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Liquidity Traps and Large-Scale Financial Crises

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-Codes: B220, C520, E520, N120, N220.

Keywords: Keynesian liquidity trap, Threshold-VAR, monetary and financial cliometrics, Great Depression, Great Recession.

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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 of this speculative activity, 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

[1] In 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 $M2$ 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 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

[3]In *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 interes 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 is neither a necessary nor a sufficient condition for the Keynesian liquidity trap to be in place. In this sense, we share Basile et al.'s (2011) view on the relevance of considering a battery of interest rates to assess the presence of a liquidity trap.

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

[4] Auerbach and Gorodnichenko (2012), Mittnik 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 cylcle. 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.

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 (see, among others, Bernanke and Mihov (1998) and Christiano, Eichenbaum, and Evans (1999)). 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 role played by 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 mentions the list of robustness checks and further discussions reported in our online Appendix. 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.

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.

[5] A 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 employes 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.

3.1 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 is 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.[7] In particular, higher (lower) realizations of the Down 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.[8] 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 (2016), 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.[9]

[6] Data availability forces us to us 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.

[7] Damette 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.

[8] Notice 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).

[9] As 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:

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

where $\boldsymbol{Y}_t$ 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, $\boldsymbol{B}_j^H$ and $\boldsymbol{B}_j^L$, $j = 1, .., k$ 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 the regime-specific reduced-form residuals feature $E(\boldsymbol{\varepsilon}_t^i) = \mathbf{0}$, $E(\boldsymbol{\varepsilon}_t^i \boldsymbol{\varepsilon}_t^i)' = \boldsymbol{\Omega}_i$, with $i \in \{H, L\}$. 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.[10] This variable is assumed to be exogenous with respect to those embedded in our vector $\boldsymbol{Y}_t$. 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 Mittnik and Semmler (2012), Auerbach and Gorodnichenko (2012), Berger and Vavra (2014), and Caggiano, Castelnuovo,

[10] Our 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.

and Groshenny (2014)). Given that the switching variable enters the model with a lag, we believe the exogeneity assumption to be reasonable.[11] The model is estimated by using the conditional least squares estimator as proposed by Tsay (1998).

Our vector of endogenous variables is the following: $\boldsymbol{Y}_t = [P_t, IP_t, M2_t, i_t]'$, 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.[12] 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.[13] 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 $\boldsymbol{\Omega}$ 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

[11] Of 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.

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

[13] Working with post-WWII U.S. data, Canova and Menz (2011) and Castelnuovo (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 model: Results. 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.[14] 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

[14] The 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.[15]

For the Great Depression period, and conditional on our baseline vector of modeled variables $\boldsymbol{Y}_t$, 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

[15] We 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.[16] 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.[17]

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.[18]

[16] The 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 t-statistic is computed as follows: $t-stat_{t,i} = (IRF^{L}_{t,i} - IRF^{H}_{t,i})/\sqrt{(st.dev.(IRF^{L}_{t,i}))^2 + (st.dev.(IRF^{H}_{t,i}))^2}$, where $IRF^{r}_{t,i}$ represents the estimated value of the impulse response at time $t = 0, ..., 23$ for the interest rate i in regime r, $r \in \{L, H\}$.

[17] This 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.

[18] Indeed, 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), 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).[19] 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

and Castelnuovo (2016).

[19] Admittedly, 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 a variable 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. 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. Table 2 reveals that a statistically relevant difference emerges when comparing the reactions estimated for the two regimes.[20] 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.

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

[20] Notice 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.

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 discussions

For the sake of brevity, a long list of robustness checks is reported in our online Appendix. This list includes: i) the results obtained by HP-filtering the transition indicator for the Great Depression period; ii) the use of the Price/Earning ratio as transition indicator; iii) the use of the 3-month TBill rate as policy instrument during the Great Recession; iv) the use of alternative price indices like the CPI and the PCE during the Great Recession period; v) a version of the model in which variables are modeled in levels; vi) a perturbation of the subsample we use to estimate the threshold; vii) the use of alternative long-term rates; viii) the computation of generalized impulse response functions, which take into account the endogeneity of the Dow Jones index as transition indicator; ix) the extension of the sample to 2016 to include all ZLB observations; x) an exercise in which we study the possibility of asymmetric effects of monetary policy shocks. Further discussions reported in our Appendix include an explanation on why we prefer to use a Cholesky identification scheme to alternatives such as sign restrictions, the narrative approach, local-projections, and high-frequency data; why we believe we do not confound speculative and normal times with financial booms and busts; why we use a stock market index as transition indicator as opposed to an interest rate; 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.

Other contributions document state-contingent effects of monetary policy shocks. Tenreyro and Thwaites (2015) use local projections and find an asymmetric effect of monetary policy shocks along the U.S. business cycle. Caggiano, Castelnuovo, and Nodari (2017) 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 (2017), Eickmeier, Marcellino, and Prieto (2016), Pellegrino (2017,2018), and Castelnuovo and Pellegrino (2017) employ nonlinear models to show that monetary policy shocks exert weaker effects on real activity when uncertainty is high. Our Appendix discusses why the nonlinearities documented in this paper are likely to relate to speculative times more than to recessions or financial volatility.

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 cannot 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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Period	*Interest rate*	*BLM*	*BW*
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.

Period	*Interest rate*	*t-stat*
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.

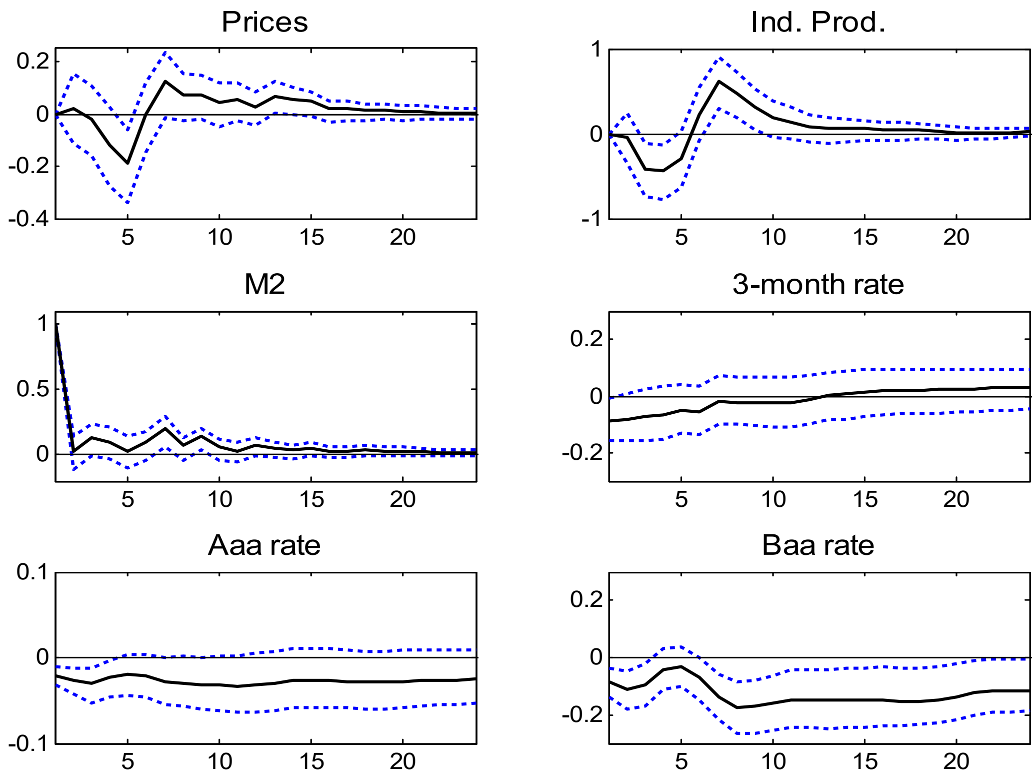

Figure 1: **Impulse Responses to a 1% Increase in Money Growth: Linear VAR, Great Depression.** Sample ranging from January 1921 to December 1940. Linear four-variate VAR estimated with variables in first differences (with the exception of the interest rates). Interest rates rotated in one at a time. 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.

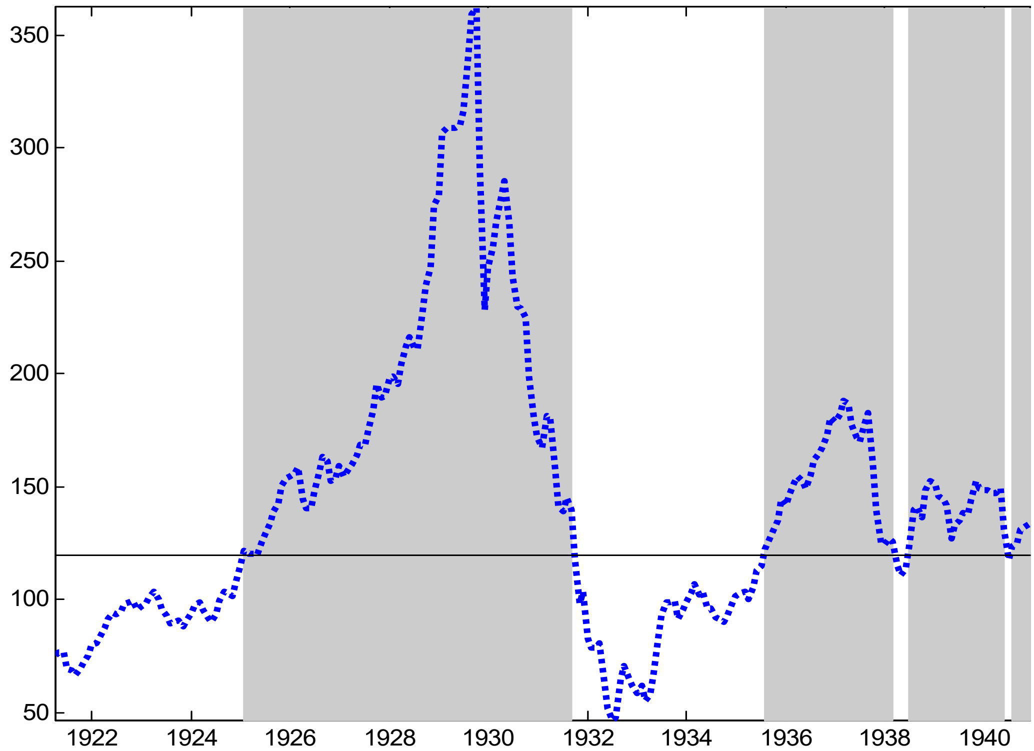

Figure 2: **Estimated Threshold, Great Depression**. Sample ranging from January 1921 to December 1940. Dow Jones index, indicated with the blue dashed line, employed as a switching variable for the identification of the "normal times" and "speculative" regimes. TVAR estimated with variables in first 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.

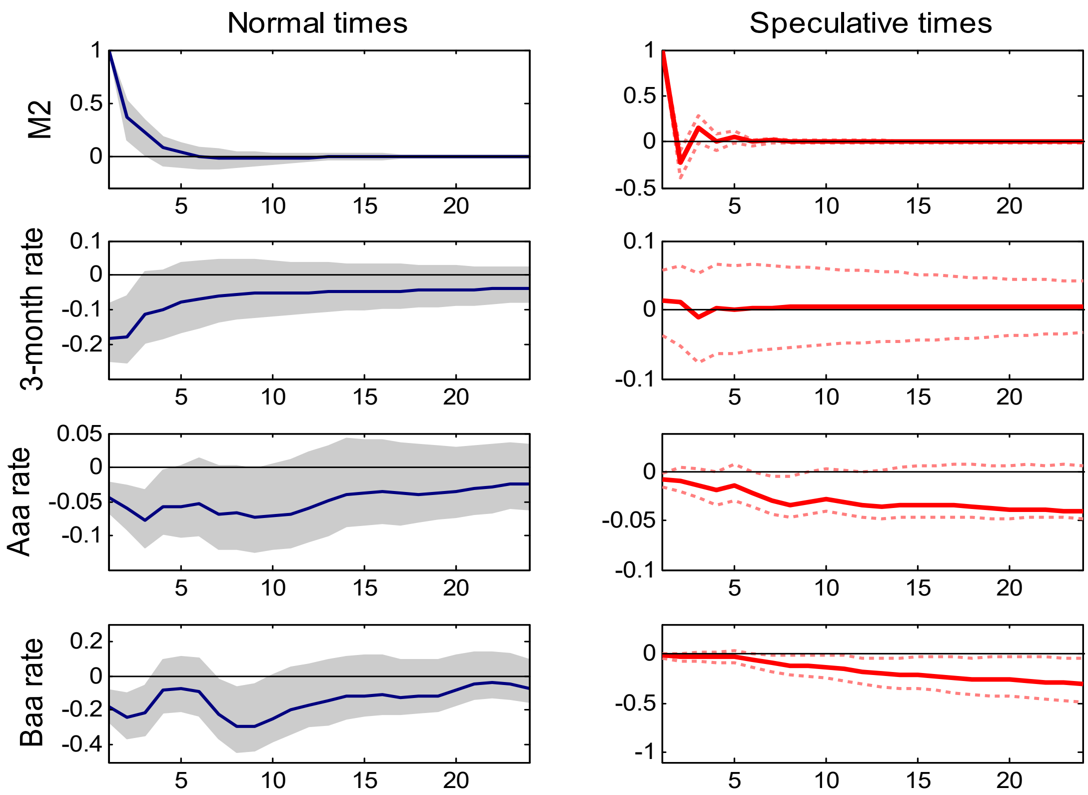

Figure 3: **State-dependent Impulse Response Functions, Great Depression**. Sample ranging from January 1921 to December 1940. Dow Jones index employed as a switching variable for the identification of the "normal times" and "speculative" regimes. TVAR estimated with variables in first differences (with the exception of the interest rates). Interest rates rotated in one at a time. 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.

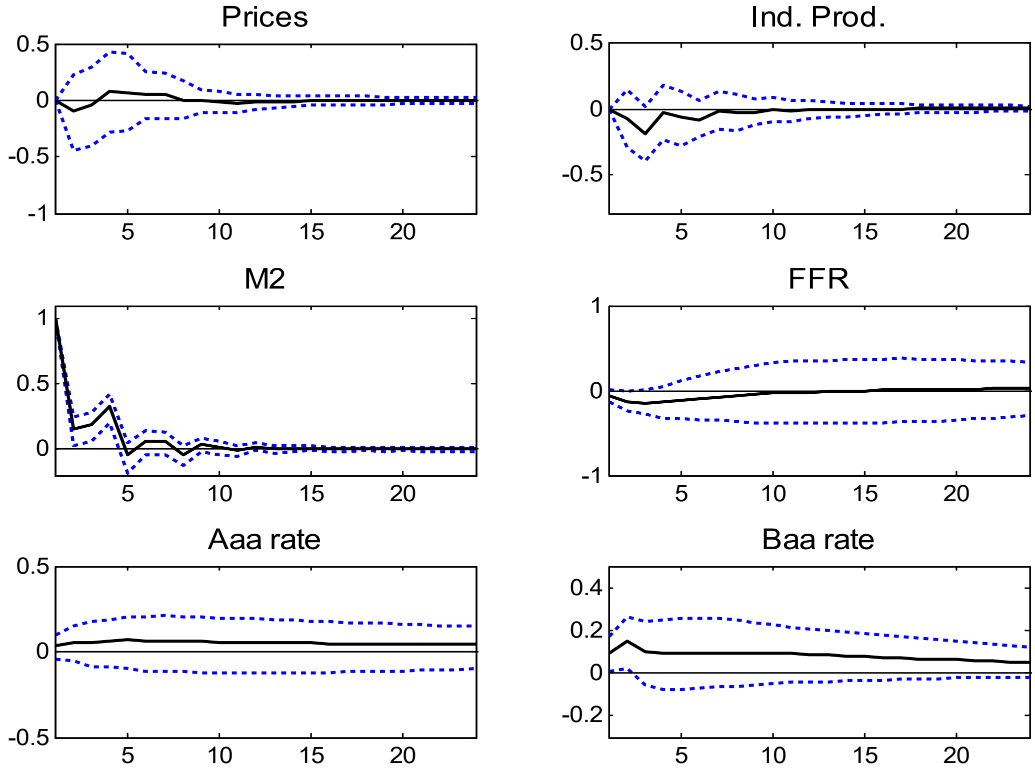

Figure 4: **Impulse Responses to a 1% Increase in Money Growth: Linear VAR, Great Recession.** Sample ranging from January 1921 to December 1940. Linear four-variate VAR estimated with variables in first differences (with the exception of the interest rates). Interest rates rotated in one at a time. 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.

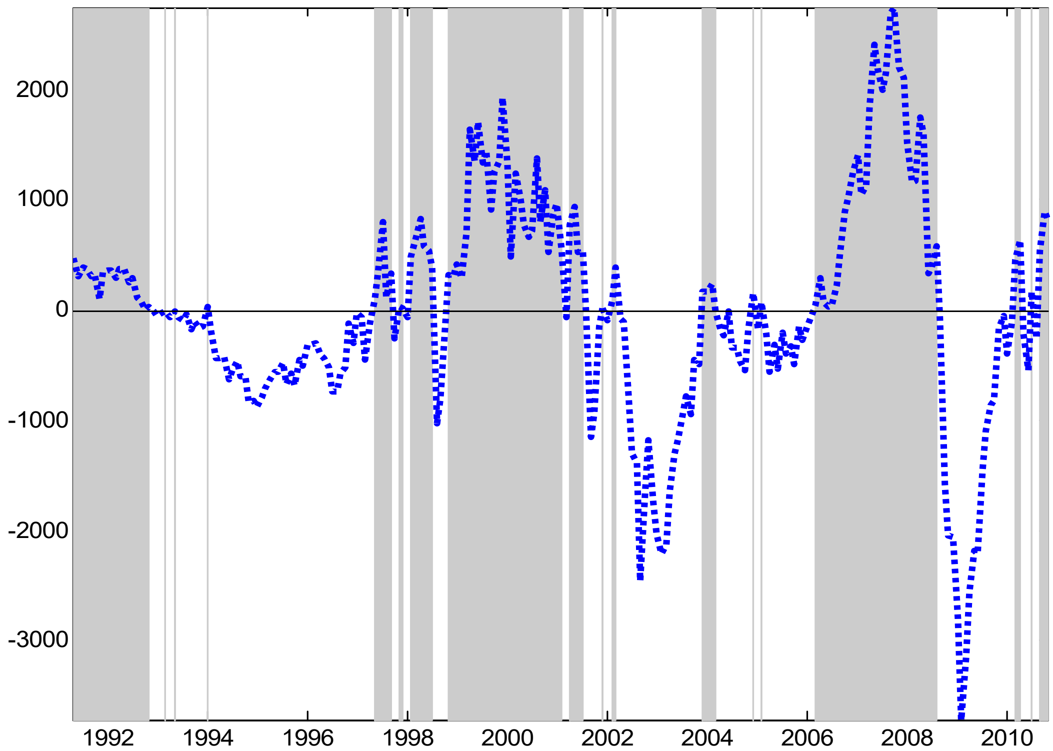

Figure 5: **Estimated Threshold, Great Recession**. Sample ranging from January 1991 to December 2010. Dow Jones index (Hodrick-Prescott filtered, smoothing weight: 129,600) employed as a switching variable for the identification of the "normal times" and "speculative" regimes. TVAR estimated with variables 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.

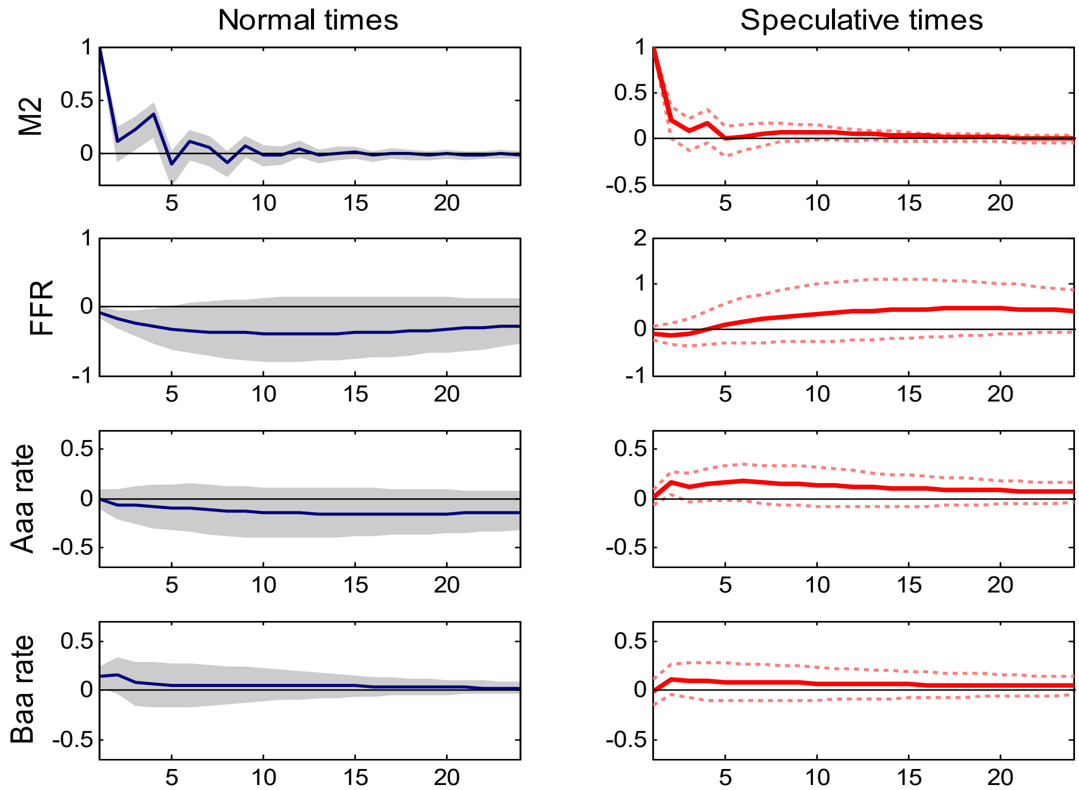

Figure 6: **State-dependent Impulse Response Functions, Great Recession**. Sample ranging from January 1991 to December 2010. Dow Jones index (Hodrick-Prescott filtered, smoothing weight: 129,600) employed as a switching variable for the identification of the "normal times" and "speculative" regimes. TVAR estimated with variables in first differences (with the exception of the interest rates). Interest rates rotated in one at a time. 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.

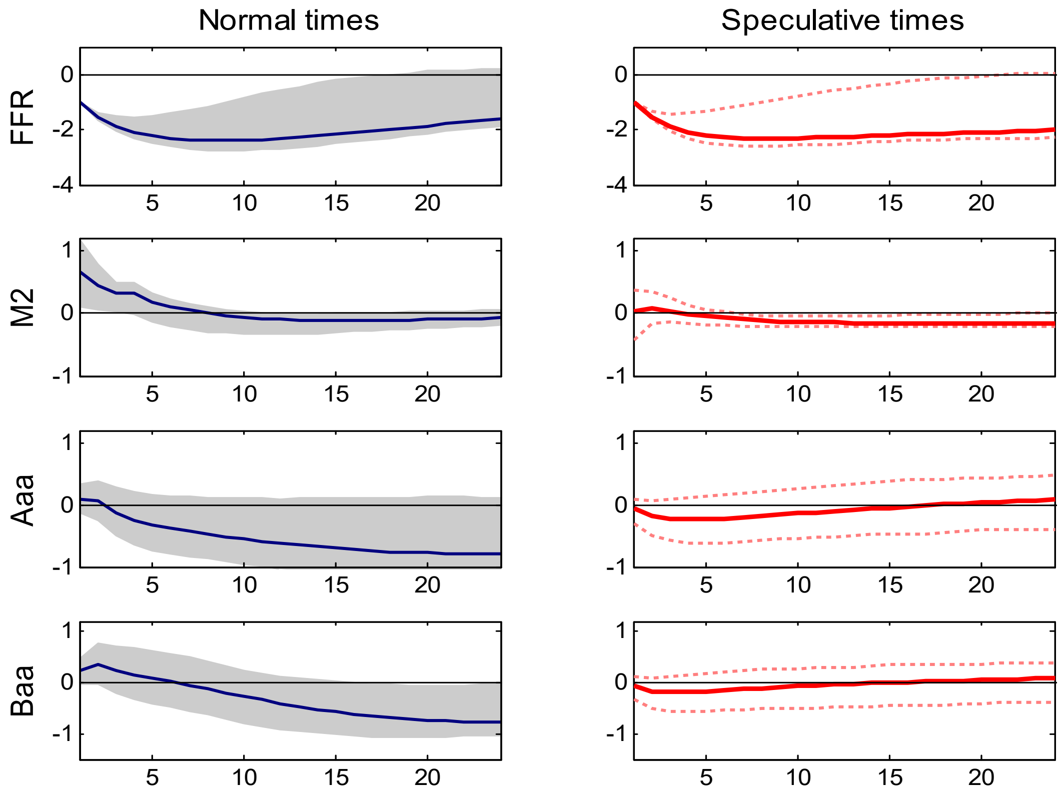

Figure 7: **State-dependent Impulse Response Functions, Great Recession: Shock to the Federal Funds Rate**. Sample ranging from January 1991 to December 2010. Dow Jones index (Hodrick-Prescott filtered, smoothing weight: 129,600) employed as a switching variable for the identification of the "normal times" and "speculative" regimes. TVAR estimated with variables in first differences (with the exception of the interest rates). Aaa and Baa rotated in one at a time. 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.

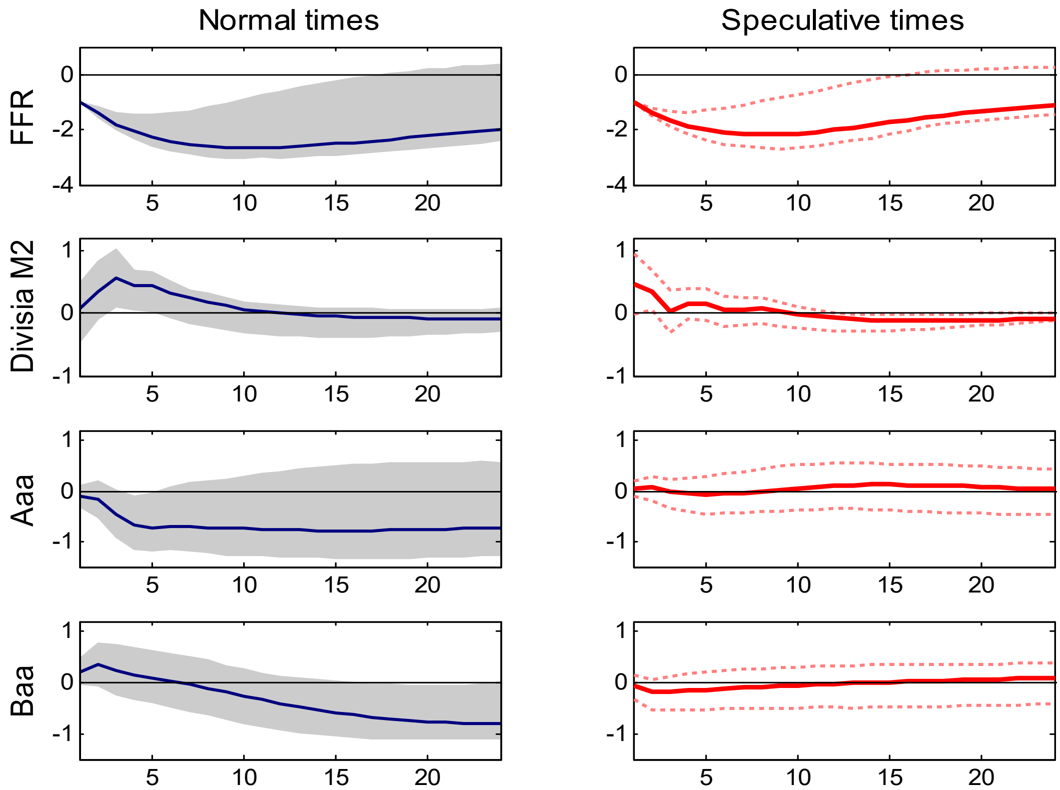

Figure 8: **State-dependent Impulse Response Functions, Great Recession: Shock to the Federal Funds Rate, Model with Divisia M2**. Sample ranging from January 1991 to December 2010. Dow Jones index (Hodrick-Prescott filtered, smoothing weight: 129,600) employed as a switching variable for the identification of the "normal times" and "speculative" regimes. TVAR estimated with variables in first differences (with the exception of the interest rates). Aaa and Baa rotated in one at a time. 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.

Appendix of the paper: "Liquidity Traps and Large-Scale Financial Crises" (not for publication)

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September 2016

A Further robustness checks

A long list of robustness checks is documented below. All checks are conducted by considering the following reference models. For the Great Depression, we model the growth rate of M2, the 3-month interest rate, the growth rate of PPI, and the growth rate of Industrial Production. In this model, the monetary policy tool is money, and the transition indicator is the unfiltered Dow Jones index. For the Great Recession, the reference model is the one modeling the federal funds rate, the growth rate of Divisia M2, the growth rate of PPI, the growth rate of Industrial Production, and a long-term interest rate (Aaa or Baa). In this model, the monetary policy tool is the federal funds rate, and the transition indicator is the HP-filtered Dow Jones index. We now turn to the list of our checks.

- **HP-filtered transition indicator, Great Depression period**. Figure A1 displays the outcome of our regressions conditional on HP-filtering the Dow Jones transition indicator used for the determination of the "speculative" and "normal times" regimes. The results of this robustness checks show that our baseline results - obtained with the unfiltered version of the transition indicator - are robust to this modeling choice. An exception appears to be the response of the 3-month rate, which stays close to zero in the very short-run before "taking off" after about 7 months. However, this response is not statistically different from zero. Figure A2 shows the responses in the HP-filtered transition indicator case along with the associated 90% confidence bands. The information displayed in Figure A2 confirms that our baseline result is robust to HP-filtering the transition indicator in the Great Depression period.

- **P/E ratio as transition indicator**. Figure A3 displays the impulse responses of the three interest rates for the Great Depression period we focus on in our analysis conditional on models in which the P/E ratio is employed as transition indicator. We model two cases, one in which the P/E ratio is not filtered and another one in which it is HP-filtered (smoothing weight: 129,600) before estimation. Our results are in line with what obtained with our baseline empirical framework. Figure A4 confirms that our results are robust to the employment of the P/E ratio as transition indicator also for the Great Recession period.

- **3 month-TBill rate as a proxy for the monetary policy instrument, Great Recession period**. Figure A5 plots the impulse responses we get when replacing the federal funds rate with the 3-month Treasury Bill rate in our VAR for the Great Recession period. Our baseline results are robust to this variation of the baseline empirical framework.

- **CPI and PCE, Great Recession period.** Our baseline vector embeds the Producer Price Index as a proxy for the level of prices. This choice is motivated by the availability of this index for both the samples we analyze. Other indices like the Consumer Price Index (CPI) and the Personal Consumption Expenditures (PCE) index are often used in investigations on the effects of monetary policy shocks. We re-run our econometric analysis by replacing the PPI with - alternatively - the CPI and the PCE index. Given the availability of these indices, we are forced to do it only for the Great Recession period. Figure A6 shows that our results are robust to the employment of these alternative indices.

- **Modeled variables: Growth rates vs. log-levels**. Our baseline exercises model trending variables in growth rates, while interest rates are kept in levels. Figures A7 and A8 show that our results are robust to the employment of trending variables in log-levels both in the Great Depression period and when using Great Recession data.

- **Observations to estimate the threshold value to identify the financial regimes: Perturbations**. In our baseline analysis, we use a trimming value equal to 40% to identify the two regimes we focus on. This implies that 20% of the observations in the sample are employed to estimate the threshold value via which we identify the regimes. It is of interest to assess the robustness of our results in light of small changes in these regimes. We do so by adding/subtracting 20% of the overall number of observations we use in the baseline analysis to estimate the threshold. Figures A9 and A10 show that our results are robust to these perturbations in both periods.

- **Other long-term interest rates**. Our results are confirmed when using alternative long-term interest rates. In particular, we consider a 10-year rate and a 30-year one, the latter just for the Great Recession period due to the lack of similar data for the Great Recession one. As regards the 10-year rate, for the Great Depression period we proxy it by using the U.S. Government Bonds taken from the U.S. Treasury Department. In particular, the rate is the long-term due or callable bond after eight years (1919-1925) and after twelve years (1925-1941).

The source of this series is Table 128, Banking and Monetary Statistics, Washington DC, 1943, Second Printing, August 1976. Figure A11 shows that, for the Great Depression period, our results are confirmed when using this rate. Figure A12 shows the responses of the 10-year Treasury Bill rate and the 30-year fixed mortgage rate (average in the United States) for the Great Recession sample. As regards the first rate, the evidence of a statistically negative response is borderline. Differently, the 30-year mortgage rate offers clear evidence in favor of a decline in normal times. 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.

- **Financial indices vs. financial volatility vs. NBER recessions**. Figure A13 plots the Dow Jones index (HP-filtered, smoothing weight: 129,600), the P/E ratio, and the VIX over the NBER recessions. As documented in the paper, the correlations between financial indices and financial volatility/NBER recessions read as follows: $\rho(DJ, VIX) = -0.26$, $\rho(DJ, NBER) = -0.12$, $\rho(P/E, VIX) = 0.05$, $\rho(P/E, NBER) = -0.18$. We then conclude that our regimes do not coincide with the ones investigated in the literature to establish the role of monetary policy shocks in high/low volatility state or in booms/busts.

- **Response of prices and industrial production**. Figures A14 and A15 document the responses of prices and industrial production in the two periods/two regimes we analyze. These responses are commented in the main text.

B Generalized Impulse Response Functions for the SE-TVAR

We present the algorithm employed to compute the GIRFs in our Self Exciting Threshold VAR (SE-TVAR). This algorithm follows Koop, Pesaran, and Potter (1996) with the modification needed to consider an orthogonal structural shock, as in Kilian and Vigfusson (2011).

The theoretical GIRF of the vector of endogenous variables $\mathbf{Y}$, h periods ahead, for a starting condition $\varpi_{t-1} = \{\mathbf{Y}_{t-1}, ..., \mathbf{Y}_{t-L}\}$, and a structural shock in date t, δ_t, can be expressed – following Koop et al. (1996) – as:

$$GIRF_{Y,t}(h, \delta_t, \varpi_{t-1}) = E\left[\mathbf{Y}_{t+h} \mid \delta_t, \varpi_{t-1}\right] - E\left[\mathbf{Y}_{t+h} \mid \varpi_{t-1}\right], \quad h = 0, 1, \ldots, H$$

where $E[\cdot]$ represents the expectation operator. Here the algorithm to estimate our state-conditional GIRF:

1. We pick an initial condition $\varpi_{t-1} = \{\mathbf{Y}_{t-1}, ..., \mathbf{Y}_{t-L}\}$, i.e., the historical values for the lagged endogenous variables at a particular date $t = L+1, \ldots, T$. Notice that, according to the lagged value of the threshold variable (also a component of Y in a SE-TVAR), y_{t-1}^{thres}, this initial condition will determine the starting regime $i = 1, 2$ from which the model will start to be iterated;

2. draw randomly (with repetition) two sequences of (n-dimensional) residuals $\{\boldsymbol{\varepsilon}_{t+h}^i\}$, $h = 0, 1, ..H = 23$, from the empirical distributions $d(\mathbf{0}, \widehat{\boldsymbol{\Omega}}^i)$, where $\widehat{\boldsymbol{\Omega}}^i$ is the estimated VCV matrix for regime $i = 1, 2$. In order to preserve the contemporaneous structural relationships among variables, residuals are assumed to be jointly distributed, so that if date t' s residual is drawn, all n residuals for date t are collected. The actual sequence of residuals used to iterate the system, $\{\boldsymbol{\varepsilon}_{t+h}\}^s$, will be a combination of the two previous sequences, as explained at point 3. s denotes the particular sequence of residuals used to iterate the system;

3. conditional on ϖ_{t-1}, on the estimated model (1)-(2) and using $\{\boldsymbol{\varepsilon}_{t+h}\}^s$ simulate the evolution of the vector of endogenous variables over the following H periods when a structural shock δ_t is imposed to $\boldsymbol{\varepsilon}_t^s$. In particular, depending on the regime $i = 1, 2$ in which the system starts the iteration, we Cholesky-decompose $\widehat{\boldsymbol{\Omega}}^i = \mathbf{C}_i \mathbf{C}_i\prime$, where $\mathbf{C}_i$ is a regime-dependent lower-triangular matrix. Then, we recover the structural innovation associated to $\boldsymbol{\varepsilon}_t^s$ by $\mathbf{u}_t^s = \mathbf{C}_i^{-1} \boldsymbol{\varepsilon}_t^s$ and add a quantity $\delta < 0$ to the scalar element of $\mathbf{u}_t^s$ that refers to the variable we want to shock. We then move again to the residual associated with the structural shock $\boldsymbol{\varepsilon}_t^{s,\delta} = \mathbf{C}_i \mathbf{u}_t^{s,\delta}$ to proceed with the iteration. Considering the fact that during the iteration onward the model can switch regimes, we select, for each time ahead, $\boldsymbol{\varepsilon}_{t+h}^s$ from $\{\boldsymbol{\varepsilon}_{t+h}^i\}$, $t+h$, $h = 1, ..H$, according to the regime $i = 1, 2$ in which the resulting path is at time $t+h$. Call the resulting (shocked) path $\mathbf{Y}_{t+h}^{s,\delta}$;

4. conditional on ϖ_{t-1} , on the estimated model (1)-(2) and using the *same* sequence $\{\boldsymbol{\varepsilon}_{t+h}\}^s$ simulate the evolution of the vector of endogenous variables over the following H periods to obtain the path $\mathbf{Y}^s_{t+h}$ for $h = 0, 1 \ldots H$. In iterating the system onward we just allow the two simulated paths $\mathbf{Y}^s_{t+h}$ and $\mathbf{Y}^{s,\delta}_{t+h}$ to iterate in two different regimes with the corresponding regime-dependent dynamics.

5. compute the difference between the previous two paths for each horizon and for each variable, i.e. $\mathbf{Y}^{s,\delta}_{t+h} - \mathbf{Y}^s_{t+h}$ for $h = 0, 1 \ldots, H$;

6. repeat steps 2-5 for a number $S = 500$ of different extractions for the residuals and then take the average across extractions s. We indicate the average across realizations with the operator $\widehat{E}$. This computation is performed per each starting quarter $t-1$, which is kept fixed when dealing with the S simulations. In this way we obtain a consistent point estimate of the GIRF for each given starting quarter in our sample, i.e., $\widehat{GIRF}_{Y,t}(\delta_t, \varpi_{t-1}) = \left\{ \widehat{E}\left[\mathbf{Y}_{t+h} \mid \delta_t, \varpi_{t-1}\right] - \widehat{E}\left[\mathbf{Y}_{t+h} \mid \varpi_{t-1}\right] \right\}_{h=0}^{23}$.[1] If a given initial condition ϖ_{t-1} brings an explosive response (namely if this is explosive for most of the sequences of residuals drawn $\{\boldsymbol{\varepsilon}_{t+h}\}^s$, in the sense that the response of the variable shocked diverges instead than reverting to zero) is discarded and not considered for state-conditional responses at the next step;[2]

7. these history-dependent GIRFs are then averaged over a particular subset of initial conditions of interest to produce our state-dependent GIRFs. To do so, an initial condition $\varpi_{t-1} = \{Y_{t-1}, ..., Y_{t-L}\}$ is classified to belong to the "speculative times" state if $y^{thres}_{t-1} \geq z$ and to the "normal times" state if $y^{thres}_{t-1} < z$, z being the threshold value, $t = L + 1, \ldots, T$. In this way we obtain our $\widehat{GIRF}_{Y,t}(\delta_t, \textit{speculative times})$ and $\widehat{GIRF}_{Y,t}(\delta_t, \textit{normal times})$.

References

Kilian, L., and R. Vigfusson (2011): "Are the Responses of the U.S. Economy Asymmetric in Energy Price Increases and Decreases?," *Quantitative Economics*, 2, 419–453.

Koop, G., M. Pesaran, and S. Potter (1996): "Impulse response analysis in nonlinear multivariate models," *Journal of Econometrics*, 74(1), 119–147.

[1] We compute the GIRFs by taking the average across simulations first and then the difference between the average response conditional on a shock δ and that not conditional on such shock. Given that the expectation operator is a linear operator, taking the difference between the two computed averages delivers the same result as taking the average of the differences across simulations.

[2] This is a theoretical possibility. In fact, it does not happen in our empirical application.

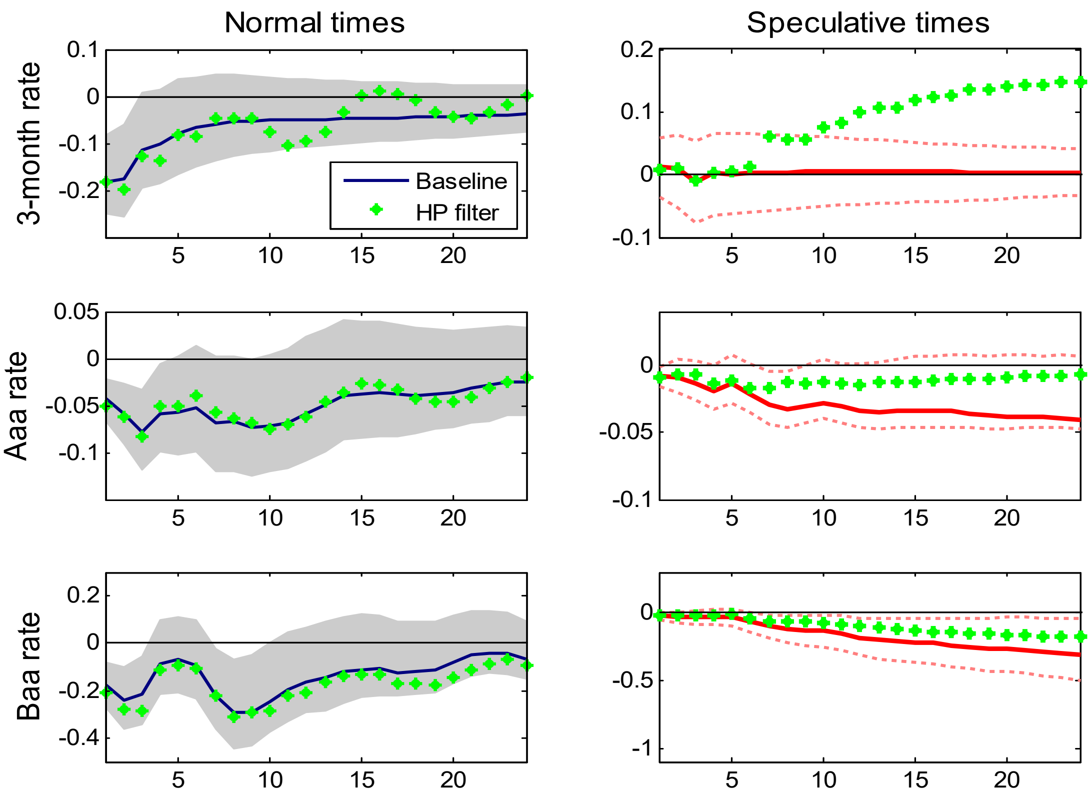

Figure A1: **State-dependent Impulse Response Functions, Great Depression: Role of HP-filtering of the transition indicator**. Sample ranging from January 1921 to December 1940. Baseline: No filtering of the transition indicator. HP filter: HP-filtered (smoothing weight: 129,600) transition indicator. 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 as indicated by the Akaike criterion. The IRF of money refers to the VAR estimated with the 3-month interest rate. 90% confidence bands associated to the Baseline case.

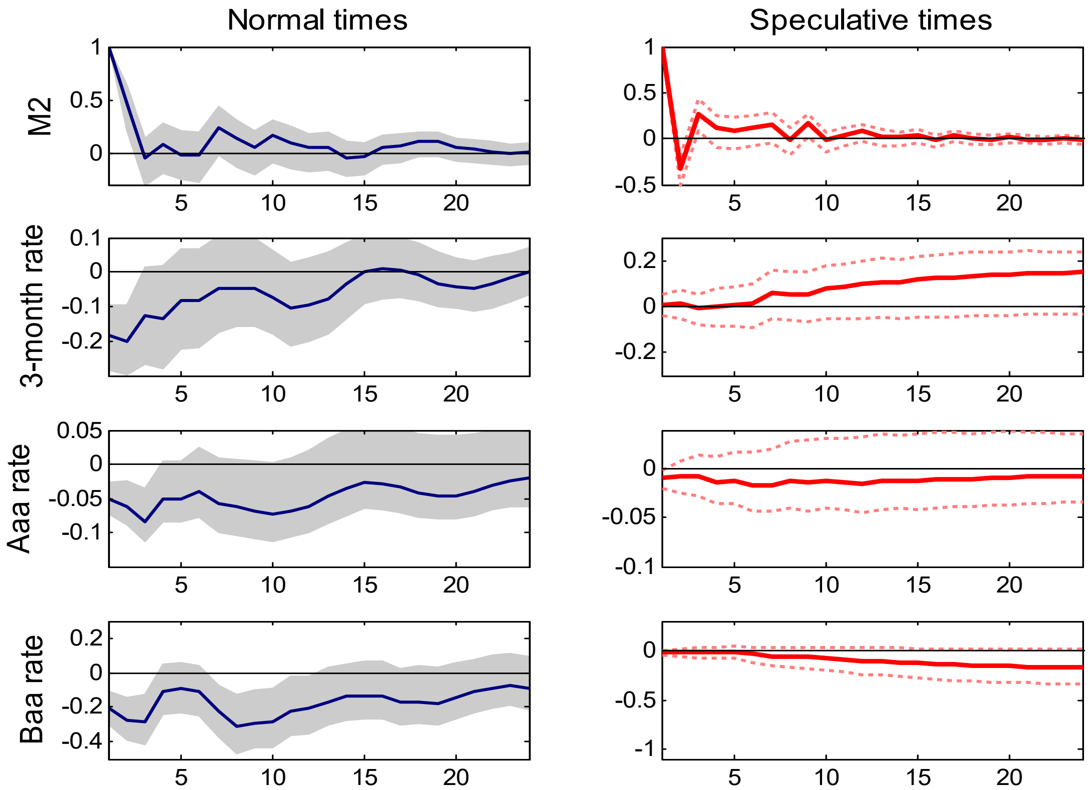

Figure A2: **State-dependent Impulse Response Functions, Great Depression: HP-filtered transition indicator**. Sample ranging from January 1921 to December 1940. Dow Jones index employed as a switching variable for the identification of the "normal times" and "speculative" regimes. TVAR estimated with 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 as indicated by the Akaike criterion. The IRF of money refers to the VAR estimated with the 3-month interest rate.

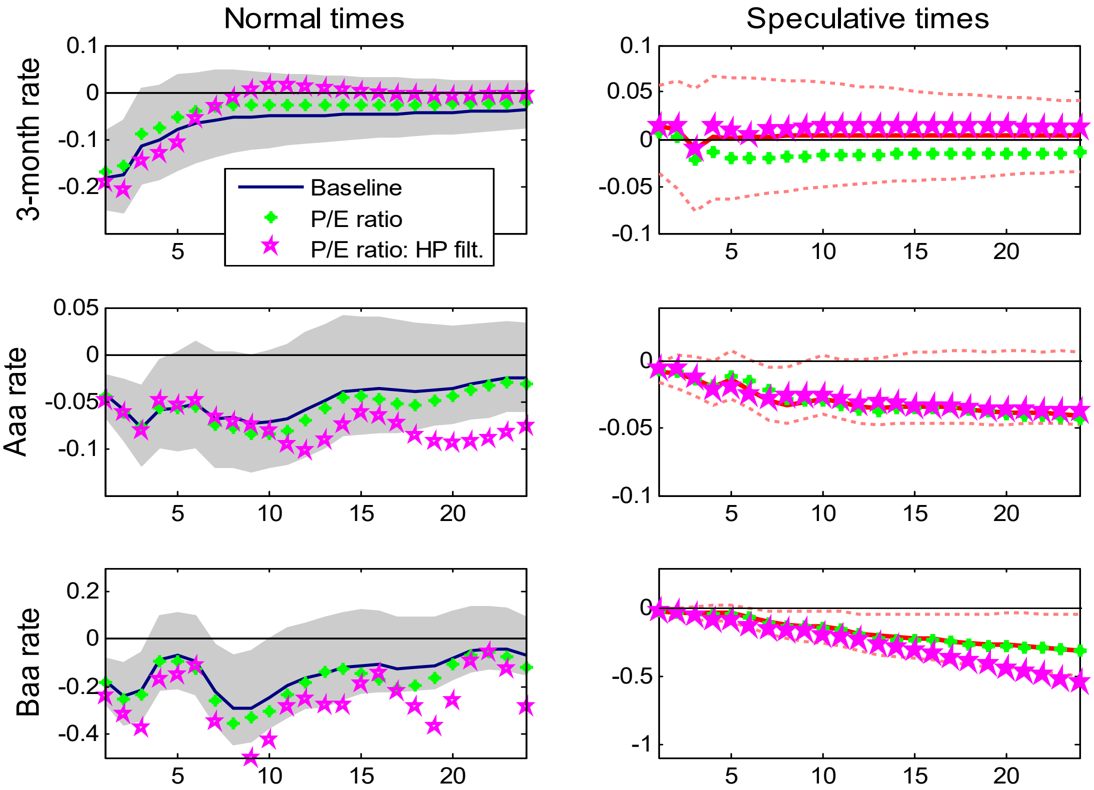

Figure A3: **State-dependent Impulse Response Functions, Great Depression: P/E ratio as transition indicator**. Sample ranging from January 1921 to December 1940. Baseline: Dow Jones (unfiltered) as transition indicator. P/E ratio: P/E ratio (unfiltered) as transition indicator. P/E ratio: HP filt.: HP-filtered P/E ratio (smoothing weight: 129,600) as transition indicator. 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 as indicated by the Akaike criterion. The IRF of money refers to the VAR estimated with the 3-month interest rate. 90% confidence bands associated to the Baseline case.

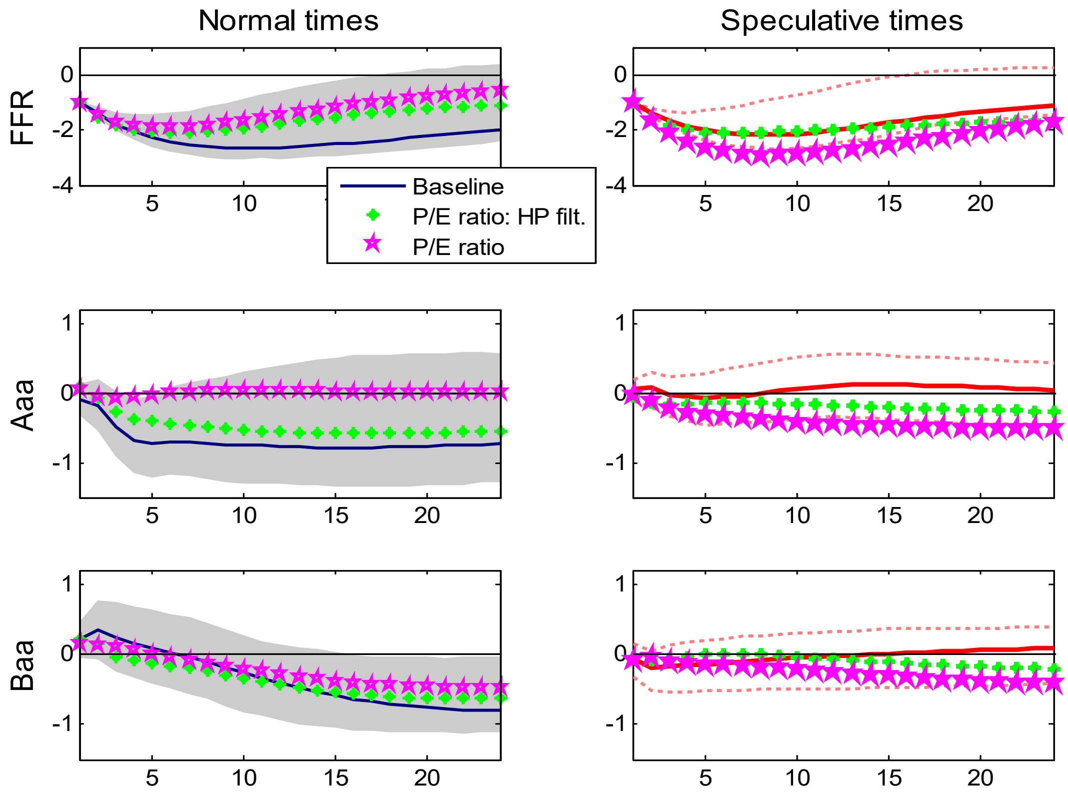

Figure A4: **State-dependent Impulse Response Functions, Great Recession: P/E ratio as transition indicator**. Sample ranging from January 1991 to December 2010. Baseline: Dow Jones (unfiltered) as transition indicator. P/E ratio: P/E ratio (unfiltered) as transition indicator. P/E ratio: HP filt.: HP-filtered P/E ratio (smoothing weight: 129,600) as transition indicator. 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 as indicated by the Akaike criterion. The IRF of money refers to the VAR estimated with the 3-month interest rate. 90% confidence bands associated to the Baseline case.

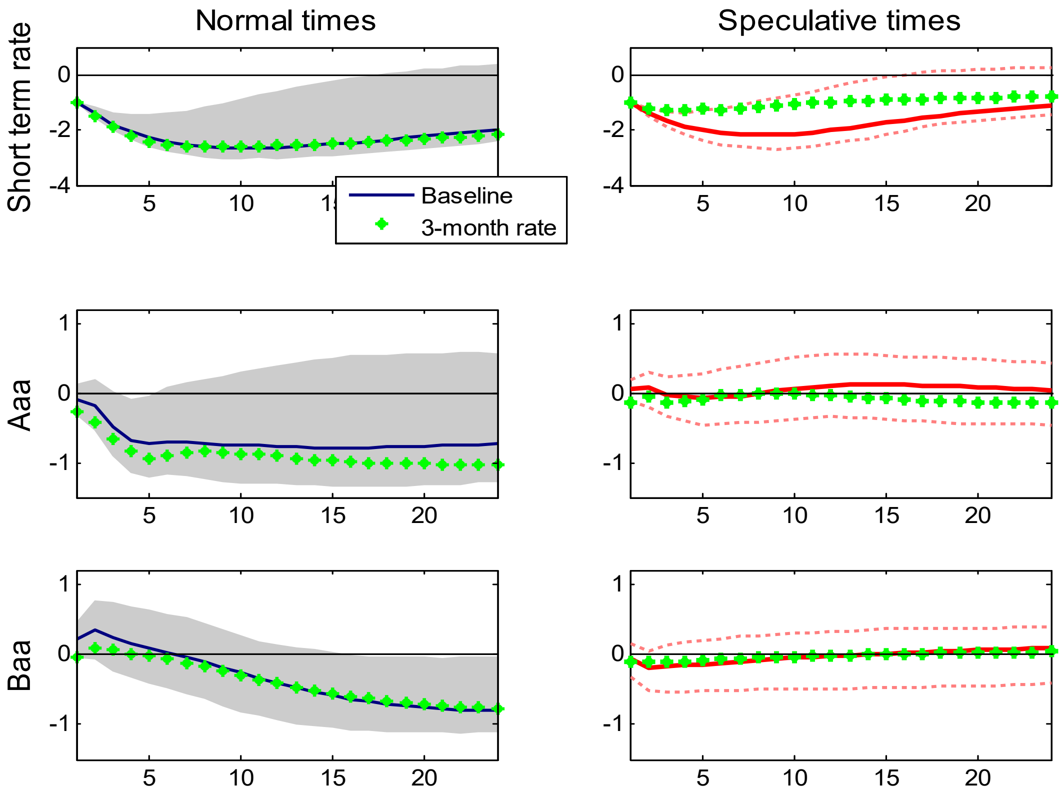

Figure A5: **State-dependent Impulse Response Functions, Great Recession: 3-month rate as policy rate**. Sample ranging from January 1991 to December 2010. Baseline: Federal funds rate as policy rate. 3-month rate: 3-month Treasury Bill rate as policy rate. Dow Jones index (Hodrick-Prescott filtered, 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 as indicated by the Akaike criterion. The IRF of money refers to the VAR estimated with the federal funds rate.

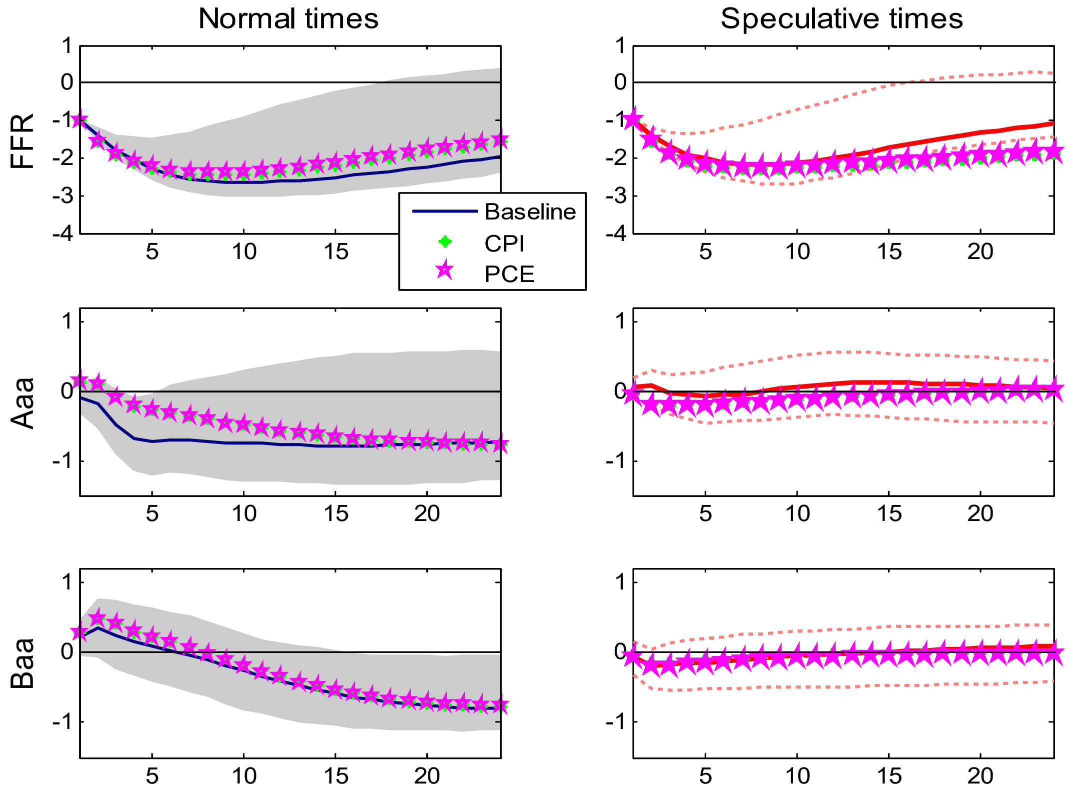

Figure A6: **State-dependent Impulse Response Functions, Great Recession: Shock to the Federal Funds Rate, Role of Price Indeces**. Sample ranging from January 1991 to December 2010. Baseline: PPI index. CPI: CPI index (all goods and services). PCE: PCE index. Dow Jones index (Hodrick-Prescott filtered, 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 as indicated by the Akaike criterion. The IRFs of the federal funds rate and money refer to the VAR estimated with the Aaa rate.

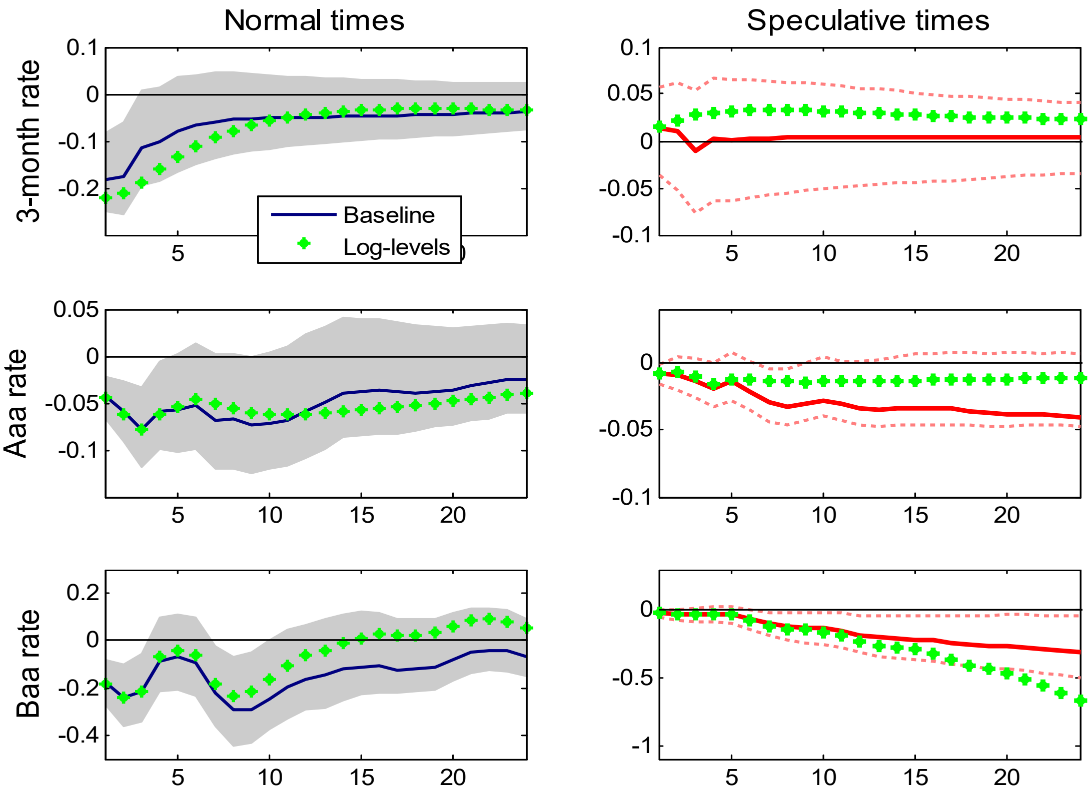

Figure A7: **State-dependent Impulse Response Functions, Great Depression: Growth Rates vs. Log-levels**. Sample ranging from January 1921 to December 1940. Baseline: Variables in growth rates (with the exception of the interest rates, which are in levels). Log-levels: Variables in log-levels (with the exception of the interest rates, which are in levels). 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 as indicated by the Akaike criterion. The IRF of money refers to the VAR estimated with the 3-month interest rate.

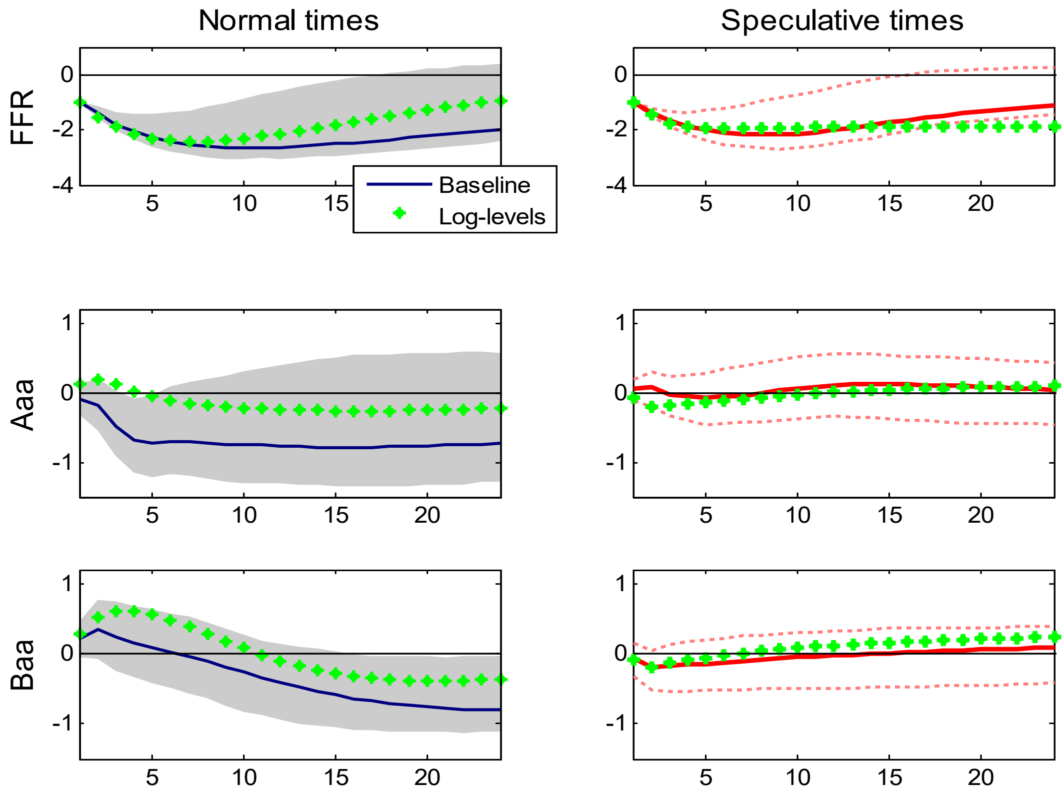

Figure A8: **State-dependent Impulse Response Functions, Great Recession: Growth Rates vs. Log-levels**. Sample ranging from January 1991 to December 2010. Baseline: Variables in growth rates (with the exception of the interest rates, which are in levels). Log-levels: Variables in log-levels (with the exception of the interest rates, which are in levels). 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 as indicated by the Akaike criterion. The IRF of money refers to the VAR estimated with the 3-month interest rate.

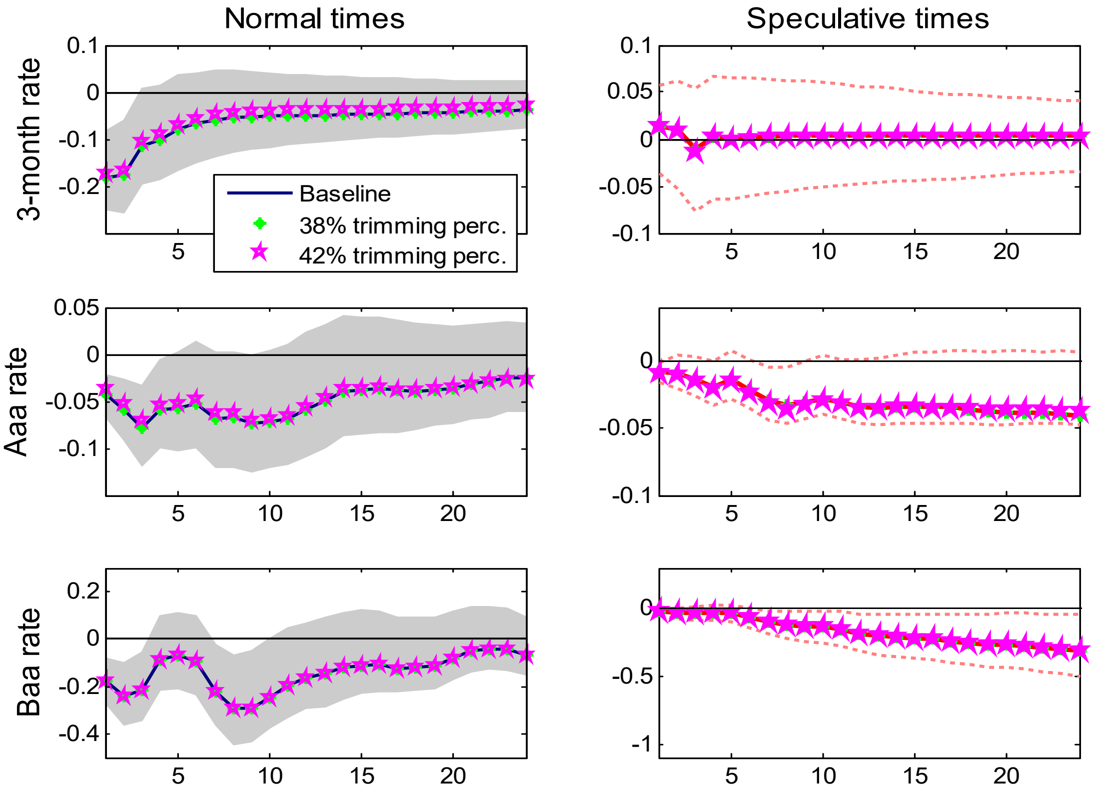

Figure A9: **State-dependent Impulse Response Functions, Great Depression: Perturbations to the Trimming Percentage**. Sample ranging from January 1921 to December 1940. Baseline: Trimming percentage equal to 40%. 38%/42% trimming percentages: Self explanatory. Dow Jones index employed as a switching 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 as indicated by the Akaike criterion. The IRF of money refers to the VAR estimated with the 3-month interest rate.

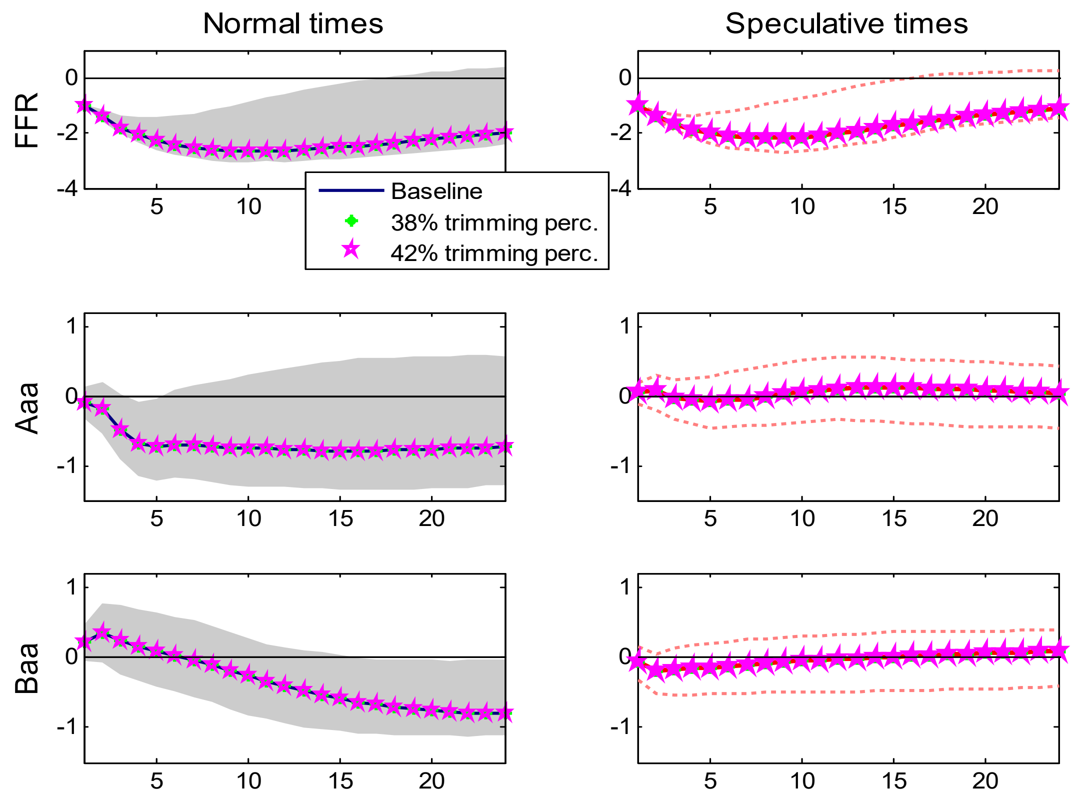

Figure A10: **State-dependent Impulse Response Functions, Great Recession: Perturbations to the Trimming Percentage**. Sample ranging from January 1991 to December 2010. Baseline: Trimming percentage equal to 40%. 38%/42% trimming percentages: Self explanatory. Dow Jones index employed as a switching 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 as indicated by the Akaike criterion. The IRF of money refers to the VAR estimated with the 3-month interest rate.

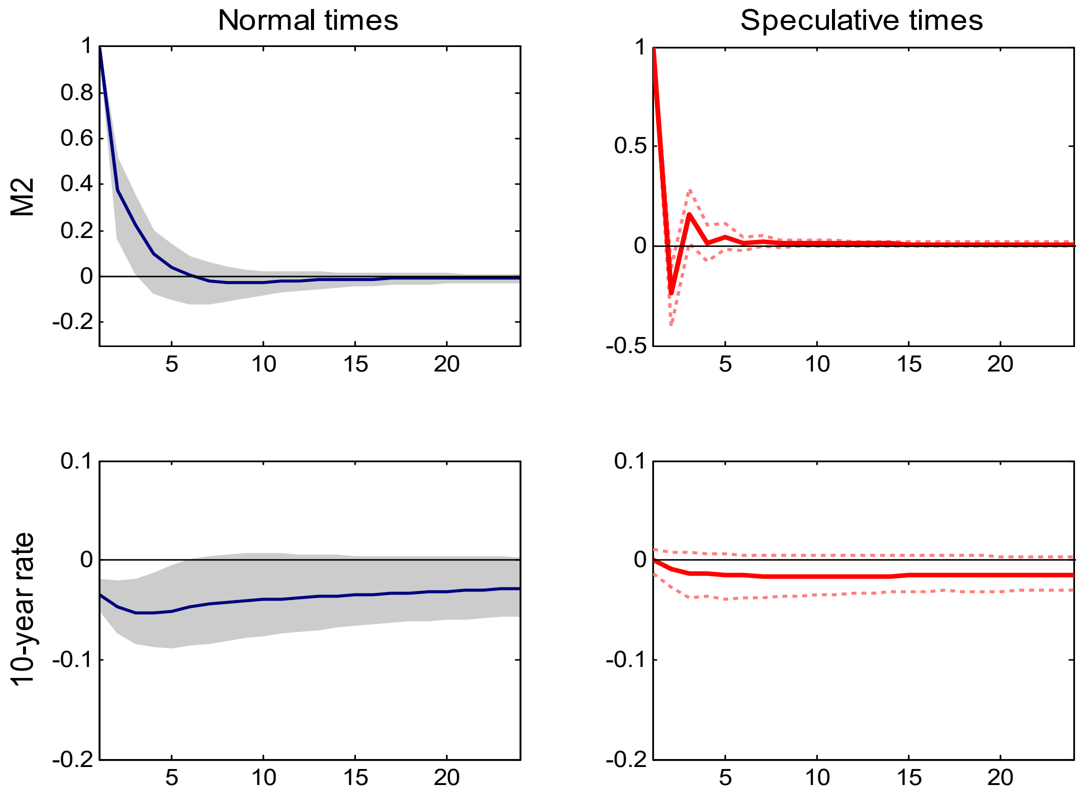

Figure A11: **State-dependent Impulse Response Functions, Great Depression: 10-year long rate.** Sample ranging from January 1921 to December 1940. 10-year rate: 10-year Treasury Bill rate employed in the reference VAR. 30-year mort. rate: 30-year fixed mortgage rate (average in the United States). Dow 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 as indicated by the Akaike criterion.

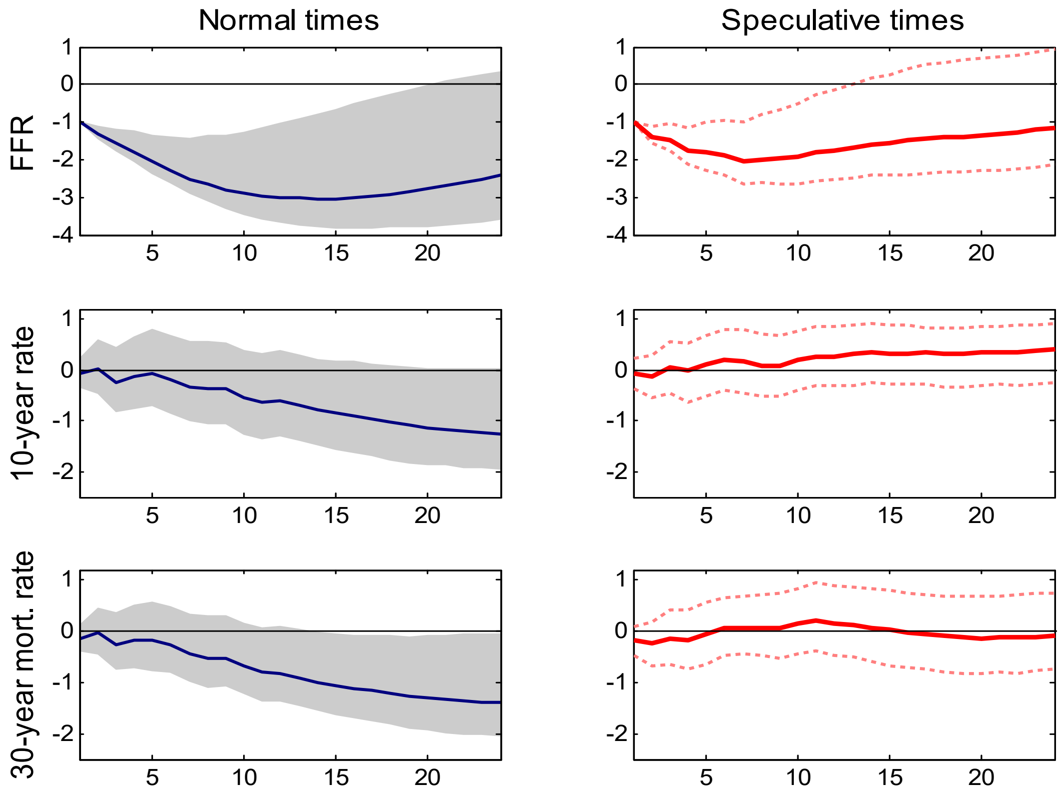

Figure A12: **State-dependent Impulse Response Functions, Great Recession: Other Long-term rates.** Sample ranging from January 1991 to December 2010. 10-year rate: 10-year Treasury Bill rate employed in the reference VAR. 30-year mort. rate: 30-year fixed mortgage rate (average in the United States). 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 as indicated by the Akaike criterion.

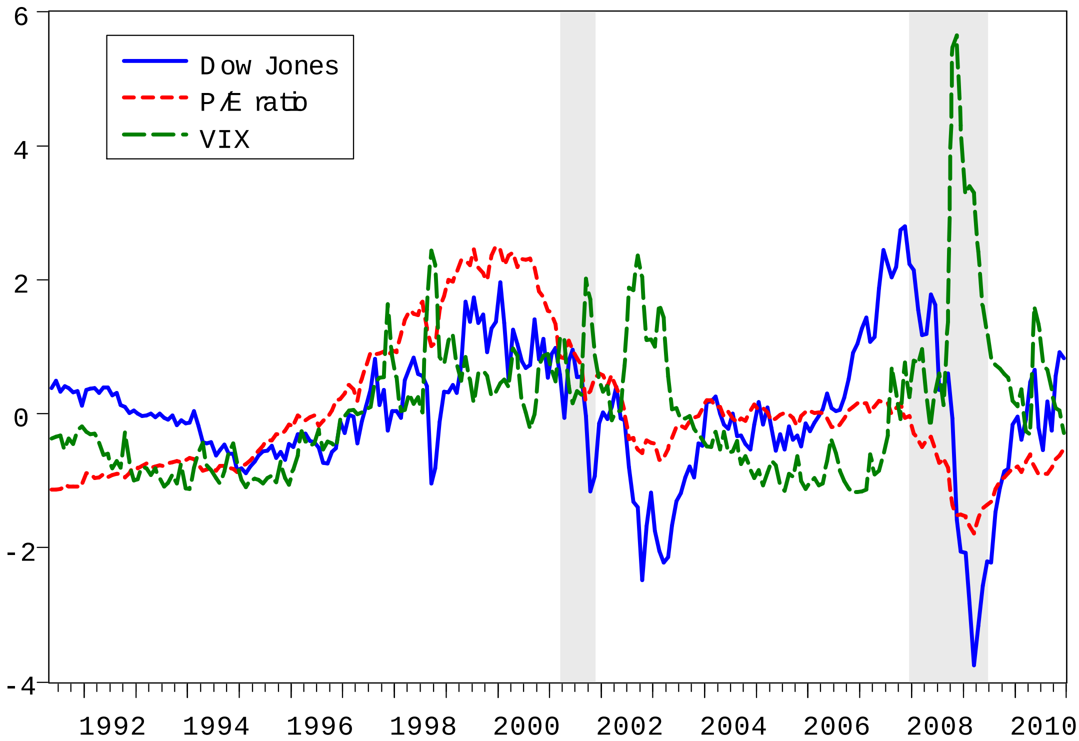

Figure A13: **Stock Price Indeces, Financial Volatility, and NBER Recessions, Great Recession: Correlations.** Sample ranging from January 1991 to December 2010. Dow Jones index (Hodrick-Prescott filtered, smoothing weight: 129,600) as in the empirical exercise.

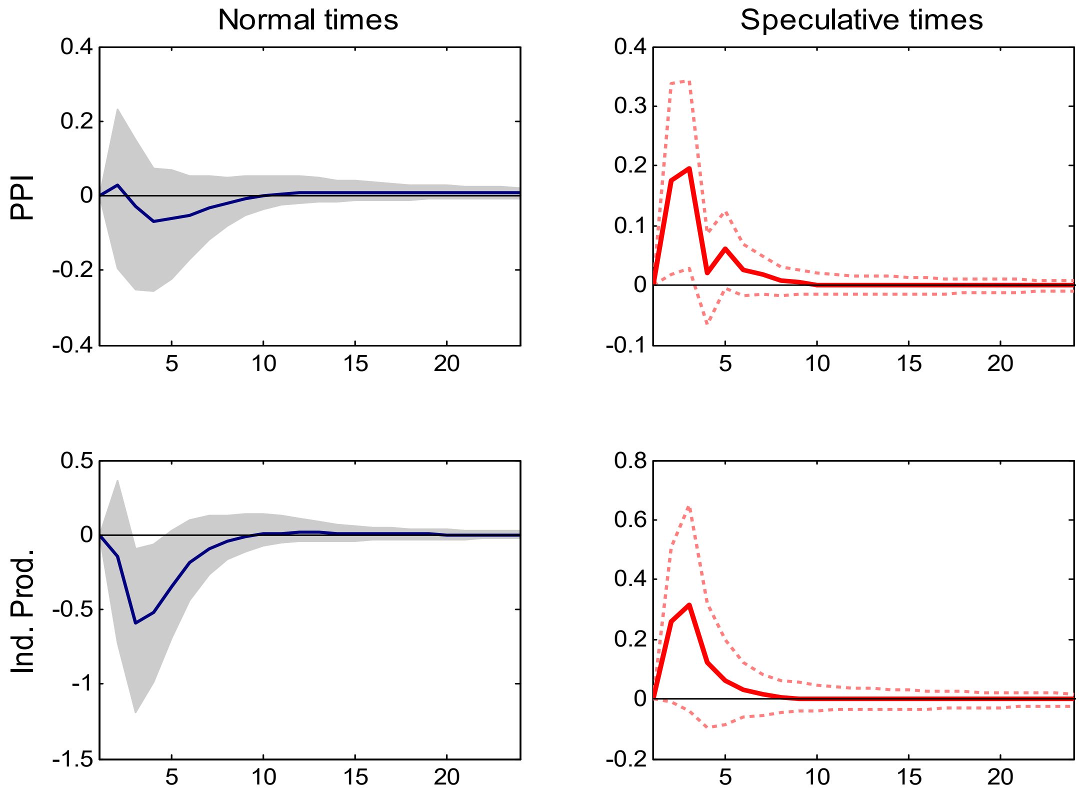

Figure A14: **State-dependent impulse Response Functions, Great Depression: Responses of Prices and Industrial Production to a 1% Shock to Money Growth.** Sample ranging from January 1921 to December 1940. TVAR estimated with variables in first differences (with the exception of the interest rates, which are rotated in the model one by one). Number of lags of the VAR as indicated by the Akaike criterion. 90% confidence bands plotted around the point estimates.

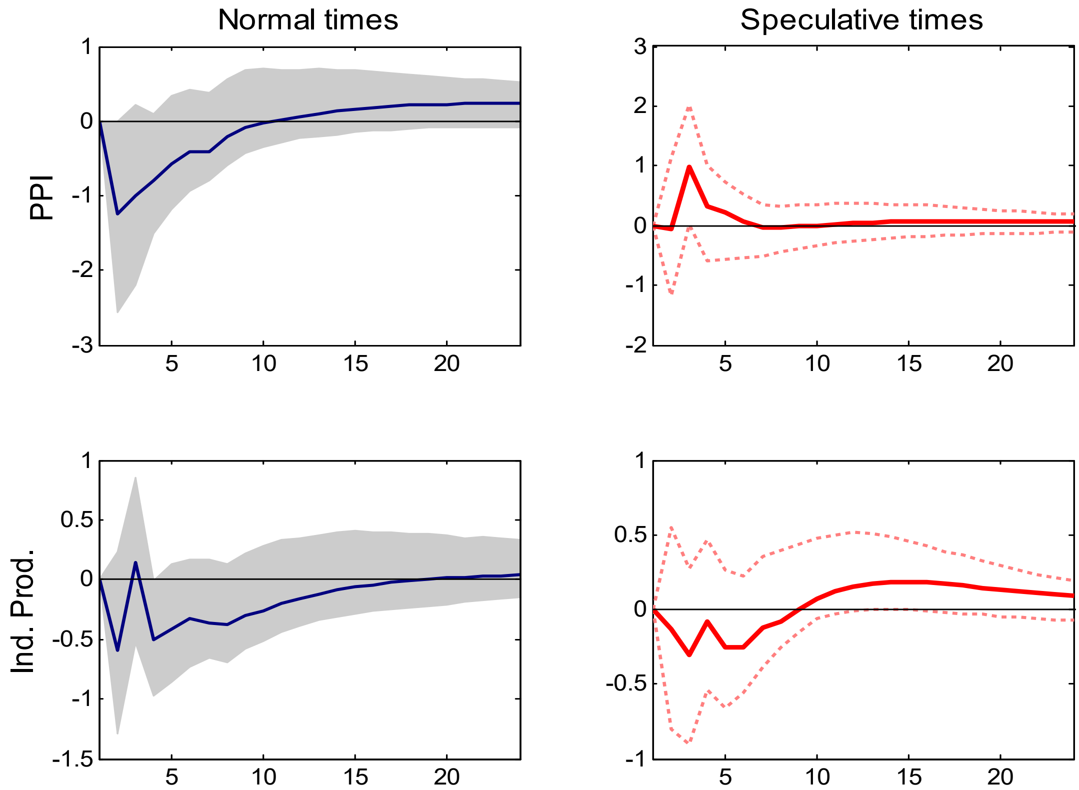

Figure A15: **State-dependent impulse Response Functions, Great Depression: Responses of Prices and Industrial Production to a -1% Shock to the Federal Funds Rate.** Sample ranging from January 1991 to December 2010. TVAR estimated with variables in first differences (with the exception of the interest rates, which are rotated in the model one by one). Number of lags of the VAR as indicated by the Akaike criterion. 90% confidence bands plotted around the point estimates.