Central Banks preferences since the Great Recession

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March 1, 2019

Abstract

We use a time-varying parameter vector autoregressive model to assess changes in central banks' preferences during and after the Great Recession. A shadow rate is used as a proxy for interest rate in the United States and the Euro Area during the zero lower bound. The results show large increases in responses to inflation and output for both the Federal Reserve and the European Central Bank after the 2008 crisis. Both preferences on current inflation and output decrease with the monetary policy normalization started in the US, whereas the contemporaneous coefficients stay at their highest level at the end of the sample period in the Euro Area, since the ECB is still dealing with unconventional measures. However, counterfactual analysis bring some evidence to the macroeconomic effect of unconventional monetary policies, and particularly in the Euro Area, where inflation rate would have been negative from 2014 to 2017 without any unconventional measures.

Keywords: Central banks preferences, Federal Reserve, European Central Bank, Taylor rule, time-varying parameter VAR, shadow rate, zero lower bound

JEL Codes: C32, E31, E32, E37, E43, E44, E52, E58

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1 Introduction

Central banks decisions may be perceived as one of the main driving force in advanced economies. Since monetary policy seems to play a crucial role in stabilizing macroeconomic fluctuations, it has also drawn the attention of many researchers, policy makers and financial markets for many years. Since the seminal work of Taylor (1993) and the so-called 'Taylor rule', in which the central bank sets its interest rate according to an inflation target and the economic growth, a huge literature has emerged to give a further insights of central banks' behavior. For instance, several studies focus on the US monetary policy in the 1970s and the 1980s and try to explain the role of the Fed in the 'Great Moderation' episode (Clarida et al. 2000). It is widely accepted that the Fed was particularly careful concerning inflationary pressures after Paul Volcker's appointment at the head of the institution. As a whole, the Fed's preference for inflation stabilization at this time led to a lower macroeconomic volatility in the following decades.

Hence, abrupt macroeconomic fluctuations during the Great Recession and historical monetary policy measures of the last decade could motivate investigations on the role played by central banks at this time. However, because this situation has been quite different than the one during the Great Moderation, it is reasonable to assume that central banks' preferences could vary over time. Lots of methodologies have been developed to disentangle shifts in monetary policy across regimes (Primiceri 2005, Sims and Zha 2006). Time-variations in central banks' preferences may reflect shifts in the monetary policy regime or changes in the reaction to macroeconomic fluctuations, whereas monetary policy volatility shocks can be interpreted as the willingness of the central bank to depart from the behavior prescribed by the estimated policy rule. The purpose of this paper is to study central banks' behavior and monetary policy shifts in the last two decades. Based on the methodology employed in Belongia and Ireland (2016), we use a time-varying parameters vector autoregression (TVP-VAR) model with stochastic volatility to estimate a Taylor-type rule (Taylor, 1993), and hence capturing changes in central banks' preferences in the US and the Euro Area. Therefore, the focus is on the Federal Reserve and the European Central Bank (Fed and ECB hereafter, respectively). To get rid of flat rates challenging Taylor rule estimations in the Zero Lower Bound (ZLB) era, we use shadow rates constructed by Krippner (2016) as a proxy for unconventional monetary policies. As a consequence, our estimations also cover the ZLB period.

The main results can be summarized as follows: contemporaneous responses to inflation and output gap in the US show a different path than in the Euro Area. Fed's short-term preferences have been characterized by a peak around the year 2013, before falling back to their pre-crisis level. The story is not the same in the

Euro Area: ECB's responses to current inflation and output gap have continuously increased since the Great Recession before reaching highest levels at the end of the sample period. These shifts in Fed's and ECB's preferences are mainly due to the different timing of the monetary policy normalization process. The Fed raised its main policy rate at the end-2015, whereas the ECB is still dealing with unconventional measures and negative rates. However, these results do not jeopardize the macroeconomic effects of unconventional monetary policies. Counterfactuals analysis give some empirical evidence about unconventional measures. Without unconventional monetary policy, the Euro Area would have suffered a deflationary episode from 2014 to 2017. Moreover, unconventional monetary policy led to higher output gaps in the US and in the Euro Area, reducing output losses at the end of the period of estimation.

The rest of the papers is organized as follows. Section 2 is dedicated to the literarure review on monetary policy rules and central banks' preferences. Section 3 describes the methodology used for the modelling framework. Thus, in section 4, we present the data. Section 5 and 6 concern the results of our estimations, including the counterfactual analysis based on our empirical model. Finally, the last section is for the conclusion.

2   Related literature

The literature review falls into two parts: the first one is on monetary policy rules and central banks' behavior, and the second focuses on monetary policy shocks and changes in central banks' preferences.

The question of optimal monetary policy and central banks' preferences has been wiedely discussed in the literature. Since the benchmark work of John B. Taylor (Taylor, 1993), lots of papers have proposed discussions on optimal monetary policy and improvements in Taylor-type rules (see Clarida et al., 1999, Woodford, 2001, and Woodford, 2003, among others). At the same time, a growing literature has emerged and found support to the use of Taylor rules as a practical tool to capture central banks' behavior across different monetary policy regimes (Judd et al., 1998). Most importantly, this extensive literature also deserved to be the landmark for any central banks' preferences analysis.

Some studies apply a monetary policy rule to identify changes in the Fed's behavior across different monetary policy regimes in the US, by disentangling pre-Volcker and post-Volcker periods. Clarida et al. (2000) advocate

that a shift in the systematic component of monetary policy has been the main source of macroeconomic stability of recent years in the US. Favero and Rovelli (2003), Ozlale (2003), Dennis (2006), and Surico (2007a) provide additional support for these findings, with a specific attention on interest rate smoothing in the reaction function. Higher persistence of lagged interest rate in the conduct of monetary policy can be justified by misspecifications of the macroeconomic dynamics, as highlighted by Rudebusch (2001), Castelnuovo and Surico (2004) and Castelnuovo (2006). Givens (2012) estimates a forward-looking model of the US economy separately under commitment and discretion over the Volcker-Greenspan-Bernake era. Although the results are almost similar, the weight on interest rate smoothing in the loss function is large under commitment and small under discretion. Using Bayesian methods to estimate a basic New Keynesian model, Ilbas (2012) also finds a break in the conduct of US monetary policy during the post-Volcker period. Based on similar methods, other studies deal with indeterminacy issue of US monetary policy during the Volcker-Greenspan era, and give further insights that allow for useful interpretations of the conduct of monetary policy at this time, including , Lubik and Schorfheide (2004), and Mavroeidis (2010). Finally, Taylor and Williams (2010) advocate that macroeconomic performances in the US have been better when the central bank follows a simple monetary policy rule, especially during the financial crisis despite asset bubbles, and underline the challenge of the conduct of monetary policy under the ZLB situation.

Since all of the papers cited above focus on Fed's preferences, other studies focus on the ECB. Taylor (1999) specifically focuses on strategies for setting interest rates by the ECB and advocates that the robustness of simple monetary policy rules for the interest rate gives much more evidence than before. For this purpose, he proposes a simple benchmark policy rule for an aggregate European Monetary Union (EMU) constructed with Germany, France and Italy in 1992. Gerlach and Schnabel (2000) estimate a simple Taylor rule with the average interest rates in the EMU-11 countries from 1990 to 1998 and find quite the same results than Taylor (1993), with a highly significant coefficient of 1.58 on inflation and 0.45 on th output gap (respectively 1.5 and 0.5 in Taylor, 1993). Relying on estimates of reaction functions, Gerdesmeier and Roffia (2003) and Garcia-Iglesias (2007) find similar results. Surico (2007b) studies the ECB's behavior in terms of asymmetric preferences. He finds that positive and negative deviations of inflation from target values lead to similar interest rate responses, whereas the response to output gap fluctuations is associated with asymmetric preferences. More precisely, an output contraction implies larger easing of monetary policy than the tightening implies by an output expansion of the same magnitude. More recently, Rühl (2015) estimates a monetary policy rule augmented with a variable

of change in money aggregate for both the ECB and the Bundesbank. One of the main result is that the ECB seems to have used interest rate smoothing and strong significant output stabilization in its interest rate decisions. Change in money aggregate also appears to be a key driver of ECB's behavior. Other papers do the same exercise including the ZLB and the financial crisis, as Gorter et al. (2010), Gerlach (2011), and more recently Gerlach and Lewis (2014). In the latter paper, the authors estimate ECB's reaction functions over the period 1999-2010, and conclude that the ECB has cut rates more aggressively than expected regarding the worsening of macroeconomic conditions during the Great Recession.

Some studies propose a comparative analysis of the conduct of monetary policy between the US and the Euro Area. Ullrich (2003) finds that there are significant differences in the reactions functions between the two central banks. Although the ECB puts less weight on inflation than its EMU national central banks aggregation before the beginning of the euro in 1999, the Fed seems to attach importance to money growth in its behavior. Belke and Polleit (2007) find that the standard Taylor rule is a better tool for modelling the behavior of the Fed rather than that of the ECB. They also find a lower wieght on inflation relative to the output gap, and highlight the plausible reason of the low inflation in the sample period. Another interesting result comes from the cautious Fed's behavior comparing to the ECB, illustrated by a higher interest rate smoothing in the US. Belke and Klose (2013) propose the same exercise during the Great Recession, and find that both central banks became less cautious and put less weight on inflation when the crisis occured. Chen et al. (2017a) compare the US and Euro Area monetary policies in the ZLB. They use a shadow rate as a policy instrument that reflects unconventional measures and is not constrained at a zero-level. As a result, they find that the conduct of monetary policy has been more efficient in the US than in the Euro Area.

Previous papers mostly lay the emphasis on the systematic component of monetary policy. They show how the conduct of monetary policy has evolved on a given period of time by investigating the central banks' reaction to inflation and growth fluctuations. But further analyses including the non-systematic part are needed to better understand changes in the conduct of monetary policy. More technically, analysis on the residual of Taylor-type rules - known as monetary policy shocks - could reflect changes in central banks' behavior as well. It could be seen as the willingness of the central bank to adopt a different behavior than the one based on the monetary policy rule. From an empirical point of view, Vector Autoregressive models and Bayesian estimations of sticky-price Dynamic and Stochastic General Equilibrium (DSGE) are often used to provide evidence on

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the effectiveness of monetary policy (see for instance Boivin and Giannoni, 2006 and Benati and Surico, 2009). Following on from Justiniano and Primiceri (2008) and using both a structural VAR and a DSGE models, more recent papers investigate the impact of time-varying volatility of monetary policy shocks on the economy (Fernández-Villaverde et al., 2011 and Mumtaz and Zanetti, 2013). More precisely, their models allows for time-varying variance of monetary policy shocks by introducing a stochastic volatiliy specification, and then a dynamic interaction between endogenous variables in the model and this time-varying volatility.

The evolution of monetary policy shocks volatility is essential to understand changes in the conduct of monetary policy, because it concerns the non-systematic part of the interest rate setting process in a time-varying dimension. However, it is reasonable to assume that central banks' preferences can also vary overtime (see Fernández-Villaverde et al., 2010). As we have seen through the literature cited in the first part of this section, monetary policies in the US and the Euro Area have been characterized by changes in preferences according to different regimes (pre-Volcker and post-Volcker in the US, pre-crisis or post-crisis during the Great Recession, for example). To capture changes in central banks' behavior, the parameters of the Taylor-type monetary policy rule are allow to change over time. For this purpose, two techniques are commonly used in the empirical literature on VAR analysis for monetary policy: the regime switching and the time-varying parameter approaches. Concerning the first one, several studies assume discrete changes in the parameters which are governed by a Markov switching variable. Therefore, they use a VAR model to investigate monetary policy regime shifts over a given period of time. Benchmark works using regime switching methodology include Sims and Zha (2006), Assenmacher-Wesche (2006), Canova and Ferroni (2012), Debortoli and Nunes (2014), and more recently Drakos and Kouretas (2015), Chen et al. (2017b) and Fiorelli and Meliciani (2019). The second approach concerns time varying parameter models. It allows for gradual changes in the parameters of the monetary policy rule, and hence a nonlinear dynamics of central banks' preferences over the entire sample period. The present paper provides a VAR model with time-varying coefficients and stochastic volatility. In a seminal paper, Primiceri (2005) (see Del Negro and Primiceri, 2015 for a corrigendum) wonders if monetary policy in the US has been less active against inflationnary pressure during the Martin-Burns period than during the Volcker-Greenspan era. For this purpose, he uses a time varying structural vector autoregression model and finds that the non-systematic part of US monetary policy was higher in the 1960s and 1970s, although monetary policy was more systematic under Greenspan in the US. However, the author raises the point that volatility in inflation and unemployment during the period of high non-systematic monetary policy mainly comes from exogenous non-policy shocks. Other

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influential studies such as Cogley and Sargent (2005), Boivin (2006), Kim and Nelson (2006), Benati and Mumtaz (2007) use a VAR with drifting coefficients and stochastic volatilities to analyse the Fed's behavior during the post-WWII period in the US. All these papers agree on the improvement in the systematic component of monetary policy after Volcker's appointment. Based on a simple sticky-price New Keynesian model, Benati and Surico (2008) estimate a structural VAR with time-varying coefficients and stochastic volatility to document that the aggressive monetary policy stance towards inflation led to a less predictable inflation in the US. As a whole, time-varying parameters VAR methodolgy has been widely employed in monetary policy analyses, including Koop et al. (2009), Canova and Gambetti (2009), Mumtaz and Surico (2009), Ikeda (2010), Trecroci and Vassalli (2010), Ang et al. (2011), Benati (2011), Baxa et al. (2014), and more recently Creel and Hubert (2015), Belongia and Ireland (2016), Lakdawala (2016), Best (2017).

3   Methodology

The methodology used in this paper is similar to Belongia and Ireland (2016). Indeed, a vector autoregressive model with time-varying parameters and stochastic volatility (TVP-VAR) is used to study changes in central banks' behavior on the period of estimation. The main difference come from the extension of the sample, that henceforth covers unconventional times. The model is based on Primiceri (2005), and its baseline version can be written as follows:

$$y_t = [\Pi_t \quad G_t \quad R_t]'$$

where Π_t is the inflation rate, G_t is the output gap and R_t is the shadow rate. The model is assumed to follow a second-order time-varying parameters vector autoregressive model in the reduced form:

$$y_t = b_t + B_{1,t}y_{t-1} + B_{2,t}y_{t-2} + u_t$$

where u_t is a 3×1 vector of heteroskedastic shocks with time-varying covariance matrix Ω_t.

With estimation strategy and sign restrictions also based on Belongia and Ireland (2016), one can give the

third row of the structural model presented as a Taylor-type monetary policy rule:

$$R_t = \gamma_{r,t} + c_{r\pi,t}\Pi_t + \gamma_{1,r\pi,t}\Pi_{t-1} + \gamma_{2,r\pi,t}\Pi_{t-2}$$

$$+ c_{rg,t}G_t + \gamma_{1,rg,t}G_{t-1} + \gamma_{2,rg,t}G_{t-2}$$

$$+ \gamma_{1,rr,t}R_{t-1} + \gamma_{2,rr,t}R_{t-2} + \delta_{r,t}\xi_t^{mp}$$

Then, this equation is estimated with the data described in the following section.

4   Data

4.a   Sources

The US data come from the Federal Reserve Bank of Atlanta's approriate database related to the 'Taylor rule utility', and run from 1960Q1 to 2018Q4. The interest rate is the federal funds rate. Core PCE inflation is taken as a relevant measure of inflation in the estimation, since the Federal Reserve seems to put more attention on it than on headline inflation (see John B. Taylor versus Ben Bernanke [1], and also Tchatoka et al. (2017) for more recent evidence on the use of core PCE inflation in US monetary policy rule estimations). It is given as a percentage annual change. The output gap variable is computed by the Congressional Budget Office as the difference between the levels of real GDP and real potential GDP, in percentage of real pontential GDP.

Prior distribution of the coefficients are obtained from the training sample period from 1960Q1 to 1969Q4. Then, the Taylor rule is estimated by the TVP-VAR model with stochastic volatility from 1970Q1 to 2018Q4. Concerning the Euro Area, both inflation and output gap data are from two different databases. The first one is the New Area-Wide Model (NAWM, Fagan et al., 2005) to get historical data from 1970Q1 to 2017Q4. Then, the data are uploaded with Eurostat. The Harmonized Index of Consumer Prices (HICP) is taken as inflation variable and the real potential GDP is estimated with an Hodrick-Prescott filter (HP, Hodrick and Prescott, 1997) to compute the output gap.

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[1]John B. Taylor claims that the Fed has not followed the prescription of the Taylor rule by keeping the interest rate too low from 2003 to 2005 and hence generated the housing bubble in the US. Ben Bernanke disagreed with that by justifying that the Fed setted the interest rate according to the Taylor rule by targeting core PCE inflation, and not GDP deflator as in Taylor's estimations. For more details on this debate: https://www.brookings.edu/blog/ben-bernanke/2015/04/28/the-taylor-rule-a-benchmark-for-monetary-policy/

The period 1971Q1 to 1980Q4 is used as the training sample. The model is estimated from 1981Q1 to 2018Q4.

Figure 1 shows the evolutions of inflation, output gap and interest rate since 1960Q1 in the US and 1971Q1 in the Euro Area, respectively. Both interest rates and inflation lastingly decrease on the sample period in the US and the Euro Area. From a two-digits rate around the 1970s, core PCE deflation substantially decreases in the US to stabilize before the 2000s. Even though it is much more volatile, the federal funds rate followed a similar path on the period before reaching the ZLB at the end of 2008. The interpretation is quite the same concerning the Euro Area: we can observe a downward trend in the HICP and Euribor 3-month since the 1980s. However, unlike the Fed, the ECB just managed to stabilize inflation rate around its target level of 'below, but close to, 2% over the medium term' after dealing with deflation episodes in 2015 and 2016. Moreover, the ECB gradually decreased interest rates to their lowest level only in 2016, while the Fed started to raise interest rate at this time.

Figure 1: Inflation, output gap and interest rate

(a) US

(b) Euro Area
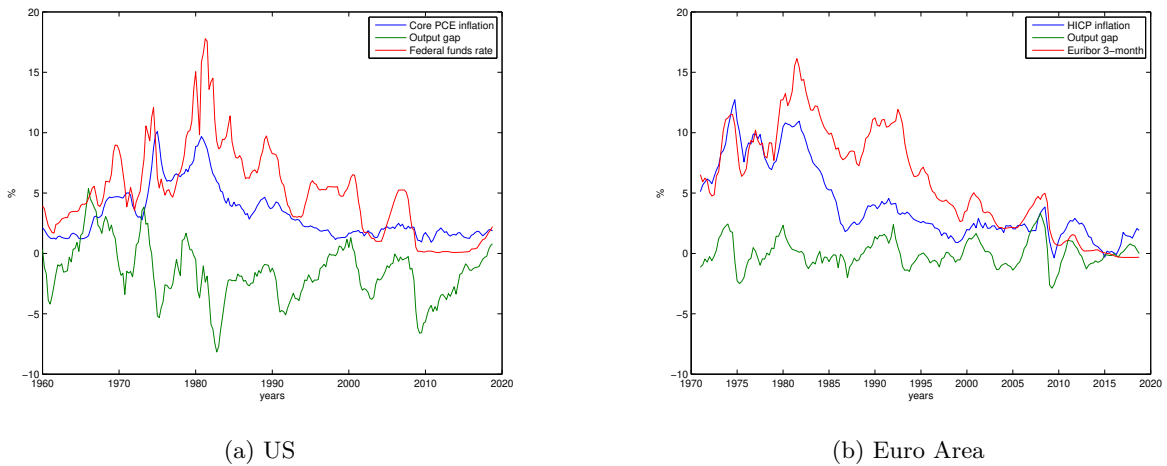
4.b   Unconventional monetary policies and shadow rates

As we have mentioned above, data are reported at quarterly frequency and mainly come from national sources. Since our estimations cover the period up to 2018, the results include both conventional and unconventional measures. Therefore, a major concern is the constrained policy rate at the zero level during periods of uncon-

ventional measures. Because of the 'flat' interest rates at the ZLB, usual policy rate does not entirely reflect the central banks' actions during unconventional times, and hence leads to biased monetary policy rule estimation. Unconventional measures have been characterized by the use of 'unconventional' instruments (i.e. other than the policy rate), such as large scale assets purchases (LSAP) or forward guidance (FG), to fulfill the objective given by central banks' mandate. Consequently, and to be able to estimate the Taylor-type rule up to 2018, the rate used as the policy instrument is replaced by the shadow short rate from Krippner (2016)[2] that takes into account unconventional measures (both large scale assets purchases and forward guidance) during this period. Then, the rate is constructed on a quarterly basis to fit the rest of the database.

Table 1: Monetary policy announcements since the Great Recession

	Fed	ECB
1st QE announcement date	Dec. 2008	June 2009
Tapering	Dec. 2012	Dec. 2016
Period of ZLB	Dec. 2008 - Dec. 2015	Mar. 2016 - ?

Sources: Federal Reserve, European Central Bank, Drumetz et al. (2010), Chen et al. (2017a)

Table 1 gives the periods of unconventional monetary policy in the US and the Euro Area. A few comments have to be done regarding to these dates: first, one can raise that unconventional monetary policies started just after the collapse of Lehman Brothers in the US (December 2008), and started in June 2009 in the Euro Area, although interest rates were not yet at the zero lower bound (ZLB). The end date of UMP comes at the moment where the central bank decides to raise its policy rate. It does not mean that at this time, the central bank's balance sheet has been reduced. In other words, this end date should be the first step for the so-called 'normalization' of monetary policy. Finally, since the ECB is still dealing with the ZLB situation and unconventional measures, there is no date for the exit from ZLB in the Euro Area.

Hence, the shadow short rate (SSR) from Krippner (2016) is used as a proxy for unconventional measures of monetary policy (Figure 2). The main question is on the relevance of the shadow rate and the plausibility to use this measure in a VAR model as a proxy for interest rate under the ZLB.

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[2]Shadow short rates data are available on the Leo Krippner's webpage: https://www.rbnz.govt.nz/research-and-publications/research-programme/additional-research/measures-of-the-stance-of-united-states-monetary-policy/comparison-of-international-monetary-policy-measures

Figure 2: Policy and shadow rates

(a) US

(b) Euro Area
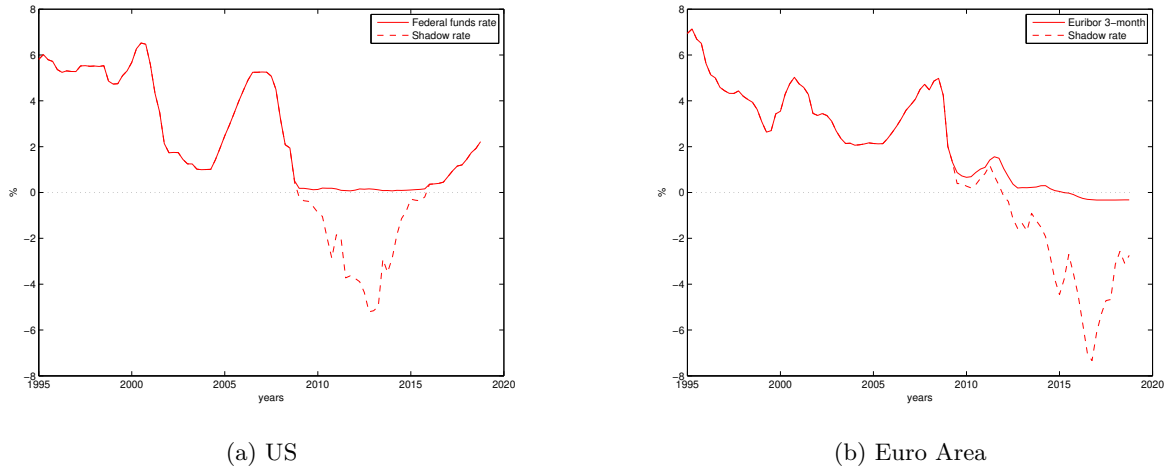
As discussed in Bauer and Rudebusch (2016), Halberstadt and Krippner (2016) and Krippner (2017), estimated shadow rates are very sensitive to the choices made in their estimation. These choices are related to several factors, such as the way to compute the lower bound or the range of rates included in the dataset. For instance, Krippner (2017) advocates that the shadow rate from (from Wu and Xia 2016) differs from other estimations because of different estimates of lower bounds or different datasets used in the model. More precisely, the Wu and Xia's shadow rate is computed with a lower bound callibrated to 25-bp and using a dataset with 3-month to 10-year interest rates. By way of comparison, Krippner (2017) proposes different estimations by changing the lower bounds and the datasets, and finds that an estimated SSR with a cumulative minimum lower bound and an extended dataset including 30-year rates data better fits unconventional monetary policy announcements than the Wu and Xia's shadow rate. However, Krippner (2016) Halberstadt and Krippner (2016) note that the shadow rate has two main issues. From an empirical perspective, point estimates in unconventional periods can be very sensitive to choices on the model specification and the data. Second, theoretically, negative SSR do not represent interest rates at which economic agents can transact. In other words, the latter point explains that negative SSR in unconventional periods are not relevant to explain the transmission mechanisms of monetary policy. Hence, VAR models for monetary policy analysis cannot easily be extended to the ZLB period by using the SSR as variable for interest rate. But one can get rid of these issues by assuming that the estimated SSR perfectly evolves according to monetary policy announcements in unconventional times and monetary policy

affects economic agents by less traditional transmission mechanisms than interest rate (moreover, the focus is on central banks' behavior in this paper).

To justify the choice of the SSR as a proxy for unconventional monetary policy rate, some papers use a VAR estimation and compare the result with the observed policy rate under conventional monetary policy with the result when the rate is proxied by the SSR during periods of unconventional monetary policy. For instance, using a factor-augmented vector autoregression (FAVAR), Wu and Xia (2016) show that the shadow federal funds rate exhibits similar dynamic correlations with macro variables of interest in the post-crisis period as the federal funds rate did prior to the Great Recession. 'This result providesus with a tool to measure the effects of monetary policy at the ZLB and offers an important insight to the empirical macro literature where people use the federal funds rate in vector autoregressive models to study the relationship between monetary policy and the macroeconomy.' Krippner (2017) uses a wide range of SSR estimations in a VAR model to investigate impulse reponses of inflation and unemployment to a monetary policy shock in unconventional period. Additionally, the author agrees with Wu and Xia (2016) on the fact that these responses are not materially different across the different SSR estimations. More recently Lombardi and Zhu (2018) construct their own shadow rate and apply it in standard VAR models. They find that the estimated monetary policy shocks provide a more realistic picture of the US economy after the crisis than the one where monetary policy shocks are estimated with the federal funds rate.

Wu and Zhang (2016) assess whether the Taylor rule is a good description of the shadow policy rate dynamics. They find that the Taylor rule seems to be a good description of monetary policy, including during the ZLB period. Moreover, they test whether a structural break in the slope of coefficients of the estimated Taylor rule exists, but they do not find any significant change in the rule during the ZLB period. Mouabbi and Sahuc (2017) also use a DSGE model to investigate the macroeconomic effects of ECB's unconventional measures with a set of shadow rates. Other recent studies use the shadow rate in VAR models to capture the effects of monetary policy at the ZLB. (see Georgiadis 2016, Horvath and Voslarova 2016, Basu and Bundick 2017, Caggiano et al. 2017, Potjagailo 2017, Plante et al. 2017 Forbes et al. 2018, Pasricha et al. 2018 and Rogers et al. 2018). In line with this methodology, we estimate the TVP-VAR model with the data represented on Figure 3.

Figure 3: Inflation, output gap and shadow rate


(a) US

(b) Euro Area
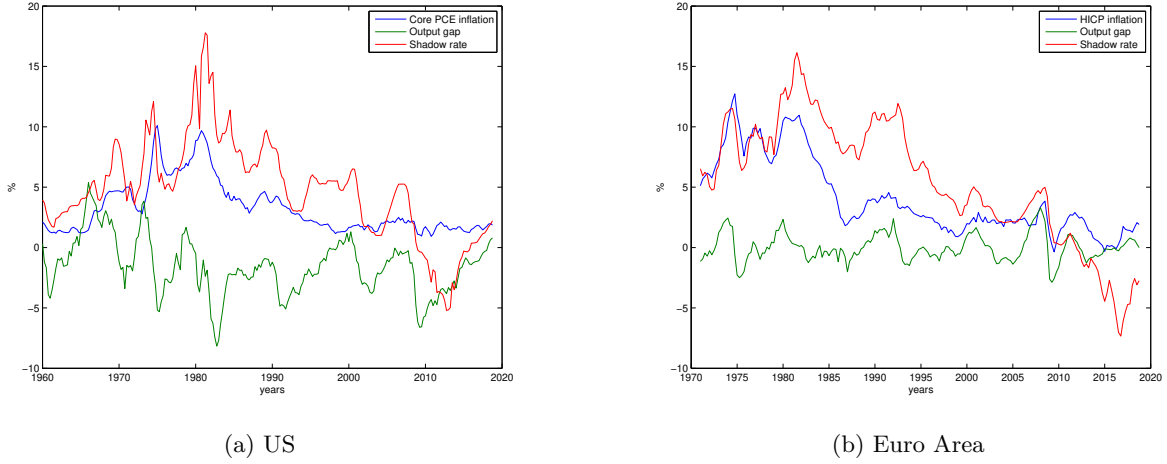
5 Results

5.a Monetary policy in the US

Figure 4 show the evolution of the impact coefficients $c_{r\pi,t}$ and $c_{rg,t}$ which represent the contemporaneous response of the shadow rate to movements in inflation (Figure 4a) and the output gap (Figure 4b), respectively. Figure 4c plots the time-varying standard deviations of the disturbances, related by the evolution of the parameter $\delta_{r,t}$. Referring to the equation of the monetary policy rule, this figure tracks the volatility of monetary policy shock.

First, the focus is on the magnitude of the impact coefficients. The contemporaneous response of the Fed to inflation is higher than the response to output gap fluctuations. However, regarding Table 2 (see Appendix), the response to the current output gap has been more stable than the response to inflation before the crisis. Indeed, the probability for the median coefficient in 2013 of being higher than the median coefficient in 2009 is at 19% for inflation and at a lower level of 11% for the output gap. This result is not surprising when the focus is on the median coefficients themselves: the median coefficient on inflation goes from 0.84 in 2009 to 1.48 in 2013, before falling to 0.52 in 2017. This coefficient is 0.53, 0.85 and 0.38 for the output gap, respectively. Concerning monetary policy shock, Figure 4c shows the sharp increase in the volatility of the shock. Table 3 (see Appendix) gives quantitative assessments about this shift: the mean of the coefficient is 0.30 before 2008 and 0.66 on the period after 2008.
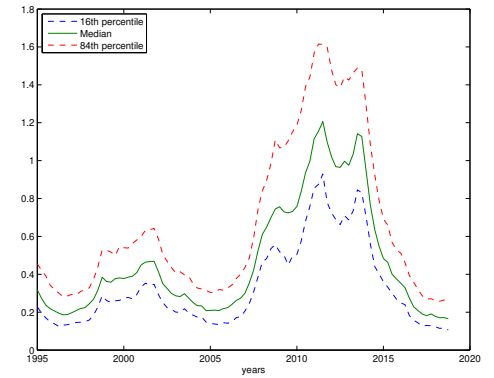
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Figure 4: Impact coefficients from the estimated monetary policy rule and monetary policy shock volatility in the US
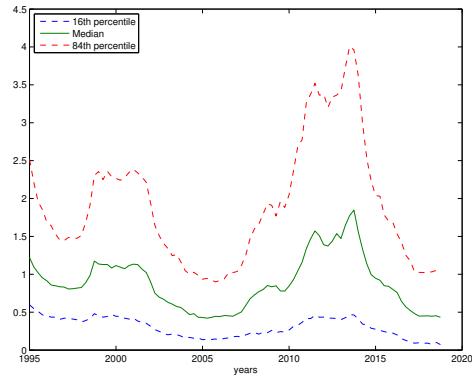
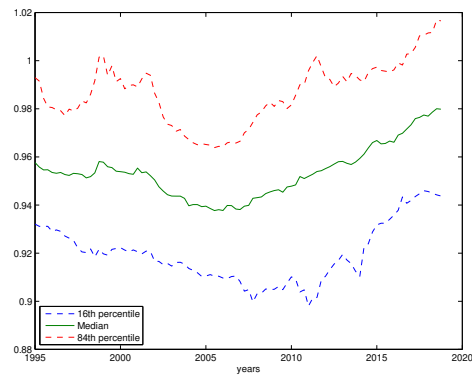
(a) Impact coefficient on inflation
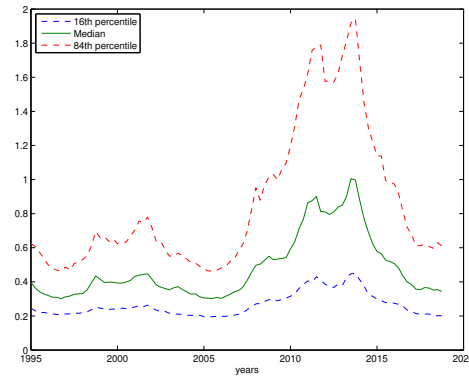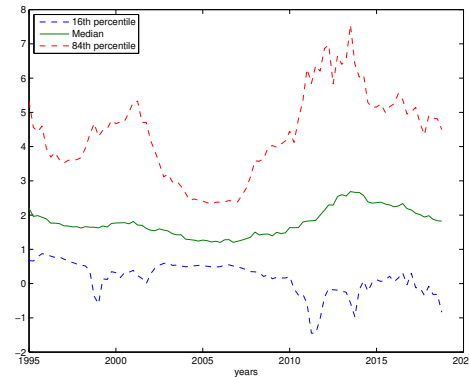
(b) Impact coefficient on the output gap

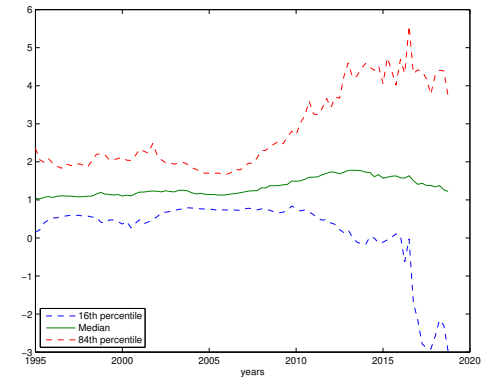(c) Monetary policy shock volatility

Figure 5: Interest rate smoothing and long-run coefficients from the estimated monetary policy rule in the US

(a) Interest rate smoothing

(b) Long-run coefficient on inflation

(c) Long-run coefficient on the output gap

Interest rate smoothing (Figure 5a) is given by the sum $\gamma_{1,rr,t}+\gamma_{2,rr,t}$ of the coefficients on the lagged interest rate terms. The higher the sum, the more the central bank uses gradualism in its decisions. We can observe that the Fed has adopted a more cautious behavior since the start of the Great Recession by setting interest rates in a more gradual way. The median coefficients is equal to 0.95 in 2009, 0.96 in 2013, and around 0.97 in 2017 as given by the Table 2.

The long-run coefficients are given by $(c_{r\pi,t}+\gamma_{1,r\pi,t}+\gamma_{2,r\pi,t})/(1-\gamma_{1,rr,t}-\gamma_{2,rr,t})$ for inflation (Figure 5b) and $(c_{rg,t}+\gamma_{1,rg,t}+\gamma_{2,rg,t})/(1-\gamma_{1,rr,t}-\gamma_{2,rr,t})$ for the output gap (Figure 5c). As for the impact coefficients, long-run responses of the shadow rate to inflation and the output gap are more agressive in periods of crisis and unconventional monetary policy. Moreover, the response to inflation is still larger than the response to the output gap and the mean of the coefficients is still higher after the Great Recession for both responses, as shown in Table 3. The long-run coefficient on inflation was at 1.57 before the 2008 crisis on average, before reaching 2.04 on the post-crisis subperiod. Note that the mean coefficient of 1.78 over the whole period is consistent with the Taylor principle. Concerning the long-run response to the output gap, the coefficient is a little bit smaller than the one on inflation, but follow the same path. As a whole, the interpretation of long-run coefficients is quite the same as the interpretation of impact coefficients given above.

Figure 12a (see Appendix) plots the time-varying inflation target fot the core PCE price index, defined by Cogley and Sargent (2005) ans Cogley et al. (2010) as the stochastic trend towards which inflation would gravitate based on draws of parameters for each period. The estimated inflation target has been fluctuated around 2% over the period. Table 3 and the graph bring some evidence for a stable inflation target on the period, with median inflation rate at 2.08, 2.25 and 2.24 in 2009, 2013 and 2017.
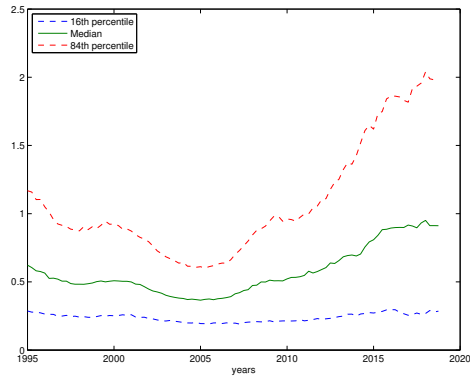
5.b Monetary policy in the Euro Area

Impact coefficients in the Euro Area are quite different than those in the US for two reasons. First, the contemporaneous response of the shadow rate to inflation is lower than the response to the output gap. Table 4 (see Appendix) shows that impact coefficients are 0.46 and 0.83 on inflation in 2009 and 2017, where the coefficients are 0.48 and 1.30 on the outptut gap in 2009 and 2017. Graphically, we can see that the latter coefficient sharply increased during the Great Recession, in a greater proportion than the coefficient on inflation. The second difference with the US comes from the strategy of the Fed and the ECB. As summarized in Table 1, the

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Fed exited from the ZLB at the end of 2015, whereas the ECB is still dealing with unconventional measures. As a result, the coefficients that peaked during unconventional measures (due to extremely negative shadow rates) decrease a lot at the end of the period of estimation in the US but stay at a high level in the Euro Area. Next section is dedicated to the comparison between the Fed and the ECB.
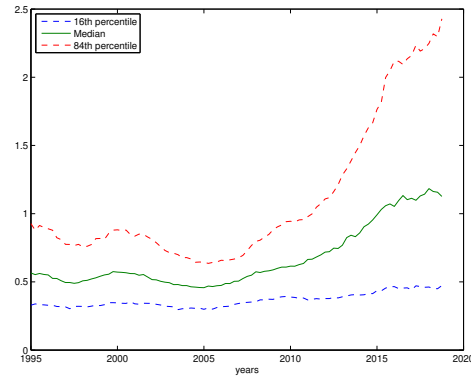
Monetary policy shock volatility follows a similar path than the impact coefficients. It has increased continuously since the 2008 crisis, as shown in Table 5 (see Appendix).

Figure 6: Impact coefficients from the estimated monetary policy rule and monetary policy shock volatility in the Euro Area

(a) Impact coefficient on inflation
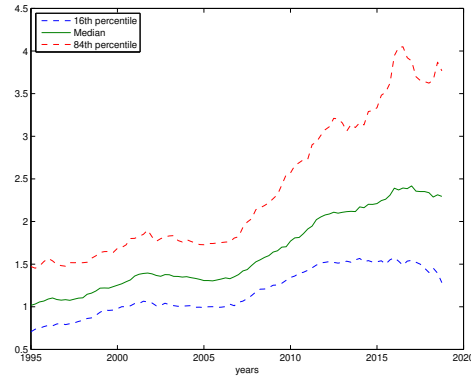
(b) Impact coefficient on the output gap
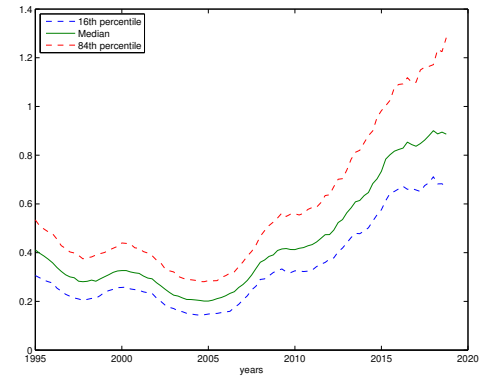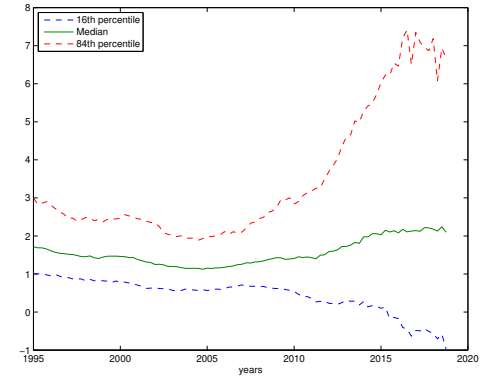
(c) Monetary policy shock volatility

Figure 7: Interest rate smoothing and long-run coefficients from the estimated monetary policy rule in the Euro Area
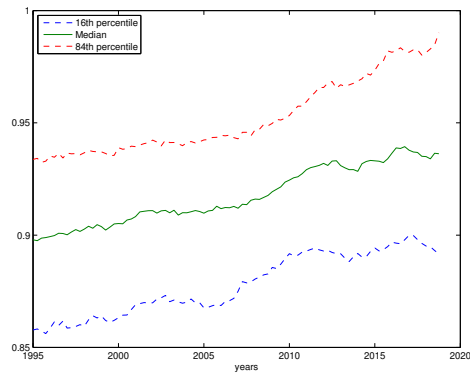
(a) Interest rate smoothing

(b) Long-run coefficient on inflation

(c) Long-run coefficient on the output gap

However, the interpretation in terms of magnitude of the coefficients is not same when one consider long-run responses to inflation and output. Indeed, although the impact coefficient is higher for output than for inflation, the long-run coefficient is high for inflation than for output gap especially after the crisis (Table 5).

Here again, the Euro Area seems to be in an inertia interest rates situation, where the coefficient on the lagged shadow rate has hugely increased since 2009.

Figure 12b (see Appendix) plots the estimated inflation target for the HICP in the Euro Area. The target is 'below, but close to 2%' over the sample period (1.77 on average since 1995).

6 A comparison between Fed's and ECB's behavior

6.a US and Eurozone: is the conduct of monetary policy so different?

Figure 8 shows the evolution of the Taylor-type rule in the US and the Euro Area. The lower part of the figure represents shocks on monetary policy acros the period of estimation. Graphically, and in accordance with Wu and Zhang (2016), the Taylor rule seems to be a good description of the way the Fed and the ECB have implemented monetary policy over the whole sample period. However, monetary policy shocks seem to be more volatile during the ZLB period, that could illustrates the departure of the central bank from the behavior prescribed by the estimated policy rule. Negative monetary policy shock means that the central bank sets interest rate at a level below the rate prescribed by the estimated monetary policy rule. In that case, monetary policy is perceived as too expansionary.
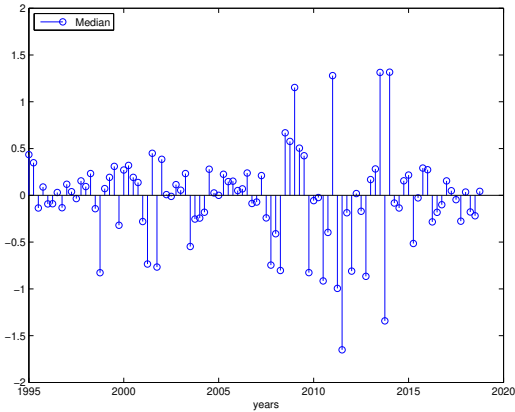
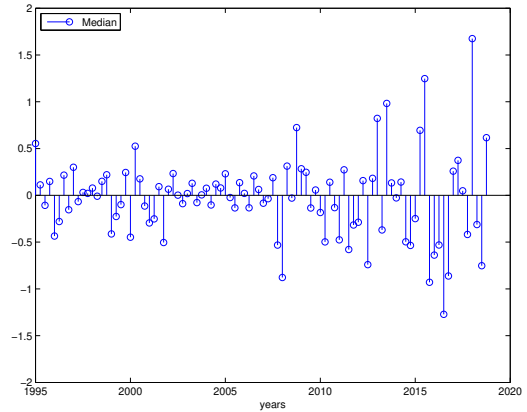Figure 8: Taylor rules and monetary policy shocks
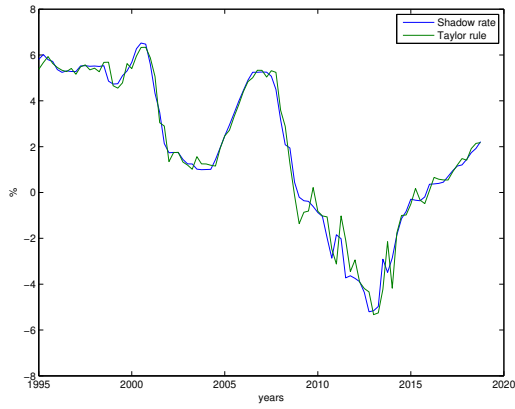
(a) Monetary policy rule in the US
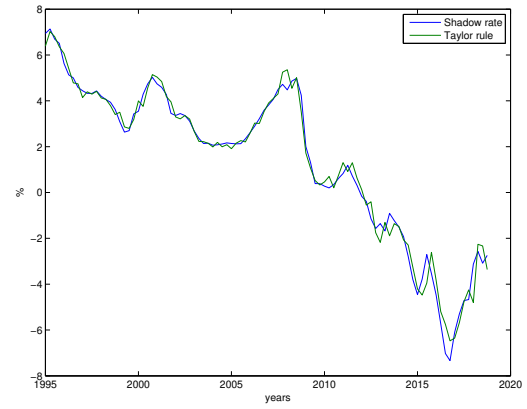
(b) Monetary policy rule in the Euro Area

(c) Monetary policy shocks in the US
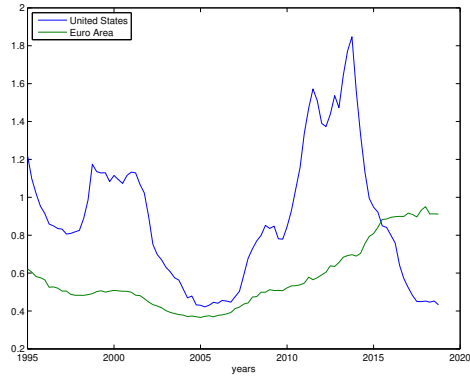

(d) Monetary policy shocks in the Euro Area

Figure 9 and 10 compare impact and long-run coefficients from the estimated Taylor rule, monetary policy shock volatility and interest rate smoothing between the US and the Euro Area.

Focusing on contemporaneous responses to movements in inflation and the gap variables (Figure 9), impact coefficients in the US follow a more volatile path than in the Euro Area: the Fed seems to response more agressively to inflation and output gap than the ECB, or at least behaves in a more discretionnary way. Moreover, lagged unconventional monetary policy in the Euro Area comparing to the US leads to a gap between the timing of ECB's responses to inflation and output gap and the Fed's actions. Impact coefficients from the ECB monetary policy rule reached an all-time high at the end of the period of estimation, whereas they came back

to a pre-crisis level in the US. This result is closely related to policy normalization in the US and in the Euro Area: the Fed began normalizing the stance of monetary policy at a time the ECB had not yet reached the ZLB.

Previous interpretations are quite the same concerning long-run coefficients on the output gap. However, the story is a little bit different for long-run coefficients on inflation, especially in the US where the coefficient did not fully come back to its pre-crisis level during exit from unconventional monetary policy in the US (Figure 10). This result could be interpreted as the willingness for the Fed to avoid any deflationary episode.
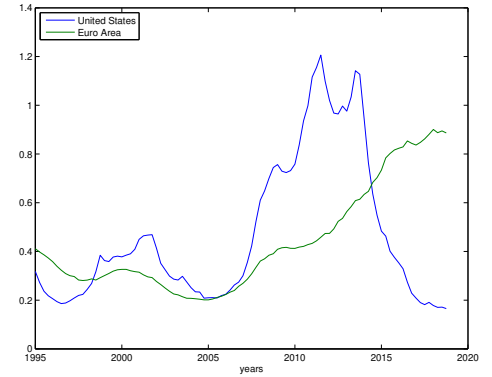
Figure 9: Impact coefficients from the estimated monetary policy rule and monetary policy shock volatility

(a) Impact coefficient on inflation
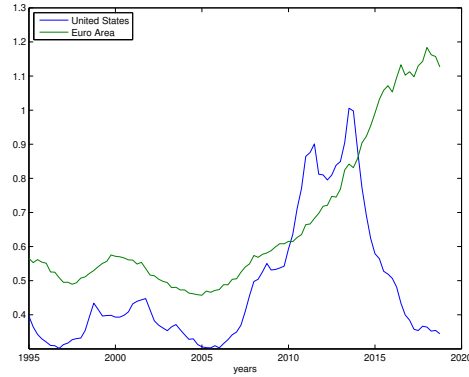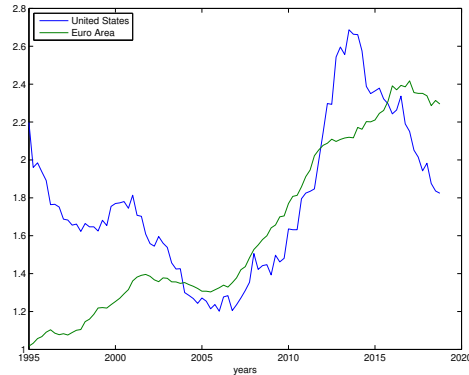
(b) Impact coefficient on the output gap

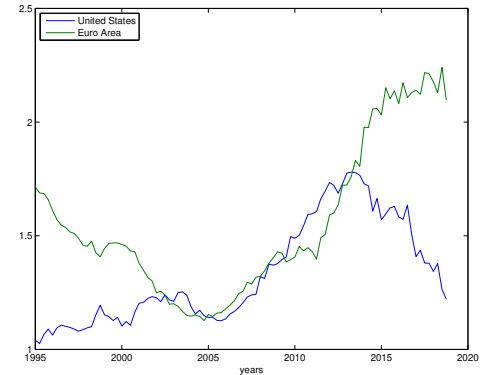(c) Monetary policy shock volatility

Figure 10: Interest rate smoothing and long-run coefficients from the estimated monetary policy rule

(a) Interest rate smoothing

(b) Long-run coefficient on inflation

(c) Long-run coefficient on the output gap

6.b Counterfactual analysis

The model with time-varying coefficients used in this paper allow a counterfactual analysis based on fixed coefficients in the estimated rule at reference date. For this purpose, we give the path that would have followed inflation, output gap and interest rate, in the US and the Euro Area, in three different scenarios. These scenarios explain what would happened if the central bank applied the 2000Q1, 2007Q4 and 2013Q1 policy rule over the period, keeping fixed coefficients in the Taylor rule at each dates. The purpose of this exercise is to compare the counterfactual path of inflation, output gap and interest rate with the observed variables. The choice of dates for fixed monetary policy rule can be justified as relatively low coefficients in 2000Q1, pre-Great Recession date in 2007Q4 and particularly high coefficients in 2013Q1.

Figure 11 gives all the counterfactuals for each variable of our model in the US and in the Euro Area. Concerning inflation rates (Figure 11a and 11b), there is no significant difference in the path according to the different scenarios in the US. Core PCE inflation would have been slightly higher than what has been observed after the crisis if the Fed would have kept fixed monetary policy rule in 2013Q1. However, the result is quite impressive in the Euro Area. Changes in ECB's monetary policy had a huge impact on HICP, especially after the Great Recession: unconventional monetary policy has strongly reduced the delfationary risk in the Euro Area. More precisely, without unconventional monetary policy, the Euro Area would have suffered a period of deflation from end-2014 to 2017. This result is consistent with Mouabbi and Sahuc (2017).

Concerning the output gap (Figure 11c and 11d), unconvetional measures implemented by the Fed and the ECB have led to positive output gap at the end of the period of estimation, whereas the US and the Euro Area would have suffered negative output gap if the central banks would have kept the 2007Q4 monetary policy rule unchanged. Moreover, we find that the output gap would have been less negative in the case of the 2000Q1 policy rule than in the case of the 2007Q4 policy rule at the end of the sample period in the Euro Area.
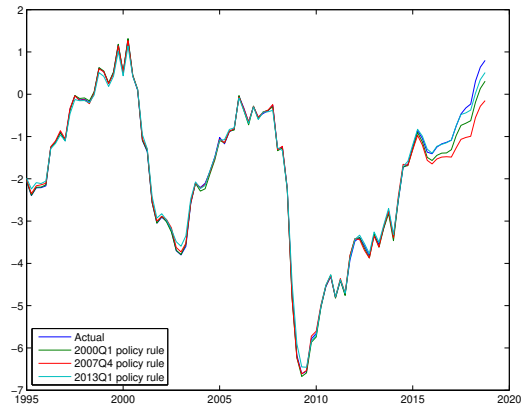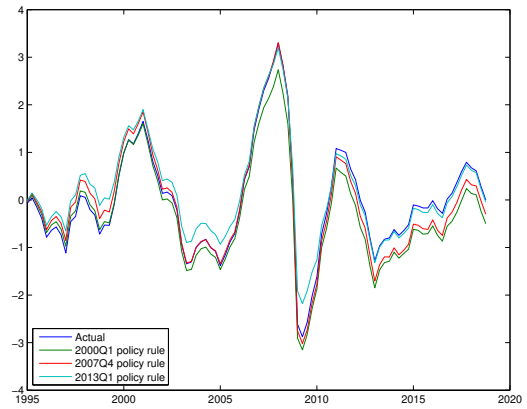
Figure 11: Counterfactual simulations
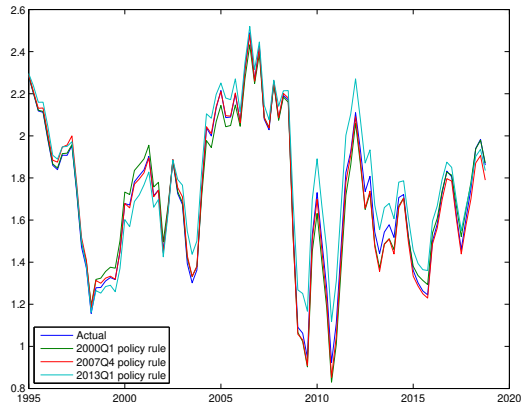
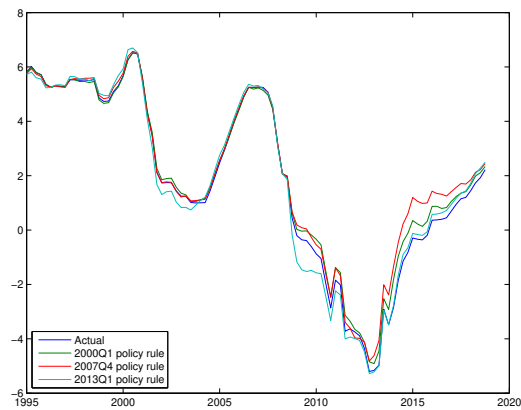(a) Inflation in the US (Core PCE inflation)
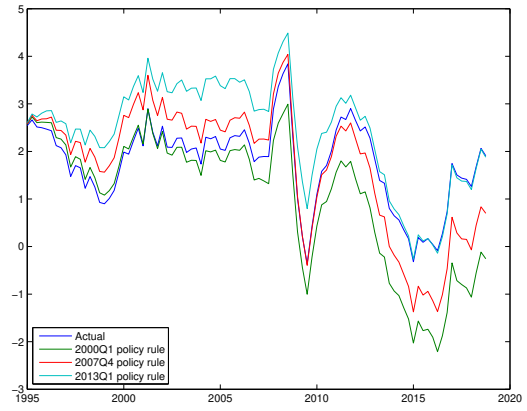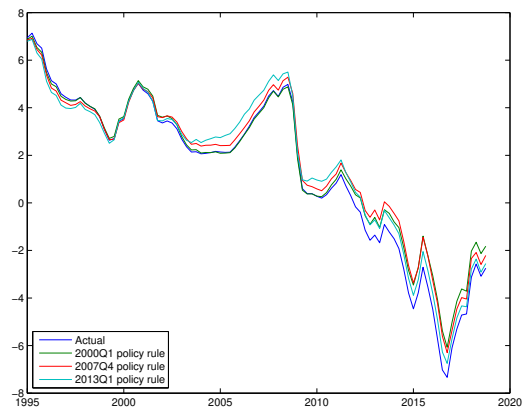
(b) Inflation in the Euro Area (HICP)

(c) Output gap in the US

(d) Output gap in the Euro Area

(e) Interest rate in the US (shadow rate)

(f) Interest rate in the Euro Area (shadow rate)

7   Conclusion

The issue of central banks preferences can be explored by assuming that the central bank follows a Taylor-type rule to guide monetary policy decisions. According to this framework, the central bank focuses attention on macroeconomic fundamentals, such as inflation and output, to determine its target value for the interest rate. Preferences concern the relative weight that the central bank put on inflation or real activity when setting its policy rate. The time-varying paramater vector autoregressive model used in this paper gives some empirical assessments of the Taylor rule in the US and in the Euro Area. It allows a better understanding of monetary policy implementations by capturing changes in Fed's and ECB's preferences in the last decades. Since the period of estimation also covers the ZLB era, we use a shadow rate as a proxy for interest rate in our model. Our empirical analyse shows that the Fed has behaved differently than the ECB since the Great Recession. Although the Fed announced starting tapering in end-2012, the ECB has not even reached the ZLB at this time. This shift in the timing of monetary policy normalization between the US and the Euro Area has led to a different path in the coefficients of the monetary policy rules: since the level of Fed's preferences went back to their pre-crisis level, the ECB is still in high-coefficients phase. However, counterfactual analysis shows in which extent unconventional measures have been efficient in the two economies, and especially in the Euro Area.

Appendix

Tables

Table 2: Monetary policy parameters in the US (coefficients)

	Median 2009:1	Median 2013:1	Median 2017:1	Pr(2009:1 > 2013:1)	Pr(2009:1 > 2017:1)
Impact coefficient on inflation	0.84	1.48	0.52	0.19	0.74
Impact coefficient on the output gap	0.53	0.85	0.38	0.11	0.82
Interest rate smoothing	0.95	0.96	0.97	0.39	0.27
Long-run coefficient on inflation	1.40	2.60	2.15	0.33	0.41
Long-run coefficient on the output gap	1.38	1.79	1.41	0.34	0.41
Monetary policy shock volatility	0.76	0.98	0.21	0.28	1.00
Inflation target	2.08	2.25	2.24	0.34	0.39

Table 3: Monetary policy parameters in the US (mean)

	Sample	$< 2008 : 1$	$\geq 2008 : 1$
Impact coefficient on inflation	0.88	0.79	0.99
Impact coefficient on the output gap	0.48	0.36	0.62
Interest rate smoothing	0.95	0.95	0.96
Long-run coefficient on inflation	1.78	1.57	2.04
Long-run coefficient on the output gap	1.33	1.15	1.54
Monetary policy shock volatility	0.47	0.30	0.66
Inflation target	2.13	2.08	2.18

Table 4: Monetary policy parameters in the Euro Area (coefficients)

	Median 2009:1	Median 2013:1	Median 2017:1	Pr(2009:1 > 2013:1)	Pr(2009:1 > 2017:1)
Impact coefficient on inflation	0.46	0.61	0.83	0.18	0.11
Impact coefficient on the output gap	0.48	0.75	1.30	0.12	0.06
Interest rate smoothing	0.92	0.93	0.95	0.33	0.23
Long-run coefficient on inflation	1.68	2.24	2.65	0.11	0.18
Long-run coefficient on the output gap	0.84	1.11	1.63	0.41	0.34
Monetary policy shock volatility	0.39	0.55	0.84	0.09	0.02
Inflation target	1.50	1.20	1.96	0.51	0.39

Table 5: Monetary policy parameters in the Euro Area (mean)

	Sample	$< 2008 : 1$	$\geq 2008 : 1$
Impact coefficient on inflation	0.52	0.40	0.65
Impact coefficient on the output gap	0.67	0.49	0.87
Interest rate smoothing	0.92	0.91	0.93
Long-run coefficient on inflation	1.73	1.34	2.21
Long-run coefficient on the output gap	1.21	1.14	1.24
Monetary policy shock volatility	0.42	0.25	0.60
Inflation target	1.77	1.89	1.63

Figures

Figure 12: Estimated inflation target
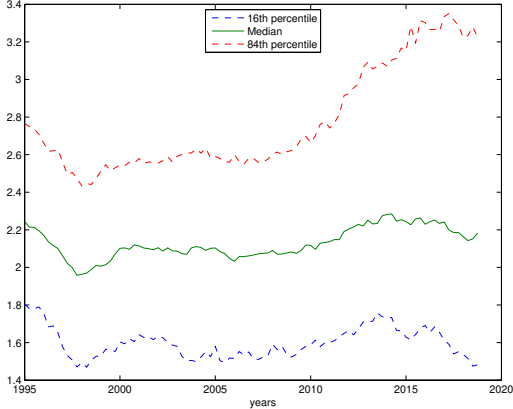
(a) US
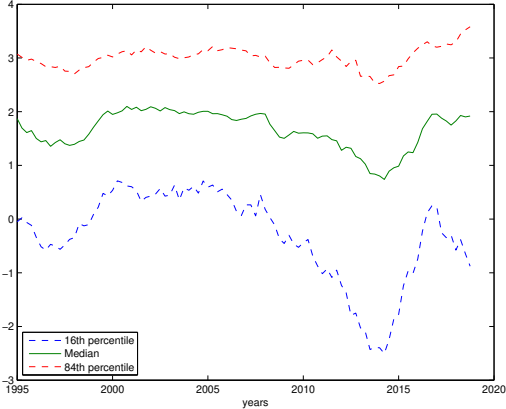
(b) Euro Area

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