# Low real rates as driver of secular stagnation: empirical assessment*

Jan Willem van den End[a], Marco Hoeberichts[a]

[a] *De Nederlandsche Bank, the Netherlands*

16 March 2015

**Abstract**

We empirically test whether there is a causal link between the real interest rate and the natural rate of interest, which could be a harbinger of secular stagnation if the real rate declines. Outcomes of VAR models for Japan, Germany and the US show that a fall in the real rate indeed affects the natural rate. This causality is significant for Japan, borderline significant for Germany and not significant for the US. The outcomes for Japan confirm that a prolonged period of low real rates can affect potential economic growth. The policy implication is that implementing measures that raise the natural rate will be more effective in avoiding secular stagnation than reducing the real rate through higher inflation expectations.

**Keywords**: interest rates, financial markets and the macroeconomy, monetary policy.
**JEL classifications**: E43, E44, E52.

* *Email addresses*: w.a.van.den.end@dnb.nl (J.W. van den End), m.m.hoeberichts@dnb.nl (M. Hoeberichts). We thank Peter van Els, Gabriele Galati, Jakob de Haan, Leo de Haan, Job Swank and participants of the DNB research seminar (2015) for their comments on a previous version of the paper. All remaining errors are our own.

## 1. Introduction

The debate on secular stagnation centres on the natural rate - the short-term real interest rate consistent with full employment - and on the real interest rate.[1] While both rates are related, they have different dimensions and different drivers. The natural rate is a structural variable, driven by real economic factors. While it is unobservable, the natural rate can be approximated by long-term potential economic growth or by the marginal product of capital. The ex-ante real interest rate – measured by the nominal rate deflated by expected inflation - is a cyclical variable, which reflects financial market conditions, inflation dynamics and monetary policy reactions.

The steady downward trend of real interest rates worldwide over the last 30 years has raised the issue of whether the natural rate has fallen in tandem. Blanchard et al. (2014) conclude that the factors that led to low real interest rates are unlikely to be reversed and that the natural rate may remain low as well. This view assumes that the fall in the real rate is a reflection of changing saving and investment patterns which also drive the natural rate. The real rate is than an indicator for the natural rate. Borio and Disyatat (2014) go even further and argue that low interest rates validate themselves, suggesting that the natural rate would fall as a result.

There are several channels through which this causality can run. According to Borio and Disyatat (2014), low real rates stimulate an increase of debts. As a consequence, countries may end-up in a debt trap. In that situation it is difficult to raise rates without damaging the economy and so the interest rate becomes structurally lower. A debt overhang can be mirrored in a suboptimal excess of the capital stock, as a low interest rate reduces the incentive to write-offs the existing capacity (Forbes, 2015). A related channel is that low real rates and high debts create resource misallocations. Choi et al. (2014) formalise this in a general equilibrium model with heterogeneous productivity of agents. If the interest rate falls, the less productive agents start to invest and this diminishes the average quality of investments and thereby potential growth (a proxy of the natural rate). White (2012) extends the misallocation channel in various dimensions, distinguishing between vertical (across time) and horizontal (across sectors) misallocation. Empirical evidence for inefficient resource allocation in the current low interest rate environment across sectors is reported for the UK, where less efficient firms continued operating, causing a substantial increase in the dispersion of firm productivity across sectors (Barnett et al., 2014). Caballero et al. (2008) describe a related channel based on the misallocation of bank credit. They find evidence that after the asset-price collapse in the early 1990s undercapitalized Japanese banks kept on lending to insolvent borrowers (zombies). This kept less productive firms alive and reduced total factor productivity (TFP) growth, which is closely related to our measure of the

[1] See Pagano and Sbracia (2014) for a critical discussion of the secular stagnation hypothesis.

natural rate.[2] Forbearance in bank lending also had some contribution to lower productivity growth in the UK during the recent crisis (Arrowsmith et al., 2013). Another channel through which the financial sphere affects the natural rate is modelled by De Fiore and Tristani (2011), who show that the natural rate falls after a financial shock, represented by rising credit spreads (risk channel). This causality is explained by the protracted decline of consumption as key determinant of the natural rate. In their model the natural rate is independent of monetary policy.

The research question of our paper is whether there is a causal effect that runs from the real rate to the natural rate. This effect has not been investigated empirically in the literature yet, which might be related to the fact that both rates have a different (time) dimension and can only be measured by approximation. The ex-ante real interest rate can be inferred from actual bond yields and market expectations on inflation. Hence, it tends to move with the financial cycle. The natural rate is the steady-state value to which the real rate converges in the long run. In that sense there is also a link running from the natural rate to the actual real rate, with the former being an attractor for the latter. The channel for this causality is that expected returns (i.e. the ex-ante real rate) on investments will be lowered if potential output growth (i.e. the natural rate) declines. This refers to the indicator function of the real rate, which can be influenced by expectations of potential output growth through an information channel.[3] Expected potential output growth can also influence the real interest rate through the credit demand channel. If improving output expectations stimulate investments and credit demand, market interest rate will rise as a result (and vice versa).

We first extend the benchmark model of the natural rate by including the effect of the real interest rate on potential output. Then we investigate the link between the natural rate and the real rate empirically. To account for the likelihood that both variables may influence each other, we estimate bivariate Vector Autoregression models (VAR) for Japan, Germany and the US. The simulation outcomes provide evidence for a (Granger) causal link running from the real rate to the natural rate, which is statistically significant for Japan, borderline significant for Germany and not significant for the US. This result confirms that low real rates can lead to economic stagnation, which has plagued Japan since the early 1990s. For Japan and Germany we find a (Granger) causal link running from the natural rate to the real rate, which reflects that market prices catch up with changing long-term growth prospects.

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[2] See Cizkowicz and Rzonca (2011) for a further discussion of channels that distort credit flows leading to lower TFP-growth.

[3] There are other factors that can influence the natural rate that are beyond the scope of this paper, but relevant in practise and important in the debate on secular stagnation. Here we would like to mention the hysteresis hypothesis for capital and labour. This hypothesis implies that potential output, and hence the natural rate, can be raised by stimulating demand for capital and labour during a recession. Jimeno et al. (2014) argue that supply-side policies will help boost demand in the current weak economic environment in the Eurozone by creating a more dynamic business environment.

Our results suggest that monetary policy actions may affect the natural rate of interest by influencing the real interest rate. The causality between the real rate and the natural rate implies that an expansionary monetary policy which successfully reduces real rates can become less effective for two reasons. First, the desired stimulus on demand, which depends on the difference between natural and real rate, will be smaller (monetary policy is expansionary if the short-term real interest rate lies below the natural rate and a decline of the natural rate thus reduces the monetary stimulus effect). Second, a decline of the natural rate, i.c. potential output growth, will affect inflation, lift the real rate and so counteracts the monetary policy stance.

The rest of the paper is structured as follows. In Section 2 we motivate how the benchmark model of the natural rate can be extended by including the relationship with the real rate. Section 3 explains how we determine the real rate and the natural rates empirically and in Section 4 we specify the VAR model. The simulation outcomes are presented in Section 5 and Section 6 draws some policy conclusions.

## 2. Benchmark model

In the literature, models used to estimate the natural rate assume that potential economic growth is independent of the real interest rate. In the benchmark model of Laubach and Williams (2003) the level of potential output ($y$*) is determined by,

$$y_t^* = y_{t-1}^* + g_{t-1} + \varepsilon_{1,t} \tag{1}$$
$$g_t = g_{t-1} + \varepsilon_{2,t} \tag{2}$$

which specifies the log level of potential output ($y$*) as a function of its growth rate $g$. The trend growth of output also determines the natural rate of interest ($r$*),

$$r_t^* = c\ g_t + z_t \tag{3}$$

where $z_t$ captures other determinants of $r_t^*$, such as households' rate of time preference. Laubach and Williams assume that $z_t$ either is a stationary autoregressive process, a random walk or that it is a constant term. In their model estimations, the coefficient $c$ (which relates the natural rate to the trend growth rate) is near unity, which implies that the natural rate by and large equals the trend growth rate (assuming that $z_t$ is a residual term with an expected value of zero). Both the natural rate of interest and potential output enter the demand curve (IS curve),

$$\tilde{y}_t^* = A_y(L)\tilde{y}_{t-1}^* + A_r(L)(r_{t-1} - r_{t-1}^*) + \varepsilon_{3,t} \quad (4)$$

where $\tilde{y}_t^* = (y_t - y_t^*)$ is the output gap, $y_t$ is real GDP and $r$ is the real interest rate. Figure 1 shows the IS curve (Equation 4) and potential output (Equation 1) in a stylized form, as in Williams (2003). The downward-sloping curve indicates a negative relationship between spending and the real interest rate. The vertical line presents the level of potential GDP, which is assumed to be unrelated to the real interest rate, as in Equations 1 and 2. At the intersection of the IS curve and the potential GDP line, the real interest rate equals the natural rate of interest.

We extend the model by assuming that the real interest rate $r$, affects the trend growth of output $g$. Although this relationship is not included in the benchmark model, Williams (2003) mentions that in principle potential output is also a function of the real rate. The various channels through which the real interest rate can affect the natural rate (as described in Section 1) also provide economic arguments to modify the model with this link. It changes Equation 2 to,

$$g_t = \beta g_{t-1} + \alpha_r r_{t-1} + \varepsilon_{4,t} \quad (5)$$

Through the adjusted trend growth rate ($g_t$) the real interest rate also influences potential output (Equation 1) and thereby the natural rate (Equation 3). The sign and the size of the effect of the real rate are captured by coefficient $\alpha_r$. If $\alpha_r$would be negative, the potential output curve is downward-sloping, as in Figure 2. If $\alpha_r$would be positive, the potential output curve is upward-sloping, as in Figure 3. In the next sections the coefficient $\alpha_r$ is estimated, together with coefficient $\beta$. If $\beta$ = 1 and $\alpha_r = 0$, then the estimated model would be similar to the benchmark model specified in Equation 2.

## 3. Data

In the literature the natural rate is proxied in three ways. First, it can be estimated as the (filtered) trend output growth as in equation 3 (see also Bouis el al., 2013). This is primarily a backward looking method and therefore less useful for our research question. Second, the natural rate can be based on theoretical models as the steady state rate in a general equilibrium set-up (e.g. Eggertsson and Mehrotra, 2014). Such approaches require assumptions on the fundamental drivers of the natural rate that are not necessarily realistic, but can have large implications. De Fiore and Tristani (2011) show that the reactions of the natural rate to shocks depend on the modelling assumptions; after a positive technology shock the natural rate can increase in a model without financial frictions and fall in a model with asymmetric information and monitoring costs. Hamilton et al. (2015) show empirically that the link between output growth and the equilibrium interest rate (measured as the average real rate) is weak, since the rate is also influenced by other factors, like regulatory and fiscal policies. Third, the natural rate can be inferred from the yield curve, in particular from market expectations on the short-term interest rate over a long horizon. The expected path of the short-term real interest rate reflects market expectations on the monetary policy stance, which in turn, is driven largely by the economic outlook. A draw-back of using market expectations is that they may deviate from fundamentals due to market distortions.

Our proxy for the natural rate relates to the third method. We use survey information on the expected long-term economic growth rate as proxy for the natural rate ($r^*$). The low frequency of survey data is usually seen as a disadvantage, but for our application it is not, since our research question relates to the longer-run properties of expectation measures. In particular, we use expectations on economic growth for the next 5 to 10 years as provided by Consensus Economics. This matches with the Consensus expectations on cpi inflation 5 to 10 years ahead ($\pi_{5..10y}$), which is used to infer the ex-ante real rate 5 to 10 years ahead ($r_{5..10y}$) from the point in time 10 years nominal bond yield ($i_{10y}$),

$$r_{5..10y} = i_{10y} - \pi_{5..10y} \tag{6}$$

An advantage of using the Consensus expectations for both $r^*$ and $r$ is that the single data source enhances the consistency of the series in terms of measurement and frequency. Moreover the series are available from 1990 to 2014 on a bi-annual basis, which is a longer time span than covered by most other sources (for instance market prices of inflation expectations[4]). We use data for Japan, the US and Germany (as proxy for the euro area; data series for the euro area only start in 2003).

Figure 4 shows that our proxy for the natural rate has a long downward trend in Japan, which - to a lesser extent – is also visible in Germany. The US natural rate has trended down only since the early 2000s, after a substantial increase at the end of the 1990s, early 2000s. Real rates have a persistent downward trend in all three countries (Figure 5). The apparent disconnect between $r^*$ and $r$ in the US at the end of the 1990s, early 2000s may be a reflection of overestimated economic growth prospects during the new economy euphoria, which were not reflected in real interest rates. The fall in the Japanese real rate accelerated in the 1990s, whereas the decline of the real rates in the US and Germany accelerated in the most recent years of the sample.

[4] Inflation expectations based on market prices can be inferred from inflation linked bonds or inflation indexed swaps, which are available from 2004 onwards for the US and the euro area and from 2007 onwards for Japan. An alternative source for survey data on long-term inflation and economic growth is the Survey of Professional Forecasters (SPF), but this survey is only available for the US, the euro area since 1999, Japan since 2009 and not for Germany.

Table 1 shows that nominal bond yields and expected inflation in Japan and the US are cointegrated in, in line with the Fisher hypothesis. The natural rate and the real rate are cointegrated only in the case of Japan. Unit root tests indicate that $r$ is only stationary in Japan, while $r^*$ in all three countries is only stationary after first differencing I(1). The unit root hypothesis with regard to $r^*$ cannot be rejected even if we control for "unknown" trends or structural breaks in the data. This result follows from the Ng and Perron (NP) tests, which is based on detrended data (Ng and Perron 2001). Controlling for structural breaks is important because the interest rate series may contain structural breaks due to regime shifts in monetary policy or fundamental changes in the functioning of financial markets. Both features are included in the NP test statistics MZt in Table 1. An important caveat with regard to the test outcomes is that our sample period may be too short to find mean reverting behaviour in interest rates.

In the robustness check in Section 4 we also use an alternative natural rate, proxied by the trend output capacity (reflecting potential economic growth) as estimated in the macro model NiGEM (Figure 6).[5] This variable ($r^{*,nigm}$) is non-stationary for Germany, Japan and the US according to most unit root tests (Table 1). However, the variable $r^{*,nigm}$ is cointegrated with the real rate $r$ in all three countries.

Our measure of $r^*$ for the US differs from the natural rate estimated by Laubach and Williams (2003). While $r^*$ based on Consensus expectations increased at the end of the 1990s, at that moment in time the rate estimated by Laubach and Williams already started to decline (Figure 7). The latter has a persistent downward trend and became negative in 2011.[6] The model outcomes of the natural rate are highly sensitive to modelling assumptions. Laubach and Williams show, for instance, that changes in shocks to $g$ (the residual term in Equation 2) have a large effect on the magnitude of time variation in the trend growth rate and thereby on estimates of the natural rate. The same holds for assumptions on the variability of $z_t$ in Equation 3. They conclude that this casts considerable doubt on the ability to estimate the natural rate of interest with much precision in real time. The difference between our measure of $r^*$ and the estimate by Laubach and Williams is primarily driven by the value of $z_t$ as assumed by Laubach and Williams. The process of $z_t$ that determines the natural rate in Figure 7 follows a random walk and $z_t$ has become substantially negative since the crisis started in 2007. This suggests that $z_t$ captures a risk premium[7], which is not included in our measure of $r^*$. However, the risk premium is included in our measure of the real rate ($r$), since the term premium, which reflects a

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5 In the National Institute Global Econometric Model (NiGEM), the capacity output variable is estimated using a CES production function. We transform this level variable to a bi-annual year-on-year growth rate, by taking annual changes of two quarters averages. The natural rate based on NiGEM is strongly correlated with the natural rate based on the Consensus forecast (correlation coefficient Germany +0.84, Japan +0.87, US +0.15).

6 The updated estimates are available at: http://www.frbsf.org/economic-research/economists/johnwilliams/Laubach_Williams_updated_estimates.xlsx.

7 The correlation between variable $z_t$ and the Baa rated corporate bond spread is high (correlation coefficient -0.68).

risk premium, is one of the components of the government bond yield and thereby of *r*. By this our approach captures the financial risk channel of De Fiore and Tristani (2011), through which the natural rate can be affected. Hamilton et al. (2015) also find a large uncertainty around the equilibrium rate and argue that the recent decline of the natural rate is partly cyclical. Following from that, they conclude that the range of the equilibrium rate is currently between 1 and 2%.

## 4. Estimation technique

To estimate the relationship the relationship between the real rate of interest and the natural rate the potential mutual interaction effect should be taken into account. This is recognized in the following VAR model, which treats the variables in the system as endogenous,

$$Y_t = A_0 + A(L)\, Y_t + e_t \tag{7}$$

where $Y_t$ is a vector containing the ex-ante real interest rate ($r$) and the natural rate ($r^*$), $A_0$ is vector with constant terms and $e$ the vector with error terms. Matrix $A(L)$ is a matrix polynomial in the lag operator whose order is $p$.

We specify two types of bivariate VAR models: model 1 with both $r$ and $r^*$ in levels and model 2 with both $r$ and $r^*$ in first differences. Outcomes of the unit root tests as reported in the previous section indicate that model 1 is more appropriate for Japan, whereas model 2 is more appropriate for Germany and the US, given the absence of cointegration between the real rate and the natural rate in those countries. The order $p$ of lag operator $A(L)$ is determined by different information criteria.[8] They indicate an optimal lag length of one for model 1 and an optimal lag length ranging between one and four for models 2 and 3 (we choose a lag length of two[9]).

We orthogonalize the shocks of the impulse responses by assuming that the natural rate ($r^*$) affects the real rate ($r$) contemporaneously, as well as with lags, while the real rate affects the natural rate only with lags. This assumption is based on the common understanding that the natural rate is a long-term structural variable, which moves slowly, whereas the real rate is a cyclical variable. In other words, the natural rate is more exogenous than the real rate. It provides an identification strategy that is similar for an unrestricted VAR model (UVAR) and a structural VAR model (SVAR). In a UVAR the shocks

8 Sequential modified LR test statistic (LR), Final prediction e Akaike information criterion (AIC), Schwarz information criterion (SC), Hannan-Quinn information criterion (HQ), each test at 5% level.

9 We experimented with different lag lengths and it turned out that the number of lags did not make a significant difference in the impulse responses.

are identified by Cholesky decomposition, by which the ordering conditions (i.e. $r$ is ordered after $r^*$) impose a similar restriction as the short-run restriction imposed to identify an SVAR in our bivariate model (Amisano and Giannini, 1997),

$$Ae_t = B\,\varepsilon_t\,, \quad \text{with} \quad \varepsilon_t = \begin{bmatrix} \varepsilon_t^{r^*} \\ \varepsilon_t^{r} \end{bmatrix} \tag{8}$$

Matrix $A$ transforms the observed, reduced form residuals ($e_t$) and generates a new vector $Ae_t$ by linear combinations (through matrix $B$) of the structural innovations ($\varepsilon_t$). Matrices $A$ and $B$ have to be estimated to recover the structural innovations ($\varepsilon_t$) from the observed residuals ($e_t$). Identification by Cholesky decomposition restricts $A$ to a lower diagonal matrix with ones on the diagonal and the element above the diagonal being zero, i.e. $a_{12}$ = 0, with $B$ being a diagonal matrix. This is equal to imposing the short-run restriction that the response of variable $r_t^*$, to structural shocks in $\varepsilon_t^r$ is zero in an SVAR (which also means that $a_{12}$ = 0). Under these restrictions $Ae_t = B\,\varepsilon_t$ can be written as,

$$\begin{aligned} e^{r^*} &= b_{11}\varepsilon^{r^*} \\ e^{r} &= -a_{21}e^{r^*} + b_{22}\varepsilon^{r} \end{aligned} \tag{9}$$

## 5. Outcomes

The impulse responses of the VAR estimated with variables $r$ and $r^*$ in levels (model 1) show that in the case of Japan both variables react significantly and positively to a shock in the other variable (Figure 8.a). Hence, a negative (positive) shock to the real rate leads to a decline (increase) in the natural rate and vice versa, which points at a (Granger) causal relationship. The response is quite persistent and substantial in economic terms; a negative (positive) shock to $r$ by 1 percentage point leads to a decline (increase) in $r^*$ by 0.26 percentage points, one year later (at t-2, when the response peaks). A negative (positive) shock to $r^*$ by 1 percentage point leads to a decline (increase) in $r$ by 0.75 percentage points (at t-3).[10] This implies that the coefficient $\alpha_r$, as defined in Section 2, is positive and significant.

For Germany and the US, the natural rate shows a positive response to a shock in the real rate as well. This effect is borderline significant for Germany, but not statistically significant for the US at the 95%

[10] The Figures show impulse responses after a shock of one standard deviation, while we scale this shock to a one percentage point shock in the text of this section to provide intuition on the economic substance of the effects.

confidence interval (Figures 9.a and 9.a). With regard to the statistical causality that runs from the natural rate to the real rate, the impulse response is significant and sizable for Germany. The simulation outcome of model 1 shows that a 1 percentage point negative (positive) shock to $r^*$ is followed by a 1.29 percentage point decline (increase) in $r$ after 3 years (t-6, when the response peaks). In case of the US there is no significant response of $r^*$ after a shock in $r$. Our results are in line with those of Burns and Reid (2014), who find for a long historical data series of 20 large advanced economies that low real yields might encourage or coincide with low real economic growth.

The impulse responses of model 2 (i.e. both $r$ and $r^*$ in first differences) also show that the response of $r^*$ after a shock in $r$ is (borderline) positive and significant in the case of Japan (Figure 8.b). For Germany and the US the impulse responses of $r^*$ after a shock in $r$ are generally positive as well, although not statistically significant at the 95% confidence interval (Figures 9.b and 10.b). In model 2 the responses of the real rate after a shock in the natural rate are not statistically significant in all three countries.

As a first robustness check we re-estimate the model with the alternative natural rate, based on the trend output capacity estimated in the macro model NiGEM. Since this variable $r^{*,nigm}$ is cointegrated with the real rate $r$ in all three countries, the VAR model can be estimated with both variables in levels. The impulse responses confirm the outcomes presented above. Both $r$ and $r^{*,nigm}$ react significantly and positive to a shock in the other variable, although the responses are not statistically significant in the US (both ways) and Germany (response of real rate to shock in natural rate, see Figure 11.a-c).

In a second robustness check we include (one by one) additional variables in the VAR. We selected variables that we expect to affect the real interest rate in the short run. In doing so, we hope to detect a potentially spurious effect from the natural rate on the real rate in our original specification. We include expected and realised growth of industrial production as well as the unemployment rate in the VAR. Although some of these variables are highly significant, they do not change the impulse responses for our variables of interest. We also obtain qualitatively identical results when we compute the impulse responses in a VECM framework.

It is often argued that demographic trends play a major role in explaining long-term developments in productivity and economic growth. Population growth could therefore also affect the relationship between real interest rates and the natural rate. For that reason we also run a robustness check with population growth included in the VAR-models for the three countries. The coefficient for (lagged) population growth turns out to be significant for the US real interest rate and almost significant for the natural rate in Japan. However, including population growth does not really change the results on the relationship between the natural rate and the real rate of interest in the three countries; the impulse responses of both variables look similar to the model excluding population growth.

The differences in the outcomes for the three countries suggest that there are fundamental differences in the channels through which the real rate can affect the natural rate. In the case of Japan the literature provides evidence on distortions in the financial sector which added to a misallocation of resources and reduced potential output growth. Japan also experienced the longest period of ultra-low interest rates of all three countries, making potential resource misallocations most likely. In the US, the recapitalisation of the banks in 2008-2009 addressed the potential distortions in the financial allocation process swiftly, which may be one explanation for the finding that there is no significant response of $r^*$ after a shock in $r$. Another explanation may be the diversified structure of the US financial system, which makes output growth less dependent on a particular source of finance. Compared to the US, the euro area is relatively dependent on bank finance. Since problems in the euro area banking sector have lingered on for longer, financial misallocation is more likely, which could explain the borderline significant response of the natural rate to shock in the real rate in Germany.

## 6. Conclusion

The theoretical literature has identified several channels through which a low real rate can lead to a fall in the natural rate, for instance by a debt trap and resource misallocations which undermine potential economic growth. We test the hypothesis empirically with a bivariate VAR model for Japan, Germany and the US. This approach is used to detect whether is a (Granger) causal relationship between the real rate and the natural rate.

The simulation outcomes show that a downward shock in the real rate indeed lowers the natural rate, which is most obvious for Japan and to a certain extent also present in Germany. The statistical causality also runs the other way for Japan and Germany, i.e. a shock in the natural rate affects the real rate. It reflects that market prices catch up with changing long-term growth prospects. For the US we do not find a link between the natural rate and the real rate that is statistically significant. Robustness checks confirm the results.

Our results lend support to concerns that a prolonged period of low real rates affects the real economy. It can undermine potential economic growth through real and financial channels. This is confirmed for Japan, where we find a significant link between the real rate and the natural rate. It illustrates the dynamics in the country over the last 15 years between the ultra-low real rates and persistent economic stagnation.

From the model results we infer two policy conclusions. First, expansionary monetary policy may become less effective, since by reducing real rates, this policy will also affect the natural rate. This diminishes the stimulus effect on demand, which depends on the difference between natural and real rate. Second, raising the natural rate will be more effective in avoiding secular stagnation than policy aimed at reducing the real rate, for instance by lifting inflation expectations. The latter may even be counterproductive in the sense that it reduces real rates and long-term potential growth. Potential growth – and thereby the natural rate – can be raised by structural reforms in labour, product and financial markets, which will unleash new dynamics in the economy. The positive growth effects of structural reforms are quantified by Jimeno et al. (2014) amongst others. They show that creating a more dynamic business environment can boost investments and thereby economic growth. Moreover, addressing problems in the banking sector, for instance through swift recapitalisation, is important to limit the risk of resource misallocation through the bank lending channel.

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**Figure 1. Determinants of the natural rate (excluding real rate)**

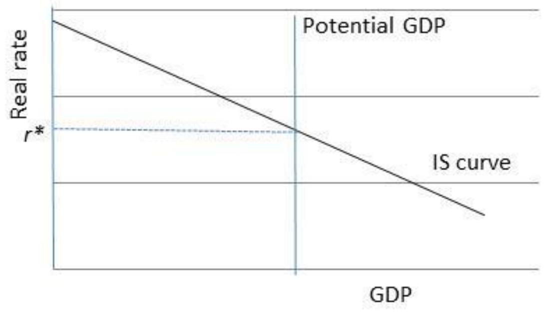


**Figure 2. Determinants of the natural rate (α with negative sign)**

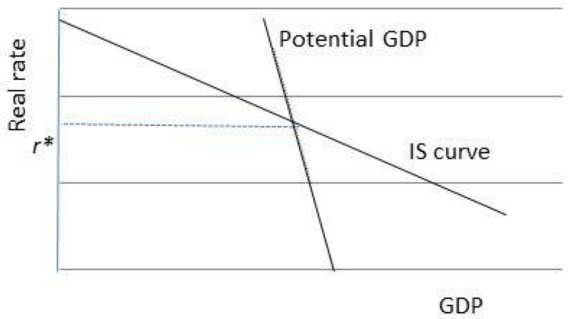


**Figure 3. Determinants of the natural rate (α with positive sign)**

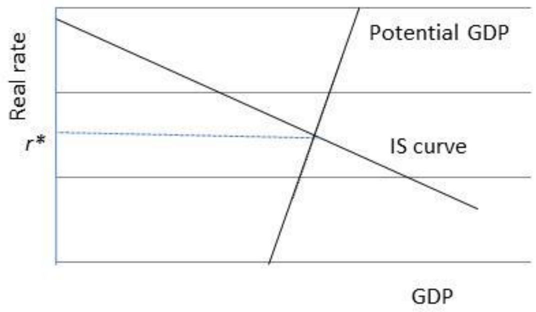

**Figure 4. Natural rates based on Consensus forecast**
Percentage

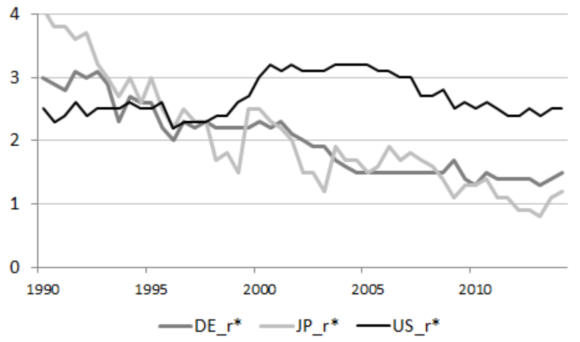


**Figure 5. Real interest rates**
Percentage

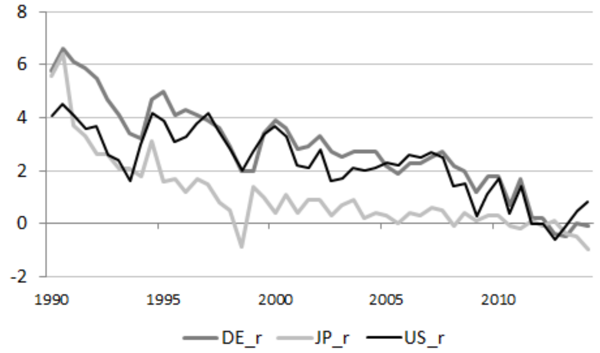


**Figure 6. Natural rates based on NiGEM**
Percentage

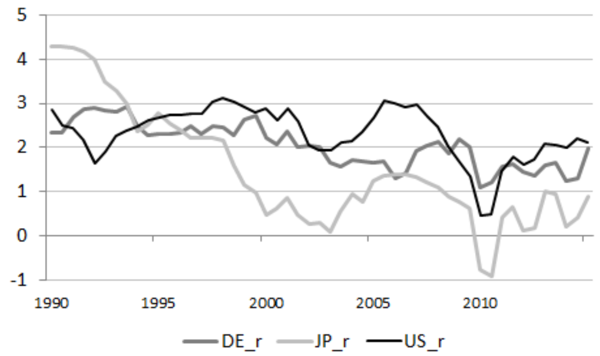


**Figure 7. Natural rates based on Consensus forecast and on Laubach and Williams**
Percentage

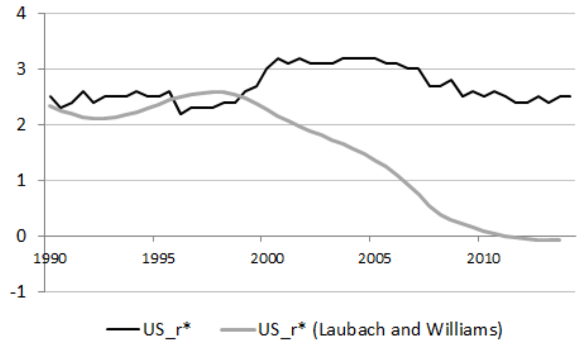

**Table 1. Test outcomes**

| | DE | US | JP |
|---|---|---|---|
| Cointegration test $(i,\ \pi)$[1] | 7.82 | 18.16** | 41.58*** |
| Cointegration test $(r,\ r^*)$[1] | 8.75 | 7.30 | 39.70*** |
| Cointegration test $(r,\ r^{*,nigem})$[1] | 16.87** | 17.02** | 37.26*** |
| Real rate $(r)$ | | | |
| ADF, unit root test[2] | -1.24 | -1.99 | -5.08*** |
| NP $MZ_t$ unit root test[3] | -0.08 | -1.29 | 0.17 |
| Natural rate $(r^*)$ | | | |
| ADF, unit root test[2] | -1.66 | -1.48 | -2.35 |
| NP $MZ_t$ unit root test[3] | -0.36 | -1.37 | -0.32 |
| Natural rate $(r^{*,nigem})$ | | | |
| ADF, unit root test[2] | -1.26 | -2.52 | -2.57 |
| NP $MZ_t$ unit root test[3] | -1.11 | -2.39** | -0.72 |

[1] Trace statistic, Johanson test for cointegration (constant, no trend),
H0: no cointegration. *** H0 rejected at 1% confidence level, ** 5%, * 10%.
[2] Augmented Dicky Fuller test (test with constant and no trend), H0: interest rate has unit root.
[3] Ng Perron test-statistic (test with constant and no trend), H0: interest rate has unit root.

**Figure 8.a. Impulse responses Japan (model 1)**

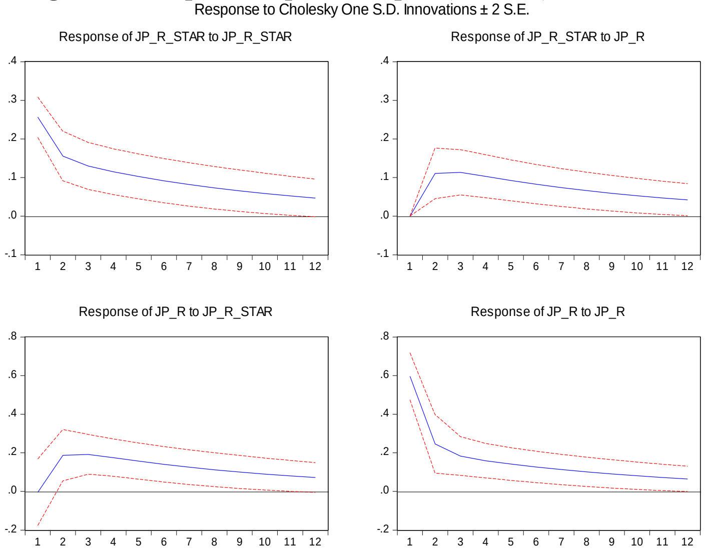


**Figure 8.b. Impulse responses Japan (model 2)**

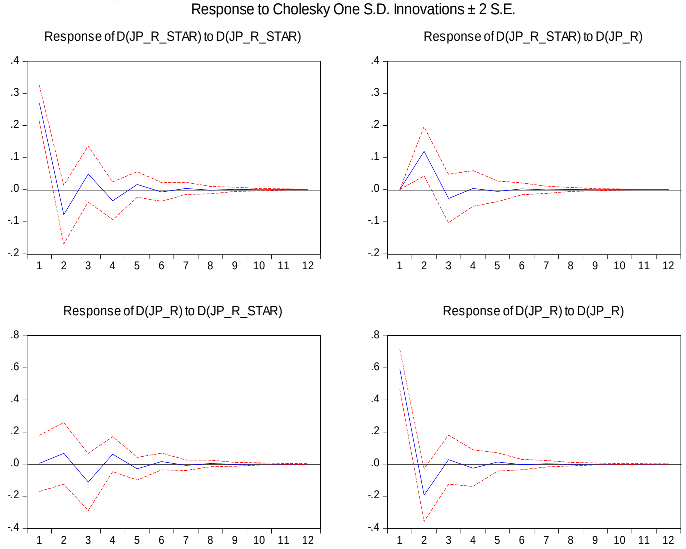


**Figure 9.a. Impulse responses Germany (model 1)**

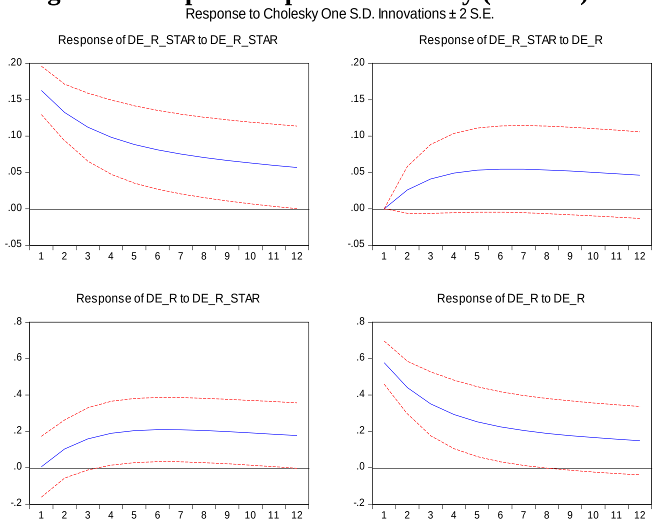


**Figure 9.b. Impulse responses Germany (model 2)**

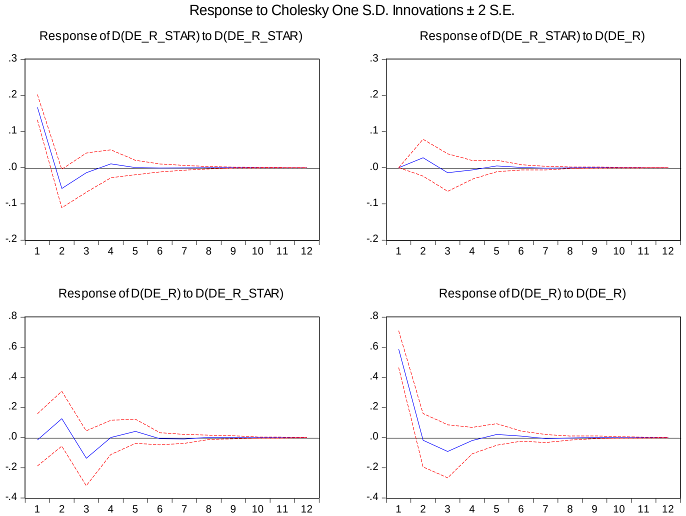

**Figure 10.a. Impulse responses US (model 1)**

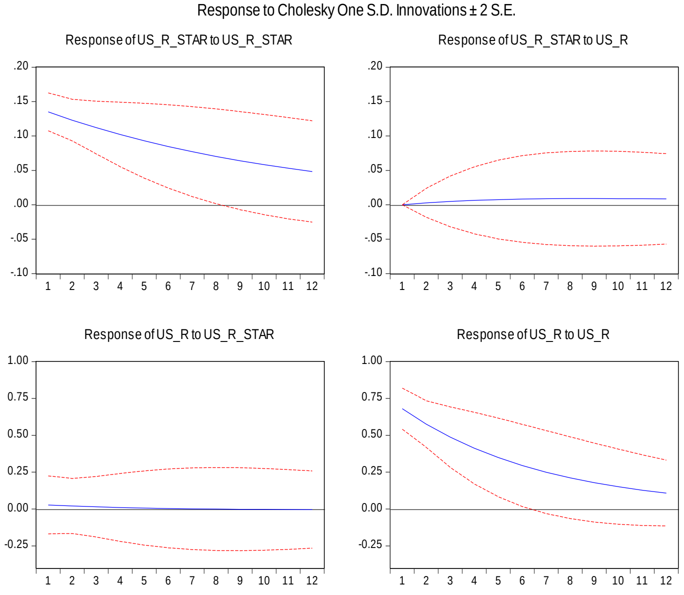


**Figure 10.b. Impulse responses US (model 2)**

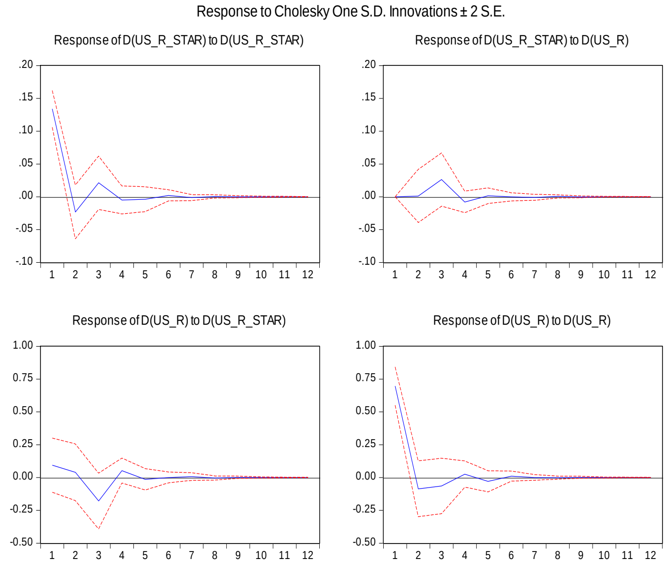


**Figure 11.a. Impulse responses Japan (model 1)**

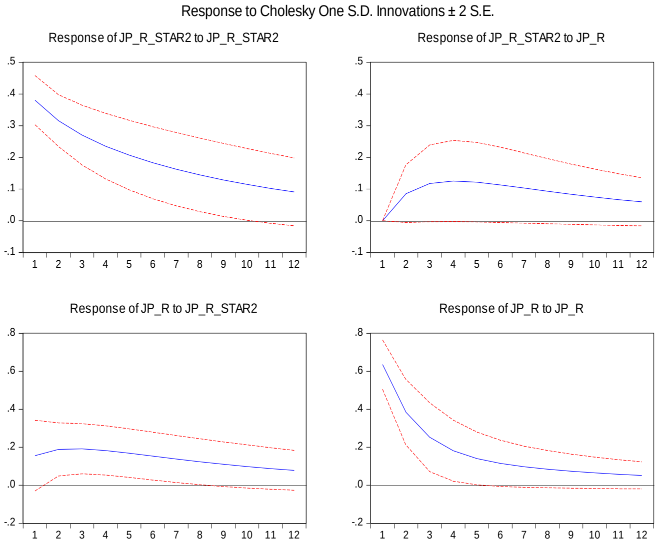


**Figure 11.b. Impulse responses Germany (model 1)**

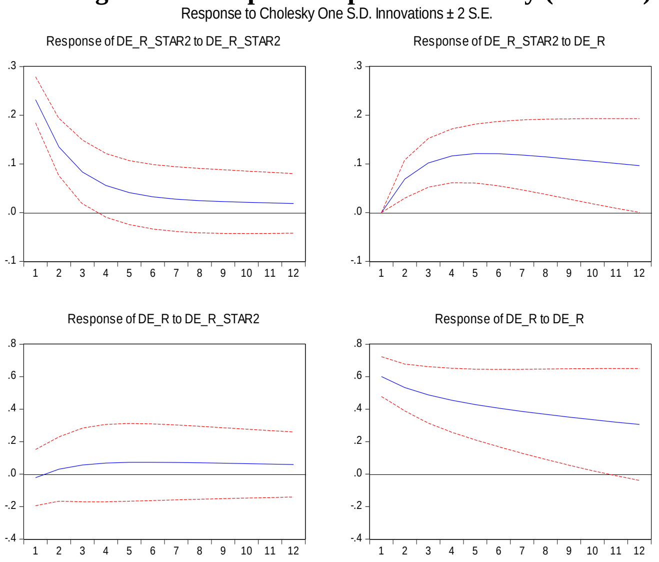


**Figure 11.c. Impulse responses US (model 1)**