Monetary policy evaluation. A counterfactual analysis based on dynamic factor models

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This paper complements the recent literature analysing the effects of the unconventional monetary stimuli applied after the Great Recession by proposing an intuitive and easy to implement method to evaluate different exit strategies towards a traditional monetary context. This approach, useful for central bankers or researchers interested in the effects of tapering, allows us to evaluate the consequences of a given monetary policy path on the future evolution of key macroeconomic indicators. Results based on this methodology provide a measurement of the differences in economic performance under contractionary and expansionary policies and support the recent success of monetary stimuli in boosting real indicators while having little effect on inflation.

Keywords: monetary policy, quantitative easing, zero lower bound, shadow rate, tapering.

JEL classification: C32, E47, E52, E58

Acknowledgements: I thank Gabriel Perez-Quiros and Mihaly Borsi (Banco de España), Maximo Camacho Alonso (Universidad de Murcia) and Ishak Demir (Birkbeck University of London) for their useful comments. This work was supported by the MINECO/FEDER under Grant ECO2015-70331-C2-2-R.

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I. Introduction

The financial crisis of 2008 was followed by a decline in real activity, employment and prices without precedent in recent economic history. In order to prevent the dramatic consequences of this financial shock in the economy, the Federal Reserve (Fed) implemented a package of unconventional monetary policies. Firstly, official interest rates were lowered to their Zero Lower Bound (ZLB). This measure was complemented with other extraordinary policies: Quantitative Easing (QE) and forward guidance. The latter entailed a more aggressive communication strategy from the central bank to influence market expectation about the duration of the ZLB period, whereas the former consisted in large scale purchases of assets with money newly created. The effectiveness of this unconventional monetary policy (Gertler and Karadi 2011) and, more recently, its spillover effects to other countries (Aizenman et al. 2014; Lutz 2014) have been previously discussed.

Thereafter, under signs of economic recovery, a vigorous debate emerged about the correct way and timing of going back to a conventional monetary situation. But central bankers must find the correct balance between a premature removal of the stimuli and delayed timing in tightening monetary conditions to ensure that the economy will not be back into recession after a monetary policy normalization (Yellen 2015). Unfortunately, as mentioned in Joyce et al. (2012), given the exceptional stimuli that have been implemented and the lack of historical precedents in this matter, to measure the contribution of the unconventional monetary policy to the economic developments in order to figure out what would be the consequences of its removal is a challenging task.

This paper tries to solve this issue by proposing an easy to implement methodology which allows us to simulate the consequences of several monetary policy paths on the key macroeconomic indicators and to identify the optimal exit strategy from the non-standard monetary environment regarding its timing and magnitude.

II. The Model

Dynamic Factor Models (DFM) have been shown as a powerful tool to summarize the aggregate behavior of the economy (Stock and Watson 1991) and for forecasting (Camacho and Perez-Quiros 2010). A particular characteristic of DFM which, as explained in the next section, is exploited for the purpose of the paper, is that they include information for different temporal horizons independently of the publication date of the series dealing with missing values at the end of the sample.

In particular, the model is based on Stock and Watson (1991). The evolution of the economy is summarized in a latent factor estimated from four series related with demand, supply, employment and income. As in Camacho and Perez-Quiros (2011), this initial set of indicators is enlarged with GDP and other indictors related to monetary policy.

It assumed that the *i* indicators included in the model are commonly affected by a latent factor plus an idiosyncratic component which only affects each of the series according to:

$$x_t^i = \beta_i f_t + u_t^i \qquad (1)$$

Each of the components of the right hand side of Equation 1 follows an autoregressive dynamic of order *p* and *q* respectively

$$f_t = a_1 f_{t-1} + ... + a_p f_{t-p} + \varepsilon_t^f \qquad (2)$$

$$u_t^1 = b_1^1 u_{t-1}^1 + ... + b_q^1 u_{t-q}^1 + \varepsilon_t^{u^1} \qquad (3)$$

$$\vdots$$

$$u_t^n = b_1^n u_{t-1}^n + ... + b_q^n u_{t-q}^n + \varepsilon_t^{u^n} \qquad (4)$$

where ε_t^f , $\varepsilon_t^{u^1}$,... and $\varepsilon_t^{u^n} \sim iN(0,\sigma_i^2)$.

Equations 1 to 4 are summarized in the following state space representation:

$$\begin{pmatrix} x_t^1 \\ \vdots \\ x_t^n \end{pmatrix} = \begin{pmatrix} \beta_1 & 0 & \cdots & 0 & 1 & 0 & \cdots & 0 \\ & & & \vdots & & & & \\ \beta_n & 0 & \cdots & 0 & 1 & 0 & \cdots & 0 \end{pmatrix} + \begin{pmatrix} f_t \\ f_{t-1} \\ \vdots \\ f_{t-(p-1)} \\ u_t^1 \\ \vdots \\ u_{t-(q-1)}^1 \\ \vdots \\ u_t^n \\ \vdots \\ u_{t-(q-1)}^n \end{pmatrix} \qquad (5)$$

$$\begin{pmatrix} f_t \\ f_{t-1} \\ \vdots \\ f_{t-(p-1)} \\ u_t^1 \\ \vdots \\ u_{t-(q-1)}^1 \\ \vdots \\ u_t^n \\ \vdots \\ u_{t-(q-1)}^n \end{pmatrix} = \begin{pmatrix} a_1 & \cdots & & & a_p & 0 & & \cdots & & 0 \\ 1 & 0 & & & & \cdots & & & & 0 \\ & & & & & \vdots & & & & \\ 0 & \cdots & 0 & 1 & 0 & & & \cdots & & 0 \\ 0 & \cdots & 0 & b_1^1 & \cdots & b_q^1 & & \cdots & & 0 \\ & & & & & \vdots & & & & \\ 0 & & \cdots & & 0 & 1 & 0 & \cdots & & 0 \\ & & & & & \vdots & & & & \\ 0 & & \cdots & & 0 & b_1^n & \cdots & b_q^n & \cdots & 0 \\ & & & & & \vdots & & & & \\ 0 & & & & & \cdots & & & 1 & 0 \end{pmatrix} \begin{pmatrix} f_{t-1} \\ f_{t-2} \\ \vdots \\ f_{t-p} \\ u_{t-1}^1 \\ \vdots \\ u_{t-q}^1 \\ \vdots \\ u_{t-1}^n \\ \vdots \\ u_{t-q}^n \end{pmatrix} + \begin{pmatrix} \varepsilon_t^f \\ 0 \\ \vdots \\ 0 \\ \varepsilon_t^{u^1} \\ 0 \\ \vdots \\ 0 \\ \varepsilon_t^{u^n} \\ \vdots \\ 0 \end{pmatrix} \qquad (6)$$

Given this representation, latent factor and parameters can be estimated by maximum likelihood using the Kalman filter. The filter is modified in order to deal with missing values at the end of the sample by avoiding the part of the Kalman gain matrix which corresponds to these missing observations in the updated equation.

III. Measuring monetary policy effects. Data, estimation and results

The policymaker's information set is larger than the information observable for other agents. Central bankers decide the future path of monetary policy according to their assessment of economic conditions and targets and what part of this plan is revealed to the public, to what extent and as of what dates.

In September 2015, Federal Open Market Committee (FOMC) stated that their long run predicted level for Federal Funds Rate (FFR) would be reached 'fairly slowly' in order to smooth market disturbances. Suppose, then, that the monetary authority has established the corresponding path to achieve this target. This paper proposes to evaluate this initial decision by enlarging the current publicly available information set included in a DFM with the future monetary policy path fixed by the central banker and its counterfactual comparison with other alternative paths.

For instance, let us assume that the Fed considers that the economy is now completely recovered from the financial crisis and decides to end all the stimuli going back progressively to a monetary policy stance similar to the one previous to 2008. If this monetary policy path is included in the dataset of a DFM, projections computed according to this information set are based on the previous dynamics of the economy, measured through the common factor, together with the contribution of the future path of the monetary policy. Then, the consequences of this path can be compared with another set of predictions based on, for example, a monetary path where the current Fed's stance remains unchanged.

An important concern for this purpose is how the different components of recent monetary policy (official interest rates, money creation and forward guidance) may be jointly evaluated for their inclusion in the empirical analysis. FFR, traditionally used as an inclusive description of the Fed´s stance, is not informative since it reached the ZLB.

Monetary base presents a similar lack of variability previous to the Great Recession. Finally, the quantitative assessment of forward guidance and FOMC´s public statements in the media presents obvious challenges.

This issue may be solved using the methodology proposed by Wu and Xia (2014). Forward rates behave as a summary of markets´ expectations about future movements of interest rates. These expectations are also conditioned by the forward guidance announcements and the magnitude of money flow issued by the central bank (QE). Thus, Wu and Xia (2014) elaborate a Shadow Rate (SR) synthesizing monetary policy conditions using the information contained in forward rates**.** This estimated policy rate is very close to FFR until 2008 and summarizes the effects of QE and forward guidance once FFR is near zero (Fig 1). Moreover, Wu and Xia (2014) show how the SR relationship with a large set of 97 macro series is equivalent to the relationship between FFR and the same set of series before 2008. It is important to note that, given that SR is related with market expectations contained in forward rates, forecasts conditional on the evolution of SR do not correspond with the effects of unexpected monetary policy shocks. Hence, the use of SR allows us to evaluate the effects of a monetary policy plan for a relatively large horizon summarized in one variable before and after the ZLB period instead of the effects of an unexpected change in the policy rule in a single moment. Furthermore, the inclusion of the simulated SR in the DFM provides forecasts taking into consideration the recent evolution of the economy reflected in the common factor. Thus, the estimated consequences of a given monetary policy path may differ for conventional and unconventional periods as discussed in Gertler and Karadi (2011).

Following Camacho and Perez-Quiros (2011), the original dataset of Stock and Watson (1991) (Total Retail Trade, Industrial Production Index, Employees on

Nonfarm Payrolls and Real Personal Income) is enlarged with GDP and monetary indicators. In this particular case, SR is selected to represent monetary conditions for the reasons explained above. Finally, Consumer Price Index (CPI) is also included to evaluate the effects of monetary policy on prices.

Data was downloaded from Federal Reserve Bank of Saint Louis on March 4, 2015 spanning the period between 1960.Q1 to 2014.Q4. SR was downloaded from the Federal Reserve Bank of Atlanta website. Before its inclusion in the model for the estimation of the common component, the series were transformed to induce stationarity and SR was included with two lags in order to introduce a delay in the reaction of real activity to monetary stimuli in the model.

According to the FOMC, changes in the level of intervention must be applied progressively in order to ensure financial stability (Yellen 2015). Thus, the simulated monetary policy paths were selected reflecting this strategy for five plausible targets for the policy rate (Fig 2). The first target is based on the assumption that the Fed decides to set monetary policy conditions similar to 2007. To achieve this target gradually, path 1 is defined as the linear interpolation from the current value of SR up to 5.25% during the next two years after the end of the sample. The second path progressively abandons the ZLB over two years and recover a conventional monetary situation. Hence, the evolution of SR is defined by linear interpolation between the current value and zero. Path 3 represents a scenario of no further intervention where SR remains unchanged assuming that tapering is still not a good decision. Path number 4 is symmetric to the second path where SR decreases up to -5.32%. Finally, path 5 is symmetric to path 1. In this case, SR reaches -10.55%.

Projections of the quarterly rate of growth of Total Retail Trade, GDP, Employees on Nonfarm Payrolls, Industrial Production Index (IPI), Real Personal

Income and CPI during the next six quarters are included in Fig 3. The estimated evolution for activity indicators and prices are consistent with the magnitude and directions of the different monetary policy paths. Dashed lines, corresponding to path 3, represent the predicted behavior of the economy under no intervention from the Fed in the current monetary environment. Estimated progress of these macro variables under a contractionary monetary policy, represented by paths 1 and 2, is depicted using the darker colors. As expected, the growth of activity and income indicators is slower if monetary conditions evolve abandoning the ZLB (path 2), and more sluggish when recovering the pre-Great Recession monetary stance (path 1).

Let us consider Retail Trade: the quarterly rate of growth of this indicator would remain at values between 0.5 and 0.4 percent with no changes in the level of intervention of the Fed, while this value would be lower than 0.3 after six quarters under the contractionary path 1. Activity and income indicators show a more vigorous pace for the expansionary policy paths represented by the lighter color lines. If the policy rate followed the expansionary path 5 the rate of growth of Retail Trade after six quarters would be 0.15% higher with respect to the case in which there were no changes in the policy rate (path 3) and 0.32% higher with respect to the most contractionary route (path 1).

This pattern is present in all the variables included for the estimation of the latent factor. GDP shows an increasing growth during the next quarters. However, the implementation of contractionary policies will slow down this progressive pace. Comparing the extreme cases, the six periods ahead forecast for quarterly rate of growth of GDP will be 0.27% higher under path 5 than under path 1. Employees, IPI and Personal Income quarterly rates show a similar predicted trend. These indicators will have growth as vigorous as previously observed only under the most expansionary policy path number 5. The predicted rate for the six periods ahead under path 1 will be 0.12%, 0.55% and 0.22% lower respectively for these three indicators.

Results describing the different CPI evolutions are also consistent with the monetary policy stance simulated in each path. The more expansionary, or less contractionary, the monetary policy path, the higher the pace of quarterly rate of growth of CPI. However, the progress of prices for each monetary scenario is very similar showing a modest but increasing rate of growth. This result is consistent with the previous literature which has shown how unconventional monetary policy has reinforced real activity without the cost of higher inflation (see Joyce et al. [2012] for a review of these results).

In order to assess the adequacy of this methodology, the predictions of the counterfactual analysis are compared with the actual evolution of the monetary policy and the macroeconomic indicators observed after the estimations of these forecasts. The Fed ended gradually the QE program during the last months of 2014. Thereafter, the Fed announced its intention to raise FFR. Finally, in December 2015 FFR were increased for first time after 2006. In consequence, SR, as a summary of market expectations about the monetary policy conditions, increased during 2015 taking values between paths 1 and 2 (Fig 2). Hence, these contractionary paths are representative of the recent decisions of the Fed within the five illustrative paths and could be reasonably anticipated under the forward guidance and the FOMC´s public statements.

To evaluate how the accuracy of one´s knowledge about the evolution of monetary conditions may improve macroeconomic forecasting we measure the deviations of the five illustrative paths with respect to the actual evolution of the SR using the Euclidean Distance (ED)[1]. The five forecasts for the macroeconomic indicators conditional on the simulated paths were also compared with their actual evolution using the same measure. Table 1 shows that the EDs of the simulated SRs with respect to the actual SR are highly and positively correlated with the EDs of each conditional prediction of the macroeconomic series with respect to their actual values, meaning that the closer the simulated path to the true evolution of the policy rate, the more precise the predictions. Furthermore, Table 2 compares the predicted average quarterly rate of growth of the macroeconomic variables under the contractionary paths with their actual values during 2015. The table shows that macroeconomic series are accurately predicted by this methodology during the period of ZLB, especially Employees, Income and CPI[2].

Additionally, the robustness of this approach is examined by exploring other ways to include market expectations about monetary policy conditions. In particular, predictions are carried out based on Federal Funds Futures (FFF) contracts offered by the Chicago Board of Trade during 2015 (Table 2). This information does not improve predictions based on SR. This is most likely due to the fact that FFF include expectations about official interest rates, but do not contain information regarding the unconventional monetary policy tools recently deployed by the Fed.

In sum, these results stress the good performance of this methodology in evaluating the consequences of the monetary policy maker´s decisions and in anticipating

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1 Root of the sum of the squared differences between each time observation.

2 The sudden decline in the IPI after the end of the sample period is not correctly captured by the model due to the recent drop in oil and gas production.

economic developments by forecasters with a reasonable prior knowledge about the monetary policy stance.

IV. Summary and concluding remarks

This paper proposes a new implementation of DFMs to evaluate the consequences of the removal of unconventional monetary stimuli. Predictions provided by this methodology are based on the recent dynamics of key macroeconomic indicators and the contribution of simulated monetary conditions to economic performance. In this way, central bankers may find the optimal policy plan depending on which area of the economy they consider imperative while evaluating the accompanying consequences of this plan on other macroeconomics aggregates. The findings presented here provide a measurement of the success of the Fed´s intervention in real economic conditions and show how this intervention has a small effect on prices after the financial crisis.

Acknowledgements: I thank Gabriel Perez-Quiros and Mihaly Borsi (Banco de España), Maximo Camacho Alonso (Universidad de Murcia) and Ishak Demir (Birkbeck University of London) for their useful comments. This work was supported by the MINECO/FEDER under Grant ECO2015-70331-C2-2-R.

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Variable	Correlation
Retail Trade	0.90
GDP	0.85
Employees	0.95
IPI	0.84
Income	0.91
CPI	0.85

Table 1: Correlations between the Euclidean Distance of the five simulated monetary policy paths with respect to SR and the Euclidean Distance of the five predictions for the macro-indicators with respect to their actual evolution during 2015.

	Average Quarterly Rate of Growth 2015	SR Path 1 Predictions	SR Path 2 Predictions	FFF Predictions
Retail Trade	0,223	0,463	0,499	0,623
GDP	0,767	1,144	1,175	1,317
Employees	0,490	0,531	0,544	0,519
IPI	-0,206	0,721	0,782	0,863
Income	0,831	0,746	0,771	0,749
CPI	0,102	0,238	0,242	0,723

Table 2: Column 1: average quarterly rate of growth of macroeconomic indicators during 2015. Columns 2 and 3: predictions based on contractionary monetary policy paths. Column 4: predictions based on Federal Funds Futures (FFF).

Figure 1. Solid line: Xu and Xia (2014) Shadow Rate. Dashed line: effective Federal Funds Rate. Shaded area: Zero Lower Bound Period.

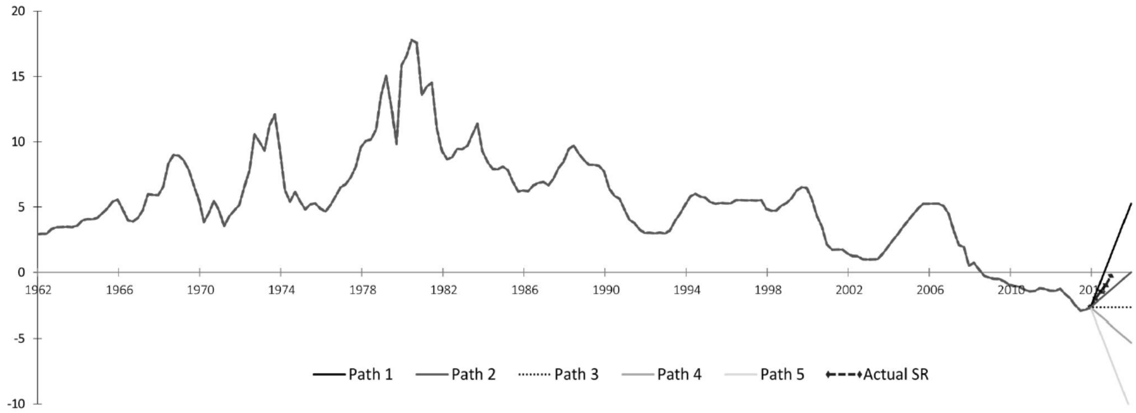

Figure 2. Gray line: Xu and Xia (2014) Shadow Rate. Path 1: linear increase to achieve values of the policy rate of the pre-Great Recession period in two years. Path 2: linear increase to achieve positive values of the policy rate. Path 3: constant policy rate. Path 4: symmetric to path 2. Path 5: symmetric to path 1.

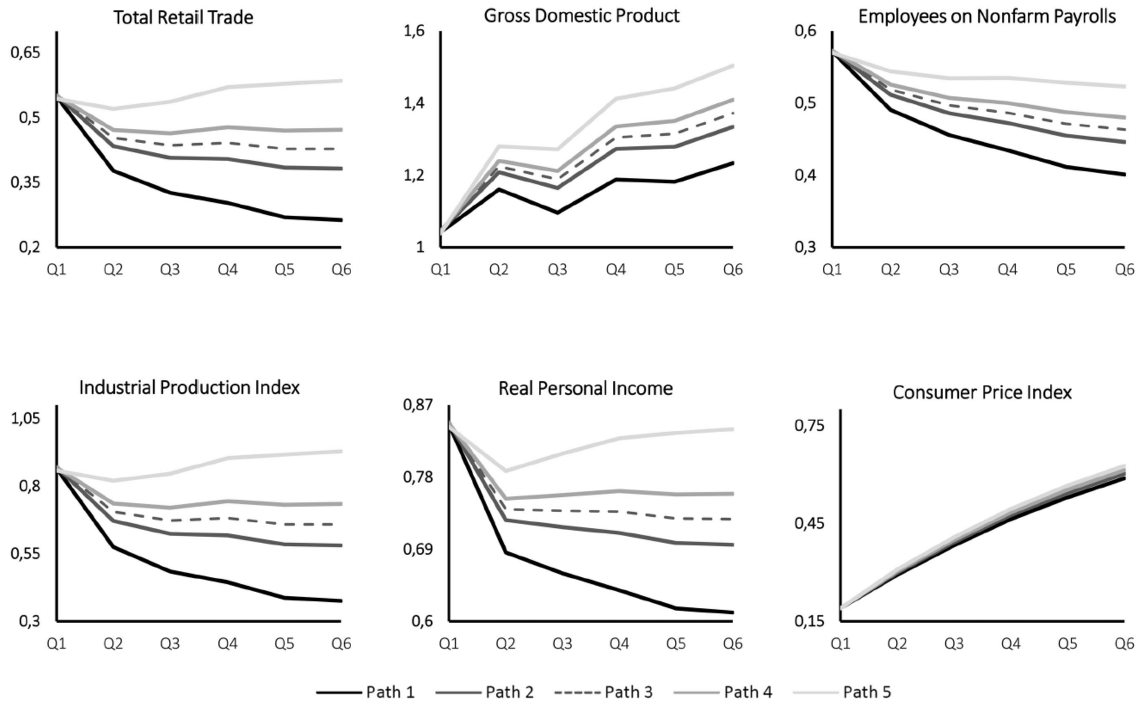

Figure 3. Forecasted quarterly rate of growth of Total Retail Trade, Gross Domestic Product, Employees on Nonfarm Payrolls, Industrial Production Index, Real Personal Income and Consumer Price Index under different monetary policy paths.