# The Taylor Curve: International Evidence

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## Abstract

We use the Taylor curve to gauge deviations of monetary policy from an efficiency locus for the United Kingdom (UK) and the four largest economies of the eurozone (Germany, France, Italy, Spain) for the period 2000-2018. For this purpose, we use shadow interest rates, which is a common metric for both conventional and unconventional monetary policies, and the newly proposed Hamilton-filter to measure output gap, which improves upon the drawbacks of the traditionally used Hodrick-Prescott filter. Our findings suggest that deviations in the UK mostly occurred amid the global financial crisis and the post-Brexit period, whereas eurozone members experienced more volatile deviations around 2001, during the global financial crisis and the eurozone sovereign debt crisis.

**Keywords:** Taylor curve, Monetary policy, eurozone
**JEL Codes:** E31, E58, C32

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## 1. Introduction

The efficacy of monetary policy implementation by central banks and its effect on the economy have received considerable interest in the macroeconomics literature. As part of this literature, a myriad of authors who analyzed the recent monetary policy experience of the US, the United Kingdom (UK) and the eurozone conclude that the substantial decrease in inflation levels and volatilities after the 1990's was – among other factors - due to effective monetary policy conduct[1]. While inflation rates remained low throughout the 2000 decade in these economies, the post-2008 period brought new challenges for central banks. Faced with the zero-lower bound for nominal interest rates and a threat of deflation, central banks of most advanced economies engaged in unconventional policies. Most authors find that these policies had desirable effects, but an important question remains to be answered regarding the appropriateness of these policies and the extent to which they deviated from an optimal policy mix. One of the models that allows one to tackle this question is the Taylor curve, which relates second moments of output and inflation and was introduced by Taylor (1979). As Friedman (2010) argues, this second order Phillips curve can be thought of as an efficiency locus through which one can gauge the appropriateness of monetary policy.

Previous works that used the Taylor curve to analyze the efficacy of monetary policy include Olson & Enders (2012) who analyzed the case of the US, and Olson & Wohar (2016) who analyzed the case of the euro area and a set of European countries. While our methodology follows Taylor (1979) and is similar to the aforementioned works, our empirical strategy departs from these studies: we analyze the time period 2000-2018, i.e. the interval that encompasses the Great Recession and resulted in the zero-lower bound for most advanced economies. Correspondingly, we make use of the shadow interest rate measure of Wu & Xia

[1] For authors who attribute the decline in inflation levels and volatilities to changes in the conduct of monetary policy, see among others Gali and Gambetti (2009) for the US, Batini & Nelson (2005) for the UK and Avouyi-Dovi and Sahuc (2016) for the euro area.

(2016) to capture the stance of central banks when nominal interest rates are constrained by the zero lower bound. Another dimension in which our work departs from previous studies is the filtering methodology that we use in order to get a measure of the output gap. In all the above cited studies, the authors use the widely used Hodrick-Prescott (HP) filter (Hodrick & Prescott, 1997). However, Hamilton (2018) argues that the HP filter produces spurious cycles, exhibits an end-of-sample bias with filtered values at the end of the sample being very different from values in the middle, and that suggested values of the smoothing parameter lambda are not appropriate for the filtering procedure. He suggests an alternative filter that one can obtain by regressing a variable at date $t+h$ on its most recent four observations that remedies these shortcomings. In analyzing monetary policy efficacy, we utilize both filters and contrast them. We implement our estimation for five large European countries: UK, France, Germany, Italy and Spain.

First, our results indicate that the filtering methodology selected for the output gap produces significant differences in our monetary policy efficacy measures. Using the Hamilton filer, we find that – with the notable exception of France - our monetary policy efficacy measures are significantly higher in the period *after* the Great Recession in comparison to the period preceding it. We deduce from these results that while most studies establish that the results of unconventional policies implemented by central banks had a desirable effect on distressed markets, they were not necessarily optimal. The paper is organized as follows: section 2 provides an overview of model, section 3 introduces the estimation strategy and data, section 4 the results and finally, section 5 concludes.

## 2. Methodology

To construct a measure for monetary policy efficacy, we first introduce the theoretical foundation of the Taylor curve, then discuss the VAR setup that will be used to estimate the parameters necessary for the construction of the Taylor curve. We assume the central bank's primary goal is to stabilize inflation around its target and keep output at its potential level. As such, the quadratic loss function of the central bank is given as in Taylor (1979):

$$L = \lambda(\pi_t - \pi_t^*)^2 + (1-\lambda)(x_t - x_t^*)^2 \tag{1}$$

where $\pi_t$ is the inflation rate, $\pi_t^*$ is the targeted inflation rate, $x_t$ is output, $x_t^*$ is potential output and $\lambda$ ($0 \leq \lambda \leq 1$) is the parameter that represents the stance of the central bank towards inflation stabilization. The aim of policy makers is then to select an interest rate rule that minimizes the dynamic loss function in (1).[2]

We utilize a setup as in Cecchetti, Flores-Lagunes, and Krause (2006):

$$y_t = \sum_{i=1}^{n} \alpha_{1,i}\, y_{t-i} + \sum_{i=1}^{n} \beta_{1,i}\, \pi_{t-i} + \sum_{i=1}^{n} \phi_{1,i}\, i_{t-i} + \varepsilon_{1,t} \tag{2}$$

$$\pi_t = \sum_{i=1}^{n} \alpha_{2,i}\, y_{t-i} + \sum_{i=1}^{n} \beta_{2,i}\, \pi_{t-i} + \sum_{i=1}^{n} \phi_{2,i}\, i_{t-i} + \varepsilon_{2,t} \tag{3}$$

where (2) is an aggregate demand function with the output gap $y_t$ depending on its own lags, lags of the inflation rate $\pi_t$ and lags of the nominal interest rate $i_t$. Similarly, equation (3) represents a Phillips curve setup in which the inflation rate depends on lagged output gap, inflation and nominal interest rate terms. For the construction of Taylor curves, we follow the methodology as outlined in Taylor (1979) and Olson and Enders (2012) where the model that was introduced in (2) and (3) is expressed in the following state-space representation:

$$\mathbf{Y_t} = \mathbf{B}\,\mathbf{Y_{t-1}} + \mathbf{c}\,\mathbf{i_{t-1}} + \mathbf{v_t} \tag{4}$$

[2] See e.g. Woodford (2003) for a derivation of this.

with

$$\mathbf{Y_t} = \begin{bmatrix} y_t \\ \vdots \\ y_{y-n} \\ \pi_t \\ \vdots \\ \pi_{t-n} \\ i_{t-1} \end{bmatrix} \mathbf{B} = \begin{bmatrix} \alpha_{11} & \cdots & \alpha_{1n} & \beta_{11} & \cdots & \beta_{1n} & \emptyset_{12} \\ 1 & 0 & \cdots & \cdots & \cdots & \cdots & 0 \\ 0 & \ddots & \cdots & \cdots & \cdots & \cdots & 0 \\ \alpha_{2n} & \cdots & \alpha_{2n} & \beta_{21} & \cdots & \beta_{2n} & \emptyset_{22} \\ 0 & \cdots & \cdots & \ddots & \cdots & \cdots & 0 \\ 0 & \cdots & \cdots & \cdots & \ddots & \cdots & 0 \\ 0 & \cdots & \cdots & \cdots & \cdots & 1 & 0 \end{bmatrix} \mathbf{C} = \begin{bmatrix} \emptyset_{11} \\ 0 \\ \vdots \\ \emptyset_{22} \\ 0 \\ \vdots \\ 1 \end{bmatrix} \mathbf{V} = \begin{bmatrix} \varepsilon_{1t} \\ 0 \\ \vdots \\ \varepsilon_{2t} \\ 0 \\ \vdots \\ 0 \end{bmatrix} \tag{5}$$

The loss function in (1) is also rewritten as:

$$\mathbf{Y_t' \Lambda Y_t} \tag{6}$$

where $\Lambda$ is an $n \times n$ weighting matrix with $\lambda$ as the first diagonal element, (1- $\lambda$) as the $n^{th}$ diagonal element and the remaining elements equal to zero. Correspondingly, it is the central bank's objective to choose the interest rate path that minimizes the loss function in (6) subject to (4) as the constraint. Given (6), the solution for the interest rate $i_t$ is given as:

$$\mathbf{i_t} = \mathbf{g}\, \mathbf{Y}_{t-1}. \tag{7}$$

Using optimal control techniques, the control vector **g** is given by:

$$\mathbf{g} = -(\mathbf{c'Hc})^{-1}\mathbf{c'HB} \tag{8}$$

with H representing the solution of the equations

$$\mathbf{H} = \mathbf{\Lambda} + (\mathbf{B} + \mathbf{cg})'\mathbf{H}(\mathbf{B} + \mathbf{cg}). \tag{9}$$

Finally, with a set of feedback coefficients, $\mathbf{g}$ is expressed by (7), and the steady-state covariance matrix of $\mathbf{Y_t}$ is given by $\mathbf{\Sigma}$:

$$\mathbf{\Sigma} = \Omega + (\mathbf{B} + \mathbf{cg})'\mathbf{\Sigma}(\mathbf{B} + \mathbf{cg}). \tag{10}$$

where $\mathbf{\Omega}$ is the covariance matrix of the residuals in $\mathbf{v_t}$ and the first and $n^{\text{th}}$ diagonal elements of $\mathbf{\Sigma}$ contain the steady-state variances. While one can determine a single point of the Taylor curve using a particular $\lambda$, varying $\lambda$ over the interval [0,1] with steady state variances in $\mathbf{\Sigma}$ results in the entire Taylor curve.

## 3. Estimation and data

We estimate the VAR setup in (2) and (3) with 120-month rolling windows, where *n*, the lag length for each VAR, was selected using the general-to-specific methodology. The Taylor curve was then derived for an estimated VAR by implementing the procedure outlined previously, allowing *n* to change for each rolling window for each country that we consider.

To construct a relative distance measure that captures monetary policy efficacy while accounting for shifts in the Taylor curve, the minimum distance at which a country operated from its Taylor curve for a specific 120 month window was calculated, then divided by the minimum distance that the Taylor curve was from the origin for the same 120 month window. We estimate the Taylor curve for Great Britain, Germany, France, Italy and Spain using monthly data spanning January 1991- December 2018. Because we use a 120 month rolling window and our first sample encompasses the period 1991-2000, our Taylor curve estimates start in 2001. Consumer Price Index and industrial production series from the OECD main economic indicators database were used to calculate the inflation rate and output gap measures respectively. Further, while for the UK the shadow interest rate measure of Wu & Xia (2016) was used for the entire period, for the remaining countries, the Eonia (Euro overnight index average) was used for the pre-2004 period and the shadow rate of Wu & Xia (2016) was used for the 2004-2018 period. Note that, the interest rate variable, is the estimated shadow rates derived from a three-factor shadow rate term structure model (SRTSM).[3]

## 4. Results

Tables 1 and 2 display our monetary policy efficacy measures. From Tables 1 and 2 it is clearly visible that the two filtering methodologies produce drastically different distance averages in quantitative terms. Specifically, the distance results that we obtained using the Hamilton filter are higher for all economies with the exception of Italy. Another important result is that the measures obtained by both filters imply that in the period after the financial crisis monetary policy efficacy deteriorated and distances increased for all countries (except for France). Below, we further discuss the distance measures that we obtained using the Hamilton filter for the five economies we have considered.

Table 1 – Distance measures obtained using the Hamilton Filter

| | UK | Germany | France | Italy | Spain |
|---|---|---|---|---|---|
| Distance – Full Period | 0.75 | 1.20 | 0.95 | 1.81 | 1.92 |
| Distance – Pre-2008 | 0.38 | 1.10 | 1.28 | 1.08 | 1.56 |
| Distance – Post-2008 | 1.00 | 1.27 | 0.74 | 2.29 | 2.13 |

Table 2 – Distance measures obtained using the HP Filter

| | UK | Germany | France | Italy | Spain |
|---|---|---|---|---|---|
| Distance – Full Period | 0.42 | 0.97 | 0.45 | 1.82 | 1.21 |
| Distance – Pre-2008 | 0.25 | 0.36 | 0.25 | 0.67 | 1.06 |
| Distance – Post-2008 | 0.52 | 1.37 | 0.58 | 2.57 | 1.31 |

[3] The data is available for download from the website of Professor Jing Cynthia Wu at: https://sites.google.com/view/jingcynthiawu/shadow-rates?authuser=0.

*4.1. Monetary policy efficacy*

***UK***

The recent monetary policy experience of the UK is shaped by the financial crisis of 2008 and the subsequent response of the Bank of England (BoE). In response to the financial crisis, the BoE did not initially engage in quantitative easing (QE) but took several measures such as the Special Liquidity Scheme (SLS) and Discount Window Facility after the collapse of Bear Stearns in April 2008. The stance of monetary policy however only changed significantly after 2008, when interest rates were decreased after the events of September 2008 and wide-ranging QE measures were introduced after March 2009 with the Asset Purchase Facility (APF) and the gilt purchase program (see Joyce et al., 2011 for an account of the measures taken by the BoE after 2008).

Corresponding to these developments, our estimates (Figure 1a) imply that the use of both filters delivers very similar Taylor curve distance estimates with two exceptions: 1) in the 2007-2009 period, the use of the HP filter does not generate any significant deviation of the Taylor curve for the period. In contrast to this, use of the Hamilton filter results in a very significant spike, suggesting that monetary policy deviated from its optimum during the Great Recession. However, this deviation is short lasted and the distance to the Taylor curve reverts back to the pre financial crisis period. 2) The distance measure that we obtain using the Hamilton filter increases once more after 2017 while using the HP filter doesn't result in a discernible change. These results are in line with the recent monetary policy experience of the UK. Notably, the benchmark interest rate was raised by the Bank of England until July 2007 and remained high until the collapse of Lehman Brothers in September 2008, while the output gap (obtained with the Hamilton filter) shows a significant drop after February 2008. Likely due to this mismatch, there is a significant increase in the distance measure during the period March 2008-September 2008. Prior to the slight increase of the distance measure at the end of

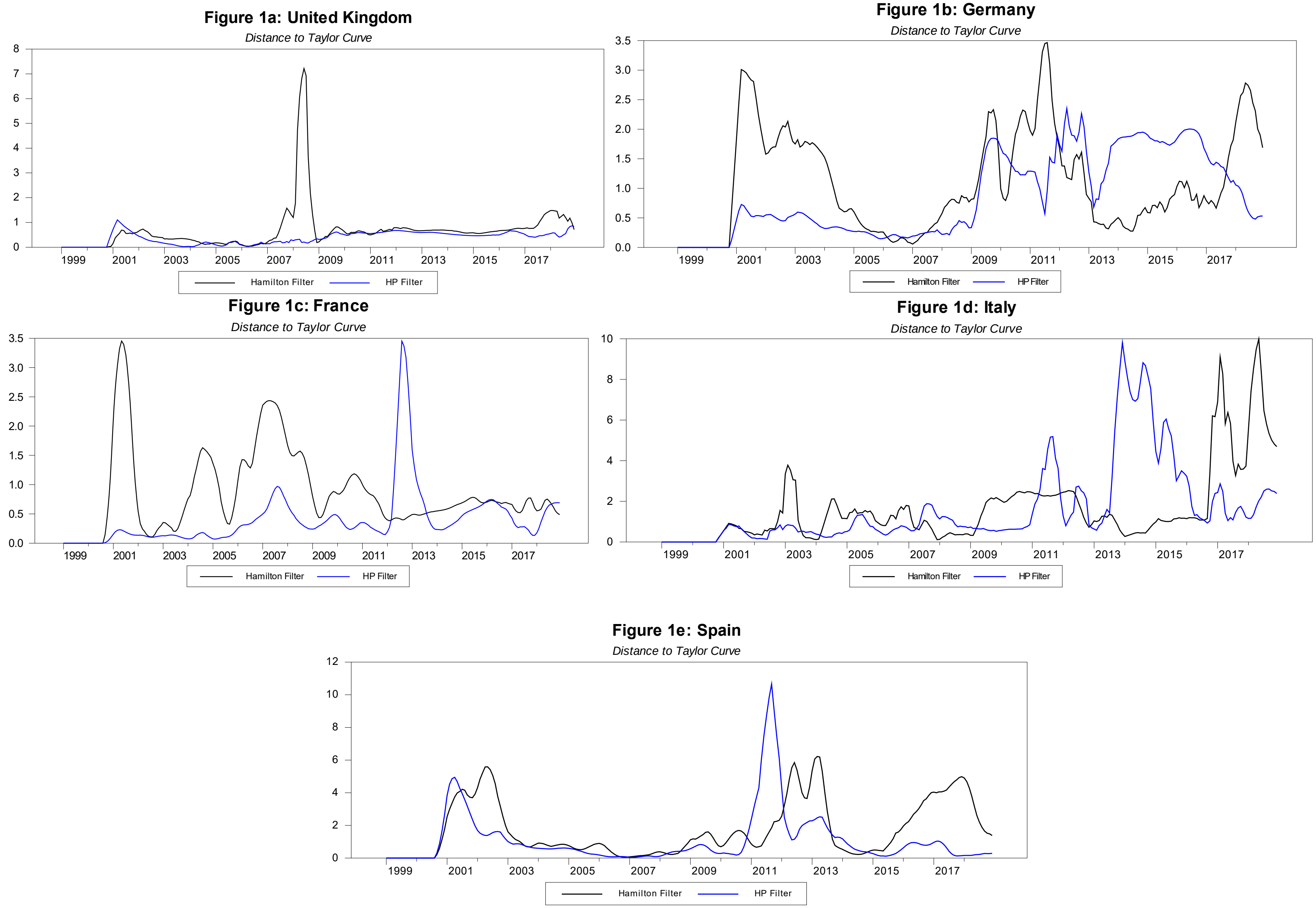


Figure 1. Distance to Taylor Curve

2017, events such as the Brexit vote and a decision by the BoE to raise interest rates occurred while the output gap measure implied that the economy operated above its potential level.

### ***ECB policies***

The ECB started its operations in 1999, having been established with the aim to conduct monetary policy for all Eurozone members. While in its first few years the ECB conducted its operations in relative peace, it faced significant challenges in later years, especially with the onset of the financial crisis in 2008 and eurozone sovereign debt crisis after 2010. The primary response of the ECB to the 2008 crisis, to lower interest rates, was quickly faced with the zero lower bound (ZLB) by the end of 2009. In response to reaching the ZLB, the ECB implemented several unconventional measures and quantitative easing policies that were similar to the measures taken by the Federal Reserve. Of these, the most relevant programs included the "Securities Markets Programme" (SMP) I and II of 2011, "Outright Monetary Transactions" (OMT) of 2012 and the "Asset Purchase Programme" (APP) of 2015 (see e.g. Fratzscher et al., 2016 for a description of unconventional policies that the ECB implemented after 2008). As summarized in Dell'Ariccia et al. (2018), studies that analyze the effect of unconventional policies implemented by the ECB on Eurozone members mostly find that the measures positively affected bond yields, output growth and prices. Despite these results, some of the policies may have been inappropriate for individual members as a consequence of the fact that the ECB conducts policy for the Eurozone as a whole and not for the needs of individual members as argued in Moons and Van Poeck (2008). In the following, we will describe our results for a set of Eurozone countries and analyze how policy may have deviated from its optimum for these countries.

***Germany***

The distance estimates for Germany differ significantly with the use of the two filters (Figure 1b): according to the HP filter, there is significant deviation of monetary policy from its optimum after the Great Recession, and another increase after 2013. In contrast, the Hamilton filter shows a significant spike after 2001, which gradually decreases until the Great Recession. During this period, the output gap increased and remained high until the first months of 2008 while interest rates remained steadily high. With the onset of the Great Recession, there was a sharp drop in the output gap while the interest rate decreased gradually. During this time, the distance increases significantly and remains high until the end of 2012. This is the time when the ECB implemented many of the unconventional quantitative easing measures to combat the effects of the eurozone sovereign debt crisis that engulfed countries such as Greece, Spain, Portugal and Ireland. Finally, the distance increases once more after June 2017 when the output gap increases significantly, while the shadow interest rate goes further into negative territory.

***France***

For France, our results suggest once more that the two filters produce very different Taylor curves (Figure 1c). The distance to the Taylor curve that is based on the HP filter increases in 2007 and in 2012 while remaining relatively low during the remaining periods. In contrast to this, the magnitude of the distance measure that is based on the Hamilton filter is higher on average and increases during several periods. In 2001, the distance is at its highest level and coincides with a high output gap and decreasing interest rates. In 2004, the distance reaches elevated levels when output gap fluctuated, and the shadow interest rate remained relatively high. Similarly, the distance increases and remains relatively high between 2006-2009 when interest rates remain on an increasing trend while the output gap fluctuates between the 2-5% band. Finally, the distance increases only slightly after the outbreak of the financial crisis but remains low for the remaining observation period. It is interesting to see that the distance measure for France is lower on average in comparison to the distance measures of other Eurozone economies under consideration and doesn't exhibit significantly elevated levels during the aftermath of the financial crisis or the eurozone crisis. This may indicate that the measures taken by the ECB were in line with monetary policy requirements of the French economy.

***Italy***

In Italy's case, the two distance measures move in relative tandem until 2009, after which significant differences appear (Figure 1d): with the HP filter, the distance increases in 2011 and between 2013-2016, whereas with the Hamilton filter, distance to the Taylor curve remains high between 2009-2013 and after 2016. The first significant increase of the distance during 2009-2013 coincides with the aftermath of the financial crisis and with the eurozone crisis which engulfed Italian bond markets and increased the cost of lending through sovereign spread movements (Albertazzi et al., 2012). As outlined above, the ECB implemented a number of unconventional measures to combat the turmoil in financial markets and authors such as Casraghi et al. (2016) find that these measures had a significant and positive effect on Italy's economy in 2011-2012. During this period, the distance measure increases which is likely due to the output gap estimate becoming negative while the shadow interest rate increased periodically. Only after 2012, the interest rate decreases again, notably after the "Whatever it takes" speech by former ECB President Mario Draghi in July 2012 and details of the Outright Monetary Purchase (OMT) measure were shared with the public in September 2012. Similarly, the drastic increase of the distance measure after October 2016 coincides with the first significant increase of the output gap after 2008 while the shadow interest rate decreased further into negative territory. It is likely due to this mismatch that the distance measure reaches its highest level during our estimation period.

***Spain***

The two distance measures for Spain also move in relative tandem until 2011 (Figure 1d). After this period, use of the HP filter produces a significant increase in the distance between mid-2010 to mid 2012, whereas with the use of the Hamilton filter, the distance increases for the periods 2001-2003, 2011-2013 and 2015-2018. During the first spike of 2001-2003, Spain was in the course of implementing a series of stability measures to comply with fiscal policy requirements set by the EU. While these policies proved successful[4] and the output gap was relatively high, the ECB policy rate was continuously decreased during this time. Interestingly, the distance measure remained relatively low during the financial crisis, but increased substantially after 2011 when the eurozone crisis encompassed Spain and other member economies. The crisis affected Spain significantly when bond premiums reached high levels in mid-2012 and the output gap decreased. At the same time, the interest rate was decreased until mid-2012 but then slightly increased until the end of 2013, likely causing the mismatch that lead to an increase in the distance measure. As referred to above, the ECB implemented a myriad of unconventional measures to support financial markets in the eurozone area, causing (shadow) interest rates to go further into the negative territory after 2013. Of these, the most significant announcement was the large asset purchasing program after 2015. Against this background, countries such as Spain recovered from the effects of the eurozone crisis and recorded falling bond premiums and positive output gaps after 2015. During this time, the distance measure increases once more and remains high until the end of 2018.

*4.2. Discussion*

A number of studies analyzed the optimality of monetary policy using policy rules or DSGE models and established that while central banks' aggressive stance towards inflation lowered inflation rates after the 1980's in most advanced economies, they were not necessarily

[4] See for example OECD Economic Surveys: Spain 2001.

optimal. For example, Chen & Macdonald (2012) show that monetary policy in the UK was suboptimal in comparison to an optimized policy rule. Similarly, Benigno & López-Salido (2006) show that over the period 1970-1997 monetary policy in a set of euro area economies was not always optimal in terms of welfare considerations.

Our results are mostly supportive of the view presented in these works that monetary policy underwent periods that deviated from an efficiency locus. But while these works don't necessarily inform the reader about the degree to which policy deviated from the optimum over time, our results give us an insight into the timing and severity of deviations from the optimum. Specifically, we find that for most of the eurozone member countries we consider (Germany, France, Spain) there is a significant deviation from the optimum at around 2001. This is likely due to the fact that in the first few years after the eurozone was established, inflation differentials were especially wide among member economies (see e.g. Lane, 2006 for this point). While inflation rates converged in subsequent years, the post-2008 period that included the global financial crisis and the eurozone criss associated with sovereign debt affected all countries to various extents. Not surprisingly, the 2008-2012 and the post-2015 periods are shaped by significant deviations from the efficiency locus for these economies, implying that the policies that the ECB implemented were not optimal. As a notable exception, our results indicate that monetary policy in France deviated from the optimum around 2001 and during the period 2004-2009, while staying close to the optimum after 2011. The most likely explanation is that France's output gap was the least volatile among the eurozone members that we consider, and its inflation volatility was the second lowest (after Germany).

These results are in line with recent evidence regarding the appropriateness of the single monetary policy regime of the ECB for individual member economies. For example, Fries et al. (2018) find that the effect of the regime was almost neutral for France in the post global financial crisis period while for Spain, it was too accommodative in the first half of the 2000 decade and too restrictive during the crisis years of 2011-2013. Finally, UK stands out in our analysis as the economy with the lowest overall distance to the efficiency locus. This is likely a reflection of the fact that the UK is not a member of the eurozone and was able to implement more targeted monetary policy measures in response to movements in the output gap and inflation rates.

## 5. Conclusion

In this work, we analyzed monetary policy efficacy for the UK and four largest economies of the eurozone using the Taylor curve for the period 2000-2018. While our approach is not novel, our empirical implementation makes use of shadow interest rates and a new output gap measure, both of which were developed recently. Our findings suggest that UK's monetary policy deviated significantly around during the global financial crisis but remains close to the efficiency locus for the remaining period. In contrast to this, with the exception of France, whose deviations from the efficiency locus remain relatively low, eurozone members' monetary policy deviated significantly around 2001, during the global financial crisis and during the eurozone crisis. The implications of our results are manifold. We find that the ECB's single policy regime likely resulted in deviations of individual members' policies from an efficiency locus, supporting previous studies (e.g. Fries et al., 2018) while the UK experienced deviations only for a brief period. This highlights the difficulties of conducting monetary policy for economies with differing output gaps and inflation differentials and calls for coordinated policies by individual member countries to complement the policies of the ECB. Our results also have implications on the methodological choice: previous studies such as Olson & Wohar (2016) used overnight rates and the HP Filter to gauge the efficacy of monetary policy using the Taylor curve. Because our sample encompasses the post-2008 period, we used the shadow rate of Wu & Xia (2016) for the stance of monetary policy and used the Hamilton Filter

(2018) to model the output gap. We believe that our results provide a more nuanced picture of events and highlight the relevance of using appropriate measures for modeling the stance and appropriateness of monetary policy.

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## Appendix

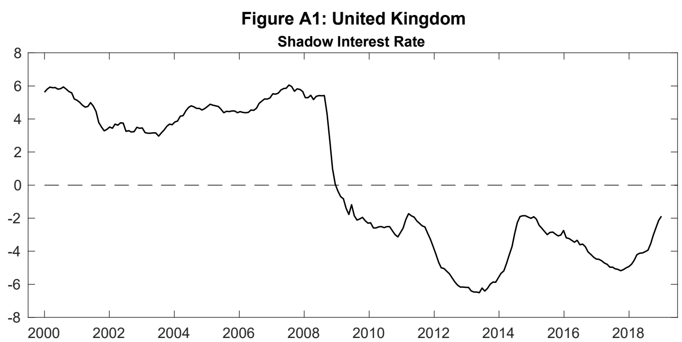
Figure A1: United Kingdom
Shadow Interest Rate
8
6
4
2
0
-2
-4
-6
-8
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018

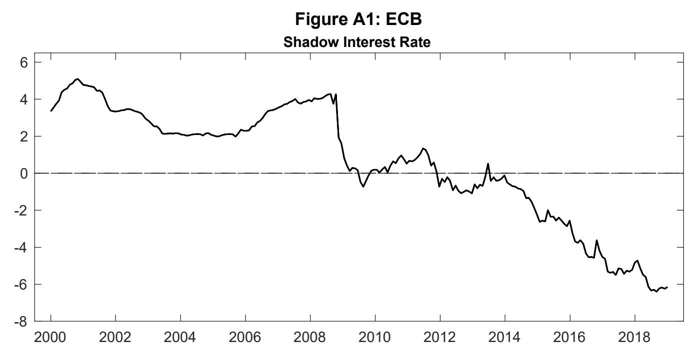
Figure A1: ECB
Shadow Interest Rate
6
4
2
0
-2
-4
-6
-8
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018

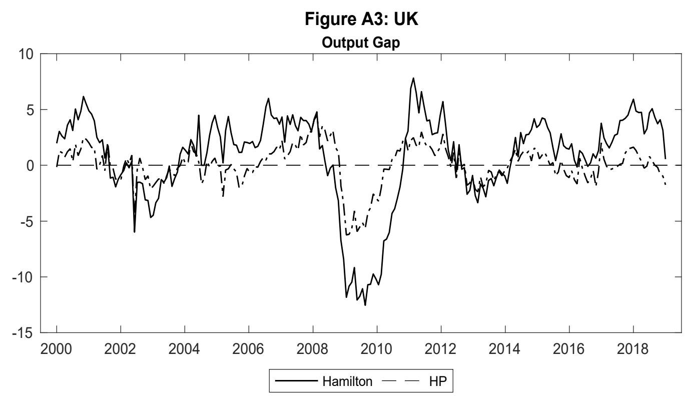
Figure A3: UK
Output Gap
10
5
0
-5
-10
-15
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Hamilton
HP

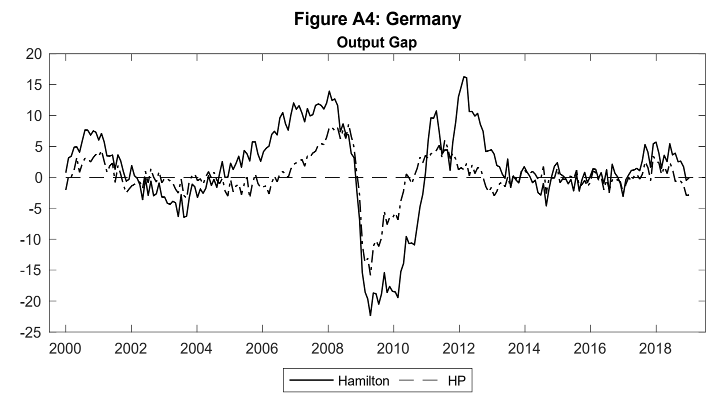
Figure A4: Germany
Output Gap
20
15
10
5
0
-5
-10
-15
-20
-25
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Hamilton
HP

**Figure A5: France**

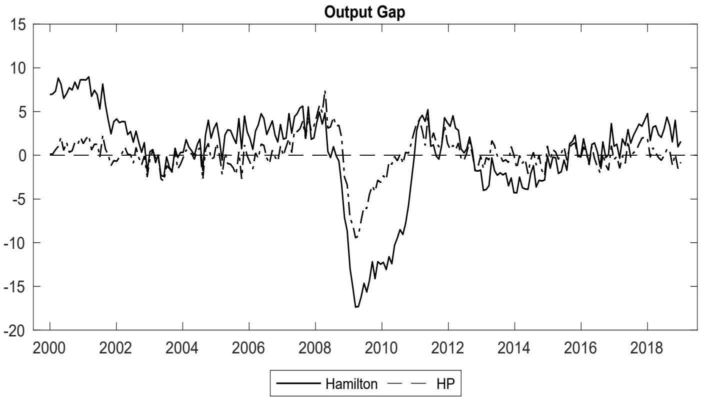


**Figure A6: Italy**

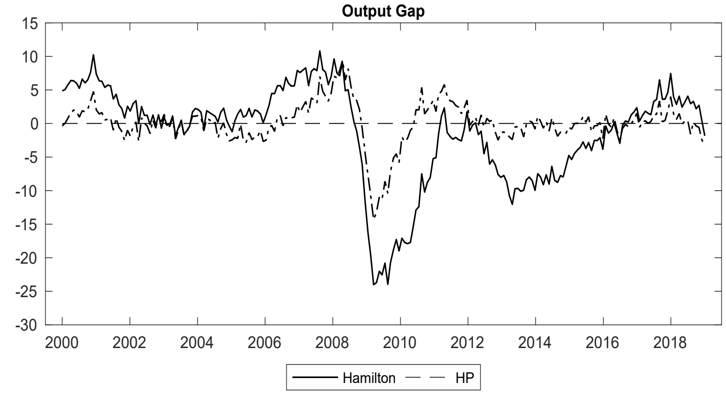


**Figure A7: Spain**