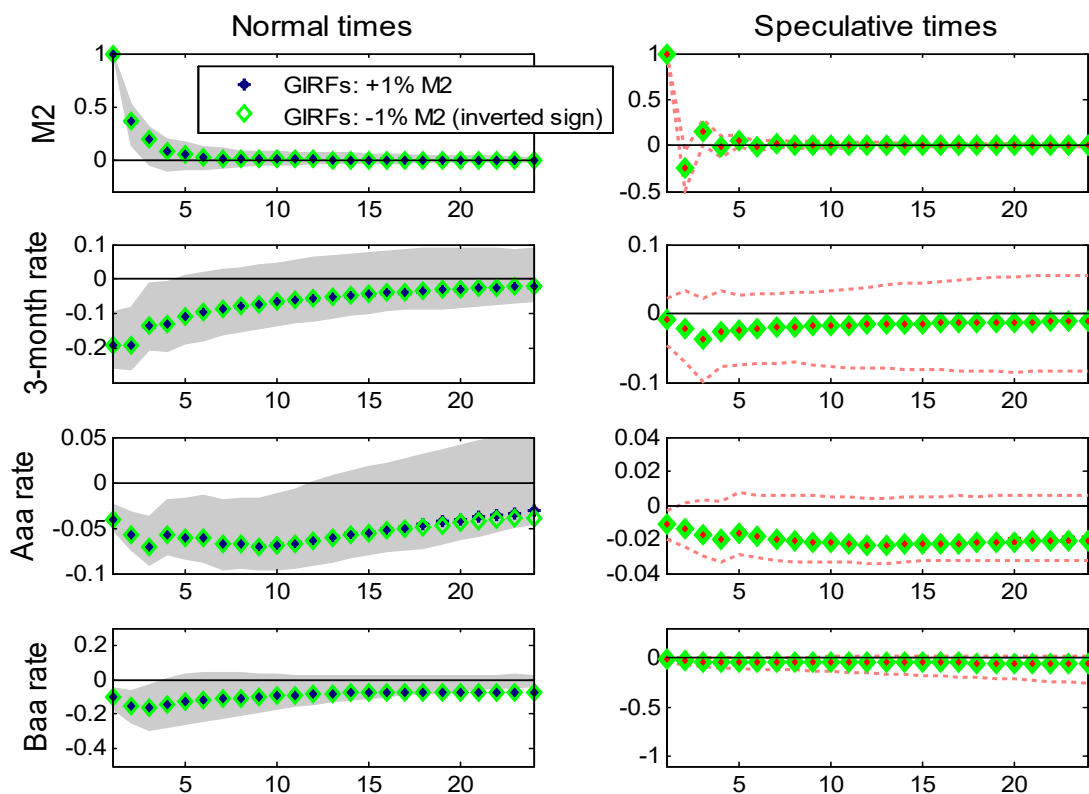


Figure 13: **State-dependent Impulse Response Functions, Great Recession: Asymmetric Effects of Monetary Policy Shocks.** Sample ranging from January 1991 to December 2010. GIRFs to a 1% decrease in the money growth rate multiplied by -1 to enhance comparability. TVAR estimated with variables in first differences (with the exception of the interest rates, which are rotated in the model one by one). Number of lags of the VAR selected according to the Akaike criterion. The GIRFs of money refers to the VAR estimated with the Aaa rate. 90% confidence bands associated to the Conditionally-linear case.

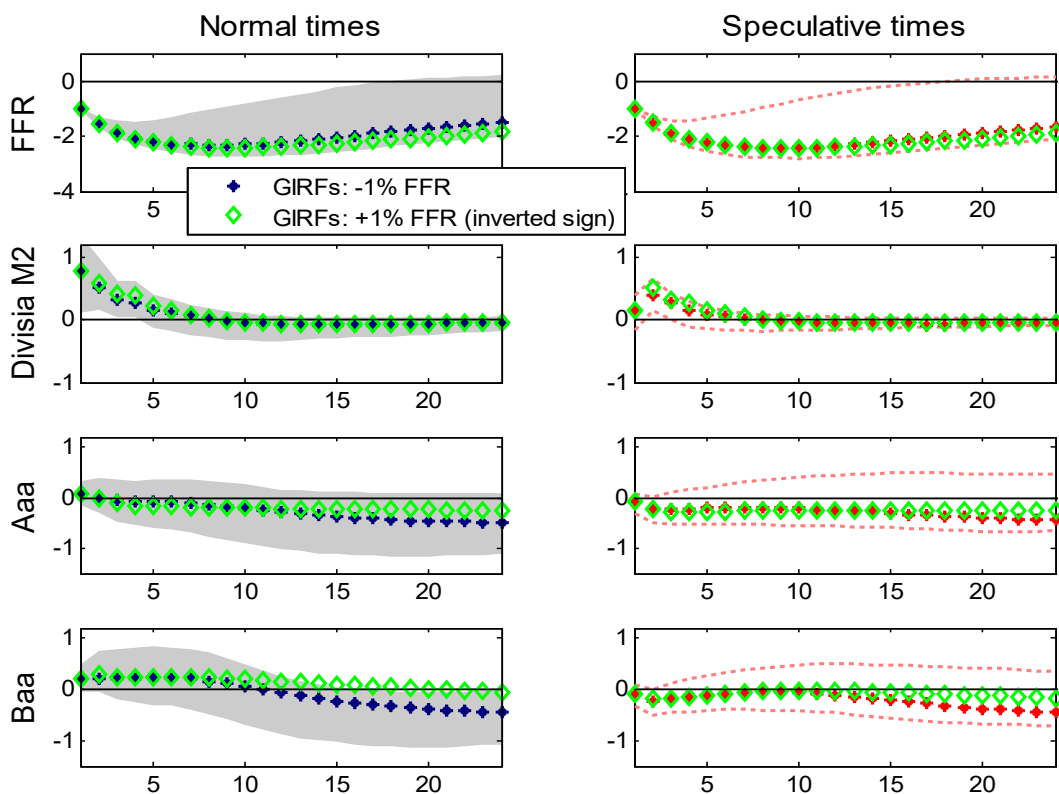


Figure 14: **State-dependent Impulse Response Functions, Great Recession: Asymmetric Effects of Monetary Policy Shocks.** Sample ranging from January 1991 to December 2010. GIRFs to a 1% increase in the federal funds rate multiplied by -1 to enhance comparability. TVAR estimated with variables in first differences (with the exception of the interest rates, which are rotated in the model one by one). Number of lags of the VAR selected according to the Akaike criterion. The GIRFs of money refers to the VAR estimated with the Aaa rate. 90% confidence bands associated to the Conditionally-linear case.