The Taylor Rule & Discretionary Policies Following the Great Recession

An Examination of Policy Outcomes in Two Advanced Economies

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Contents

1 Abstract

The Taylor rule has been the subject of extensive analysis as a guideline for setting monetary policy since it was first proposed by economist John B. Taylor in 1993. In the aftermath of the Global Financial Crisis and atypical macroeconomic events of the Great Recession in 2007-2009, monetary policy has adapted unconventional approaches to targeting interest rates and ensuring price stability through programs of quantitative easing. This analysis investigates whether the Taylor rule has continued to serve as a relevant guideline for policymakers in the United States and in the United Kingdom by examining the period from 2008-2015 and comparing interest rates prescribed by the Taylor rule to the typical overnight interbank lending rates and atypical shadow interbank rates that become relevant when an economys policy rates approach the zero lower bound and enter into a liquidity trap.

Using these shadow policy rates as a measure of target interest rates, this investigation finds a monetary policy rule more accommodating to the output gap to be more descriptive of policy in these two countries throughout the period of 1990-2015, while also finding the impact of their quantitative easing programs to be varied. Real GDP per capita during the period of 2009-2011 suggests that fiscal tightening or the delay of quantitative easing around 2010 in the United Kingdom was likely harmful to the economy's recovery, with an increase in prescribed interest rates by policy rules and a spike in inflation and shadow interbank rates. In the United States, as shadow policy rates remained below the zero lower bound throughout this period, quantitative easing seems to have had more success. While mostly ambiguous, the sub-optimal economic outcomes following fiscal tightening in the United Kingdom very weakly suggest that the discretionary fiscal stimulus undertaken in the U.S. in 2009 had a positive impact on the economy's performance.

2 Introduction

2.1 Motivation

The Great Recession in the U.S. and the ensuing economic downturn abroad has had a distinctive impact on macroeconomic prosperity in advanced economies. Since 2008-2009, interest rates have been persistently low and in close proximity to the zero lower bound, while output growth has remained slow. (Figure 1). Prior to the recession, macroeconomics was primarily concerned with the use of monetary policy to reduce small amplitude fluctuations of economic variables from a given trend while also maintaining price stability through feedback rules and empirical optimization of these feedback rules. [1] At present, in the aftermath of the recession, policymakers long for the problem of minimizing fluctuations around a satisfactory trend as long-term growth continues to appear dismal. Moreover, since the recession, there has been reasonable doubt cast on whether "the [business] cycle actually cycles" (Summers 2014), and what countries can do to escape this period of slow growth and interest rates near the zero lower bound.

In light of these recent macroeconomic trends, assessing the efficacy of expansionary policies by central banks and elected government to the recession will help these countries evaluate the credibility of macroeconomic policy rules. The Taylor rule is one of these long-established theoretical frameworks that historically proved to be a pivotal rule-of-thumb for policymakers in central banks deliberating on monetary policy.In terms of monetary policy, when it comes to stimulating the economy, the conventional monetary policy instrument is the overnight interest rate or interbank lending rate. A model which prescribes interest rates based on deviations in targeted inflation and the output gap, the Taylor rule is typically used as a guideline to assist policymakers in deliberating on the target interest rate. In scenarios such as in the United States and the United Kingdom in the fourth quarter of 2008, when the nominal interest rate approaches the zero lower bound, this conventional means of monetary policy becomes ineffective as economies enter into what has come to be called the liquidity trap, as specified in Krugman, Dominquez, and Rogoff 1998. When in a liquidity trap, a central bank's injections of reserves into the commercial banking system fail to decrease interest rates, hence conventional monetary policy loses its effectiveness. Since the end of 2008, in response to this liquidity trap, institutions such as the Federal Reserve and the Bank of England have pursued unconventional means of monetary policy through waves of quantitative easing.

Quantitative easing in these two countries has been similar in nature. Blinder (2010) outlines the policy goals and motivation of the unconventional monetary policy of quantitative easing. In practice, quantitative easing involves the change in composition and size of the central banks balance sheet in an effort to ease

[1] This claim references the secular stagnation hypothesis as outlined by Lawrence Summers. See the reference for Summers (2014).

liquidity and credit conditions. A basic premise of this policy is that if real interest rates rather than nominal interest rates are what really influences an economy, where the real interest rate is approximated as $r_t = i_t - \pi_t$, then at the zero lower bound, we end up with a real interest rate of $-\pi_t$, which implies that in times of deflation as might be experienced in a severe economic downturn, the real interest rate could still be positive. In this manner, conventional monetary policy can no longer respond to changes inflation, which could invite deflationary implosion. By means of quantitative easing, the central bank can attempt to reduce interest rate spreads such as term premiums and risk premiums, which might then in turn function to flatten the yield curve. This reduction of interest rate spreads occurs when the central bank uses open market purchases to attain long-term government securities instead of the usual shorter-term securities, or when it purchases private debt instruments such as mortgage-backed securities and other riskier assets, which then reduces their spread over relatively riskless government treasury securities. The former of these two methods aims to reduce the spread in term premiums, while the latter aims to reduce risk premiums.

In the U.S., the first phase of quantitative easing (QE1) occurred in early 2008 when the Federal Reserve began selling its holdings of Treasury bonds in return for less-liquid assets, which resulted in a change in composition of the central banks balance sheet. This initial phase sought to reduce risk premiums, however, financial institutions continued to deteriorate. In the next part of this initial phase, the U.S. Treasury began borrowing ahead of time, depositing these funds in the Federal Reserve in anticipation of asset purchases. This operation was largely fiscal, and it was also the first time fiscal and monetary policies intersected. (Blinder 2010). By the end of 2008, the U.S. had begun its large-scale asset program, and by the end of the first quarter of 2009 it held nearly $2 trillion of bank debt, mortgage backed securities, and long-term government securities, later peaking at $2.1 trillion in June of 2010. By November 2010, the Federal Reserve began the second phase of quantitative easing (QE2), purchasing another $600 billion worth of long-term government treasury notes, which continued until June 2011. In the third and final phase of quantitative easing (QE3) in the U.S., the Federal Reserve underwent an $85 billion per month purchasing program of mortgage-backed securities, while also vowing to keep the federal funds rate near zero through 2015. The asset purchase program finally came to a close in the third quarter of 2014.

In the U.K., the Bank of England also began a program of quantitative easing from March 2009 until January 2010, purchasing £200 worth of assets composed largely of long and medium-term government securities and some higher quality private sector securities. Later, in October 2011, the Bank of England announced another round of quantitative easing, conducting a further £125 billion of asset purchases between October 2011 and May 2012, and another £50 billion by the end of 2012 for total of £375 billion. Along with other initial liquidity support measures to the banking sector, such as was conducted in the U.S., this program tripled the Bank of Englands balance sheet relative to GDP. (Joyce, Tong, and Woods 2011).

The similarities in monetary policy in the U.K. and U.S., both conventional and unconventional, makes the comparison of these two countries quite compelling given their dissimilar fiscal responses to the Great Recession. In the United States, the American Reinvestment and Recovery Act (ARRA) of 2009 provided an expansionary fiscal policy, with an estimated fiscal multiplier of an additional 0.5 to 2.5 percentage points to GDP between 2009-2012, with the peak effect occurring in the second quarter of 2010.(Economic Advisors 2014) To contrast, in the United Kingdom, government spending was slashed and tax rates increased in 2009-2011 upon the departure of the Labour Party from the central government in 2010. This fiscal austerity arose as the United Kingdom began to implement its Government Deficit Reduction Programme, for which "...the June 2010 budget laid out a 5-year adjustment plan that would cut the deficit to 1 percent of GDP by FY15/16..." (Fund 2011). Additionally, the same IMF Country Report from 2011 found that while the "Economic recovery was strong for most of 2010...[growth] slowed in recent quarters...growth turned flat in late 2010/early 2011 This slowdown partly reflects intensifying fiscal consolidation..."

As evident in Table 1, a comparison of the composition of GDP in these two economies suggests that they are well-suited for comparison. While dissimilar in size and scale, and with a much more open economy in the U.K., as apparent in the larger proportion of imports and exports, these limitations are trivial enough that analyzing the contrasting policy outcomes in these two economies could provide insight into what fiscal or monetary policy responses were particularly effective in mitigating the economic downturn of the Great Recession.

2.2 Research Question

In light of fixed policy rates near the zero lower bound and programs of quantitative easing undertaken in these two countries, the Taylor rule framework has become somewhat silent as mechanical policy guideline for policymakers. This investigation aims to examine the potential obsolescence of the Taylor rule in these countries during the period of quantitative easing, using interbank shadow policy rates as a proxy measure of the effect quantitative easing had on risk premiums and term premiums. This analysis will examine and utilize the framework of the Taylor rule to determine the efficacy of these advanced economies policy responses to the recession. Additionally, using simple regression techniques with the shadow policy rate as a proxy measure for quantitative easing, this analysis will attempt to isolate the impact of quantitative easing in these economies. By comparing the results to similar empirical work conducted by Taylor (1999), these outcomes will hopefully suggest which simple monetary policy rule has been most relevant to policymakers in recent years.

In addition to assessing the impact of monetary policy, due to the disparate fiscal responses, the analysis

will also attempt to comment on whether these fiscal responses were appropriate given interest rates, inflation, and real GDP growth over this period.

3 Foundations and Development

3.1 Theoretical Framework

The underlying theory surrounding the Taylor rule was established in Taylor (1993), where output and inflation levels are taken as inputs in the policy rule to prescribe a target interest rate, in particular, the interbank overnight lending rates, to be set by a country's central bank:

$$f_t = r_t^* + \pi_t + \beta_1(\pi_t - \pi_t^*) + \beta_2(y_t - \bar{y}_t), \qquad \beta_1 = \frac{1}{2}, \quad \beta_2 = \frac{1}{2},$$

f_t = the prescribed federal funds rate/overnight interbank lending rate
r_t^* = the desired real interest rate
π_t = the actual rate of inflation, lagged
π_t^* = the targeted rate of inflation
y_t = real gross domestic product (GDP)
$\bar{y}_t$ = real potential gross domestic product (GDP)

In this framework, the original Taylor rule relies on a generous number of assumptions about the economy. It assumes that it is preferable for banks to set interest rates based on price level and real output, where the interbank overnight lending rates rise if inflation increases above a target rate or if real GDP rises above trend GDP. Based on these assumptions, if both inflation and real GDP approach their target rate or trend, the interbank rate will approach the targeted real interest rate and inflation rate in real terms. Moreover, since these decisions for setting interest rates must be made ex ante, Taylor's original equation uses lagged inflation rate over previous four quarters as a proxy measure for expected inflation. In the original policy rule outlined in Taylor (1993), the targeted real interest rate and inflation rate are both 2%, which is due to the fact that the 2% equilibrium real rate is close to the assumed steady state growth rate of 2.2% in the United States. Additionally, this policy rule is assumed to have the same coefficient on deviation of real GDP from trend as the coefficient on deviation in the inflation rate from a target.

In Taylor (1999), John Taylor assesses the robustness of five policy rules, which are evaluated based on their differing macroeconomic outcomes. In a departure from Taylor (1993), Taylor advocates for these rules as guidelines comprising a general monetary theory versus a tightly specified model, and iterating that

policymakers ought to consult a portfolio of rules. In this portfolio of policy rules, Taylor specifies that the policy rule III and policy rule IV evaluated in his paper should be included in this selection. Policy rule III [equation (1)] corresponds to the original rule from Taylor (1993),[2] while policy rule IV [equation (2)] proposed by Laurence Ball and John Williams advocates for a higher, more accommodating coefficient on the output gap:

$$f_t = (1 + \alpha_1)\pi_t + \alpha_2(y_t - \bar{y}_t), \qquad \alpha_1 = \frac{1}{2}, \quad \alpha_2 = \frac{1}{2}, \tag{1}$$

$$f_t = (1 + \beta_1)\pi_t + \beta_2(y_t - \bar{y}_t), \qquad \beta_1 = \frac{1}{2}, \quad \beta_2 = 1, \tag{2}$$

f_t = the prescribed overnight interbank lending rate
π_t = the actual rate of inflation
y_t = real gross domestic product (GDP)
$\bar{y}_t$ = real potential gross domestic product (GDP)

In his empirical research investigating the robustness of these particular rules, Taylor finds that the variability of real output is less with equation (2) than with equation (1), however, with equation (1), the variability of inflation and interest rates is then lower. Due to contrasting efficiencies of these equations with different macroeconomic variables, these particular equations are quite attractive for an analysis of the behavior of interbank policy rates following the Great Recession. For instance, if a central bank's policy goals are more oriented towards stability in prices and interest rates and less towards stability in real output, this would be a case for equation (1), while policy goals fixed on establishing stability in real output would suggest equation (2) as a guideline. As we do not have complete information on the beliefs and interests of the policymakers at the central bank, it is reasonable to consider both of these equations as they relate to specific guidelines for setting monetary policy. Since the proposal of these policy rules, central bank policymakers at the Bank of England in the U.K. and at the Federal Reserve in the U.S. have vocally expressed their consideration of both of these variants, as in Nikolov (2002), Nikolov confirms the use of both the simple and adapted policy rules of equation (1) and equation (2) at the Bank of England, while Bernanke (2010) also acknowledges use of these equations at the Federal Reserve.

Since monetary policy has been pursued by unconventional means since 2008 in these countries, it will be important to use a proxy measure for the effect of quantitative easing on interest rates during this period. For this analysis, the Wu-Xia shadow rate provides such a measure. When overnight interbank rates are above the zero lower bound, comparing the Taylor rule approximation for the prescribed interbank policy rate with

[2]Note that equation (1) is a reduced form equation of policy rule in Taylor (1993), where the intercept terms are omitted.

the actual effective federal funds rate provides insight into whether or not monetary policy adheres closely to a policy rule. In recent years with the quantitative easing programs, central banks such as the Bank of England and the Federal Reserve have sought other unconventional means of stimulating the economy that are silent in the simple policy rule prescribed by John Taylor. Comparing the Taylor rules prescribed policy rate to a shadow policy rate during this period of quantitative easing provides insight into whether the quantitative easing program was justified and whether it was impactful based on this framework. The Wu-Xia shadow policy rates are determined through an approximation technique that makes a nonlinear term structure model applicable to the analysis of an economy operating near the zero lower bound by modeling the dynamics of interest rates when the short end of the yield curve is stuck near zero. (Wu and Xia 2014). This approach is not without precedent, however, as it stems from a shadow rate model first proposed by Black (1995), which hypothesized the existence of a shadow short-term interest rate which could be negative. In these models, when the short-term interest rates are above the zero lower bound, the shadow rate is positive and coincides with this policy rate, however, when the shadow rate falls below the zero lower bound, an implied negative shadow rate is calculated as if it followed the usual dynamics of the term structure of interest rates. The Wu and Xia model utilizes the current behavior of the yields on government securities of multiple maturities, therefore if one of the aims of quantitative easing is to stimulate the economy by reducing the yields on these securities, the Wu-Xia shadow rate series can be used as a means of determining the impact of unconventional policy measures such as large-scale asset purchases and forward guidance.

3.2 Further Review of Literature

Previous publications have examined the performance of monetary policy rules such as the Taylor rule and whether they have helped to establish price stability and output growth. In an effort to determine whether the interest rates prescribed by the Taylor rule provided a justification for quantitative easing, an evaluation in Nikolsko-Rzhevskyy and Papell (2013) determined that if the Taylor rule were to prescribe negative interest rates once the federal funds rate hit the zero lower bound, there would have been a sound argument for quantitative easing. In their analysis of Federal Reserve policy following the recessions of the early-to-mid 1970s, the early 1990s, and the early 2000s with the original Taylor rule, they found that historical experiences justified the original Taylor rule, which did not prescribe negative interest rates, while variants of the Taylor rule with larger output gap coefficients do prescribe negative interest rates but are not justified by the same historical experience under which monetary policy regimes using Taylor rule have achieved price stability and economic growth.

Since his analysis in Taylor (1999), Taylor has taken a harder approach to "discretionary" monetary policies. In Taylor (2012), he outlines the advantages of monetary policy rule regimes over discretionary policy regimes, specifying that in the period from 1985-2003, adherence to monetary policy rule guidelines such as the simple rule outlined in Taylor (1993) ensures that policy instruments are predictable and there is considerably less uncertainty surrounding monetary policy. Meanwhile, the era of discretionary policy, which Taylor names as the "Ad Hoc Era" from 2003 onward, was rife with unusual and unorthodox monetary policy intervention, and unconventional policies such as quantitative easing that contributed to "monetary overhang" or an expansion of the U.S. Federal Reserves balance sheet. Taylor remarks that these policies often hardly constituted monetary policy, and more accurately resembled fiscal policy or credit allocation policy, which increased the likelihood of political interference and unpredictability. Taylor (2007) infers that lower interest rates than those prescribed in period from 2003-2005 were likely a contributing factor in the housing boom and risk-taking that led to foreclosures and the proliferation of toxic assets on the balance sheets of the financial sector during this period. Based on these findings, Taylor asserts that a more rules-based federal funds rate would have prevented most of this boom and bust. Supporting research by Kahn (2010) also found that deviations from policy rules correlate with housing bubbles.

4 Model Design

This model and respective analysis will serve as a response to the literature authored by John Taylor suggesting that quantitative easing and "discretionary" policies of this period are harmful to an economy. In order to evaluate the monetary policy responses to the Great Recession in the United States and United Kingdom, this investigation will estimate approximations of the Taylor rule originally proposed in Taylor (1993) [Equation (3)] with the policy rule compared with it in Taylor (1999) [Equation (4)] with a larger coefficient on the output gap. From this perspective, this aspect of the analysis will therefore allow for an assessment of whether equation (4), which is more accommodating to the output gap, is more descriptive of monetary policies since the crisis than equation (3), recalling the dissimilar efficiencies of these approximations as outlined in the theoretical framework.

Monetary policy rule from Taylor (1993):

$$f_t = r_t^* + \pi_t + \beta_1(\pi_t - \pi_t^*) + \beta_2(y_t - \bar{y}_t), \qquad \beta_1 = \frac{1}{2}, \quad \beta_2 = \frac{1}{2}, \tag{3}$$

Variant of Taylor (1993) monetary policy rule as considered in Taylor (1999):

$$f_t = r_t^* + \pi_t + \beta_1(\pi_t - \pi_t^*) + \beta_2(y_t - \bar{y}_t), \qquad \beta_1 = \frac{1}{2}, \quad \beta_2 = 1, \tag{4}$$

f_t = the prescribed overnight interbank lending rate
r_t^* = the desired real interest rate
π_t = the actual rate of inflation, lagged
π_t^* = the targeted rate of inflation
y_t = real gross domestic product (GDP)
$\bar{y}_t$ = real potential gross domestic product (GDP)

4.1 Analysis of Policies in the United States

In order to assess the monetary policy response of the U.S. Federal Reserve, the Taylor rule approximation from equations (3) and (4) will be estimated using the Federal Reserve inflation target of 2%, with a specified 2% real interest rate. For the input variables, inflation will be measured by averaging the percent change in price levels across the previous four quarters for the core personal consumption expenditures (PCE) deflator and GDP implicit deflator. The core PCE index is the preferred measure of inflation used by the Federal Reserve, so it is the most appropriate measure of inflation for assessing the monetary response of the Federal

Reserve. These two measures are also less volatile than other measures of inflation such as CPI index (See Figure 2). Additionally, two measures of the output gap as deviations from real potential GDP will be used, with one from the Congressional Budget Office (CBO) and the other as calculated for the IMF Economic Outlook Report. This will help to identify whether different institutions' projections have a significant impact on this measure, which is an important consideration given that the coefficient on the output gap has been manipulated for the two Taylor rule equations used in the model (See Figure 5 for the comparison of the two output gap measures). While inevitably a point of contention arising from the numerous approaches that can be used to estimate potential GDP (Weidner and Williams 2009), the methodology and results surrounding the estimation of the output gap will not be discussed at length in this paper.[3]

Using the data series previously described, the appropriate Taylor rule equation will be used to generate prescribed interbank lending rates, which will then be compared to the federal funds rate and the Wu-Xia shadow federal funds rate to identify deviations from monetary policy rules, considering both Equation (3) and Equation (4).

4.2 Analysis of Policies in the United Kingdom

Using a similar approach, in order to assess the monetary policy response of the Bank of England, the Taylor rule approximation from equations (3) and (4) will be estimated using the Bank of Englands inflation target of 2.5%, with a specified 2% real interest rate. For the input variables, inflation will be measured by averaging the percent change in price levels across the previous four quarters for the consumer price index (CPI) and the GDP implicit deflator. CPI is the preferred measure of inflation used by the Bank of England, which makes it the more appropriate measure of inflation for assessing the central banks monetary policy response. The prescribed interbank lending rates will then be compared to the London Interbank Offered Rate (LIBOR) and the Wu-Xia shadow funds rate to identify deviations from monetary policy rules, considering both Equation (3) and Equation (4).

[3]The reference provided for Weidner and Williams discusses how the output gap could differ based on how it is estimated.

4.3 Econometric Estimation of Taylor Rule

In addition to comparing the shadow funds rates to the prescribed rates from the Taylor rule equations, using the model outlined in Taylor (1999), the following regression models will be estimated with ordinary least squares (OLS) to provide a rough approximation of the Taylor rule equation:

$$s_t = \delta_0 + \delta_1 \pi_t + \delta_2 \Delta y + \delta_3 QE + u_t, \qquad \Delta y = y_t - \bar{y}_t \tag{5}$$

$$s_t = \delta_0 + \delta_1 \pi_t + \delta_2 \Delta y + \delta_3 QE + \delta_4 QE * \Delta y + u_t, \qquad \Delta y = y_t - \bar{y}_t \tag{6}$$

$$s_t = \delta_0 + \delta_1 \pi_t + \delta_2 \Delta y + \delta_3 QE + \delta_4 QE * \pi_t + u_t, \qquad \Delta y = y_t - \bar{y}_t \tag{7}$$

$$s_t = \delta_0 + \delta_1 \pi_t + \delta_2 \Delta y + \delta_3 QE + \delta_4 QE * \pi_t + \delta_5 QE * \Delta y + u_t, \qquad \Delta y = y_t - \bar{y}_t \tag{8}$$

s_t = the shadow funds rate
π_t = the actual rate of inflation, lagged
y_t = real gross domestic product (GDP)
$\bar{y}_t$ = real potential gross domestic product (GDP)
QE = binary Variable for time of QE program in U.S./U.K.

The binary variable for quantitative easing will correspond to the dates of the quantitative easing programs undertaken in these countries. The addition of interaction terms for the quantitative easing dummy variable with the output gap and inflation hypothesizes the impact of quantitative easing on the magnitude of the Taylor rule coefficients. All of these regression models use annual time series data for 1990-2015 and will apply heteroskedasticity-robust standard errors. [4] For this portion of the analysis, the regression models will utilize each country's preferred measure of inflation and the output gap. In the U.S., this preferred measure of inflation is the core PCE index, while in the U.K. the preferred measure is the CPI index.

5 Results

5.1 United States Policy Rules and Estimates

In the United States, as reflected in the results in Figure 10[5], the Taylor rule approximation from equation (4) prescribes negative policy rates for a majority of the period during which quantitative easing took place. This result suggests that with policy rates at the zero lower bound, unconventional monetary policy would

[4] The author acknowledges that the econometric rigor of these regression models is elementary at best; nonetheless, these estimates will still prove to contribute to the cross-country analysis. The small sample size is another limitation.

[5] When examining the figures for U.S. and U.K., the vertical red bars represent the beginning and end of quantitative easing for the two countries.

have been justified within this framework in order to reduce term premiums and risk premiums for other interest rate spreads. Additionally, these unconventional policies seem to be reflected in the Wu-Xia shadow funds rate during this period, which steadily declines until the end of quantitative easing in late 2014. These particular indicators provide a compelling case for quantitative easing, by both suggesting it was justified as reflected in the negative interest rates prescribed by the policy rule, and by suggesting it was effective as evident in the gradual decline in the Wu-Xia shadow rate until late 2014 at the end of quantitative easing. It should be noted, however, that if one were to advocate for a more mechanical, hard-line approach to rules-based policy with the Taylor (1993) policy rule from equation (4), then monetary policy during this time period would be interpreted as being exceptionally discretionary, as prescribed policy rates according to this equation only approach zero around 2010, and quickly rebound to ordinary levels around 2%. If considering a portfolio of interest rates as advocated in Taylor (1999), however, this alternative policy rule seems to indicate that policy rules have maintained a certain degree of relevance since the Great Recession in the United States.

After examining the econometric estimation of the Taylor rule for the U.S., a few of the results of these regression models are particularly remarkable. In Table 2, the coefficients for these regression models all seem to very closely resemble equation (4) with a greater coefficient on the output gap. Regression model (2) [equation (6)] in this table with an added interaction term between quantitative easing and the output gap was found to carry the highest level of statistical significance at a significance level of 0.001. These results found that quantitative easing lowered the shadow federal funds rate by approximately 8%, however, with the interaction term on the output gap, this made the output gap coefficient zero during the period of quantitative easing. This would seem to make some intuitive sense, as during this period, quantitative easing is perhaps not directly reacting to the output gap, but rather to the zero lower bound and ineffectiveness of conventional monetary policy. When adding interaction terms for inflation as well into the model, the results of model (2) [equation (9)] in Table 3 indicate that the event of quantitative easing led to a 6% decrease in the shadow policy rate. Furthermore, the interaction term coefficients indicate that quantitative easing made the coefficients on the output gap and inflation approximately zero during this time period, which by the same line of reasoning makes intuitive sense given that quantitative easing is an unconventional monetary policy. These coefficients were similarly found to be statistically significant at the 0.001 significance level. The results from the econometric estimation of the simple Taylor policy rule suggest that quantitative easing was effective in lowering interest rates as indicated by the Wu-Xia shadow rate, and that monetary policy from 1990-2015 seems to more closely follow equation (4) as outlined in Taylor (1999).

5.2 United Kingdom Policy Rules and Estimates

In the United Kingdom, as reflected in the results in Figure 12, the Taylor rule approximations from equations (3) and (4) do not prescribe negative policy rates for the majority of the United Kingdom's quantitative easing program. In addition, the Wu-Xia shadow rate dips below the zero lower bound only just before 2010, and thereafter rebounds into the positive interest rate range around 2010, without much fluctuation in the final years of quantitative easing. This seems to suggest that perhaps quantitative easing was less effective in the United Kingdom as it pertains to reducing alternate interest rate spreads. This result might not carry an enormous amount of significance, however, considering that there was not as clear a justification as was prevalent from the negative prescribed rates in the U.S. When considering the economic performance of the U.K. economy during this period, as evident in Figure 7 and Figure 8, around 2010 the economy appears to stumble further into a recession. It should also be noted that after quantitative easing, the Wu-xia shadow rate falls below the zero lower bound and remains there through 2016, which indicates that perhaps some exogenous event such as the fiscal austerity programs implemented during 2010-2011 (Krugman 2015) are counteracting the effects of these unconventional monetary policies during this time period. With regard to the positive prescribed policy rates, Figure 3 presents a spike in inflation during this period around 2010 that might also be related to some exogenous factor.

After examining the econometric estimation of the Taylor rule for the U.K., the results of these regressions tended to differ from policy rule estimates of the U.S. In Table 2, the coefficients for the U.K. regression models similarly resemble equation (4) for the policy rule with a greater coefficient on the output gap. Regression model (4) [equation (5)] in the table is found to carry the highest level of statistical significance at the 1% and 0.1% significance levels. These results found that quantitative easing lowered the shadow policy rate by approximately 3%, and without any interaction terms in this model, the normal Taylor rule coefficients remained constant. It is possible that this is due to the shadow policy rate reacting to other inflationary pressures around 2010. When adding additional interaction terms for inflation and the output gap into the model, the estimators become less efficient and the standard errors increase as the statistical significance becomes more negligible. For regression model (2) in Table 3 [equation (8)], when adding all of these interaction terms into the regression, the statistical significance of these estimates of the coefficients increases, however, the economic significance is more ambiguous. These estimates suggest larger, negative coefficients on the output gap and inflation during the period of quantitative easing, which could perhaps be descriptive of counter-cyclical macroeconomic policies undertaken in this country during 2009-2011. The results from the econometric estimation of the simple Taylor policy rule suggest that quantitative easing was less effective in the U.K. than in the U.S. in lowering interest rates as indicated by the Wu-xia shadow rate,

and that monetary policy from 1990-2015 also seems to more closely follow equation (4) as outlined in Taylor (1999).

6 Conclusions

In light of fixed policy rates near the zero lower bound and programs of quantitative easing undertaken in the United States and in the United Kingdom, the Taylor rule framework has become somewhat silent as mechanical policy guideline for policymakers in these two countries. This analysis has examined the potential obsolescence of the Taylor rule in these countries during the period of quantitative easing, using interbank shadow policy rates as a proxy measure for the effect of quantitative easing had on risk premiums and term premiums that in turn reduced other interest rate spreads. Using the econometric estimates of the simple Taylor policy rule model suggested in Taylor (1999), with binary variables for the period of quantitative easing and interaction terms between this variable and the Taylor rule coefficients, quantitative easing was found to have a profound effect on the shadow policy rate, with an estimated a 6% decrease for the U.S. and 3% decrease for the U.K. This finding provided evidence to support the claim that quantitative easing had a more substantial impact in the U.S. than in the U.K., which is confirmed by comparing the Wu-Xia shadow policy rate in these two countries, which declines steadily in the U.S., but later rises in the U.K.(Figure 6). This increase in the shadow rate in the U.K. in 2010, which is also evident in the increase in the prescribed policy rate during this period, is likely due to some relevant exogenous event such as the temporary halting of quantitative easing or the announcement of fiscal austerity measures by the newly elected Conservative Party.

Further examining the results of the regression models, the variant of the Taylor rule from equation (4) was found to best fit the data for the Wu-Xia shadow rates, inflation (core PCE index for the U.S., CPI for the U.K.), and output gaps in these countries. While the econometric rigor of this estimation technique was elementary and ill-suited for proposing these coefficients as the better policy rule, they do seem to suggest that monetary policy is more accurately described by this policy rule for the period 1990-2016.

With the policy rates of these two countries fixed near the zero lower bound from 2008-2015, as evident in the LIBOR overnight rate and effective federal funds rate, Taylor rule was found to be more relevant to describing the policies of the U.S. if policymakers are considering equation (4) from Taylor (1999) with core PCE inflation (Figure 10). In contrast, even when considering equation (4) variant of the original Taylor rule, this policy rule has prescribed strictly higher policy rates for the United Kingdom than have been implemented, as overnight rates have been at the zero lower bound despite a period from 2009-2011 where policy rates were prescribed to be close to 5% (Figure 12).

The fiscal responses of these two countries were somewhat dissimilar, as the U.S. implemented the American Recovery and Reinvestment Act (ARRA) in 2009, while the U.K. began a program of fiscal austerity that took place between 2009 and 2011 (Fund 2011). These contrasting fiscal policy responses likely had an

impact on these two economies and their relevant macroeconomic variables. However, the Taylor rule is silent when it comes to interpreting these effects, except for when they have an impact on inflation and output gap. The divergence of the general macroeconomic trend in these two countries can be seen very clearly in Figure 7 and in Figure 8. In these graphs, the United Kingdom experiences lackluster economic growth in this period, while the United States proceeds to recover from the recession. This is consistent with the larger impact of quantitative easing observed in the econometric estimation of the Taylor rule for the two countries.

The limitations of this analysis and respective results are numerous. Additionally, the econometric estimation of the Taylor policy rule was rather simplistic, and more robust econometric techniques are necessary to validate these estimates. Future extensions of this analysis would certainly necessitate a more rigorous, robust estimation of the Taylor rule, considering the potential for serial correlation in the standard errors of the estimators and similar data issues. Furthermore, adding the Eurozone into the analysis could be insightful for comparison, although this would also likely introduce more confounding measures into the analysis, given the special institutional circumstances faced European Union by countries under the European Central Bank.

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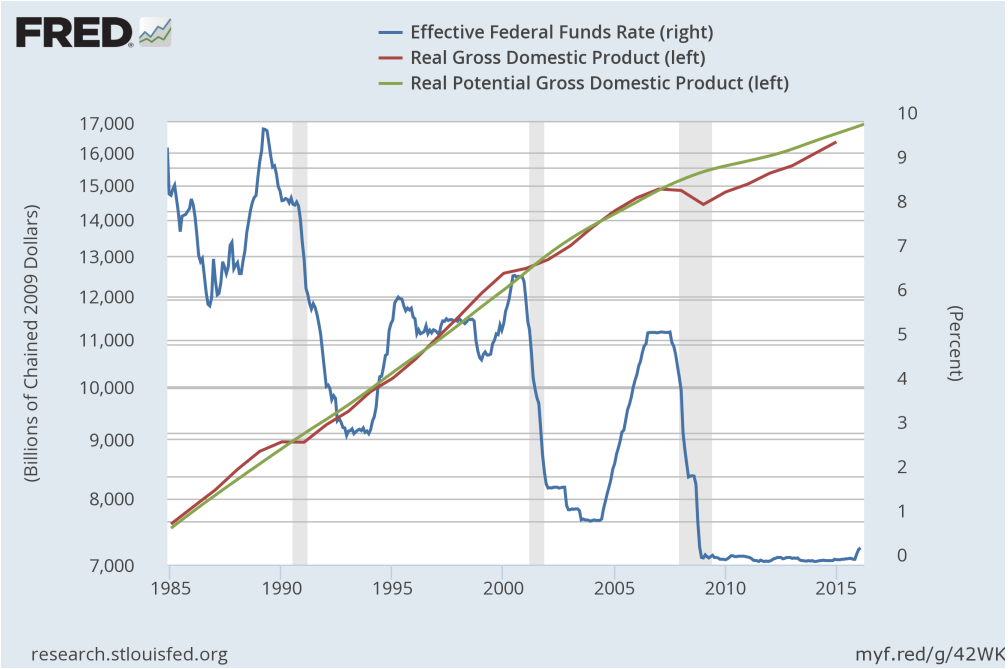


Figure 1: U.S. Output Gap as Effective Federal Funds Rate Approaches Zero Lower Bound

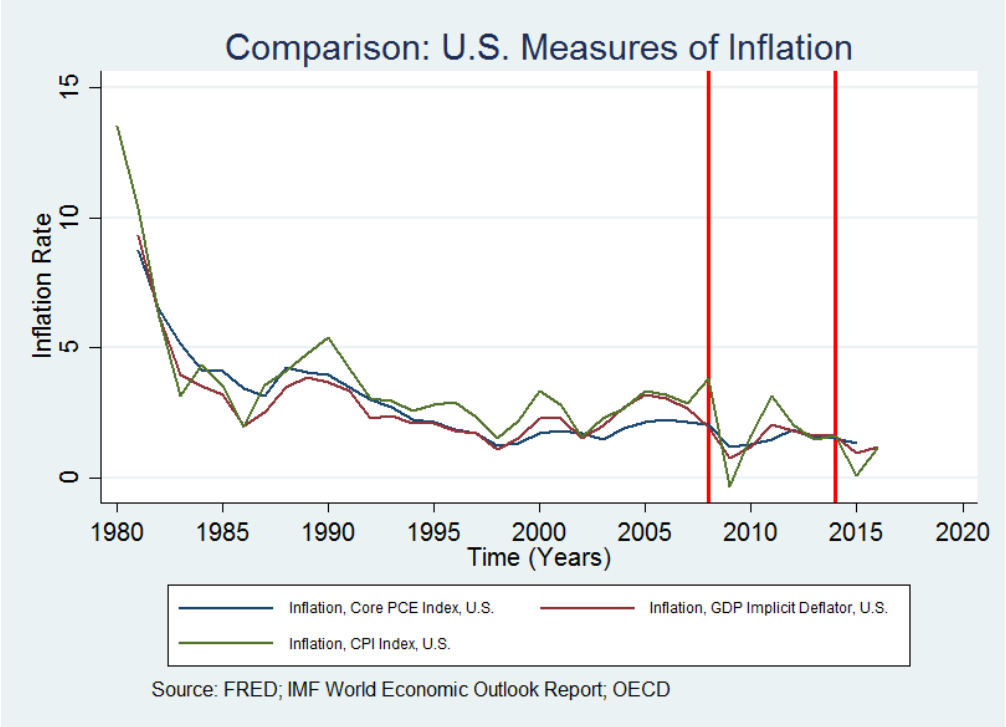


Figure 2: U.S. Measures of Inflation

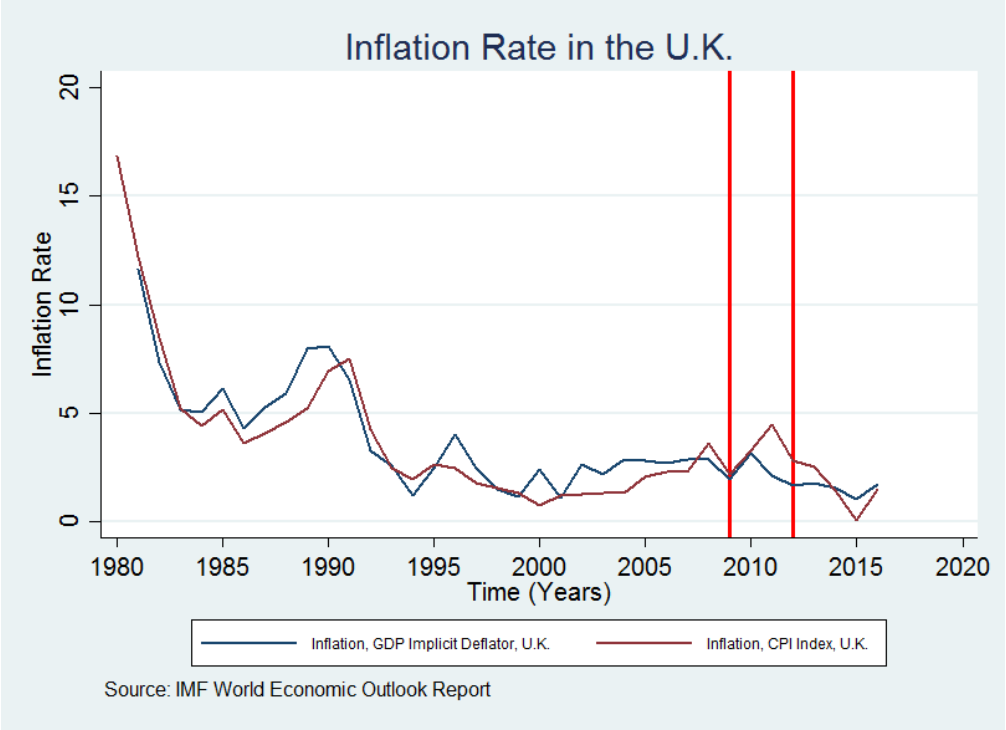


Figure 3: Measures of Inflation in the United Kingdom

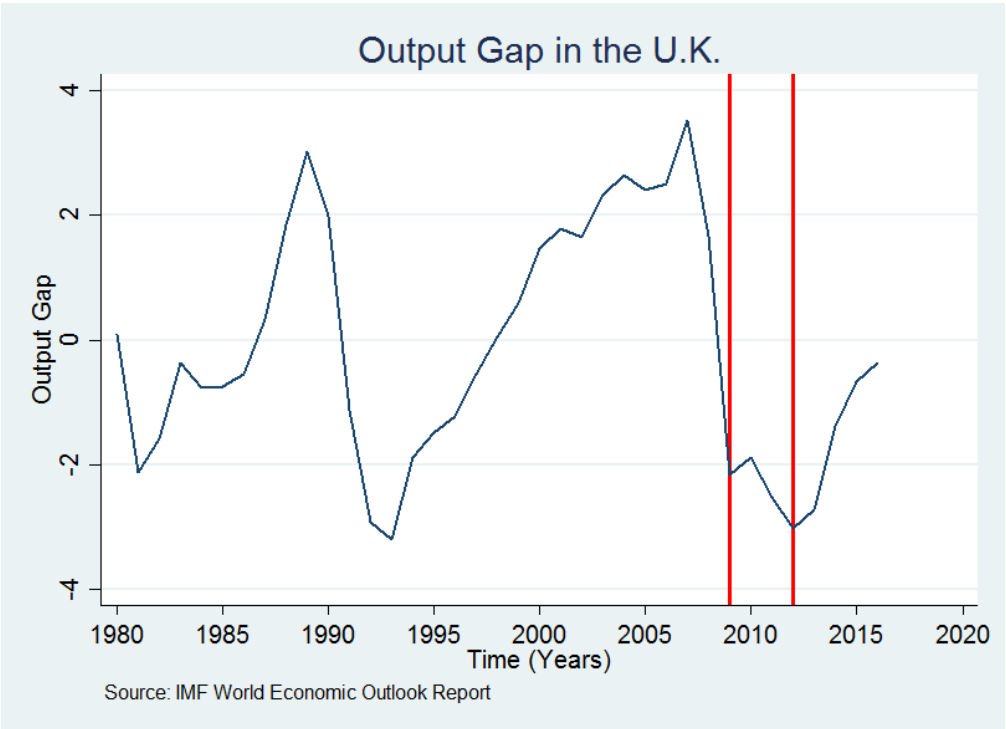
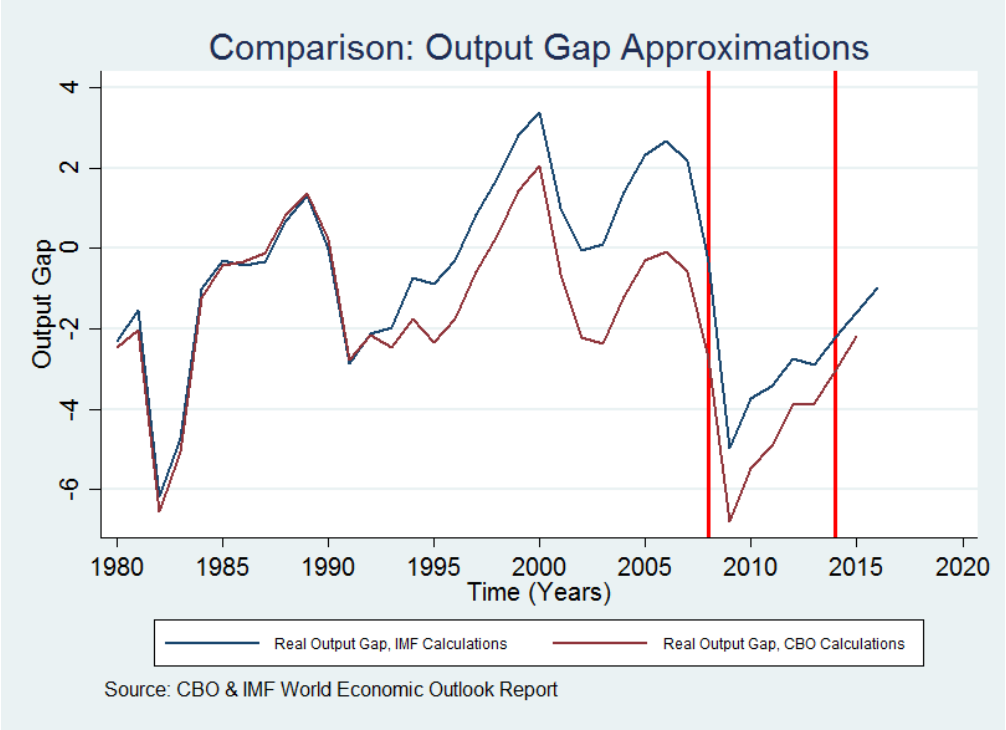


Figure 4: The Output Gap in the United Kingdom



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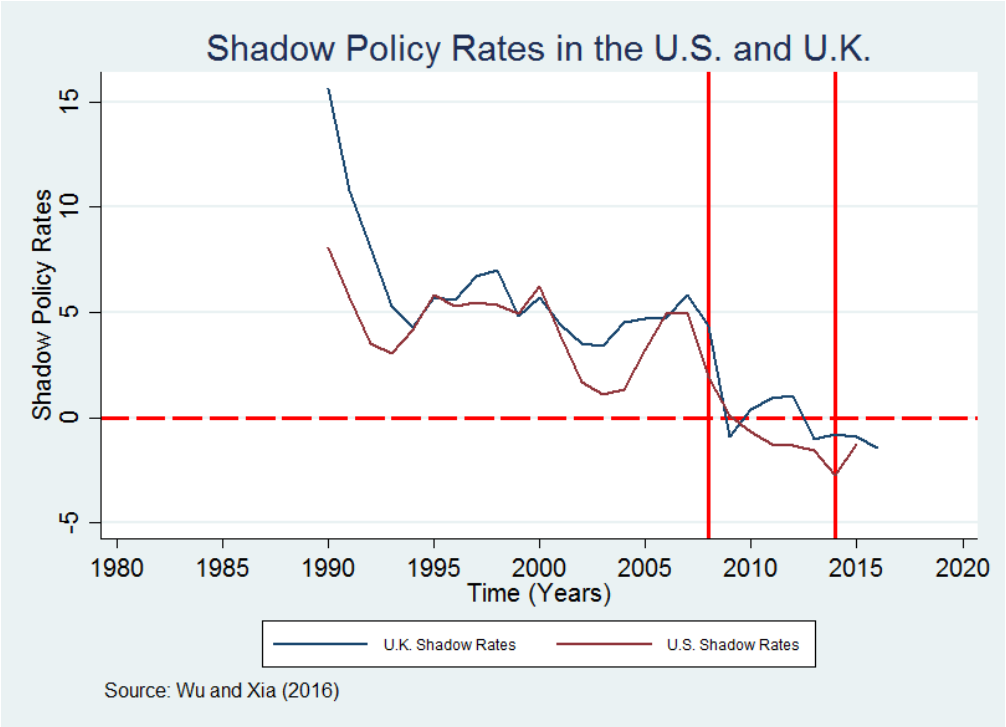

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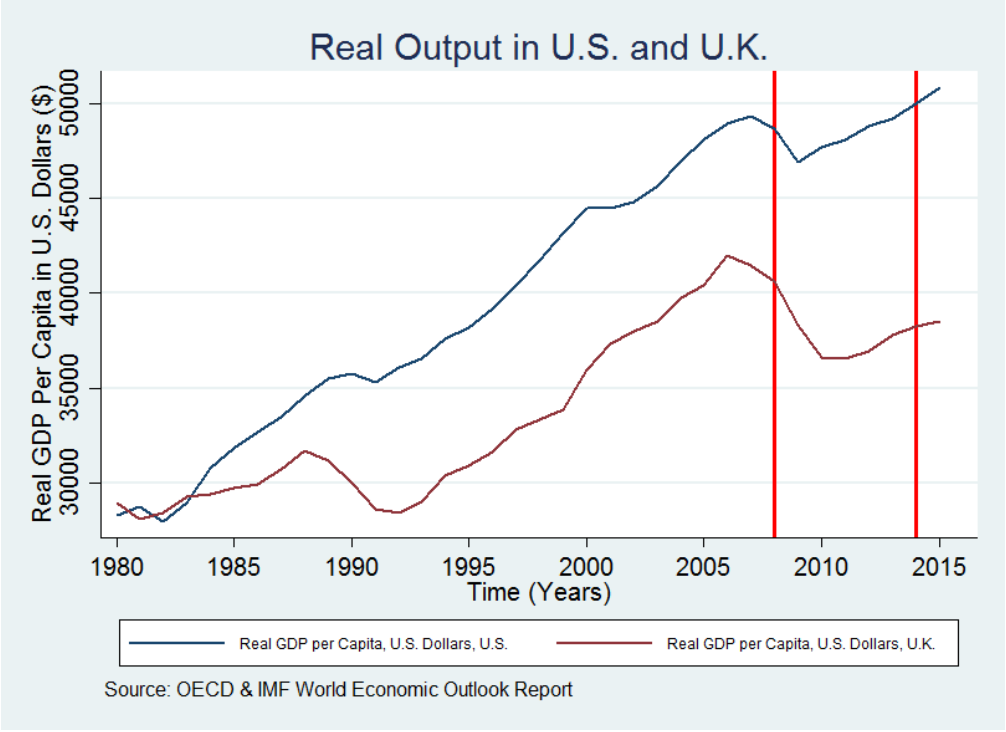

Figure 7: Real Per Capita GDP in the U.S. and U.K.

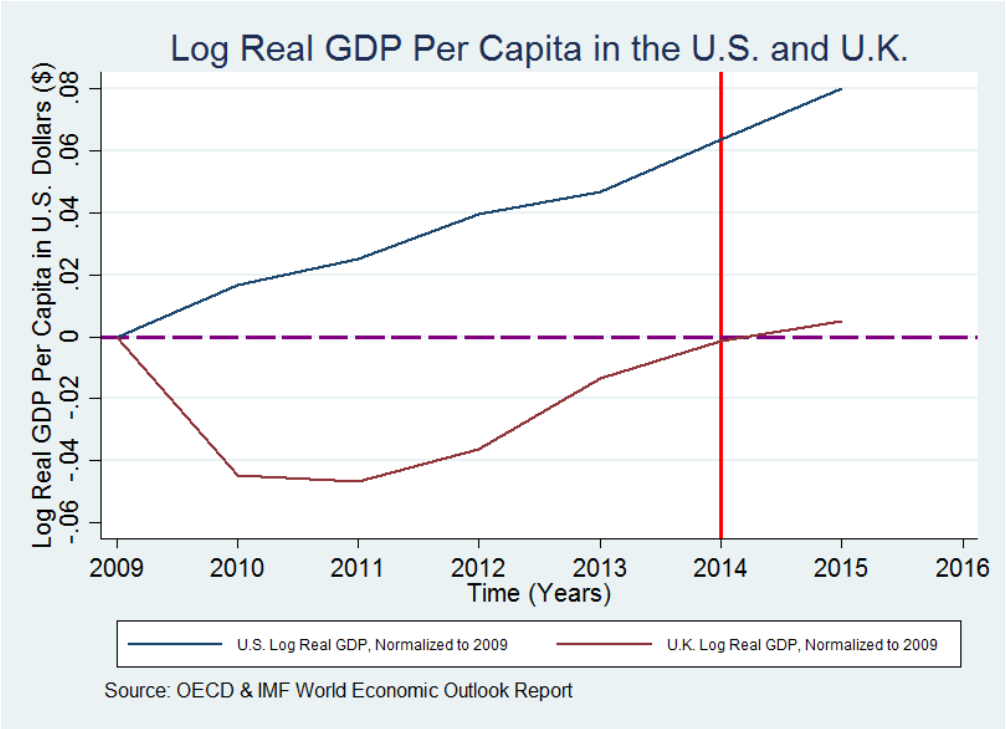

Figure 8: Log Real Per Capita GDP in the U.S. and U.K.: Normalized to 2009=0

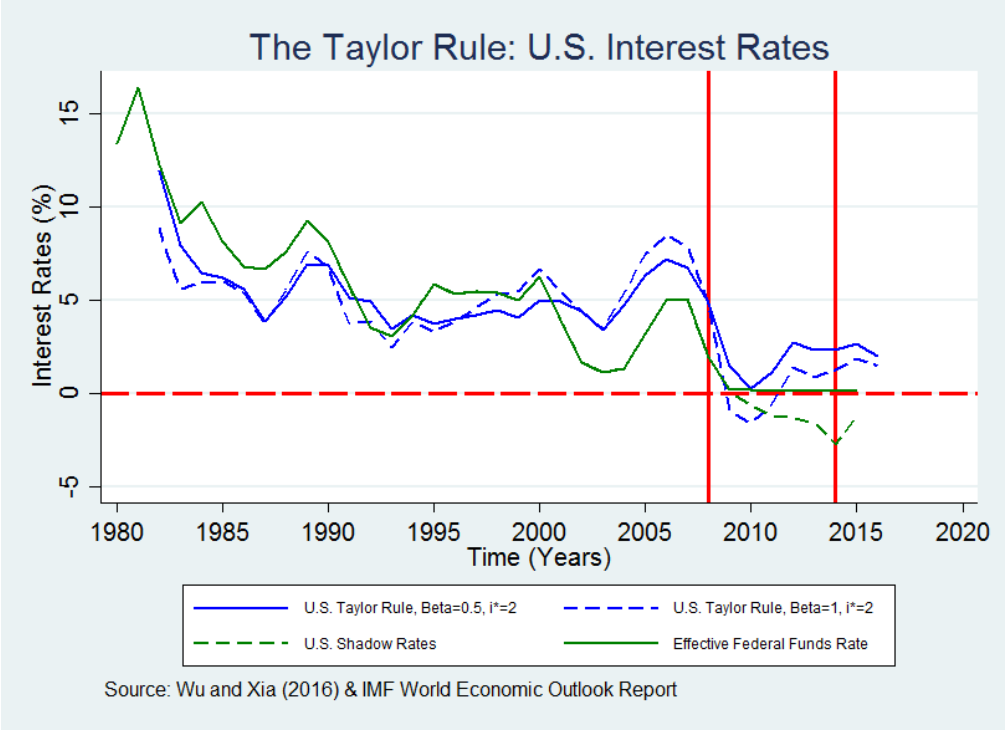

Figure 9: U.S. Interest Rates and the Taylor Rule with GDP Implicit Deflator Inflation

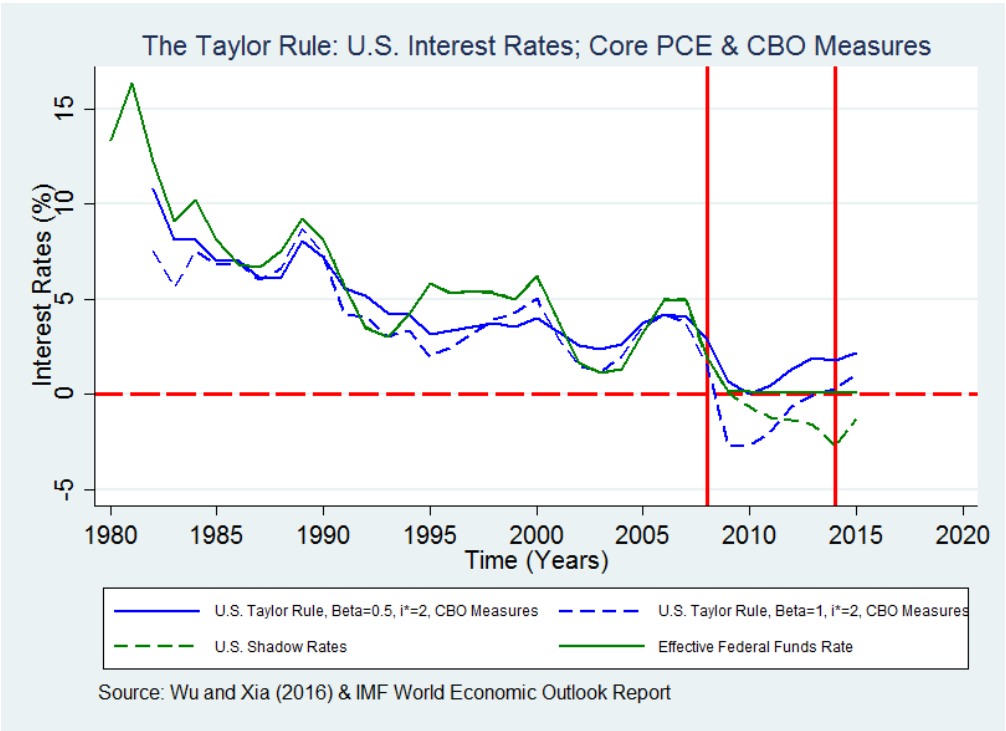

Figure 10: U.S. Interest Rates and the Taylor Rule with CBO Output Gap, Core PCE Inflation

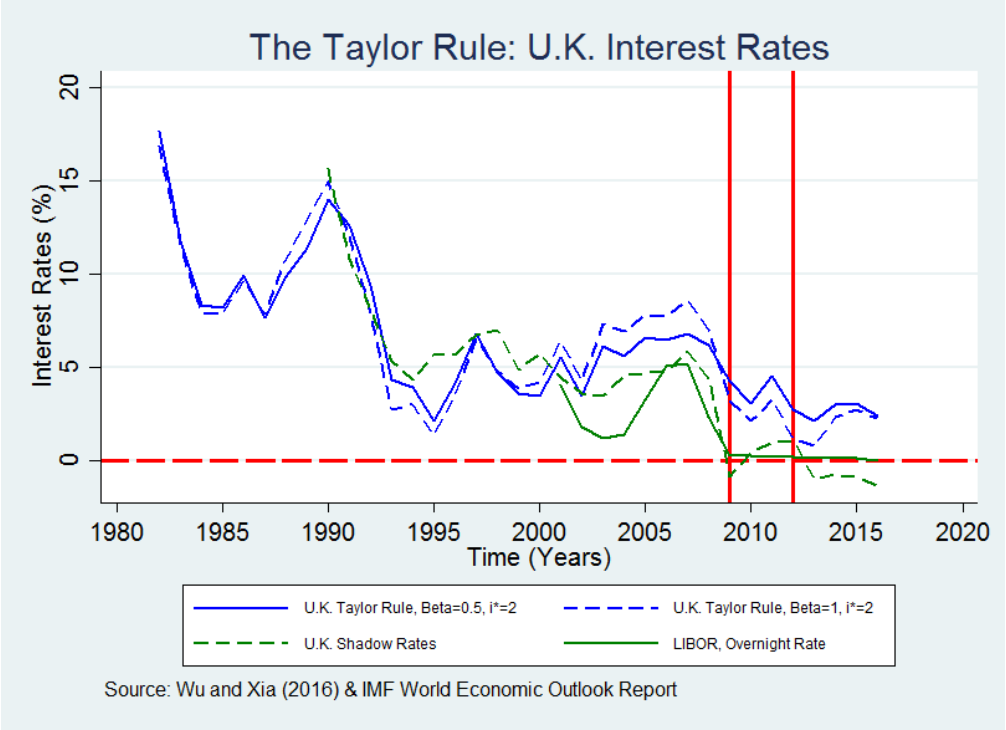

Figure 11: United Kingdom Interest Rates and the Taylor Rule with GDP Implicit Deflator Inflation

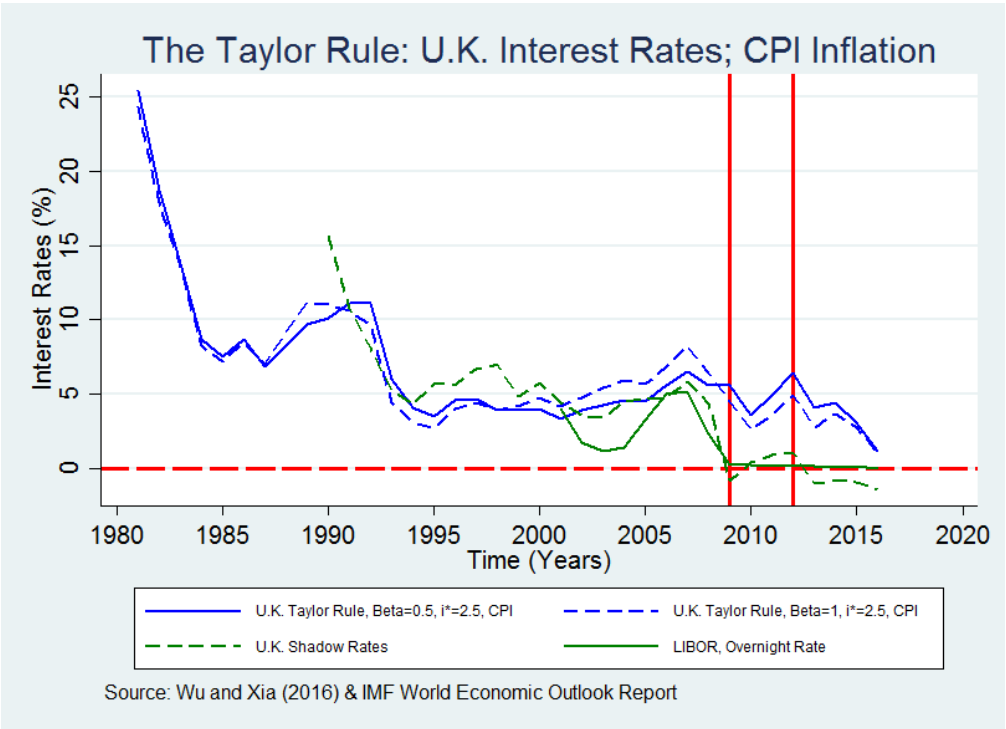

Figure 12: United Kingdom Interest Rates and the Taylor Rule with CPI Inflation

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Table 1: Comparing the Composition of GDP in the U.S. and U.K.

GDP Composition (End Use)		
	U.S	U.K.
Household Consumption	68.8%	64.7%
Government Consumption	17.6%	19.1%
Investment (Fixed Capital)	16.3%	17.2%
Investment (Inventories)	0.6%	0.2%
Exports	12.7%	27.6%
Imports	16%	28.8%
GDP Composition (Sector)		
	U.S	U.K.
Agriculture	1.6%	0.6%
Industry	20.8%	19.7%
Services	77.6%	79.6%

Source: CIA World Factbook 2015

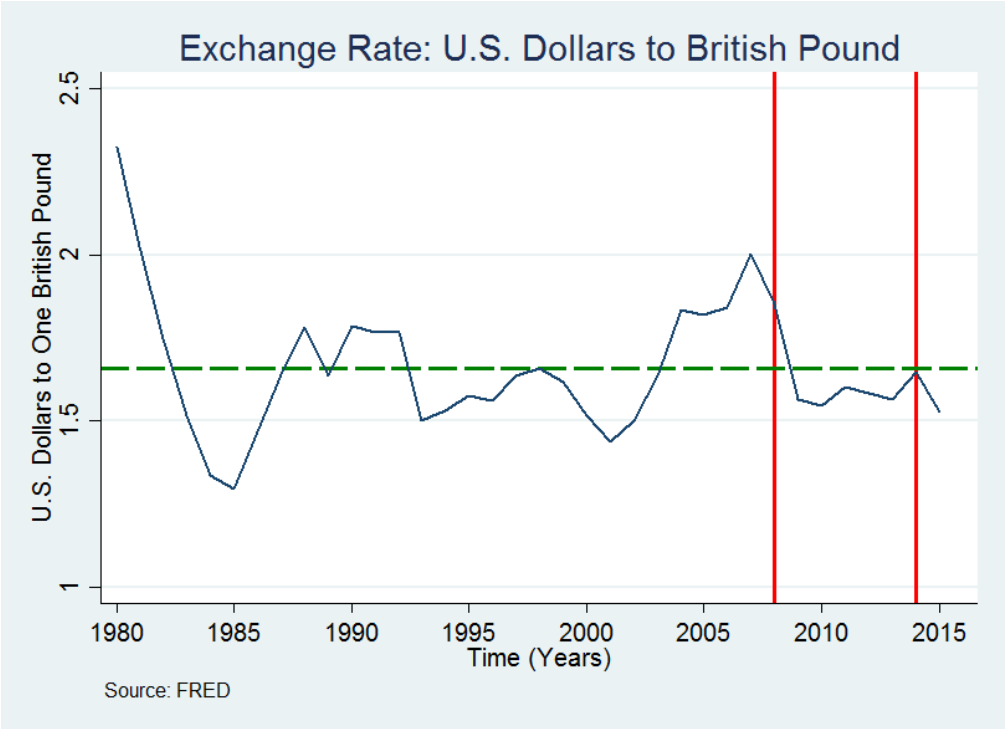

Figure 13: Exchange Rate: U.S. Dollars to British Pound

Table 2: Three Taylor Rule Estimations for the United States and the United Kingdom

	(1) U.S. Estimates	(2) U.S. Estimates	(3) U.S. Estimates	(4) U.K. Estimates	(5) U.K. Estimates	(6) U.K. Estimates
Inflation, Core PCE Index, U.S.	1.516***	1.674***	1.523***			
	(0.381)	(0.345)	(0.392)			
Real Output Gap, U.S CBO Approximation.	0.785**	1.150***	0.784**			
	(0.264)	(0.218)	(0.269)			
QE Dummy, U.S.	-1.442	-8.017***	-1.155			
	(1.530)	(1.102)	(4.583)			
Output, QE Interaction, U.S.		-1.712***				
		(0.312)				
Inflation, QE Interaction, U.S.			-0.181			
			(2.719)			
Inflation, CPI Index, U.K.				1.791***	1.786***	1.798***
				(0.332)	(0.339)	(0.342)
Real Output Gap, U.K.				1.095**	1.098**	1.094**
				(0.312)	(0.319)	(0.318)
QE Dummy, U.K.				-3.629**	-6.846	-1.100
				(1.147)	(3.778)	(4.355)
Output, QE Interaction, U.K.					-1.256	
					(1.372)	
Inflation, QE Interaction, U.K.						-0.669
						(1.005)
Constant	1.467	1.517	1.450	0.0141	0.0272	-0.00229
	(0.923)	(0.788)	(0.938)	(0.971)	(0.992)	(0.996)
Observations	26	26	26	27	27	27

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3: Additional Taylor Rule Estimation for the United States and the United Kingdom

	(1) U.S. Estimates	(2) U.K. Estimates
Inflation, Core PCE Index, U.S.	1.754***	
	(0.373)	
Real Output Gap, U.S CBO Approximation.	1.166***	
	(0.226)	
QE Dummy, U.S.	-5.696***	
	(1.024)	
Output, QE Interaction, U.S.	-1.824***	
	(0.251)	
Inflation, QE Interaction, U.S.	-1.734***	
	(0.425)	
Inflation, CPI Index, U.K.		1.802***
		(0.349)
Real Output Gap, U.K.		1.104**
		(0.326)
QE Dummy, U.K.		-3.700**
		(1.017)
Output, QE Interaction, U.K.		-4.831***
		(0.326)
Inflation, QE Interaction, U.K.		-3.254***
		(0.349)
Constant	1.358	-0.0154
	(0.830)	(1.017)
Observations	26	27

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$