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Unconventional monetary policy reaction functions: evidence from the US

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Abstract:

We specify unconventional monetary policy reaction functions for the Fed using linear and nonlinear econometric frameworks. We find that nonstandard policy measures are largely driven by the dynamics of inflation and the output gap, with the effect being particularly strong during QE rounds. Moreover, we uncover the presence of asymmetry and regime dependence in central bank's actions since the global financial crisis, especially concerning the response of the term spread and the shadow short rate to the growth rate of central bank reserves. From a policy perspective and given the lack of a systematic response of monetary policy to asset price growth in nonstandard times, our findings seem to corroborate the view that concerns about asset price bubbles, financial sector pro-cyclicality and systemic risk should be part of the macro-prudential policy toolkit.

Keywords: asset prices, central bank reserves, inflation, nonlinear models, output gap, shadow short rate, term spread, unconventional monetary policy reaction function

JEL classification: E21, E43, E51, E53

DOI: 10.1515/snde-2018-0088

1 Introduction

During the so-called Great Moderation, the goal of monetary policy was to preserve medium- to long-term price stability. The belief in policy circles was what Blanchard and Galí (2007) called the “divine coincidence,” namely, that by stabilizing inflation, one would mechanically stabilize the (welfare-relevant) output gap. To achieve it, central banks conducted monetary policy by announcing a target (short-term) interest rate and intervening in open market operations to align interbank rates with this target.

Yet, in the wake of the Great Recession, central bank rates have become constrained from below at the zero lower bound.¹ Accordingly, boosting an economy confronted with deflationary pressures or near-zero inflation is complicated if no further monetary stimulus can be deployed via cuts in nominal interest rates. Moreover, even in countries where nominal rates are negative, monetary authorities prefer a non-negative bound to avoid the breakdown of interbank activity.

As a consequence, central banks have turned to unconventional policies, especially the so-called “Quantitative Easing” (QE). Under this policy setup, the monetary authority compresses the term spread – i.e. the difference between the long-term (e.g. 10-year) government bond yield rate and the short-term (e.g. 3-month) Treasury bill rate – via large-scale asset purchases. By doing so, it engineers an expansion of its own balance sheet to support economic activity and promote higher inflation (Blinder, 2000; Bernanke and Reinhart, 2004).

Such unconventional monetary policies have stabilized financial markets and reduced yields on targeted assets, but retaining them for too long might also induce excessive risk-taking, causing potential disruptions on financial stability (Mostak Ahamed and Mallick 2017a; 2017b; 2019). How long such unconventional monetary policies should last is at the centre of the current debate.

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Many of the current discussions focus on the impact of unconventional monetary policies on financial markets. While some economists call for the end of central banks' massive policy interventions to avoid further uncertainty concerning the emergence of potential asset bubbles, others highlight the need of a cautious withdrawal of QE policies due to the increased sensitivity of the balance sheets of financial intermediaries to changes in interest rates (Turner, 2017).²

Against this background, the main contribution of our paper to the existing literature is to propose simple models, which might be used to evaluate the way the Fed reacted to the financial crisis and conducted monetary policy since then. More specifically, we account for the fact that the aim of unconventional monetary policies is to flatten the slope of the yield curve by compressing the term spread. Thus, using the same approach of the seminal paper by Taylor (1993), we formulate a nonstandard monetary policy rule, whereby the term spread (not the short-term policy rate) responds to macro-financial developments. Alternatively, we consider the reaction of the shadow short rate, i.e. a synthetic indicator of unconventional monetary policy actions (Krippner, 2013; Lombardi and Zhu, 2014; Christensen and Rudebusch, 2016; Wu and Xia, 2016). These rules provide a more adequate characterization of the "unconventional monetary policy reaction function" followed by the Fed in times of "zero" or "near-zero" policy rates.

We estimate monetary reaction functions for the Fed using monthly data for the post-Lehman collapse period as this marks the beginning of US unconventional monetary policy. First, we start by relying on a simple linear rule based on the Dynamic Ordinary Least Squares (DOLS) estimator. Next, we assess the existence of potential nonlinearities and consider formulations based on a Markov-Switching Regression (MSR), which enables us to describe the conduct of unconventional monetary policy in a more flexible framework. Interestingly, these econometric approaches are useful at capturing major QE policy actions and the asymmetry and regime dependence embedded in the response of the central bank to economic and asset market developments. More specifically, the nonlinear modelling framework imposes more economic structure than the linear approach. In particular, the parameters associated with the variables included in the unconventional monetary policy rule are allowed to change at a particular moment in time, with the probabilities governing the transition between states of the world being fixed in the case of the MSR regression. Since our rule is based on the dynamics of the term spread or the shadow short rate, we include among the information set of the monetary authority not only the inflation rate and the output gap (which are drivers of standard monetary policy actions), but also other variables considered by the literature as key determinants of the yield curve, especially those linked with the financial cycle, such as stock and housing prices (Dufrénot and Malik, 2012).

We find that the term spread and the shadow short rate are largely driven by the dynamics of inflation and the output gap. Specifically, the DOLS estimator suggests that both indicators of nonstandard monetary policy measures are reduced (in reflex of an acceleration of large-scale asset purchases by the central bank) when inflation rises or the economy recovers, in particular, during QE rounds.

Considering the nonlinear econometric framework, the results from the MSR model support the presence of regime-dependence in unconventional monetary policy actions. This mainly accrues to an asymmetric (switching-type of) response of the nonstandard policy instrument to the growth rate of central bank reserves. Since the global financial crisis, this characterization of the monetary policy reaction function captures "early" and "ending" phases of main Federal Open Market Committee (FOMC) actions in a particularly good fashion.

Overall, our findings point to the interest of incorporating nonlinearity in a flexible framework that is specifically designed for the estimation of unconventional monetary policy rules during turbulent and abnormal times.³

The remainder of the paper is organized as follows. Section 2 briefly discusses the related literature. Section 3 presents the econometric methodologies. Section 4 describes the data and summarizes the empirical results. Finally, Section 5 concludes.

2 Literature review

Our paper lays at the heart of the literature that studies the channels via which monetary policy operates at the zero lower bound and how the central bank responds to a series of macro-financial indicators in such circumstances.

The first strand of related research focuses on theoretical considerations and argues that, in a "liquidity trap," monetary expansions are not able to provide further stimulus, because portfolio rebalancing effects do not materialize when short-term interest rate are very low (Keynes, 1936). Assuming a perfect degree of substitution between money and bonds, Krugman (1998) highlights that the liquidity trap is a credibility problem, as economic agents do not believe that the monetary expansion can be sustained unless the central bank credibly commits to a sufficiently high-inflation target. Eggertsson and Woodford (2003) also show that the zero lower

bound restricts stabilization outcomes, and emphasize that fighting a deflationary slump requires managing expectations about the future path of interest and inflation rates through signaling effects.

Other authors, such as Auerbach and Obstfeld (2005), rely on the assumption that money is an imperfect substitute for a wide range of financial and real assets. Hence, monetary policy measures can induce portfolio rebalancing effects by affecting different assets' demands and agents' wealth. Similarly, Cúrdia and Woodford (2011) consider heterogeneity in spending opportunities available to different households at any point in time, and point out to the fact that this financial friction prevents the private sector from adjusting its asset purchases in response to central bank purchases. Consequently, equilibrium asset prices change after such nonstandard monetary policy actions. Farmer and Zabczyk (2016) develop a general equilibrium model that shows that variation in the composition risk of the central bank's balance sheet – i.e. a form of unconventional monetary policy – stabilizes both non-fundamental stock market fluctuations and economic activity, thus, being Pareto efficient.

The second strand of the literature looks at the empirical evidence instead. In this context, the existing studies provide a compelling ground for the influence of unconventional policy on financial markets (namely, by lowering long-term interest rates and narrowing term spreads), whereby the impact of QE is dominated by the portfolio rebalancing channel. For instance, Bernanke, Reinhart, and Sack (2004) find no significant relationship between 1-year-ahead expectations and BOJ policy statements, but unconventional policy effectively lowers long-term interest rates. Gagnon et al. (2011) uncover a persistently negative effect of the Fed's asset purchases on long-term interest rates of a wide range of securities, including those outside the scope of the programs. Using UK data, Joyce and Tong (2012) claim that the Bank of England's asset purchases have lowered yields on risky assets via portfolio rebalancing effects, and improved liquidity conditions.

Despite this, there is no consensual view about the impact of QE on real economic activity. Some authors show that unconventional monetary operations are ineffective in boosting aggregate demand and reversing deflation (Keister and McAndrews, 2009). The findings of Joyce and Tong (2012) reveal an important degree of uncertainty about the effect of the BOE's purchase program on the wider economy. And Chung et al. (2011) show that, by increasing stock prices and lowering the US dollar exchange rate, the Fed's large-scale asset purchases stimulated the real economy.

Moreover, while the bulk of the above mentioned studies focus on the effects of unconventional monetary policies, the literature concerning the (systematic) policy response to various macro-financial developments in nonstandard times is scarce. Indeed, despite numerous extensions of Taylor rule,⁴ these have typically been formulated in standard monetary policy frameworks (where short-term policy rates respond to fluctuations in the output gap and the inflation rate)⁵ or “leaning against the wind” monetary policies (where policy rates are set at a somewhat higher level than what would be required for pure inflation targeting reasons to safeguard financial stability).⁶

More recently, Caggiano, Castelnuovo, and Nodari (2018) and Ma, Olson, and Wohar (2018) consider the response of central bank to heightened financial and macroeconomic uncertainty, and show that it normally encompasses aggressive policy rate cuts. This result is also uncovered in previous studies, such as Giannoni (2002) and Sonderstrom (2002), but Kuttner and Posen (2001), Bernanke and Reinhart (2004), and Evans et al. (2015) point to an asymmetric reaction by the central bank depending on whether policy rates are near or far away from the zero lower bound.

However, in a zero-interest rate environment, the main difficulty associated with the estimation of central bank reaction function is that short-term policy rates are no longer operational. For this reason, some authors have developed frameworks that allow one to quantify the stance of monetary policy when the zero lower bound is binding. This is done via the estimation of a synthetic indicator called “shadow short rate,” which makes it possible to gauge unconventional monetary policy measures against Taylor-rule model specifications (Krippner, 2013; Lombardi and Zhu, 2014; Christensen and Rudebusch, 2016; Wu and Xia, 2016). For instance, Lombardi and Zhu (2014) propose a shadow policy rate for the US, and show that the Fed's asset purchases and the term premia are its key drivers. Similarly, Christensen and Rudebusch (2016) and Wu and Xia (2016) address the zero lower bound problem by accounting for nonlinearities in the term structure. Both shadow rate models are able to address the macroeconomic effects of unconventional monetary policy (Krippner, 2013).

We contribute to the existing literature along three main dimensions. First, we investigate the reaction function of the Fed in the context of unconventional measures by considering the dynamics of the term spread and the shadow short rate. This represents the major novelty of this work, as previous studies have generally focused on rather different questions, such as the macroeconomic and the wealth effects of unconventional monetary policy (Jawadi, Namouri and Ftiti, 2018). Second, we use a broad range of econometric techniques to distinguish between linear and nonlinear monetary policy rules adopted in nonstandard times. In particular, this allows us to assess the presence of nonlinearity and regime dependence in a flexible manner. Third, we account for the response of monetary policy to a number of macro-financial indicators. More specifically, the policy instruments react to macroeconomic activity (as proxied by the inflation rate and the output gap), asset

prices (i.e. the growth rate of the stock price index and the growth rate of the housing price index) and liquidity effects of monetary expansion (as captured by the growth rate of central bank reserves).

3 Econometric methodologies

3.1 Dynamic ordinary least squares (DOLS) regressor

We assess the performance of the term spread and the shadow short rate as alternatives to conventional monetary policy. We start by estimating an unconventional monetary policy reaction functions using the dynamic ordinary least squares (DOLS) regressor of Stock and Watson (1993). We consider two potential policy instruments: (1) the term spread (TS); and (2) the shadow short rate (SSR). Thus, we specify the following equations

$$TS_t = c + \beta_{INFL}INFL_t + \beta_{OG}OG_t + \beta_{RG}RG_t + \beta_{SPG}SPG_t + \beta_{HPG}HPG_t + \sum_{i=-k}^k \beta_{INFL,i}\Delta INFL_{t+i} + \sum_{i=-k}^k \beta_{OG,i}\Delta OG_{t+i} + \sum_{i=-k}^k \beta_{RG,i}\Delta RG_{t+i} + \sum_{i=-k}^k \beta_{SPG,i}\Delta SPG_{t+i} + \sum_{i=-k}^k \beta_{HPG,i}\Delta HPG_{t+i} + \varepsilon_t \quad (1)$$

$$SSR_t = c + \beta_{INFL}INFL_t + \beta_{OG}OG_t + \beta_{TS}TS_t + \beta_{SPG}SPG_t + \beta_{HPG}HPG_t + \sum_{i=-k}^k \beta_{INFL,i}\Delta INFL_{t+i} + \sum_{i=-k}^k \beta_{OG,i}\Delta OG_{t+i} + \sum_{i=-k}^k \beta_{TS,i}\Delta TS_{t+i} + \sum_{i=-k}^k \beta_{SPG,i}\Delta SPG_{t+i} + \sum_{i=-k}^k \beta_{HPG,i}\Delta HPG_{t+i} + \varepsilon_t \quad (2)$$

where $INFL_t$ is the inflation rate, OG_t is the output gap, RG_t is the growth rate of central bank reserves (RG), SPG_t is the growth rate of the stock price index, HPG_t is the growth rate of the housing price index, Δ denotes the first difference operator, c is a constant, k is the number of leads and lags of the explanatory variables, and ε_t is the error term.⁷ The parameters, β_{INFL} , β_{OG} , β_{RG} , β_{SPG} and β_{HPG} denote the response of the policy instrument to the inflation rate, the output gap, the growth rate of central bank reserves, the growth rate of the stock price index and the growth rate of the housing price index, respectively.

3.2 Markov-switching regime (MSR) model

To account for nonlinearity in nonstandard monetary policy reaction functions, we consider an alternative approach based on a Markov-Switching Regression (MSR). The idea behind this modeling strategy is that many economic series might obey to different regimes associated with events, such as financial crises or abrupt policy changes (Hamilton, 1988). Thus, we assess if either the term spread or the shadow short rate dynamics is regime-dependent, that is, whether it changes across different regimes associated with the growth rate of central bank reserves.⁸

We consider the following MSR models:

$$TS_t = \Psi L^k Z_{1t} + \Gamma(s_t) L^k Z_{2t} + \varepsilon_t \quad (3)$$

$$SSR_t = \Psi L^k Z_{1t} + \Gamma(s_t) L^k Z_{2t} + \varepsilon_t \quad (4)$$

where TS_t is the term spread, SSR_t is the shadow short rate, Z_t denotes the vector of explanatory variables (including the intercept), Ψ is the vector of non-switching parameters, $\Gamma(s_t)$ represents the vector of parameters that vary across different regimes s_t , with $s_t \in \{1, \dots, m\}$, L^k is the lag operator, and ε_t is the error term with a variance that may also be regime-dependent, i.e. $\varepsilon_t | s_t \sim N(0, \sigma^2(s_t))$.

Let us denote by p_{ij} , the unconditional transition probability that $s_t = i$ given that $s_{t-1} = j$, i.e. $p_{ij} = P(s_t = i | s_{t-1} = j)$. The MS model assumes that the transition probability matrix, P , is time-invariant and sums up all time-dependence between states, that is, $p_{i1} + p_{i2} + \dots + p_{im} = 1$.⁹ Under these conditions, the model can be

estimated using a Maximum-Likelihood Estimator (MLE) and an Expectation-Maximization (EM) algorithm as discussed by Hamilton (1990).

From an empirical point of view, we consider that only the coefficient associated to the growth rate of central bank reserves is regime-switching, while the response of the term spread (or the shadow short rate) to all the remaining variables is linear. Therefore, equations (3)–(4) can be rewritten as

$$TS_t = \sum_i \psi_{1i} INFL_{t-i} + \sum_i \psi_{2i} OG_{t-i} + \sum_i \psi_{3i} SPG_{t-i} + \sum_i \psi_{4i} HPG_{t-i} + \sum_i \gamma_i(s_t) RG_{t-i} + \varepsilon_t \quad (5)$$

$$SSR_t = \sum_i \psi_{1i} INFL_{t-i} + \sum_i \psi_{2i} OG_{t-i} + \sum_i \psi_{3i} SPG_{t-i} + \sum_i \psi_{4i} HPG_{t-i} + \sum_i \gamma_i(s_t) RG_{t-i} + \varepsilon_t \quad (6)$$

where s_t is the regime, and i denotes the number of lags, which is set equal to one.

4 Data and empirical results

4.1 Data

We use monthly frequency data for the US over the period 2008:11–2017:12. Our sample concerns the post-Lehman Brothers' collapse period, which marks the beginning of unconventional monetary policy. Moreover, the FOMC's plan for reducing holdings of securities and decreasing reinvestments was announced after its June 2017 meeting, and the Federal Reserve's balance sheet started to pare back towards the end of 2017, thus, setting the end of nonstandard monetary policy measures.

We assume that, since the financial crisis, monetary policy actions are captured by the dynamics of the term spread, i.e. the difference between the long-term (10-year) government bond yield rate and the short-term (3-month) Treasury Bill rate.¹⁰ Over the time frame considered in the analysis, short-term rates are mostly set at the zero lower bound. As a result, the dynamics of the term spread mainly reflects changes in long-term rates (associated with unconventional monetary policy actions) rather than variation in short-term rates (due to conventional monetary policy measures). Additionally, while inflation expectations, risk perceptions or uncertainty could have all affected the term spread before QE started to be implemented in 2008, large-scale asset purchases dominate movements in the term spread afterwards. Indeed, as Jawadi, Namouri, and Ftiti (2018) show, the conduct of monetary policy suffered important changes from "standard" to "exceptional" times. More specifically, models based on the short-term interest rate are well suited to capture the impact of conventional monetary policy in "standard" times, while models based on the term spread are a good characterization of unconventional monetary policy in "exceptional" times.¹¹

In addition to the term spread, we have also considered the Fed's shadow short rate as an alternative non-standard monetary policy instrument. Following Krippner (2015), we use the shadow short rate estimated from two-factor shadow/lower-bound term structure models (SLMs), which are robust compared to three-factor SLMs and can be particularly relevant to monitor and quantitatively assess nonstandard monetary policy conditions.

These policy instruments respond to the macroeconomic environment (i.e. inflation and output gap) and asset price developments (i.e. the growth rates of stock prices and housing prices).¹² In line with standard monetary policy rules (Taylor, 1993), the inflation and the output gap are included in the Fed's nonstandard monetary policy reaction function to account for the effect of economic conditions and the business cycle phase. As for the inclusion of asset price developments, it allows us to capture their predictive content about inflation and economic activity (Cecchetti et al., 2000; Chadha, Sarno and Valente, 2004), while controlling for the possibility that the Fed reacts differently to stock prices and housing prices (Castro and Sousa, 2012) and the term spread also responds to changes in risk appetite (Backus and Wright, 2007).

The central bank reserves' growth rate, which is computed using data for the reserves of depository institutions and is expressed in natural logs of real terms, is also part of its information set. As pointed out by Krogstrup, Reynard, and Sutter (2012), the increase in zero-yield reserves associated with the Fed's large-scale asset purchases induces banks to search for a higher return on their assets. Hence, the demand for higher yields on medium- to long-term assets, such as government bonds, increases. This, in turn, reduces the yields of these assets and, ultimately, the term spread. Consequently, an increase in the growth rate of the central bank's reserves should be related with a fall in long-term rates and a reduction of the term spread, as a result of the "liquidity" effect of monetary expansion.

Figure 1 plot the Fed's shadow short rate (*SSR*), the term spread (*TERM_SPREAD*), the long-term (10-year) government bond yield rate (*LTRATE*) and the short-term (3-month) Treasury bill rate (*STRATE*). With the exception of the last observations of the sample (i.e. after the Tapering process and the Fed's "liftoff"), it can be seen that short-term rates have been at the zero-lower bound throughout the whole sample period. As a result, these rates lost their effectiveness as policy instruments. In this context, the term spread (*TERM_SPREAD*) and the Fed's shadow short rate (*SSR*) are much better at capturing the diversity of nonstandard policy measures that were implemented. The dynamics of the two variables is also similar, with a downward pattern until the first half of 2013 and a rise afterwards.

Figure 1: Fed's shadow short rate (*SSR*), term spread (*TERM_SPREAD*), long-term (10-year) government bond yield rate (*LTRATE*) and short-term (3-month) Treasury bill rate (*STRATE*). Fed's shadow short rate (*SSR*), long-term (10-year) government bond yield rate (*LTRATE*), short-term (3-month) Treasury bill rate (*STRATE*) and term spread (*TERM_SPREAD*).

Both the term spread and the central bank reserves' growth rate come from the Board of Governors of the Federal Reserve System. Inflation is computed using data for the Consumer Price Index (CPI) – All Urban Consumers (all items less food and energy, 1982–1984 = 100) from the Bureau of Labor Statistics (BLS). The output gap is calculated using data for the total industrial production and capacity utilization index, which is obtained from the Board of Governors of the Federal Reserve System. The industrial production index is transformed into natural log terms and the Hodrick-Prescott filter is applied to generate the output gap in percentage of potential industrial production. The stock price index corresponds to the S&P500 index. The housing price index is based on the median sales price for new houses sold in the US, which is gathered by the Federal Reserve Bank of St. Louis. Both asset price indices are expressed in natural logs of real terms.

Table 1 reports a summary of the descriptive statistics of all variables included in the analysis. The average term spread was 228 basis points and the average shadow short-term rate was -1.53% , while the average central bank's reserve growth rate was 1.67% . Among the macro-financial variables, asset price (i.e. housing and stock price) growth rates are the most volatile in terms of unconditional standard deviation. Moreover, while the term spread, the housing price growth rate and the central bank's reserves growth rate are positively skewed, all other variables are negatively skewed. Similarly, the term spread and the shadow short-term rate display a platykurtic behaviour pattern, while the central bank's reserve growth rate, the inflation rate and the stock price growth rate exhibit a leptokurtic distribution. The central bank's reserve growth rate has the highest excess kurtosis. Finally, the Jarque-Bera test (JB) strongly rejects the hypothesis of a normal distribution for all variables, except the housing price growth rate.

Table 1: Descriptive statistics.

	<i>TERM_SPREAD</i>	<i>INFL</i>	<i>OUTPUTGAP</i>	<i>SP_GR</i>	<i>HP_GR</i>	<i>SSR</i>	<i>RESERVES_GR</i>
Mean	2.2821	0.1455	-0.5217	0.8978	0.2664	-1.5317	1.6663
Median	2.1800	0.1474	0.0594	1.2079	0.1000	-0.9202	0.8002
Maximum	3.6900	0.3075	2.2957	10.1174	12.5548	1.4525	65.9372
Minimum	1.0800	-0.1218	-8.0744	-11.8395	-11.0782	-5.3693	-20.6805

Std. Dev.	0.7020	0.0738	2.1480	3.8436	4.5182	1.8975	8.2918
Skewness	0.2775	-0.6840	-1.8545	-0.5210	0.0098	-0.4827	4.4760
Kurtosis	2.0946	4.4666	6.1853	3.8758	2.9972	2.0671	35.4313
Jarque-Bera	5.1692*	18.4367***	109.5555***	8.4916***	0.0018	8.2604**	5187.9910***
Observations	110	110	110	110	110	110	110

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

4.2 Dynamic ordinary least squares (DOLS) regressor

A summary of the results concerning the term spread reaction functions estimated using the DOLS approach can be found in Table 2. We note that the macroeconomic environment plays an important role in the conduct of unconventional monetary policy. Indeed, both the inflation rate and the output gap enter negatively and significantly in the model. This means that the monetary authority further expands its stance – i.e. it puts in place additional asset purchases that lead to a compression in the term spread – in response to a recovery of the inflation rate or an improvement in real economic activity. In doing so, it aims at guaranteeing that these macroeconomic developments are sustained over time. Stock prices also appear to influence the term spread but the effect is weak, as it is only significant at the 10% level.

Table 2: Unconventional monetary policy rule: term spread equations – DOLS model.

Variables	(1)	(2)	(3)
<i>Constant</i>	4.1364*** [24.800]	3.8351*** [17.698]	3.4618*** [12.536]
<i>INFL</i>	-1.1102*** [-11.846]	-0.9726*** [-9.144]	-0.7931*** [-6.018]
<i>OG</i>	-0.1381*** [-6.450]	0.0568 [1.069]	0.0864 [1.593]
<i>RG</i>	0.0450*** [3.370]	0.0720* [1.837]	0.0517 [1.246]
<i>SPG</i>	-0.0586* [-1.913]	-0.0729** [-2.246]	-0.0727** [-2.270]
<i>HPG</i>	0.0139 [0.402]	0.0720* [1.776]	0.0782* [1.958]
<i>QE</i>			1.4959*** [3.039]
<i>INFL × QE</i>		0.0223 [0.256]	-0.6971*** [-3.116]
<i>OG × QE</i>		-0.1777*** [-3.028]	-0.2192*** [-3.660]
<i>RG × QE</i>		-0.0381 [-0.758]	-0.0607 [-1.322]
<i>SPG × QE</i>		0.1050* [1.831]	0.0734 [1.289]
<i>HPG × QE</i>		-0.1069** [-2.264]	-0.1371*** [-3.149]
Observations	107	107	107
R-squared	0.701	0.798	0.817

Robust *t*-statistics in brackets. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. As is standard in the literature and for brevity, the coefficients associated with the leads and lags of the first-differences of regressors are not reported. However, they are available upon request.

Finally, the growth rate of central bank reserves enters positively and significantly the policy rule. On the one hand, the amount of aggregate reserves is largely determined by policy actions operating on the asset side of the central bank's balance sheet. On the other hand, the motivation behind reserves accumulation by banks is a function of the impact of changes in the economic environment on these institutions. In this case, precautionary motives might play an important role. As a result, the positive link between the term spread and the growth rate of central bank reserves suggests that an increase in the size of large-scale asset purchases by the monetary authority signals further purchases in the future. It can also be interpreted as an indication that the large injection of liquidity by the Fed started to restore the functioning of interbank market and promoted credit expansion, encouraging banks to minimize their holdings of excess reserves.¹³

To better account for the impact of the various Quantitative Easing (QE) rounds on the response of the term spread to macro-financial variables, we also perform an exercise where we add interaction terms between the explanatory variables and a QE dummy variable to the set of controls. This dummy variable takes the value of one during the QE1, QE2 and QE3 rounds, and zero otherwise. We note that the QE1 program ran from December 2008 until March 2010; the QE2 program was launched in November 2010 and concluded in June 2011; and the QE3 program began in September 2012 and ended in December 2013. Following Brambor, Clark, and Golder (2006), we include both the dummy variable term, the interaction term between the dummy variable and the control variables, and the control variables in the model specification.

The results are shown in Columns (2)–(3). As can be seen, the results are quite similar to those reported in Column (1). However, it is important to highlight that, during QE rounds, there is an amplified response of the term spread to the dynamics of inflation. Indeed, both the coefficient associated with inflation (*INFL*) and the one associated with the *INFL* $\times$ *QE* interaction term are negative and statistically significant. Similarly, the significant reaction of the term spread to the output gap seems to accrue to the different QE rounds. In fact, while the coefficient associated with the output gap (*OG*) is not statistically significant, that associated with the *OG* $\times$ *QE* interaction term is negative and statistically significant.

The empirical findings associated with the shadow short rate functions are summarized in Table 3. They show that the dynamics of the output gap is particularly relevant to understand the response of the shadow short rate: an increase in the output gap leads to a statistically significant reduction of the synthetic indicator of nonstandard monetary policy actions. However, from a qualitative point of view, shadow short rate equations appear to perform worse than term spread equations, as the inflation rate is only weakly significant and the central bank's reserves growth rate is not consistently significant across all model specification. Despite this, the sign of the coefficients associated with these variables is negative, suggesting that the Fed puts in place further expansionary policies – as captured by a fall in the shadow short rate – in response to a recovery of the inflation rate or an acceleration of central bank's reserves.

Table 3: Unconventional monetary policy rule: shadow short rate equations – DOLS model.

Variables	(1)	(2)	(3)
<i>Constant</i>	−0.9545 [−1.318]	1.1928 [1.229]	1.5743 [1.246]
<i>INFL</i>	−0.2990 [−0.697]	−0.9472* [−1.761]	−1.1307* [−1.692]
<i>OG</i>	−0.3867*** [−4.957]	−1.0440*** [−4.237]	−1.0743*** [−4.187]
<i>RG</i>	−0.2019*** [−3.072]	0.1954 [1.545]	0.2162 [1.563]
<i>SPG</i>	−0.1048 [−0.838]	−0.1261 [−0.952]	−0.1262 [−0.928]
<i>HPG</i>	−0.1568 [−0.928]	0.2115 [1.142]	0.2051 [1.108]
<i>QE</i>			−1.5288 [−0.794]
<i>INFL</i> $\times$ <i>QE</i>		−2.9835*** [−9.694]	−2.2482** [−2.214]
<i>OG</i> $\times$ <i>QE</i>		0.4592* [1.782]	0.5016* [1.839]
<i>RG</i> $\times$ <i>QE</i>		0.0782 [0.448]	0.1013 [0.599]
<i>SPG</i> $\times$ <i>QE</i>		0.3035 [1.287]	0.3358 [1.365]
<i>HPG</i> $\times$ <i>QE</i>		−0.3474* [−1.817]	−0.3165* [−1.734]
Observations	107	107	107
R-squared	0.202	0.669	0.671

Robust *t*-statistics in brackets. ****p* < 0.01, ***p* < 0.05, **p* < 0.1. As is standard in the literature and for brevity, the coefficients associated with the leads and lags of the first-differences of regressors are not reported. However, they are available upon request.

We also condition the reaction of the synthetic indicator of monetary policy to the different control variables on the implementation of the various QE rounds. While Columns (2)–(3) of Table 3 do not suggest a systematically different response of the Fed, they point to a more aggressive posture vis-à-vis the dynamics of inflation. Thus, the *INFL* $\times$ *QE* interaction term is negative and significant at the 1% level, which imply that, during QE rounds, the shadow short rate falls more sharply in response to a rise in inflation.

Additionally, we assess the robustness of our nonstandard monetary policy reaction functions by looking more closely into the volume and the structure of the Fed's assets. Specifically, we start by considering factors affecting reserve balances of depository institutions at Federal Reserve Banks using (week average) data from Table 1 (H.4.1) of the Board of Governors of the Federal Reserve System. Among such factors, securities held outright by the Fed capture the bulk of reserve bank credit, and we can distinguish between: (i) US Treasury securities (which include bills, notes and bonds (nominal), notes and bonds (inflation-indexed) and inflation compensation); (ii) Federal agency debt securities; and (iii) mortgage-backed securities. Thus, we construct the shares of the three types of securities in total securities held outright by the Fed (i.e. *TREASURY*, *ABS* and *MBS*, respectively), and add them to the set of control variables considered in our DOLS specifications. To avoid multi-collinearity, securities' shares are added one at time.

The empirical results are summarized in Table 4 and Table 5 for the term spread and the shadow short rate equations, respectively. For comparison, Column (1) in both tables reports the findings for the baseline model, which does not include such securities' shares among the set of controls, while Columns (2)–(4) summarize the results for the extended versions of the baseline model.

Table 4: Unconventional monetary policy rule: term spread regressions and composition of securities held outright by the Fed – DOLS model.

Variables	(1) baseline	(2)	(3)	(4)
<i>Constant</i>	4.1364*** [24.800]	4.5532*** [9.259]	3.1884*** [10.380]	4.7593*** [8.332]
<i>INFL</i>	−1.1102*** [−11.846]	−0.9137*** [−4.219]	−0.7064*** [−5.184]	−1.2125*** [−9.181]
<i>OG</i>	−0.1381*** [−6.450]	−0.0991** [−2.492]	−0.0943*** [−2.822]	−0.1243*** [−3.185]
<i>RG</i>	0.0450*** [3.370]	0.0552*** [3.004]	0.0422*** [3.073]	0.0395** [2.273]
<i>SPG</i>	−0.0586* [−1.913]	−0.0535* [−1.748]	−0.0529** [−2.012]	−0.0611* [−1.898]
<i>HPG</i>	0.0139 [0.402]	0.0024 [0.064]	0.0043 [0.132]	0.0083 [0.232]
<i>TREASURY</i>		−0.0135 [−0.974]		
<i>ABS</i>			0.0833*** [3.634]	
<i>MBS</i>				−0.0110 [−1.131]
Observations	107	107	107	107
R-squared	0.701	0.708	0.746	0.707

Robust *t*-statistics in brackets. ****p* < 0.01, ***p* < 0.05, **p* < 0.1. As is standard in the literature and for brevity, the coefficients associated with the leads and lags of the first-differences of regressors are not reported. However, they are available upon request.

Table 5: Unconventional monetary policy rule: shadow short rate regressions and composition of securities held outright by the Fed – DOLS model.

Variables	(1) baseline	(2)	(3)	(4)
<i>Constant</i>	−0.9545 [−1.318]	3.6106* [1.867]	6.1021*** [6.468]	−17.4153*** [−6.894]
<i>INFL</i>	−0.2990 [−0.697]	1.5130* [1.726]	−3.2856*** [−7.450]	2.3702*** [4.190]
<i>OG</i>	−0.3867*** [−4.957]	−0.1921 [−1.549]	−0.6219*** [−5.859]	−0.1912 [−1.583]
<i>RG</i>	−0.2019*** [−3.072]	−0.1366* [−1.671]	−0.1797*** [−3.086]	−0.0353 [−0.458]
<i>SPG</i>	−0.1048 [−0.838]	−0.0410 [−0.302]	−0.1579* [−1.932]	−0.0001 [−0.001]
<i>HPG</i>	−0.1568 [−0.928]	−0.1809 [−1.021]	−0.0791 [−0.597]	−0.1916 [−1.359]
<i>TREASURY</i>		−0.1365** [−2.532]		
<i>ABS</i>			−0.6047***	

			[-8.198]	0.2896*** [6.841]
MBS				
Observations	107	107	107	107
R-squared	0.202	0.254	0.550	0.449

Robust *t*-statistics in brackets. ****p* < 0.01, ***p* < 0.05, **p* < 0.1. As is standard in the literature and for brevity, the coefficients associated with the leads and lags of the first-differences of regressors are not reported. However, they are available upon request.

Accordingly, even with the inclusion of securities' shares in the monetary policy reaction function, the main findings remain both quantitatively and qualitatively unchanged. Thus, the inflation and the output gap exert a negative and significant effect on the term spread, while the impact of the central bank's reserve growth rate is positive and significant. Additionally, the evidence of a negative and significant effect of the stock price growth rate on the term spread is weak.

Concerning the composition of securities, neither the share of US Treasuries, nor the share of mortgage-backed securities (as percentage of total securities held outright by the Fed) significantly affect the term spread. By contrast, a rise in the relative importance of Federal agency debt securities seems to be associated with a significant rise in the term spread.

Regarding the shadow short rate equations (i.e. Table 5), the results are also in line with the benchmark model, as the dependent variables loads negatively and significantly on the output gap and the central bank's reserve growth rate. Yet, the effect of inflation becomes inconsistent across model specifications. Interestingly, while a rise in the share of Treasury securities and Federal agency debt securities (as percentage of total securities held outright by the Fed) is associated with a significant fall in the shadow short term rate, a rise in the share of mortgage-backed securities has the opposite effect.

Summing up, despite some evidence corroborating the role played by the composition of securities on the term structure of the interest rates (Hamilton and Wu, 2012; Krogstrup, Reynard and Sutter, 2012) and the so called "portfolio balance channel of monetary policy" (Bernanke 2010), it does not affect the key conclusions about the response of the Fed to macro-financial developments in nonstandard times.

Finally, we look at the maturity distribution of securities (i.e. US Treasuries, Federal agency debt and mortgage-backed securities) held by the Fed. We use data about remaining maturity (Wednesday level) from Table 2 (H.4.1) of the Board of Governors of the Federal Reserve System, which allows us to distinguish between securities maturing: (i) within 15 days (*MAT_L15D*); (ii) in 16 days–90 days (*MAT_16D_90D*); (iii) in 91 days to 1 year (*MAT_91D_1YR*); (iv) in over 1 year–5 years (*MAT_1YR_5YR*); (v) in over 5 years–10 years (*MAT_5YR_10YR*); and (vi) in over 10 years (*MAT_H10YR*). We also consider a simpler maturity structure, where we disaggregate total securities held outright by the Fed into securities with a remaining maturity within 1 year (*MAT_L1YR*) and securities with a remaining maturity over 1 year (*MAT_H1YR*). All maturity buckets are computed as percentage of total securities held by the central bank, and maturity shares are added to the set of control variables considered in the linear formulation of nonstandard monetary policy reaction functions. To avoid multi-collinearity, these shares are included one at time.

A summary of the empirical findings for the term spread and the shadow short rate equations is reported in Table 6 and Table 7, respectively. Column (1) presents the results for the baseline model, while Columns (2)–(8) describe its extended versions. Again, we find that controlling for the maturity structure of securities held outright by the central bank does affect (either quantitatively or qualitatively) our main results about the nonstandard response of the Fed to macro-financial developments.

However, it is interesting to see that while a rise in the share of securities maturing in 91 days to 1 year (*MAT_91D_1YR*) and securities maturing in over 10 years (*MAT_H10YR*) is associated with a significant reduction of the term spread, an increase in relative holdings of securities maturing in over 5 years–10 years (*MAT_5YR_10YR*) is linked with a significant uptick in the term spread. This evidence is in line with the works of Vayanos and Vila (2009) and Hamilton and Wu (2012), who show that, in the presence of both investors that care only about the risk-return trade-off (i.e. arbitrage investors) and investors that have a preference for bonds of a specific maturity (preferred-habitat investors), large-scale asset purchases by the central bank can lead to portfolio balance effects (Bernanke, 2010).

Table 6: Unconventional monetary policy rule: term spread regressions and maturity structure of securities held outright by the Fed – DOLS model.

Variables	(1) baseline	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<i>Constant</i>	4.1364*** [24.800]	4.7058*** [21.852]	3.9407*** [17.414]	4.2783*** [19.517]	4.7190*** [25.280]	4.5213*** [12.498]	3.8913*** [22.289]	5.1936*** [11.798]
<i>INFL</i>	-1.1102***	-1.2577***	-1.0289***	-1.1480***	-1.2503***	-1.0651***	-1.2357***	-1.2044***

	[−11.846]	[−12.457]	[−9.128]	[−10.525]	[−14.376]	[−10.101]	[−12.225]	[−11.586]
OG	−0.1381***	−0.1390***	−0.1153***	−0.1487***	−0.1484***	−0.1562***	−0.1657***	−0.1162***
	[−6.450]	[−4.513]	[−3.518]	[−4.862]	[−5.332]	[−4.634]	[−6.354]	[−3.353]
RG	0.0450***	0.0269**	0.0459***	0.0387***	0.0246**	0.0362**	0.0192	0.0368**
	[3.370]	[2.074]	[3.294]	[2.912]	[2.006]	[2.341]	[1.213]	[2.388]
SPG	−0.0586*	−0.0799***	−0.0610**	−0.0532*	−0.0938***	−0.0623*	−0.0635**	−0.0602*
	[−1.913]	[−3.230]	[−2.023]	[−1.865]	[−4.011]	[−1.879]	[−2.190]	[−1.891]
HPG	0.0139	−0.0192	0.0151	0.0044	−0.0279	0.0042	−0.0041	0.0100
	[0.402]	[−0.573]	[0.438]	[0.127]	[−0.838]	[0.108]	[−0.122]	[0.289]
MAT_L1YR		−0.0713***						
		[−4.620]						
MAT_L15D			0.1599					
			[1.405]					
MAT_16D_90D				−0.1057				
				[−1.524]				
MAT_91D_1YR					−0.0969***			
					[−4.897]			
MAT_1YR_5YR						−0.0183		
						[−1.287]		
MAT_5YR_10YR							0.0262***	
							[3.510]	
MAT_H10YR								−0.0169**
								[−2.568]
Observations	107	107	107	107	107	107	107	107
R-squared	0.701	0.803	0.706	0.730	0.823	0.708	0.756	0.719

Robust *t*-statistics in brackets. ****p* < 0.01, ***p* < 0.05, **p* < 0.1. As is standard in the literature and for brevity, the coefficients associated with the leads and lags of the first-differences of regressors are not reported. However, they are available upon request.

Table 7: Unconventional monetary policy rule: shadow short rate regressions and maturity structure of securities held outright by the Fed – DOLS model.

Variables	(1) baseline	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<i>Constant</i>	−0.9545 [−1.318]	−3.3649*** [−4.154]	−0.3122 [−0.298]	−1.7562* [−1.727]	−3.3706*** [−4.601]	−10.3135*** [−12.399]	1.4922*** [4.475]	−13.7875*** [−8.450]
<i>INFL</i>	−0.2990 [−0.697]	0.3206 [0.847]	−0.5749 [−1.061]	−0.0899 [−0.179]	0.2921 [0.846]	−1.0111*** [−3.276]	0.9151*** [5.100]	0.5953 [1.442]
<i>OG</i>	−0.3867*** [−4.957]	−0.4178*** [−4.166]	−0.5240*** [−3.917]	−0.3009** [−2.524]	−0.3286*** [−3.419]	−0.2086** [−2.176]	−0.0104 [−0.290]	−0.4549*** [−4.682]
<i>RG</i>	−0.2019*** [−3.072]	−0.1209* [−1.972]	−0.2190*** [−3.168]	−0.1875*** [−2.949]	−0.1224* [−1.944]	−0.0415 [−0.955]	0.0784*** [2.858]	−0.1079 [−1.539]
<i>SPG</i>	−0.1048 [−0.838]	0.0014 [0.013]	−0.0830 [−0.681]	−0.1416 [−1.135]	0.0124 [0.103]	−0.0832 [−0.701]	−0.0255 [−0.588]	−0.0508 [−0.525]
<i>HPG</i>	−0.1568 [−0.928]	−0.0121 [−0.072]	−0.1551 [−0.916]	−0.1316 [−0.737]	−0.0253 [−0.156]	0.1216 [0.835]	−0.0079 [−0.127]	−0.1948 [−1.442]
<i>MAT_L1YR</i>		0.3017*** [5.001]						
<i>MAT_L15D</i>			−0.3373 [−0.621]					
<i>MAT_16D_90D</i>				0.6444* [1.965]				
<i>MAT_91D_1YR</i>					0.4037*** [5.403]			
<i>MAT_1YR_5YR</i>						0.4223*** [13.071]		
<i>MAT_5YR_10YR</i>							−0.2642*** [−30.353]	
<i>MAT_H10YR</i>								0.2117*** [8.975]
Observations	107	107	107	107	107	107	107	107
R-squared	0.202	0.473	0.225	0.248	0.482	0.665	0.929	0.471

Robust t -statistics in brackets. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. As is standard in the literature and for brevity, the coefficients associated with the leads and lags of the first-differences of regressors are not reported. However, they are available upon request.

In what concerns the shadow short rate equations, the results are also in accordance with those associated with the baseline model. Indeed, despite some inconsistency regarding the statistical significance of the coefficient associated with inflation, they confirm the dynamics of the output gap and the central bank's reserve growth rate as the key drivers of the shadow short term rate. Moreover, the maturity structure of the Fed's balance sheet also affects the shadow short rate in a significant manner: a rise in the share of securities maturing within 1 year (MAT_L1YR) is linked with an increase of the shadow short rate, with the effect being larger at short- to medium-term maturities compared to long-term maturities.

4.3 Markov-switching regime (MSR) model

In this Section, we present the main findings associated with the estimation of the two-stage Markov-Switching Regression (MSR). Our model embeds a regime-specific mean and regime-specific error variances. Since regime transition probabilities are time-invariant, the only probability regressor is the constant.

Table 8 presents the (constant) transition probability matrix. It shows that there is considerable state dependence in the transition probabilities, with a relatively higher probability of remaining in regime 1 (0.9471) than in regime 2 (0.9140).

Table 8: (Constant) Transition probability matrix – term spread equations.

	Regime 1	Regime 2
Regime 1	0.9471	0.0529
Regime 2	0.0860	0.9140

$p_{ij} = P[s_t = i | s_{t-1} = j]$, where i = column, j = row.

Table 9 summarizes the results of the MSR model estimation of the term spread. To overcome potential endogeneity issues, we consider all explanatory variables in lagged terms. Thus, from an empirical point of view, our specification assumes that the term spread (TS_t) responds to the first lag of the growth rate of central bank reserves (RG_{t-1}) in a nonlinear fashion (i.e. the panel of “switching parameters” in the table) and linearly vis-à-vis the first lag of the inflation rate ($INFL_{t-1}$), the output gap (OG_{t-1}) and the growth rate of stock prices (SPG_{t-1}) and housing prices (HPG_{t-1}) (i.e. the panel of “non-switching parameters” in the table).¹⁴

Table 9: Unconventional monetary policy rule: term spread equations – MSR model.

	Non-switching parameters
$L.INFL$	−1.1233*** [−14.5642]
$L.OG$	−0.1854*** [−12.8818]
$L.SPG$	−0.0012 [−0.1548]
$L.HPG$	0.01249** [2.2168]
	Switching parameters
	Regime 1 ($S = 1$)
$L.RG$	0.0072* [1.6225]
$Constant$	3.8397*** [26.1723]
$Log(\sigma_1)$	−1.1486*** [−12.3866]
	Regime 2 ($S = 2$)
$L.RG$	0.0116*** [6.7802]
$Constant$	4.5979*** [32.6560]

$\text{Log}(\sigma_2)$

−1.7871***
[−1.7871]

Robust z-statistics in brackets. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Looking at the estimates of non-switching parameters, we find that the term spread is negatively and significantly associated with the output gap and the inflation rate. Thus, the term spread is compressed when these variables increase. Moreover, there is only some evidence supporting the inclusion of asset price growth rates in the monetary policy reaction function. In fact, while the housing price growth rate is significant at the 5% level, the stock price growth rate is not statistically significant.

Turning to regime-dependent parameter estimates, we show that changes in the supply of central bank reserves play a key and asymmetric role in shaping the dynamics of the term spread. More specifically, in regime 1, the growth rate of central bank reserves exerts a positive effect on the term spread, but this is only significant at the 10% level. By contrast, in regime 2, the impact is statistically significant and the influence of such changes on the term spread is also stronger.

The explanation for this asymmetric impact can be drawn from the inspection of Figure 2. It plots the two series of interest (i.e. term spread (red solid line) and the growth rate of central bank reserves (blue solid line)) and the dating of regime 1, which is embedded in its smoothed probability (grey shaded area). It also depicts the timing of Federal Open Market Committee (FOMC) actions, namely, the three quantitative easing programs (i.e. QE1, QE2 and QE3 (green dotted line)), the Operation Twist (green solid line), the tapering process (yellow solid line) and the interest rate hikes since the historical decision taken in December 2015 (yellow square markers).

Figure 2: Term spread, growth rate of central bank reserves, FOMC actions and smoothed probability (regime 1).

Apart from the three rounds of QE, the Fed launched the Operation Twist between the QE2 and QE3 programs, which was initially announced in September 2011 and further extended in June 2012. In December 2013, the FOMC started the tapering process and, in October 2014, the Fed ended its large-scale asset purchase program. Towards the end of 2016 and the beginning of 2017, government bond yields started to rise as a result of the normalization of the Fed's balance sheet and various interest rate hikes that were put in place.

Overall, with the exception of the QE2 program, regime 1 captures well the “early” phase of the launch of different rounds of QE aimed at counteracting tensions in fixed income markets characterized by a rise in the term spread. It also embeds the “early” phase of FOMC actions that followed the tapering process and introduced interest rate hikes with the goal of promoting the normalization of monetary policy. By contrast, regime 2 tracks the “ending” phase of various QE rounds (except for the Operation Twist) and the tapering process. During this regime, the sharp variation in the central bank reserves' growth rate appears to have translated into a fall in the term spread, that is, the “liquidity” effects of nonstandard monetary expansions seem to be at work.

Finally, Table 10 summarizes the results of the estimation of the MSR model for the shadow short rate. They are very similar to those found for the term spread, which lends support to the idea that both the term spread and the shadow short rate track the panoply of monetary policy measures put in place at the zero lower bound. Thus, among non-switching parameters, the synthetic indicator of nonstandard monetary policies responds

negatively and significantly to a rise in the inflation rate and the output gap. Regarding the regime-dependent parameter estimates, we find that the central bank's reserve growth rate exerts a positive, large and significant effect on the shadow short rate in regime 2, but not in regime 1.

Table 10: Unconventional monetary policy rule: shadow short rate equations – MSR model.

	Non-switching parameters
<i>L.INFL</i>	−1.6648*** [−6.8008]
<i>L.OG</i>	−0.4648*** [−10.6629]
<i>L.SPG</i>	−0.0076 [−0.3299]
<i>L.HPG</i>	0.0080 [0.4344]
	Switching parameters
	Regime 1 ($S = 1$)
<i>L.RG</i>	0.0068 [0.2526]
<i>Constant</i>	3.2700*** [6.7960]
<i>Log(σ_1)</i>	−0.3648*** [−3.0120]
	Regime 2 ($S = 2$)
<i>L.RG</i>	0.0399*** [5.5751]
<i>Constant</i>	−0.4608 [−1.1288]
<i>Log(σ_2)</i>	−0.1358 [−1.4103]

Robust z-statistics in brackets. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

5 Conclusion

This paper estimates unconventional monetary policy rules using both linear and nonlinear econometric frameworks and monthly data for the US over the post-Lehman Brothers' collapse period. The linear model (which is based on a DOLS estimator) shows nonstandard monetary policy actions (captured by movements in the term spread and variation in the shadow short rate) largely react to developments in the inflation rate and the output gap. Additionally, large-scale asset purchases by the central bank seem to signal further purchases in the future. Asset prices do not significantly impact unconventional monetary policy measures.

When extending this specification to a nonlinear framework, we uncover some additional interesting findings. Thus, the results associated with the MS regression corroborate the existence of an asymmetric (switching-type of) response of the term spread (and the shadow short rate) to the growth rate of central bank reserves. This modeling approach captures particularly well the "early" and "ending" phases of main FOMC actions put in place in the aftermath of the global financial crisis.

From a policy perspective, our findings highlight that, under certain circumstances (e.g. when zero lower bound has been reached), standard policy instruments are no longer effective stabilizing tools and conventional policy reaction functions are not a suitable characterization of monetary policy behavior (Jawadi, Namouri and Ftiti, 2018). However, the central bank still responds to a diversity of macroeconomic developments, namely, by allowing the term spread to react to the dynamics of inflation and the output gap as a way of boosting the former and stimulating the latter.

In addition, our results also emphasize that, in nonstandard times, the conduct of monetary policy is guided by fluctuations in the growth rate of central bank reserves. In this sense, our results shed some light on the design of unconventional monetary rules with the goal of promoting growth and medium-term price stability. Given the lack of evidence of a systematic response of monetary policy to asset price growth, our findings seem to be in line with the authors claiming that considerations about asset price bubbles aimed at dampening financial sector pro-cyclicality and minimizing the macroeconomic costs of systemic crisis episodes should be

part of the policy toolkit of specialized macro-prudential regulators, not the monetary authority (Rotemberg, 2014; Allen, 2015; Kenç, 2016; Łupiński, 2018; Turner, 2018).

Acknowledgements

We are grateful to the Editor, Bruce Mizrach, and two anonymous referees, to participants to the 2nd Annual Conference of the Society for Economic Measurement (SEM, Paris) and the 16th Annual Conference of the European Economics and Finance Society (EEFS) for their constructive comments and suggestions that considerably helped us to improved this paper.

Funding

AMSE is financed by French National Research Agency grant ANR-17-EURE-0020. NIPE is financed by National Funds of the FCT – Portuguese Foundation for Science and Technology within the project “UID/E-CO/03182/2019”.

Notes

1 On the nonstandard monetary policy front, several central banks (including the Bank of Japan, the Danmarks Nationalbank, the European Central Bank, the Sveriges Riksbank and the Swiss National Bank) have also set negative policy rates for an extended period of time, facing an effectively negative lower bound compared to the nominal zero lower bound. The Czech Republic and Switzerland have also introduced exchange rate floors (vis-a-vis the Euro), which successfully prevented inflation from turning negative, as highlighted by Bruha and Tonner (2017) and Caselli (2017).

2 The roots of the Global Financial Crisis (GFC) were laid down on the housing market boom-bust cycle (Agnello, Castro and Sousa, 2015). This triggered substantial asset wealth volatility and financial stress (Granville and Mallick, 2009; Jawadi, Sousa and Traverso, 2017), spikes in sovereign debt and counteracting fiscal adjustment programs (Agnello, Castro and Sousa 2012; 2013; Chortareas, 2013; Dufrénot, Jawadi and Khayat, 2018; Jalles, 2018). Meanwhile, the heightened bank-sovereign nexus and the significant links between monetary and financial stability (Agnello, Castro and Sousa, 2018a; Castro, 2011; Castro and Sousa, 2012; Jawadi, Mallick and Sousa, 2014; Jawadi, Namouri and Ftiti, 2018) materialized into severe disruptions in real economic activity (Castro, 2010; Mallick and Mohsin 2010; 2016), losses of access to international capital markets by sovereigns (Agnello, Castro and Sousa 2018b; 2018c), and a large reduction in total factor productivity (TFP) growth (Jalles, 2015). All in all, its impact on agents' expectations (Araujo and Vicente, 2018) and the size of its damaging economic consequences is mirrored in significant macroeconomic forecast errors (Jalles, 2017). It also questioned the role of banking intermediation for economic growth in poor institutional frameworks (Jalles, 2016), and emphasized the importance of regulation measures for the finance industry (Araujo and Leão, 2016).

3 This result is close in spirit with the finding of Araujo and Vicente (2018) that the tail of distribution of current stock prices provides valuable information about future states of the economy.

4 These formulations include adding equity prices (Chadha, Sarno and Valente, 2004; Rigobon and Sack, 2004; Bernanke and Kuttner, 2005), housing prices (Aoki, Proudman and Vlieghe, 2004; Iacoviello, 2005; Iacoviello and Minetti, 2008; Bjornland, Jacobsen and Henning, 2010), asset wealth and its composition (Sousa, 2010; Castro and Sousa, 2012), debt service-to-income and leverage ratios (Field, 2015), the financial cycle (Turner, 2017, 2018), or the asset growth of non-bank financial intermediaries (e.g. securities' brokers and dealers and shadow banks) (Agnello et al., 2019) to otherwise standard Taylor-type monetary policy reaction functions.

5 See, for instance, Clarida, Gali, and Gertler (1998), Woodford (2003), and Orphanides (2001, 2003) and Rudebusch (2002).

6 See, for example, Borio and Lowe (2002) and BIS (2014, 2016) and Svensson (2017).

7 The inclusion of the sum of leads and lags of the first-differences of the regressors eliminates the effects of regressor's endogeneity on the distribution of the least squares estimator (Stock and Watson, 1993). Despite this, we also employ an Instrumental Variable – Two-Stage Least Squares (IV-2SLS) estimator (with normal, robust, and heteroskedasticity and autocorrelation consistent (HAC) standard-errors) and an Instrumental Variable – Generalized Method of Moments (IV-GMM) estimator, where heteroscedasticity and autocorrelation are controlled for using the HAC procedure. The empirical findings do not corroborate the presence of endogeneity. Moreover, they are both quantitatively and qualitatively similar to that based on the DOLS estimator. These results are not reported in the paper, but are available upon request.

8 In contrast with the case of an exogenously-defined threshold variable (e.g. a linear model specification with interactions between a dummy variable (i.e. a binary outcome) and the set of controls), our MS specification does not require any assumption about the timing of regime switches. Indeed, it models the transition between different regimes as an hidden Markov chain, and it estimates the probability of being in a specific state, as well as the probability of switching from one state to another state. Therefore, regime probabilities in a MS regression model can be interpreted as a transition function that is directly estimated from the data and it does not require the choice of a transition variable (which is a task subject to “ad-hoc” subjective criteria).

9 For the estimation of Markov regime-switching regression models with endogenous switching, see Kim, Piger, and Startz (2008).

10 We do not define the term spread in terms of the difference between the 10-year government bond yield and the 3-month inter-bank rate because, during and shortly after the global financial crisis, the inter-bank market virtually stopped being operational. Moreover, given the relatively strong interest rate pass-through, the use of the inter-bank rate has the same disadvantages as the central bank's repo rate, i.e. zero variance at the zero lower bound.

11 In this context, we find that the parameters of the unconventional monetary policy reaction function change substantially when models are estimated over the longest time span for which data are available, and not just over the period over which QE has been at place. Therefore, term spread movements capture well unconventional monetary policy actions and our model delivers predictions that are in accordance with economic theory in “exceptional” circumstances. These results are not reported in the paper, but are available upon request.

12 Araujo and Vicente (2017) show that the short-term implicit inflation (or break-even inflation) is a good predictor of future inflation. As such, it can be extremely valuable for the conduct of monetary policy, as well as for participants in financial markets.

13 To address the endogeneity issues in our model, we also employ an Instrumental Variable – Two-Stage Least Squares (IV-2SLS) estimator (with normal, robust and HAC standard-errors) and an Instrumental Variable – Generalized Method of Moments (IV-GMM) estimator, where heteroscedasticity and autocorrelation are controlled for using the Heteroscedasticity-and-Autocorrelation-Consistent (HAC) procedure. No significant evidence of endogeneity was found and the findings are consistent with the ones reported in the DOLS approach. For brevity, results are not reported in the paper, but they are available from the authors upon request.

14 Our findings are robust when we assume alternatively that the term spread (or the shadow short rate) responds to both the first and the second lags of the control variables. In particular, they are qualitatively and quantitatively similar to those shown in the paper. For brevity, we do not report them, but they are available from the authors upon request.

References

- Agnello, L., V. Castro, and R. M. Sousa. 2012. "How does Fiscal Policy React to Wealth Composition and Asset Prices?" *Journal of Macroeconomics* 34 (3): 874–890.
- Agnello, L., V. Castro, and R. M. Sousa. 2013. "What Determines the Duration of a Fiscal Consolidation Program?" *Journal of International Money and Finance* 37: 113–134.
- Agnello, L., V. Castro, and R. M. Sousa. 2015. "Booms, Busts and Normal Times in the Housing Market." *Journal of Business & Economic Statistics* 33 (1): 25–45.
- Agnello, L., V. Castro, and R. M. Sousa. 2018a. "Economic Activity, Credit Market Conditions and the Housing Market." *Macroeconomic Dynamics* 22 (7): 1769–1789.
- Agnello, L., V. Castro, and R. M. Sousa. 2018b. "The Legacy and the Tyranny of Time: Exit and Re-Entry of Sovereigns to International Capital Markets." *Journal of Money, Credit and Banking* 50 (8): 1969–1994.
- Agnello, L., V. Castro, and R. M. Sousa. 2018c. "Financial Markets' Shutdown and Re-Access." *Economic Inquiry* 56 (1): 562–571.
- Agnello, L., V. Castro, F. Jawadi, and R. M. Sousa. 2019. "How does Monetary Policy Respond to the Dynamics of the Shadow Banking Sector?" *International Journal of Finance and Economics* forthcoming.
- Allen, W. A. 2015. "Asset Choice in British Central Banking History, the Myth of the Safe Asset, and Bank Regulation." *Journal of Banking and Financial Economics* 2 (4): 18–31.
- Aoki, K., J. Proudman, and G. Vlieghe. 2004. "House Prices, Consumption, and Monetary Policy: A Financial Accelerator Approach." *Journal of Financial Intermediation* 13: 414–435.
- Araujo, G., and S. Leão. 2016. "OTC Derivatives: Impacts of Regulatory Changes in the Non-Financial Sector." *Journal of Financial Stability* 25 (C): 132–149.
- Araujo, G., and J. Vicente. 2017. Estimação da inflação implícita de curto prazo. Central Bank of Brazil, Research Department, Working Paper no. 460, August.
- Araujo, G., and J. Vicente. 2018. "What does the Tail of the Distribution of Current Stock Prices Tell us about Future Economic Activity?" *Journal of Forecasting* 37 (4): 506–516.
- Auerbach, A. J., and M. Obstfeld. 2005. "The Case for Open-Market Purchases in a Liquidity Trap." *The American Economic Review* 95 (1): 110–137.
- Backus, D. K., and J. H. Wright. 2007. "Cracking the Conundrum." *Brookings Papers on Economic Activity* 1: 293–329.
- Bernanke, B. S. 2010. "The Economic Outlook and Monetary Policy." Speech presented at the Federal Reserve Bank of Kansas City Economic Symposium, Jackson Hole, Wyoming, August 27.
- Bernanke, B. S., and V. R. Reinhart. 2004. "Conducting Monetary Policy at Very Low Short-Term Interest Rates." *American Economic Review* 94 (2): 85–90.
- Bernanke, B., and K. Kuttner. 2005. "What Explains the Stock Market's Reaction to Federal Reserve Policy?" *Journal of Finance* 60 (3): 1221–1257.
- Bernanke, B. S., V. R. Reinhart, and B. P. Sack. 2004. "Monetary Policy Alternatives at the Zero Bound: An Empirical Assessment." *Brookings Papers on Economic Activity* 35 (2): 1–100.
- BIS. 2014. *84th Annual Report*. Basel, Switzerland: Bank for International Settlements.
- BIS. 2016. *86th Annual Report*. Basel, Switzerland: Bank for International Settlements.
- Bjornland, H., C. Jacobsen, and D. Henning. 2010. "The Role of House Prices in the Monetary Policy Transmission Mechanism in Small Open Economies." *Journal of Financial Stability* 6: 218–229.
- Blanchard, O., and J. Galí. 2007. "Real Wage Rigidities and the New Keynesian Model." *Journal of Money, Credit and Banking* 39 (S1): 35–65.
- Blinder, A. 2000. "Monetary Policy at the Zero Lower Bound: Balancing the Risks." *Journal of Money, Credit and Banking* 32 (4): 1093–1099.
- Borio, C., and P. Lowe. 2002. "Asset Prices, Financial and Monetary Stability: Exploring the Nexus." BIS Working Paper no. 114.
- Brambor, T., W. R. Clark, and M. Golder. 2006. "Understanding Interaction Models: Improving Empirical Analyses." *Political Analysis* 14 (1): 63–82.
- Bruha, J., and J. Tonner. 2017. "An Exchange Rate Floor as an Instrument of Monetary Policy: An Ex-Post Assessment of the Czech Experience." *Finance a úvěr-Czech Journal of Economics and Finance* 68 (6): 537–549.
- Caggiano, G., E. Castelnuovo, and G. Nodari. 2018. "Risk Management-Driven Policy Rate Gap." CESifo Working Paper no. 7177.
- Caselli, F. 2017. "Did the Exchange Rate Floor Prevent Deflation in the Czech Republic?" International Monetary Fund, IMF Working Paper no. 206.
- Castro, V. 2010. "The Duration of Economic Expansions and Recessions: More than Duration Dependence." *Journal of Macroeconomics* 32: 347–365.

- Castro, V. 2011. "Can Central Banks' Monetary Policy be Described by a Linear (Augmented) Taylor Rule or by a Nonlinear Rule?" *Journal of Financial Stability* 7 (4): 228–246.
- Castro, V., and R. M. Sousa. 2012. "How do Central Banks React to Wealth Composition and Asset Prices?" *Economic Modelling* 29 (3): 641–653.
- Cecchetti, S., H. Genberg, J. Lipsky, and S. Wadhvani. 2000. "Asset Prices and Central Bank Policy." *Geneva Report on the World Economy* 2. CEPR and ICMB.
- Chadha, J., L. Sarno, and G. Valente. 2004. "Monetary Policy Rules, Asset Prices, and Exchange Rates." *IMF Staff Papers* 51: 529–552.
- Chortareas, G. 2013. "Fiscal Policy Rules in Monetary Unions." *Journal of Post Keynesian Economics* 36 (1): 85–104.
- Christensen, J., and G. D. Rudebusch. 2016. "Modeling Yields at the Zero Lower Bound: Are Shadow Rates the Solution?" In *Dynamic Factor Models, Advances in Econometrics*, edited by E. Hillebrand and S. J. Koopman, vol. 35, 75–125. Emerald Group Publishing Limited.
- Chung, H., J.-P. Laforte, D. Reifschneider, and J. C. Williams. 2011. "Estimating the Macroeconomic Effects of the Fed's Asset Purchases." *Federal Reserve Bank of San Francisco Economic Letter* 3: 1–5.
- Clarida, R., J. Gali, and M. Gertler. 1998. "Monetary Policy Rules in Practice. Some International Evidence." *European Economic Review* 42: 1033–1067.
- Cúrdia, V., and M. Woodford. 2011. "The Central-Bank Balance Sheet as an Instrument of Monetary Policy." *Journal of Monetary Economics* 58 (1): 54–79.
- Dufrénot, G., and S. Malik. 2012. "The Changing Role of House Price Dynamics Over the Business Cycle." *Economic Modelling* 29 (5): 1960–1967.
- Dufrénot, G., F. Jawadi, and A. Khayat. 2018. "A Model of Fiscal Dominance under the 'Reinhart Conjecture'." *Journal of Economic Dynamics and Control* 93: 332–345.
- Eggertsson, G. B., and M. Woodford. 2003. "Zero Bound on Interest Rates and Optimal Monetary Policy." *Brookings Papers on Economic Activity* 2003 (1): 139–233.
- Evans, C., J. D. M. Fisher, F. Gourio, and S. Krane. 2015. "Risk Management for Monetary Policy near the Zero Lower Bound." *Brookings Papers on Economic Activity* Spring: 141–196.
- Farmer, R., and P. Zabczyk. 2016. "The Theory of Unconventional Monetary Policy." National Bureau of Economic Research, NBER Working Paper no. 22135.
- Field, A. J. 2015. *The Taylor Rule in the 1920s*. Santa Clara University, Department of Economics, manuscript.
- Gagnon, J., M. Raskin, J. Remache, and B. Sack. 2011. "Large-Scale Asset Purchases by the Federal Reserve: Did they Work?" *Federal Reserve Bank of New York Economic Policy Review* 17 (1): 41.
- Giannoni, M. P. 2002. "Does Model Uncertainty Justify Caution? Robust Optimal Monetary Policy in a Forward Looking Model." *Macroeconomic Dynamics* 6 (6): 111–144.
- Granville, B., and S. K. Mallick. 2009. "Monetary and Financial Stability in the Euro Area: Pro-Cyclicality versus Trade-Off." *Journal of International Financial Markets, Institutions & Money* 19 (4): 662–674.
- Hamilton, J. D. 1988. "Rational-Expectations Econometric Analysis of Changes in Regime: An Investigation of the Term Structure of Interest Rates." *Journal of Economic Dynamics and Control* 12: 385–423.
- Hamilton, J. D. 1990. "Analysis of Time Series Subject to Changes in Regime." *Journal of Econometrics* 45: 39–70.
- Hamilton, J. D., and J. C. Wu. 2012. "The Effectiveness of Alternative Monetary Policy Tools in a Zero Lower Bound Environment." *Journal of Money, Credit and Banking* 44(S1): 3–46.
- Iacoviello, M. 2005. "House Prices, Borrowing Constraints, and Monetary Policy in the Business Cycle." *American Economic Review* 95: 739–764.
- Iacoviello, M., and R. Minetti. 2008. "The Credit Channel of Monetary Policy: Evidence from the Housing Market." *Journal of Macroeconomics* 30: 69–96.
- Jalles, J. T. 2015. "Is there a Long-Run Relationship between Unemployment and Productivity?" *Comparative Economic Research* 18 (2): 57–75.
- Jalles, J. T. 2016. "A New Theory of Innovation and Growth: The Role of Banking Intermediation and Corruption." *Studies in Economics and Finance* 33 (4): 488–500.
- Jalles, J. T. 2017. "Forecasting Performance of Private Sector's Unemployment Forecasts in Advanced Economies." *International Review of Applied Economics* 31 (6): 707–733.
- Jalles, J. T. 2018. "What Determines the Share of Non-Resident Public Debt Ownership? Evidence from Euro Area Countries." *Annals of Finance* 14 (3): 379–414.
- Jawadi, F., S. K. Mallick, and R. M. Sousa. 2014. "Fiscal Policy in the BRICs." *Studies in Nonlinear Dynamics and Econometrics* 18 (2): 201–215.
- Jawadi, F., R. M. Sousa, and R. Traverso. 2017. "On the Macroeconomic and the Wealth Effects of Unconventional Monetary Policy." *Macroeconomic Dynamics* 21 (5): 1189–1204.
- Jawadi, F., H. Namouri, and Z. Ftiti. 2018. "An Analysis of the Effect of Investor Sentiment in a Heterogeneous Switching Transition Model for G7 Stock Markets." *Journal of Economic Dynamics and Control* 91: 469–484.
- Joyce, M., and M. Tong. 2012. "QE and the Gilt Market: A Disaggregated Analysis." *The Economic Journal* 122 (564): F348–F384.
- Keister, T., and J. J. McAndrews. 2009. "Why are Banks Holding so Many Excess Reserves?" *Federal Reserve Bank of New York, Current Issues in Economics and Finance* 15 (8): 1–10.
- Kenç, T. 2016. "Macroprudential Regulation: History, Theory and Policy." *BIS Papers* 86: 1–15.
- Keynes, J. M. 1936. *General Theory of Employment, Interest and Money* Royal Economic Society. London, UK: Macmillan Cambridge University Press.
- Kim, C.-J., J. Piger, and R. Startz. 2008. "Estimation of Markov Regime-Switching Regression Models with Endogenous Switching." *Journal of Econometrics* 143 (2): 263–273.
- Krippner, L. 2013. "Measuring the Stance of Monetary Policy in Zero Lower Bound Environments." *Economics Letters* 118 (1): 135–138.
- Krippner, L. 2015. "A Comment on Wu and Xia (2015), and the Case for Two-Factor Shadow Short Rates." Australian National University, Crawford School of Public Policy, Centre for Applied Macroeconomic Analysis, CAMA Working Paper no. 48.
- Krogstrup, S., S. Reynard, and B. Sutter. 2012. "Liquidity Effects of Quantitative Easing on Long-Term Interest Rates." Swiss National Bank, SNB Working Paper no. 2.
- Krugman, P. R. 1998. "It's Baaack: Japan's Slump and the Return of the Liquidity Trap." *Brookings Papers on Economic Activity* 29 (2): 137–205.

- Kuttner, K. N., and A. S. Posen. 2001. "The Great Recession: Lessons from Macroeconomic Policy from Japan." *Brookings Papers on Economic Activity* 32: 93–186.
- Lombardi, M., and F. Zhu. 2014. "A Shadow Policy Rate to Calibrate US Monetary Policy at the Zero Lower Bound." Bank for International Settlements, BIS Working Paper no. 452.
- Łupiński, M. 2018. "Macroprudential Tools of Systemic Risk Analysis." In *Macroprudential Policy and Practice*, edited by P. Mizen, M. Rubio, and P. Turner, Chapter 10, 225–247. Cambridge, UK: Cambridge University Press.
- Ma, J., E. Olson, and M. E. Wohar. 2018. "Nonlinear Taylor Rules: Evidence from a Large Dataset." *Studies in Nonlinear Dynamics & Econometrics* 22 (1): 1–14.
- Mallick, S. K., and M. Mohsin. 2010. "On the Real Effects of Inflation in Open Economies: Theory and Empirics." *Empirical Economics* 39 (3): 643–673.
- Mallick, S. K., and M. Mohsin. 2016. "Macroeconomic Effects of Inflationary Shocks with Durable and Non-Durable Consumption." *Open Economies Review* 27 (5): 895–921.
- Mostak Ahamed, M., and S. K. Mallick. 2017a. "Does Regulatory Forbearance Matter for Financial Stability? Evidence from Creditors' Perspective." *Journal of Financial Stability* 28: 163–180.
- Mostak Ahamed, M., and S. K. Mallick. 2017b. "House of Restructured Assets: How do they Affect Bank Risk in an Emerging Market?" *Journal of International Financial Markets, Institutions and Money* 47: 1–14.
- Mostak Ahamed, M., and S. K. Mallick. 2019. "Is Financial Inclusion Good for Bank Stability? International Evidence." *Journal of Economic Behavior & Organization* 157: 403–427.
- Orphanides, A. 2001. "Monetary Policy Rules Based on Real-Time Data." *American Economic Review* 91: 964–985.
- Orphanides, A. 2003. "Monetary Policy Evaluation with Noisy Information." *Journal of Monetary Economics* 50: 605–631.
- Rigobon, R., and B. Sack. 2004. "The Impact of Monetary Policy on Asset Prices." *Journal of Monetary Economics* 51: 1553–1575.
- Rotemberg, J. 2014. "The Federal Reserve's Abandonment of its 1923 Principles." NBER Working Paper no. 20507.
- Rudebusch, G. D. 2002. "Term Structure Evidence on Interest-Rate Smoothing and Monetary Policy Inertia." *Journal of Monetary Economics* 49: 116–187.
- Sonderstrom, U. 2002. "Monetary Policy with Uncertain Parameters." *Scandinavian Journal of Economics* 104 (1): 125–145.
- Sousa, R. M. 2010. "Housing Wealth, Financial Wealth, Money Demand and Policy Rule: Evidence from the Euro Area." *North American Journal of Economics and Finance* 21: 88–105.
- Stock, J., and M. Watson. 1993. "A Simple Estimator of Cointegrating Vectors in Higher Order Integrated Systems." *Econometrica* 61 (4): 783–820.
- Svensson, L. E. O. 2017. "Leaning Against the Wind: The Role of Different Assumptions about the Costs." National Bureau of Economic Research, NBER Working Paper no. 23745.
- Taylor, J. B. 1993. "Discretion versus Policy Rules in Practice." *Carnegie–Rochester Conference Series on Public Policy* 39: 195–214.
- Turner, P. 2017. "Did Central Banks Cause the Last Financial Crisis?" Will they cause the next? LSE Financial Markets Group (FMG) Paper Series, Special Paper no. 249, November.
- Turner, P. 2018. "The Macroeconomics of Macroprudential Policies." In *Macroprudential Policy and Practice*, edited by P. Mizen, M. Rubio, and P. Turner, Chapter 1, 19–45. Cambridge, UK: Cambridge University Press.
- Vayanos, D., and J.-L. Vila. 2009. "A Preferred-Habitat Model of the Term Structure of Interest Rates." National Bureau of Economic Research, NBER Working Paper no. 15487.
- Woodford, M. 2003. *Interest and Prices: Foundations of a Theory of Monetary Policy*. Princeton, USA: Princeton University Press.
- Wu, J. C., and F. D. Xia. 2016. "Measuring the Macroeconomic Impact of Monetary Policy at the Zero-Lower Bound." *Journal of Money, Credit and Banking* 48 (2–3): 253–291.