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Central banking and monetary policy:
What will be the post-crisis new normal?

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3. Reflections on the natural rate of interest, its measurement, monetary policy and the zero lower bound

Alex Cukierman[1]

3.1. Introduction

Wicksell (1898) conceptualized the natural rate of interest as the rate at which the price level is stable. This notion is a basic element of the modern New-Keynesian (NK) framework (Woodford, 2003; Gali, 2008). In this framework the natural rate is the real rate at which the output gap, and therefore inflation are equal to zero (or more generally to the inflation target) in the absence of temporary shocks. Given that shocks are stationary monetary policy is expected to gradually move inflation (as well as inflationary expectations when they are unanchored) toward the inflation target. In the standard NK model efficient monetary policy can be viewed as using the riskless short term policy rate to gradually move this rate toward its natural rate counterpart.

Since most investments are risky and their gestation period of longer duration this paper argues that it is important to also consider natural long term and risky rates of interest and their implications for the economy and for monetary policy. The investigation and estimation of a risky long term natural rate of interest is likely to bring to the surface real life factors that are abstracted from in existing literature. This is particularly important during crisis times when those two rates move in opposite directions[2].

The persistent decrease in long term interest rates since the beginning of the twenty first century and the intensification of this trend with the onset of the global financial crisis (GFC) nurtured the view that there has been a substantial and persistent decrease of the natural rate into the negative range (Laubach and Williams, 2015; Curdia *et al.*, 2015).

In many developed economies actual short term policy rates reached the zero lower bound already early in the crisis and have mostly stayed in this range since then. This, along with persistently low and even negative inflation rates, imply that actual real short term rates are bounded from below by zero. Given those

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I am indebted to Tommaso Monacelli for bringing recent estimates of the natural rate of interest to my attention. E-mail: alexcuk@post.tau.ac.il.

2 Figure 1 in Gilchrist and Zakrajšek (2012) shows that the spread between risky and riskless US rates was at an all times high precisely when the short term policy rate reached the zero lower bound.

observations the finding that the real natural rate of interest is negative and is likely to remain in this range for a while constitutes a non-negligible constraint on the efficient conduct of monetary policy. It is therefore important to evaluate the extent to which recent estimates of the natural rate are as low as implied by recent research.

Since both the natural rate and the output gap are unobservable they have to be inferred from observables. Recent literature achieves this objective by applying either the Kalman filter or Bayesian estimation to alternative versions of the NK model. This paper argues that, since the NK model abstracts from credit rationing and from the financial stability motive on the part of monetary policymakers, existing estimates of the natural rate are likely to be biased downward, particularly so since the onset of the GFC[3].

It is well accepted that small and medium size borrowers are likely to be credit rationed due to moral hazard, insufficient collateral and other reasons. (Bernanke and Gertler, 1989; Bernanke, Gertler and Gilchrist, 1999). The decrease in the value of financial assets in the wake of the GFC increased the degree of credit rationing, first by reducing the value of borrower's collateral and second by reducing banking capital. Both factors reduce credit and aggregate demand. Since there is no proxy for this effect in the conventional NK IS relation the decrease in aggregate demand is interpreted by the estimation procedures above as a decrease in the natural rate of interest.

This potential bias is shared by both the Laubach and Williams (2015) as well as by the Curdia *et al.* (2015) papers. Since it also utilizes the monetary rule of the Fed to extract the natural rate the second paper is likely to suffers from an additional downward bias due to the fact that the monetary rules used in the paper do not feature a proxy for the financial stability motive of the central bank (CB)[4]. As a consequence the highly expansionary policies of the Fed in reaction to the subprime crisis are interpreted as a decrease in the natural rate further biasing this estimate downward[5].

The paper's organization follows. Section 2 documents the downward trend in (mainly) riskless long and short term interest rates since the start of the twenty first century and discusses the causes underlying it. Section 3 briefly reviews and compares alternative natural rate concepts. The following two sections analyse in some detail how changes in credit rationing and in monetary policy in the wake of the crisis might have biased recent estimates of the natural rate downward.

3 Broadly similar, but somewhat less structured, arguments are made by Taylor and Wieland (2016).
4 Chapter 7 in Cukierman (1992) discusses the impact of this motive on monetary rules.
5 Interestingly the natural rate projections derived from the Curdia *et al.* (2015) framework are substantially more negative than those of Laubach and Williams (2015) who do not rely on the monetary rule to estimate the natural rate (compare Figure 3 with Figure 6).

Section 3 demonstrates this for the Laubach and Williams (2015) framework and section 4 for the Curdia *et al.* (2015) model. In the second model the natural rate is conceptualized as the rate of interest that would exist in the absence of monopolistic competition distortions. Since such distortions **are present in reality** their estimate of the natural rate appears to suffer from an additional downward bias. Section 5 makes a plea for defining and measuring a risky natural rate of interest and argues that such a concept is a useful complement to the existing riskless natural rate concept, particularly so, during times of financial turmoil. This is followed by concluding remarks.

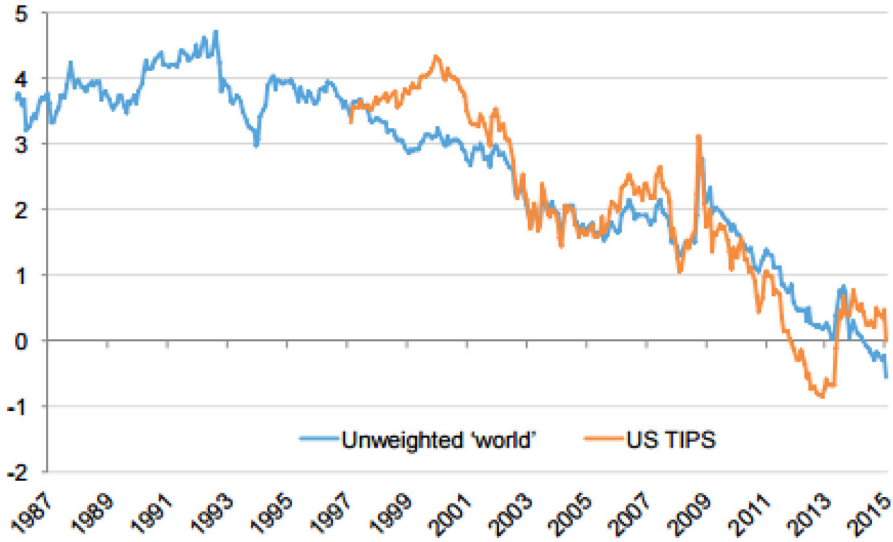
3.2. BRIEF LOOK AT THE RECENT BEHAVIOR OF RISKLESS LONG TERM INTEREST RATES AND ITS CAUSES

Long term risk free interest rates have been on a downward path since about the beginning of the twenty first century. This trend intensified with the outbreak of the CFC and persists to this day. **Figure 1** shows the behaviour of a simple average of real yields on C7 ten years government bonds excluding Italy between 1987 and 2015. The figure shows that this rate fluctuated between three and four percent prior to the beginning of the current century. It dropped to the two percent range between 2002 and 2007. Following some temporary violent fluctuations in the aftermath of Lehman's collapse and unusually expansionary monetary policies, first in the US and subsequently in the Euro area and other countries the long term risk free rate decreased further to the range between zero and one percent and even became negative occasionally.

3.2.1. What caused the downward trend in riskless interest rates?

Bean *et al.* (2015) usefully classify the potential factors underlying the descent in the riskless long term rate into the following three factors: Upward shifts in the propensity to save, downward shifts in the propensity to invest and an increase in the relative demand for safe assets. The empirical evidence is consistent with the view that the increase in the propensity to save is the most important factor. Several developments underlie the increase in the propensity to save: Increases in life expectancy not matched by increases in retirement age raised the urge to save more for retirement. This effect was particularly evident in developed economies and in China. The Chinese one child policy in conjunction with a very partial pension system in this country kept the saving rate in China at unusually high levels.

Figure 1. 'World' ten year risk-free real interest rate



Notes: 'World' real interest rate is an unbalanced simple average of G7 ex Italy ten-year real yields. Sliced UK indexed gilts were used to proxy world real yields from 1985-1996. From 1997-2006, 'World' rates were calculated using a simple average of spliced US ten-year TIPS and UK IGs. From 2007-2008, 'World' rates were calculated using a simple average of spliced ten-year US, UK, Canada, Japan, and France indexed bonds. From 2008-2015, 'World' rates were calculated using a simple average of spliced 10-year US, UK, Canada, Japan, France, and Germany.
Source: Bean et al. (2015), Figure 1.4.

This tendency was reinforced by an increase in the share of middle income individuals relatively to old individuals over the twenty years starting in the early nineties. Since the bulk of savings is done by middle income individuals whereas old individuals dissave an increase in this ratio raises the aggregate propensity to save. The importance of Chines savings for the behaviour of long term rates in developed economies was reinforced by large current account surpluses, gradual removal of Chinese capital controls and a sustained increase in the relative size of the Chinese economy. All those factors combined to create, particularly in the US, a 'global saving glut'[6].

Large current account surpluses in China and other East Asian countries led to the accumulation of foreign exchange reserves in the vaults of their central banks. Since central banks traditionally invest their reserves in a conservative manner this spurred an increase in relative world demand for safe assets. The dismal performance of some of those countries during the 1998/1999 East Asian crisis further increased the precautionary demand for global safe assets. Caballero *et al.*

[6] This term was coined by Bernanke (2005) and elaborated further in Bernanke (2007).

(2008) argue that, due to their stable political systems, wide capital markets and strong protection of private property this led to an increase in the demand for long term government bonds in the US and Europe and reduced interest rates on those safe assets.

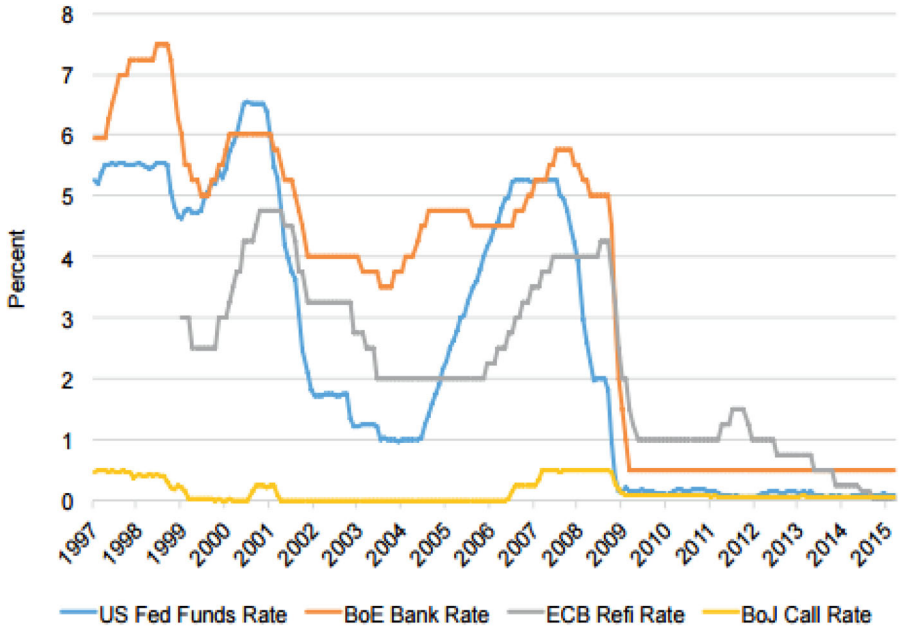
Prior to the crisis some of this demand for safe assets was also directed at high grade corporate and mortgage backed securities (MBS). Between 2009 and 2014 net new issues of MBS were mostly in the negative range (Cukierman, 2016; Figure 6). Caballero and Farhi (2014) argue that this partial extinction in the global supply of safe assets reinforced the downward trend in riskless long term rates. However, due to the large quantitative easing operations of major central banks it is likely that this effect is temporary.

Of the three long term potential channels conducive to low rates the long term decrease in the propensity to invest is the most controversial. This 'secular stagnation' hypothesis argues that the decrease in the real riskless rate is due to a decrease in the expected future output growth triggered by a slowdown in technological innovations in the advanced economies. The revival of this hypothesis is due to Gordon and Summers. In addition to a persistent lack of aggregate demand Gordon (2012, 2014) argues it is unlikely that the future will bring new general purpose technologies like the steam engine; railroads; electricity; the internal combustion engine and the digital revolution. Summers (2013) bases his secular stagnation hypothesis on the presumption that the natural rate of interest has fallen below the zero bound. Due to this bound monetary policy is unable to sufficiently revive aggregate demand which induces, through hysteresis, a secular slowdown in the rate of output growth. Both views imply there should be a positive correlation between expected output growth and real interest rates. Figure 2.A from Bean *et al.* (2015) suggests that this is hardly the case.

Although the downward trend in interest rates started some time prior to the GFC this trend was substantially reinforced by extraordinarily expansionary monetary policies of major central banks. **Figure 2** shows that shortly after Lehman's collapse the policy rates of the Fed, the Bank of England and the Bank of Japan quickly declined to the vicinity of the zero lower bound (ZLB)[7]. This was followed by massive quantitative easing operations over a number of years. Although central banks directly control only short term rates it is highly likely that the post-Lehman further decrease in long term rates and its persistence is largely due to those unusually expansionary policies. The ZLB constraint on monetary was bypassed by means of massive large scale purchases of assets.

[7] The policy rate of the, initially more conservative, ECB reached this range only in 2014 (further details appear in Figure 1.1 of Bean *et al.* (2015)).

Figure 2: Official policy rate



Source: Bean et al. (2015), Figure 1.1.

In the US a non-negligible part of the Fed's asset purchases were explicitly designed to reduce the term premium on long term bonds by acquiring such bonds and financing those purchases by the sale of short term bonds (Titan and Swanson, 2011). This downward effect was, and still is, reinforced by forward guidance concerning the path of future short term policy rates by Fed officials who periodically announce that the return to higher policy rates will be very gradual.

The post-crisis persistence of low interest rates is also related to the attempt by many central banks to preserve the competitiveness of their economies by prevention of domestic currency appreciation due to expansionary monetary policies in the rest of the world. This 'shadow currency war' pulls long term world riskless rates downward and prolongs the period over which the ZLB is binding.

3.3. THE MULTIPLE FACETS OF THE NATURAL RATE OF INTEREST

Wicksell (1898) characterized the natural rate of interest as follows: "There is a certain rate of interest on loans which is neutral in respect to commodity prices,

and tends neither to raise nor to lower them." Woodford (2003) and others embed this concept into the modern New-Keynesian (NK) framework. A basic building block of this framework is the NK IS relation that connects inflation to expected inflation and to the output gap. In this framework the natural rate of interest is conceptualized as the real interest that produces a zero output gap when both actual and expected inflations are equal to the inflation target and temporary shocks are set to zero. Since the shocks in the model are stationary and monetary policy is expected to gradually anchor both inflation and inflationary expectations to the inflation target, efficient monetary policy can be viewed as using its policy instruments to gradually move the policy rate toward the natural rate. At a more fundamental level the natural rate depends on the expected secular rate of growth of potential output and on the long run behaviour of intertemporal preferences.

A basic challenge to the implementation of this scheme is that potential output and, therefore, the natural rate are not observable variables. Consequently they have to be inferred from observable variables by means of a theory that links unobservable to observable variables. As a result empirical estimates of the natural rate and of potential output become model dependent. Recent empirical work attempts to overcome this challenge by using the Kalman Filter or Bayesian estimation to pin down the (a priori) unknown parameters needed to obtain estimates of the natural rate and of potential output. A related difficulty is that those methodologies and the theoretical models they are applied to still leave substantial freedom in the conceptualization of the natural rate of interest.

This freedom arises for two main reasons: First because, although related, short term and long term interest rates behave differently. Similarly, although related, risky and riskless rates also behave differently. The Cartesian product of those two classifications yields four possible conceptualization of the natural rate: A short term natural riskless rate, a long term natural riskless rate, a short term natural risky rate and a long term natural risky rate. Section 6 below argues that, of those four concepts, the one that is most important for investment and aggregate demand is the last one. However, it appears that to this date, the literature has not attempted to formulate and estimate a risky long term natural rate. Laubach and Williams (2015) interpret their estimates as referring to a long term natural rate. On the other hand Curdia *et al.* (2015) who are mainly interested in a comparison of two alternative monetary policy rules provide estimates of a short term natural policy rate.

Although neither of those papers explicitly states whether those estimates refer to risky or to riskless rates it appears that the second interpretation is more relevant since the observed interest rate they use is mainly the short term policy rate. This view is backed further by the fact that in the post crisis era all those estimates flirt

with the ZLB whereas, as shown in Gilchrist and Zakrajšek (2012), longer term **risky** rates are substantially above zero over the same period. Section 6 below elaborates on the desirability of formulating and estimating a long term risky natural rate.

3.4. ARE RECENT ESTIMATES OF THE RISK FREE NATURAL RATE OF INTEREST BIASED DOWNWARD?

The depth and persistence of low long term riskless rates both before and after the GFC nurtured the view that the natural rate of interest is currently lower than it used to be in the past. Structural empirical work by Laubach and Williams (2003, 2015), Curdia *et al.* (2015) and others confirms this view. Curdia (2015) even concludes that the natural rate is likely to be very low by historical standards for a long period of time.

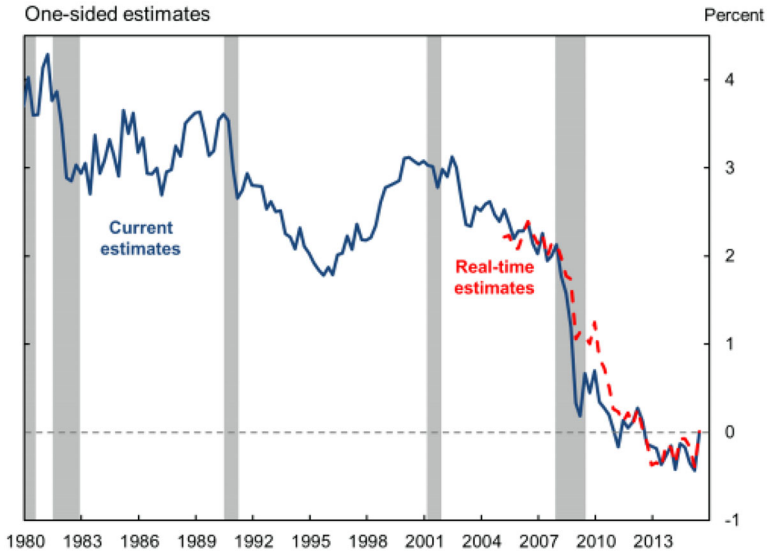
3.4.1. The Laubach and Williams estimates of the natural rate of interest

Laubach and Williams (2003) is one of the first attempt to estimate the long run natural rate of interest and the closely related secular rate of growth of potential output. Using their 2003 methodology Laubach and Williams (2015) (LW in the sequel) update their original estimates to include the period of the GFC. **Figure 3** summarizes the evolution of their risk free natural rate of interest. The figure shows that between 1980 and 2008 this rate decreased from a bit less than four percent to two percent with a dip to two percent in the mid-nineties, a recovery to 3 percent at the beginning of the twenty first century and a decrease back to two percent just prior to the downfall of Lehman Brothers. Following this event the estimated natural rate takes a further abrupt dip to the vicinity of zero and even becomes slightly negative from the end of 2013 and on.

This pattern is generally mirrored by LW's estimates of the rate of growth of potential output. In particular following the subprime crisis this estimate also decreases sharply from around 3 percent to the vicinity of two and a half percent (**Figure 4**). The co-movements between the natural rate and the rate of growth of potential output are a consequence of the fact that the structural model postulated and confirmed in LW implies that, up to a persistent stationary preference shock, there is a positive linear association between the natural rate and the rate of growth of potential output.

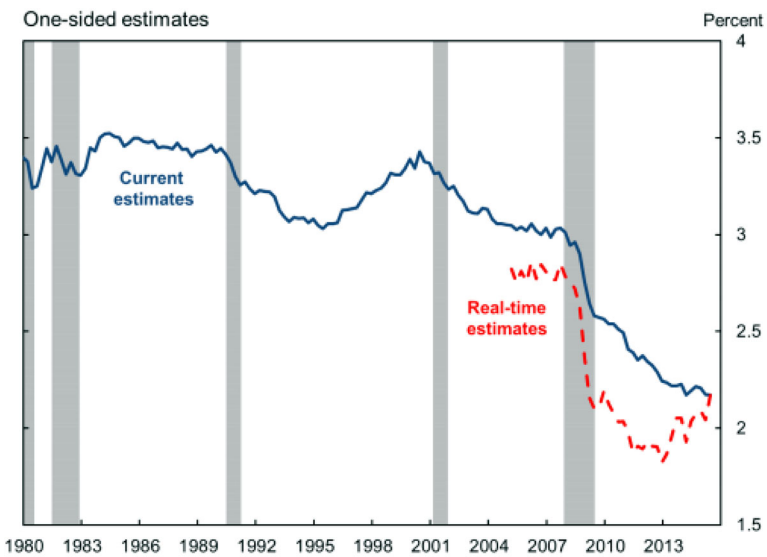
Since both the natural rate of interest and the rate of growth of potential output are unobservable LW postulate a standard New-Keynesian (NK) model and apply

Figure 3. Laubach-Williams model estimates of the natural rate of interest



Note: Real-time estimates represent the estimate of the natural rate based solely on data available a few months after the end of the quarter for which the estimate is reported.
Source: Laubach and Williams (2015), Figure 5.

Figure 4. Laubach-Williams model estimates of the trend growth rate of potential output



Note: Real-time estimates represent the estimates of the trend rate of growth of potential output based solely on data available a few months after the end of the quarter for which the estimate is reported.
Source: Laubach and Williams (2015), Figure 6.

Kalman filter methods to observable variables like actual output and inflation to estimate the unobservable time paths of the natural rate and the related trend rate of growth of potential output. Abstracting from lags, future expected potential output, relative prices and shocks the essence of their model is captured by the following two NK equations

$$y - y^p = -\beta(r - r^n) \tag{1}$$

$$\pi = \pi^e + \theta(y - y^p) \tag{2}$$

along with a structural equation that relates the (real) natural rate of interest, r^n, to the rate of growth of potential output, g^p

$$r^n = \delta g^p \tag{3}$$

Here y and y^p are the logs of actual and potential output, r is the actual risk free real rate of interest, π and π^e are actual and expected inflation, and β, θ and δ are positive parameters. The first equation is the NK IS relation that relates the output gap to the interest rate gap, $r - r^n$, and the second equation is the NK Phillips equation that relates actual inflation to expected inflation and to the output gap[8].

3.4.2. The impact of credit rationing on LW's estimates of the natural rate of interest

In the presence of some credit rationing aggregate demand and economic activity depend not only on the cost of credit but also on the availability of credit. To reflect this fact the NK IS relation in equation (1) is replaced by

$$y - y^p = -\beta(r - r^n) + \gamma L \tag{4}$$

where L is the volume of available credit and γ is a positive parameter. Equation (4) states that the output gap depends both on the cost and the availability of credit. Possible micro-foundations for such an equation may include a model in which the aggregate demand of borrowers with plenty of collateral reacts only to the cost of credit while the aggregate demand of borrowers with little collateral respond mainly or only to the degree of credit rationing. Credit rationing is likely to be particularly important for small and medium size enterprises that do not have direct access to the capital market and have to rely, therefore, on banking credit.

[8] The LW Phillips relation features a distributed lag on past rates of inflation that is summarized here by expected inflation on the ground that a main determinant of future expected inflation is past inflation. This compactification does not affect the main arguments that follow below.

Omission of a proxy for the degree of credit rationing as proxied by the level of credit from the NK IS relation creates a downward bias in the estimate of the natural rate of interest (and of potential output) when L goes down. The intuition underlying this claim follows: Due to the fact that both the output gap and the natural rate of interest are unobservable the Kalman filter procedure infers those two variables from observations on the actual values of output and inflation. Since it does not appear in equation (1) a decrease in L that reduces both output and inflation is attributed by the Kalman filter procedure entirely to a decrease in the natural rate of interest. This can be demonstrated more formally by expressing inflation in terms of the interest rate gap by substituting equation (4) into equation (2)

$$\pi = \pi^e - \theta\beta(r - r^n) + \theta\gamma L. \tag{5}$$

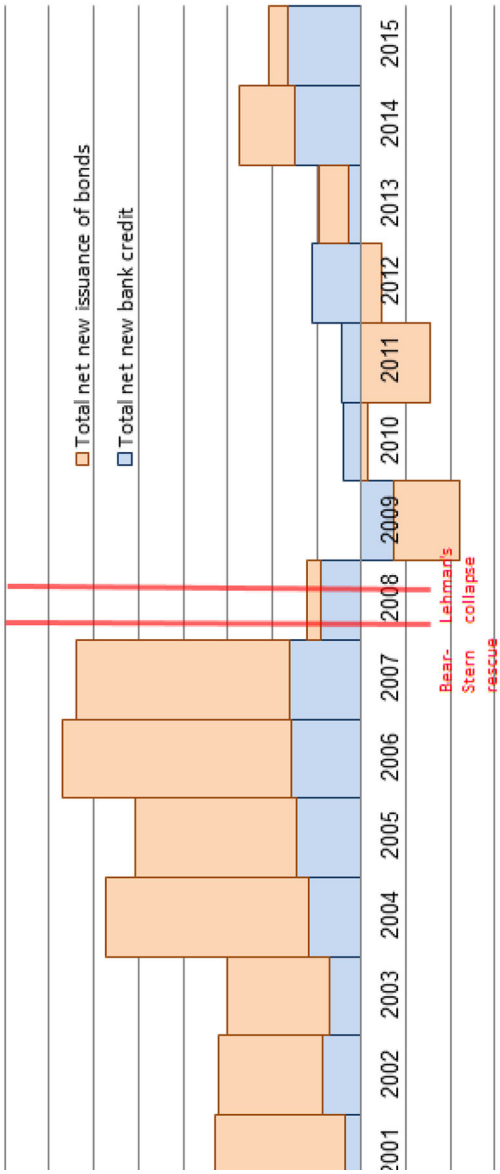
Equation (5) implies that a ceteris paribus decrease in L reduces inflation. Since the LW procedure omits L the Kalman filter interprets the decrease in inflation as a reduction in the natural rate (and through equation (3) also as a reduction in the secular rate of growth of potential output) in spite of the fact that, by assumption, there was no change in either of those variables[9]. Since there were no discernible changes in credit rationing prior to the subprime crisis this bias might have been relatively unimportant prior to the crisis.

But there is little doubt that it went up dramatically due to the credit arrest observed in the aftermath of Lehman's collapse. As a matter of fact it is likely that a large part of the decrease in the estimated natural rate of interest from around two percent just prior to Lehman's collapse to a bit above zero during 2009 is explainable in terms of a dramatic increase in credit rationing rather than in terms of a decrease in the natural rate. **Figure 5** shows that credit growth in the post Lehman era has been extremely sluggish at least through 2013. This observation is consistent with the view that the persistent decline of inflation is due, in large part, to a persistent decline in credit growth rather than to a further decrease in the natural rate. Cukierman (2016) argues that this persistent drop is due to a combination of the following three factors: A decrease in the value of collateral due to the decrease in asset prices, toughening of regulation on financial institutions and the collective trauma experienced by financial market participants once they realized that even a SIFI will not always be bailed out[10].

[9] Relatedly, Taylor and Wieland (2016) argue that a similar downward bias in the natural rate arises when financial regulation is toughened.

[10] The theoretical underpinnings of the last mechanism appear in Cukierman and Izhakian (2015).

Figure 5. Total net new bank credit + Total net new issuance of bonds in the US, excluding treasury bills (Billions of $)



Source: Cukierman (2016), Figure 5.

3.5. CURDIA'S *ET AL.* ESTIMATES OF THE NATURAL RATE OF INTEREST

Using a combination of calibration and Bayesian estimation Curdia *et al.* (2015; Figure 1) find that the natural rate dropped sharply to around minus ten percent in the aftermath of Lehman's collapse. They use a conventional NK model to compare the performance of the Taylor rule to an alternative Wicksellian rule in which the monetary authority gradually adjusts the federal funds rate (FFR) so as to attain the natural rate of interest in the no shocks long run equilibrium. They refer to those two monetary rules as the T and the W rules respectively and find that the second rule provides a more plausible description of actual US monetary policy during the sample period. Abstracting from lags, future expected potential output and shocks their model of the economy is also described by equations (1) and (2). As was the case in the LW framework their estimates of the natural rate are, therefore, potentially subject to a bias due to omission of a proxy for credit rationing in the NK IS relation.

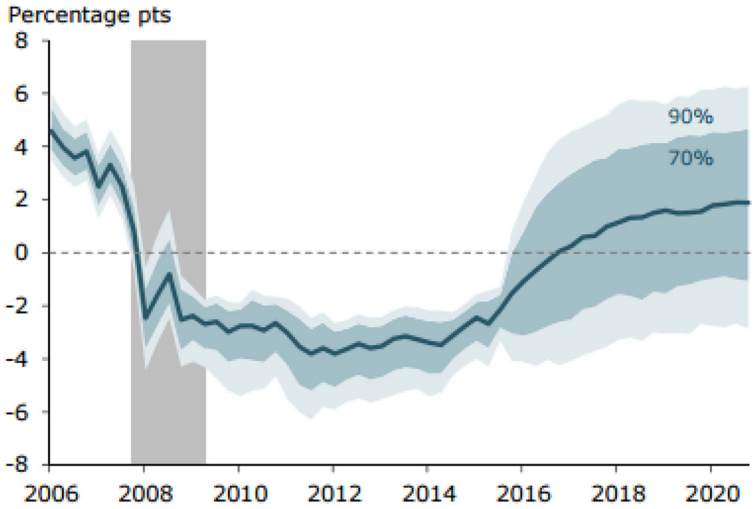
Although the spirit of the Curdia *et al.* (2015) and LW models of the economy is similar their methodologies differ in a number of important respects. In particular Curdia *et al.* (2015) interpret potential output as the efficient level of output. As in Woodford (2003) and Gali (2008) this is the level of output in a perfectly competitive flexible price economy. Correspondingly the natural rate of interest is defined as the rate at which actual output is equal to efficient output. Given that monopolistic competition is a more realistic approximation of markets than perfect competition the efficient output level requires that there exists a system of taxes and transfers that maintains all mark-ups at zero. Second, in order to compare the empirical performance of the T and W rules Curdia *et al.* (2015) add either of those rules or some combination thereof to the structure to be estimated and assume that the Fed sets the FFR by using either the T or the W rule. Finally they perform a large numbers of sensitivity tests.

3.5.1. The impact of the crisis on Curdia (2015) estimates of the natural rate of interest

Curdia (2015) utilizes an updated version of the framework in Curdia *et al.* (2015) to derive in sample and out of sample estimates of the natural rate of interest. **Figure 6** that summarizes those estimates shows that after becoming negative at the end of 2007 the natural rate decreased to around minus four percent during 2009, remained in this range over the entire 2010-2014 period, and is predicted to become positive again only in 2017. As was the case with the LW estimates the big drop in 2008/2009 raises again the suspicion that a large

part of the drop is due to a persistent increase in credit rationing rather than to a persistent decrease in the natural rate of interest.

Figure 6. Curdia's estimates of the natural rate of interest (annual rate)



Note: Blue shaded areas represent the range of possible estimates with 70% (darker) and 90% (lighter) probability. Gray bar indicates NBER recession dates.
Source: Curdia (2015), Figure 1.

But in the case of Curdia's estimates there is an additional factor that, most likely reinforces the post-Lehman downward bias in those estimates. The model used by Curdia *et al.* (2015) partially relies on either the T or the W monetary rule in order to estimate parameters and ultimately identify the path of the natural rate. The specifications of both rules abstract from the fact that since the onset of the subprime crisis the Fed's monetary policy was largely motivated by the financial stability motive[11]. As a consequence both interest rate and quantitative easing (QE) policies were largely responsive to the elevated demands for liquidity by the private sector.

Since both the T and the W rules do not feature a proxy for this reaction, the low interest rate policy of the Fed, as well as the substantial QE operations deployed with the arrival of the ZLB, are attributed to a low and even negative natural rate when, at least part of those policies is due to the reaction of the Fed to the decrease in credit and in asset prices. This omission biases the estimate of the natural rate downward. This can be seen more precisely by adding to both rules a proxy for the financial stability motive of the central bank (CB). A simple way

[11] An early analysis of the impact of this motive on the monetary rule appears in chapter 7 of Cukierman (1992).

to do that is to add a proxy for the deviation of the rate of growth of aggregate credit from a target level of this variable to the right hand sides of both rules. This is illustrated in what follows for the W rule (since the argument is identical for the T rule it is omitted). Abstracting from shocks and the adjustment lag in the CB nominal rate, *i*, the expanded W rule can be written as

$$i - \pi^e = r^n + \phi_\pi(\pi - \pi^T) + \phi_L(l - l^T) \tag{6}$$

where π^T is the inflation target, l is the rate of growth of credit, l^T is the target level for this rate and ϕ_π, ϕ_L are positive coefficients. The expanded rule states that when inflation and the rate of growth of credit are equal to their respective targets the CB conducts monetary policy so as to track the Wicksellian natural rate of interest, r^n [12]. But when the rate of growth of credit is below its target level, the CB reduces the policy rate and, if the zero lower bound (ZLB) is binding, engages in QE operations that are equivalent to further reductions in the policy rate.

The deep and persistent arrest in credit growth in the post-Lehman era documented in Figure 5 is consistent with the view that, during this period the credit growth gap, $l - l^T$, was negative implying that monetary policy was expansionary due to the financial stability motive. When, as is the case in Curdia *et al.* (2015), the term $\phi_L(l - l^T)$ is omitted from the monetary rule the Bayesian estimation procedure interprets the post-Lehman expansionary policies of the Fed as a decrease in the natural rate of interest inducing a further downward bias in the estimates of this variable[13].

Before concluding this section it may be useful to point out an implication of the notion that potential output is identical to the 'no distortions' level of output. As reported above, unlike LW, Curdia *et al.* (2015) interpret r^n as the no shocks interest rate at which actual output is equal to the level of output for which the monopolistic competition distortion is zero. Maintenance of this efficient output level calls for the existence of subsidies that eliminate the monopolistic competition distortion (Gali, 2008; chapter 5).

As a conceptual matter, and since such subsidies do not exist in practice, the natural rate in the model has to be sufficiently low in order to offset this distortion. This calls for a natural rate of interest that is permanently lower than the rate that would have existed if monetary policy had not been burdened with offsetting of the steady state monopolistic competition distortion. The extent to which this consideration pulls the entire path of estimated natural rates

[12] Implicit in this statement is the requirement that expected inflation is also equal to the inflation target.

[13] Relatedly, Taylor and Wieland (2016) attribute the downward bias in natural rate estimates to the omission of regulation from the NK IS relation and to a post-crisis downward deviation of the Fed's rate from the traditional Taylor rule.

downward is not a priori clear. This issue clearly deserves further scrutiny which, however, is beyond the scope of this paper.

3.6. THE CASE FOR DEFINING AND MEASURING A RISKY NATURAL RATE OF INTEREST

Since most investment activity is risky it is likely that such activity is more tightly related to interest rates that account for risk than to riskless rates. Real estate investment as well as consumption durables are also risky activities and are, similarly, more tightly related to risky rates. Investment and consumption demands are major components of aggregate demand. Hence aggregate economic activity should be more tightly related to risky than to riskless rates of interest.

This view is supported by empirical findings in Gilchrist and Zakrajšek (2012) ('CZ' in the sequel) that produce a broadly based index of interest rate spreads between risky corporate bonds and riskless US Treasury bonds during the 1973-2010 period ('CZ credit spread' in the sequel). CZ show that this index possesses substantial predictive ability for future economic activity. They further decompose this index of risk into two components: a component capturing the usual counter-cyclical movements in expected defaults, and a component representing the cyclical changes in the relationship between measured default risk and the CZ credit spreads to which they refer as an 'excess bond premium'. While the first component captures changes in the actual risk of default it is likely that the second is a proxy for changes in the pricing of risk.

CZ show that shocks to the excess bond premium that are orthogonal to the current state of the economy lead to economically and statistically significant declines in consumption, investment, and output, as well as to appreciable disinflation. Figure 4 in CZ also suggest that the positive relationship between the excess bond premium and economic activity is particularly in evidence during the 2007-2009 recession. This finding is consistent with the view that a non-negligible part of this recession was driven by increases in the pricing of risk.

The previous observations suggest that defining and measuring a natural rate of interest that also accounts for 'natural' long term risk and risk preference in the economy is a potentially fruitful extension of the existing riskless natural rate concepts. Risk and the pricing of risk are important determinants of both the supply and the demand for credit. Different secular components of risk and of its pricing imply, therefore, different levels of potential output and of the risky natural rate.

Recognition of the role of this concept opens the door for a more direct link between the health of the financial system, on one hand, and potential output and

the risky natural rate on the other. Since the health of the financial system depends, in turn, on the quality of supervision and of regulation such an approach paves the way for models that would more tightly relate potential output to financial institutions. It also may help establish a more direct link between economic performance, 'financial mood' and underlying financial institutions. By changing risk and risk premia long term changes in the structure of financial institutions and of regulation affect the long run level of credit and with it risky natural rates of interest. Highly visible traumatic events like letting a SIFI institution such as Lehman fail after bailing out many other such institutions are likely to have persistent effect on the "financial mood" and through it on the risky natural rate[14].

During periods of acute financial tensions the spread between longer term risky and riskless debt instruments widens providing an explanation for the fact that, in spite of extremely low short term policy rates, economic activity remains depressed as was the case during the GFC. Since risky long term rates have a substantially stronger impact on both the demand and the supply of credit than short term policy rates it is not surprising that economic activity was depressed during the crisis in spite of policy rates at the ZLB. Furthermore, during crisis times the importance of risk and the pricing of risk become more important determinant of economic activity relatively to the risk free rate than during normal times. Importantly, during a financial crisis risky rates go up rather than down – which pulls the risky natural rate up. A prolonged recession in the aftermath of a financial crisis can therefore be understood as arising from a persistent increase in the natural risky rate of interest due to increases in both risk and its pricing.

Those considerations suggest that during panics and acute financial crises the monetary authority should aim mainly at reducing the natural **risky** rate. Reductions in the short term policy rate is one way to achieve this objective. More important are measures aimed at the reduction of risk and of its pricing on longer term financial instruments. Demonstration of a strong determination to act as a lender of last resort also for risky assets on the part of the central bank is essential. From this perspective, the large scale purchases of long term riskless and risky assets by some major central banks during the GFC were essential for reduction of the risky long term natural rate.

During a financial crisis the capital constraints of financial intermediaries become more severe – which depresses their willingness to supply credit. He and Krishnamurthy (2013) argue that, in such circumstances, injections of equity capital by the CB are particularly effective. This finding along with the relative effectiveness of unconventional monetary policy instruments deployed during the crisis,

[14] Cukierman and Izhakian (2015) argue that the decision not to bailout Lehman and the ensuing panic permanently raised the public's aversion to bailout uncertainty.

suggest that the ZLB constraint on the short term riskless policy rate might be of lesser significance than currently believed.

3.7. CONCLUDING REMARKS

In conventional NK models of monetary policy the short term (real) riskless natural rate plays an important role as a guiding rod for the interest rate policy of the CB. With the onset of the GFC in 2007/2008 nominal policy rates of major central banks quickly reached the ZLB on the (nominal) policy rate and largely remain in this range to this day[15]. With very low and even negative inflation rates this implies that, approximately, the actual real short term policy rate is bounded from below by zero. Consequently if the real short term natural rate is negative the ZLB constitutes a serious constraint on conventional monetary policy.

Recent estimates of the natural rate imply that in the post crisis era the natural rate has been negative, and is expected to remain in this range for some time, supporting the view that the ZLB is a binding constraint on monetary policy. This paper argues that, due to substantial increases in credit rationing and omission of the financial stability motive from the monetary rule during the GFC, existing estimates of the natural rate are likely to be biased downward[16]. Hence the ZLB constraint may not be as serious as implied by those estimates.

There also are conceptual reasons which support the view that the ZLB constraint might not be as serious as it recently appeared to be. It is well accepted that long term risky rates are more important determinants of the output gap and inflation than the short term policy rate. As a matter of fact the conventional view of the transmission mechanism is that, by changing the short term policy rate, the CB will be able to sufficiently move long term risky rates and credit rationing so as to have an appreciable impact on the output gap and inflation. This mechanism is rather indirect even during normal times. But, as demonstrated by the experience of the GFC, it loses much of its punch during crisis times. Recognizing this fact the Fed and other central banks engaged in large scale asset purchases of varying maturities and risks.

This experience suggests that more attention should be payed to the long term risky rate and to the natural counterpart of this rate. Although this appears as a fruitful future research avenue at all time it is particularly important during financial crises when long term risky rates and the short term policy rates often move in opposite directions.

[15] An important factor in the developed world's race to the ZLB is the early and persistent reduction of the federal funds rate to this range by the Fed. This forced other central banks to follow suit in order to prevent excessive appreciations of their own currencies.

[16] Those factors existed also prior to the financial crisis but their relative importance increased substantially with its outbreak. The discussion in Taylor and Wieland (2016) also supports this conclusion.

Introduction of a long term risky natural rate into the analysis of monetary policy is likely to shed more light on the role of regulation and of other financial institutions in the determination of potential output and economic activity. Unlike the short term policy rate risky long term rate are seldom subject to the ZLB. As a matter of fact, during crises, they usually go up. This observation along with the higher relevance of risky long term rates for economic activity implies that the ZLB on the short term riskless policy rate may be of secondary importance. As a matter of fact it is possible that, even in the absence of a ZLB during crises, conventional short term interest rate policy loses much of its punch due to huge increases in demand for liquidity at such times.

Using a model of occasionally binding equity issuance constraints He and Krishnamurthy (2013) show that, in a crisis, equity injection is a superior policy compared to interest rate cuts or bond purchasing programs by the central bank. Incorporation of the natural levels of risk and of risk aversion into a natural risky rate concept is likely to pave the way for shedding new light on the relative desirability of alternative asset purchases programs.

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