Nationaløkonomisk Tidsskrift 150 (2012): 21-41

Rules versus Dictation: A Taylor Rule for Denmark

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SUMMARY: *As Denmark has pegged its currency to the euro, the Danish short-term interest rate is effectively dictated by the European Central Bank (ECB). This implies an inherent risk that the interest rate set by the ECB might fall 'out of sync' with respect to the Danish business cycle. In the present paper, I compare the actual interest rate in Denmark during the period 1994-2009 to the interest rate that would have been prescribed by the Taylor rule. As the Taylor rule proposes that the interest rate should be adjusted to stabilize output and inflation around their target values, this rate reflects the business cycle situation in Denmark. I find that while the movements in the actual interest rate display a large correlation with those of the Taylor rule rate, the two rates differ substantially from time to time. A high correlation is prevalent especially since 1999, when the euro replaced the D-mark as the currency to which the Danish Krone is pegged. However, a number of episodes can be identified in which the actual interest rate was considerably lower than what would have been prescribed by the Taylor rule. Thus, while the interest rate 'dictated' by the ECB has not in general been out of sync with the Danish business cycle, it does occasionally display sizeable deviations from the interest rate warranted by the business cycle situation in Denmark.*

1. Introduction

Since 1982, Denmark has been pursuing a fixed exchange rate policy. Initially, the Danish Krone was pegged to the German D-mark, and since 1999 the exchange rate has been fixed towards the euro. As a result, monetary policy in Denmark has been concerned with the sole objective of keeping the exchange rate at its fixed level. In practice, this implies that the interest rate in Denmark largely follows the movements of the interest rate set by the European Central Bank (ECB).

The author wishes to thank Niels Blomquist, Henrik Jensen, Morten Spange, seminar participants at Danmarks Nationalbank, and an anonymous referee for helpful comments and discussions. Any remaining errors are my own. The views expressed in the paper are those of the author, and do not necessarily correspond to those of Danmarks Nationalbank.

However, the fact that Denmark does not use its monetary policy to actively stabilize the economy does not mean that the interest rate has no effect on business cycle fluctuations in Denmark. In this paper, I compare the actual interest rate in Denmark during the period 1994-2009 to the interest rate that would have been prescribed by a simple interest rate rule, the Taylor rule, Taylor (1993). According to this rule, the interest rate should be adjusted so as to stabilize output around its trend and inflation around a target level chosen by the central bank. Hence, the Taylor rule is an example of an active, yet non-discretionary stabilization policy, and the interest rate it suggests can to some extent be interpreted as the level that 'fits' the current, domestic business cycle situation.[1]

I argue that a flexible exchange rate with an inflation target is the most relevant alternative to a fixed exchange rate for Denmark. However, I do not claim to answer the question of what would have happened if Denmark had adopted a different exchange rate policy. Given the counterfactual nature of that question, it would not be possible to arrive at a certain answer. Rather, the Taylor rule provides an interesting theoretical benchmark against which to compare the actual interest rate, and in particular, the appropriateness of the actual interest rate given the stance of the Danish business cycle at any point in time.

The main result of the paper is that apart from a few periods of considerable deviations, the movements of the actual interest rate have to a relatively large extent been similar to those of the Taylor rule-based interest rate for the post-1999 period, i.e. since the euro replaced the D-mark as the currency to which the Krone is fixed. This conclusion is broadly in line with that of DØRS (2009). The correlation between the actual and the hypothetical rate is quite high for this period, and is relatively robust to different parametrizations of the Taylor rule. The two interest rates do, however, differ substantially on some occasions, as discussed in subsection 3.1. On the other hand, during the period 1994-1998, the actual rate differs considerably from the 'Taylor rate'. These findings are consistent with the results of Dam (2008), who concludes that the correlation between the Danish business cycle and that of the euro area increased markedly towards the end of the 1990's, and has since then remained high. To the extent that the movements in the interest rate of the ECB (and thus in the Danish interest rate) reflect the current stance of the business cycle in the euro area, one would expect a higher correlation of Danish and euro area business cycles to result in a higher correlation between the actual interest rate and the Taylor rate for Denmark.

A central argument against fixed exchange rates (and, in particular, against monetary unions) is the possibility of asymmetric or country-specific shocks. Such shocks

1. This is not the same as saying that this rate is 'optimal'. In this paper, I abstain from discussing the optimal monetary policy for Denmark.

call for different monetary policy reactions across countries, which is impossible under fixed exchange rates. If Denmark had been hit by asymmetric shocks relative to the euro area, these are likely to have resulted in large deviations between the Taylor rate and the actual interest rate. However, not only is the correlation between the two rates for the period 1999-2009 quite high. I also find that most of the episodes of considerable deviation are attributable to factors not specific to the Danish economy. This suggests that during this period, the concern of asymmetric shocks has not been very relevant empirically for Denmark.

The rest of the paper is organized as follows. Section 2 describes actual monetary policy in Denmark as well as the alternative of a flexible exchange rate with an inflation target. The Taylor rate for Denmark is calculated in Section 3. In Section 4, I discuss the robustness of the Taylor rate to a number of changes in the specification and parametrization of the Taylor rule, while Section 5 concludes.

2. Rules versus dictation: Monetary policy in Denmark

As described in the introduction, since 1982 monetary policy in Denmark has been entirely devoted to the sole objective of maintaining the fixed exchange rate vis-a-vis the euro (respectively, the D-mark before 1999). In other words, Danish interest rate policy is largely dictated by the ECB. In the following, I compare the interest rate in Denmark during the period 1994-2009 to the alternative of a floating exchange rate and a rule-based conduct of monetary policy with an inflation target. This alternative is of course not the only possible scenario. Indeed, one might think of infinitely many paths for monetary policy. As an example, Denmark could have chosen to carry on its highly discretionary monetary policy of the 1970's.

However, the choice of a flexible exchange rate regime with an inflation target as the relevant alternative is not at all arbitrary. Over the last two decades, inflation targeting has obtained a central position in the academic literature on monetary policy. During the same period, a number of small, open economies (including Norway, Sweden and New Zealand) have adopted this monetary policy regime. Hence, I consider this the most obvious alternative. This seems to be supported by Sørensen and Whitta-Jacobsen (2005), who present a flexible exchange rate with an inflation target as the natural alternative to a fixed exchange rate, and by Dam and Linaa (2005), who evaluate the possible welfare gain if Denmark replaced its currency peg by a Taylor rule.[2] In the present paper, I consider a regime where inflation targeting is in practice pursued by a rule-based conduct of monetary policy through the Taylor rule. This does not

2. To be precise, Sørensen and Whitta-Jacobsen suggest a flexible exchange rate with inflation *forecast* targeting. This is highly similar in spirit to inflation targeting. In subsection 4.5, I discuss the possible use of expected instead of actual inflation in the policy rule.

mean that inflation targeting and the Taylor rule are two sides of the same coin. An exhaustive discussion of the differences and similarities between inflation targeting and Taylor rule-based monetary policy is beyond the scope of this paper, see instead Svensson (2003). However, as discussed by both Rudebusch and Svensson (1999) and Taylor (2000), the Taylor rule is one way of implementing an inflation targeting policy. In any case, even if a central bank is conducting its inflation targeting in a different way – for instance by the minimization of a social loss function – the Taylor rule might still provide a reasonable description of the policy outcome. As a consequence, I will restrict my attention to a rule-based approach. The impact of the Taylor rule on actual monetary policymaking is witnessed by the fact that, as documented by Asso et al. (2010), several members of the Federal Open Market Committee (FOMC) have referred to the Taylor rule in discussions about the appropriate interest rate level.[3] Norges Bank uses three different versions of the Taylor rule 'to cross-check [their] interest rate path', Alstadheim et al. (2010). This lends support to the choice of an inflation-targeting, Taylor rule-driven monetary policy as the most relevant alternative for Denmark.

2.1 Counterfactual interest rate paths – a word of caution

As observed by Taylor (2007b), comparing the actual interest rate path to the one prescribed by the Taylor rule has become a popular exercise among economists. As the Taylor rule is a highly simplified, theoretical rule, one would think that the purpose of this exercise would be to evaluate the performance of this rule against the natural benchmark that the actual interest rate path provides. This would be similar, for instance, to the way macroeconomic models are often judged based on their ability to replicate various characteristics of real-world data. However, in recent years the burden of proof seems to have been reversed, with the interest rate prescribed by the Taylor rule serving as a benchmark for an evaluation of the performance of central banks. Indeed, Taylor (2007a) criticizes the US Federal Reserve for deviating from the policy rule during the years 2002-2006. In the aftermath of the financial crisis, this deviation has been criticized (Taylor 2007a) for having contributed to the boom and bust of the US housing market and the subsequent financial crisis. Bernanke (2010) addresses this critique but, while emphasizing the limitations of the simple, rule-based approach, devotes substantial attention to the comparison between the actual interest rate in the US and that prescribed by the Taylor rule.

Gerdesmeier et al. (2007) discuss some of the limitations of the Taylor rule. In particular, they point to three types of criticism. First, by only considering (in the simplest

3. Asso et al. (2010) study transcripts from FOMC meetings during the period 1995-2003. Transcripts are made available to the public with a five-year delay.

form of the rule) the current inflation rate and output gap, a lot of information is ignored that could in principle be relevant for monetary policymakers, such as, for example, financial factors, exchange rates, or inflation and output forecasts. Second, while different types of shocks (e.g., supply or demand shocks; transitory or permanent shocks) may warrant different policy reactions, this is not allowed for by the Taylor rule. Third, unless the Taylor rule calls for the central bank to raise the nominal interest rate more than one-for-one in response to an increase in inflation, ensuring an increase also in the real interest rate (the so-called 'Taylor principle'), the economy may be subject to self-fulfilling expectations-driven fluctuations. These are relevant drawbacks that must be kept in mind when using the Taylor rule as a tool for evaluating actual monetary policy. For further discussion of the shortcomings of the rule-based approach to monetary policy, see Svensson (2003).

In principle, one could argue, the exercise of computing rule-based interest rates back in time is an impossible one. At any point in time, it is of course possible to compute the interest rate resulting from a rule such as the Taylor rule, and compare it to the actual interest rate. However, a researcher who is comparing actual and counterfactual interest rates *over time* will encounter severe problems. If the Fed, in the example above, had stuck to the Taylor rule throughout the period 2002-2006, the interest rate would have been higher during that period. However, this higher interest rate would have then depressed output and curbed inflation. In turn, lower output and lower inflation would have induced the Fed to cut the interest rate, and so on. Thus, if the Fed had indeed stuck strictly to the Taylor rule, the interest rate path is likely to have been somewhat closer to the actual interest rate path than what Taylor (2007a) argues.[4]

In short, it is impossible to know the exact course of economic events if monetary policy had been following a different path. As a result, it is entirely correct to look at alternative interest rate rules only at a single point in time. In my opinion, this argument does not render investigations of alternative scenarios useless or uninteresting, but it does provide a serious word of caution when interpreting these scenarios.

In the specific case of Denmark, this critique has an extra dimension. The Danish interest rate has typically been somewhat higher than that of the euro zone despite the currency peg. This interest rate spread is due to the risk premium demanded by investors. If Denmark had been following a different exchange rate regime, the risk premium is likely to have been different. The impact of a higher or lower spread on the level of the interest rate would then have led to different paths for output and inflation, which would in turn have had implications for the interest rate (and possibly for the risk premium).

4. This is also pointed out by Bernanke (2010), citing work by Federal Reserve staff trying to quantify this effect through model simulations.

3. The Taylor rule for Denmark

The calculation of the rule-based interest rate for Denmark starts out from the following formulation of the standard Taylor rule, as it was originally suggested by Taylor (1993):

$$i_t = \bar{r} + \pi_t + \phi_\pi (\pi_t - \pi^*) + \phi_y (y_t - \bar{y}) \tag{1}$$

Here, i_t denotes the nominal interest rate set by the central bank. $\bar{r}$ is the natural real interest rate, π_t is inflation, and y_t is output. The parameters ϕ_π and ϕ_y thus determine, respectively, the reaction of the policy rate to deviations of inflation from its target level, π^*, and to deviations of output from its natural (or trend) level, $\bar{y}$. Taylor (1993) suggests that these parameters are both set at 0.5. Importantly, this implies that the nominal interest rate reacts more than one-for-one to changes in the inflation rate (note that the inflation rate appears twice on the right hand side). This is the aforementioned 'Taylor principle', which must be satisfied in order to create an increase in the real interest rate in response to a rise in inflation.

In order to compute the Taylor rate for Denmark, an appropriate choice of ϕ_π and ϕ_y is essential. In principle, there is no difference between computing the rule-based interest rate for countries which, like the US, actively uses its monetary policy in an attempt to stabilize the economy, and doing the same for a country like Denmark, whose monetary policy is devoted to maintaining its currency peg. However, as Denmark does not have a history of conducting a monetary policy that can reasonably be argued to have been guided by a rule-based approach, it does not seem sensible to estimate these parameters from historical data, as is typically done for other countries (e.g. Taylor, 2007a for the US). Another possible approach could be to estimate a Taylor rule for the euro area. However, the purpose of this study is to compare the actual interest rate to a hypothetical measure of an interest rate that would 'fit' the business cycle, which is not necessarily the case for an estimated interest rate rule. Instead, I will use the values suggested by Taylor (1993) ($\phi_\pi = \phi_y = 0.5$) as benchmark values. In section 4.4, I then investigate the robustness with respect to different parameter values.

Furthermore, the inflation target and the natural real rate of interest need to be chosen appropriately. In effect, manipulating these values will lead to vertical shifts in the curve for the counterfactual interest rate. As for the inflation target, the natural choice is a an annual target rate of inflation of 2%. This is not only in line with the value suggested by Taylor (1993), but also with the actual inflation target adopted by a number of inflation targeting central banks: The ECB ('below but close to 2%'), the Bank of England (2%) and the Riksbank ('around 2%'). In Norway, Norges Bank targets an inflation level ’close to 2.5%’, while the Reserve Bank of New Zealand targets inflation to be ’between 1 and 3%’. In sum, a target of 2% seems reasonable.

Setting the value of the natural real interest rate is not quite simple, as no precise estimate of this variable for Denmark is available to my knowledge. Taylor (1993) suggests that for the US, the natural real rate of interest is around 2%. In theory, the natural real rate of interest should equal the trend growth rate in GDP plus a time preference premium. According to Danmarks Nationalbank (2007), this premium equals 0.1% per year on average for Denmark for the period 1875-2003, i.e. it is quite small. If the trend growth in GDP is around 2% per year, it therefore seems reasonable to set $\bar{r} = 2$ also for Denmark for the entire sample period.

Choosing which measure of inflation to use is not straightforward. Taylor (1993) originally suggested using the GDP deflator. One practical problem with this measure, however, is that it relies on national accounts data, which are often subject to substantial revisions. The GDP deflator, in my opinion, is therefore unlikely to be the most precise measure of current inflation at any point in time. Bernanke (2010) discusses the use of various inflation measures in the Taylor rule, and reveals that the Federal Open Market Committee (FOMC) has ’typically focused’ on the so-called Personal Consumption Expenditures (PCE) index because this index is less sensitive to the imputed rent of owner-occupied housing than the standard consumer price index (CPI). Bernanke further notes that the FOMC often uses the core version of the PCE as an indicator of underlying inflation. Translating these insights to a Danish context would suggest using the EU-harmonized consumer price index (HICP), as this differs from the Danish consumer price index only in leaving out the price of owner-occupied housing. However, as the HICP index is available only from 1996, I use the CPI published by Statistics Denmark in the baseline scenario, as measured by the quarterly average of the monthly year-on-year inflation.[5] As this measure is quite sensitive to movements in food and energy prices, I use the core inflation rate, which leaves out these components, as a robustness check in subsection 4.2, along with Taylor’s suggestion of using the GDP deflator.

I use national accounts data for output, with the natural level of output calculated using the band pass filter of Christiano and Fitzgerald (2003). The band pass filter implicitly transforms the data to its frequency domain, and then removes the components of the data above and below certain frequency thresholds. If these thresholds are chosen to correspond to the business cycle, the band pass filter returns only the business cycle components of the data. This filtered series is then employed as a measure of the output gap. The possibility of explicitly choosing the frequency band is a major advantage of the band pass filter compared to another popular filter, the Hodrick-Prescott

5. For the period 1996-2009, the difference between the CPI and the HICP is very small.

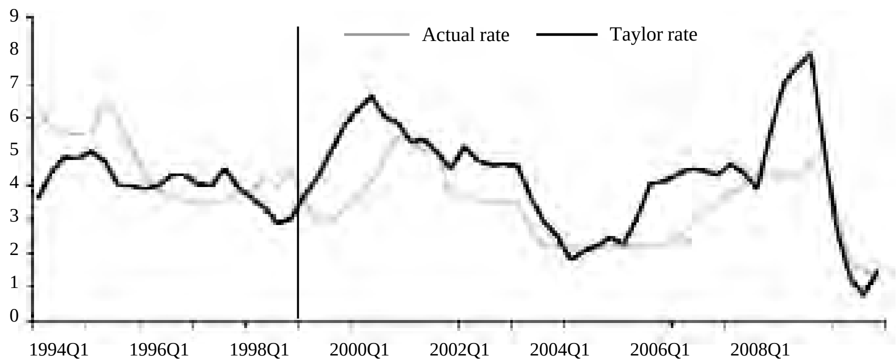

Figure 1. The Taylor rate for Denmark.

(HP) filter, Hodrick and Prescott (1997). When using the HP filter, the researcher instead has to choose the value of a smoothing parameter with no theoretical foundation.[6] I follow Christiano and Fitzgerald (2003) and define business cycle frequencies to be 6 to 32 quarters. I can then plot the Taylor rate against the central lending rate of Danmarks Nationalbank.[7]

From figure 1, it appears that for large parts of the sample, the movements in the actual interest rate are comparable to those in the Taylor rate. However, some episodes of substantial dispersion stand out. These are discussed in the next subsection. The vertical bar marks the first quarter of 1999, when the euro replaced the D-mark as the currency towards which the Krone is fixed. The correlation between the two interest rates is 0.57 for the entire period, but substantially higher; 0.80, for the period 1999-2009, i.e. since the introduction of the euro. Except for the episodes discussed below, the gap between the actual rate and the Taylor rate is never above 2%-points. In other words, while the two interest rates do display considerable differences from time to time, the actual interest rate generally does not seem to be 'out of sync' with the stance of the Danish business cycle, as proxied by the Taylor rate.

The strong positive comovement reflects the fact that the Danish business cycle is strongly correlated with that of the entire euro area. Dam (2008) studies the correlation between the Danish business cycle and that of a core of five euro countries (Germany, France, Austria, Belgium and the Netherlands). He finds that while the Danish business cycle was largely disconnected from that of the core countries in the 1980's and the first half of the 1990's, the correlation increased markedly towards the end of

6. See section 4.3 for a comparison to the Taylor rule using HP filtered output data.

7. *Udlånsrenten* in Danish, available from *www.nationalbanken.dk*. One could have chosen to use the interest rate on certificates of deposit (*Indskudsbevisrenten*). However, this rate only differs from the lending rate in the last 7 months of the sample, in which the numerical difference is quite small.

the 1990's, and has since then remained very high. Thus, to the extent that the monetary policy of the ECB is well described by a Taylor rule, as suggested by Gerdesmeier et al. (2007, 2010) and Hansen (2012), among others, one should indeed expect a strong link between actual and rule-based interest rates also for Denmark, especially in the post-1999 period.[8]

Moreover, in the first quarter of 1999, when the euro was introduced as a virtual currency and Denmark pegged its Krone to it, Germany itself accounted for 21.2% of Danish foreign trade (imports plus exports), while the euro area in total accounted for 48.9% (Statistics Denmark). Thus, shocks hitting the euro area after 1999 are likely to have a larger impact also on the Danish economy than shocks hitting Germany before 1999, pointing towards a larger comovement after 1999. On the other hand, to the extent that the Danish business cycle is likely to have a higher *unconditional* correlation with the German business cycle than with that of the euro area as such, one would expect a higher correlation of interest rates before 1999.

The actual interest rate seems to be consistently lower than the Taylor rate. Once again, this pattern is more pronounced after 1999 than before. The level of the counterfactual interest rate is obviously heavily influenced by the value chosen for $\bar{r}$, the natural or equilibrium real interest rate. As discussed above, this choice is surrounded by some uncertainty, and the level of $\bar{r}$ is transmitted one-for-one to the level of the Taylor rate. Moreover, the level of the Taylor rate is directly affected by the choice of inflation target, which is also subject to some arbitrariness. As a robustness check, I therefore compute the sample averages for the period 1994-2009 for the inflation rate and the real interest rate, and use these as alternative measures of the inflation target and the natural real interest rate. This gives alternative values of $\pi^* = 2.11$ and $\bar{r} = 1.55$. The resulting Taylor rate using these alternative values is shown in figure A1 in the appendix. As illustrated, these changes remove the tendency for the Taylor rate to be constantly above the actual interest rate.

In any case, due to the problems in interpreting the level of the actual and hypothetical interest rates, one should be extremely careful when comparing them in levels. Instead, more robust results can be drawn from comparing the *changes* in the interest rates from quarter to quarter. This eliminates the problem of choosing the (constant) level of $\bar{r}$.[9]

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8. On the contrary, Jensen and Aastrup (2010) find that the interest rate setting of the ECB is not driven by 'anything remotely close to a Taylor rule' for the period 1999-2010.

9. The level of the actual interest rate is also influenced by the Danish risk premium. As the risk premium is not constant, looking at interest rate *changes* does not eliminate this factor as a potential problem, but it reduces it substantially, as the risk premium usually fluctuates within a small band.

3.1 What causes the episodes of large deviations?

While the movements of the actual and the hypothetical interest rate are highly correlated, figure 1 also highlights some periods in which they differ markedly. In the following, I evaluate the reasons for these deviations. In particular, it is interesting to investigate whether these episodes are caused by asymmetric shocks, i.e. situations where the business cycle situation in Denmark is significantly different from that of the euro area. This allows me to assess the empirical relevance of one of the most common objections against a fixed exchange rate.

From figure 1, I identify four episodes of substantial difference between the two rates, each of which is discussed in turn. First, the actual rate was substantially above the Taylor rate at the beginning of the sample period. The reason is that in 1994, the Danish interest rate was still coming down from a very high level after the European Monetary System (EMS) crisis in 1993. In fact, in 1993 (not shown) the actual interest rate was often in double digits, and never below 7%.[10] At the same time, the combination of a recession and low inflation warranted a Taylor rate around 2% for Denmark. The large deviations throughout 1994 and 1995 should be seen in this context. Moreover, the interest rate spread between Denmark and Germany increased in the wake of the EMS crisis, reflecting a higher risk premium for Denmark as a result of a flight of investors to the safe, German haven. Thus, the difference between the actual and the hypothetical interest rates in 1994 and 1995 was to a large extent driven by the EMS crisis and its consequences.

Second, the actual rate seems to be increased only with a lag with respect to the Taylor rate in the years 1998-2000. To be specific, the Taylor rate for Denmark started to increase in the fourth quarter of 1998 (driven by output growth), whereas the actual interest rate was raised starting only in the fourth quarter of 1999. The primary explanation for this delay is the turmoil in financial markets in the second half of 1998 following the Russian crisis and the collapse of the hedge fund Long Term Capital Management. As a response, interest rates were cut in the US as well as in the euro countries.[11] In fact, it was observed at the meeting of the US Federal Open Market Committee on September 29, 1998, that the interest rate cut agreed upon at that meeting was not warranted by a Taylor rule for the US, but rather by 'developments overseas and in US financial markets'.[12] The financial turmoil is therefore likely to have put a downward pressure on interest rates also in the euro area and in Denmark in late

10. With the exception of the last ten days of 1993, in which the interest rate was 6.75%.
11. As the euro had not yet been introduced in 1998, these cuts had to be undertaken by the national central banks. For instance, on December 3, 1998, following a decision by the ECB's Governing Council, national central banks across the eurozone jointly cut their interest rates.
12. This argument was put forward by Donald Kohn; at that time a staff member. See the transcripts of the FOMC meeting of September 29, 1998, p. 77.

1998 and early 1999, giving rise to the observed deviation from the hypothetical Taylor rate for Denmark, which is not influenced by financial market conditions.[13]

Third, the actual interest rate was substantially lower in 2002 and in 2005-2006 than the rate prescribed by the Taylor rule. The actual, Danish interest rate was cut significantly in 2001, especially after the terrorist attacks in the US on September 11. During 2005, rising inflation and output in Denmark warranted an increase in the Taylor rate that was only matched by the actual interest rate with a delay. This pattern is roughly similar to that pointed out by Taylor (2007a) for the US during the period 2002-2006, and by Gerdesmeier et al. (2010), who document that the ECB's interest rate setting was not in line with (but instead, more expansionary than) the prescriptions of the Taylor rule in the years 2005-2007. In the US, the Federal Funds rate was cut drastically in the wake of the stock market crash in 2000 and the September 11 attacks, and was kept at low levels even as economic growth picked up in the following years. As the interdependence between monetary policy in the US and the euro area has been documented extensively, see e.g. Ehrmann and Fratzscher (2004); or Scotti (2006), it is therefore not surprising that the monetary expansion in the US eventually (although with a lag, and to a lesser extent) was followed by lower interest rates in the euro area and, in turn, Denmark. Moreover, in Denmark the years 2005-2007 were characterized by a sustained increase in government spending, despite an ongoing economic boom. The present analysis suggests that also monetary policy was quite expansionary in these years. As the interest rate is effectively dictated by the ECB, this would have called for a much more contractionary fiscal policy than actually observed during these years.

Finally, in 2008 the Taylor rate suddenly increased drastically, while the increase in the actual interest rate was a lot more modest. As will become evident is subsection 4.2, this spike in the Taylor rate was largely attributable to an increase in inflation, which was primarily driven by higher food and energy prices at the global level. Hence, one should expect this dispersion to be a lot smaller when the core inflation rate is used instead, as this inflation measure leaves out exactly these movements. As already discussed, it is not obvious which inflation measure should be of most interest to monetary policymakers; and *in casu*, whether higher food and energy prices should lead to a rise in the interest rate.

This discussion suggests that the theoretical concern about asymmetric shocks might not have been very relevant in practice for Denmark over the period under consideration. If country-specific shocks had been important drivers of the Danish business cycle, this would have been likely to result in large differences between the Taylor rate and the actual interest rate; at least in short periods after the occurence of each shock. Of the episodes discussed above, however, only the deviation around 1994 seems to be

13. Unless, of course, these have an effect on inflation or the output gap.

interpretable as an asymmetric shock which had different effects on Denmark and Germany. On the other hand, the rise in food and energy prices in 2008 was a global phenomenon, and thus not attributable to asymmetric shocks. The apparent mismatch between actual interest rates and Taylor rates during some or all of the period 2002-2006 has also been documented for the US and the euro area (although the expansionary, domestic economic policy in Denmark in these years could in principle be interpreted as an asymmetric shock to the Danish economy). Finally, to the extent that the deviation between the actual and the hypothetical rate in 1999 can be attributed to the financial turbulence in 1998, this episode can also hardly be characterized as an asymmetric shock. In sum, while the risk of asymmetric shocks remains an important, theoretical objection against fixed exchange rates, this concern does not seem to have been very important empirically in the case of Denmark in the recent past.

4. Robustness of the Taylor rate

In order to make up for the speculative element in the above analysis, it is interesting to check how robust the above path for the Taylor rate is to different specifications and parametrizations of the interest rate rule, as well as to the use of different data measures.

4.1 Adding interest rate smoothing

One popular extension of the basic Taylor rule, following Clarida et al. (1999) is to allow for more persistence in the interest rate. The central bank might have a preference for avoiding large and abrupt changes in the interest rate, giving rise to inertia in the interest rate process. This can be formalized by setting the interest rate as a weighted average of the desired, rule-prescribed interest rate and the interest rate in the last period:

$$i_t = \rho_r (i_{t-1}) + (1 - \rho_r) (\bar{r} + \pi_t + \phi_\pi (\pi_t - \pi^*) + \phi_y (y_t - \bar{y})) \tag{2}$$

Here, ρ_r is the parameter governing the weight attached to smoothing the interest rate. According to Clarida et al. (1999), monetary policy inertia is quantitatively quite important; they estimate the parameter $\rho_r = 0.79$ for the US during the period 1979-1996. In a recent contribution, Gerdesmeier et al. (2010) estimate a smoothing parameter for the euro area of 0.76 for the period 1999-2008. In the following, I set $\rho_r = 0.7$, keeping all other parameters fixed. This results in the following path for the Taylor rate:

Not surprisingly, with this relatively high degree of persistence in the interest rate setting, the Taylor rate is unable to reproduce some of the high-frequency movements

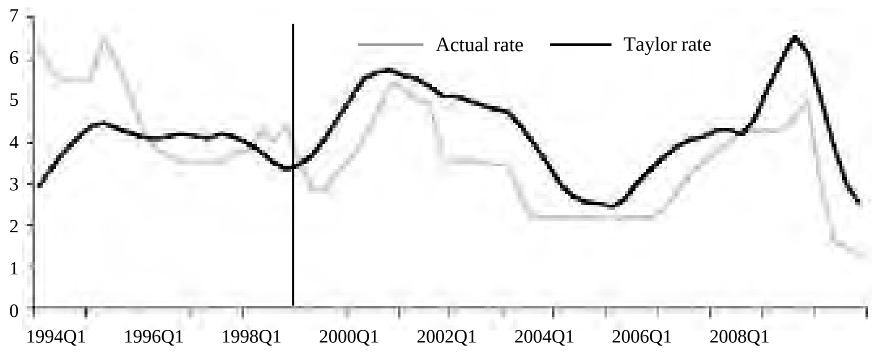

Figure 2. Taylor rate for Denmark with interest rate smoothing.

in the actual interest rate. However, it still appears to give a reasonable description of actual monetary policy. Note that the patterns observed without interest rate smoothing are still present: The link between the actual and the Taylor rate is much stronger after 1999, and the Taylor rate is still consistently above the actual interest rate.[14] Moreover, the episodes of significant differences between the two rates identified above still stand out. The correlation for the entire sample is now 0.51, which is somewhat lower than without interest rate smoothing. However, if attention is once again restricted to the subsample 1999-2009, the correlation is 0.86, i.e. even higher than in the no-smoothing case.

4.2 Alternative measures of inflation and output gap

So far, I have used the CPI inflation rate in the analysis. However, as already discussed, the core inflation rate is less sensitive to transitory, exogenous movements in food and energy prices, and may therefore be a better measure of the underlying trend of domestic inflation. I therefore compute Taylor rates using the core HICP inflation rate.[15] In addition, I follow the suggestion of Taylor (1993) and use the GDP deflator in the Taylor rule. Figure 3 shows the effects of using each of these alternative inflation measures.

As anticipated in section 3, the large dispersion between the Taylor rate and the actual rate in 2008 disappears almost entirely when core inflation is employed. This confirms that the jump in the Taylor rate for this period was largely driven by large in-

14. This tendency can once again be removed by using the sample averages of inflation and the real interest rate as measures of the inflation target and the natural real rate of interest.

15. As mentioned, the HICP index only goes back to 1996. For the earlier years, I use the core inflation rate calculated by Hansen and Knudsen (2005).

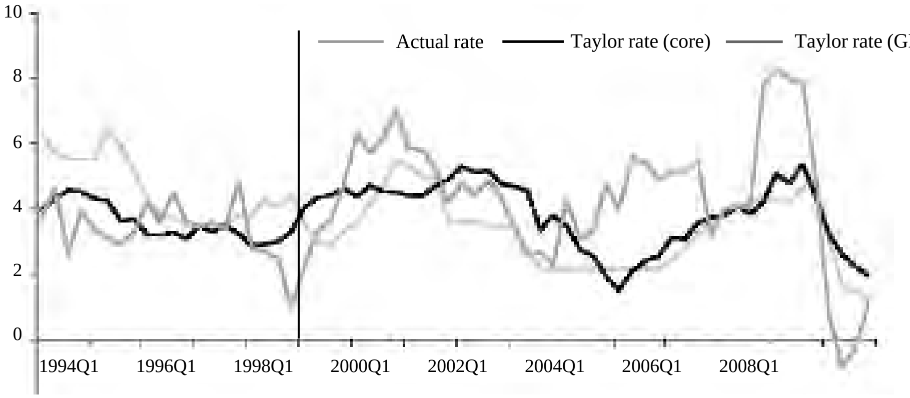

Figure 3. The Taylor rate for Denmark with HICP core inflation or GDP deflator.

creases in food and energy prices. Further, the tendency for the Taylor rate to be higher than the actual rate also disappears, reflecting that the core inflation rate is lower than the CPI throughout most of the sample.[16]

The strong positive comovement between the two rates remains, as the correlation is now 0.57 and 0.75 for the periods 1994-2009 and 1999-2009.

On the other hand, the large dispersion in 2008 remains when the GDP deflator is used in the rule. More generally, the GDP deflator tends to lead to larger differences between actual and rule-based interest rates. This is confirmed by the correlation coefficients, which are now, respectively, 0.30 (1994-2009) and 0.64 (1999-2009). In other words, the choice of which inflation measure to use seems to have some influence on the extent of the positive comovement between the actual and the hypothetical interest rate.

I have also experimented with different measures of the output gap. So far, I have used the band pass filter to compute the output gap from the actual output data series, but a number of alternative methods exist. I evaluate the robustness of my results to the use of the popular Hodrick-Prescott (HP) filter.[17] Figure A2 in the appendix displays the difference between the Taylor rates calculated under the two different filtering methods. As can be seen from the figure, the Taylor rate essentially follows the same path when the HP filter is used, but is substantially less smooth. Some of the high-frequency movements in the HP-based Taylor rate are not captured by the BP-based rate. This is not surprising, as the band pass filter removes all components of frequencies higher than 6 quarters. In fact, Christiano and Fitzgerald (2003) argue that the HP

16. Adjusting the inflation target down correspondingly does not alter the picture substantially.
17. I set the smoothing parameter $\lambda = 1600$, as is standard using quarterly data.

filter (with λ =1600) can be interpreted as a band-pass filter removing all components lower than the business cycle frequencies. Of course, as the band pass filter leaves out also the high-frequency components, it produces a smoother series for the output gap. This smoothness is then inherited by the Taylor rate series, as seen in the figure.[18]

The effects of using the HP filter can be illustrated by comparing the correlations between the actual and the hypothetical interest rates to those calculated using the band pass-filtered data. For the entire sample, the correlation drops from 0.57 to 0.51 when the HP filter is used instead of the band pass filter. For the sample 1999-2009, the correlation drops from 0.80 to 0.76. Thus, the detected, strong correlation is robust to the filtering method.

4.3 Alternative parameter values

As discussed above, the initial selection of the parameters ϕ_π and ϕ_y was somewhat arbitrary. It is therefore important to illustrate the effect of changing these parameters. Below, I investigate how the correlation between the actual and the hypothetical interest rate is affected when the parameters are changed. By looking at the coefficient of correlation, the potential problems in comparing the level of the two rates discussed above is largely eliminated, as the correlation coefficient is insensitive to the level of the variables. Figure 4 illustrates how the correlation between the hypothetical Taylor rate and the actual interest rate depend on the choice of these parameters. In the figure, the coefficients in the Taylor rule (ϕ_π and ϕ_y) are allowed to vary over a range of values. ϕ_π fluctuates between -0.5 and 2, which is a fairly broad band around the benchmark value of 0.5. Note that I include values for ϕ_π for which the Taylor principle is no longer satisfied. I do not engage in the discussion of the possible consequences thereof for equilibrium uniqueness and stability. For my purposes, the computation of the correlation between the two rates is not affected by whether the Taylor principle is satisfied or not. For ϕ_y, the band captures values between 0 and 2, as negative values of this parameter would imply a procyclical monetary policy, which is not very likely.

Figure 4 illustrates that for small values of ϕ_y, the reaction to output in the Taylor rule, the correlation over the entire sample is quite sensitive to the choice of this parameter. Once this parameter increases above Taylor's prescription of 0.5, however, the sensitivity decreases. On the other hand, it seems that the choice of ϕ_π is less important. With the aforementioned Taylor principle in mind, this is perhaps a bit surprising. Specifically, the correlation is relatively invariant with respect to whether ϕ_π is larger or smaller than 0.5, i.e., whether the Taylor principle is satisfied or not. It should be

18. In fact, the Taylor rate computed with band pass filtered data but without interest rate smoothing ($\rho_r = 0$) is almost identical to the Taylor rate based on HP-filtered data and with interest rate smoothing ($\rho_r = 0.7$).

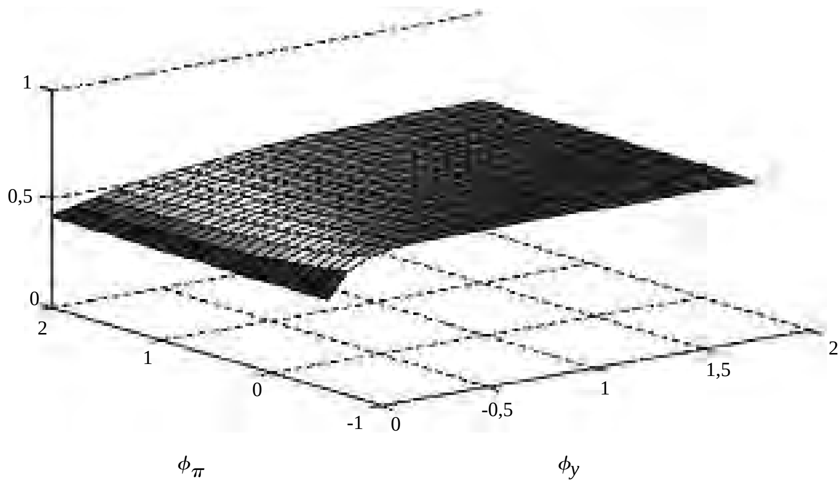

Figure 4. Sensitivity of correlation coefficient, 1994-2009, no smoothing.

noted, however, that when ϕ_π is changed there is a substantial effect on the level of the Taylor rate. Lowering the value of ϕ_π leads to a downward shift in the Taylor rate. Still, the high correlation indicates that the *movements* in the two rates are closely related.

Additional illustrations (not reported) confirm that the correlation coefficient is quite robust to the chosen parameter values also for the subsample 1999-2009, as well as for the entire sample when interest rate smoothing is included. Moreover, these illustrations confirm that the correlation is in general substantially higher for the post-1999 period. The bad fit for the period 1994-1998 therefore does not seem to be due to bad parameter choices in the Taylor rule. Finally, I find that while the correlation coefficient for the overall sample dropped with the addition of interest rate smoothing, it actually rises slightly for the post-1999 sample. These results are all available upon request. In sum, the main findings of this study seem to be robust to the values of the parameters entering the Taylor rule, as long as the output gap reaction (ϕ_y) is not *too close* to zero.

4.4 Forward looking Taylor rule

In an influential modification of the original Taylor rule, Clarida et al. (1999) suggest that the interest rate rule should be of a forward-looking nature, with the expected level of inflation entering the rule instead of the current level. Contributing to the recent debate about the role of the Federal Reserve in the build-up of the recent financial crisis, Bernanke (2010) supports the forward-looking approach and demonstrates that when expected inflation enters the Taylor rule instead of current inflation, the gap between the Taylor rate and the actual interest rate in the US during the years 2002-2006 diminishes somewhat. On the other hand, Taylor (2010) rejects the use of expected inflation for a number of reasons, including the problem that the central bank might have different expectations of future inflation than private agents.

In any case, it seems relevant to compare the Taylor rate calculated using current inflation to that computed with expected inflation entering the rule. Here, one encounters exactly one of the problems in using expected inflation: how is this measured? For the US, various measures of expected inflation exist, some of which are made available to the public. For Denmark, finding an estimate of expected inflation is even more troublesome.[19]

Instead, I use actual inflation two quarters ahead to proxy for expected inflation in a given quarter. In this step, I implicitly assume that all agents have perfect foresight. As this is no perfect estimate for expected inflation, the results should be interpreted with care.[20] This is especially the case in 2008, when higher food and energy prices drove up actual inflation without necessarily affecting inflation expectations to the same extent. As figure 5 illustrates, allowing expected inflation to enter the Taylor rule does not alter the main conclusions. However, the deviation between the two interest rates in 2008 is now even larger than in the baseline scenario. The reason for this is the rise and fall of inflation during 2008 and 2009. Inflation rose significantly during 2008, implying that future inflation (i.e., expected inflation in this setting) was higher than actual inflation, calling for a higher Taylor rate. Once inflation started falling in 2009, future inflation was lower than current inflation, implying that the Taylor rate with future inflation would prescribe a lower interest rate than a rule with actual inflation. This explains why the forward-looking Taylor rate starts falling earlier than the actual rate. In general, however, the conclusions of the paper are not overturned when a forward-looking Taylor rule is applied.

4.5 Use of real-time data

The above analysis has been carried out using final data. Another approach would be to look at the data available to policymakers at the time when monetary policy decisions had to be made. National accounts data are subject to (often substantial) revisions, and the same is true for inflation. Thus, at any point in time, monetary policymakers do not have access to final data, and instead must base their decisions on provisional estimates. If the objective of this paper had been a counterfactual analysis of

19. The Danish central bank and the finance ministry do publish forecasts for inflation, but these publications are too infrequent to be useful in this context.
20. Using actual inflation one, three or four quarters ahead yields very similar results.

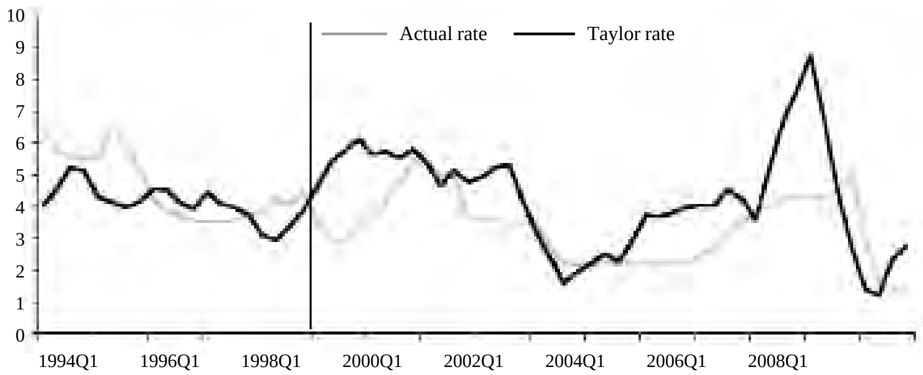

Figure 5. The Taylor rate for Denmark with a forward-looking Taylor rule.

what would have happened, had Denmark adopted a Taylor rule in 1994, the use of such real-time data would probably have been more correct. However, as already discussed, the scope of this study is instead to perform an ex-post evaluation of the actual interest rate path, and how this compares to an interest rate that 'fits' the Danish business cycle at any point in time; without suggesting that this interest rate path would in fact have resulted if the monetary policy regime had been different. As a consequence, I consider the use of ex post data more appropriate for my purposes. Moreover, reconstructing the series of most recent available data for output and inflation at any point in time back to 1993 is a substantial task, and is not the object of this paper. In the US, Federal Reserve staff prepares a collection of the most recent data (the so-called Greenbook) before each meeting of the Federal Open Market Committee, at which most interest rate decisions have been made since 1994. This provides researchers with accessible real-time data, as exploited by Fuhrer and Tootell (2008) among others. For Denmark, however, no such collection of data exists. Moreover, interest rate decisions are in practice made on a less regular basis in Denmark than in the US, which further complicates the task.

4.6 Augmented Taylor rules

While various moderations of the original Taylor rule have been discussed above, such as including interest rate smoothing or using expected instead of current inflation, I have abstained from more substantial alterations of the policy rule. In the literature, various augmented Taylor rules have been proposed, suggesting that central banks should and/or do in practice react to other macroeconomic variables than output and inflation. As examples, it has been suggested that central banks might react to exchange rates, Taylor (2001), to housing prices, Finocchiaro and Queijo von Heideken, (2009), or to stock prices, Rigobon and Sack (2003). However, including any such reactions in the present study would heavily increase the speculative element of the study, and would blur the picture of what an interest rate set to fit the Danish business cycle would look like. Hence, I choose not to take any steps in this direction.

5. Conclusion

The present paper offers a comparison between the actual interest rate in Denmark during the period 1994-2009 and the rate that would have been prescribed by the Taylor rule for the same period. I conclude that since 1999, the path for the actual interest rate has usually not been too different from the path prescribed by the Taylor rule, although certain episodes stand out during which the two rates are quite different. These results are relatively robust to the measure of the output gap, and to some extent to the measure of inflation, as well as to various changes in the specification of the Taylor rule. An important part of the explanation for these findings is the high correlation between the Danish business cycle and that of the euro area in recent years. Moreover, I argue that most of the episodes of substantial deviation between the actual and the hypothetical interest rates have not been driven by asymmetric or country-specific shocks, suggesting that one of the most common objections against a fixed exchange rate has not been very relevant empirically for Denmark during the period considered here.

As stated in the introduction, the present paper should not be interpreted as an analysis of what would have happened in practice, had Denmark chosen a different monetary policy regime over this period. I do not claim that the path of the interest rate would in fact have been equal to any of the paths suggested above. Not only is it impossible to know the exact course of economic events in this type of counterfactual analysis. It is also highly likely that monetary policy would not in practice have been in accordance with the Taylor rule at every point in time. Hence, the Taylor rates presented above should not be seen as an attempt at counterfactual writing of history, but merely as a benchmark against which to compare the actual interest rate.

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Appendix

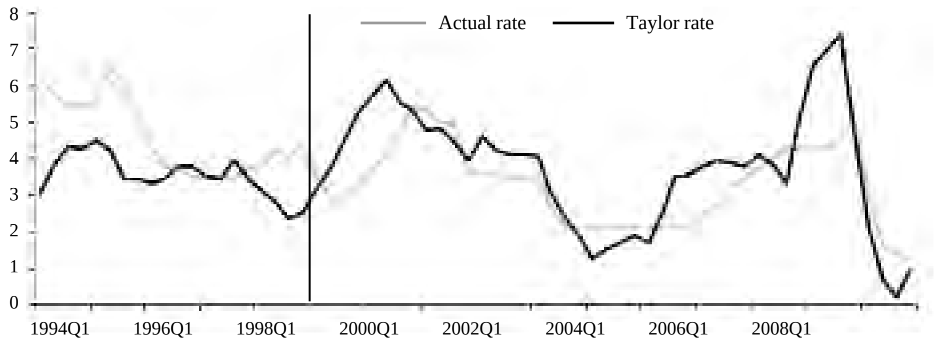

Figure A1. The Taylor rate for Denmark with alternative measures of inflation target and the natural real interest rate.

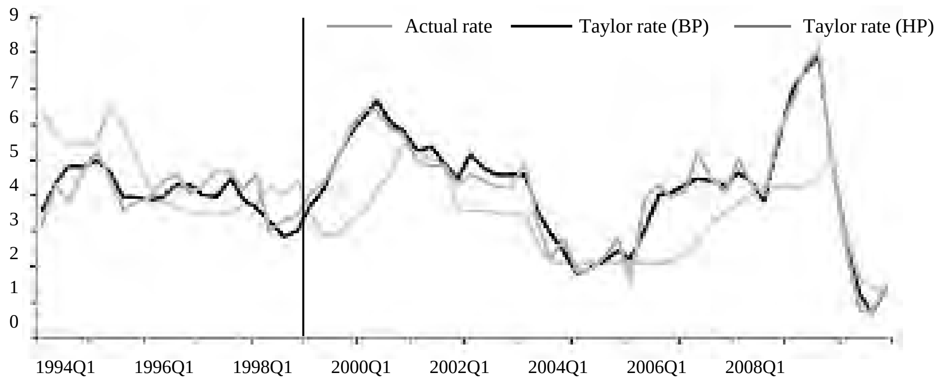

Figure A2. Taylor rate with HP-filtered versus BP-filtered output gap.