



S

Ε

R

G

Ε

S

R

Κ

S

В

Α

Sveriges Riksbank Economic Review

2017:1

Ν

Κ

SVERIGES RIKSBANK ECONOMIC REVIEW is issued by Sveriges Riksbank.

Publisher: CLAES BERG

Editors: CLAES BERG, MARTIN W JOHANSSON, JESPER LINDÉ, DILAN OLCER, JESSICA RADESCHNIG AND THE COMMUNICATIONS DIVISION Sveriges Riksbank, SE-103 37 Stockholm, Sweden Telephone +46 8 787 00 00

Advisory editorial committee: Heidi Elmér, Marianne Nessén, Kasper Roszbach and Anders Vredin

The opinions expressed in signed articles are the sole responsibility of the authors and should not be interpreted as reflecting the views of Sveriges Riksbank.

The Review is published on the Riksbank's website http://www.riksbank.se/Economic-Review

Order a link to download new issues of Sveriges Riksbank Economic Review by sending an e-mail to: pov@riksbank.se

ISSN 2001-029X

Dear readers,

In this issue, we present articles covering different types of important central banking issues: from new methods of extracting information on the financial markets to broader issues regarding monetary policy objectives and the possible role of electronic central bank money in the future.

• What does a financial index for Sweden show?

Lina Fransson and Oskar Tysklind have constructed an index that provides a snapshot of the overall general financial conditions in Sweden. The index is based on twelve financial variables that together show how the financial conditions have developed between 1998 and 2016. The analysis shows that the index captures both events on the financial markets and historical economic fluctuations relatively well and that it has been an early indicator of GDP development. Another conclusion is that the index includes information that complements other early indicators that are normally used to make forecasts for GDP growth in the short term, for example the Purchasing Managers' Index and the Economic Tendency Survey.

Have the Riksbank's forecasts been governed by the models?

Jesper Lindé and André Reslow analyse how much influence macroeconomic models have had on the Riksbank's forecasts for GDP growth, inflation and the repo rate. The analysis shows that the models do not explain the Riksbank's forecasts to the extent sometimes claimed by external critics and reviewers. The Riksbank's mediumterm forecasts are mainly based on assessments rather than on models – the direct contribution from the models has actually been rather small during the period 2006-2016. The view that the Riksbank blindly relies on and follows its models is, according to the authors, misleading and merely a myth. They also claim that the perception that the Riksbank relies on models in which inflation always returns to the target "by itself" within the forecast horizon is a myth.

What are the alternatives to inflation targeting?

Björn Andersson and Carl Andreas Claussen present the discussion on monetary policy with an inflation target that has taken place in a number of countries after the global financial crisis of 2007-2009. It has been claimed, for instance, that inflation targeting does not give sufficient consideration to the real economy and to risks and imbalances in the financial system. Moreover, it has been claimed that so-called level targets are better than the inflation target, particularly in the current situation when inflation is below the target and the interest rate is close to its lower bound.

The authors analyse the criticism of inflation targeting and the alternatives proposed. When discussing alternatives to inflation targeting, they point out that it is important to remember that monetary policy with an inflation target both could and should be flexible. It should stabilise both inflation and the real economy. It can also take imbalances and risks in the financial markets into consideration, even if this is an issue that is still being discussed, both internationally and in Sweden.

Inflation target and interval – what are the pros and cons?

Mikael Apel and Carl Andreas Claussen analyse the pros and cons of different variants of an inflation target that involves an interval. They first review the international debate of ten to fifteen years ago on how an inflation target should best be designed, and then discuss the arguments in the Swedish debate in light of this. One central conclusion is that, if the inflation target is credible, monetary policy can be flexible and consider factors other than inflation, such as output and employment, even without an interval. However, a *tolerance interval* could contribute towards increased flexibility if it increases the credibility of the inflation target. However, it could also reduce flexibility if it creates more inflation uncertainty or if ending up outside the interval is very costly. A *target interval* entails a major change to the monetary policy framework. Such an interval would provide the possibility of aiming at different levels for inflation, but, as inflation expectations may become less firmly anchored, economic fluctuations may become greater.

How can term structure models be used by central banks?

Rafael Barros De Rezende provides an overview of recent developments in term structure modelling and its uses by central banks. It is very much a question of extracting economically relevant information from long-term market rates and of how the interest rate level can be affected by policy measures. The author analyses models with timevarying risk premia that can be used by central banks to estimate the expectations of market participants regarding future policy rates and the effects of unconventional monetary policy measures. In addition, the models can be used to estimate inflation and liquidity risk premia on the inflation-indexed bond markets. Another important area is the analysis of the aggregate effect of different types of monetary policy measures, where the normal policy rate is close to its lower bound, with the aid of the so-called shadow rate.

• Can banknotes and coins be complemented by electronic central bank money?

Gabriele Camera shows how the concept of money rapidly changes as a result of innovations in the area of computer-based encryption technology. Technological development has made it possible to create cost-effective electronic alternatives to banknotes and coins. The author takes the scientific literature in the field as his starting-point and defines what money is and how it is used. Deeper analysis follows of the opportunities and difficulties involved in issuing new types of money or means of payment. A central issue is to what extent the central bank is more suited to issuing electronic money than private agents.

Read and enjoy!

Claes Berg

Contents

An index for financial conditions in Sweden 6 Lina Fransson and Oskar Tysklind

It's a myth that the Riksbank's forecasts have been governed by models 28 Jesper Lindé and André Reslow

Alternatives to inflation targeting 51 Björn Andersson and Carl Andreas Claussen

Inflation targets and intervals – an overview of the issues 83 Mikael Apel and Carl Andreas Claussen

How can term structure models be used by central banks? 104 Rafael B. De Rezende

A perspective on electronic alternatives to traditional currencies 126 Gabriele Camera

An index for financial conditions in Sweden

Lina Fransson and Oskar Tysklind *

At the time of writing, Lina Fransson worked in the Monetary Policy Department of the Riksbank.

Oskar Tysklind works in the Monetary Policy Department of the Riksbank.

Understanding financial conditions is important for a central bank as it is primarily via the financial markets that monetary policy can affect the economy. In this article, we construct an index that captures the overall financial conditions in Sweden. The index is aggregated with the assistance of principal component analysis and is based on twelve financial variables. Together, they give an overall view of how financial conditions, related to real economy developments, have developed in Sweden. The analysis shows that the index captures both events on the financial markets and historical economic fluctuations relatively well and that it has been an early indicator indicator of GDP development. Another conclusion is that the index includes information that complements other early indicators that are usually used to make forecasts for GDP in the short term, for example the Purchasing Managers' Index and the Economic Tendency Survey.

1 Why does the Riksbank monitor financial conditions?

Developments on the financial markets are an important component of the Riksbank's analysis and it is primarily via various financial channels that the Riksbank can affect the economy with the assistance of its monetary policy. Financial conditions are also affected by many other factors. Consequently, it is important for a central bank to understand the interplay of monetary policy, financial conditions and the real economy.

A central bank's monetary policy affects the economy through several different channels. One important channel lies through various interest rates in the economy, both interest rates determined on financial markets and interest rates faced by households and companies, for example interest rates for mortgages. The Riksbank's most important instrument for governing these interest rates is the repo rate. When the repo rate is raised, both market rates and final interest rates for households and companies usually rise.¹ When interest rates rise, households and companies face higher borrowing costs, which leads them to consume and invest less. Another channel is through lending in the economy. In Sweden, it is primarily the Swedish banks that grant credit to households and companies. Various types of uncertainty and risk in the economy also affect the financial conditions. Of course, this very much applies to risks and vulnerabilities in the financial system. If the risks increase and the banks' access to funding becomes impaired, this may lead the banks to raise their lending rates and reduce their lending, which, in turn, reduces consumption and investments.²

Monetary policy also affects various asset prices, which, in turn, affect the willingness and ability of households and companies to consume or invest. If the repo rate is raised and

^{*} The authors wish particularly to thank Claes Berg, Ulf Söderström, Peter Sellin, Ola Melander and David Kjellberg. The opinions expressed in this report are those of the author and are not necessarily shared by the Riksbank.

¹ For a more detailed description of the framework for the implementation of monetary policy, see, for example, Nessén, Sellin and Å. Sommar (2011).

² See, for example, Bomfim, D. and Soares (2014) and Basel Committee on Banking Supervision (2012).

prices for assets such as housing or equities become subdued or fall, the value of households or companies' assets will also become subdued or fall. If these assets also form collateral for loans, the lenders may tighten collateral requirements or make the loan conditions for the household or company less favourable. Increased uncertainty in the form of large price fluctuations on the financial markets may also lead to precautionary saving among households and companies, which reduces consumption and investments.³

The development of the Swedish krona primarily affects Swedish companies with large amounts of exports. If the Riksbank raises the repo rate, the krona will get stronger, making it more expensive for foreign customers to purchase goods and services from Sweden, which will restrain demand. There is also a direct link between the krona and inflation, as a stronger krona makes it cheaper to import from abroad, leading to lower inflation. Monetary policy and other factors affecting financial conditions thus affect households and companies through several different channels and have a close connection to the development of the real economy (see Figure 1).





Note. This is a simplified figure and only shows the schematic link between financial markets and the real economy.

The connection between the development of the financial markets and the real economy has been particularly substantial in the last decade. This can be seen first in the shape of the financial crisis that paralysed the global economy in 2008 and then in the subsequent debt crisis in the euro area. At the same time, the complexity of the financial markets has increased and different financial markets are becoming increasingly interconnected, both via financial instruments and between different countries. This means that the financial conditions need to be analysed more broadly so as, for example, to capture different contagion effects.⁴ Central banks and various participants have therefore had to modify several of the economic models used to make forecasts for the economy. This applies, for example, to models that have previously only used a short interest rate to capture the monetary policy transmission mechanism and financial conditions.⁵

In this article, we construct an index to capture the development of the financial conditions, based on information from various financial channels. The index includes a broad spectrum of financial variables, with the aim being the creation of a quantitative measure that may have several areas of use. For example, a central bank may need to make an overall assessment of how the financial conditions have developed between two monetary policy meetings. Many financial variables are available in real time and are usually measured at a high frequency. Events affecting both the financial markets and the real economy can, therefore, be observed at an early stage on the financial markets and can contribute towards predicting economic developments. The aim of creating an index is to avoid capturing

³ See, for example Hopkins, Linde and Söderström (2009).

⁴ Noyer (2007), Singh, Razi, Endut and Ramlee (2008).

⁵ Angelopoulou, Balfoussia and Gibson (2013).

temporary movements in individual variables and, instead, to attempt to capture those overall trends on the financial markets that we also judge affect the real economy.

The index includes twelve financial variables that are aggregated with the assistance of principal component analysis. The method is not based on a structural description of the economy. Instead, the weights of the financial variables included are based solely on historical correlations in which the weights are determined by covariation between the financial variables. In such a framework, it can be difficult to separate exogenous financial shocks from endogenous events that depend on monetary policy and the development of the real economy, as these can mutually affect each other. But, by including a broad spectrum of financial variables, we can capture both movements derived from monetary policy and those arising exogenously on the financial markets, for example after a shock on a specific market. In the analysis, monetary policy is deemed to make a significant contribution to the financial conditions and therefore the repo rate, among other such factors, is included as a variable in our index. But other variables in the index will also be affected in the event, for example, of an interest rate adjustment. To further capture the effects of monetary policy on the financial conditions, it would also have been desirable to be able to include a measure of the Riksbank's reportate path in the index, but this is not possible as the Riksbank did not start to publish its repo rate path until 2007.

Our analysis shows that the index manages to capture historical economic fluctuations relatively well and that this has been an early indicator for the development of GDP. The ability to forecast GDP also improves when we aggregate different financial variables, compared with when we only use individual variables. In addition to this, our results indicate that the index includes information that complements other early indicators that are usually used to make forecasts for GDP in the short term, for example the Purchasing Managers' Index and the Economic Tendency Survey.

2 Background

2.1 A broader analysis of the financial conditions is needed

Studies of the monetary policy transmission mechanism have a long history. One early study is Friedman and Schwartz (1963), who identified monetary policy shocks in the United States and estimated their effects on the real economy. But econometric models used to make forecasts of real variables or to study the effects of shocks include, in most cases, only one monetary policy interest rate. This is probably not sufficient to capture the interaction between the financial conditions and the real economy as the complexity of the financial markets has increased. Neither is it sufficient in periods of disruption on the financial markets.

There has consequently been some interest in creating broader measures of the financial conditions. The Bank of Canada is one of the pioneers in this area and presented, in the mid-1990s, what is known as a Monetary Conditions Index (MCI), which is an aggregate of the policy rate and the exchange rate.⁶ In the latter part of the 1990s, this index was extended to include more financial variables, at which point it started to be called the Financial Conditions Index (FCI).⁷

In the 21st century, banks and international institutions started to create their own indices for financial conditions. Consequently, there are today a number of established indices that are used by private agents, institutions and central banks. Some examples are Goldman Sachs, Deutsche Bank, OECD, IMF, ECB and Chicago Fed.⁸

⁶ Freedman (1994)

⁷ Hatzius, Hooper, Mishkin, Schoenholtz and Watson (2010).

⁸ Dudley and Hatzius (2000), Hooper, Mayer and Slok (2007), Guichard and Turner (2008), Swiston (2008), Angelopoulou, Balfoussia and Gibson (2013), Brave and Butter (2011).

Over the years, a number of different methods have been developed to construct an index and to determine which variables should be included. The literature describes two main empirical methods.⁹ The first method involves constructing an index with the assistance of principal component analysis, with the aim of attempting to capture the common variation in a large number of financial variables. The second method is based on an aggregate index in which the weights are determined in the basis of the different variables' relative effects on, for example, GDP or inflation. In this article, we use the first method, which is to say principal component analysis.

Since 2011, the Riksbank has used an index that measures financial stress in Sweden and just recently also constructed an early warning indicator of fragility in the financial system.¹⁰ The index that measures financial stress is used as a tool for analysing the development on financial markets and financial stability. However, the index differs from the index we present here both in terms of its aim and of how it is constructed. The index for financial stress is primarily used to identify disruptions that can damage the financial markets' ability to efficiently fulfil their role as intermediary between borrower and lender or buyer and seller. This is done by studying measures of risk of various types. A clear indicator of financial stress is when different risk measures are highly correlated with each other. Instead, in this article, we attempt to create a financial index that captures the overall financial conditions to give a comprehensive view of the development of the financial markets, related to real economy developments. Such an index could also include various measures of risk, but is also based on other financial variables. In Figure A1 in the appendix, we show how the two indices differ markedly. However, it can be seen that periods of less favourable financial conditions usually coincide with period of increased financial stress. The early warning indicator of financial fragility is in turn designed to give a numerical assessment of the build-up of systemic fragility in the credit sector of the economy.

3 An index for financial conditions in Sweden

In this paragraph, we start by describing the empirical method we have used to aggregate a large number of different financial variables. We discuss which financial variables should be included in an index for financial conditions in Sweden and evaluate their connection with the real economy. We then study the index's development and analyse how it has moved in various periods. We also examine more closely which variables have had the greatest effect on the index's development.

3.1 Aggregating financial variables with principal component analysis

One way of constructing an aggregate index for financial conditions is to use principal component analysis.¹¹ This is a statistical method that captures the common variation in a set of variables and identifies different patterns in the data. In this way, the number of variables can be condensed into a smaller number of components that capture the common variation in the variables. The components can be arranged according to their information content and the first components are normally enough to capture the primary driving forces in the relevant data set.

The advantage of principal component analysis is that the construction does not require a structural model in which we would have to make various assumptions to estimate the weights of the different variables. The disadvantage is that it is difficult to make a direct economic interpretation of the index. According to the construction, the index only captures

⁹ Hatzius, Hooper, Mishkin, Schoenholtz and Watson (2010).

¹⁰ For more information, see Johansson and Bonthron (2013) and Giordani, Spector and Zhang (2017).

¹¹ Angelopoulou, Balfoussia and Gibson (2013).

the shared variation in the financial variables and thus does not necessarily have any connection to the development of GDP, for example. But many studies nevertheless show that an aggregate index of financial variables would have a better forecasting ability for GDP in the short term compared with models that only include lagged values of GDP or individual financial variables.¹² The weights for the variables in those components included in the index can also be examined to identify the forces driving the development of the index. We do this in the next section.

3.2 Financial variables that can be included

There exist a large number of variables that, in various ways, capture the financial conditions and the selection of variables differs from study to study and from country to country. Our aim is to create a relatively broad index that captures different parts of the financial channels in Sweden. We therefore divide the financial variables into the following groups: asset prices, volumes, interest rate differentials and measures of risk.

3.2.1 Asset prices

In financial theory, it is often assumed that participants on financial markets are forwardlooking, which means that all available information should be reflected in the asset price. The theory thus says that, if the financial markets are functioning perfectly and no frictions are present, the price of various financial instruments should suffice to completely describe the financial conditions.¹³ A higher price for a financial asset is interpreted to mean that the financial conditions are more expansionary. The relationship between price and rate is such that, when the price of an interest-bearing asset rises, the expected yield on the asset decreases and the rate falls. This makes it easier for households and companies to borrow and consume more. Commonly-occurring variables included in different studies are interest rates with various maturities, stock market movements and the exchange rate.¹⁴ Housing prices are also included in many studies as housing usually forms collateral for loans.

3.2.2 Volumes

However, the financial markets do not always function perfectly and, occasionally, frictions arise. Consequently, particularly in periods of financial stress, we deem that the asset price does not fully reflect the financial conditions. For example, many studies show that variables that capture volumes or the availability of credit in the economy provide important information.¹⁵ Examples of series that are usually used include lending to households and companies, issues of corporate bonds, various measures of credit terms in the economy and the money supply. For example, Swiston (2008) argues that the availability of credit growth. Credit growth only reflects companies' external funding and demand for external funding tends to increase at the start of a downturn, when access to internal funding deteriorates.

3.2.3 Interest rate differentials

The difference in the rate between various types of asset may reflect both different maturities between asset types and different risk profiles such as credit and liquidity risks, for example. When a shock occurs on the financial markets, there is normally a rise in the risk premium that investors demand to hold higher-risk assets. An increase in the interest rate differential between safe and higher-risk assets thus reflects generally tighter financial

¹² Hatzius, Hooper, Mishkin, Schoenholtz and Watson (2010).

¹³ Swiston (2008).

¹⁴ Angelopoulou, Balfoussia and Gibson (2013).

¹⁵ Swiston (2008), Hatzius, Hooper, Mishkin, Schoenholtz and Watson (2010).

conditions. For example, an increase of the interest rate differential between Stibor and a treasury bill with an equivalent maturity indicates a shock on the interbank market which means that the banks are demanding a higher interest rate when lending money to each other. A rising risk premium can also be captured by an increased interest rate differential between higher risk bonds, such as corporate and mortgage bonds, and safe bonds such as government bonds. A company would then need to pay a higher interest rate to borrow money on the bond market and thus the company's funding costs would rise.

Many studies also include variables that capture the slope of the yield curve, which is to say the difference between a government rate with a longer maturity and one with a shorter maturity.¹⁶ A reduced interest rate differential may mean that the financial conditions are becoming more expansionary, as it is becoming cheaper to obtain funding over the long term. But the slope of the yield curve can also be seen as an indicator that captures the sentiment on the financial markets. According to the expectation hypothesis, longer-term rates are determined by expectations of the future short-term rate plus a term premium that investors usually demand due to the uncertainty surrounding how the rate may change over the long term. If sentiment on the financial markets deteriorates and more participants expect a downturn, the long-term interest rates should fall, as the short-term rate will be expected to eventually become lower. In turn, the short-term rate is steered to a greater extent by the central banks' policy rates and the market's expectations of monetary policy. The central bank does not necessarily have to cut its policy rate as soon as sentiment deteriorates. The central bank's actions also depend on how expansionary monetary policy is to start with. In recent years, many central banks have been restricted by their policy rates being close to what is considered to be a lower limit. Studies also show that, over short periods ahead of an economic slowdown, the yield curve can be inverted, which is to say that the shorter-term rates are higher than the long-term rates.¹⁷ A lower interest rate differential between long-term and short-term rates can thus indicate lower future growth.

3.2.4 Measures of risk

Other measures that can capture tensions on the financial markets include various measures of risk that measure the actual or expected volatility of pricing on various markets. Rising volatility on, for example, the stock or bond market is often a sign of increased uncertainty and stress on the financial markets. These measures can thereby be used to capture the overall risk sentiment on the financial markets.

3.3 Which variables should be included?

Many of the studies made of financial indices use data from the United States. Access to corresponding Swedish data is more limited, but our goal is to use similar variables as far as is possible and to include variables that capture the various financial channels. One purpose is to create an index that can be used to better understand the connection between the financial conditions and the real economy. Most studies that have been made of both central banks and other participants are aimed at trying to understand the development of GDP.¹⁸ One way of selecting the variables that should be included in the index is thus to test the individual variables' covariation with the development of GDP.

One advantage of creating an index with the assistance of principal component analysis is that the number of variables does not need to be limited. Based on previous studies, we analyse a large number of financial variables and evaluate their ability to explain the development of the real economy.¹⁹ We evaluate the coefficient of determination in a

¹⁶ Hatzius, Hooper, Mishkin, Schoenholtz and Watson (2010).

¹⁷ See, for example, Estrella and Hardouvelis (1991) and Rudebusch and Williams (2009).

¹⁸ See, for example, Dudley and Hatzius (2000), Hooper, Mayer and Slok (2007), Guichard and Turner (2008), Swiston (2008),

Angelopoulou, Balfoussia and Gibson (2013), Brave and Butter (2011).

¹⁹ See, for example, Hatzius, Hooper, Mishkin, Schoenholtz and Watson (2010).

regression in which we attempt to explain the development of GDP two or four quarters ahead with the use of lagged values of GDP and lagged values of the financial variable (see equation 1).

(1)
$$y_{t+h} - y_t = \beta_0 + \sum_{i=1}^{p_y} \beta_1 \Delta y_{t+1-i} + \sum_{i=i}^{p_x} \beta_2 x_{t+1-i} + e_{t+i}$$

The data included stretches from 1998 until the first six months of 2016. GDP is expressed as the logarithm of real GDP, in which $y_{t+h} - y_t$ shows the percentage change between quarter t+h, which is two or four quarters ahead, and the last quarter. x_t indicates the financial variable and p_y and p_x indicates the number of lagged values of Δy and x that are included in the regression, which, in this study, is four. Among the financial variables are interest rates and survey data expressed in levels, while other variables refers to the first difference of the log transformed variables. The regression is estimated from quarterly data, and the coefficient of determination of the financial variables is evaluated using an F-test that jointly tests whether the coefficients for the financial variable are separated from zero. A p-value for the F-statistic close to zero indicates that we can reject the hypothesis that the coefficient of determination for the development of GDP. In Table 1 below, we show the result for the variables we consider to be of greatest interest.

Variable	F-test*	
	h=2	h=4
Repo rate	0.00	0.00
Stibor 3 months	0.00	0.00
Stibor – T-bill, 3 months	0.00	0.00
Government bond yield, 5 years	0.31	0.07
Government bond yield, 10 years	0.36	0.11
Government bond yield, 10 years – Repo rate	0.00	0.00
Government bond yield Sweden – Germany, 2 years	0.09	0.03
Mortgage bond yield – Government bond yield, 5 years	0.06	0.05
Stock market, OMX Stockholm	0.01	0.07
Volatility Index, VIX	0.06	0.18
House prices, HOX-index	0.00	0.00
KIX-index	0.54	0.70
Lending to non financial companies	0.06	0.01
Lending to households	0.18	0.17
Money, M2	0.00	0.02
Lending conditions, companies	0.00	0.02

Table 1. Evaluation of various financial variables' ability to predict GDP development

*The tabel shows p-values. A value less then 0.10 indicates that we can reject the null hypothesis that the coeficients are not significantly different from zero.

In the table, it can be seen that the development of most financial variables seems able to help explain the development of GDP. For many variables, the p-value is close to zero both two and four quarters ahead. The variables that stand out in the table and which do not seem to have any coefficient of determination for GDP development are mostly longer government bond yields and KIX, which is a competition-weighted index for the krona exchange rate.

However, it seems reasonable to believe that the effects a specific shock would have on the economy would depend on its nature. For example, positive news on the development of the real economy would probably contribute towards a strengthening of the exchange rate at the same time as GDP would grow faster. On the other hand, an exogenous shock on the exchange rate causing only the krona to appreciate would probably lead to lower growth. The results shown in Table 1 thus need not mean that exogenous changes in longterm interest rates or the KIX index have no significance for the future development of GDP. In equation 1 above, we only include earlier values for the financial variables. When we also include simultaneous movements for the financial variables, the coefficient of determination improves in general (see Table A1 in the appendix). This indicates that GDP development also covaries with the financial conditions over the current quarter. In this test, the fiveyear government bond yield and the KIX index also seem to improve the coefficient of determination for GDP development.

The results shown in Table 1 form the basis for the financial variables that we have chosen to include in the index. Other important selection criteria include the data available over the entire period, the variables considered to be most important to the financial conditions according to economic theory and the manner in which the variables affect the composition of the index. Based on this, we have chosen to include, for example, both the five-year government bond yield and the KIX index, as they are central variables in the discussion of the financial conditions.

In Table 2, we have compiled the variables we include in the index. A more in-depth description of the data is available in Table A2 in the appendix. The financial markets usually move faster than the real economy and many variables become available on a daily basis. However, to capture more overall trends in the financial conditions, we have chosen to construct the index on a monthly basis. All variables have been normalised to ensure that the index is not affected by the measurement of the variables in different units. This means that the index is based on an average of the financial variables over the period we study and that the scale specifies the number of standard deviations by which the index deviates from the average. The variables are also transformed so that a higher value means that the financial conditions are becoming more expansionary. This means that we change the signs for interest rates and interest rate differentials, for example. This is to facilitate the interpretation of the weights in the index. However, the interest rate differential between the ten-year government bond yield and the reporate is an exception, as our analysis shows that an increase in the interest-rate differential coincides with periods in which the financial conditions are becoming more expansionary. It is also worth noting that, as in other studies, we have chosen to use surveys for companies' credit terms instead of credit growth for companies, as these better capture the supply of credit.²⁰

20 Swiston (2008), Hatzius, Hooper, Mishkin, Schoenholtz and Watson (2010).

Table 2. Variables in the index

Variable
Repo rate
Stibor – T-bill, 3 months
Government bond yield, 5 years
Government bond yield, 10 years – Repo rate
Government bond yield Sweden – Germany, 2 years
Mortgage bond yield – Government bond yield, 5 years
Stock market, OMX Stockholm
Volatility Index, VIX
House prices, HOX-index
KIX-index
Lending to households
Lending conditions, companies

3.4 An index for financial conditions in Sweden

To aggregate the financial variables in Table 2 into an index, we use principal component analysis. Our goal is to find the primary driving forces in the data, at the same time as we wish to capture different parts of the financial conditions. This means that we have to strike a balance regarding how many components we will include, which is to say how large a part of the variation in the data set the index will be based on. As in other studies, we set the value at about 70 per cent.²¹ In our data set, the first three components explain about 70 per cent of the total variation in the 12 financial variables we include. We therefore base the index on the first three components. The component can explain. The first component can explain about 32 percentage points of this variation. As we include the first three components that together explain 70 per cent divided by 70 per cent. This means that the first component is given a weight corresponding to 32 per cent divided by 70 per cent. This means that the first component is given about half of the weight in the index.

Figure 2 shows the financial index on a monthly basis from January 1998 until May 2016. As the variables are normalised, the index measures the financial conditions in relation to the index's average over the period and deviations from zero are shown in the number of standard deviations. In general, we can note that there have been three cycles in the financial conditions in Sweden since the end of the 1990s. The downturns in the index coincide well with the IT crash at the start of the 21st century, the financial crisis of 2008-2009 and the debt crisis in the euro area in 2011-2012. Following these periods, there has been a clear recovery of the financial conditions. In the mid-2000s above all, we can see a relatively long period of expansionary financial conditions in the figure. The financial conditions have also been expansionary in recent years.

21 See, for example, Angelopoulou, Balfoussia and Gibson (2013).



Sources: Thomson Reuters and Sveriges Riksbank

3.5 What is driving the development in the index?

To more closely study what is driving the index, we can study how much weight the different variables have in the principal components. Table 3 shows the weight of the different variables in the three components, as well as the aggregated total weight of the variable in the three components. The variables have been sorted into descending order on the basis of how large a proportion of the total variation they can explain.

Variable	PC 1	PC 2	PC 3	Aggregated weight
Repo rate	6.4	52.5	24.4	17.7
Lending conditions, companies	27.0	35.5	-6.1	16.2
Volatility Index, VIX	34.0	26.9	-13.8	15.4
House prices, HOX-index	43.4	-5.4	12.0	14.3
Government bond yield, 5 years	-8.3	52.8	26.0	13.3
Stock market, OMX Stockholm	33.4	21.1	-17.9	13.3
Government bond yield Sweden – Germany, 2 years	20.3	-9.6	60.8	12.5
Stibor – T-bill, 3 months	40.7	-10.7	-6.5	9.7
Government bond yield, 10 years – Repo rate	26.4	4.2	-0.7	9.4
Mortgage bond yield – Government bond yield, 5 years	39.7	-25.8	-1.8	6.4
KIX-index	-6.8	-11.6	64.2	3.7
Lending to households	25.0	-31.1	13.2	2.5
Share of total varians	32.1	23.5	13.5	69.1

Table 3. The individual variables' weight in the three first principal components

A first stage is to look for patterns in the three components that reflect different influences in the data. Most variables have a relatively large weight in the first component. In total, it explains about 32 per cent of the variation in the entire data set. The variables that have the greatest weight in the first component are primarily various measures of risk, which is to say interest rate differentials between higher risk and safe assets, and variables that are linked to the stock market. Housing prices also have a relatively high weight. The second component explains a further 24 per cent of the variation in the data set. In this component, various interest rates stand out. Both the repo rate and the five-year government bond yield have high weights. Finally, the third component explains about 14 per cent of the variation. In this component, above all the KIX index and the interest rate differential between Sweden and Germany have high weights. As we have discussed above, we deem that the Riksbank's monetary policy affects several financial variables. But the analysis of the components shows that the direct effect of monetary policy is most substantial in the second and third components, while the first component to a greater extent reflects the overall development of the financial markets.²²

The aggregate weight of the different variables is shown in the final column of Table 3. Many variables have about the same weight in the index, which indicates that most variables are important for the development of the index. On the other hand, lending to households, the KIX index and the interest rate differential between a five-year housing bond and a government bond have little weight in the index. One conclusion is that these variables probably follow another pattern than many of the others. However, we deem that the variables still contain valuable information and may be particularly important during certain periods. For example, the Riksbank has placed relatively heavy emphasis on the development of the krona in recent years to cause inflation to rise towards target. The development of the krona has therefore been important for the financial condition in recent years.

3.6 A closer analysis of the development of the index

Another way of analysing the contribution made by the different variables is to study how they have contributed towards the development of the index over time. Figure 3 shows the financial index together with the contribution made by the different variables. It provides an indication of which variables have been important over different periods. As we described above, the principal components capture the common variation in the financial variables and the weight of each variable is thereby affected, to a certain extent, by which variables we include. It is also important to remember that the weights for the different variables are based on historical correlations.



Figure 3. Index for financial conditions in Sweden and contributions from the different variables

Sources: Thomson Reuters and Sveriges Riksbank

As we describe in the introduction to this article, it is difficult to separate the effects of monetary policy from other financial shocks and several variables are affected when, for example, the Riksbank raises or cuts the repo rate. We have therefore chosen to include

²² See Figure A2 in the appendix for the development of the individual components.

monetary policy as a part of the financial conditions. The repo rate is also the variable that is given the greatest weight in the index. To study the role of monetary policy in the financial conditions, we also use the repo rate as the basis of our analysis of how individual variables have affected the index.

The dark blue columns in Figure 3 illustrate the contribution made by the repo rate. The figure also shows that the repo rate has been relatively important over the entire period and that monetary policy, via the repo rate, has contributed towards both tighter and more expansionary financial conditions. However, before we analyse the repo rate's effects in more detail, it is important to point out that the contribution made by each variable depends on the average for the variable over the period we are studying. This means that monetary policy has contributed negatively to the index's value at the points in time at which the repo rate has been higher than average. As interest rates have shown a falling trend in recent decades, we deem, that this has affected the development of the index to a certain extent. Partly to manage this problem, we have chosen not to start the index until 1998. This allows us to avoid the large interest rate cuts taking place in the mid-1990s after the Riksbank introduced inflation targeting in 1993 (see Figure A3 in the appendix).²³

Figure 3 shows that the repo rate made a negative contribution to the index from the mid-2000s. This can primarily be explained by the fact that the repo rate was relatively high at this point and, except for a brief period at the end of the 1990s, the repo rate was around 4 per cent. This can be compared with the average for the entire period, which is just over 2 per cent. Financial conditions periodically deteriorated over this period, but, in general, the index was close to its historical average all the way until 2001. The financial conditions then deteriorated markedly in conjunction with the so-called IT crash. This resulted in heavy downturns on the world's stock exchanges and economic activity in Sweden declined.²⁴ But, at this point, inflation was nevertheless above the Riksbank's target of 2 per cent. Consequently, it took until the end of 2002 until the Riksbank cut the repo rate, from just over 4 per cent to a low point of 1.5 per cent at the end of 2005.

In general, the financial markets were characterised by a positive mood in the mid-2000s with relatively low interest rates, rising share and housing prices and strong credit growth. To dampen the strong development that was characterising both the financial markets and the real economy, the Riksbank raised the repo rate by just over 3 percentage points between 2006 and September 2008. But in 2007, the financial conditions started to deteriorate. At this point, increasingly serious problems were discovered on the US mortgage market and this uncertainty spread to other financial markets. In 2008, financial conditions in Sweden deteriorated markedly, which can be explained by falling asset prices and rising risk premiums on several markets. High inflation also led the Riksbank to continue to raise the repo rate for a period.

The financial crisis became acute in the autumn of 2008, when the US investment bank Lehman Banks filed for bankruptcy. A lack of confidence in counterparties' credit ratings reduced access to credit and certain markets more or less ceased to function. Many financial institutions that had earlier funded themselves cheaply through short-term loans had problems renewing their loans, and if they obtained new loans, these were much more expensive than before. This development on the financial markets contributed towards an international economic slowdown with falling growth and rising unemployment in many countries. Public authorities around the world began to implement strong measures to stop the negative trend. In Sweden, the Riksbank, the Government and other Swedish authorities took a number of measures to alleviate the effects of the international financial crisis and to

24 See, for example, Dillén and Sellin (2003).

²³ See, for example, Armelius, Bonomolo, Lindskog, Rådahl, Strid and Walentin (2014) and Ohlsson (2016).

improve the functioning of the financial markets in Sweden. During a short time period, the Riksbank also cut the repo rate from 4.75 per cent to 0.25 per cent.²⁵

These measures contributed towards the improvement of the financial conditions at the end of 2009 and in 2010. During this period, the Swedish economy had also recovered and inflation had started to rise, which led the Riksbank to raise the repo rate to 2 per cent in 2010-2011. But at the end of 2011, the economic outlook in the euro area deteriorated again, at the same time as inflationary pressures in Sweden eased off. The debt crisis in Europe resulted in a new crisis of confidence on the financial markets, and the financial conditions deteriorated again.

Since 2011, the Riksbank has conducted an expansionary monetary policy to get inflation to rise towards the target. Since February 2015, the repo rate has been negative and, in addition, the Riksbank has made its monetary policy even more expansionary through the purchase of government bonds. Low interest rates, both in Sweden and abroad, have contributed towards falling funding costs for both households and companies, which, in Sweden, has also led to strong credit growth. These low interest rates have also led investors both in Sweden and abroad to turn to other, higher-risk assets, which has resulted in the strong development of the world's stock markets, falling risk premiums and low volatility. Housing prices have also continued to rise. Recent years' expansionary financial conditions are deemed to be one of the causes of the strong economic development in Sweden.

The index thus seems to be able to capture the major events on the financial markets. In the index, it is possible to follow how monetary policy has affected the financial conditions, in particular via the direct contribution made by the repo rate. But monetary policy also directly and indirectly affects many other financial variables. For example, the turquoise columns in Figure 3 indicate that a low five-year government bond yield has contributed towards the expansionary conditions of recent years. Our assessment is that it has fallen partly as a result of lower interest rates internationally, but also as a result of the Riksbank's more expansionary monetary policy in the form of a lower repo rate and purchases of government bonds.²⁶ However, according to the index, the average financial conditions have been affected relatively marginally by the development of the krona. But the expansionary monetary policy of recent years has, on the other hand, contributed towards a weakening of the krona, which is also captured by the index. For example, the light blue columns in Figure 3, which show KIX, indicate that a weaker krona contributed towards slightly more expansionary financial conditions in 2014 and 2015.

3.7 The index covaries with the development of GDP

The method used constructing the index is a statistical method that only captures the common variation in the variables we analyse. The different variables' weight in the index is thus not optimised to covary with GDP development. But, as we have described above, we partly base our selection of variables for the index on their ability to help explain GDP development. It is therefore reasonable to believe that the index may include information that can help predict GDP development in the short term. Figure 4 shows the financial index together with the quarterly change in GDP. In this figure, the index has been levelled out with a three-month moving average to match GDP, which uses quarterly data. It has also been projected forward by one month, as the index seems to lead GDP development slightly. In Figure 4, it can also be seen that the index seems to be able to capture the development of GDP relatively well and the correlation between the two series is 0.64. When we estimate the index for GDP development, the coefficient of determination becomes 0.59.²⁷

²⁵ Elmér, Guibourg, Kjellberg, Nessén (2012).

For a more in-depth description of how purchases of government securities are deemed to have affected the economy, see, for example, Alsterlind, Erikson, Sandström and Vestin (2015), De Rezende (2015) and De Rezende, Kjellberg and Tysklind (2015).
To avoid the wide fluctuations of the financial crisis, we include a dummy variable for this period.



Figure 4. Index for financial conditions and GDP on a quarterly rate Standard deviations and percentages

Note. The index has been normalised and has an average of zero and a standard deviation of one. GDP is expressed as a percentage quarterly change and the financial index has been levelled out by a three-month moving average and projected forward by one month. Sources: Thomson Reuters and Sveriges Riksbank

Figure 4 shows the index based on data for the entire period. To fully evaluate the index's ability to tell us anything about GDP development in real time, we also recursively estimate an index from 2006. This involves estimating the index anew for each month after 2006 using the information that was available at that point. We do this to see whether the index can also capture, in real time, the fluctuations it captures when we estimate it over the entire period. It also gives us an indication of how well we would have been able to describe the financial conditions at various turning points, for example. Figure 5 shows such a retrospective construction of a real-time index, together with the index for the entire period. We can see that they correspond well and that the real-time index manages to capture most of the upturns and downturns of the financial conditions. However, it is worth noting that, during the financial crisis, the real-time index did not really fall to the same extent as the index based on the entire period. Furthermore, it fell slightly later. This shows that it is usually more difficult to gain an overview of the effects of major shocks when they are in the process of occurring, as compared with studying them afterwards. As we include more historical data in the real-time index, the more stable we expect it to become, and, in recent years, the development of the two indices has been largely the same. The covariation with GDP on a quarterly rate is also largely the same for the real-time index as for the index estimated on data for the entire period.



Figure 5. Indices for financial conditions estimated recursively Standard deviations

Note. The indices have been normalised and have an average of zero and a standard deviation of one. The real-time index has been estimated using data up until 2006, after which the index is estimated anew for every new month. Sources: Thomson Reuters and Sveriges Riksbank

3.8 Does the index include any new information?

As a final stage in the evaluation of the financial index's ability to predict GDP development, we investigate the index's information value in relation to other indicators, such as the Purchasing Managers' Index and the Economic Tendency Survey, which are usually used to predict Swedish GDP development in the short term. In Figure 5, our index can be seen together with the Purchasing Managers' Index for the industrial sector and the Economic Tendency Survey in which all indices are normalised. The Figure shows that these series covary relatively well but diverge in certain periods, which indicates that our index may provide further important information. During the period we study, the correlation between the financial index and the Purchasing Managers' Index and Economic Tendency Survey is 0.58 and 0.56 respectively, while the correlation between the Purchasing Managers' Index and the Economic Tendency Survey is almost 0.8.

In Figure 6, we can see how the three indices have developed over time. Overall, the financial index seems to fluctuate less than the other indices. All three indices manage to capture the large upturns and downturns in the economy, but the financial index seems to lead the development slightly. However, it is worth noting that the financial index's 'leading' characteristics decrease slightly when we study the financial index that is estimated in real time, above all in comparison with the Purchasing Managers' Index. One advantage of the financial index, compared with the others, is that it can be updated on an ongoing basis, as many of the variables included are available as daily data.

When we study the three indices in detail, we also see that there are periods in which they diverge. One such example is in recent years, when the financial index has successively risen and indicated expansionary financial conditions. But the Purchasing Managers' Index and the Economic Tendency Survey have been more volatile and are now close to their historical averages. This difference corresponds relatively well with recent years' economic development. The financial conditions have been expansionary, with low interest rates, rising asset prices and strong credit growth, which we consider has contributed towards strong domestic demand. On the other hand, development within the export-heavy industrial sector has been weaker, and this has been the case both in Sweden and abroad.

We therefore consider that the indicators capture different parts of the economy and may, therefore, be good complements to each other. When we attempt to explain GDP development with the help of the three different indices, the coefficient of determination

becomes about the same. At the same time, regressions show that, when the financial index is included in estimates together with the other indicators, the coefficient of determination rises slightly. This indicates that the financial index complements the other indicators.



standard deviation of one. Sources: Thomson Reuters and Sveriges Riksbank

4 Conclusion

In this article, we have created an index for the financial conditions in Sweden. For a central bank, it is important to understand the development of the financial markets, as it is through various financial channels that monetary policy acts. Economic developments in recent years, with first the financial crisis and then the debt crisis in the euro area, also bear witness to a close link between the financial markets and the real economy. Our approach is therefore to create a financial index that aggregates twelve financial variables that capture the development of the financial markets. The variables' weights are determined by using principal component analysis, which is a statistical method that compresses the number of variables to capture the common variation in the variables. Our assessment is that an aggregated financial index could provide an overall view of the financial conditions and thereby facilitate the discussion of how the financial markets are developing and what effect this could have on the real economy.

According to the construction, the index only captures the common variation in the financial variables. It is therefore important to point out that no direct statistics or theoretical link exists between the index and the development of the real economy. Despite this, however, our assessment is that many of the financial variables contain valuable information for the prediction of GDP development in the short term, for example. We therefore partly base our selection of financial variables on their ability to explain GDP development, but also on our desire to have a broad selection of series that together cover a large part of the development of the financial markets.

Our analysis shows that the financial index manages to capture the major events on the financial markets and explains the economic fluctuations relatively well. The analysis shows that the Riksbank's monetary policy has been an important factor for the financial conditions. We also deem that the financial index can be used as an early indicator of GDP development, and that the coefficient of determination for GDP improves when we aggregate the financial variables, compared with when we only use individual variables. In addition to this, our

results indicate that the index includes information that could complement other early indicators that are usually used to make forecasts for GDP in the short term, for example the Purchasing Managers' Index and the Economic Tendency Survey.

Our conclusion is therefore that a financial index complements other analyses of the financial conditions in Sweden. The index is a quantitative measure that helps describe the common significance of different financial channels. Of course, as with other economic models, this measure has deficiencies and, in particular, uncertainty can be associated with the method and data we use. But, as long as the index is interpreted with a degree of caution, it can provide valuable information.

5 References

Alsterlind, Jan, Hanna Armelius, David Forsman, Björn Jönsson and Anna-Lena Wretman (2015), "How Far Can the Repo Rate be Cut?", *Economic Commentaries*, No. 11, Sveriges Riksbank.

Alsterlind Jan, Henrik Erikson, Maria Sandström and David Vestin (2015), "How Can Government Bond Purchases Make Monetary Policy More Expansionary?", *Economic Commentaries*, No. 12, Sveriges Riksbank.

Angelopoulou, Eleni, Hiona Balfoussia and Heather Gibson (2013), "Building a Financial Conditions Index for the Euro Area and Selected Euro Area Countries: What does it Tell Us About the Crisis?", Working Paper Series 1541, European Central Bank.

Basel Committee on Banking Supervision (2012), "The Policy Implications of Transmission Channels Between the Financial and the Real Economy", BCBS Working Paper No. 20, Bank for International Settlements.

Bonfirm, Diana and Carla Soares (2014), "The Risk-Taking Channel of Monetary Policy – Exploring All Avenues", Working Paper No. 2, Bank of Portugal.

Brave, Scott and Andrew Butter (2011), "Monitoring Financial Stability: A Financial Conditions Index Approach", *Economic Perspectives*, Vol. 35, No. 1, pp. 22-43, Federal Reserve Bank of Chicago.

De Rezende, Rafael B. (2015), "The Interest Rate Effects of Government Bond Purchases Away from the Lower Bound", Working Paper No. 324, Sveriges Riksbank.

De Rezende, Rafael B., David Kjellberg and Oskar Tysklind (2015), "Effects of the Riksbank's Government Bond Purchases on Financial Prices", *Economic Commentaries*, No. 13, Sveriges Riksbank.

Dillén, Hand and Peter Sellin (2003), "Financial Bubbles and Monetary Policy", Sveriges Riksbank Economic Review, No.3, pp. 94-118.

Dudley, William and Jan Hatzius (2000), "The Goldman Sachs Financial Conditions Index: The Right Tool for a New Monetary Policy Regime", *Global economics paper No. 44,* Goldman Sachs.

Elmér, Heidi, Gabriela Guibourg, David Kjellberg and Marianne Nessén (2012), "The Riksbank's Monetary Policy Measures During the Financial Crisis – Evaluation and Lessons Learnt", *Sveriges Riksbank Economic Review*, No. 3, pp. 8-30, Sveriges Riksbank.

Estrella Arturo and Gikas A. Hardouvelis (1991), "The Term Structure as a Predictor of Real Economic Activity", *Journal of Finance*, Vol. 46, No. 2, pp. 555-576.

Fransson, Lina and Oskar Tysklind (2016), "The Effect of Monetary Policy on Interest Rates", Sveriges Riksbank Economic Review, No. 1, pp. 36-56.

Freedman, Charles (1994), "The Use of Indicators and of the Monetary Conditions Index in Canada", in *Frameworks for Monetary Stability: Policy Issues and Country Experiences*, pp. 458-476, ed. Baliño, Tomás J. T. and Carlo Cottarelli, International Monetary Fund.

Giordani, Paolo, Erik Spector and Xin Zhang (2017), "A New Early Warning Indicator of Financial Fragility in Sweden", *Economic Commentaries*, No. 1, Sveriges Riksbank.

Guichard, Stéphanie and David Turner (2008), "Quantifying the Effect of Financial Conditions on US Activity", OECD Economics Department Working Papers No. 635, OECD Publishing: Paris.

Hatzius, Jan, Peter Hooper, Frederic S. Mishkin, Kermit L. Schoenholtz and Mark W. Watson (2010), "Financial Conditions Indexes: A Fresh Look After the Financial Crisis", Working Paper No. 16150, National Bureau of Economic Research.

Hooper, Peter, Thomas Mayer and Torsten, Slok (11 June 2007), "Financial Conditions: Central Banks Still Ahead of Markets", *Global Economic Perspectives*, Deutsche Bank.

Hopkins, Elisabeth, Jesper Linde and Ulf Söderström (2009), "The Monetary Transmission Mechanism", Sveriges Riksbank Economic Review, No. 2, pp. 31-50.

Johansson, Fredrik and Tor Bonthron (2013), "Further Development of the Index for Financial Stress in Sweden", *Sveriges Riksbank Economic Review*, No. 1, pp. 45-63.

Nessén, Marianne, Peter Sellin and Per Å. Sommar (2011) "The Framework for the Implementation of Monetary Policy, the Riksbank's balance sheet and the financial crisis", *Economic Commentaries*, No. 1, Sveriges Riksbank.

Noyer, Christian (2007), "Financial Innovation, Monetary Policy and Financial Stability", 27-28 April, Spring Conference of the Bank of France/Deutsche Bundesbank: Eltville, Germany.

Rudebusch, Glenn. D and John C. Williams (2009), "Forecasting Recessions: The Puzzle of the Enduring Power of the Yield Curve", *Journal of Business & Economic Statistics*, Vol. 27, No. 1, pp. 495-503.

Singh, Sukudhew, Ahmad Razi, Norhana Endut and Helmi Ramlee (2008), "Impact of Financial Market Developments on the Monetary Transmission Mechanism", BIS Paper No. 39, Bank for International Settlements.

Swiston, Andrew (2008), "A U.S. Financial Conditions Index: Putting Credit Where Credit is Due", Working Paper No. 161, International Monetary Fund.

Appendix



Figure A1. Index for financial conditions and index for financial stress Standard deviations, index units

Note. The financial condition index has been normalised by an average of zero and a standard deviation of one. The index for financial stress is constructed according to the method in Johansson and Bonthron (2013). Sources: Thomson Reuters and Sveriges Riksbank

Table A1. Evaluation of various financial variables'	ability to predict GDP	development,
including current movements		

Variable	F-test*	
	h=2	h=4
Repo rate	0.00	0.00
Stibor 3 months	0.00	0.00
Stibor – T-bill, 3 months	0.00	0.00
Government bond yield, 5 years	0.04	0.01
Government bond yield, 10 years	0.35	0.12
Government bond yield, 10 years – Repo rate	0.00	0.00
Government bond yield Sweden – Germany, 2 years	0.13	0.05
Mortgage bond yield – Government bond yield, 5 years	0.01	0.01
Stock market, OMX Stockholm	0.00	0.00
Volatility Index, VIX	0.00	0.00
House prices, HOX-index	0.00	0.00
KIX-index	0.02	0.02
Lending to non financial companies	0.08	0.02
Lending to households	0.00	0.00
Money, M2	0.00	0.00
Lending conditions, companies	0.00	0.00

*The table shows p-values. A value less than 0.10 indicates that we can reject the null hypothesis that the coeficients are not significantly different from zero. h indicates the number of quarters ahead in time.

Table A2. Description of data

Variable	Description of data
Repo rate	The repo rate expressed in level and per cent, opposite sign (Sveriges Riksbank)
Stibor – T-bill, 3 months	The difference between Stibor 3 month and Swedish 3-month T-bills, expressed in percentage points, opposite sign. Zero coupon rate interpolated from bond prices using the extended Nelson-Siegel method. (Thomson Reuters, Sveriges Riksbank)
Government bond yield, 5 years	5 year Swedish government bond yield expressed in per cent, opposite sign. Zero coupon rate interpolated from bond prices using the extended Nelson-Siegel method. (Thomson Reuters, Sveriges Riksbank)
Government bond yield, 10 years – Repo rate	Difference between 10 year government bond yield and the repo rate expressed in percentage points. Zero coupon rate interpolated from bond prices using the extended Nelson-Siegel method. (Thomson Reuters, Sveriges Riksbank)
Government bond yield Sweden – Germany, 2 years	Difference between Swedish and German 2 year government bond yields expressed in percentage points, opposite sign. Zero coupon rate interpolated from bond prices using the extended Nelson-Siegel method. (Thomson Reuters, Bundesbank, Sveriges Riksbank)
Mortgage bond yield – Government bond yield, 5 years	Difference between 5 year Swedish mortagage and government bond yields expressed in percentage points, opposite sign. Zero coupon rate interpolated from bond prices using the extended Nelson-Siegel method. (Thomson Reuters, Sveriges Riksbank)
Stock market, OMX Stockholm	OMX Stockholm Benchmark Index (OMXSPI), price return, yearly change (Thomson Reuters)
Volatility Index, VIX	Chicago Board Option Exchange (CBOE) Volatility Index, S&P 500, 30 days implied volatility, opposite sign (Thomson Reuters)
House prices, HOX-index	Nasdaq OMX Valueguard-KTH Housing Index (HOX), yearly change. Before 2005 we use SCB real estate price index (FASTPI), seasonally adjusted (Valueguard, SCB, Sveriges Riksbank)
KIX-index	Nominal effective exchange rate for the Swedish krona, index 1992-11-18=100, yearly change (Sveriges Riksbank)
Lending to households	Lending to household from MFI, yearly change (SCB)
Lending conditions, companies	Economic Tendency Survey conducted by National Institute of Economic Research, credit- and lending conditions among companies, diffusion index, standardized. Between 2004 and 2008 we use the lending indicator from ALMI and before 2004 we use Senior Loan Officer Opinion Survey (SLOOS) for the US, standardized (SCB, ALMI, Federal Reserve, Sveriges Riksbank)



Sources: Thomson Reuters and Sveriges Riksbank



Sources: Thomson Reuters and Sveriges Riksbank

It's a myth that the Riksbank's forecasts have been governed by models

Jesper Lindé and André Reslow*

Jesper Lindé is on leave from his position of Head of Research at the Riksbank to serve as resident scholar at the International Monetary Fund (IMF), while André Reslow is on leave from the Riksbank for postgraduate studies at Uppsala University

In this study, we analyse how influential macroeconomic models have been on the Riksbank's published forecasts for GDP growth, inflation and the reporate from 2006 to date. The analysis shows that the models are not so important in explaining the Riksbank's published forecasts. Rather, a great deal of judgments appear to provide the basis for the Riksbank's forecasts. Therefore, our findings show that the common view that the Riksbank blindly relies on and follows its models, recently fuelled anew by Goodfriend's and King's report, is merely a myth.

1 Introduction

A discussion has emerged lately about how the Riksbank uses models in its forecasting process. For example, the two external evaluators appointed by Swedish Parliament, Goodfriend and King (2016) raise the question in their evaluation of the Riksbank's monetary policy during the period 2010-2015. The evaluation criticises the Riksbank for being overly reliant on its models, and focusing too heavily on the models when constructing the forecasts. For instance, they write:

"...there was heavy reliance, among both the majority of the Board and the dissenters alike, on forecasts produced by models developed by Riksbank staff."

The evaluators also express this criticism as an important reason why the Riksbank have overestimated inflationary pressure in the economy during the evaluation period. Their conclusion is thus that the Riksbank ought to put less weight on the models in the future.

The conclusions of Goodfriend and King appear to have spread both in the mass media and in academia. For example, in the leading newspaper Svenska Dagbladet of 20 January 2016, financial journalist Louise Andrén Meiton wrote:1

"The investigators also want the Riksbank to be less reliant on its models and focus more on reality. The inflation forecasts have pointed towards 2 per cent even though reality has been completely different."

We are indebted to Anders Vredin for very helpful comments on an earlier draft. In addition, we also want to thank Claes Berg, Stefan Laséen, Christina Nyman, Ingvar Strid and Ulf Söderström for their valuable input and comments. We also thank Goran Katinic for assistance with diagrams and Caroline Richards for valuable proofreading of the Swedish version. Finally, we are grateful to Amanda Silver for translating the article from Swedish into English. However, the authors are themselves responsible for any remaining ambiguities and errors. The opinions expressed in this article are the sole responsibility of the authors and should not be interpreted as reflecting the views of Sveriges Riksbank. A simpler and abridged version (in Swedish) of this paper has been published previously in Ekonomisk Debatt, see Lindé and Reslow (2016).

¹ See Meiton (2016), translated from Swedish to English by the authors.

The economists Lars Jonung and Fredrik N. G. Andersson at Lund University write in their consultation response to Goodfriend's and King's inquiry:²

"Lund University wishes to extend G&K's recommendation to include an overview of the weight that should be put on forecasts and statistical models in monetary policy decisions."

"Lund University shares G&K's view that it is necessary for the Riksbank to review how it works with statistical models and forecasts. The University recommends a broader approach than that employed by the Executive Board in the past five years."

Furthermore, professor Annika Alexius at Stockholm University writes in her reaction to Goodfriend's and King's inquiry:³

"One of the main reasons why the Riksbank always projects that inflation will return to 2 per cent is its very overconfidence in (erroneous) models which are discussed in the section above. Over the years, the Riksbank has been the object of much criticism on this very point, but nevertheless continues to produce inflation forecasts that always entail an imminent return to the inflation target."

But, have Goodfriend and King evoked a straw man, or is there any substance to the criticism? In order to find out the answer, two questions must be answered – one positive and one more normative.

The positive question is: Have the Riksbank's forecasts been dominated *de facto* by formal models, or have judgments beyond the models had a greater influence? In purely general terms, whether too little or too much consideration is given to models in the forecasting process tends to depend on how good the models are, and the confidence that officials and Executive Board members have in them. Everybody involved in the decision-making process is of course driven by the desire to perform a sound analysis and making the best possible monetary policy decision with the given information and tools at hand. If the models appear to give reasonable forecasts with good accuracy and otherwise have credible characteristics, it naturally follows that decision-makers and the staff give them greater consideration. In the same way, they normally pay less attention to them if they show poor forecasting capacity and have characteristics that diverge from the institution's view of the functioning of the economy.

The more normative question is: To what extent should the Riksbank take account of formal models in its forecasting process? Iversen et al. (2016) have compared the forecasting ability in the Riksbank's general equilibrium model "Ramses" and the Riksbank's primary statistical time series model (hereinafter "BVAR") with the official forecasts published by the Riksbank during the period 2007-2013.⁴ *In the study, the authors show that the model-based forecasts have often been more accurate than the published forecasts.* In particular, it turns out that the BVAR model forecasts for inflation and the repo rate have been much better at predicting outcomes in relation to the forecasts published by the Riksbank for these variables during the period 2007-2013. The results can thus be used to argue in favour of the view

² See Lund University (2016), translated from Swedish to English by the authors.

³ See Alexius (2016), translated from Swedish to English by the authors.

⁴ The first version of Ramses is described in Adolfson et al. (2008). Since the beginning of 2010, a second version of Ramses is used, which is described in Adolfson et al. (2013). Regarding BVAR, see Adolfson et al. (2007) for a description of the model used at the Riksbank, and Villani (2009) for a description of the methodology behind the estimation of this model.

that, insofar that the Riksbank really has put considerable weight on the forecasts of the models, it has had good reason for doing so.⁵

However, although it could be then argued that the Riksbank should give considerable attention to the models in the forecasting process, the question as to whether the models *have actually had a significant influence* on the Riksbank's published forecasts is still an openended question. This question should of course be answered *before* drawing the conclusion, like Goodfriend and King, that too great or too little consideration has been given to models when devising the main scenario in the forecast.

This paper therefore focuses on this question. To do so, we analyse the extent of influence that the models have had on the Riksbank's published forecasts in the medium term (2-12 quarters ahead) for GDP growth, inflation and the repo rate from 2006 to date.⁶ The models that we consider are the Riksbank's main general equilibrium model Ramses and the time series model (BVAR) used for medium-term forecasts.

Our conclusion, which appears to be very robust, is that the Riksbank's published forecasts in the medium term are based on judgments rather than model forecasts. The direct contribution from the models has in fact been rather small in 2006-2016. This conclusion – which might appear unexpected following the argumentation in Goodfriend and King, 2016 – is, upon deeper contemplation, the only one that is reasonable. Although model forecasts are an important feature of the Riksbank's forecasting process, there is no rule as to how they should be incorporated into the published judgmental forecasts. Furthermore, the staff and Executive Board do not usually discuss the model forecasts in detail at the large forecasting meeting at which the forecast is largely determined.

It is important to make clear that forecasts for the short term (present plus one or sometimes even two quarters ahead) are based on various statistical indicator models (see for example Andersson and Löf, 2007, and Andersson and den Reijer, 2015). Our analysis is not about either these statistical models or forecast horizons; is aimed at the macro models that are the object of Goodfriend's and King's criticism: the Riksbank's macro models used for the medium term, which is the Riksbank's target horizon.

The remaining of the paper is structured as follows: We start by describing the data we use and describe how we measure the influence of models and judgments when the Riksbank devises a new forecast. After the data and methodology discussion, we describe our findings. Finally, we comment on the policy implications of the findings and make suggestions for further analysis.

2 Data and methodology

In this section, we first present the data we use in our analysis. We then study the informal interaction between the official forecasts and the model forecasts, before looking at the regression analysis we use to formally evaluate the extent of influence the macro models have had on the official forecasts.

2.1 Forecasts stored in real time

In order to conduct the analysis, we need data. The Riksbank's published forecasts are available on the Riksbank's website.⁷ Model forecasts stored in real time are available in internal data systems at the Riksbank.⁸ Model forecasts are saved at several different fixed points during the forecasting process, so there is therefore more than one model forecast

⁵ It should be remembered, however, that it is not uncommon for different models to be better or worse in different periods. Just because a model is good during a certain period does not necessarily mean that the same model will always be better.

^{6 2007} for the repo rate.

⁷ http://www.riksbank.se/en/Press-and-published/Published-from-the-Riksbank/Monetary-policy/Monetary-Policy-Report/

⁸ Since 2013, model forecasts have been stored in the Riksbank's data management system Doris. Forecasts prior to 2013 are stored in the Riksbank's former data system called Databiblioteket.

in each round of forecasting (see Hallsten and Tägström, 2009, for a description of the forecasting process). Because we consider the model forecasts to be a basis for the final forecast, we use the model forecasts established some time before the final forecast is published. The model forecasts are presented from time to time together with the staff's overall assessment to the Executive Board at the major forecasting meeting, referred to as the main forecast meeting (MFM) in the following. Although the model forecasts are not always presented at the MFM meeting, the Executive Board always receives the model forecasts in the written materials distributed ahead of this meeting. The MFM meeting usually falls two to three weeks before the formal monetary policy meeting when the Executive Board makes a decision on the final forecast, and monetary policy. In this study we therefore use the model forecasts done and saved at the point of MFM.⁹

It should also be remembered that models can be used in many different ways. For example, forecasts for the variables of interest to us can be generated conditionally or unconditionally on forecasts for other variables.¹⁰ In this study, we use model forecasts that are conditional on a nowcast and a forecast for international developments.¹¹ In the Riksbank's forecasting process, various conditioning assumptions are used, but the most common is probably conditioning on the nowcast and international forecast. Another common analysis often performed is conditioning on various different interest rate paths to analyse the different inflation forecasts they give.

In our analysis we disregard the forecasts included in the nowcast on which the models are conditioned because we want to compare the models' endogenous forecasts with the Riksbank's published forecasts beyond the nowcast which is taken to be given exogenously in the models. Had we included the horizons covered by the nowcast conditioning in the analysis, this would have given a false illusion of the macro models having had a significant influence despite their forecasts actually being determined by various indicator models and staff assessments, see the studies of Andersson and Löf (2007) and Andersson and den Reijer (2015). The horizons that are included in the nowcast vary between different forecasting occasions. Usually, the nowcast covers the current and next quarter. For most forecasting rounds in our data, what the nowcast covers is quite clear, but there are some forecasting rounds in which this is not obvious, mainly before 2013. In cases where it is unclear, we therefore make two assumptions when we remove the nowcast from the data. The first assumption is that the current quarter in the published forecast is always a nowcast. The second assumption is that the next quarter is a nowcast in the forecasting rounds in which the stored Ramses forecast is the same as the BVAR forecast.¹²

2.2 Visual inspection of the forecasts

Figure 1 presents the forecasts that we use in the study (the thin red lines) together with the last known outcome for each variable (the thick blue line). The first row in the diagram shows three charts of the Riksbank's published forecasts for GDP growth, inflation (CPIF) and the repo rate. The second row shows the forecasts from BVAR and the third from Ramses. From the diagram, it can be seen that the Riksbank has tended to overestimate the underlying inflationary pressure during the period, and has hence also overestimated how quickly the repo rate can be normalised. In qualitative terms, Ramses has similar forecasts for inflation

⁹ This applies to data from 2013. Prior to 2013, the Riksbank did not have a system with fixed points for *storing* model forecasts. Because of this, the point in time of model forecasts before 2013 can vary somewhat.

¹⁰ When a model is conditional on a forecast for another variable, the model considers the forecast for that variable to be given exogenously; its forecast is thus determined outside of the model. In an unconditional forecast, the forecasts are instead determined for all variables endogenously, i.e. entirely within the model. See Iversen et al. (2016) for a comparison of conditional and unconditional model forecasts.

¹¹ The models therefore take the nowcast and forecast for international developments to be given exogenously when endogenous forecasts are established for other variables such as GDP growth, inflation and the repo rate on medium-term horizons.

¹² It can be considered totally improbable that Ramses and BVAR would generate the same endogenous forecasts down to an exactitude of two decimals unless they are conditional on the staff's nowcast.



Figure 1. Published forecasts and model forecasts

and the interest rate. It is interesting to see how the BVAR model deviates with systematically lower inflation and repo rate forecasts that are much closer to the actual outcome during the period. For GDP growth, it is difficult to see any substantial differences between the Riksbank's and the model's forecasts. From Figure 1, it can also be seen very clearly that the models' inflation forecasts have not at all always generated forecasts with an imminent return to the 2 per cent inflation target.

In order to get a deeper understanding of the relationship between the model forecasts and the Riksbank's published forecasts, we can in a chart plot the published forecast on the y axis and the equivalent model forecast on the x axis. These charts are shown in Figure 2. The first row also depicts the relationship between the current published forecast and the published forecast from the previous forecasting round. It illustrates the forecast revisions made by the Riksbank. In the charts we have also drawn a 45-degree line to facilitate interpretation. If the line cuts through the middle of the dots in the top row, we have no systematic upward or downward revision in the forecasts. In the charts in the second and third rows, it can be seen whether the published forecasts have been higher or lower on average than suggested by the models. If the dots are below the 45-degree line, the published forecasts have been lower on average. If they are above the 45-degree line, the forecasts have been higher on average. For example, it can be seen that the models' inflation forecasts have on average been lower than the Riksbank's published forecasts, and that Ramses has on average forecast a higher repo rate compared with the published forecasts. For the BVAR model, however, we see that almost all official forecasts for inflation and the repo rate have exceeded those generated by the model.

Note. The blue line depicts outcome and the red lines depict forecasts. Sources: Statistics Sweden and the Riksbank



Figure 2. The relationship between the published forecast, previous forecast and model forecasts

Another important insight from Figure 2 is that the spread between the model forecasts and the Riksbank's own forecasts is much wider than the spread between the Riksbank's new and previous forecast. The figure clearly shows that the Riksbank's new forecast and previous forecasts tend to be close to the 45-degree line. This indicates that often, the Riksbank has not made substantial forecast revisions in relation to the level of the forecasts. It also indicates that the previous forecast is often a very good prediction of the subsequent forecast. The same cannot be said about the models, however. Despite awareness of the current model forecasts, the figure shows that it is much more uncertain to use them to predict the new official forecast.

2.3 Our method for measuring models' influence on Riksbank's forecasts

We now go on to discuss how we measure the extent of influence the various models and judgments have had on the Riksbank's forecasts. An important distinction is to differentiate between the models' influence on the *level* and the *revision* of the forecast. We start by describing the extent of influence the models have had on the level, which we consider to be most important. We then go on to discuss a couple of different ways of measuring how they have contributed to the revision.

In order to measure the impact the models (Ramses and BVAR) have had on the *level* of the Riksbank's forecasts, we estimate the following simple regression model:

(1)
$$F_{i,t+h}^{New} = \omega_R F_{i,t+h}^R + \omega_R F_{i,t+h}^B + (1 - \omega_R - \omega_R) F_{i,t+h}^{Old} + \varepsilon_{i,t+h}$$

Note. The line shows a 45-degree angle. Source: The Riksbank

In the equation the published forecast F^{New} for variable j's outcome in time t + h, established in time t, is explained by the model forecasts from Ramses $(F_{j,t+h}^{R})$ and BVAR $(F_{j,t+h}^{B})$ established at the same time (i.e. forecasting round).¹³ Equation (1) also allows the published forecast to be partially explained by the previous published forecast $(F_{j,t+h}^{Old})$, known as forecast smoothing. $F_{j,t+h}^{New}$ and $F_{j,t+h}^{Old}$ thus refer to two subsequent forecasts (forecasting rounds) for variable j's outcome in period t + h. An example is the repo rate forecasts established for the monetary policy reports (MPR) in April 2015 and February 2015, respectively, for the same outcome. The coefficients ω_R and ω_B , respectively, which we initially assume are the same for all horizons (h), thus measure the weights the Riksbank puts on Ramses and BVAR.¹⁴ The idea behind Equation (1) is thus that the new forecast is based on an existing forecast, $F_{j,t+h}^{Old}$, which is either updated with the two models or with a new judgment, i.e. $\varepsilon_{i,t+h}$, in order to derive a new forecast $F_{j,t+h}^{New}$.

So, how do we measure the element of judgments in the published forecasts? When the regression in Equation (1) is executed using the least squares method, we obtain a coefficient of determination R^2 . It is often referred to as the degree of explanatory power. The model's coefficient of determination, R^2 , thus measures how much of the variation in the forecast in levels is explained by the models and by the previous forecast. This means that $1 - R^2$ is a natural measure of the extent to which new judgments explain the variation in the *forecast in levels*, because it measures the variance in the judgments (ε) in relation to the variance in the new forecasts.

We now go on to discuss the influence models have had on *the revision* in the forecast. On can do this in different ways, and we present two possible approaches below. Our first approach is a simple rewrite of Equation (1) as follows:

(2)
$$F_{j,t+h}^{New} - F_{j,t+h}^{Old} = \omega_R(F_{j,t+h}^R - F_{j,t+h}^{Old}) + \omega_B(F_{j,t+h}^B - F_{j,t+h}^{Old}) + \varepsilon_{j,t+h}$$

This equation can then be interpreted such that the forecast is revised if the model forecasts deviate from the previous published forecast, or if a new judgment is introduced through $\varepsilon_{j,t+h}$. It is important to understand that the parameters (ω_R and ω_B) and $\varepsilon_{j,t+h}$ are the same in both Equations (1) and (2). The difference is how the influence of the judgment is interpreted. The coefficient of determination will be lower in Equation (2) than in Equation (1) because forecast revisions in practice tend to occur gradually, and the previous forecast thus explains part of the variation in the new forecast. This means that *the influence of new judgments will be greater for the revision of the forecast than for the forecast in levels*.

Another important insight from Equation (2) is that equilibrium dynamics are embedded in this specification. If ω_R and/or ω_B are positive, and if one of the model forecasts starts to deviate systematically from the previous official forecast, the official forecast will be updated in the direction of the model unless the models' suggestion for a revision is "overridden" by judgments in several forecasting rounds. This means that $\varepsilon_{j,t+h}$ might very well be correlated between different forecasting rounds (*t*) and over the forecasting horizon (*h*) in a given forecasting round. A simple example is if ω_B is 0.5 ($\omega_R = 0$) and the BVAR model's inflation forecast is 1 per cent at the two- and three-year horizon while the Riksbank's previous official forecast is 2 per cent for both of these horizons. According to Equation (2) the Riksbank should then trim its forecast by 0.5 per cent on these horizons. If the Riksbank does not do so, a positive judgment ε of 0.5 per cent is thus used for these horizons. The positive judgment keeps the forecast unchanged at 2 per cent. If the same thing happens in the next forecasting round – i.e. that the model has a lower forecast than that ultimately published by the Riksbank – the judgment will be positive once more for those horizons. We study the characteristics of the judgments in more detail in section 4.

¹³ The same point in time refers to the same forecasting round.

¹⁴ However, it should be remembered that the Riksbank has more models than Ramses and BVAR, and that the other models can explain part of the forecast as well. Those models are most commonly used in the short term, primarily in the nowcast, but sometimes up to a one-year horizon for some variables.

Our second specification for measuring the models' influence when the Riksbank revises its forecasts is a simple difference model. This approach, which does not features any explicit equilibrium dynamics, quite simply says that the Riksbank's revisions are explained by model revisions and judgments. Equation (3) below describes such an idea. The difference from the previous specification is that the models' forecasts are not related to the current official levels of the forecasts, $F_{j,t+h}^{Old}$, but instead to the models' forecast in the previous forecasting round, i.e. only to their own revision tendencies.

(3)
$$F_{j,t+h}^{New} - F_{j,t+h}^{Old} = \omega_R(F_{j,t+h}^R - F_{j,t+h}^{R,Old}) + \omega_B(F_{j,t+h}^B - F_{j,t+h}^{B,Old}) + \varepsilon_{j,t+h}$$

In Equation (3), $F_{j,t+h}^{R,Old}$ and $F_{j,t+h}^{B,Old}$ denote the model forecasts presented at the previous forecasting round MFM. If the models' forecasts between the present and previous forecasting rounds have not changed much, Equation (3) implies that there is no reason for the Riksbank to revise its official forecast, unless it wishes to introduce new judgments. An important reason for why Equation (3) may be a better description of how the Riksbank uses the information from the models than Equations (1) and (2) is that there may be scepticism about a level forecast from a given model (for example Ramses' interest rate forecast), but nevertheless a belief that the revision tendencies, i.e. how the model interprets new information, deserves to be taken seriously.¹⁵

One difficulty with regression (3) is the choice of the previous model's forecast. Our benchmark choice is the model forecast generated at the previous MFM. This choice provides a relatively pure model revision from the perspective in that it uses the current and previous model forecasts that were available in real time for policymakers in calculating the revision. A possible issue with this approach, however, is that the previous model forecast is conditioned on a different nowcast than the previous final official forecast (i.e. the nowcast may have changed notably between the time of the MFM and when the official forecast were finally decided in the previous forecasting round). An alternative to measuring the old model forecasts using the previous official forecast in the new nowcast quarters. This alternative method provides a clear revision tendency from the models based on the most recent nowcast and the previous official judgments.¹⁶ However, this information is not stored over a longer period of time and we thus cannot use it for our entire estimation period. However, when we discuss the estimation results we will comment on how the findings change if Equation (3) is estimated for the forecasting rounds for which this information is available.¹⁷

Note also that by comparing the adjusted coefficient of determination for the forecast revision in the estimated Equations (2) and (3), we gain an indication of which method best describes the Riksbank's actions over the entire period. If the weights ω_R and ω_B are both close to 0 and the coefficient of determination is consequently close to 0, this means that the forecast revision is basically only explained by new judgments that do not correlate at all with the revision of the model forecasts.

We estimate Equations (1), (2) and (3) for three different variables: GDP growth, inflation (CPIF) and the repo rate separately. We also estimate the equations on a multivariate basis, i.e. for all three variables at the same time, to see if *one* set of weights can be found

¹⁵ There are at least two reasons for this. First, the potential growth capacity of the economy can change over time, which changes the level of the growth rate and the reportate level in the longer term. Furthermore, the model's forecasts can be associated with a different monetary policy stance than that the Executive Board intends to pursue.

¹⁶ This means that if the assessment of the current situation (which may include a new outcome in the national accounts, along with a new appraisal for the next quarter) has changed only marginally (for example, if a stronger than expected GDP outcome in the national accounts is deemed to be transient in the appraisal for the subsequent quarter), the suggested revision from the models will tend to be small. An alternative approach that would likely tend to provide bigger revisions from the models is to limit the updated nowcast to quarters for with new outcomes are available, that is not condition on any further quarters after the new outcome. One would then calculate the revisions from the models contingent upon the same (but fewer) quarters. 17 This is from the MPR in July 2014. However, comprehensive data is absent for MPU September 2014, MPR October 2014 and MPR February 2015.

that explains how the forecast in levels and revision have been changed for all variables simultaneously. If a substantial weight is given to either of or both macro models, it is not entirely unreasonable to use the same weight for all variables to maintain model consistency for the different variables in the forecast. As we have mentioned previously, we use forecasts constructed during the period 2006-2016.¹⁸ The estimations are based on data over all horizons h = 2, 3, ..., H excluding certain nowcasts for h = 2 because these are occasionally determined outside of the models, as discussed previously. In each forecasting round, *H* is selected as to be as high as possible subject to be able to calculate a difference between the new and previous forecast for the same outcome (quarter). The maximum horizon, however, is 12 quarters.

3 Are Riksbank's forecasts and forecast revisions explained by models or judgments?

In Figure 2 we showed that the relationship between the published forecast and equivalent model forecasts appears to be weak, particularly for inflation and the interest rate. In this section we present the more formal results from our estimations. First, we present results for how influential the models have been for the level of the forecast, and then we move on to analyse the influence on the revisions.

3.1 The models' influence on the forecast in levels

Table 1 shows the estimation results from Equation (1) where we look at the influence on the *level of the forecast*. From the table, we see that the weights for Ramses (ω_R) and BVAR (ω_B) are low and that the previous forecast has a large weight in explaining the present forecast. This is a sign of a strong degree of *forecast smoothing* in the forecasting process, since the previous forecast obtains a significantly larger weight than the models' forecasts. In Table 1 we can also see that the coefficient of determination, R^2 , which states how much of the variation in the forecast in levels can be explained by the models and the previous forecast, is high. This also leads to $1 - R^2$ being low. As we have described previously $1 - R^2$ measures to which extent judgments explain the variation in the forecast in levels can immediately draw the conclusion that the degree of new judgments in each forecasting round is relatively limited in relation to the level of the forecasts for all variables.

	GDP	Inflation	Interest rate	All
Previous forecast $(1 - \omega_R - \omega_B)$	0.78	0.91	0.86	0.87
Ramses (ω_R)	0.12	0.09	0.00	0.02
BVAR ($\omega_{\scriptscriptstyle B}$)	0.09	0.00	0.14	0.11
Coefficient of determination (R ²)	0.89	0.77	0.94	0.92
Degree of judgment (1 – R ²)	0.11	0.23	0.06	0.08

Table 1. Estimates and coefficient of determination for the forecast in levels: regressions according t	to
Equation (1)	

Note. GDP is defined as annual GDP growth as a percentage (fourth difference). Inflation is measured as the annual change in CPIF as a percentage (fourth difference). The interest rate refers to the reporate. All of the variables are measured as integers (one per cent has the figure 1.00 and not 0.01). "All" pertains to the weights obtained when selecting the weights to fit all variables simultaneously.

¹⁸ We include forecasts up to the April 2016 forecasting process. Comprehensive data for inflation forecasts from the models is absent from the MPR July 2008 to the MPR February 2009 reports, and is therefore excluded.
A potential problem with the estimations in Table 1 is that the model forecasts can be highly correlated with each other. In addition, they can be strongly correlated with the previously published forecast. Estimates of the weights can thus be unreliable due to multicollinearity problems, whereby different weights on both the models and the previous forecast can result in almost the same R^2 value. For this reason, we do not include any standard deviations for the weights in the table, but instead calculate the R^2 values for different values for ω_R and ω_B between 0 and 1 for the regression in Equation (1). We do so to see if we can obtain almost the same value for R^2 for distinctly different weights on the models and the previous forecast.

Figure 3 shows the results in the form of R^2 heatmaps, or R^2 contours for different combinations of $\omega_{\rm p}$ and $\omega_{\rm p}$ when we look at the forecasts at levels (the regression in Equation (1). The x axis shows the weight on the BVAR model ($\omega_{\rm B}$). The y axis shows the weight on Ramses (ω_{R}). The weight on the previous forecast is subsequently indirectly derived by calculating $1 - \omega_R - \omega_R$.¹⁹ The colour scale to the right of each panels shows R² for the various parameter combinations. From the figure, we see that we obtain the highest R^2 value when the model weights are low and close to zero. We also see that the point where $\omega_R = \omega_R = 0.5$, i.e. the previous forecast has the weight 0, is associated with the lowest coefficient of determination for all the variables. In order to further clarify how the figures should be interpreted, we can look at the point estimates for GDP from Table 1. From the table, we see that Ramses is given the weight 0.12 and BVAR the weight 0.09. If, in Figure 3, we look at the point where we have 0.12 on the y axis and 0.09 on the x axis, we can see that this point is associated with a dark red colour. We also see that dark red is associated with the highest R^2 value. Table 1 shows that the coefficient of determination, R^2 , for GDP is 0.89. We can also observe this value in Figure 3 from the bar to the right of the GDP chart, which shows that dark red indicates a R^2 value of over 0.88. Moreover, the figure clearly shows that if either or both of the models are assigned a higher weight than those reported in Table 1 - and hence a smaller weight is assigned to the previous forecasts – this results in a considerable drop in the coefficient of determination for all variables, both individually and combined. We can therefore firmly conclude that the models have been of secondary importance when the Riksbank has constructed the forecast. The previous forecast has, together with new judgments, had a much greater impact when the Riksbank has devised the new forecast in levels.

¹⁹ Note that Figure 3 only shows the results where ω_R and ω_B vary between 0 and 0.5, as we find it unintuitive to have negative weights on the previous forecast, which we would have had if we'd allowed the model weights to vary between 0 and 1. It is however important to realise that R^2 drops drastically for higher weights on either of the two models, irrespective of which variable we are looking at in Figure 3.



Figure 3. R^2 -heatmaps for the level of the forecast; different combinations of ω_R and ω_B from Equation (1)

3.2 The models' influence on the forecast revisions

In order to analyse the effect of the models on *forecast revisions*, we use the two approaches in Equations (2) and (3). The results from the calculations according to Equation (2) can be seen in Table 2. As we have described previously, Equation (2) puts, by construction, the same weights on the models but with different coefficients of determination, R^2 , because the regression must now explain the variation in the revisions instead of the variation in the level of the forecasts. Hence, the value of R^2 now measures how much of the revisions are explained by the models' deviation from the previously published forecast. As can be seen in Table 2, these values are very low and even negative for the reportate.²⁰ The degree of judgments, $1 - R^2$, is thus very high and close to one for all variables according to the results from Equation (2). This approach thus suggests that the Riksbank's forecast revisions are largely explained by new judgments. The reason why the influence of judgments is lower in Equation (1) than in Equation (2) is quite simply that the variation in the level of the forecast is considerably greater than the variation in the revision of the forecast. Hence, a given size of a judgment, ε , which is introduced will be relatively small in relation to the level of the forecasts (the coefficient of determination increases), but greater in relation to the change in the forecast (the coefficient of determination decreases).

20 R^2 is calculated as: $1 - RSS/TSS = 1 - \sum_{i=1}^{n} (y_i - \hat{y}_i)^2 \sum_{i=1}^{n} (y_i - \bar{y}_i)^2$. Hence, a negative R^2 is obtained if the mean of the series \bar{y} is a better explanation of y_i than the model's estimator \hat{y}_i .

	GDP	Inflation	Interest rate	All
Ramses (ω_R)	0.12	0.09	0.00	0.02
BVAR ($\omega_{\scriptscriptstyle B}$)	0.09	0.00	0.14	0.11
Coefficient of determination (R ²)	0.12	0.06	-0.07	0.04
Degree of judgment (1 – R²)	0.88	0.94	1.07	0.96

Table 2. Estimates and coefficient of determination for forecast revisions: regressions according to Equation (2)

Note. See the notes to Table 1.

Table 3 shows the results from our second approach, the estimations according to the specification in Equation (3). In this specification, the model projections are not related to the actual levels of the forecasts, but only to their own revision tendencies. The idea is hence that the Riksbank looks at which revisions the models make when revising its own forecast. In Equation (2) the models were related to the Riksbank's previous forecast, which can deviate from how the models viewed the situation at the same point in time.

Table 3 demonstrates that the estimations for the model weights (ω_R and ω_B , respectively) with the specification from Equation (3) are substantially higher than those from Equation (2) in Table 2. However, even if the sum of the weights for GDP growth and the repo rate now amounts to around 0.5, they are still well below 1. It can also be noted that the R^2 value is now somewhat higher and that the amount of judgments, $1 - R^2$, then declines somewhat. Nonetheless, R^2 amounts to 0.35 at the most (GDP growth). This means that the Riksbank's forecast revisions are still largely determined by judgments.

Table 3. Estimates and coefficient of determination for forecast revisions: regressions according to Equation (3)

	GDP	Inflation	Interest rate	All
Ramses (ω_R)	0.28	0.15	0.42	0.29
BVAR ($\omega_{\scriptscriptstyle B}$)	0.15	0.15	0.12	0.15
Coefficient of determination (R ²)	0.35	0.13	0.10	0.23
Degree of judgment (1 – R²)	0.65	0.87	0.90	0.77

Note. See the notes to Table 1.

In order to ensure that the results in Tables 2 and 3 are robust when we vary the weights ω_R and ω_B , we present in Figures 4 and 5 R^2 heatmaps once again. We calculate them in the same way as we have described for Figure 3, except that we now calculate R^2 using the specifications in Equation (2) and (3) for different weights ω_R and ω_B . In relation to Figure 3, we see that the R^2 values are much lower, especially for high weights on the models for which the coefficients of determination now becomes negative. The only exception is the repo rate in our second approach (the regression in Equation (3)), for which the coefficient of determination remains close to 0. These figures thus strongly support our conclusion that judgments have a substantial impact on the revisions of the forecasts as well.

Because, as discussed earlier, it is not clear which model revisions one should compare, we also estimated Equation (3) when the revision of the model forecast is calculated as the new conditional forecast minus a forecast conditional on the previous official projection for the same quarters as the new forecast. Even this variant of the regression, which is likely to maximize the pre-conditions for a major impact of the models on the official forecast, implies that informal judgments explain a large part of the forecast revisions. More specifically, $1 - R^2$ is in this specification equals 0.54, 0.49 and 1.30 for the variables GDP growth, inflation and

0.1

0.2

0.0

0.3

Weight on BVAR

0.4

0.5

the policy rate.²¹ Accordingly, it implies a somewhat lower degree of judgements for GDP growth and inflation but an even larger role of judgements for the repo rate in relation to our benchmark results in Table 3 (which calculated the models revisions as the difference in the conditional models forecasts made at the current and previous MFM). Nevertheless, even if the impact of the models is more notable with this specification (the sum of the weights ω_R and ω_B is above unity for all three variables in this specification whereas their average about 0.45 in Table 3), our conclusion that new judgments exert a large influence on the forecasts revisions holds up also for this method.



0.1

0.2

0.0

0.3

Weight on BVAR

0.4

0.5

Figure 4. R^2 -heatmaps heatmaps for forecast revisions: different combinations of ω_R and ω_B from Equation (2)

²¹ However, please note that we cannot directly compare these figures with those in Table 3 since they are calculated on far fewer forecast rounds (see footnote 15). When we re-estimate our version of regression (3) for the same time period, the estimated degree of judgement ($1 - R^2$ values) equal 0.60, 0.72 and 1.54. Because these estimates are relatively similar to those you get with the alternative way to measure model revisions, it is reasonable to believe that, the results in Table 3 would compare reasonably well to the alternative way to calculate the forecast revisions had the data for this method been available farther back in time.



Figure 5. R^2 -heatmaps heatmaps for forecast revisions: different combinations of ω_R and ω_B from Equation (3)

3.3 The impact of the models over horizon and time

Until now we have studied how much of an impact the models have had over all horizons h = 2, 3, ..., 12 simultaneously during the period of time 2006-2016. That analysis shows how the Riksbank has incorporated the models into its forecasts and forecast revisions on average. The conclusion thus far is that the models only have a moderate role in explaining the forecast in levels, and that a great deal of new judgments form the basis of the Riksbank's forecast revisions. Breaking down the data into different horizons and different periods of time might potentially provide deeper knowledge about how the Riksbank has used the models over time. If we divide up the data into different horizons (quarters), 2-4, 5-8 and 9-12, we can see how the relationship looks in the "short", "medium" and "longer" term in the forecast.²² Such an analysis shows that the weight of the models is generally somewhat greater in the short term. The short term refers to the first year of the forecast horizon (quarters 2-4). The R^2 values too appear to be somewhat higher in the short term than in the medium and longer term.

Data can also be broken down into different periods of time to study how the impact of the models changes over time. We have chosen to study four different periods of time: 2006:1-2008:4, 2008:5-2010:6, 2011:1-2014:2 and 2014:3-2016:2.²³ We have chosen these specific periods to attempt to characterise different phases in monetary policy recently. The first period, 2006:1-2008:4, refers to the time before the financial crisis broke out. The second period, 2008:5-2010:6, refers to the time during the turbulence of the financial crisis, but before the post-crisis rate hikes. The third period, 2011:1-2014:2, refers to a time when the Riksbank hiked the interest rate, before subsequently starting to cut it again. The Riksbank has been criticised by some experts for having "leaned against the wind"

²² All results in this section are reported in Table A1 and A2 in the Appendix.

²³ The serial number after the year refers to which report in the order during the year is concerned. For example, 2014:2 refers to MPU 2014:1 because that report was the second report in 2014.

during that period. The fourth and final period, 2014:3-2016:2, refers to a time of highly expansionary monetary policy with bond purchasing and a negative repo rate. The results from this breakdown show that the impact of the models has varied to quite some extent over time. This applies both to their total impact, and their relative weight. Nonetheless, the picture remains of the models having a low weight in explaining the forecasts over time, both at levels and in terms of revision. Rather, it is still informal judgments that are most important in understanding how the forecasts have changed between forecasting rounds.

4 What are judgments?

The results thus suggest that the Riksbank's forecasts are to a large extent explained by informal judgments. So, where do these judgments come from? A potential explanation is that they come from macro models other than those we use. However, Ramses and BVAR are the Riksbank's primary models, and it is therefore improbable that other models would have had a large impact. However, the two models we have considered contain far from all variables and mechanisms present in society, and they are based on different assumptions with the purpose of simplifying the economy they attempt to explain. The variables and mechanisms that are not included in the models can, at times, be observed by the Executive Board and the various experts that work in the Riksbank's forecasting process. All of this information that is not captured in the models affects the judgment that the Riksbank ultimately makes.

A trivial example of judgments is managing the effects associated with the Easter weekend. When consumption forecasts for the first and second quarter of a calendar year are made, consideration must be given to whether Easter falls in the first or second quarter. At Easter, households' consumption expenditure usually rises substantially, resulting in GDP growth for the entire quarter being higher than it would have been had Easter not occurred in that particular quarter. Because Easter does not always fall in the same quarter, it is not captured by common seasonal patterns, and an active judgment thus needs to be made to adjust the forecast for the quarter that contains Easter.

A perhaps more important example of when judgments are needed is the management of the impact of energy prices on inflation. Energy prices fluctuate sharply at times in connection with supply shocks, which the Riksbank's macro models cannot fully capture because they do not explicitly contain an energy sector. So, the Riksbank must use supplementary methods, such as partial models based on forward prices of oil and electricity, to adjust the inflation forecast.

Many of the judgments are thus based on capturing the factors that the models do not capture. It can often be the case that different models give different forecasts, because they contain different mechanisms and put emphasis on different variables. A large structural model can give one forecast, while at the same time various small indicator models can give another. Because all models are incomplete by necessity and can sometimes even provide partially contradictory results, an overall judgment is ultimately needed. In the Riksbank's annual account of monetary policy, many of the aspects that formed the basis of the monetary policy decisions in the past year are summarised. In the latest reports, for example, recurring discussion topics have been the exchange rate, high household indebtedness, rising house prices and substantial uncertainty about the economic development in the euro area.²⁴

Before turning to the judgments that we calculate based on our forecast regressions, it is important to point out that we are not the first to do so for the Riksbank. Earlier studies of judgments in simple rules for the Riksbank notably includes Jansson and Vredin (2003) and Berg et al. (2004). These studies address a period of time before ours, in which divergences can be explained by factors such as creditability issues and substantial uncertainty about the

state of the economy. Nyman and Söderström (2016) also discusses informally the role of judgments in the Riksbank forecasting process.

4.1 Analysis of the Riksbank's judgments

So, how do the Riksbank's judgments look? Because judgments are important in explaining the forecast revisions, their characteristics are of key interest. From the estimated regressions in Equations (1) and (2), we obtain a measure of judgments $\varepsilon_{j,t+h}$. By analysing $\varepsilon_{j,t}$, we can get a better picture of how the Riksbank has used judgments in its forecasts. We prefer to base our analysis on the specification in these regressions because they have built-in equilibrium dynamics.²⁵

An initial simple analysis that can be performed is to calculate a correlation matrix for the judgments for the different variables GDP growth, inflation and the repo rate. Table 4 shows such a matrix. The correlations shown there have been prepared by firstly calculating the average judgment

(4)
$$\bar{\varepsilon}_{j,t} = \left(\frac{1}{H-1}\right) \Sigma_{h=2}^{H} \varepsilon_{j,t+h}$$

over all horizons h = 2,..., H for variable j on each forecasting occasion, t. In each forecasting round, H is selected as far as it is possible to calculate a difference between the new and previous forecast for the same outcome (quarter). The maximum horizon, H, is however 12 quarters. The correlations are then based on the $\bar{e}_{j,t}$ series between the different variables (GDP growth, inflation and the repo rate). In the table we see that the judgments for the repo rate in different forecasting rounds correlate positively with the judgments both for GDP growth and inflation. This means that the Riksbank, given positive judgments for GDP and inflation, has typically added a positive dose of judgment into the repo rate forecast. It is natural that both positive average judgments for the repo rate, given that the Riksbank's target variable (CPI inflation) and resource utilisation (GDP growth) are normally considered important in predicting future inflationary pressure. It should also be noted that we measure the average judgment in a forecasting round. The judgment can thus differ in relation to the various models. An average positive judgment can be a negative judgment in relation to one of the models.

	GDP	Inflation	Interest rate
GDP	1.00	-0.13	0.36
Inflation	-0.13	1.00	0.39
Interest rate	0.36	0.39	1.00

Table 4. Correlation matrix for average judgments in different forecasting rounds

Note. The judgments have been calculated using the regression results in Tables 1 and 2 (which give the same residual), after which the average has been calculated according to the formula in Equation (4). See also the notes to Table 1 for the definition of the variables included in these regressions.

We can also estimate a simple regression according to the following equation:

(5)
$$\bar{\varepsilon}_{repo,t} = \beta_1 \bar{\varepsilon}_{Inflation,t} + \beta_2 \bar{\varepsilon}_{GDP,t} + u_t$$

²⁵ We are aware that the results in Tables 2 and 3 indicate that the regression in Equation (3) better captures how the Riksbank works in practice (as the R^2 values are higher in Table 3 than in Table 2). Nonetheless, we argue that the regression in Equation (3) should be incorrectly specified, because there are no equilibrium dynamics incorporated into it. This implies that the level of the forecast in levels could basically be anything over time. This feature impinge on the statistical properties of the judgments measured with this regression. The judgments in Equations (1) and (2) are however immune to this criticism. We show in the appendix, however, that the results we present here are robust if we instead use the judgments from Equation (3). See Tables A3-A5.

In the equation above, the judgments in the reportate are explained by the judgments for inflation and GDP growth. Note that we do not include an intercept because the mean for the assessments is by construction 0. The estimation can thus be seen as a test for whether the Riksbank follows the "Taylor rule" in its judgments. The Taylor rule, based on John Taylor's seminal paper from 1993 (see the study by Taylor, 1993), says that central banks can stabilise the economy by changing the interest rate by more than one-to-one in response to changes in inflation (see the study by Davig and Leeper, 2007, for an indepth discussion on this issue). In Equation (5) we should therefore expect β_1 to be greater than 1 if the Riksbank has followed the Taylor rule in its judgment. The results of that exercise is provided in Table 5. There, we see that the Riksbank has, in its judgment, changed the interest rate by a factor of 0.9 in response to altered judgments in inflation outlook, i.e. somewhat lower than one-to-one. However, there is considerable uncertainty about the point estimate, and taking this uncertainty into account, we cannot reject that the Taylor principle does not hold up since the null hypothesis that β_1 is greater than 1 cannot be rejected. Moreover, it is (almost) not possible to reject the original coefficients proposed by Taylor in his paper -1.5for inflation and 0.5 for the GDP gap (however, we have GDP growth instead of the GDP gap in our regression). It is also important to point out that when we estimate the equation for the judgments measured with the regression in Equation (3), we obtain the coefficients 1.31 and 0.14 (see appendix), which satisfy the Taylor rule. Another aspect is that the coefficient of determination in the regression is relatively low, 0.19, implying that a substantial part of the judgments for the reportate are not mechanically associated with the judgments for inflation and GDP growth. Many more aspects have been incorporated into the judgments for the repo rate path. However, even though the judgments made can undoubtedly be criticised retroactively for various reasons, it is nevertheless important to note that they fulfil this (Taylor's) fundamental principle for practical monetary policy.

	β	Std. Dev.	p-value
Inflation (β_1)	0.907	0.300	0.004
GDP (β_2)	0.315	0.192	0.109

Table 5. Regression of judgments for the repo rate on judgments for inflation and GDP growth

Note. Results from the estimations according to Equation (5). Inflation is measured as the annual change (fourth difference) in CPIF. GDP refers to the annual change (fourth difference) in GDP. The estimation has a coefficient of determination, R^2 , of 0.19.

The analysis in Tables 4 and 5 is based on average judgments for each variable in each forecasting round. We can also study the characteristics of the judgments in a given forecasting round. By estimating Equation (6) below we obtain a measure of the persistence over the horizons h = 2, ..., H in each forecasting round. According to this equation, the judgment for a certain horizon is explained using the judgment in the previous horizon in the same forecasting round, *t*.

(6)
$$\varepsilon_{j,t+h+1} = \beta_0 + \beta_1 \varepsilon_{j,t+h} + u_{j,t+h+1}$$

Table 6 reports the estimations for each variable. The results show that persistence is quite high for the judgments in each forecasting round, especially for the interest rate, for which it is as high as 0.97. A persistence coefficient close to 1 suggests that when the Riksbank establishes a new judgment in the near-term, it tends to add a similar dose on longer-term horizons as well. For GDP growth and inflation, the persistence is much smaller. Our estimations indicate that memory in a forecasting round for those variables is much shorter. This means that when a positive judgment is assigned to GDP growth or inflation in the near future, say for h = 2, relatively little of this judgment tends to spill over into the next year in

the forecast. Some persistence in the judgments for GDP growth and inflation is reasonable because we measure the variables as fourth differences. Hence, the results imply that the judgments for inflation and GDP growth in the near-term typically have moderate indirect effects on the judgment in the following year within a given forecasting round.

Finally, it should be mentioned that we allow for a constant when we estimate the regression in Equation (6). In principle, the constant could indicate systematic positive or negative judgments. However, because of our method of measuring judgments, the constant will, by necessity, be small for all variables (especially bearing in mind that the judgments are measured as integers, i.e. one percentage point is 1.00 and not 0.01). This is so because we measure the judgments from the estimated equations using the method of the least squares, which means that they will be zero on average.

	GDP	Inflation	Interest rate
$oldsymbol{eta}_{0}$	-0.008	0.005	0.008***
	(0.007)	(0.004)	(0.003)
$oldsymbol{eta}_1$	0.712***	0.740***	0.970***
	(0.021)	(0.022)	(0.008)

Table 6. Persistence in the judgments during a given forecasting round

Note. Results from the estimations according to Equation (6). *** refers to significance at the 1 per cent level. Standard deviation in brackets.

5 Concluding remarks

In light of the recent discussion about how the Riksbank uses models in its forecasting process, we have in this study looked at how much the Riksbank *de facto* incorporates model forecasts into the final published forecasts. Goodfriend and King (2016), for example, directed sharp criticism at the Riksbank for being overly reliant on models and placing too much focus on models when devising forecasts. We have in this paper therefore studied to which extent the Riksbank's two main macro models, Ramses and BVAR, explain the published forecasts (and forecast revisions). The analysis shows that the models do *not* have a critical role for explaining the Riksbank's published forecasts, and that judgments account for a large share of the Riksbank's forecast revisions.

However, an important factor to bear in mind is that our method only measures the direct contribution from the macro models. Because the models often serve as conceptual frameworks for the functioning of the economy, they can nevertheless have a significant indirect influence on the official forecasts. Having said that, there is in principle no simple answer to the question as regards to the influence of the macro models on the forecasts, although our conclusion that the direct impact is relatively small indicates that the indirect influence ought also to be limited in practice.²⁶ There are, however, exceptions. An area in which the models are used frequently in normal circumstances is to perform alternative simulations for more expansionary or contractionary monetary policy. However, such simulations are most commonly about alternative scenarios for monetary policy, even though the monetary policy transmission mechanism embedded in the model may be used to adjust the main scenario when the Executive Board decides on an alternative rate path. According to our way of thinking, it is entirely misleading to go from these calculations to say that the forecast comes from the model. Instead, it's about preferred monetary policy stance, including a judgment of the effects on GDP growth and inflation.

²⁶ For example, the macro models have the characteristics of inflation ultimately returning to the target (although, in the models, it usually takes much longer than two to three years before this occurs) and of monetary policy being neutral (i.e. it does not affect economic activity) in the longer term. These are examples of features of the model that informally affect how monetary policy is devised, but which are not necessarily captured in our analysis.

Despite this possible objection, our results show in all clarity that the view disseminated by Goodfriend and King - that the Riksbank blindly relies on and follows its models - is entirely misleading and is merely a myth. We have also shown that their perception of the Riksbank relying on models in which inflation always returns to the target "by itself" within the forecast horizon is a myth.

It is important to discuss and debate the Riksbank's forecasts and models, because this benefits the future development of new models and forecasting methods. However, it is also important to have a solid basis for what is expressed in the debate. With this study, we have attempted to contribute to the debate with a solid basis regarding how much the models actually affect the Riksbank's forecasts.

As discussed in greater detail in Nyman and Söderström (2016), it should also be remembered that there is not necessarily anything surprising about the Riksbank's published forecasts diverging from the models' forecasts. The Riksbank is a policy institution that conducts monetary policy to attain an inflation target. In other words, the Riksbank will decide on a repo rate that brings the inflation forecast close to, or to, the 2 per cent inflation target during the target horizon. The models can often have an inflation forecast that does not return to the target within the forecast horizon. Those forecasts are contingent on an endogenous reportate in the models that is not necessarily consistent with the reportate decided by the Executive Board. This ultimately implies that an overall judgment for inflation has to be made for the published forecast based on the stance on monetary policy decided by the Executive Board.

Backed by our analysis, we can thus eliminate the hypothesis that major forecast inaccuracies during the evaluation period are due to the Riksbank being overly reliant on its formal models. Instead, one should proceed by analysing the more normative question of whether the Riksbank's forecasting ability and interest rate decisions would benefit from relying more on macro models. The findings in Iversen et al. (2016) suggest that this might be the case, but the question should be investigated thoroughly.

References

Adolfson, Malin, Michael K. Andersson, Jesper Lindé, Mattias Villani and Anders Vredin (2007), "Modern Forecasting Models in Action: Improving Macroeconomic Analyses at Central Banks", International Journal of Central Banking, Vol. 3, No. 4, pp. 111-144.

Adolfson, Malin, Stefan Laséen, Lawrence J. Christiano, Matthias Trabandt and Karl Walentin (2013), "Ramses II – Model Description", Occasional Paper No. 12, Sveriges Riksbank.

Adolfson, Malin, Stefan Laséen, Jesper Lindé and Mattias Villani (2008), "Evaluating an Estimated New Keynesian Small Open Economy Model", *Journal of Economic Dynamics and Control*, Vol. 32, No. 8, pp. 2690-2721.

Alexius, Annika (2016), "Förståndig men blodfattig utvärdering av penningpolitiken 2010–2015 [Sensible but Unaemic Evaluation of Monetary Policy 2010-2015]", *Ekonomisk Debatt*, Vol. 44, No. 2, pp. 67-72.

Andersson, Michael K. and Mårten Löf (2007), "The Riksbank's New Indicator Procedures", Sveriges Riksbank Economic Review, No. 1, pp. 77-90.

Andersson, Michael K. and Ard H.J. den Reijer (2015), "Nowcasting", *Sveriges Riksbank Economic Review*, No. 1, pp. 73-86.

Berg, Claes, Per Jansson and Anders Vredin (2004), "How Useful are Simple Rules for Monetary Policy? The Swedish Experience", Working Paper No. 169, Sveriges Riksbank.

Davig, Troy and Eric M. Leeper (2007), "Generalizing the Taylor Principle", *American Economic Review*, Vol. 97, No. 3, pp. 607-635.

Goodfriend, Marvin and Mervyn King (2016), "Review of the Riksbank's Monetary Policy 2010-2015" "Utvärdering av Riksbankens penningpolitik 2010–2015 [Review of the Riksbank's Monetary Policy 2010-2015]", Riksdagstryckeriet [Parliament printing house]: Stockholm.

Hallsten, Kerstin and Sara Tägström (2009), "The Decision-Making Process – How the Executive Board of the Riksbank Decides on the Repo Rate", *Sveriges Riksbank Economic Review*, No. 1, pp. 69-84.

Iversen, Jens, Stefan Laséen, Henrik Lundvall and Ulf Söderström (2016), "Real-Time Forecasting for Monetary Policy Analysis: The Case of Sveriges Riksbank", Working paper No. 318, Sveriges Riksbank.

Jansson, Per and Anders Vredin (2003), "Forecast-Based Monetary Policy: The Case of Sweden", International Finance, Vol. 6, No. 3, pp. 349-380.

Lindé, Jesper and André Reslow (2016), "En myt att Riksbankens prognoser styrts av modeller" [It's a Myth that the Riksbank's Forecasts have been Governed by Models], *Ekonomisk Debatt*, 44, No. 8, pp. 18-30.

Lund University (2016), "Yttrande över remissen 'Utvärdering av Riksbankens penningpolitik 2010–2015' [Statement regarding the consultation 'Evaluation of the Riksbank's Monetary Policy 2010-2015']", Ref V 2016/112, Lund University.

Meiton, Louise Andrén (2016), "Sylvass kritik mot Riksbanken [Scatching Criticism Against the Riksbank]", Svenska Dagbladet Näringsliv, January 20th.

Nyman, Christina and Ulf Söderström (2016), "Forecasts and Monetary Policy", *Economic Commentaries*, No. 6 (December 5th), Sveriges Riksbank.

Sveriges Riksbank (2014), "Account of Monetary Policy 2013", Sveriges Riksbank: Stockholm.

Sveriges Riksbank (2015), "Account of Monetary Policy 2014", Sveriges Riksbank: Stockholm.

Sveriges Riksbank (2016), "Account of Monetary Policy 2015", Sveriges Riksbank: Stockholm.

Taylor, John B. (1993), "Discretion Versus Policy Rules in Practice", *Carnegie-Rochester Conference Series on Public Policy*, Vol. 39, pp. 195-214.

Villani, Mattias (2009), "Steady-State Priors for Vector Autoregressions", *Journal of Applied Econometrics*, Vol. 24, No. 4, pp. 630-650.

Appendix

Table A1. The models' impact over different horizons

Horizon (quarter):	2-4	5-8	9-12		
GDP					
Ramses (ω_R)	0.58	0.04	0.04		
BVAR ($\omega_{\scriptscriptstyle B}$)	0.17	0.00	0.06		
Coeff. of determination (R ²)	0.52	-0.09	0.10		
	Inflation				
Ramses (ω_R)	0.24	0.08	0.00		
BVAR ($\omega_{\scriptscriptstyle B}$)	0.24	0.01	0.01		
Coeff. of determination (R ²)	0.31	0.00	-0.02		
	Interest rate				
Ramses (ω_R)	0.06	0.00	0.00		
BVAR ($\omega_{\scriptscriptstyle B}$)	0.10	0.15	0.13		
Coeff. of determination (R ²)	-0.11	-0.08	-0.03		
All					
Ramses (ω_R)	0.27	0.00	0.00		
BVAR ($\omega_{\scriptscriptstyle B}$)	0.18	0.10	0.09		
Coeff. of determination (<i>R</i> ²)	0.23	-0.05	0.12		

Note. Results according to estimations based on Equation (2).

Period of time:	2006:1-2008:4	2008:5-2010:6	2011:1-2014:2	2014:3-2016:2	
		GDP			
Ramses (ω_R)	0.08	0.09	0.25	0.04	
BVAR ($\omega_{\scriptscriptstyle B}$)	0.48	0.15	0.06	0.12	
Coeff. of determination (<i>R</i> ²)	0.27	0.09	0.29	0.16	
		Inflation			
Ramses (ω_R)	0.32	0.09	0.09	0.00	
BVAR ($\omega_{\scriptscriptstyle B}$)	0.00	0.25	0.00	0.03	
Coeff. of determination (<i>R</i> ²)	0.16	0.29	0.13	0.01	
		Interest rate			
Ramses (ω_R)	0.43	0.27	0.17	0.00	
BVAR ($\omega_{\scriptscriptstyle B}$)	0.00	0.10	0.08	0.28	
Coeff. of determination (<i>R</i> ²)	0.03	-0.19	0.21	-0.37	
All					
Ramses (ω_R)	0.17	0.11	0.13	0.00	
$BVAR(\omega_{\scriptscriptstyle B})$	0.07	0.15	0.05	0.11	
Coeff. of determination (<i>R</i> ²)	0.06	0.03	0.18	-0.02	

Table A2. The models' impact over different periods of time

Note. Results according to estimations based on Equation (2).

Analysis of the Riksbank's judgments according to the error terms from the specification in Equation (3).

Table A3. Correlation matrix for average ju	dgments in different	forecasting rounds
---	----------------------	--------------------

	GDP	Inflation	Interest rate
GDP	1.00	-0.02	0.30
Inflation	-0.02	1.00	0.52
Interest rate	0.30	0.52	1.00

Note. The judgments have been calculated using the regression results in Table (3), after which the average has been calculated according to the formula in Equation (4). See also the notes to Table 1 for the definition of the variables included in these regressions.

Table A4. Regression of judgments for the repo rate on judgments for inflation and GDP growth

	β	Std.Dev.	p-value
Inflation ($m{eta}_1$)	1.310	0.283	0.000
GDP (β_2)	0.146	0.201	0.473

Note. Results from the estimations according to Equation (5). Inflation is measured as the annual change (fourth difference) in CPIF. GDP refers to the annual change (fourth difference) in GDP. The estimation has a coefficient of determination, , of 0.33.

Table A5. Persistence in	the judgments	during a given	forecasting round
--------------------------	---------------	----------------	-------------------

	GDP	Inflation	Interest rate
$oldsymbol{eta}_{0}$	-0.011	-0.006	-0.010***
	(0.007)	(0.004)	(0.003)
$eta_{ extsf{i}}$	0.628***	0.728***	0.964***
	(0.021)	(0.022)	(0.008)

Note. Results from the estimations according to Equation (6). *** refers to significance at the 1 per cent level. Standard deviation in brackets.

Alternatives to inflation targeting

Björn Andersson and Carl Andreas Claussen* The authors work in the Monetary Policy Department of the Riksbank.

Since the financial crisis, there has been an intensive discussion of the inflation targeting framework for monetary policy. Critics claim that inflation targeting central banks are too focused on inflation; they give to little consideration to the real economy and to financial risks and imbalances. Moreover, critics claim that so-called level targets are superior to inflation targets, particularly now when inflation is low and policy rates are at their lower bound. In this article we take a closer look at the discussion and some of the proposed changes.

1 Introduction

In the aftermath of the financial crisis there has been an intensive discussion of the inflation targeting framework and the monetary policies pursued, both internationally and in Sweden. In brief, the critique can be summarised in three points:

- i. Inflation targeting policies do not take unemployment and production sufficiently into account, and that contributed to unnecessarily passive and restrictive monetary policy during and after the crisis.
- ii. Inflation targeting policies take to little account of finacial risks and imbalances.
- iii. Inflation targeting cannot stimulate demand sufficiently when the interest rate is close to its lower bound, something which has been a problem in recent years.

These arguments are not new. They have been around ever since inflation targets were introduced at the beginning of the 1990s. Similarly, the proposed alternatives have been debated for a long time. But recently the critical arguments and the proposed alternatives have acquired new topicality. The reason is the financial crisis and the protracted recession that followed.

So what alternatives are proposed? The Riksbank and other inflation targeting central banks already take developments in the real economy – that is, developments in output, unemployment and so on – into account in monetary policy. But to further increase their focus on the real economy, some propose to give central banks a 'dual mandate'. With a dual mandate the central bank has two explicit goals for monetary policy; to stabilize inflation *and* the real economy. Another suggestion is a target for nominal GDP growth instead of inflation. Other alternatives are supposed to induce monetary policy to prevent the buildup of imbalances and risks on the financial markets. Finally, alternatives like price level targets and targets for the nominal GDP level have been suggested as ways to make monetary policy more effective when policy rates cannot be reduced.

In this article we take a closer look both at the critique of inflation targeting and the alternatives that have been suggested. The alternatives we focus on might seem disparate, but they have common denominators. They are meant to make monetary policy put greater weight on the real economy and/or are supposed to make monetary policy more effective. By "effective" we mean that the stabilisation of inflation or the real economy or both will be better than with inflation targeting. We will also discuss alternatives that are supposed to make monetary policy take more account of financial imbalances and risks. These latter

* We would like to thank Claes Berg, Roberto Billi, Gabriela Guibourg, Øistein Røisland, Ulf Söderström and Anders Vredin for valuable comments. The opinions expressed here are those of the authors and are not necessarily shared by the Riksbank.

alternatives are perhaps better described as modifications or complements rather than proper alternatives to the current inflation targeting framework.¹

The article has six main sections. In section 2 we present and discuss the critique of the inflation-targeting policy framework. In section 3 we look at alternatives suggested in order to make monetary policy more flexible with respect to the real economy and financial stability. In section 4 we discuss alternatives that should make monetary policy more effective. In section 5 we discuss nominal GDP targeting in levels, an alternative that should both enhance the focus on the real economy and the potency of monetary policy. Finally, we summarise and draw conclusions in section 6.

2 The critique of inflation targeting

2.1 Inflation targeting can and should be flexible

The overall aim of economic policy is to enhance growth and welfare. Monetary policy is an integral part of these policies, and in the short run an expansionary monetary policy will contribute to higher growth and lower unemployment. But history has shown that in the long run a systematically expansionary monetary policy only leads to high and varying inflation, not higher growth and employment. This is the reason why many central banks' has been assigned the task of keeping inflation low and stable.

When inflation targeting was introduced in Sweden and other countries at the beginning of the 1990s, it followed a period when high and varying inflation had been a major problem. It was important to establish credibility for the new policy and quickly build confidence in the inflation target. The focus of monetary policy was therefore on inflation. But with time, as confidence in the inflation target grew, monetary policy could take more account of the real economy. *Flexible inflation targeting* was introduced as a generic term to describe a monetary policy where the central bank aims at stabilizing both inflation has to take the real economy into account, since developments in the product and labour markets will affect the outlook for inflation. But with flexible inflation targeting, stabilizing the real economy is a goal of its own.²

In recent years, arguments have been put forward that the flexibility should be extended so that monetary policy also can be used to counteract financial imbalances and risks. Like real economic developments, these imbalances and risks should be taken into account to the extent that they influence the expected outlook for inflation and the real economy. One question is if that is actually done since forecasts typically only extend 2-3 years ahead, while the risks may materialise after a longer period. However, the main question is whether central banks should "lean against the wind", and actively counteract imbalances and risks on the financial markets – even if that runs counter to the stabilisation of inflation and the real economy.³ This was also a topic at the start of the new millennium when there was a debate on whether monetary policy should prevent or 'prick' asset bubbles. There were arguments both for and against, but a consensus was formed that monetary policy should refrain from this. Rather than leaning against bubbles, it was better to clean up after they burst. Following the financial crisis, this earlier consensus has been put into question.

¹ Our idea has been to limit the article to alternatives to the inflation-targeting policy as it has generally been conducted. We have chosen not to discuss, for instance, the proposal that inflation targets should be raised to reduce the risk of the interest rate hitting its lower bound in economic downturns. This does not mean, of course, that this proposal and other similar ones are less relevant. A description of alternative means and so-called complementary monetary policy measures can be found, for instance, in the article "The Riksbank's complementary monetary policy measures" in Sveriges Riksbank (2015). See also Bank of Bank of Canada (2015).

² See Svensson (1999a) and Woodford (2003) for a theoretical explanation of flexible inflation targeting.

³ See, for example, Woodford (2012a) and Smets (2013). The question here concerns imbalances and risks in the financial system. Of course, central banks always have a responsibility for the financial system as such, see Billi and Vredin (2014).

To summarise, inflation targeting in its canonical version both can and should be flexible. The policy should stabilise both inflation and the real economy, and perhaps also reduce imbalances and risks in the financial system, even if this is more controversial.

2.2 ... but may in practice focus to little on stabilising the real economy

However, despite the fact that inflation targeting should be flexible, some have argued that it has not taken the real economy sufficiently into account. For example, some argue that exessive focus on stabilising inflation explains the weak economic recovery in the EU and the United Kingdom during the first years after the financial crisis.⁴ Similarly, but with opposite sign, the Riksbank is criticised at present for pursuing too expansionary monetary policy in times of strong GDP growth and rising house prices and household debt.⁵

We do not intend to evaluate or take a stance on whether inflation targeting policies has taken the real economy sufficiently into account, either generally or in Sweden. Here we merely note that there is such criticism, and use this as a base for a hypothetical discussion: If it is true that inflation targeting in general does not take sufficient account of the real economy, what might the causes be?

To begin with, we should emphasise that subjective judgements will always play a large role in monetary policy. Thus, the central bank and those who criticise it can quite simply make **different judgements** regarding the appropriate trade-off between the stabilising inflation and the real economy. For instance, the central bank may be more concerned about the credibility of its inflation target than what its critics are. The central bank may then choose a policy with greater emphasis on stabilising inflation than what its critics think is correct.⁶ In this case it is not the inflation targeting framework per se that is criticised, but rather the central bank's judgements.

Measurement issues can be one reason why stabilisation of the real economy receives too little weight in monetary policy decisions. Developments in the real economy are often summarised by some measure of spare capacity. But **it is not possible to directly observe the degree of spare capacity**, and there is no generally-accepted view of how to measure it. Different measures cover different things and may give a different and conflicting picture. Moreover, the measures are usually based on data which is published with time lags and often revised afterwards. With hindsight developments of the real economy might have been quite different from what the central bank believed when decisions were made.⁷ Because of these measurement issues monetary policy might put too little (or too much) weight on the real economy.⁸ It is also conceivable that the central bank focuses on other measures of the real economy than what the bank's critics do.

An important reason why it is hard to gauge the capacity of the economy is that it is hard to determine what is "normal" or "long run sustainable". Normal and sustainable levels of production, unemployment et cetera are determined by factors such as the productivity and labour force growth, how well the labour market is functioning, and so on. This differs from inflation, where "normal" is defined by the inflation target.

A third cause, which to some extent is related to the causes above, is that in practice there is an **asymmetry in the way the monetary policy objectives are formulated.** The price stability objective is concretized in an *inflation target*; it is a quantified target for the change in a particular price index. But the real economy stability objective is not concretized

⁴ See, for example, Sumner (2011a) and Wren-Lewis (2013).

⁵ See, for example, Mitelman (2014) and Cervenka (2015). For responses to the criticism of the Riksbank see, for instance, Jansson (2014).

⁶ There are also arguments suggesting that the central bank actually should put greater emphasis on inflation than the

economic agents would on average prefer, as that gives a better development in the economy generally. See Rogoff (1985).

⁷ See, for example, Orphanides (2003).

⁸ Of course, the common increase in all prices in the economy is not directly observed either.

in a corresponding *stability target*; there is no quantified target for a particular economic variable. This asymmetry might induce monetary policy to focus more on stabilising inflation where the target is concrete and explicit, and less on stabilising the real economy where the target is less so.

2.3 ... and focus too little on financial imbalances and risks

As we explained earlier, a central bank with an inflation target can use monetary policy for financial stability purposes, even if this is controversial. This means that it is not necessarily the inflation target per se that is the problem if a central bank take insufficient account of imbalances and risks in the financial system. The problem, if there is a problem, is rather that the central bank in practice does not put enough weight on financial imbalances and risks.⁹

This can, in the same way as for the real economy, reflect that the central bank and its critics make **different judgements**. For instance, it is difficult to assess the costs and benefits from using monetary policy to reduce financial imbalances and risks. A related issue is that it is **difficult to say whether or not there are financial imbalances and risks**. There is no generally-accepted view of how to understand and measure financial imbalances and risks and it is difficult to determine what levels are normal and what levels are too high. As with the real economy, an **asymmetry in the formulation of the objectives for monetary policy** may also play a role. While the inflation target is quantified and applies to a specific and observable variable, there are typically no specific, observable and quantified target for financial stability in the monetary policy mandates and strategies. A related, but practical problem is that the **risks related to these imbalances are uncertain and may materialise many years ahead**, while policies are based on forecasts that only extend 2-3 years ahead.

2.4 Can inflation targeting become too flexible?

Instead of criticising inflation targeting for not being flexible enough, there are those who argue that inflation targeting in practice attempts to be too flexible; too concerned with stabilising the real economy or counteracting financial imbalances and risks. A core question in this regard is how flexible monetary policy can be without endangering the nominal anchor – see the discussion in Section 2.1. One argument is that monetary policy risks becoming overloaded unless the main focus is always on stabilising inflation.¹⁰ Another argument is that flexible inflation targeting risks leaving other and more effective economic policy measures underutilized.¹¹

Some agree that monetary policy should take the real economy and maybe even financial imbalances and risks into account, but suggest that monetary policy should follow simple rules, rather than trying to pursue "optimal" policies. The argument behind this claim is that it makes monetary policy predictable and more robust, for instance, with regard to incorrect assumptions about the transmission mechanism. The criticism is not against monetary policy stabilising both inflation and the real economy, but rather against the way inflation targeting is usually formalised in terms of a loss function (see appendix) and the endeavour to attain an "optimal" policy.¹²

⁹ See, for example, Disyatat (2010), Woodford (2012a), BIS (2015) Gjedrem (2016) and Schnabel (2016).

¹⁰ See, for example, Orphanides (2013), Taylor (2016) and Archer (2016).

¹¹ Davig and Gürkaynak (2015) and Taylor (2016).

¹² See, for example, Orphanides and Williams (2008), Taylor and Williams (2010) and Hansen et al. (2016).

2.5 Inflation targeting is not the most effective way to manage inflation expectations

Above we discussed the argument that inflation targeting is not sufficiently flexible. In this subsection we discuss the criticism that says that there are alternative regimes that are more effective than inflation targeting in stabilising inflation and the real economy. These alternatives could be particularly useful in situations where central banks' policy rates are at or close to their lower bound. Since several central banks are experiencing this situation today the arguments in favour of these alternative targets for monetary policy have been put forward more forcefully in recent years.

To understand the potential advantage of these alternative targets, it is necessary to focus on the significance of expectations for monetary policy. Ultimately, inflation is determined by the decisions of economic agents, such as households, companies and financial market participants. These decisions are based on the current economic situation as well as expectations about the future, including expectations about future monetary policy. Thus, by influencing the expectations about future monetary policy, the central bank can influence the economic agents' decisions today and, in turn, future economic developments including inflation. A great deal of monetary policy is therefore about influencing the economic agents' expectations, and that is why it is often described as "the management of expectations".

Inflation targeting has proved effective in anchoring economic agents' inflation expectations. It creates a *nominal anchor*, whereby the economic agents expect monetary policy to bring inflation back on target if it deviates. If, for instance, inflation undershoots the target, the economic agents expect monetary policy to bring inflation back up to the target again. With such a policy "bygones are bygones"; the agents know that the central bank does not attempt to compensate periods when inflation is below target with periods with above-target-inflation. This lack of *'history-dependence'* is a drawback since it implies a less effective use of the expectations channel of monetary policy.¹³

When economic agents are forward-looking, they base their decisions on expectations of the future. If the central bank can raise inflation expectations, it will bring down real interest rates, stimulate demand, and contribute to firms increasing their prices more today. Thus, with inflation below target, it would help if central banks could use the expectations channel in this way; aim at overshooting their targets and create expectations of above target inflation in the future. Vice versa if inflation is above target.

However, the problem is that it is not credible for a central bank to do this under an inflation targeting framework, whether strict or flexible. Forward-looking economic agents realise that if future inflation starts to overshoot the target, the central bank has strong incentives in the future to deviate from the previously announced monetary policy and instead conduct a stricter policy. That would give better target fulfilment seen from that future point in time. Under inflation targeting the central bank cannot credibly commit itself to a policy which aims to overshoot the inflation target later on. It is not time consistent and therefore the policy will not have the desired effect on inflation and the real economy via the expectations channel.

This is where so called level targets come in. In sections 4 and 5 we will see that targets for the price level and the level of nominal GDP can overcome this problem and in the best case make monetary policy history-dependent and thereby more effective.¹⁴

¹³ See, for example, Woodford (1999).

¹⁴ Targets for nominal GDP growth, as discussed in Section 3, can make monetary policy history-dependent, but not in a way that is useful when the interest rate is close to zero. The rationale behind such a target therefore appears to be that one wants to force central banks to take the real economy into account. This is discussed in greater detail in Section 3.2.

3 Proposals to make monetary policy more flexible

As we explained above, inflation targeting is criticised for not taking sufficient account of the real economy and of financial imbalances and risks. Several alternatives have therefore been proposed. We discuss some of these below.

Regarding greater weight on the stabilisation of the real economy, we look at the proposal to give central banks a so-called dual mandate, as well as the proposal to replace inflation targets with targets for nominal GDP growth. As we will see, a target for nominal GDP growth can also be considered a dual mandate. Targets for the level of nominal GDP are discussed separately in Section 5.¹⁵ We will discuss arguments in favour and against these alternatives. We then take a closer look at the proposals for making monetary policy more flexible when it comes to counteracting financial imbalances and risks.

3.1 Dual mandate – makes little difference in practice? What is meant by a "dual mandate"?

The term 'mandate for monetary policy' normally means a central bank's monetary policy objectives, as specified in legislation and regulations stipulated by governments and parliaments. In Sweden for example, the Riksbank Act stipulates that the Riksbank shall maintain price stability. Furthermore, it is stipulated in the preparatory works for the Act, that the Riksbank, as an authority under the Riksdag (the Swedish parliament), shall without prejudice to the price stability target support the goals of general economic policy with a view to maintaining sustainable growth and a high rate of employment.

It is important to distinguish between the central bank's monetary policy mandate and its monetary policy strategy. The monetary policy *strategy* is usually formulated by the central bank itself, but there are also examples where it is formulated in a collaboration between the central bank and the government. The mandate comprises the base for the central bank's monetary policy strategy, while the strategy "operationalises" the mandate and governs monetary policy. The strategy makes the monetary policy objectives concrete and describes how the central bank shall work to attain the objectives.

According to a study by the Bank for International Settlements, price stability is the prime monetary policy objective in the mandates of most OECD countries. However, the mandates often also stipulate, in slightly different ways, that the central bank shall stabilise the real economy.¹⁶ It can therefore be argued that most central banks in OECD countries actually already have a dual mandate in the sense that the mandate in some way specifies that the objective of monetary policy is both price stability and real economic stability.

However, 'dual mandate' is often used to characterise a mandate that is specifically formulated like the mandate for the Federal Reserve (Fed). The Fed's (dual) mandate states that monetary policy shall promote the goals of maximum employment and stable prices.¹⁷

How does this mandate differ from those of other central banks? The Fed's objective for the real economy is made concrete (employment) and partly quantified ("maximum"). The mandates for other central banks also often specify that the central bank shall work to attain a high level of employment and growth, or support the general objectives for employment, growth, unemployment and so on. But usually other central banks' mandates stipulate that the bank shall attain this objective without prejudice to the objective of price stability. In the

¹⁵ In fact, it is not evident that a changeover from a flexible inflation targeting to nominal GDP growth targeting would lead the central bank to give greater consideration to the real economy – this depends on how much consideration it gives to the economy to start with.

¹⁶ BIS (2009)

¹⁷ The law also stipulates moderately high long-term interest rates as a goal. The wording in the Federal Reserve Act is: "The Board of Governors of the Federal Reserve System and the Federal Open Market Committee shall maintain long run growth of the monetary and credit aggregates commensurate with the economy's long run potential to increase production, so as to promote effectively the goals of maximum employment, stable prices and moderate long-term interest rates."

Fed's mandate there is no corresponding wording. Therefore, the objectives for employment and price stability are often considered "on an equal footing" in the Fed's mandate, unlike in the mandates of other central banks, where price stability is the principal target.

Do central banks with a dual mandate give greater consideration to the real economy?

Thus, the monetary policy mandate of the Fed appear to put greater weight on the objective to stabilise the real economy than the mandates of other central banks. This is sometimes expressed as the Fed having a "dual" mandate rather than a "hierarchical" one like other central banks. Therefore, some argue, changing mandates to be more like the Fed's would increase the real economy focus of monetary policy. However, whether a less hierarchical mandate actually matter for the monetary policy strategy is an open question. It is the monetary policy strategy that describes how the central banks put the mandate into operation, as explained above. For instance, if we compare the Federal Reserve's strategy with that of the Riksbank the differences in the descriptions of the trade-off between stabilising inflation and the real economy appear to be relatively small, see the box below.

Svensson (2004) comes to a similar conclusion regarding the significance of dual vs. hierarchical mandates. He points out that the central bank can determine long-run inflation, but not long-run growth and output. Thus, there is an asymmetry between inflation and output when it comes to their long-run levels. That can be interpreted as a hierarchical mandate. But when it comes to stabilising deviations in inflation from the target and deviations in output from the long-run level, there is no asymmetry. That can be interpreted as a dual (non-hierarchical) mandate. It is, according to Svensson (2004), not meaningful distinguishing hierarchical from dual mandates when central banks' conduct policies that can be characterised as trying to minimize an intertemporal loss function, with losses depending on both inflation deviations from target and some measure of the real economy fluctuating around its long-run level, see appendix. This characterization fits both the Fed and other inflation-targeting central banks.

Can flexibility be reinforced and made clearer in the mandate?

Thus, introducing mandates more in line with the Federal Reserve's less hierarchical one would perhaps not change much in terms of practical policies. But other changes might have a greater effect. One such change could be to make the objective to stabilise the real economy more explicit and concrete in the mandate. Alternatively, the mandate can stipulate that the central bank itself shall make the objective concrete.¹⁸ Such a change could for instance involve specifying what variables monetary policy should focus on.¹⁹ An even larger change would be to specify the trade-off between price stability and real economic stability in the mandate, or to state that the central bank itself has to explicitly specify the trade-off.²⁰

We would like to emphasise that these proposals would entail far-reaching changes compared to existing monetary policy mandates. We can also note that with current mandates central banks could choose to specify the real economy objective and trade-off in this way in their monetary policy strategies. But few central banks have chosen to go very far in this direction.²¹ There are probably several reasons for that. One could be that it would restrict the room for manoeuvre. Less room for manoeuvre would, arguably, make monetary policy less fit to adapt to changing circumstances.

¹⁸ See, for example, Gjedrem (2016).

¹⁹ Here, too, the Federal Reserve differs somewhat from other central banks in that the mandate clearly focuses on employment.

²⁰ See Taylor (2016) for a discussion of some such proposals.

²¹ The central bank that has gone the furthest in making the balance between price stability and real economic stability more concrete is Norges Bank (the Norwegian central bank). Norges Bank previously stated an explicit loss function (see appendix) which included an output gap with an explicit weight, see Norges Bank (2012). However, this output gap was not something that could be measured directly, it represented a quantified level of Norges Bank's assessment of the output gap.

It may also be the case that this way of making the real economy objective more concrete entails other problems and potential disadvantages. For example, there is no generallyaccepted view of how developments in the real economy in general and spare capacity in particular should be measured (see discussion in Section 2.1). This is, for instance, an argument that the Riksbank has emphasised.²² Different measures paint different pictures and may even suggest different policies. Moreover, since monetary policy is typically decided by a committee it may be difficult to agree on a specific measure and its "normal" level. Going one step further, and for example quantify the objective in terms of a target for employment would, according to many – including the Federal Reserve and the Riksbank –, be a mistake, as monetary policy is not able to influence employment and the real economy in a lasting way (see the box below). Finally, some would argue that objectives for the real economy can undermine confidence in an inflation target, as we saw earlier in section 2.4.

BOX – A comparison of the Federal Reserve's and the Riksbank's monetary policy strategies²³

The committee at the Federal Reserve that makes decisions on monetary policy is called the Federal Open Market Committee (FOMC). In its strategy the FOMC observes first of all that inflation over a longer period of time is primarily determined by monetary policy and hence that FOMC can specify a longer-run goal for inflation – an inflation rate of 2 per cent being the most consistent with the mandate in the longer run. With regard to the objective of "maximum employment", the FOMC observes that what is considered maximum employment is primarily determined by non-monetary factors that affect the structure and dynamics of the labour market, that is, factors that may change over time and may not be directly measurable. It is therefore not appropriate for the FOMC to specify a fixed goal for employment is on different occasions, and these assessments will be based on a wide range of indicators.²⁴

After specification of the objectives, the FOMC observes that "In setting monetary policy, the Committee seeks to mitigate deviations of inflation from its longer-run goal and deviations of employment from the Committee's assessments of its maximum level." On the occasions when the objectives are not complementary, the FOMC states that they will follow a balanced approach in promoting them. The Committee will then take into account the magnitude of the deviations and how quickly employment and inflation are projected to return to the levels judged consistent with the mandate.

With regard to the Riksbank's mandate, the Sveriges Riksbank Act states that the objective of the Riksbank's activities shall be to maintain price stability. In addition, the government bill behind the Act states that the Riksbank shall in addition, without prejudice to the objective of price stability, support the objectives of general economic policy with a view to achieving a sustainable level of growth and high rate of employment. It was not

²² Sveriges Riksbank (2010).

²³ The Federal Reserve's strategy is described in the document "Statement on Longer-Run Goals and Monetary Policy Strategy". The Riksbank's strategy is described in detail in the document Monetary policy in Sweden and summarised in points in the box at the front of the Monetary Policy Reports.

²⁴ Four times a year the members of the FOMC report their personal assessments of the long-run or "normal" levels for GDP growth and unemployment. In September 2016, for instance, the median assessment of normal unemployment was 4.8 per cent.

considered necessary to stipulate this in the act as it follows from the Riksbank's position as a public authority under parliament.

The Riksbank has specified the price stability objective as a target for the annual rate of change in CPI inflation of 2 per cent. With regard to the real economy, the Riksbank observes in its strategy, like the Federal Reserve, that monetary policy cannot raise growth and employment in a lasting way. These are largely determined by other factors in the long run. It is neither useful nor appropriate to set lastingly high growth or high employment as targets for monetary policy. On the other hand, monetary policy can affect the average inflation rate and in accordance with this, the overriding objective for monetary policy is to maintain price stability.

However, the Riksbank states that even if monetary policy is not able to contribute to lastingly high growth and employment, it can affect growth and employment in the short term and contribute to stabilising growth and employment around their long-run, or sustainable, levels. So the fact that the Riksbank aims its monetary policy at attaining the inflation target does not prevent it from giving consideration to the real economy. The Riksbank expresses this as: "At the same time as monetary policy is aimed at attaining the inflation target, it is also to support the objectives of general economic policy for the purpose of attaining sustainable growth and a high level of employment. This is achieved through the Riksbank, in addition to stabilising inflation around the inflation target, also endeavouring to stabilise production and employment around paths that are sustainable in the long term."

3.2 Nominal growth targeting forces monetary policy to take account of the real economy

In this section we focus on targets for the growth rate of nominal national income or total production. This is usually measured by nominal GDP growth, and in the following we refer to targets for nominal GDP growth as *nominal growth targets*. We discuss the related proposal to stabilise the GDP level in Section 5.

In the 1980s and early 1990s nominal growth targets were proposed as alternatives to targets for the money supply.²⁵ When inflation targeting was introduced in the 1990s, the alternative to target the nominal growth rate was put aside. More recently this proposal have received renewed interest.²⁶ This is partly because a nominal growth target forces the central bank to take account of the real economy.

Nominal GDP differs from the measure of GDP growth that is normally discussed. Normally, GDP growth refers to **real** GDP growth which is the growth rate of production expressed in fixed prices. Thus, it is a measure of the growth rate of output volume. Nominal GDP reports the value of what is produced when expressed in current prices. It is thus a measure that reflects both price and volume. In principle, nominal GDP growth is the sum of inflation (measured as the change in the so-called GDP deflator) and growth in output volume (real GDP growth).

²⁵ Two early advocates were Meade (1978) and Tobin (1980). Örn (1999) note that the question goes back even further. During the interwar period Professor David Davidson at Uppsala university in Sweden proposed a norm for monetary policy that with modern terminology means that monetary policy would stabilise the nominal national income.

²⁶ The debate is at its most intense on various economic blogs, where two of the most eager supporters are Scott Sumner (themoneyillusion.com) and Jeffrey Frankel (jeffrey-frankel.com). More cautiously positive contributions have been made by Simon Wren-Lewis (mainlymacro.blogspot.com), while Tony Yates has been openly critical (longandvariable.wordpress.com). An interesting exchange between Greg Ip and Ryan Avent on The Economist's blog "Free Exchange" on 1 November 2011 reflects many of the arguments for and against that have arisen in the debate. For a survey of research-based literature, see for instance Billi (2015) and Garín, Lester, and Sims (2016). Most of the research-based literature and general discussion concerns objectives for the level of nominal income and not the growth rate (which was the case in the earlier literature). However, there are those who specifically discuss targets for growth in nominal income. Røisland (2001) shows that nominal growth targets can be better than inflation targeting in a traditional model. Jensen (2002) and Guender (2007) shows that nominal growth targets can be better than inflation targeting in a New-Keynesian model. See also McCallum (2011).

A nominal growth target entails an implied inflation target. For instance, if the nominal growth target is 5 per cent and the long-term growth potential of GDP is 3 per cent the implicit inflation target is 2 per cent. A nominal growth target also implies that monetary policy shall put equal weight on stabilising inflation and stabilising real GDP growth, see appendix.²⁷ Note that the equal weight refers to what is implied by the target for nominal growth, not monetary policy in general. In principle a central bank with a nominal growth target could also stabilise a measure of the real economy like output, in the same way that a central bank with an inflation target also have the objective of stabilising the real economy.

Below, we first look at the arguments in favour and against nominal growth targeting separately. We then compare nominal growth targeting to flexible inflation targeting and look at the results of studies where the mechanisms behind several of these arguments can interact.

Arguments in favour nominal growth targeting

As explained above, nominal growth targeting implies that the central bank stabilises the total of inflation and real output growth. A possible advantage of a nominal growth target is therefore that it **forces the central bank to take account of the real economy**. A closely linked argument is that it **allows the central bank to react to supply shocks in a better way** than under inflation targeting.²⁸ Supply shocks refer to disruptions to the economy that makes inflation and growth "go in different directions". For instance, a higher oil price will cause inflation to increase in the short run. But at the same time it raises production costs and thereby slows down growth. For inflation targeting, this leads to a conflict between the objectives of price stability and real economic stability since bringing inflation back to target will dampen growth even further. However, with a nominal growth target such a conflict need not arise as the two effects tend to offset each other, leaving nominal growth more or less unchanged by the increase in the oil price. There might therefore be no need for monetary policy to react to this shock and developments in the real economy is "automatically" taken into account.

There are also arguments in favour of nominal growth targets that are not revolved around the stabilisation of the real economy. One is that it can **simplify the communication** of monetary policy.²⁹ There will be less need to distinguish between developments of prices and developments in the real economy. Furthermore, the problem of finding a measure of spare capacity, such as an output gap, might be reduced. Economic agents may also find it easier to relate to a target for nominal income growth than an inflation target, making it easier for the general public to understand monetary policy.

A third argument is that **it is easier to hold a nominal growth-targeting central bank accountable** as it is easy to evaluate nominal growth targeting policies ex post.³⁰ With a nominal growth target there is only one target and it is easy to determine whether it has been attained or not.

A forth argument is that **nominal growth targets can reduce risks in the financial system**. The argument is linked to the fact that it is difficult for borrowers to insure themselves against unexpected income losses in the future. A stable and predictable (national) nominal growth rate may help stabilise household income growth, making it more predictable. This can in itself improve welfare for households, but it can also reduce risks in the economy and in the financial system.³¹

Finally, **a nominal growth target may make monetary policy history-dependent**. In order for an output gap to close, real growth must differ from the potential long-run real growth. And if, for example, real growth is higher than potential this will, in isolation generate above

²⁷ See also Svensson (1999a).

²⁸ See, for example, Frankel (2012), McCallum (2011) and Bhandari and Frankel (2015).

²⁹ See, for example, McCallum (2011), Sumner (2011b) and The Economist (2015).

³⁰ See, for example, Bean (2013).

³¹ Koenig (2013) and Sheedy (2014).

target nominal growth. Consequently, economic agents can expect that if the monetary policy conducted does not close an output gap today, it will not close it tomorrow either.³²

Arguments against a nominal growth target

As we explained above, a nominal growth target can be taken to imply that monetary policy shall weigh stabilisation of inflation and GDP-growth equally. But having an **equal weight on stabilising inflation and GDP growth might not be optimal.**³³

Another argument against a nominal growth target is that **inflation expectations may be weakly anchored**.³⁴ This has to do with the fact that with a nominal growth target there is only an implicit inflation target, making it harder for economic agents to form their inflation expectations. Furthermore, the implicit inflation target is defined in terms of the GDP deflator, a measure that does not specifically measure consumer price changes like the CPI. If the link between inflation measured in terms of the GDP deflator and in terms of CPI is weak, or if the general public does not understand the link, inflation expectations may be poorly anchored.

Another problem is that with a constant nominal growth target the implicit inflation target will change if the economy's long-term sustainable real growth rate changes. If sustainable growth changes often, then the implicit inflation target will change often. A further complication is that changes in the sustainable growth rate can be difficult to detect. This means that there can be temporary undetected changes to the implicit inflation target. If an implicit inflation target changes frequently, temporarily, and in a way that cannot be detected, the inflation expectations may be poorly anchored.

An often mentioned practical problem with nominal growth targeting is that data on **nominal growth is published with long time lags and revised substantially and often**.³⁵ It may be difficult to determine monetary policy without data on the current level of the target variable. Furthermore, substantial revisions and less reliable data could lead to incorrect assessments. It may also be difficult to evaluate monetary policy ex post if the target variable is revised substantially afterwards. GDP statistics differ in this way from inflation statistics which is published rapidly on a monthly basis and rarely revised.

Some have also objected to the argument that a nominal growth target would be easier for the central bank to communicate. They claim that, on the contrary, **it may be more difficult to communicate monetary policy with a nominal growth target**.³⁶ The argument is based on the notion that nominal GDP is a variable that few non-economists are familiar with, making it a hard target to relate to for most people.

Another practical problem may arise if **monetary policy impacts inflation and the real economy with different time lags**. In theoretical models nominal growth targeting might lead to increasingly volatile inflation and growth if monetary policy works with different time lags and inflation expectations are backward looking.³⁷ However, the problem disappears in models where monetary policy works with similar lags and inflation expectations are forward-looking.³⁸

A nominal growth target works poorly when resource utilization is low and the policy rate is close to its lower bound. With a nominal growth target monetary policy should counteract a nominal growth which is higher than the nominal growth target. That may imply that monetary policy will be tightened at a time when the economy is recovering from

³² Jensen (2002) and Guender (2007).

³³ In the simple New Keynesian model optimal monetary policy coincides with a nominal growth target only in one special case where the weight of the real economy in the central bank's loss function is equal to the slope of the Phillip's curve, see for instance Jensen (2002) and Walsh (2003).

³⁴ See, for instance, Bean (2009) and H M Treasury (2013) and the references there.

³⁵ Bean (2013) and H M Treasury (2013).

³⁶ See, for example, Posen (2013).

³⁷ Ball (1999) and Svensson (1999a).

³⁸ See, for example, Guender (2007).

a recession. Understanding this, economic agents will lower their expectations regarding future growth and that gives a negative impulse to the economy today. To counteract this effect the central bank will have to lower the policy rate even more, something which is not possible when it is already at its lower bound.

Little difference between nominal growth targeting and flexible inflation targeting in practice

It is of course true that nominal growth targeting will stabilise the real economy more than strict inflation targeting where the central bank always try to bring inflation back to the target as quickly as possible. But inflation targeting central banks are not strict but flexible inflation targeters, as described earlier. The most relevant comparison is therefore between nominal growth targeting and flexible inflation targeting, not nominal growth targeting and strict inflation targeting.

Comparing nominal growth targeting with flexible inflation targeting it is not obvious that the existence of supply shocks speaks in favour of the nominal growth target. A central bank with flexible inflation targeting can overlook supply shocks, for instance a temporary increase in the oil price, in the same manner as a central bank that targets nominal growth. The fact is that inflation targeters make such trade-offs routinely. Being aware of the temporary nature of the effects of some shocks they can choose to focus on measures for underlying inflation instead of measures of headline inflation.

For the sake of symmetry, we should also point out that a central bank with a nominal growth target could stabilise some measure of the real economy in addition to the nominal growth target, as we explained above. In that case policies will be closer to optimal policies.³⁹ Furthermore, the problems with a nominal growth target in situations where the interest rate is close to its lower bound is reduced if the central bank explicitly stabilise the real economy in addition to nominal growth.

As we explained above, some argue that it can be difficult to anchor inflation expectations with a nominal growth target. This problem can be reduced if the central bank is explicit about the level of the implicit inflation target, that is, the level that together with the growth potential of the economy adds up to the nominal growth target. To make it easier for economic agents, the central bank could also be more explicit about its views on the relationship between the GDP deflator and a more consumer-related index, such as the CPI. However, such communication could on the other hand also make the agents more uncertain over which measure of inflation is actually the central bank's target, which can hamper the anchoring of inflation expectations.

All these arguments for and against aside, some have pointed out that nominal growth targeting should in practice result in more or less the same monetary policy as flexible inflation targeting. In the long run policies under both regimes should stabilise nominal GDP growth. And in the shorter run a central bank that pursues flexible inflation targeting should take the real economy into account in much the same way as under nominal growth targeting.⁴⁰

As far as we know, there is no country that has tested a nominal growth target for monetary policy. There is therefore no empirical evidence to rely on to make comparisons and assess whether monetary policy with a nominal growth target is better than flexible inflation targeting.⁴¹

However, there are a few studies where the two alternatives are compared in theoretical models. In these studies, some of the mechanisms and arguments that were discussed above are in play, but not all. None of the studies allow for inflation expectations to become less

³⁹ See, for example, Rogoff (1985), Røisland (2001) and Jensen (2002).

⁴⁰ For instance, Bean (2013) shows that the Bank of England has implicitly tried to stabilise nominal GDP. See also Koenig (2012) and Blot, Creel, and Ragot (2015).

⁴¹ Örn (1999) notes that the revaluation of the Swedish krona after the Second World War was based on theoretical reasoning linked to targets for nominal income.

anchored with a nominal growth target. On the other hand, they do not include the potential gains from improved accountability and financial stability. Studies that try to capture the problem with unreliable data suggest that nominal growth targeting can stabilise inflation and the real economy better than a Taylor-rule based variety of flexible inflation targeting when there can be major errors in the estimates of the output gap.⁴²

Studies that focus on the history dependency of nominal growth targeting suggest that it stabilises inflation and the real economy better than inflation targeting if (i) the relationship between inflation and unemployment is weak –that is, the so-called Phillip's curve is relatively flat– (ii) the economy is mostly exposed to supply shocks, and (iii) the central bank's loss function puts considerable more emphasis on stabilising inflation relatively to the real economy.⁴³ However, it is unclear how robust these results are.

All in all, our conclusion from reading the academic literature is that there is neither empirical nor theoretical support for the notion that nominal growth targeting should be better than flexible inflation targeting when it comes to stabilising the real economy. Nor does the academic literature speak strongly for one or the other alternative when it comes to the other arguments in favour of or against a nominal growth target. An exception is that there can be significant gains from history-dependence under nominal growth targeting. However, as we have also seen, the type of history dependence that arise under nominal growth targeting can be a disadvantage when the policy rate is close to its lower bound. Even though nominal growth targeting might not be a preferable regime to flexible inflation targeting, we believe that nominal GDP growth can be a relevant indicator in the monetary policy analysis of flexible inflation targeting central banks, in line with simple monetary policy rules, for instance.

3.3 Inflation targeting and risks in the financial system

In the previous sections we described proposals put forward for making inflation targeting central banks more flexible when it comes to stabilising the real economy. But as we discussed in section 2.3, the flexibility may also be about using monetary policy to safeguard financial stability. In this section we look at proposals aimed at increasing the flexibility in this respect. The few concrete proposals that have been put forward would not really involve a change in regime. The discussion has mainly concerned supplementing and improving inflation targeting policy as it is conducted today.

A ternary mandate can lead to greater consideration for financial stability

Maintaining financial stability is usually considered one of the central bank's main tasks. And indeed, the large majority of central banks have this responsibility, stated either through laws and statutes, or more self-imposed.⁴⁴

However, traditionally central banks have chosen not to allow the connection between financial stability and price stability influence monetary policy to any great extent. Critics claim that this needs to be reconsidered. Pointing to the experiences from the financial crisis they argue that financial stability and monetary policy are more interconnected than previously assumed.⁴⁵ Furthermore, theoretical models suggest that market failures and imperfections in the credit markets may need to be counteracted, possibly by monetary

⁴² Beckworth and Hendrickson (2016).

⁴³ See Jensen (2002) and Guender (2007). See also Kim and Henderson (2005) and Walsh (2003). In Section 5 we take a closer look at studies that analyse targets for nominal income in levels.

⁴⁴ BIS (2009).

⁴⁵ See Billi and Vredin (2014).

policy.⁴⁶ Therefore, there may be reason to add financial stability to the dual monetary policy mandate, thus giving central banks a ternary mandate for monetary policy. There are examples of central banks whose monetary policy strategies now specify that consideration to financial stability concerns could be included in their monetary policy, for instance Norges Bank and the Bank of England.⁴⁷

If central banks' principals want monetary policy to focus more on safeguarding financial stability they could consider amending the monetary policy mandates with a third objective, making them ternary. Going one step further, the principal could specify indicators and targets in the mandate, or state that the central bank should specify this itself. A far reaching move would be to require the central bank to specify the weight it will put on safeguarding financial stability relative to the other objectives.

But, analogously to the objective of stabilising the real economy, there might be problems and disadvantages with making the target more concrete in this way. One problem is that it is difficult to determine what is meant by financial stability. It is generally interpreted as meaning that the financial system is functioning efficiently and is resilient to shocks. But from a monetary policy perspective counteracting risks and imbalances in the financial markets may be the crucial issue, not strengthening the financial system as such. Financial shocks can have large negative consequences for the macroeconomy without necessarily threatening the functioning of the financial system. However, imbalances and risks on financial markets are not particularly concrete as a concept either, and there may be differing opinions as to how they should be understood and measured. Different measures paint different pictures and it is difficult to determine what levels are desirable.

Furthermore, it is debated if and to what extent monetary policy should actually take imbalances and risks in the financial system into account. In theoretical models it is typically better to use macroprudential policy to counteract financial imbalances.⁴⁸ A ternary mandate would also risk increasing uncertainty over the inflation target, and thereby endangering the nominal anchor. Finally, some fear that expanding the monetary policy mandate this way may weaken the support for independent central banks among politicians and the general public, as monetary policy would then have to make trade-offs that normally fall under fiscal policy.⁴⁹

A concrete proposal: Look beyond the forecast horizon

In the section above we pointed out that as of yet there are relatively few concrete proposals on how to increase the financial stability focus of monetary policy. Some have concentrated on finding measures of financial risks to include in monetary policy deliberations.⁵⁰ Others have focused on the practical problem that monetary policy decisions are based on forecasts that only reach 2 to 3 years ahead, while financial risks may materialise after this period. In an article in the Monetary Policy Report published in July 2013 the Riksbank described a possible framework for dealing with this problem. The starting point was to assume that four years ahead, that is, beyond the forecast horizon, there was some probability that a financial risk would materialise and force the economy into a deep recession with inflation and the real economy far below target levels. The probability of this crisis was assumed to be connected to the growth of household debt, the build-up of which could be mitigated by restrictive monetary policy today. Improved target attainment for inflation and the real economy in the short run would then be weighted against the costs of increased risks for a

⁴⁶ See, for example, Woodford (2012a) who explains why this could be a desirable wording of the central banks' objectives. His argument is in brief that deficiencies in the credit markets can reduce welfare via mechanisms that are not entirely captured by the central bank's forecasts for inflation and economic activity. Note that it is not necessarily the case that monetary policy should give consideration to this if there are other available tools, such as macroprudential policy, which can be used to counteract these deficiencies.

⁴⁷ See Norges Bank (2016) and H M Treasury (2016). The Riksbank mentions in its strategy that "risks linked to developments on the financial markets are taken into account in the monetary policy decisions".

⁴⁸ IMF (2015) and the references there.

⁴⁹ See Billi and Vredin (2014) and the references there.

⁵⁰ See, for example, Stein (2014) and Borio (2004).

very bad target attainment in the longer run. The Riksbank concluded that this framework for including financial stability considerations in monetary policy would require a lot of judgements and would probably not provide simple answers.

Later studies and research confirm this conclusion. In the majority of studies the costs of using monetary policy to reduce the risk of a future crisis largely outweigh the gains.⁵¹ An important reason is that empirically monetary policy have very little impact on the probability of a future crisis. Other studies, however, conclude that the gains from using monetary policy to lean against the risk of a future crisis outweigh the costs. In these studies monetary policy has a greater impact on the probability of a crisis and can also influence the severity of the crisis if it happens.⁵²

4 Proposals for a more effective monetary policy

As we described in Section 2.4, there may be alternatives to inflation targeting that are more effective in the sense that they make better use of the expectations channel. They could therefore stabilise prices and the real economy better. In this section we take a closer look at two of these alternatives: price level targeting and average inflation targeting.

4.1 Price level target – gains due to strong assumptions

With a price level target the aggregate price level is supposed to develop according to a specific path, for instance a path where the CPI increases by 2 per cent annually. The objective of monetary policy is to stabilise the price level on this path. If prices deviate from the target the objective is not to bring inflation back to 2 per cent, but to bring the price level back to the level it would have had if the index had increased by 2 per cent a year. Unlike an inflation target, a price level target thus requires that historical deviations are "made up for" in later periods. If, for instance, inflation is lower than 2 per cent in one period, it must be higher than 2 per cent in later periods. Otherwise the price level would not return to its target path.

The difference between a price level target and an inflation target is illustrated in Chart 1. The left-hand panel shows the price level and the right-hand panel shows inflation. The solid red lines show inflation and the price level when prices increase in line with the target of 2 per cent annually. Let us now assume that some shock occurs that make inflation fall for 12 months, as indicated by the blue lines in the right panel. Suppose as well that monetary policy responds to this by bringing the price level or inflation back on target, depending on whether the target concerns the price level or the inflation rate. The solid blue lines in the two panels show what happens to the price level and inflation respectively with a price level target. The dotted blue lines show the development with an inflation target. With a price level target the period with inflation below 2 per cent is offset by a period with inflation above 2 per cent so that the price level will return to the target path (solid red line). With an inflation target the central bank does not compensate for below-target inflation but simply brings inflation back to 2 per cent. When inflation is back at this level, prices will again rise by 2 per cent a year, but now along a path below the original path for the price level.

⁵¹ See Bank of Canada (2016), Svensson (2016a), IMF (2015), Ajello, Lopez-Salido, and Nakata (2016) and Norges Bank (2016). 52 Adrian and Liang (2016) show that the gains exceed the costs if one makes different assumptions from Svensson (2016a) regarding, for instance, how much unemployment would increase during a crisis. However, Svensson (2016b) argue that Adrian and Liang's assumptions are hardly realistic. Gerdrup, Hansen, Krogh, and Maih (2016) find in their model that the gains of using monetary policy to try to reduce the development of imbalances and risks in the financial system outweigh the costs if the economic agents underestimate the risks and if the size of potential crises depends on indebtedness in the economy. Clouse (2013) uses a stylised theoretical model to show that monetary policy should give consideration to stability risks if monetary policy can affect these risks, but that the relationship is complicated and depends on what model one uses. See also BIS (2016) and Filardo and Rungcharoenkitkul (2016).



Figure 1. Price level and inflation with a price level target and an inflation target Vertical axis measures index value (price level) and per cent (inflation). Horizontal axis measures number of months.

Arguments in favour of a price level target

The most common argument for a price level target is that **it makes monetary policy historydependent and thereby more effective**. In Section 2.4 we explained how monetary policy becomes more effective if it over- or undershoots the inflation target before converging back to the target. We also explained why such a policy is time-inconsistent and therefore not credible under inflation targeting. But with a price level target such a policy may become credible as deviations from the implicit inflation target must later be followed by deviations in the opposite direction, as illustrated in figure 1.⁵³ However, for there to be gains in effectiveness, a number of relatively strong assumptions must hold. In particular, it is important that economic agents are forward – rather than backward looking when they form their expectations. We will return to this below.

With a price level target, monetary policy becomes more effective in general (as long as the underlying assumptions hold true). But an argument often put forward in favour of price level targeting is that it can be **particularly useful in situations where the interest rate is at or close to its lower bound** when it might be harder to stimulate demand using traditional monetary policy.⁵⁴

Other arguments in favour of a price level target are based on the fact that **a price level target reduces the uncertainty surrounding the future price level**. With a price level target, economic agents can be more certain about the price level in the future since, if the central bank lives up to its commitments, the price level will only deviate from the set path temporarily, and over time prices will return to the target. This differs from an inflation target where previous deviations are not made up for. The future price level is therefore very uncertain. If, for instance, the central bank misses the inflation target on the downside more than the upside, the price will in the longer run be much lower than if inflation rises in accordance with the inflation target. With more certainty around the future price level, the risks are smaller for those who save and invest and wealth transfers between borrowers and savers will not be as arbitrary.⁵⁵

⁵³ The insight that there are such short-term stabilisation gains with a price level target is relatively new. Svensson (1999b), using a more traditional model, showed that a price level target can help to make monetary policy time consistent. Vestin (2006) showed how a price level target can implement optimal (time consistent) monetary policy in a modern New-Keynesian model.
54 See, for example the discussion in Côté (2007). Svensson (2003) and Evans (2012) argues that one can introduce a temporary price level target if the interest rate has reached its lower bound and there is at the same time considerable spare capacity in the economy.

⁵⁵ See, for example, Côté (2007).

Arguments against a price level target

For a price level target to be more effective than an inflation target, **several assumptions must hold**. A key assumption is that economic agents are forward-looking when they form expectations. Furthermore, they must understand how monetary policy works under a price level target and adapt their expectations accordingly. Put simply, for a price level target to make monetary policy more effective, the expectations must change in the "right" direction when a shock occurs. The economic agents must understand and base their decisions on the notion that low inflation today implies high inflation tomorrow, and vice versa.

If expectations only change slightly in the right direction, the stabilisation gains with a price level target is reduced. If the expectations do not change at all, a price level target may even be less effective than an inflation target.⁵⁶ The reason is relatively straightforward. Assume that inflation is currently higher than 2 per cent, and that there are expectations that it will remain high rather than decline in the coming period. It will then take a more substantial monetary policy tightening to bring inflation down to 1 per cent (which would be needed with a price level target) than to 2 per cent (which would be needed with an inflation target). Thus, if inflation expectations are adaptive, a price level target implies greater fluctuations in the real economy than an inflation target.

How realistic is the assumption that the expectations of households and companies change in the "right" direction? Ultimately, this is a question of how the economic agents form their expectations, an issue which is heavily debated. The gains in effectiveness from a price level target arises in theoretical models where agents have full information on how the economy works. Their expectations are assumed to be rational in the sense that they are based on this information. If the central bank starts to target the price level, agents will immediately base their expectations on this new target. If prices fall below the level target, the agents would expect inflation to overshoot the implicit inflation target during a later period, and adjust their decisions today to those expectations.⁵⁷ In reality, even though economic agents probably are somewhat forward-looking, empirically they seem to be less forward looking than what theory assumes. Consequently, it is not evident that expectations would change in the "right" direction if a price level target is introduced.⁵⁸

One reason why economic agents may not necessarily change their expectations in such a way is that they may not perceive the price level target as credible. They may, for example, doubt that the central bank is willing to create an economic downturn to counteract a large one-off increase in, say, the oil price (see below). In that case, expectations will not change as required for a price level target to be more effective than an inflation target.⁵⁹

Another potential challenge, which is related to the point above, is that under price level targeting **the central bank cannot disregard shocks with only temporary effects on inflation**. Let us assume that the oil price suddenly soars. The direct effect is that prices of petrol, fuel etc. rise, pushing up CPI inflation temporarily. Under flexible inflation targeting the central bank can disregard this initial effect on inflation and concentrate on mitigating any second round effects. If there is scope, monetary policy could even become more expansionary to counter the negative effects from rising production costs on the real economy.

But with a price level target the central bank cannot disregard this initial increase in inflation, as low inflation today must be offset by high inflation tomorrow. The central bank either has to tighten monetary policy to counteract the direct effect on CPI inflation or not react and instead allow negative indirect effects to affect the economy thereby lowering future inflation that way.⁶⁰ Of course, this argument assumes that the price level target is

⁵⁶ See, for example, Gaspar, Smets, and Vestin (2007).

⁵⁷ One implication of this is that the size of the efficiency gains provided by a price level target will be model-dependent, that is, they will vary depending on which model one assumes for the economy.

⁵⁸ See Amano, Engle-Warnick, and Shukayev (2011) and Kryvtsov, Shukayev, and Ueberfeldt (2008a).

⁵⁹ See, for example, Masson and Shukayev (2011).

⁶⁰ There are also those who argue that an inflation target and a price level target become equally good/bad if one takes into account in the analysis that the economy consists of several different sectors, see for instance Ortega and Rebei (2006).

defined in terms of headline CPI inflation and not in terms of an underlying measure that is adjusted for energy prices.

Gains with a price level target in theory, but uncertain gains in practice

As far as we know, there is only one example of a central bank with a price level target, namely the Riksbank during the period 1931-1937. As a crisis measure the Riksbank was then given the task of maintaining a constant purchasing power for the krona, that is, it was to maintain a constant price level.⁶¹ During this period the Swedish economy performed relatively well. But it is difficult to draw any general conclusion from this example. Firstly, this was a brief and very unusual period in the Swedish economy and the world economy. Secondly, there was no country with an inflation target during that period to compare with.⁶²

In the academic literature there are studies that compare price level targeting with inflation targeting in quantified macroeconomic models. Some of these find that there are benefits of a having a more predictable price level in the long run.⁶³ Other studies focus on the short term stabilisation gains and find that the gains from having a more effective monetary policy are significant, especially if there is a lower bound for the policy rate.⁶⁴ But it turns out that these gains disappear fairly quickly when several sectors are allowed in the model, if the economic agents are backward-looking rather than forward-looking, or if they do not adjust their expectations as assumed in the theory.⁶⁵

To summarise, our conclusion is that it is still unclear whether price level targeting would be better than flexible inflation targeting in practice. Price level targeting has hardly been tried and the theoretical gains do not clearly exceed the costs. Furthermore, the assumptions required for price level targeting to be beneficial might not hold in practice. This was also the conclusion reached by the Bank of Canada when its monetary policy was reviewed in 2011, and by H M Treasury in the United Kingdom in 2013.⁶⁶

4.2 A target for average inflation – a mid-way solution

An alternative to the inflation target, which may give similar gains as a price level target, is a target for average inflation. With this type of target the central bank shall stabilise average inflation over a fixed number of years at a certain level. For example, if the average is taken over 2 years, then a yearly inflation rate 1 percentage point below the target one year, must followed by an inflation 1 percentage point above the target the following year. This means that monetary policy becomes history-dependent, as with a price level target, but not to the same extent. With a price level target all historical deviations from the target path for the price level must be recovered. So if the path for the price level implies that prices should increase by 2 per cent a year, all deviations from 2 per cent inflation must be compensated for, otherwise the price level will not return to the target path. With an average target the central bank does not need to compensate for all of the historical deviations, only the most recent.

⁶¹ See Berg and Jonung (1999).

⁶² Straumann and Woitek (2009) refer to various historical sources and empirical data and argue that the Riksbank's monetary policy during this period was actually governed by a wish to maintain a stable weak exchange rate – not an "innovate monetary policy/price level target".

⁶³ See, for example, Dib, Mendicino, and Zhang (2008) and Meh, Ríos-Rull, and Terajima (2010).

⁶⁴ See, for example, Resende, Dib, and Kichian (2010) and Coibion, Gorodnichenko, and Wieland (2010).

⁶⁵ See, for example, Cateau, Kryvtsov, Shukayev, and Ueberfeldt (2009), Masson and Shukayev (2011) and Kryvtsov, Shukayev,

and Ueberfeldt (2008b).

⁶⁶ Bank of Canada (2011) and H M Treasury (2013)



Figure 2. Targets for average inflation

Note. Constructed example of the difference between a target for inflation and a target for average inflation

This is illustrated in figure 2. The broken lines show what inflation has to be in year 5 if inflation has been 1 percentage point below a target of 2 per cent during the three previous years. As we can see, it depends on whether the target is defined as an average over 1 year (as current inflation targets), 2 years, 3 years or 4 years. If the average is defined over 4 years, all deviations from the earlier years must be recovered, in the same way as with a price level target. Thus, if the target is explicitly defined in terms of average inflation over, for instance. 3 years, it is a mid-way solution between an inflation target and a price level target.

We should emphasise that in figure 2 we have disregarded what happens after year 5. Looking beyond year 5 reveals a potential disadvantage of average inflation targeting, namely that it can cause oscillating inflation. Let us assume, for instance, that the target is defined as an average inflation of 2 per cent over a period of 3 years. Given the numbers in figure 2, inflation would then need to be 1 per cent in years 6 and 7 respectively. In year 8 we would once again need an inflation of 4 per cent, and so on. However, if the central bank also tries to stabilise the real economy, the fluctuations would gradually disappear over time.⁶⁷

We would also like to point out that the inflation targets of most central banks, including the Riksbank's target, are not a targets for average inflation. The dotted blue line in figure 1 in section 4.1 illustrates how inflation would evolve with an inflation target. When inflation undershoots the target the central bank will aim to bring inflation back on target. It does not have to recover previous deviations from it. Thus, there is nothing in the current monetary policy strategies that says that average inflation will be on the inflation target. However, if economic shocks are symmetrical over time, and monetary policy reacts in a symmetric way, we can expect long term average inflation to coincide with the inflation target.

Arguments for and against a target for average inflation

The theoretical arguments in favour of average inflation targets are the same as the arguments in favour of price level targets. Compared with an inflation target, the uncertainty regarding the future price level is reduced, monetary policy becomes history-dependent and it may be easier to escape a situation where the interest rate is at or near its lower bound. However, as we explained earlier, under average inflation targeting it is only the most recent deviations from the inflation target that will be recovered. These arguments in favour of a target for average inflation are the same as for a price level target, but they are somewhat weaker.

Similarly, the arguments against a target for average inflation are more or less the same as the arguments against a price level target. First, some benefits only accrue under assumptions that may not hold in practice. Second, with a target for average inflation the central bank cannot disregard shocks that affect inflation temporarily. These arguments against average inflation targeting become weaker the shorter is the period for the average, in the same way as the arguments in favour becomes weaker when the period for the average is shortened.

However, an argument that particularly speaks in favour of a target for average inflation is that it may actually function better than both a price level target and an inflation target if some of the economic agents have backward-looking expectations. This can be explained as follows. We described earlier how a price level target can give a more stable development of the real economy and inflation than an inflation target if the economic agents have forward-looking expectations. But with a price level target there will be larger variation in these variables if the economic agents have backward-looking expectations. If there are both forward-looking and backward-looking expectations of inflation among economic agents, a trade-off arises. A well-adapted target for average inflation can then stabilise both inflation and the real economy better than an inflation target.⁶⁸ In general, the average should be defined over a short period if the agents are mainly backward-looking and over a longer period if they are mainly forward-looking.

Few studies comparing average target with inflation target

As far as we know, there is no examples of central banks with a target for average inflation.⁶⁹ The mandate for the central banks in Australia and New Zealand could be interpreted as targets applying to average inflation, but other information indicates that they also have "normal" inflation targets and conduct flexible inflation targeting. The Reserve Bank of Australia is explicit about this.⁷⁰ The Reserve Bank of New Zealand is less explicit – as far as we know –, but from the bank's communication we interpret its target as a traditional inflation target.⁷¹

There are a few studies that compare targets for average inflation with inflation targets in quantified models.⁷² The studies find that there are net benefits from stabilising average inflation compared to stabilising inflation if the period for the average is well adapted to how forward-looking the economic agents are when forming inflation expectations (see the section on arguments in favour of a target for average inflation above). However, it is difficult to say anything about the gains of a target for average inflation more generally and in practice on the basis of these few studies.

5 Proposal for both more flexible and more effective monetary policy – target for the level of nominal GDP.

A proposal that in theory may imply that monetary policy takes the real economy into account to a larger extent, and at the same time in a more effective way, is the proposal that monetary policy should stabilise the level of nominal GDP around a targeted path.

A target for the level of nominal GDP concretise the monetary policy target in the same way as a nominal growth target (see Section 3.2). The central bank shall target a concrete

⁶⁸ Nessen (2002) and Nessen and Vestin (2005).

⁶⁹ Strictly speaking, all central banks where the inflation target is expressed as the annual rate of inflation have an average target for inflation where the average is taken over 1 year.

⁷⁰ Debelle (2009).

⁷¹ See Bollard (2002) and Lewis and McDermott (2016).

⁷² Nessen and Vestin (2005) and Lewis and McDermott (2016).

and explicit variable around a quantified target path. For instance, the target can be to stabilise nominal GDP along a path where it grows by 5 per cent a year. As the target is a level target policy becomes history-dependent in a similar manner as with a price level target.

We saw earlier that a nominal growth target – a target for nominal GDP growth – can be regarded as an inflation target and a target for real GDP growth. Similarly, a target for the level of nominal GDP can be regarded as a price level target and a target for the level of real GDP. The central bank shall also give the same weight to the two targets (see appendix).⁷³

Arguments for and against a target for the level of nominal GDP

A target for the level of nominal GDP has the same presumed advantages as a nominal growth target (see Section 3.2): Monetary policy automatically takes the real economy into account and does not need to react to temporary supply shocks, it is simple to communicate and easy to evaluate ex post. Furthermore, financial risks may be reduced as the target could reduce uncertainty about the future income of households and companies.

Also, with a target for the level of nominal GDP, it will be the price level and not just inflation that is targeted (see Section 4.1). Thus, it would reduce the uncertainty about the future price level in a similar way to a straightforward price level target. Moreover, monetary policy can be more effective with a target for the level of nominal GDP compared to a target for the growth rate. That is particularly useful if the policy rate is at or close to its lower bound, as is the situation now. Economists who have called for more monetary policy stimulus during the recession in recent years have mainly highlighted this argument, together with the increased consideration to the real economy, as a reason why the current inflation target should be replaced – permanently or maybe temporarily – with a target for nominal GDP.⁷⁴

In the same way as a target for the level of nominal GDP shares potential advantages with a nominal growth target, it also shares conceivable problems and challenges. For instance, it may be too restrictive to weight stabilisation of inflation and the real economy equally in every situation. Furthermore, the price-level part of the target is only implicitly defined and refers to the GDP deflator, which is not a measure that specifically covers the prices of consumers' purchases. This can lead to inflation expectations becoming poorly anchored, in the same way as for a nominal growth target. It may also be difficult to communicate monetary policy as the less well-known nominal GDP measure might be hard for economic agents to relate to. A practical problem may be that data on nominal GDP is published with long lags and revised substantially and often. An increase in economic volatility may arise if monetary policy affects inflation and the real economy with different time lags.

When we discussed the price level target we noted that with such a target it may be difficult to disregard shocks that affect inflation temporarily. This also applies to a target for the level of nominal GDP, as the central bank must then compensate for deviations of nominal GDP below the target arising from temporary changes in inflation. But with a level target for nominal GDP this effect is counteracted since shocks affecting inflation also impact the real economy. If inflation increases as a result of a temporary supply shock, that may at the same time reduce GDP growth, and vice versa. This means that it may require less monetary policy response from the central bank with a target for the level of nominal GDP than with a straightforward price level target.

As with the price level target, the gains in effectiveness of monetary policy only prevail under fairly restrictive assumptions with regard to the formation of households' and companies' expectations.

⁷³ See also Svensson (1999a).

⁷⁴ See, for example, Hatzius and Stehn (2011), Romer (2011), Woodford (2012b) and The Economist (2013, 2016).

No clear indications that a target for the level of nominal GDP is preferable to flexible inflation targeting

As we noted earlier, there are potential advantages, but also potential problems and challenges with a target for the level of nominal GDP. This means that a comparison with well-functioning flexible inflation targeting may very well come out in favour of flexible inflation targeting. But it is difficult to draw any clear conclusion since it will depend on a number of factors, which may differ from country to country and from period to period.

No central bank has had a target for the level of nominal GDP, as far as we know. Thus, there is no empirical or comparative study to draw conclusions from. Several studies have been conducted using quantified macroeconomic models, but the results from these give no clear indications as to which alternative is preferable.⁷⁵

A study that has received considerable attention recently does find that there are advantages with a target for the level of nominal GDP.⁷⁶ However, this analysis is based on a specific model, and the comparison is made with a strict inflation targeting policy instead of a flexible policy, making it difficult to draw any general conclusions from the study.

6 Conclusion

Since the financial crisis, there has been intensive international discussion of inflation targeting. It has been proposed that inflation targets should be replaced with different targets, for instance a price level target or a target for nominal GDP. The proposals stem from the notion that current inflation targeting focuses too much on stabilising inflation and that monetary policy is less effective than it could be, especially now that the interest rate is at its lower bound. In this article we have taken a closer look at the debate and some of the alternatives proposed.

When we discuss alternatives to inflation targeting, it is important to remember that monetary policy with an inflation target both can and should be flexible. It shall stabilise both inflation and the real economy. It could also take imbalances and risks in the financial markets into account, although this is more controversial. Several of the proposals now being discussed are aimed at making central banks to take greater account of the real economy or financial stability in their monetary policy deliberations.

One proposal is to give the central banks a so-called dual mandate, where the objectives for price stability and real economic stability are formulated more equally than in current hierarchical mandates. However, the question is whether this would make much difference in practice. Even with a less hierarchical wording of the mandate an inflation targeting central bank must safeguard confidence in the inflation target. The problem, if it actually is a problem, is rather that there is an asymmetry in how concrete the targets are. The price stability objective is very explicitly formulated, while the objective for stabilising the real economy is normally formulated more vaguely. This may lead inflation targeting central banks to perhaps put too much weight on stabilising inflation relative to stabilising the real economy. A solution might be to stipulate in the mandate that the central bank shall define concrete target variables and levels for both inflation and the real economy. However, there are potential problems with this, for example, there is no generally-accepted view of what the appropriate measure of developments in the real economy should be.

Another proposed alternative that, at least in theory, could make the central bank stabilise the real economy to a greater extent is a target for the growth rate of nominal GDP. A nominal growth target implies that the central bank puts stabilisation of inflation and real growth on an equal footing. An argument against this alternative is that inflation

⁷⁵ Honkapohja and Mitra (2014) and Billi (2015) find that in many situations it may be better to conduct inflation targeting. This also applies if there is a lower bound for the interest rate, which in isolation favour a level target. Benchimol and Fourçans (2016) find larger net gains from a nominal GDP-growth target.

⁷⁶ Garín, Lester, and Sims (2016).
expectations may become poorly anchored as the inflation target will be implicitly defined and difficult to communicate. There are no real-world examples and the theoretical research gives no clear-cut answers as to what is preferable when it comes to choosing between flexible inflation targeting and nominal GDP growth targeting.

When it comes to imbalances and risks in the financial system, the proposals first and foremost concern supplementing the current inflation targeting policy, for example introducing a ternary monetary policy mandate whereby the central bank shall stabilise inflation, the real economy and also counteract financial imbalances and risks. Another proposal is that inflation targeters should look beyond the normal forecast horizon when making monetary policy decisions. However, recent research indicates that it might be better to allow macroprudential policies to take care of financial imbalances and risks in the financial system. A much-debated question is whether it is possible to recoup any net gain from trying to counteract financial imbalances and risks with monetary policy. Would costs in the form of weaker economic performance in the short run outweigh uncertain gains in the longer run? The relatively limited research on this question indicates that the costs weigh heavier. But the answer is not clear-cut and there are definitely reasons for central banks to regularly analyse financial stability risks and assess expected gains and losses of monetary policy measures.

In theory, a target for the price level or for the level of nominal GDP can make monetary policy more effective than current inflation targeting. However, the gains require that economic agents fully understand how level targets work and what they mean for monetary policy. Moreover, they require economic agents to be forward-looking. If they are backward-looking and largely believe, for instance, that inflation tomorrow will be the same as yesterday, level targets may be a disadvantage and increase fluctuations in both inflation and the real economy. There is not much empirical work to base a choice between inflation targeting and level targeting on and theoretical work does not provide clear-cut answers as to which alternative is preferable.

References

Adrian, Tobias and Nellie Liang (2016), "Monetary Policy, Financial Conditions, and Financial Stability", Staff Report No. 690, Federal Reserve Bank of New York.

Ajello, Andrea, David Lopez-Salido, and Taisuke Nakata (2016), "Financial Stability and Optimal Interest-Rate Policy", Finance and Economics Discussion Series No. 067, Federal Reserve Board.

Amano, Robert, Jim Engle-Warnick, and Malik Shukayev (2011), "Price-Level Targeting and Inflation Expectations: Experimental Evidence", Working Paper No. 18, Bank of Canada.

Archer, David J. (2016), "A Coming Crisis of Legitimacy?", *Sveriges Riksbank Economic Review*, No. 3, pp. 86-95.

Ball, Laurence (1999), "Efficient Rules for Monetary Policy", *International Finance*, Vol. 2, No. 1, pp. 63-83.

Bank of Canada (2011), "Renewal of the Inflation-Control Target: Background Information – November 2011", Bank of Canada.

Bank of Canada (2015), "Framework for Conducting Monetary Policy at Low Interest Rates", Bank of Canada.

Bank of Canada (2016), "Renewal of the Inflation Target: Background Information – October 2016", Bank of Canada.

Bean, Charles (2009), "'The Meaning of Internal Balance' Thirty Years On", *The Economic Journal*, Vol. 119, No. 541, pp. 442-460.

Bean, Charlie (2013), "Nominal Income Targets: an Old Wine in a New Bottle", speech at Conference on the State of the Economy, February 27th, Institute for Economic Affairs: London.

Beckworth, David and Joshua R. Hendrickson (2016), "Nominal GDP Targeting and the Taylor Rule on an Even Playing Field", mimeo.

Benchimol, Jonathan och André Fourçans (2016), "Nominal Income versus Taylor-Type Rules in Practice", Working Paper No. 1610, ESSEC.

Berg, Claes and Lars Jonung (1999), "Pioneering Price Level Targeting: The Swedish Experience 1931-1937", *Journal of Monetary Economics*, Vol. 43, No. 3, pp. 525-551.

Bhandari, Pranjul and Jeffrey A. Frankel (2015), "Nominal GDP Targeting for Developing Countries", *Working Paper No. 20898*, National Bureau of Economic Research.

Billi, Roberto M. (2011), "Output Gaps and Monetary Policy at Low Interest Rates", *Economic Review*, No. 1, Federal Reserve Bank of Kansas City.

Billi, Roberto M. (2015), "A Note on GDP Targeting and the Zero Lower Bound", Working Paper No. 270, Sveriges Riksbank.

Billi, Roberto M. and Anders Vredin (2014), "Monetary Policy and Financial Stability – a Simple Story", *Sveriges Riksbank Economic Review*, No. 2, pp. 7-22.

BIS (2009), "Issues in the Governance of Central Banks", Central Bank Governance Group, Bank for International Settlements: Basel.

BIS (2015), "85th Annual Report", Bank for International Settlements: Basel.

BIS (2016), "86th Annual Report", Bank for International Settlements: Basel.

Blot, Christophe, Jérôme Creel, and Xavier Ragot (2015), "Flexible Inflation Targeting vs. Nominal GDP Targeting in the Euro Area", in *Is Nominal GDP Targeting a Suitable Tool for ECB Monetary Policy?*, European Parliament: Brussels.

Bollard, Alan (2002), "The Evolution of Monetary Policy in New Zealand", speech at Rotary Club of Wellington, November 25th: Wellington.

Borio, Claudio (2004), "Securing Sustainable Price Stability: Should Credit Come Back from the Wilderness?", Working Paper No. 157, Bank for International Settlements.

Cateau, Gino, Oleksiy Kryvtsov, Malik Shukayev, and Alexander Ueberfeldt (2009), "Adopting Price-Level Targeting under Imperfect Credibility in ToTEM", Working Paper No. 17, Bank of Canada.

Cervenka, Andreas (2015), "Stefan Ingves gör självmål", Svenska Dagbladet, September 3rd.

Clouse, James A. (2013), "Monetary Policy and Financial Stability Risks: An Example", *Finance and Economic Discussion Series No. 41*, Federal Reserve Board.

Coibion, Olivier, Yuriy Gorodnichenko, and Johannes F. Wieland (2010), "The Optimal Inflation Rate in New Keynesian Models", Working Paper No. 16093, National Bureau of Economic Research.

Côté, Agathe (2007), "Price-Level Targeting", Discussion Papers No. 8, Bank of Canada.

Davig, Troy and Refet PP. Gürkaynak (2015), "Is Optimal Monetary Policy Always Optimal?", International Journal of Central Banking, Vol. 11, No. 4, pp. 353-382.

Debelle, Guy (2009), "The Australian Experience with Inflation Targeting", speech at XI Annual Seminar on Inflation Targeting, 15 May, Banco Central do Brasil: Rio de Janeiro.

Dib, Ali, Caterina Mendicino, and Yahong Zhang (2008), "Price Level Targeting in a Small Open Economy with Financial Frictions: Welfare Analysis", Working Paper No. 40, Bank of Canada.

Disyatat, Piti (2010), "Inflation Targeting, Asset Prices, and Financial Imbalances: Contextualizing the Debate", *Journal of Financial Stability*, Vol. 6, No. 3, pp. 145-155.

Evans, Charles L. (2012), "Monetary Policy in a Low Inflation Environment: Developing a State Contingent Price Level Target", *Journal of Money, Credit and Banking*, Vol. 44, No. 2, pp. 147-155.

Filardo, Andrew and Phurichai Rungcharoenkitkul (2016), "A Quantitative Case for Learning Against the Wind", Working Paper No. 594, BIS.

Frankel, Jeffrey (2012), "Time for Nominal Growth Targets," Project Syndicate, January 12th, 2016 at www.project-syndicate.org.

Garín, Julio, Robert Lester, and Eric Sims (2016), "On the Desirability of Nominal GDP Targeting", *Journal of Economics and Control*, Vol. 69 pp. 21-44.

Gaspar, Vítor, Frank Smets, and David Vestin (2007), "Is Time Ripe for Price Level Path Stability?", Working Paper No. 0818, European Central Bank.

Gerdrup, Karsten R., Frank Hansen, Tord Krogh, and Junior Maih (2016), "Leaning Against the Wind when Credit Bites Back", Working Paper No. 9, Norges Bank.

Gjedrem, Svein (2016), "Central banks' role, Objectives and Accountability", *Sveriges Riksbank Economic Review*, No. 3, pp. 104-108.

Guender, Alfred V. (2007), "A Comparative Analysis of the Stabilizing Properties of Nominal Income Growth Targeting", *Economics Letters*, Vol. 95, No. 2, pp. 217-222.

H M Treasury (2013), "Review of the Monetary Policy Framework: Report Presented to Parliament", Chancellor of the Exchequer by Command of Her Majesty: London.

H M Treasury (2016), "Remit for the Monetary Policy Committee", H M Treasury: London.

Hansen, Lars Peter, et al., (2016), "Statement on Policy Rules Legislation," viewed October 25th, 2016, Available at http://www.johnbtaylor.com/.

Hatzius, Jan and Jari Stehn (2011), "The Case for a Nominal GDP Level Target", US Economics Analyst No. 41, Goldman Sachs.

Honkapohja, Seppo and Kaushik Mitra (2014), "Targeting Nominal GDP or Prices: Guidance and Expectation Dynamics", Discussion Paper No. 9857, Centre for Economic Policy Research.

IMF (2015), "Monetary Policy and Financial Stability", Staff Report, International Monetary Fund: Washington, D.C.

Jansson, Per (2014), "Swedish Monetary Policy after the Financial Crisis – Myths and Facts", speech at Bank Summit 2014, 12 December, Svenska Dagbladet: Stockholm.

Jensen, Henrik (2002), "Targeting Nominal Income Growth or Inflation?", *The American Economic Review*, Vol. 92, No. 4, pp. 928-956.

Kim, Jinill and Dale W. Henderson (2005), "Inflation Targeting and Nominal-income-growth Targeting: When and Why are they Suboptimal?", *Journal of Monetary Economics*, Vol. 52 pp. 1463-1495.

Koenig, Evan F. (2012), "All in the Family: the Close Connection between Nominal-GDP Targeting and the Taylor Rule", *Staff Paper No. 17*, Federal Reserve Bank of Dallas.

Koenig, Evan F. (2013), "Like a Good Neighbor: Monetary Policy, Financial Stability, and the Distribution of Risk", International Journal of Central Banking, Vol. 9, No. 2, pp. 57-82.

Kryvtsov, Oleksiy, Malik Shukayev, and Alexander Ueberfeldt (2008a), "Adopting Price-Level Targeting under Imperfect Credibility", Working Paper No. 3, Bank of Canada.

Kryvtsov, Oleksiy, Malik Shukayev, and Alexander Ueberfeldt (2008b), "Adopting Price-Level Targeting under Imperfect Credibility: An Update", Working Paper No. 37, Bank of Canada.

Lewis, Michelle and Dr J. McDermott (2016), "New Zealand's Experience with Changing its Inflation Target and the Impact on Inflation Expectations", Discussion Paper No. 7, Reserve Bank of New Zealand.

Masson, Paul R. and Malik D. Shukayev (2011), "Are Bygones not Bygones? Modeling Price-level Targeting with an Escape Clause and Lessons from the Gold Standard", *Journal of Macroeconomics*, Vol. 33, No. 2, pp. 162-175.

McCallum, Bennett, (2011), "Nominal GDP Targeting," Shadow Open Market Committee, viewed October 1st, 2016, Available at http://shadowfed.org/.

Meade, James (1978), "The Meaning of "Internal Balance"", *The Economic Journal*, Vol. 88, No. 351, pp. 423-435.

Meh, Césaire A., José-Víctor Ríos-Rull, and Yaz Terajima (2010), "Aggregate and Welfare Effects of Redistribution of Wealth under Inflation and Price-level Targeting", *Journal of Monetary Economics*, Vol. 57, No. 6, pp. 637-652.

Mitelman, Henrik (2014), "Nu blir Ingves börsens bästis", Dagens Industri, October 29th.

Nessen, Marianne (2002), "Targeting Inflation over the Short, Medium and Long Term", *Journal of Macroeconomics*, Vol. 24, No. 3, pp. 313-329.

Nessen, Marianne and David Vestin (2005), "Average Inflation Targeting", *Journal of Money, Credit and Banking*, Vol. 37, No. 5, pp. 837-63.

Norges Bank (2012), "Monetary Policy Report 2/12", Norges Bank: Oslo.

Norges Bank (2016), "Monetary Policy Report With Financial Stability Assesment 3/16", Norges Bank: Oslo.

Orphanides, Athanasios (2003), "The Quest for Prosperity Without Inflation", *Journal of Monetary Economics*, Vol. 50, No. 3, pp. 633-663.

Orphanides, Athanasios (2013), "Is Monetary Policy Overburdened?", *Working Paper No. 435*, Bank for International Settlement.

Orphanides, Athanasios and John C. Williams (2008), "Imperfect Knowledge and the Pitfalls of Optimal Control Monetary Policy", in *Monetary Policy under Uncertainty and Learning*, Vol. 13, Klaus Schmidt-Hebbel, Carl E. Walsh, Norman Loayza, and Klaus Schmidt-Hebbel, red., Central Bank of Chile: Santiago.

Ortega, Eva and Nooman Rebei (2006), "The Welfare Implications of Inflation versus Price-Level Targeting in a Two-Sector, Small Open Economy", *Working Paper No. 12*, Bank of Canada.

Posen, Adam (2013), "Cheap Talk is No Alternative to Inflation Targeting", in *Is Inflation Targeting Dead? Central Banking After the Crisis*, Lucrezia Reichlin and Richard Baldwin, red., Centre for Economic Policy Research: London. Resende, Carlos d., Ali Dib, and Maral Kichian (2010), "Alternative Optimized Monetary Policy Rules in Multi-Sector Small Open Economies: The Role of Real Rigidities", Working Paper No. 9, Bank of Canada.

Rogoff, Kenneth (1985), "The Optimal Degree of Commitment to an Intermediate Monetary Target", *The Quarterly Journal of Economics*, Vol. 100, No. 4, pp. 1169-1189.

Romer, Christina (2011), "Dear Ben: It's Time for Your Volker Moment", New York Times, October 29th.

Røisland, Øistein (2001), "Institutional Arrangements for Monetary Policy When Output Is Persistent", *Journal of Money, Credit and Banking*, Vol. 33, No. 4, pp. 994-1014.

Schnabel, Isabel (2016), "What role for Central Banks in Safeguarding", *Sveriges Riksbank Economic Review*, No. 3, pp. 49-54.

Sheedy, Kevin D. (2014), "Debt and Incomplete Financial Markets: A Case for Nominal GDP Targeting", Brookings Papers on Economic Activity, Vol. 48, No. 1, pp. 301-373.

Smets, Frank (2013), "Financial Stability and Monetary Policy: How Closely Interlinked?", Sveriges Riksbank Economic Review, No. 3, pp. 121-160.

Stein, Jeremy C. (2014), "Incorporating Financial Stability Considerations into a Monetary Policy Framework", speech at International Research Forum on Monetary Policy, 21 March: Washington, D.C.

Straumann, Tobias and Ulrich Woitek (2009), "A Pioneer of a New Monetary Policy? Sweden's Pricelevel Targeting of the 1930s Revisited", *European Review of Economic History*, Vol. 13, No. 2, pp. 251-282.

Sumner, Scott (2011a), "Re-Targeting the Fed", National affairs, Vol. 9, No. Fall, pp. 79-96.

Sumner, Scott (2011b), "The Case for NGDP Targeting: Lessons from the Great Recession", Adam Smith Institute: London.

Svensson, Lars E. O. (1999a), "Inflation Targeting: Some Extensions", Scandinavian Journal of Economics, Vol. 101, No. 3, pp. 337-61.

Svensson, Lars E. O. (1999b), "Price-Level Targeting versus Inflation Targeting: A Free Lunch?", *Journal of Money, Credit and Banking*, Vol. 31, No. 3, pp. 277-95.

Svensson, Lars E. O. (2003), "Escaping from a Liquidity Trap and Deflation: The Foolproof Way and Others", *Journal of Economic Perspectives*, Vol. 17, No. 4, pp. 145-166.

Svensson, Lars E.O. (2004), "Commentary", Federal Reserve Bank of St. Louis Review, Vol. 86, No. 4, pp. 161-164.

Svensson, Lars E. O. (2012), "Comment on Michael Woodford 'Inflation Targeting and Financial Stability'", *Sveriges Riksbank Economic Review*, No. 1, pp. 33-39.

Svensson, Lars E. O. (2016a), "Cost-Benefit Analysis of Leaning Against the Wind: Are Costs Larger Also with Less Effective Macroprudential Policy?", *Working Paper No. 21902*, National Bureau of Economic Research.

Lars E.O. Svensson (2016b), "How Robust Is the Result That the Cost of "Leaning Against the Wind" Exceeds the Benefit? Response to Adrian and Liang", mimeo.

Sveriges Riksbank (2010), "Monetary Policy in Sweden", Sveriges Riksbank: Stockholm.

Sveriges Riksbank (2015), "Monetary Policy Report: February 2015", Sveriges Riksbank: Stockholm.

Taylor, John B. (2016), "Independence and the Scope of the Central Bank's Mandate", *Sveriges Riksbank Economic Review*, No. 3, pp. 96-105.

Taylor, John B. and John C. Williams (2010), "Simple and Robust Rules for Monetary Policy", in *Handbook of Monetary Economics*, Vol. 3, Benjamin M. Friedman and Michael Woodford, red., Elsevier.

The Economist (2013), "Shake 'em up Mr. Carney", The Economist, February 2nd.

The Economist (2015), "After the Hold, be Bold: It Will Take More than Patience to free Rich Economies from the Zero-interest-rate World", *The Economist*, September 26th.

The Economist (2016), "When 2% is not Enough", August 27th.

Tobin, James (1980), "Stabilization Policy Ten Years After", *Brookings Papers on Economic Activity*, Vol. 11, No. 1, pp. 19-90.

Vestin, David (2006), "Price-Level versus Inflation Targeting", *Journal of Monetary Economics*, Vol. 53, No. 7, pp. 1361-1376.

Walsh, Carl E. (2003), "Speed Limit Policies: The Output Gap and Optimal Monetary Policy", *The American Economic Review*, Vol. 93, No. 1, pp. 265-278.

Woodford, Michael (1999), "Commentary: How Should Monetary Policy be Conducted in an Era of Price Stability?", in *Proceedings from Economic Policy Symposium at Jackson Hole*, Federal Reserve Bank of Kansas City.

Woodford, Michael (2003), Interest and Prices: Foundations of a Theory of Monetary Policy, Princeton University Press.

Woodford, Michael (2012a), "Inflation Targeting and Financial Stability", *Sveriges Riksbank Economic Review*, No. 1, pp. 7-32.

Woodford, Michael (2012b), "Methods of Policy Accomodation at the Interest-Rate Lower Bound", in *The Changing Policy Landscape, Economic Policy Symposium Proceedings*, Federal Reserve Bank of Kansas City.

Wren-Lewis, Simon, (2013), "Carney and the Treasury Select Committee: Episode One Preview," Mainly macro, vieved January 12th, 2016, Available at www.mainlymacro.blogspot.se.

Örn, Gunnar (1999), "Vad är det för fel på Davidsons norm? [What's Wrong with Davidson's Norm?]", Ekonomisk Debatt, Vol. 27, No. 6, pp. 113-323.

Appendix

Flexible inflation targeting

In this subsection we describe flexible inflation targeting more formally. This description is then used to compare flexible inflation targeting with other targeting regimes below.

Let P_t represent the price level in the period t, and p_t be the logarithm of the price level in period t. We can then write inflation in period t as $\pi_t = \rho_t - \rho_{t-1}$.

With an inflation target for monetary policy, the central bank attempts to stabilise inflation at a given level π^* (the inflation target). A common way of describing this formally is that the central bank tries to minimise the total of the squared deviations from the inflation target from period *t* and onwards, that is, the central bank minimises

(1)
$$\sum_{t=0}^{\infty} \beta^{t} (\pi_{t} - \pi^{*})^{2},$$

where β^t is a discount factor. By using the squared deviations as a base, positive and negative deviations from the inflation target will be treated symmetrically, and the cost of a deviation is increasing in the deviation. In other words, it is better to have several small deviations than one large one. The sum in (1) is not the only way of measuring the costs of deviating from the inflation target, but it is the most common in the academic literature.

With a flexible inflation targeting framework the central bank also strives to stabilise the real economy. The most common way of formally describing this is that the central bank in addition to stabilising inflation also stabilises the output gap, which is a measure of the degree of capacity utilisation in the economy. Let Y_t be the level of real GDP in the period t, and y_t the logarithm of Y_t . Let Y_t^* be the normal level, or equilibrium level of GDP in period t (see the discussion in Section 2.2) and y_t^* be the logarithm of Y_t^* . In the same way as for inflation, the loss in the event of deviations from the normal level is written as

(2)
$$\sum_{t=0}^{\infty} \beta^{t} (y_{t} - y_{t}^{*})^{2}$$

The central bank normally uses only one tool, the policy rate, to attain both targets: stabilising inflation around the inflation target and stabilising production around a long-term sustainable level. If there is a conflict between these two targets, the central bank has to trade them off against one another. This is often formulated as the central bank choosing a level for the policy rate that gives as little combined loss as possible, that is, the central bank minimises a loss function according to

(3)
$$L = \sum_{t}^{\infty} \beta^{t} [(\pi_{t} - \pi^{*})^{2} + \lambda (y_{t} - y_{t}^{*})^{2}],$$

where λ represents the weight the central bank gives to stabilising the real economy in relation to inflation. Thus, λ measures the degree of flexibility in monetary policy. Of course, there is not always a conflict between stabilising inflation and the output gap. In some cases, inflation and output will move in different directions in relation to their "targets" and sometimes they will move in the same direction. This depends on what shocks hit the economy. But even when they are moving in the same direction, there may be justification for the central bank to give explicit consideration to developments in the real economy.

Dual mandate

Above we explained how flexible inflation targeting theoretically can be modelled as minimisation of a loss function like equation (3). Further, we pointed out that the weight λ in the theoretical description determines which policy alternative should be chosen on each decision-making occasion.

If the authorities wish to give a central bank a very concrete dual mandate, they could consider specifying in the mandate that the central bank shall minimise the loss function (3) which also specifies the value of λ . Alternatively, they can state the arguments in the loss function and leave the weighting of the two targets to the central bank to determine.

Target for nominal GDP growth

Let *N* be the level of nominal GDP, i.e. N = PY. If we take the logarithm of this expression and look at the change over two periods, we see that growth in *N* is equal to the sum of inflation (the change in prices), π , and real economic growth, *g*,

$$nt = \pi + g$$

where *nt* is growth in *N*.

To define a nominal growth target, the central bank begins by defining the level of sustainable or long-term growth in the economy, g^* . This level is unobservable, and judgment is needed to arrive at a number. It depends on assessments of the long-term growth in productivity and labour, structural conditions with regard to the functioning of the labour market, and so on. It is important to note that if monetary policy is neutral in the long run, that is, it cannot raise output in a sustainable manner, the growth potential g^* will not be affected by monetary policy.

The central bank also needs to define an inflation target π^* . The target for nominal growth (*nt*^{*}) will now become the sum of these two, that is

$$nt^* = q^* + \pi^*$$
.

The target for monetary policy is to hold nominal growth (*nt*) at or near *nt**.

To tie in with the formal monetary policy theory above, we can assume that the central bank tries to minimise the sum of the squared deviations from the target $(nt_t - nt_t^*)^2$. This can in turn be written as the central bank trying to stabilise the loss function.

$$L = \sum_{t}^{\infty} \beta^{t} \left\{ \underbrace{(p_{t} - p_{t}^{*})^{2} + (y_{t} - y_{t}^{*})^{2}}_{a} + 2\underbrace{(p_{t} - p_{t}^{*})(y_{t} - y_{t}^{*})}_{b} \right\}.$$

The first part of the expression, marked *a*, is similar to (3), but with $\lambda = 1$ and *y* is replaced with *g*. The second part, the covariance term marked *b*, is an effect of the target applying to the variance of the sum of the two. Thus, we see that a nominal growth target in practice means that the central bank shall stabilise inflation around an inflation target and the real economy around a sustainable level (the real economy's growth potential) with the same weight given to both of these targets.

To show that monetary policy can become history-dependent with a nominal growth target, we first observe that target attainment in period t means that $nt_t - nt^* = 0$. This in turn can be written as

$$(\pi_t - \pi^*) + (y_t - y_t^*) - (y_{t-1} - y_{t-1}^*) = 0,$$

where y_t is the output level, $(y_t - y_t^*)$ is the output gap and where we have used $g_t = (y_t - y_{t-1})$. We thus see that history is important to target fulfilment. If there was a positive output gap in period *t*-1, a positive output gap and/or inflation gap is needed in period *t*. This will not be the case with a flexible inflation target.

Ternary mandate

While the targets for monetary policy are normally described by means of the loss function (3), a ternary mandate would mean that we add a further element that represents financial stability risks. The loss function could then take the form

(4)
$$L = \sum_{t}^{\infty} \beta^{t} [(\pi_{t} - \pi^{*})^{2} + \lambda (y_{t} - y_{t}^{*})^{2} + \delta \Omega_{t}^{2}],$$

where is Ω_t a measure of financial risks, see Woodford (2012). Disyatat (2010) suggests that a weighted sum of asset prices and household debt in relation to an equilibrium level could work as a proxy for the risks in the financial system.

Looking beyond the forecast horizon

The proposal to look beyond the forecast horizon can be formally described as follows. The central bank minimise the loss function

(5)
$$L = \sum_{k}^{k} \beta^{t} [(\pi_{t} - \pi^{*})^{2} + \lambda (y_{t} - y_{t}^{*})^{2}] + pL(crisis),$$

where p is the probability of a crisis after the forecast horizon k and L(crisis) is the expected loss if there is a crisis. Monetary policy can influence p and L(crisis), in addition to inflation and output for t < k.

Price level target

A price level target can be described as follows. The central bank sets a path for the aggregate price level measured by for instance CPI. The path may be consistent with a target for inflation, π^* , and can then be written as

$$p_{t}^{*} = p_{0} + t\pi^{*}, \quad t = 0, 1, \dots, \infty$$

where p_t^* is the logarithm of the price level that shall be attained in period t, p_0 is the logarithm of the price level in the period when the price level target was introduced and π^* is the yearly increase in the price level. The target for monetary policy is to stabilise the price level on this path.

More formally, the central bank tries to minimise the total of the squared deviations from the inflation target from period *t*, that is, the central bank minimises

(6)
$$\sum_{t=0}^{\infty} \beta^{t} (p_{t} - p_{t}^{*})^{2}.$$

If the central bank conducts a flexible policy, it will also take developments in the real economy into account. Formally, the central bank can then be seen as minimising the loss function

(7)
$$L = \sum_{t}^{\infty} \beta^{t} [(p_{t} - p_{t}^{*})^{2} + \lambda (y_{t} - y_{t}^{*})^{2}],$$

Where $(y_t - y_t^*)$ is the output gap as described above, and λ represents the weight the central bank attaches to stabilising the real economy relative to the price level.

Target for average inflation

Average inflation over a period of length j is given by

$$\overline{\pi}_{j,t} = \frac{1}{j} \sum_{s}^{j-1} \pi_{t-s} = \frac{1}{j} (\boldsymbol{p}_t - \boldsymbol{p}_{t-j})$$

where p_t and p_{tj} are the logarithm for the price level in period t and period t-j respectively.

The target for monetary policy will be to stabilise average inflation at the target level π^* . As for the inflation target, we can see this as the central bank minimising the squared sum of deviations from the inflation target

$$\sum_{t=0}^{\infty} \beta^{t} (\overline{\pi}_{j,t} - \pi^{*})^{2}.$$

If j = 1 then the target is $\overline{\pi}_{1,t} = (p_t - p_{t-1})$, which is the same as a normal inflation target. If $j = \infty$ the target corresponds to a price level target as described above.

Here, too, we can imagine that the central bank takes the real economy into account and minimises

(8)
$$L = \sum_{t}^{\infty} \beta^{t} [(\overline{\pi}_{j,t} - \pi^{*})^{2} + \lambda (y_{t} - y_{t}^{*})^{2}].$$

Target for the level of nominal income

In brief, a target for the level of nominal income works as follows. As for a nominal growth target, the central bank first defines the long-term growth potential in the economy, g^* , and the implicit inflation target π^* . The target for the level of the nominal income in logarithms, ni^* , is then

(9)
$$ni_t^* = ni_0 + t(g^* + \pi^*)$$

where ni_0 is the logarithm of the nominal GDP level in the period when the target was introduced. The objective of monetary policy is to stabilise ni_t at ni_t^* . Unlike a nominal growth target of 5 per cent, a nominal income level target thus requires that deviations from 5 per cent in one period must "be compensated" in later periods when growth in nominal income must be higher than 5 per cent.

If we assume that the central bank tries to minimise the sum of the quadratic deviations from target $(n_t - n_t^*)^2$ this can be written as

$$L = \sum_{t}^{\infty} \beta^{t} \left\{ \frac{(p_{t} - p_{t}^{*})^{2} + (y_{t} - y_{t}^{*})^{2}}{a} + 2 \frac{(p_{t} - p_{t}^{*})(y_{t} - y_{t}^{*})}{b} \right\}.$$

The first part of this expression, *a*, is similar to (3) but now is λ =1 and π is replaced by *p*. The second part, b, represents the fact that the aim is to minimise the variability of the sum of output and prices. Thus, we see that a target for the nominal GDP level in practice implies that the central bank shall stabilise prices around a target path and GDP along a target path and that both these goals shall be given equal weight. The target thereby entails a strict concretisation of the targets for monetary policy.

Inflation targets and intervals – an overview of the issues

Mikael Apel and Carl Andreas Claussen* The authors work in the Monetary Policy Department of the Riksbank

In this article, we analyse the advantages and disadvantages of different ways of formulating inflation targets that involve an interval. We first review the international debate of ten to fifteen years ago on how an inflation target should best be designed. We then discuss the arguments in the current Swedish debate in light of this. One central conclusion is that if the inflation target is credible, monetary policy can be flexible and consider factors other than inflation – such as output and employment – even without an interval. A 'tolerance band' can open for more flexibility if it increases the credibility of the inflation target, but it could also reduce flexibility if it creates more inflation uncertainty or if ending up outside the interval is very costly. A 'target range' entails a major change to the monetary policy framework. It would allow the central bank to aim at different levels for inflation at different times. But as inflation expectations may become less firmly anchored, economic fluctuations may become greater.

1 There are different types of inflation targets

Almost all of the OECD's 35 member countries can be characterised as inflation targeters. They either conduct their own inflation targeting policy, or they are members of the euro area where the European Central Bank (ECB) conducts inflation targeting.¹ Monetary policy in many emerging market economies, such as Ghana, Indonesia and the Philippines, is also based on an inflation target. In total, there are currently about sixty countries that use a quantified target for inflation in one way or another.²

Inflation targets can be designed in different ways. They can be what is known as *point targets* where the inflation target is specified in terms of a single number, or they can be so-called *target ranges* where the target is specified in terms of an interval. As it is difficult to attain a point target exactly, point targets are often complemented with a *tolerance band*. The tolerance band specifies which deviations from the point target can be considered 'acceptable' in normal times.

1.1 The difference between a tolerance band and a target range

The difference between a tolerance band and a target range is illustrated in Figure 1. The figure shows CPIF inflation since 2006, an inflation target of 2 per cent and two possible intervals: a tolerance band of ± 1 percentage point around the target, and a target range from 1 to 3 per cent. The important difference between the two intervals is how the central bank regards the desirable level of inflation in the period ahead. The tolerance band refers

^{*} We would like to thank Claes Berg, Gabriela Guibourg, Ulf Söderström and Anders Vredin for valuable comments and suggestions. The opinions expressed in this article are our own and should not be regarded as the Riksbank's view.

¹ The only exception is Denmark, whose currency is pegged to the euro. A difference between the euro countries and regular inflation-targeting countries is that the ECB's inflation target applies to average inflation across the euro area. This means that inflation in individual countries can vary.

² A list of central banks' inflation targets for 2016 can be found at www.centralbanknews.info.

to inflation outcomes. In this sense it is backward-looking, but it may also affect current monetary policy and thereby also future inflation. Most importantly, with a point target and a tolerance band, the central bank always aims at bringing inflation back to the point target, as in path A.

With a target range it is different. Then there is no requirement for the central bank to always bring inflation back to the middle of the interval. The central bank can, in principle, aim for any level within the interval, for example as in paths A, B or C.



Note. The broken line represents fictitious forecasts. Sources: Statistics Sweden and the Riksbank

1.2 Point target with tolerance band is the most common in practice

It is most common for central banks to have a point target and a tolerance band.³ This is the case in Chile, the Czech Republic and Hungary, for example. However, a number of countries only have a point target. This is the case in Norway, Sweden, and the United States, for example. The Riksbank had a tolerance band up to 2010. A few countries have a target range, for example Australia and Israel. Switzerland, where the aim is for inflation "to be below 2 per cent", can also be included here as zero can be regarded as the lower bound (as a negative rate of price increase is not inflation but deflation).

There are also several countries whose inflation targets are harder to characterise. These include Colombia and New Zealand, which both have formal target ranges but also have the expressed ambition of bringing inflation close to the midpoint of the range – implying that it also has the characteristics of a point target.⁴ In the euro area, inflation must be below 2 per cent which, like Switzerland, could be interpreted as a target range of zero to 2 per cent. But the wording of the target specifies that inflation is to be "close to 2 per cent", which indicates an ambition to be closer to the upper limit of the interval. The United Kingdom is often included among the countries which only have a point target.⁵ At the same time, the United Kingdom is one of the relatively few countries where a sufficiently large deviation from target has concrete consequences. If inflation deviates from target by more than one percentage point, the Governor of the Bank of England must write an open letter to the Government and explain why this has happened.⁶ Thus, according to the definition above, this arrangement

³ A complete list of different countries' targets can be found in Table A1 in Appendix 1.

⁴ See, for example, Lewis and MacDermott (2016) for a historical review of New Zealand's inflation target. The aim for future inflation to be held "near the 2 percent target midpoint" was added in September 2012.

⁵ See, for example, Hammond (2012).

⁶ The clarification of the inflation target that the Riksbank presented in conjunction with the appointment of the Executive Board in 1999 is somewhat reminiscent. See Heikensten (1999).

has the characteristics of a tolerance band, even if the Bank of England seems to prefer not to use this term.⁷

2 The debate about point targets vs. intervals

So, which type of inflation target is to be preferred? About ten to fifteen years ago, there was a quite intensive international discussion on how an inflation target should best be designed. One central issue concerned whether the target should be a point target or an interval.⁸ But it was not always clear whether the interval discussed was a tolerance band or a target range: was it the target *in itself* that should be a point or an interval, or was it that a point target should be surrounded by a tolerance band? Below, we go through the arguments presented. Even today these arguments provide a fairly complete view of the advantages and disadvantages of the various targets.

The review may also be useful for the recent debate in Sweden. The discussion here has focused on whether the Riksbank should (re)introduce some type of interval. But neither here has there been complete clarity as to whether the interval under discussion is a tolerance band or a target range.⁹ We will return to the Swedish debate later in the article.

2.1 Intervals that are supposed to illustrate uncertainty and the impossibility of fine-tuning

An argument in the earlier international debate that must be interpreted as referring to a tolerance band is that the interval should reflect inflation uncertainty and the fact that the central bank cannot perfectly control inflation. The interval would illustrate that actual inflation may differ from the target. The aim of this type of interval would be for the central bank to avoid giving the impression that monetary policy can fine-tune inflation with a high degree of precision. The size of the interval would provide information on the central bank's assessment of the normal level of uncertainty about shocks and about the effects of monetary policy. The interval would show what variation in inflation that could reasonably be expected over time.

Some argued that uncertainty could better be illustrated in other ways, for example by the uncertainty band around the central bank's forecasts, such as, for example, those in the Riksbank's Monetary Policy Reports (the so-called "fan charts").¹⁰ Uncertainty can also be illustrated by alternative scenarios. Some also argued that economic agents already understand that a point target will never be exactly fulfilled, and that deviations will always exist. A tolerance band would therefore be unnecessary, according to this point of view.

However, it cannot be ruled out that a tolerance band is a more pedagogical way of illustrating this uncertainty and that economic agents would gain a better understanding of the uncertainty if there was an interval. A tolerance band may then make moderate deviations from the point target less dramatic, as inflation would still be within the tolerance band. In contrast, if there is no tolerance band the same deviations could be perceived as a clear miss of the target and could thereby reduce the confidence in the central bank and

⁷ For example, Charles Bean (2003), former Chief Economist and member of the Bank of England's Monetary Policy Committee, has explained that: "It is worth stressing that the Open Letter is part of the arrangements for public accountability, not an elaboration of the target into a de facto 1.5%-3.5% tolerance band. Sending an Open Letter is not therefore to be seen as a sign that we have 'failed', rather it is a trigger for a public explanation as to why the deviation has occurred."
8 See, for example, Bernanke et al. (1999), Mishkin (2000), Castelnuovo, Nicoletti-Altimari and Rodríguez Palenzuela (2003) and

Meyer (2004).

⁹ See, for example, Österholm (2016) for one interpretation of the debate. The advantages and disadvantages of various intervals were discussed in a Riksbank Study in September. The study was intended to form the basis of a broad and open discussion of the issue (Sveriges Riksbank, 2016b). The study also looked at alternative target variables. See also Jansson (2015). 10 For example, Bernanke et al. write (1999), p. 321: "[I]n 1995, the Bank of England switched [...] to a point target, and it has used the Inflation Report and other channels to communicate the inherent uncertainties in the control of inflation to the public, rather than leaving those uncertainties to be inferred from the target range." For an example of uncertainty bands, see Figure 1:3 in the Monetary Policy Report, September 2016. This interval is intended to show the probability of various outcomes over various forecast horizons, and is based on the Riksbank's historical forecasting errors.

the inflation target. In that (hypothetical) case, a tolerance band could facilitate the central bank's communication and contribute to confidence in the point target.

But there is also a downside. If the aim of the tolerance interval is unclear, it might be interpreted as a target range and thereby create more uncertainty regarding the inflation target, see section 2.2.

Furthermore, when inflation falls outside the interval, it may be perceived as much more alarming and a serious failure of policy. The negative effect on confidence may be greater than without the interval.¹¹ This could, in turn, lead to a non-linear monetary policy reaction pattern where the central bank reacts relatively weakly to a shock causing inflation to stay just inside the interval, but strongly to a marginally greater shock causing inflation to move to just outside the interval. The result could be a stop-go policy that increases uncertainty and contributes to greater macroeconomic fluctuations.¹²

It is important that the interval (tolerance band) is well-adapted

It is of course important that a tolerance band is well-adapted. Inflation should be within the band most of the time, but it should not be so wide that inflation always will lie within it. Neither should it be too narrow. The tolerance band around the Riksbank's inflation target until 2010 was not well-adapted. When that band – which was specified as ±1 percentage point around 2 per cent CPI inflation – was removed, inflation had been outside the band just as often as it had been inside. The memorandum published when the band was removed noted the following: "There is considerable understanding for the fact that inflation commonly deviates from the target and that the deviations are sometimes larger than 1 percentage point. Inflation can thus be outside of the tolerance band without threatening the credibility of the inflation target. Such deviations have proved to be a natural part of monetary policy."¹³ Thus, at this time the Riksbank assessed that a point target was sufficient and that the tolerance band was superfluous.

2.2 Intervals that show which levels of inflation the central bank can target

Another argument that was raised was that an interval could allow monetary policy to take more account of factors such as resource utilisation, which is to say monetary policy could be more flexible with an interval than without.¹⁴ Another argument for flexibility has (re) emerged in the discussion after the financial crisis, namely the argument that monetary policy should counteract the accumulation of financial imbalances.¹⁵ People arguing that an interval will increase flexibility may have a target range in mind. With a target range the central bank can choose to aim for different inflation levels at different times. Alternatively, they may be thinking of a tolerance band that opens for longer periods of deviations from target.

However, it is not clear exactly why flexibility would increase with an interval. An intuitive interpretation is that the central bank would not need to bring inflation back as rapidly to a given point target. In other words, the central bank – according to this way of thinking – would not have to be so much of an "inflation nutter", as the previous Governor of the Bank of England, Mervyn King, has put it. If monetary policy is strictly aimed at minimising target deviations in all situations, the real economy will vary more. In this sense, monetary policy may become more flexible with an interval. We will discuss this argument later in the article.

¹¹ Bernanke et al. (1999) state, for example, that "the damage to credibility of missing a target range entirely is greater than that of missing a target point" (p. 32).

¹² See, for example, Mishkin (2008).

¹³ Sveriges Riksbank (2010).

¹⁴ See, for example, Bernanke et al. (1999) and Castelnuovo, Nicoletti-Altimari and Rodríguez Palenzuela (2003).

¹⁵ See, for example, Banerjee, Cecchetti and Hofmann (2013) and Blanchard, Dell'Ariccia and Mauro (2013).

Another argument for a target range is that the 'optimal' inflation rate varies over time, and that there therefore is reason to aim at different levels of inflation at different times. An example referred to in the international debate ten to fifteen years ago was that structural factors could raise the real equilibrium interest rate.¹⁶ The cost of permanently low inflation would then be lower as the risk of reaching the lower bound for the nominal interest would be lower. When the advantages and disadvantages are weighed up, it could be optimal to permanently aim at a lower inflation level than before.

The situation today is of course the opposite. The real equilibrium interest rate is unusually low and the risk of reaching the lower bound for the interest rate is high. The implication is then that the central bank should aim for the upper part of a target range.

But if the motivation for a target range is to be able to adjust for changes in the optimal rate of inflation, it seems more reasonable to discuss and evaluate the appropriate level of a point target. After inflation targeting was introduced at the start of the 1990s, inflation of around 2 per cent became more or less a standard inflation target in industrialised countries. This worked well for a long time. It was not until recent years that this level came under question to any great extent. Due to the reasons we mention above, many debaters have now advocated raising the central banks' inflation target to 3 or 4 per cent.¹⁷

It is more difficult to anchor expectations with a target range

A central bank that utilises a target range to occasionally change the point target may experience detrimental movements in inflation expectations. It is more difficult to anchor inflation expectations with a target range than with a point target.¹⁸ A specific figure is easier to communicate, easier to remember, and forms a more precise benchmark for price and wage formation; it forms a firmer nominal anchor. When inflation expectations vary more, wage growth will also vary more. That will in turn lead to larger variations in inflation, and so on. This is a common and central argument against a target range.

If inflation expectations are poorly anchored, real economic stabilisation becomes difficult and there will be larger fluctuations in economic activity. To see why, suppose that a negative demand shock causes inflation to fall to the bottom of the target range. If that causes inflation expectations to fall, the real interest rate increases. The higher real rate reinforces the original shock and weakens the economy further, as it is the real interest rate that affects companies and households' investment and consumption decisions. In a corresponding way, a positive shock to demand can make inflation and inflation expectations rise towards the upper bound of the interval. This lowers the real interest rate and contributes towards further increasing demand. Thus, the result of weaker anchoring of inflation expectations is larger economic fluctuations.

The argument can be illustrated using Figure 2.

¹⁶ See Castelnuovo, Nicoletti-Altimari and Rodríguez Palenzuela (2003).

See, for example, Ball (2014), Krugman (2014) and De Grauwe and Ji (2016). In the latest review of the monetary policy framework which the Bank of Canada publishes every five years, for example, an increase in the target was one of the areas examined. However, its conclusion was to maintain the target of 2 per cent. See Bank of Canada (2016).
 See, for example, Svensson (2001).



The curves in the diagram are called Taylor curves and illustrate the alternatives facing a central bank that trades off stabilising inflation against stabilising the real economy.¹⁹ If the central bank prioritises stabilising the real economy relatively more than inflation it will choose an alternative on the lower right of the Taylor curve, for instance point B. That alternative entails relatively little variation in the real economy (or output). A central bank that prioritises stabilising inflation relative to output will chose an alternative on the upper left of the curve, for instance point A where the real economy varies more and inflation less. The lower solid Taylor curve shows the alternatives that are available when inflation is well anchored at one point – the "efficient frontier". Points to the left of the efficient frontier, with lower variation in inflation and the real economy, are not attainable.

As we explained above, economic stabilisation becomes more difficult and economic fluctuations increase when inflation expectations are not anchored at one point, but vary across an interval. This is illustrated in Figure 2, where the Taylor curve that applies if the central bank has a target interval, the dotted line, lies to the right of the efficient Taylor curve that applies with a credible point target.

Figure 2 also illustrates that monetary policy can be flexible and stabilise inflation *and* the real economy without a target range. Given that the point target is credible, the central bank can choose any point on the effective Taylor curve, for example point B.²⁰ There is nothing to be gained by introducing a target range as the corresponding Taylor curve lies above the efficient frontier. For every given variation in the real economy, the variation in inflation will be greater with a target range than with a point target (compare points A and C).

It is of course difficult to say how much the Taylor curves would differ in practice. Inflation expectations may very well be reasonably well-anchored even with the target ranges that central banks commonly use today (1-2 percentage points). With such a narrow target range there is not much room for targeting different levels of inflation at different times. Narrow ranges may therefore in fact correspond closely to point targets.

There are very few empirical studies that compare how well central banks with a point target anchor long-term inflation expectations relative to central banks with a target range. The few studies that exist indicate that there is not any major difference between the two.²¹ One explanation could be that central banks in countries with formal target ranges in practice tend to aim at the midpoint of the interval and, in that sense, act as if they had a point target.²²

The Taylor curve is named after the US economist John Taylor, who first drew attention to this connection (see Taylor, 1979).
 However, not even with a point target is it possible to go arbitrarily far to the right. The more the participants in the economy believe that the central bank only cares about stabilising the real economy and ignores inflation, the looser the nominal anchor becomes.

²¹ See Castelnuovo, Nicoletti-Altimari and Rodríguez Palenzuela (2003).

²² Svensson (2010) argues that the differences between different types of inflation target "does not seem to matter in practice. A central bank with a target range seems to aim for the middle of the range".

Analysts who weigh the arguments mostly conclude that a point target is preferable to a target range.²³ We may also note that in the real world point targets (with or without tolerance bands) are significantly more common than target ranges.²⁴

3 There are few formal studies of intervals

Most of what is written about tolerance bands and target ranges is based on intuitive arguments and anecdotal evidence. There are very few formal theoretical and empirical studies. In Appendix 2, we review some of the theoretical studies.

Although few, the formal studies provide some important insights. One is that the central bank will have an incentive to react to changes in inflation even when it is inside the interval. Thus, it does not necessarily remain completely passive until inflation moves outside the interval. The reason is that there is uncertainty. The larger the uncertainty, the larger is the risk that inflation will move outside the interval. The central bank can reduce this risk by keeping inflation close to the middle of the interval.

Another insight is that it matters whether the interval has 'hard' or 'soft' edges. Hard edges means that it is very costly to be outside the interval and that this cost increases sharply with the deviation. An example could be when it is considered to be particularly alarming and negative for confidence in the central bank if inflation strays outside a fairly broad interval. Soft edges means that the cost for moving outside the interval increases with the size of the deviation, but the increase is fairly small. If the interval has hard edges, the central bank will work significantly more actively to hold inflation close to the middle of the interval than if the interval had soft edges.

In summary, the academic literature on intervals is very limited and mainly descriptive rather than normative. It analyses what happens if there is an interval of some sort, not whether the point target *should* be surrounded or replaced by an interval. In standard monetary policy theory, there is no interval and no compelling reasons for having one.

4 The current Swedish debate

As we noted above, there is an ongoing discussion on whether the Riksbank should reintroduce some kind of interval. Some argue that an interval would facilitate the Riksbank's communication by reminding people that monetary policy cannot fine-tune inflation. Others go further and suggest that an interval could increase the choices and the flexibility of monetary policy. In particular, some seem to believe that the Riksbank could conduct a less expansionary policy today if there was an interval.

We will devote the rest of this article to the Swedish debate and review the arguments made more closely. When possible, we will refer back to what we have gone through so far.

Would an interval – a tolerance band or a target range – have opened for a different monetary policy than the one that the Riksbank has actually conducted? Will a tolerance band open for a different policy in the period ahead? To answer these questions, it is natural to start by examining the conditions under which monetary policy operates today, with a point target of 2 per cent and no interval.

4.1 Monetary policy can be flexible without an interval

The Riksbank uses forecasts for inflation and other relevant variables when it determines monetary policy. The reason is that monetary policy works with a time lag: the policy conducted today cannot affect inflation and the real economy today. Different monetary policy alternatives lead to different forecasts. The Executive Board selects the monetary

²³ For example, Bernanke et al. (1999), Meyer (2003) and Mishkin (2000, 2008).

²⁴ See Table A1 in Appendix 1.

policy alternative that gives forecasts with the best possible balance between the objectives for monetary policy. The approach is described as follows:

"In connection with every monetary policy decision, the Executive Board makes an assessment of the repo-rate path needed, and any potential supplementary measures necessary, for monetary policy to be well-balanced. It is thus normally a question of finding an appropriate balance between stabilising inflation around the inflation target and stabilising the real economy." (Sveriges Riksbank, 2016a, p. 2)

This means that normally there are many alternatives even if there is no interval. The Riksbank can choose to place great emphasis on bringing inflation back to the inflation target quickly or it can be more flexible and allow it to take a little longer. Allowing it to take a little longer may, for example, be justified if a rapid tightening aimed at bringing inflation quickly to target is considered to seriously weaken the real economy.

Figure 3 shows some of the alternatives the Riksbank had in July 2014. The Riksbank then chose the dark blue main scenario. The policy rate was not cut as much as in the scenario that would bring inflation back to target faster ("lower interest rate"). The Riksbank justified its choice by arguing that the low level of interest rates had already contributed towards households' debts as a proportion of their incomes increasing relatively quickly: "An even lower repo rate will strengthen this tendency, thus increasing the risk of the economy developing in an unsustainable way in the long run." (Press release no. 14, 2014)



Sources: Statistics Sweden and the Riksbank

4.2 ... but confidence in the inflation target must not be undermined

However, the existence of alternatives does not mean that the Riksbank can choose *any* monetary policy. One condition that has to hold is that the selected monetary policy does not risk undermining confidence in the inflation target. This usually means that monetary policy must not make economic agents stop expecting that inflation will reach the point target. The central bank can therefore only choose a monetary policy that brings inflation back to the point target. It cannot choose an alternative where inflation and inflation expectations will be stabilised at a lower (or higher) level, or where it rise or fall according to some trend.

Which alternatives are available is, of course, a question of judgement. It is not something that simply follows from a model or calculations. The key question is how long inflation can deviate from the inflation target without undermining confidence in the point target. If this period is judged to be brief, there are few policy alternatives. In this case, the central bank must try to quickly bring inflation back on target. If the period is judged to be long, there are more alternatives and the central bank can allow it to take longer before inflation is brought back to target. We will return to the Riksbank's more recent assessments below.

4.3 A fixed horizon can limit flexibility

The number of policy alternatives may be limited if there is a fixed and explicit horizon within which inflation shall return to the point target. For example, with a fixed horizon of two years it would not be possible to select the alternative with a higher interest rate in Figure 3, where it takes more than two years for inflation to reach the target.

One way to mitigate the effect of a fixed horizon and increase the number of alternatives could be to introduce a tolerance band. The band would show which level of inflation would be acceptable at the fixed horizon. As long as inflation reaches the target later on, it would only have to be within the interval at the horizon.

But a combination of a fixed time horizon and a tolerance band appears to be unnecessarily complicated. A simpler way to eliminate the problems of the fixed horizon would be to remove the fixed horizon.

The Riksbank has reasoned as follows regarding the horizon:

"There is no general answer to the question of how quickly the Riksbank aims to bring the inflation rate back to 2 per cent if it deviates from the target. A rapid return may in some situations have undesirable effects on production and employment, while a slow return may have a negative effect on confidence in the inflation target. The Riksbank's ambition has generally been to adjust monetary policy so that inflation is expected to be fairly close to the target in two years' time." (Sveriges Riksbank 2016a, p. 2.)

The wording "generally" and "fairly close to the target" shows that the two-year horizon is not considered to be fixed.

One circumstance that could potentially complicate matters is that central banks, including the Riksbank, only publish forecasts for two to three years ahead. If it is considered problematic to publish inflation forecasts that do not reach the point target within the forecast horizon, this may limit the available alternatives. It seems that the solution to this problem would be to publish forecasts that stretch further ahead in time.

However, here it may be relevant to mention that Norges Bank on several occasions has published forecasts that do not reach the target within their three-year forecast horizons. As far as we know, this has not damaged confidence in the inflation target in Norway, nor created any other problems. Figure 4 shows Norges Bank's inflation forecast in the Monetary Policy Report no. 2, 2016.²⁵ Three years ahead, the inflation forecast falls below target by about 0.75 percentage points. This does not seem to have significantly impacted confidence in the inflation target. Inflation expectations five years ahead lay at 2.45 per cent at this point, which is only marginally below the target of 2.5 per cent.



Source: Monetary Policy Report with financial stability assessment 2/16

In the rest of this article we assume that there is no fixed horizon for when inflation is supposed to reach the point target. The only condition is that monetary policy should not risk undermining confidence in the inflation target.

5 Does a tolerance band increase monetary policy's room for manoeuvre?

We can use Figure 5 as a starting point when we analyse whether the central bank will have more alternatives to choose from – its room for manoeuvre will increase – with a tolerance band.



Note. The horizontal axis shows the number of quarters. The paths are fictitious examples produced by changing the parameters of the monetary policy rule in an otherwise identical quantified new-Keynesian model.

In the diagram, we have drawn four hypothetical inflation paths and a tolerance band of +/-1 percentage point around the point target of 2 per cent. In three of the paths, paths *a*, *b* and *c*, inflation stabilises at the inflation target, but at different horizons. In path *d*, inflation stabilises at 1 per cent, that is, at the lower limit of the tolerance band.

Alternatives *a*, *b* and *c* can be chosen regardless of whether the central bank has a tolerance band or not. However, alternative *d* cannot be chosen when the central bank has a point target of 2 per cent. This illustrates that the central bank would not automatically have more alternatives if a tolerance band were to be introduced. All monetary policy alternatives that bring inflation back to the point target can be chosen both with and without a tolerance

band. No monetary policy alternative that does not bring inflation back to the point target can be selected as long as the central bank has a point target, regardless of whether there is a tolerance band or not.

5.1 A tolerance band can increase the room for manoeuvre if it increases confidence in the point target

As we discussed above, it has been argued that deviations from a point target could be seen as less serious if there is a tolerance band than if there is only a point target. If this is the case, it may imply that there are more monetary policy alternatives to choose from if there is a tolerance band than if there is not. We can illustrate this in Figure 5. Assume that with no tolerance band, confidence in the inflation target risks being undermined if inflation deviates from the *point target* for more than one year. Assume too that, with a point target and a tolerance band, confidence in the inflation target risks being undermined if inflation deviates from the *tolerance band* for more than one year. In this case, only alternative *a* could be chosen with a point target and no interval, while alternatives *a*, *b* and *c* could be chosen if the point target was surrounded by a tolerance band. In this example, a tolerance band would provide greater room for manoeuvre for monetary policy.

5.2 ... but can also reduce the room for manoeuvre if it has 'hard edges'

However, we can also construct examples where there would be *fewer* alternatives to choose from with a tolerance band. Assume that the tolerance band has 'hard edges', which is to say that the central bank sees it as very costly if inflation moves outside the interval (as we discussed above).²⁶ Assume too that a central bank with a tolerance band with hard edges in practice will choose the monetary policy alternative that most quickly takes inflation back to the interval. In Figure 5, this would mean that alternative *b* would be the only real alternative. Thus, in this example the tolerance band would give fewer alternatives to choose from (if alternative *b* and at least one of alternatives *a* or *c* would be feasible without a tolerance band).

As we noted above, a tolerance band with hard edges could also affect which alternatives could be selected when inflation is *inside* the tolerance band. The reason is that the risk of moving outside the interval is greater if inflation is close to the edge of the interval than if it is closer to the point target. The central bank would therefore be keener on getting inflation back to the point target quickly when there is a tolerance band with hard edges than if there is no interval.²⁷

Considering the review in this section, we can draw the following conclusions:

Monetary policy can be flexible even without a tolerance band. Only if the tolerance band strengthens the confidence in the point target can a tolerance band increase monetary policy's room for manoeuvre. If the tolerance band creates more uncertainty regarding future inflation or has 'hard edges', the room for manoeuvre may instead decrease.

A tolerance band does not *per se* increase the room for manoevre for monetary policy. Thus, it is not obvious that monetary policy would have been different in recent years if there had been a tolerance band, or that it will become different if a tolerance band is introduced. But neither can it be ruled out. Thus, if one argues that a tolerance band would indeed increase the scope for flexibility, as some debaters seem to do, one has to be prepared to explain exactly why one thinks this would be the case.

²⁶ See also the reasoning in Appendix 2 and Figure A2.

²⁷ Bernanke et al. (1999), Mishkin and Schmidt-Hebbel (2002) and Mishkin (2003) argue that the tolerance band's edges may start to "live a life of their own" and become harder than intended. Monetary policy may then become suboptimal in the way we describe here. As we have noted in Appendix 2, Medina and Valdés (2002) show how an interval with hard edges can give such effects.

6 A target range is a bigger change

With a target range, the central bank can choose any policy alternative that keeps inflation within the range. If we assume that the interval of +/- 1 percentage points in Figure 5 constitutes a target range, all alternatives in the figure – including d – can be chosen.

Introducing a target range would be a significantly bigger step than introducing a tolerance band, and the consequences could be much more sweeping.

It is not entirely clear whether any debater has actually advocated that the Riksbank should have a target range. However, it has often been suggested that monetary policy should target a rate of inflation lower than 2 per cent. The argument has been that factors such as globalisation and digitisation have made it very difficult, if not impossible, to bring inflation up to 2 per cent.²⁸

A reasonable interpretation of this is that people argue for greater freedom of choice, such that the inflation target can be adjusted to different circumstances. As we noted above, one justification for a target range in the earlier international debate was that there may be reason to aim at different levels of inflation in different periods. Alternatively, people argue that the *point target* of 2 per cent should be lowered. However, the consequences of lowering the point target or introducing a target range and aiming at the lower part of the interval are similar in a number of important ways.

From a short-term perspective, it might be reasonable to think that the Riksbank could conduct a less expansionary policy if it were to target a lower inflation rate, either under the framework of a target range or by lowering the inflation target.²⁹ However, this would only be temporary. When expectations adjust, monetary policy will be the same even if the inflation target is lowered from 2 or 1 per cent. It is the real interest rate that matters, and this rate will eventually be the same on average because inflation and nominal interest rates will both become proportionally lower when the target is lower.

Furthermore, if the problem is that monetary policy is too expansionary at the moment – that is to say a basically short-term problem – it seems fairly drastic to undertake such a large change as introducing a target range or lowering the target. For reasons of continuity and credibility the monetary policy framework should not be amended all too often and we would probably have to live with such a change for a long time.

6.1 Targeting lower inflation may reduce the future room for manoeuvre

Problems could arise in the long run if the Riksbank were to aim for lower inflation, and inflation expectations permanently became 1 per cent, for example. The main problem is that it becomes more difficult to stimulate the economy in the future when economic activity is weak or inflation is below target. When inflation is low on average, the average policy rate is also low. This reduces scope for cutting the policy rate, as it will hit its lower bound more frequently. When average inflation is low, it is therefore more difficult to achieve the really low or even negative real interest rates that are sometimes needed.

Therefore, if low nominal interest rates in general are a source of concern, it would be better to increase average inflation. This is the reason why people in the international debate have proposed that the central banks' inflation targets should be raised.

²⁸ See, for example, Mitelman (2013).

²⁹ However, it is not self-evident that this means that the nominal interest rate can be raised. If inflation expectations fall, the real interest rate will rise and monetary policy will thereby become less expansionary even with an unchanged nominal policy rate.

6.2 If inflation varies more, expectations may be more difficult to anchor

One specific problem regarding a target range is, as we explained above, that it may make it more difficult to anchor expectations. This is quite natural if the target range is indeed utilised as a target range, that is, if the central bank actually aims at different levels of inflation at different times. This would be like having the central bank change the point target every now and then. Most analysts argue that the mere point of having an inflation target is that, once a level has been decided, this level is maintained so that it can act as a stable and credible benchmark for price and wage formation.

Poorly-anchored inflation expectations may make it difficult for monetary policy to stabilise the real economy. Instead, fluctuations risk becoming larger in the way we have described above.

A number of complications are thus inherent in a target range. It would be a big change in the monetary policy framework and it risks making inflation and inflation expectations stick at a low level. That may in turn make it more difficult to conduct a sufficiently expansionary monetary policy later on. In the long run, a target range could make inflation expectations overall less firmly anchored and the fluctuations in the economy larger. Thus, people that argue for a target range should provide support for why the (supposed) advantages should more than balance out the disadvantages.

7 If monetary policy can be flexible without an interval – why such an expansionary policy today?

If monetary policy can be flexible and take the real economy and financial stability concerns into account, why is it then that the Riksbank has pursued what many consider a very expansionary policy?

The Riksbank has justified its policy by arguing that inflation had undershot the target so long that there was a risk that the economic agents would start to doubt whether the Riksbank had the ambition and capacity to actually meet the inflation target. The inflation target that has been the nominal anchor for economic agents for more than twenty years could loosen. The Riksbank therefore gradually saw it as more and more important to get inflation to rise towards the target.

Figure 6 illustrates that these concerns were justified. From 2010 until the start of 2014, long-term inflation expectations (measured as the median value among money market participants) were firmly anchored at 2 per cent. But in 2014, expectations started to fall. Actual inflation, measured as both the CPI and the CPIF, had then long been below target and showed no sign of rising. The Riksbank deemed that a more expansionary monetary policy was needed to bring up inflation. This reasoning has characterised monetary policy over the last years. Both actual inflation and inflation expectations have risen, but it is still seems an open question whether they are again anchored at the target.



One argument that has been made against the recent monetary policy of the Riksbank and for the introduction of a tolerance band, is that the Riksbank has been altogether too strongly tied to the point target of 2 per cent as such. If an interval had been present, it is argued, the Riksbank could have chosen a higher interest rate path and would not have had to bring inflation back to the point target so quickly.³⁰

But this is not an accurate description of the motives behind the Riksbank's actions. The expansionary policy has been based on the assessment that confidence in the inflation target was becoming undermined, not on a short-term desire to meet the inflation target under any circumstances and at any price.³¹

At the same time, as we have noted above, it is a question of judgement as to how large room for manoeuvre there actually is in any given situation. It cannot be ruled out that the Riksbank has underestimated the confidence in the inflation target and hence also its room for manoeuvre. Debaters that think this is the case should of course focus on presenting arguments that support this view.

8 Conclusion

Inflation targets can be designed in different ways. Internationally it is common to have point targets, with or without a tolerance band. But there are also examples where the inflation target is formulated in terms of an interval, a 'target range'. The Riksbank's inflation target is defined solely as a point target. Before 2010 the Riksbank's point target was also surrounded by a tolerance band. Recently, it has been argued that the Riksbank should (re)introduce some sort of interval.

Ten to fifteen years ago, there was an international debate on the advantages and disadvantages of having an interval. In this article, we have reviewed the arguments in this debate and interpreted the current Swedish discussion in the light of them. One central conclusion is that monetary policy can be flexible even without an interval. A tolerance band might increase flexibility if it increases the credibility of the inflation target. However, it could also reduce flexibility if it increases inflation uncertainty or if moving outside the interval is very costly. A target range entails a major change to the current monetary policy framework. It would allow the central bank to aim at different levels for inflation. But as inflation expectations become less firmly anchored, economic fluctuations may increase.

³⁰ See, for example, Jonung (2015), who also argues that the interval should be broader than the one removed in 2010, amounting to +/-2 percentage points.

³¹ See, for example, Flodén (2015).

References

Banerjee, Ryan, Stephen Cecchetti and Boris Hofmann (1993), "Flexible Inflation Targeting: Performance and Challenges", in "Is Inflation Targeting Dead? Central Banking After the Crisis", Edited by Lucrezia Reichlin and Richard Baldwin, Centre for Economic Policy Research.

Bernanke, Ben S., Thomas Laubach, Frederic S. Mishkin and Adam S. Posen (1999), Inflation Targeting – Lessons from the International Experience, Princeton University Press.

Blanchard, Olivier, Giovanni Dell'Ariccia and Paolo Mauro (2013), "Rethinking Macro Policy II: Getting Granular", Staff Discussion Note 03, International Monetary Fund.

Castelnuovo, Efrem, Sergio Nicoletti-Altimari and Diego Rodríguez Palenzuela (2003), "Definition of Price Stability, Range and Point Inflation Targets: The Anchoring of Long-Term Inflation Expectations", Background Study for the Evaluation of the ECB's Monetary Policy Strategy, Working Paper No. 273, European Central Bank.

De Grauwe, Paul and Yuemei Ji (2016), "Inflation Targets and the Zero Lower Bound in a Behavioral Macroeconomic Model", Discussion Paper No. 11320, Centre for Economic Policy Research.

Flodén, Martin (2015), "Sweden Needs its Inflation Target," speech, 13 October at Fores, Stockholm.

Hammond, Gill (2012), *State of the Art of Inflation Targeting*, Handbook – No. 29, Centre for Central Banking Studies, Bank of England.

Heikensten, Lars, (1999), "The Riksbank's Inflation Target – Clarifications and Evaluation", Sveriges Riksbank Quarterly Review, No. 1.

Jansson, Per (2015), "Time to Improve the Inflation Target?", speech, 3 December at Handelsbanken: Stockholm.

Jonung, Lars (2015), "Professor varnar för låga räntan" [Professor warns of low interest rate], interview in Svenska Dagbladet by Louise Andrén Meiton, November 18th.

Krugman, P. (2014), "Inflation Targets Reconsidered," Essay presented at the ECB Sintra conference, May.

Lewis, Michelle and C. John McDermott (2016), "New Zealand's Experience with Changing its Inflation Target and the Impact on Inflation Expectations", Discussion Paper No. 07, Reserve Bank of New Zealand.

Medina, Juan Pablo and Rodrigo O. Valdés (2002), "Optimal Monetary Policy Rules under Inflation Range Targeting", in *Monetary Policy: Rules and Transmission Mechanisms*, Series on Central Banking, Analysis, and Economic Policies, vol. 4, eds. Loayza N. and K. Schmidt-Hebbel, Central Bank of Chile, pp. 95-115.

Meyer, Laurence H. (2004), "Practical Problems and Obstacles to Inflation Targeting", Federal Reserve Bank of St. Louis Review, July/August 2004, Vol. 86, No. 4, pp. 151-60.

Mishkin, Frederic S. (2000), "Issues in Inflation Targeting", in *Price Stability and the Long-Run Target for Monetary Policy*, Proceedings of a seminar held by the Bank of Canada, June 2000.

Mishkin, Frederic S. (2008), "Comfort Zones, Shmumfort Zones", speech, March 27th, The Sandridge Lecture of the Virginia Association of Economists and the H Parker Willis Lecture of Washington and Lee University, Lexington, Virginia, Board of Governors of the US Federal Reserve System.

Mishkin, Frederic S. and Klaus Schmidt-Hebbel (2002), "One Decade of Inflation Targeting in the World: What Do We Know and What Do We Need to Know?", in *Inflation Targeting: Design, Performance, Challenges*, eds. Loayza N. and R. Soto, Central Bank of Chile, pp. 117-219.

Mishkin, Frederic S. and Niklas J. Westelius (2008), "Inflation Band Targeting and Optimal Inflation Contracts", *Journal of Money Credit and Banking*, Vol. 40, No. 4, pp. 557-582.

Mitelman, H. (2013), "Dags sänka inflationsmålet [Time to reduce the inflation target]", commentary, Dagens Industri, December 4th. Orphanides, Athanasios and Volker Wieland (2000), "Inflation Zone Targeting", *European Economic Review*, Vol. 44, No. 7, pp. 1351-1387.

Rogoff, Kenneth (1985), "The Optimal Degree of Commitment to an Intermediate Monetary Target", *Quarterly Journal of Economics*, Vol. 100, No. 4, pp. 1169-1189.

Svensson, Lars E.O. (2001), "The Fed Does Not Provide the Solution to the Eurosystem's Problems", Briefing Paper for the Committee on Economic and Monetary Affairs (ECON) of the European Parliament, May.

Svensson, Lars E.O. (2010), "Inflation Targeting", Chapter 22 in *Handbook of Monetary Economics* Volume 3B, eds. Freidman, B. M. and M. Woodford, Elsevier and North-Holland: San Diego and Amsterdam.

Sveriges Riksbank (2010), "The Riksbank Removes the Tolerance Interval from its Specified Monetary Policy Target", Memorandum, Basis for Decision 31 May 2010, available at http://www.riksbank.se/Upload/Dokument_riksbank/Kat_publicerat/ Pressmeddelanden/2010/nr27_beslutsunderlag.pdf.

Sveriges Riksbank (2016a), "Monetary Policy Report, July".

Sveriges Riksbank (2016b), "The Riksbank's Inflation Target – Target Variable and Interval", *Riksbank Studies*, September.

Taylor, John B., (1979), "Estimation and Control of a Macroeconomic Model with Rational Expectations", *Econometrica*, Vol. 47, No. 5, pp. 1267-1286.

Walsh, Carl E. (1995), "Optimal Contracts for Central Bankers", American Economic Review, Vol. 85, No.1, pp. 150-167.

Österholm, Pär (2016), "Flexibelt mål kan ge problem" [Flexible target may lead to problems], SvD Debatt, September 12th.

Appendix 1 – Inflation targets in various countries

Table A1. Type of inflation target in various countries

Type of inflation target	Countries or currency areas
Point target	Albania, Argentina, Bangladesh, Belarus, China, Georgia, Iceland, India, Japan, Kyrgyzstan, Malawi, Mongolia, Mozambique, Norway, Pakistan, Russia, Samoa, South Korea, Sweden, Ukraine, United Kingdom, United States, Vietnam, Zambia
Point target with tolerance band	Armenia, Brazil, Canada, Chile, Colombia, Costa Rica, Czech Republic, Dominican Republic, Ghana, Guatemala, Hungary, Indonesia, Kenya, Mexico, Moldavia, New Zealand, Paraguay, Peru, Philippines, Poland, Romania, Serbia, Thailand, Turkey, Uganda, West African Economic and Monetary Union
Target range	Australia, Azerbaijan, Botswana, the euro area*, Israel, Jamaica, Kazakhstan, Nigeria, South Africa, Sri Lanka, Switzerland*

Note. *Inflation must be below 2 per cent (but close to 2 per cent in the euro area's case). Sources: www.centralbanknews.info and central banks' websites.

Appendix 2 – The academic literature on intervals

There are very few formal theoretical and empirical studies of tolerance bands and target ranges.

One example is Orphanides and Wieland (2000). They investigate conceivable arguments for why central banks specify the inflation target as an interval and not as a point. Among other things, they analyse a case where the central bank's loss function (a concept described in more detail below) is entirely horizontal at zero in a certain interval, which is to say that limited deviations from the middle of the interval are not considered costly.³² The loss function may then look like the broken curve in Figure A1, in which as is the horizontal interval. For comparison, the unbroken curve shows a conventional loss function.





The loss function can be described as follows. The central bank's task is, at each point in time t, to find an interest rate path $\{r_{t+\tau}\}_{\tau=0}^{\infty}$ that minimises the intertemporal loss function

(1)
$$L_t = E[\sum_{\tau=0}^{\infty} I(x_{t+\tau})]$$

where

(2)
$$l(x_t) = (\pi_t - \bar{\pi})^2 + \lambda y_t^2$$

 $l(x_t)$ is the loss function at each point in time t, π_t is inflation, $\bar{\pi}$ the inflation target and y_t the output gap or resource utilisation. Thus, the loss function is the sum of (squared) deviations, partly for inflation from the inflation target, partly for the output gap from the normal value (zero).

The solid curve in Figure A1 shows the first term in (2), which is to say the 'loss', or cost, that arises when inflation deviates from a point target.

Suppose instead that the loss function is the following:

(3)
$$I(x_t) = \begin{cases} (\pi_t - \overline{\pi}_L)^2 + \lambda y_t^2 & \text{if } \pi_t \in (-\infty, \overline{\pi}_L) \\ \lambda y_t^2 & \text{if } \pi_t \in (\overline{\pi}_L, \overline{\pi}_H) \\ (\pi_t - \overline{\pi}_L)^2 + \lambda y_t^2 & \text{if } \pi_t \in (\overline{\pi}_L, \infty) \end{cases}$$

³² Another case analysed is that in which the short-term Phillips curve is horizontal in one segment, which is to say that inflation does not react to changes in resource utilisation as long as the latter is sufficiently close to its normal level.

There is no loss if inflation is larger than $\bar{\pi}_{L}$ but smaller than $\bar{\pi}_{H}$, and the central bank can then focus on stabilising the output gap. The broken curve in Figure A1 shows a loss function as in (3), where the interval aa represents the interval between $\bar{\pi}_{L}$ and $\bar{\pi}_{H}$.

Orphanides and Wieland represents how the broken loss function implies a monetary policy reaction function with what they call a "zone of inaction" where the central bank reacts less to inflation (and more to resource utilisation). They interpret this zone as the central bank's "interval".

Among other things, they find that the size of the zone of inaction greatly depends on uncertainty, which is to say the size and frequency of shocks to the economy. The greater uncertainty, the smaller zone of inaction. The reason is that the risk that inflation will move beyond the interval aa increases when uncertainty increases. By attempting to keep inflation close to the middle of aa, the central bank can reduce this risk. So even small changes in inflation deviations from the middle of the interval cause the central bank to react. When uncertainty increases, monetary policy reacts more to inflation deviations and the zone of inaction becomes smaller.

Notice that the zone of inaction is something different to the interval aa in Figure A1, even if the latter, of course, affects the size of the former. Orphanides and Wieland's zone of inaction can be seen as the optimal monetary policy in a model where the central bank has a loss function like the broken curve. With a conventional unbroken curve there would be no zone of inaction.³³

A more natural approach is therefore to consider the interval aa in Figure A1, rather than the zone of inaction, as the central bank's "interval". The interpretation of Orphanides and Wieland's model then becomes as follows. The Government or Parliament has assigned the central bank the loss function represented by the broken line in Figure A1 with an interval aa within which inflation is expected to remain. Compared with a conventional loss function and as expected, monetary policy will not react as much when inflation deviates from the middle of the interval (except in the case where uncertainty is very high).

Medina and Valdés (2002) analyse the implications of different loss functions using a similar model, but their 'interval' refers to and is specified in terms of the central bank's loss function. They distinguish two types of target ranges: those with "hard edges" and those with "soft edges". Hard edges means that it is very costly to be outside the interval and that this cost increases sharply with the size of the deviation. An example could be that it is considered to be particularly alarming and negative for confidence in the central bank if inflation strays beyond a fairly broad interval – in the manner we have described above. Soft edges means that the cost for moving outside the interval certainly increases with the size of the deviation, but the increase is fairly small. Figure A2 shows a loss function with hard edges and one with soft edges, in which costs arise when inflation deviates from the target range, but at different rates.

³³ However, one exception concerns the second case that Orphanides and Wieland analyse using a partial horizontal short-term Phillips curve.



Medina and Valdés find that there are no zones of total inaction as regards inflation. Monetary policy must always react to shocks, even when inflation is well inside the interval.

An interval with soft edges can make monetary policy less aggressive than it would have been with a point target. More specifically, interest rate fluctuations become smaller in their model. But they also find that, if the loss function has very hard edges – that is, if deviations from the target range are considered to be highly undesirable – monetary policy can actually become more aggressive than in the case of a point target. Put differently, the central bank may, in such a case, become more of an "inflation nutter". Of course, with a point target, all deviations from target are unwanted, but, compared with the case in which a deviation from an interval is considered to be extremely costly, monetary policy nevertheless reacts less.

Mishkin and Westelius' (2008) analysis has a slightly different starting point. They start from the Barro and Gordon (1983) model where inflation becomes too high as there is a constant temptation to conduct an excessively expansionary monetary policy.

In the model, the Government wants unemployment to be below its natural equilibrium and it also places excessive emphasis on stabilising unemployment. This results in two biases: an inflation bias with excessively high inflation and a stabilisation bias that means that fluctuations in inflation are higher (and fluctuations in unemployment lower) than optimal. In the earlier literature, two solutions have been suggested to eliminate these biases. Either a central bank governor is appointed who is "conservative" in the sense that he or she prefers lower inflation and has a lower weight on fluctuations in unemployment than society in general has (Rogoff, 1985). Or a contract is prepared that entails that the central bank governor is 'punished' in various ways if inflation becomes too high and if fluctuations in inflation become large (Walsh, 1995). Both of these solutions are linked with practical problems and would be difficult to implement.

Mishkin and Westelius argue that one alternative to both of these solutions would be for the central bank to be assigned the task of holding inflation within an interval in which it is associated with some form of cost for the bank if inflation moves beyond the interval. Such an interval could solve the time inconsistency problem in a simpler way than appointing a "conservative" central bank governor or preparing a contract with the management of the central bank.³⁴

³⁴ It is worth noting that, even if Mishkin and Westelius call their interval 'band target' or 'target range', it seems to differ from the definition of target range we use in this article. For example, in their analysis, it is the outcome of inflation outside the interval that triggers sanctions. In this sense, the interval instead corresponds to what we have called a tolerance band. Mishkin and Westelius also take up the Bank of England as an example. As we have noted above, the Bank of England has a point target of 2 per cent and it could be argued that it also has a tolerance band of ±1 percentage point. However, the Bank of England's target is not categorised as a target range.

Studies that attempt to draw normative conclusions by comparing the development in different countries with different targets are even rarer. In the main text, we mention Castelnuovo, Nicoletti-Altimari and Rodríguez Palenzuela (2003). They study how well central banks with a point target or target range, respectively, manage to anchor long-term inflation expectations. They find no major difference between the types of inflation target in this respect.

How can term structure models be used by central banks?

Rafael B. De Rezende*

The author works in the Monetary Policy Department of the Riksbank

Abstract

This article provides an overview of recent developments in term structure modeling and its uses by central banks. The topic is important to central banks and policymakers, who are often interested in extracting economic information from long-term interest rates, and elaborating policies to influence them. I review some of the term structure models that allow for time-varying risk premia and that have served as the workhorse models in the analysis of the term structure of interest rates by central banks. These models have been used to measure policy rate expectations, to study the interest rate transmission mechanisms of unconventional monetary policies, to estimate inflation and liquidity risk premia in real government bond markets and to obtain useful policy indicators in an interest rate lower bound environment, such as the shadow rate.

1 Introduction

The term structure of interest rates is the relationship between the interest rates, or yields, on bonds of different maturities that are traded at each point in time. As it describes investors' choices on bonds and interest rates across maturities, the term structure thus carries information about market participants' expectations of future short-term interest rates and future economic conditions, as well as their willingness to bear interest rate risk.

Policymakers are often interested in term structure analysis as they wish to extract economic information from long-term interest rates, and elaborate policies to influence them (see Woodford 1999). The aim of this article is thus to provide an overview of recent developments in term structure modeling and its uses by central banks.

The simplest approach for term structure modeling is the one designed for its estimation. Because available data provide us with an incomplete set of points relating interest rates to maturities, the estimation of term structure curves is often desirable, providing central banks with a continuous set of interest rates that can be used for various purposes.

One important aspect of the standard approaches of term structure modeling, however, is that they are consistent with the expectations hypothesis, which asserts that long-term interest rates are formed from investors' expectations of future short-term interest rates. However, economic theory predicts that investors are typically risk-averse, implying that long-term interest rates may also be driven by the interest rate compensation that investors demand for buying and holding an *n*-year bond until maturity rather than rolling over a short-term interest rate (see Friedman and Savage 1948, Cochrane 2001), a measure that is often called the term premium. I discuss this phenomenon using term structure models that allow for time-varying term premia and discuss why these models are better at capturing many aspects of interest rates that are puzzling from the perspective of the expectations hypothesis.

^{*} I would like to thank Jan Alsterlind, Ulf Söderström, Claes Berg, Ola Melander, David Vestin and David Kjellberg for comments and suggestions. All remaining errors are my own. The opinions expressed in this article are the sole responsibility of the author(s) and should not be interpreted as reflecting the official views of Sveriges Riksbank.

Although the quest for more robust estimates of time-varying term premia is still ongoing, several studies have used term structure models to investigate the transmission mechanisms of bond purchases to interest rates.¹ By analyzing the recent experience of unconventional monetary policy in Sweden, I also discuss how government bond purchases have affected interest rates, by measuring their impacts on short-rate expectations and term premia.

Policymakers are also often interested in measuring market participants' inflation expectations. As markets for inflation-linked securities have grown in recent years, the interest rates on these instruments, in combination with those on nominal government bonds, have become an important source of information on investors' inflation expectations.² However, these rates also include inflation and liquidity risk premia that compensate investors for the risk of facing higher inflation rates than they previously expected and for the risk of holding an instrument with low market liquidity. I also review some of the term structure models that have been used to estimate time-varying inflation and liquidity risk premia, in an attempt to obtain a "cleaner" measure of inflation expectations embedded in government bond interest rates.

Finally, in a world where policy interest rates have reached record lows, I also discuss term structure models that have been recently proposed to deal with a situation where the policy interest rate reaches its lower bound (see Wu and Xia, 2016, Bauer and Rudebusch, 2016, among others). Besides allowing for more reasonable estimates of short-rate expectations, these term structure models also allow for the estimation of other informative indicators such as the time to the expected interest rate liftoff, the expected pace of monetary policy tightening and the policy rate that would prevail if the interest rate lower bound did not exist.

The remainder of this article is organized as follows. The next section describes the formation of interest rates in a market economy and the transmission mechanisms of monetary policy to these interest rates. The third section introduces some existing term structure models and describes some of their uses by central banks. The fourth section concludes.

2 The formation of interest rates and the transmission of monetary policy

2.1 Interest rates: basic concepts

The most basic interest rate in fixed income analysis is the interest rate on the default-riskfree zero coupon bond. This security gives the holder SEK 1 at maturity and is priced at discount at time *t*, with no risk of default. More specifically, letting P_t^n denote the price of an *n*-maturity zero-coupon bond at time *t*, bond prices are obtained according to the following,

(1)
$$P_t^n = exp(-ny_t^n),$$

where y_t^n is the annualized continuously compounded nominal yield on this bond, i.e. the return the investor will receive at maturity. Similarly, one can solve (1) for y_t^n to obtain

(2)
$$y_t^n = -\frac{1}{n} \ln (P_t^n).$$

¹ A number of term structure models have been used for this purpose (see Vayanos and Vila 2009, Christensen and Rudebusch 2012, Greenwood and Vila 2014, Bauer and Rudebusch 2014, among others). This article is focused on the use of no-arbitrage affine term structure models (see Duffie 2001, Singleton 2006 and Piazzesi 2010 for a comprehensive review).

² As explained later, this is often called the "break-even inflation", i.e. the rate of inflation that would give an investor the same return at maturity on a nominal and a real bond.

The term structure of interest rates, or yield curve, is then a function that maps interest rates and bond prices into maturities at a given point in time. Although the average yield curve is often found to be positively sloped and slightly concave, its shape varies over time, carrying useful information about investors' expectations of the future state of the economy.

Alternatively, one can characterize the term structure of interest rates in terms of forward rates, which is the interest rate the investor would require today to invest in a bond over a period in the future.³ In that case, the return the investor would receive on that investment is the *n*- to *m*-maturity forward rate, which is given by

(3)
$$f_t^{n,m} = \frac{1}{m-n} \left(m \times y_t^m - n \times y_t^n \right).$$

As the limit of the maturity difference m - n goes to zero, $\lim_{m \to n} f_t^{n,m}$, one can then obtain the *n*-maturity instantaneous forward rate, f_t^n , which is the interest rate required today to invest in a bond with the shortest possible maturity at a future point in time, *n*.

One can then construct the relationship between bond yields and forward rates as the following,

(4)
$$y_t^n = \frac{1}{n} \int_0^n f_t^i \, di,$$

which simply states that a zero-coupon bond yield is equal to the average of instantaneous forward rates over the lifetime of the bond.

As will be explained later, because short-term interest rates tend to follow very closely the interest rate set by the central bank, from a central bank perspective, forward rates are useful because they allow for a better understanding of the movements in longerterm interest rates caused by factors other than the current policy rate, such as policy rate expectations.

2.2 The expectations hypothesis and the transmission of monetary policy to interest rates

In its strong form, the expectations hypothesis is a proposition that states that investors price bonds as if they were risk-neutral, meaning that they do not care about the level of uncertainty in a long-term investment. This means that long-term bond interest rates are determined by current and future expected short-term interest rates, in such a way that the return on the investment in a long-term bond is the same as the expected return obtained from rolling a short-term interest rate over the lifetime of the same bond.

This hypothesis assumes that the various maturities are perfect substitutes, and suggests that the expectations of future short-term interest rates is the only factor needed to construct a complete term structure, determining its shape at each point in time.⁴ However, economic theory predicts that investors have some degree of risk-aversion and are typically concerned about the risk that short-term interest rates do not evolve as expected over the lifetime of the bond. This implies the existence of a gap between long-term interest rates and the average of expected short-term rates. This gap is often called the term premium and serves as a measure of the compensation that investors demand for buying and holding a long-term zero-coupon bond until maturity rather than rolling over a short-term interest rate.

³ The forward rate is the interest rate that makes a risk-neutral investor indifferent to buying and holding a longer-maturity bond until maturity or buying and rolling over a shorter-maturity bond. For instance, an investor can buy a two-year bond and hold it for two years, or he can buy a one-year bond, and then at the end of the first year, buy another one-year bond. Under these two scenarios, the investor knows the interest rates for both the two-year bond and the first one-year bond, but he does not know the actual interest rate for the second one-year bond, because it is an interest rate in the future. In this case, the forward rate is the predicted interest rate on the second one-year bond, which would give the investor the same return under either investment strategy.

⁴ As is customary in the literature, I am disregarding here the Jensen's inequality term, which is modest at maturities up to ten years when volatility is low.

Empirically, the expectations hypothesis has failed to fully explain the behavior of interest rates. Several seminal studies including Fama (1984), Fama and Bliss (1987), Campbell and Shiller (1991), Stambaugh (1988), Cochrane and Piazzesi (2005), among others, have uncovered evidence of non-zero and time-varying risk premia in bond markets, thus violating the expectations hypothesis. Indeed, if the expectations hypothesis was sufficient to explain the term structure, then long-horizon short-rate expectations would typically converge to its steady state.⁵ However, the fact that long-term yields and forward rates are highly time-varying is at odds with the expectations hypothesis implying that these may also be driven by time-varying term premia (see Figure 1 for a comparison between long-term yields, forward rates and survey expectations). This has led financial economists to reformulate the determination of interest rates, with equation (4) being rewritten as,

(5)
$$y_t^n = \frac{1}{n} E_t \left(\int_0^n r_{t+1} \, di \right) + t p_t^n,$$

where r_t is the short-term interest rate, E_t (×) is an expectation operator and tp_t^n is the corresponding term premium. It is interesting to note that if the expectations hypothesis is valid, we then have that $f_t^n = E_t$ (r_{t+n}), that is, the *n*-maturity instantaneous forward rate is the expectation of the short-term rate at time t + n, measured at time t.

Notice from (5) that bond yields are directly affected by movements in the short-term interest rate and its expectations. This implies that conventional monetary policy has a direct impact on the term structure of interest rates. In Sweden, the Riksbank implements conventional monetary policy by setting the repo rate and by steering the overnight rate towards this rate through short-term market operations, such as daily fine-tuning transactions and weekly issues of Riksbank certificates.





Although changes in the repo rate primarily affect interest rates in the interbank market, government bonds of different maturities are also directly impacted. A cut in the repo rate by the Riksbank commonly leads to a fall in repo rate expectations, which in turn tends to move longer-maturity market rates in the same direction. The Riksbank can also influence repo rate expectations directly by communicating its future monetary policy intentions or by providing forward guidance more directly through its repo rate path, i.e. the Riksbank's own

⁵ The short-rate steady state may be constant or time-varying, depending on one's underlying (model) assumptions.

repo rate forecasts. Since February 2015, the Riksbank has also purchased nominal and real government bonds of different maturities in the secondary market as a means of lowering longer-maturity interest rates in the economy and providing further monetary stimulus. This unconventional monetary policy is expected to operate by lowering expectations of future repo rates as well as by lowering term premia across maturities, which arises from the reduction in the available supply of the assets purchased.

Changes in the interbank and government bond interest rates for different maturities then tend to impact other borrowing rates for banks, such as interest rates on deposit bank accounts and bonds of mortgage institutions. Changes in banks' borrowing rates in turn affect their lending rates to households and firms, as well as interest rates on corporate debt securities such as commercial paper and corporate bonds.

One can then augment (5) to describe the different interest rates in the economy through the following,

(6)
$$\tilde{y}_t^n = \frac{1}{n} E_t \left(\int_0^n r_{t+i^*} di \right) + t p_t^n + x_t^n,$$

where x_t^n is anything beyond short-rate expectations and term premia that may affect \tilde{y}_t^n such as credit risk, liquidity risk, banks' profit margins or banks' funding costs. Swedish government bond interest rates are typically free of default and credit risk and are then determined by repo rate expectations and term premium only.⁶ The other interest rates in the economy typically embed some liquidity and credit risks.

3 The uses of term structure models by central banks

Term structure models are important tools that central banks use to describe and better understand the behavior of interest rates. In this section, I describe the various uses of term structure models by central banks. These range from simple curve fitting techniques to models that deal with more complex issues such as the decomposition of interest rates into short-rate expectations and their various premiums.

3.1 Term structure estimation

Term structure estimation is a benchmark in the analyses of the interest rate behavior. The issue is that available data commonly provide us with an incomplete set of points relating interest rates to maturities. However, obtaining continuous, interpolated term structure curves is often desirable, and this is what constitutes term structure estimation, or yield curve fitting.

The literature on term structure estimation can be divided into parametric and nonparametric methods. Parametric methods, which have the Nelson and Siegel (1987) and the Svensson (1994) models as their flagship, have at least two reasons for their popularity. First, they are relatively easy to estimate. In fact, if some of their parameters are assumed to be fixed over time, they can be estimated by simple linear regression techniques.⁷ If not, one has to resort to non-linear regression methods. Second, their functional forms impose more smoothness on the shapes of the estimated curves, as desirable by macroeconomists and many central banks (see Gürkaynak et al. 2007).

⁶ For practical purposes, I assume in this article that government bonds are free of credit risk. However, it is important to note that sovereign credit risk is not negligible in some countries, being an important source of determination of interest rates on government bonds.

⁷ Typically, one can estimate the Nelson and Siegel (1987) and the Svensson (1994) models using linear regressions by simply assuming that the decay parameters in their exponential terms are constant over time.
However, parametric methods are not immune to problems. For instance, they do not impose the presumably desirable theoretical restriction of absence of arbitrage across maturities (Filipovic 1999 and Diebold et al. 2005) and face some problems in fitting more flexible curves and curves with long maturity spectrums.

On the other hand, nonparametric methods, which have the spline methods of McCulloch (1971, 1975), Vasicek and Fong (1982) and Fisher et al. (1995) as their flagship, do not assume a particular functional form, being more robust to misspecification and exhibiting greater flexibility by fitting all kinds of term structure curves with very small fitting errors. The greater flexibility, however, comes at a cost. These methods tend to exhibit greater instability in fitting the shorter and longer-term maturities of the term structure, and their estimation typically involves a large number of parameters. Another problem is that the location and the number of interpolation points in the maturity space must be typically chosen before estimation.

Hence, when one must decide what estimation method to use, one is basically confronted by the issue of how much flexibility to allow in the term structure estimation. If a nonparametric method is chosen, a very flexible curve could be estimated, but it would be done with considerable variability in yields and forward rates. On the other hand, through parametric methods, more smoothness could be imposed on the shapes of the term structure, while some of the fit would be sacrificed. The choice in this dimension depends on the purpose that the curves are intended to serve. A trader looking for small pricing anomalies may be very concerned with how a specific security is priced relative to those securities immediately around it and would, probably, choose the more flexible method to estimate the term structure curve. By contrast, a macroeconomist may be more interested in measuring monetary policy expectations through the forward curve or in understanding the fundamental determinants of the yield curve, preferring a greater degree of smoothness. The BIS (2005) states that out of the thirteen main central banks of the world, at least nine use the parametric methods of Nelson and Siegel (1987) and Svensson (1994) with the Svensson (1994) method being the most popular one. The other typical methods used are the smoothing spline method proposed by Fisher et al. (1995) and the variable roughness penalty method that is used by the Bank of England.

The Riksbank uses the Svensson (1994) method to estimate daily term structure curves for a number of debt securities, including government bonds, mortgage bonds and corporate bonds. Figure 2 shows estimated term structure curves for these assets. Notice that the government bond curve has the lowest interest rates, followed by mortgage bonds and corporate bonds. This has to do with the fact that government bonds have typically lower credit risk and are more liquid than the other securities.



Figure 2. Term structure of interest rates for different asset classes (May 26, 2016)

Note. The yield curves shown were estimated using the Syensson (1994) method. Source: The Riksbank

In order to obtain a measure of market participants' expectations of the reportate in the future, the Riksbank also estimates smoothed forward curves on FRA (Forward Rate Agreements) and RIBA (Riksbank Futures) contracts' interest rates. These types of instruments have been popular among central banks in the last years mainly due to their availability in high frequencies as well as their good predictive power regarding future central bank actions in the near term (see Gürkaynak et al. 2007). Besides estimating forward curves for Sweden, the Riksbank also estimates daily forward curves for the US, the UK and the Euro Area (see Figure 3) in order to track market participants' expectations of future policy rates in these economies.



Note. The forward curves shown were estimated using the Svensson (1994)

method. Source: The Riksbank

3.2 Decomposing government bond interest rates into short-rate expectations and term premia

Although the ordinary term structure estimation methods described above have the advantage of being relatively simple to handle and estimate, they do not allow for the decomposition of interest rates into short-rate expectations and term premia, and are, therefore, consistent with the expectations hypothesis.⁸ For instance, it is not uncommon to assume that the forward rates calculated from these methods are a pure measure of shortrate expectations, as term premia are thought to be constant and/or equal to zero. However, as explained above, empirical research has shown that the expectations hypothesis has failed to explain the behavior of interest rates in several bond markets, which has led researchers to develop more theoretically founded methods to deal with this issue.

Affine term structure models (ATSM henceforth) provide an alternative to the common term structure estimation methods and have become enormously popular among central banks in the last ten years. This class of models (ATSM) encompasses the pure expectations hypothesis but also allows for a tractable and structured way of modeling constant as well as time varying term premia. By imposing the desirable theoretical restriction of absence of arbitrage across maturities, ATSMs allow for a convenient decomposition of government bond interest rates into the average of short-term interest rate expectations and a corresponding time-varying term premium. Through this decomposition, central banks are able to better understand the behavior of interest rates over time as well as to study the transmission of monetary policy to interest rates more directly. Furthermore, obtaining more sensible measures of short-rate expectations is crucial, as interest rate expectations are an important input for central banks' macroeconomic models in which private agents' decisions about consumption, investment, labor supply and price-setting are driven by the current policy rate as well as its expectations.

The literature on ATSMs is vast and covers a large range of models. I discuss here some of the models that have been used by central banks more recently. They differ mainly according to the estimation method and the number and type of variables, or factors, included in the model specification.

The first model is the one proposed by Kim and Wright (2005), which is one of the ATSMs estimated by the Federal Reserve Board staff. Its main distinct feature is the assumption that the behavior of any *n*-maturity yield and the corresponding short-rate expectations and term premium components are driven by three latent factors that are filtered from yields within the model estimation. This model has been quite popular among central banks and has been used by the Federal Reserve Board staff for many years, serving as a benchmark for several other studies.⁹

The second model is proposed by Joslin et al. (2011). Its main innovation is the inclusion of factors that are observables, and that can be linear combinations of yields, such as its three or four first principal components, or even the yields themselves. Moreover, part of the parameters of the model can be estimated by ordinary least squares (OLS), which facilitates the model estimation enormously, helping to solve one of the most serious problems with ATSMs (see Ang and Piazzesi 2003).

Interest rates tend, however, to be very persistent, meaning that typical data samples used in dynamic term structure estimation may be too short to capture a sufficient number of interest rate cycles. This induces the appearance of the problem of small-sample bias that may arise in the estimation of ATSMs and that affects the decomposition of yields into short-rate expectations and term premia (see Kim and Orphanides 2012 and Bauer et al. 2012, 2014).

Several studies have then proposed ways to get around this problem. For instance, Kim and Orphanides (2012) propose a way of providing additional relevant information to the Kim and Wright (2005) model by incorporating information from surveys of financial market participants about short-term interest rate forecasts. The basic idea is that the additional information on short-rate expectations can help in the estimation of more precise

Moreover, they have no clear foundation on economic and financial theory. For instance, they allow for arbitrage opportunities across interest rates of different maturities (see Christensen et al. 2009 and Christensen et al. 2012).
 The Federal Reserve Board makes available daily estimates from the model. The estimates can be downloaded from

https://www.federalreserve.gov/pubs/feds/2005/200533/200533abs.html.

parameters, delivering more realistic estimates of the short-rate expectations and term premia components.

Another attempt to solve the small-sample bias problem is provided by Bauer et al. (2012), who propose a number of simulation-based methods that can be applied to the Joslin et al. (2011) for example. The idea behind their approach is to correct for the bias that tends to underestimate the interest rate persistence in ATSMs so that short-rate expectations converge more slowly to their sample mean than in non-bias-corrected models. This may deliver estimates of term premia and short-rate expectations that are more consistent with economic theory (see Bauer et al. 2012, 2014).

Figure 4 shows estimates of the short-rate expectations and term premium components for the five-year Swedish government bond yield. These are obtained from the four ATSMs discussed above. The Kim and Orphanides (2012) model is enriched with monthly repo rate expectations of money market participants obtained from surveys.¹⁰ Notice that the Kim and Wright (2005) and the Kim and Orphanides (2012) model deliver similar estimates of the five-year yield decomposition, suggesting that the survey expectations do not provide much information to the Kim and Wright (2005) model. As noted by Bauer et al. (2012) results also suggest that more variation is attributed to the expectation component of the five-year yield after applying the bias-correction method to the Joslin et al. (2011) model. Interestingly, in this case, the five-year expectation component is much lower than for the other models at the end of the sample. This can be explained by the higher interest rate persistence captured by the Bauer et al. (2012) model, which induce short-rate forecasts to revert to its sample mean at a much slower speed.

From Figure 4 we also observe that most models deliver estimates of the short-rate expectations and term premium components that both contribute to the decline in the five-year yield, with the declines in term premium being, in general, more pronounced. Notice also that the five-year term premium has been low and even negative in more recent periods, according to most models.

¹⁰ These are measured by TNS Sifo Prospera.



Figure 4. Decompositions of the five-year Swedish government bond yield into the average of short-rate expectations and the associated term premium

There are at least four possible explanations for why long-term term premia have been compressed in Sweden. The first is the low inflation environment in Sweden, Europe and the United States observed since late 2013, which has led bondholders to be willing to accept less compensation for bearing inflation risk.¹¹ Another important factor is the low uncertainty about the near-term outlook for policy rates in Sweden and major economies. The low inflation environment increases the likelihood that policy rates around the world will remain low for some time, lowering uncertainty about future policy rates and helping to compress term premia in long-term yields. It is likely that the zero-lower bound in the US policy rate also contributed to lowering uncertainty about future policy rates in the US, as investors were quite sure that the Fed would keep the fed funds rate at zero for some time. Another possible explanation for the observed decline in Swedish government bond term premia is the bond purchases by the Riksbank (see De Rezende 2016), in Europe, Japan and elsewhere. It is likely that bond purchases in foreign economies have possibly caused a "spillover" effect into the demand for Swedish bonds, pushing down their term premia. And lastly, it is important to note that government bonds typically work as a hedge against different types of risk that may hurt returns on other riskier assets, and may be especially demanded by certain institutional investors due to liquidity and regulatory reasons. Investors may then be willing

Note. The estimates of short-rate expectations and term premium components were obtained using the affine term structure models of Kim and Wright (2005), Kim and Orphanides (2012), Joslin et al. (2011) and Bauer et al. (2012). Sources: The Riksbank and own calculations

¹¹ Historically, the most important risk for long-term bondholders has been the risk of unexpected inflation increases, as they deteriorate the returns associated with a nominal bond.

to accept low or even negative compensation for holding long-term government bonds, which helps to explain why term premia have been negative more recently.

Although term structure models have been quite popular in the last ten years, central banks have also used two other methods for measuring policy rate expectations. One first common method is the use of interest rate futures and forwards. Besides being considered good predictors of future central bank actions, its main distinctive feature is its availability in high frequencies, providing central banks with information about investors' expectations at any point in time. Its main drawback, however, is that interest rate futures and forwards are not free of risk premia, tending to overestimate – or underestimate in some cases – the right policy rate expectations (see Piazzesi and Swanson 2008). Another common method is the use of surveys, which have been especially popular for being clean from the risk premia that plague financial market instruments. The main drawback of surveys, however, is their availability in low frequencies. In addition, they may be subject to measurement error due to the typical availability of different respondents at each time they are conducted, which may bias the estimates of policy rate expectations such as the consensus forecast.¹²

Figure 5 shows measures of repo rate expectations for the two-year horizon. They were obtained from surveys, interest rate futures and forwards, and from affine term structure models. Notice that although the three measures are similar in terms of dynamics, they seem to differ in terms of levels. For instance, the term structure model predicts the repo rate to be lower than the estimates of interest rate futures for the period before mid-2014 and higher from 2015. This is expected since forward premia were mostly positive before 2014, turning negative afterwards (see Figure 4). Notice also that surveys deliver the highest estimates of repo rate expectations before 2015, but gets quite close to the affine models afterwards.



Note. The survey expectations are the average of money market participants' expectations obtained from TNS Sifo Prospera. The interest rate futures/forwards were obtained using the Svensson (1994) model and data of RIBA and FRA contracts. The term structure expectations were obtained from the average of estimates from two term structure models: Joslin et al. (2011) and Bauer et al. (2012). Sources: The Riksbank and own calculations

3.3 Studying the interest rate transmission mechanisms of unconventional monetary policies

In the aftermath of the global financial crisis of 2008, and in the face of deteriorating economic conditions and deflationary pressures, a number of central banks reduced their

¹² The consensus forecast is typically the mean or the median of individual forecasts.

policy interest rates to their effective lower bounds. With limited room for further rate cuts, central banks have then taken actions to lower longer-term interest rates mainly by purchasing large amounts of government debt and other types of assets, and by providing forward guidance.

The Riksbank has been implementing unconventional monetary policy through the purchase of nominal and real government bonds. With the slower than expected recovery in foreign economies and the considerable downward pressure on Swedish consumer prices, in February 2015, the Executive Board of the Riksbank announced that the Riksbank would start buying nominal government bonds with maturities of up to five years on the secondary market to the amount of SEK 10 billion. The purchases took place by means of auctions in which the Riksbank's monetary policy counterparties and the Swedish National Debt Office's primary dealers were able to participate. Later on, further monetary policy easing continued to be desirable, in particular because of concerns about the strengthening of the Swedish krona (SEK), and the Riksbank announced further extensions of its bond purchase program. At the same time, the repo rate was gradually lowered, reaching the level of –0.50 per cent in February 2016. The Riksbank has also published its projected repo rate path since 2007 as a way to inform the public about its future monetary policy intentions. Table 1 shows a description of the Riksbank's monetary policy announcements in the period ranging from February 2015 to April 2016.

Date	Announcement description
Feb 12, 2015	Riksbank cuts repo rate to -0.10 percent, buys government bonds for SEK 10 billion and is prepared to do more at short notice
Mar 18, 2015	Riksbank cuts repo rate to -0.25 percent and buys government bonds for SEK 30 billion
Apr 29, 2015	Riksbank buys government bonds for SEK 40-50 billion and lowers the repo-rate path significantly
Jul 2, 2015	Repo rate cut to -0.35 percent and purchases of government bonds extended by SEK 45 billion
Sep 3, 2015	Repo rate unchanged at –0.35 per cent
Oct 28, 2015	The Riksbank purchases government bonds for a further SEK 65 billion and keep the repo rate at –0.35 per cent for a longer time
Dec 15, 2015	Repo rate unchanged at -0.35 per cent – still highly prepared to act
Feb 11, 2016	Repo rate cut to –0.50 per cent
Apr 21, 2016	Riksbank to purchase government bonds for a further SEK 45 billion and repo rate held unchanged at –0.50 per cent

Table 1. Riksbank's monetary policy announcements from February 2015 to April 2016

The reasoning behind these policies lies in their transmission to interest rates. For instance, by announcing asset purchases, central banks may send a signal to market participants that they intend to keep policy rates low for longer than otherwise, lowering the expected path of future policy rates and, consequently, long-term interest rates. This is the signaling channel of government bond purchases, which works through changing expectations of future policy rates. The other is the portfolio balance channel, which arises from the reduction in the available supply of the assets purchased. In this channel, under the assumption that bonds of different maturities are not perfect substitutes and that maturity-specific bond demands by certain investors exist (see Vayanos and Vila 2009), central banks may be able to affect bond yields by changing the risk premia that investors require for holding the securities purchased. Central banks may also influence market expectations by communicating their future monetary policy intentions and by providing forward guidance about their future policy rate path.

While it is widely accepted that asset purchases have helped to reduce long-term interest rates, the understanding of their interest rate transmission channels is still partial and has become an important topic in this literature. For instance, using data for the US, Gagnon et al. (2011) argue that the Federal Reserve's Large Scale Asset Purchases primarily lowered long-term government bond rates through the portfolio balance channel. This is also emphasized by D'amico and King (2013). On the other hand, Krishnamurthy and VissingJorgensen (2011), Christensen and Rudebusch (2012) and Bauer and Rudebusch (2014) discuss that the signaling channel was the main driver of the observed fall in the US long-term interest rates. Using ATSMs together with event study regressions De Rezende (2016) shows that government bond purchases have had important portfolio balance and signaling effects in Sweden, which seem to operate by mainly lowering intermediate maturity short-rate expectations and longer-maturity term premia. In addition, De Rezende (2016) discusses that the Riksbank was effective in lowering government bond yields across the full yield maturity spectrum when implementing conventional and unconventional policies together.

The monetary policy announcement made by the Riksbank on July 2, 2015 is a good example of how conventional and unconventional policies seem to work and interact. On that day, the decisions to cut the reportate by 10 basis point and to purchase government bonds for a further SEK 45 billion were largely unexpected by market participants. The surprise regarding the interest rate cut affected short-rate expectations strongly, driving the fall observed in short-term government bond yields. At the same time, bond purchases contributed, to a large extent, to lowering the short-rate expectations and term premia components in the two-year to five-year and in the five-year to ten-year segments of the yield curve, respectively, suggesting that both the signaling and the portfolio balance channels seemed to have contributed to the fall in mid- and long-term yields (see Figure 6 and De Rezende 2016 for more details).



Figure 6. Effects of the monetary policy announcement of July 2, 2015

Effect of government bond purchase on term premium component

Effect of government bond purchase on expectations component

Effect of conventional monetary policy plus foreign yield on term premium component

Effect of conventional monetary policy plus foreign yield on expectations component

Notes. the effects of bond purchase announcements on term premia and the average of short-rate expectations are computed using an event study regression approach (please see De Rezende 2016 for more details). Sources: The Riksbank and own calculations

3.4 Measuring inflation expectations

Markets for inflation-protected debt securities have grown dramatically in recent years. The idea behind their issuance is to provide investors with the possibility of eliminating inflation risks in fixed-income investments while providing a real rate of return guaranteed by governments. Interestingly, the interest rates on these securities, when used in combination with those of nominal bonds, have allowed central banks to compute measures of investors' expectations of future inflation. This is often called the "break-even inflation", i.e. the rate of inflation that would give an investor the same return at maturity on a nominal and a real bond. However, as for nominal bonds, real bond issues only happen for particular maturities and coupon rates, meaning that it is not possible to get measures of inflation expectations directly from these issues. As for nominal bonds, central banks have then used term structure models to obtain interpolated real term structure curves that can be used to obtain measures of inflation expectations for any horizon.

The Riksbank estimates real term structure curves daily using inflation-linked securities issued by the Swedish National Debt Office and computes different measures of break-even inflation. Figure 7 shows forward break-even inflation rates for the period from January 2014 to July 2016.



Note. The forward breaks-even inflation rates shown were computed using the difference between nominal and real forward rates. These were estimated using the Svensson (1994) method. Sources: The Riksbank and own calculations

3.5 Other uses

As discussed above, as markets for inflation-protected securities have grown in recent years, the interest rates on these instruments have been used by central banks as an important source of information about investors' expectations of future inflation. Unfortunately, these rates also include risk premia that compensate investors for inflation risk, which may add noise in break-even inflation rates. In an attempt to obtain a "cleaner" measure of the inflation expectations embedded in nominal and real government bond interest rates, some studies have then used term structure models to estimate time-varying inflation risk premia present in break-even inflation rates. Typical models in this literature were developed by Christensen et al. (2010), Joyce et al. (2009), García and Werner (2010), Abrahams et al. (2015), among others.

Another typical problem with inflation-linked bonds is the lack of liquidity in certain markets and in specific periods of time. As discussed by Sack and Elsasser (2004), Shen (2006), Pflueger and Viceira (2011), among others, this induces the appearance of liquidity risk premia on inflation-linked bonds' interest rates, which may distort the measures of

break-even inflation commonly used by central banks. Some articles have then proposed term structure models to get around this problem by estimating the liquidity risk premia in these markets and using them together with estimates of inflation risk premia to obtain more reasonable measures of investors' inflation expectations. For instance, D'Amico et al. (2010) show that ignoring the liquidity premia in the US index-linked bond market produces large pricing errors for these securities. Abrahams et al. (2015) shows that adjusting break-even rates for inflation and liquidity risks substantially improves forecasts of US inflation. Haubrich et al. (2012) suggests that the US index-linked bonds were significantly underpriced prior to 2004 and again during the 2008-2009 financial crisis, with the lack of liquidity being one of the possible explanations for this phenomenon.

As the policy rate approaches its lower bound, standard ATSMs may lose their ability to fit short-term interest rates, generate point and distributional short-rate forecasts, and extract accurate policy rate expectations. A modified version of the more common ATSMs has then been proposed to deal with these situations. These are the so-called shadow-rate term structure models, which have been popularized by Wu and Xia (2016), Bauer and Rudebusch (2016), Krippner (2012), among others. Besides allowing for the estimation of more reasonable short-rate expectations, these models also allow for the estimation of useful indicators for central banks such as the time to the expected interest rate liftoff, the expected pace of monetary policy tightening, as well as the shadow rate, which is commonly understood as a measure of the policy rate that would prevail in case the lower bound was not present.

Figure 8 shows estimates of the shadow rate for the US and the Euro Area obtained from the Wu and Xia (2016) model. Notice that as policy rates approach their respective lower bounds in both economies, the estimated shadow rates start decoupling from the actual policy rates. The divergence between the shadow and the actual policy rate becomes larger when the interest rate lower bound is binding and increases as longer-maturity interest rates become particularly compressed and assumedly constrained by the lower bound. As some of the unconventional monetary policies put in practice in these economies are expected to affect longer-term interest rates primarily, the shadow rate has then been used as a measure of the current stance of monetary policy. Some studies, however, have criticized this idea. For instance, Bauer and Rudebusch (2016) argue that common shadow rate estimates are highly sensitive to model specification, the choice of the lower bound value and the data choice at the short end of the yield curve. Similarly, Krippner (2014) argues that shadow rates are subject to variation with modelling choices. He then proposes the use of economic stimulus measures, which are based on the area between the expected shadow rate path and the long-term nominal interest rate level, as an alternative measure of the stance of monetary policy.



Figure 8. Shadow rate for the US and the Euro Area Per cent per year

Rate on deposit facility
 Rate on main refinancing operations
 Rate on marginal lending facility
 Shadow rate
 Note. The estimates of the shadow rates were obtained from Jing Cynthia Wu's

website: http://faculty.chicagobooth.edu/jing.wu

4 Concluding remarks

This article provides an overview of the recent developments on term structure modeling and its uses by central banks. The topic is important for central banks and policymakers who wish to extract economic information from long-term interest rates, and elaborate policies to influence them. The simplest proposition of the determination of the term structure of interest rates is the expectations hypothesis. I describe some of the term structure models that are consistent with the expectations hypothesis and discuss why they are insufficient for explaining the behavior of interest rates. I then review term structure models that allow for time-varying risk premia and discuss why they are more consistent with economic theory and data. These models have been especially useful for studying the interest rate transmission mechanisms of unconventional monetary policy such as government bond purchases and forward guidance, which are expected to affect long-term interest rates through short-rate expectations and term premia. In addition, I describe how central banks have used term structure models to estimate inflation and liquidity risk premia in real government bond markets, in order to obtain "cleaner" measures of market participants' inflation expectations. Finally, as policy rates have approached their lower bounds in many economies, some term structure models have been developed to deal with this situation.

Besides allowing for the estimation of more reasonable short-rate expectations, these models also allow for the estimation of useful policy indicators such as the shadow rate, which is commonly understood as a measure of the policy rate that would prevail in case the lower bound was not present.

References

Abrahams, M., Tobias Adrian, R.K. Crump and Emanuel Möench (2015), "Decomposing Real and Nominal Yield Curves", Staff Reports No. 570, Federal Reserve Bank of New York.

Ang, Andrew and Monika Piazzesi (2003), "A No-Arbitrage Vector Autoregression of Term Structure Dynamics with Macroeconomic and Latent Variables", *Journal of Monetary Economics*, Vol. 50, pp. 745-787.

Bauer, Michael and Glenn D. Rudebusch (2014), "The Signaling Channel for Federal Reserve Bond Purchases", *International Journal of Central Banking*, Vol. 10, No. 3, pp. 233-289.

Bauer, Michael, Glenn D. Rudebusch and Cynthia Wu (2012). "Correcting Estimation Bias in Dynamic Term Structure Models", *Journal of Business & Economic Statistics*, Vol. 30, pp. 454-467.

Bauer, Michael, Glenn D. Rudebusch and Cynthia Wu (2014), "Term Premia and Inflation Uncertainty: Empirical Evidence from an International Panel Dataset: Comment", *American Economic Review*, Vol. 104, No. 1, pp. 323-337.

Bauer, Michael and Glenn D. Rudebusch (2016), "Monetary Policy Expectations at the Zero Lower Bound", *Journal of Money, Credit and Banking*, Vol. 48, No. 7, pp. 1439-1435.

Campbell, John Y. and Robert J. Shiller (1991), "Yield Spreads and Interest Rate Movements: A Bird's Eye View", *Review of Economic Studies*, Vol. 58, No. 3, pp. 495-514.

Christensen, Jens and Glenn Rudebusch (2012), "The Response of Interest Rates to US and UK Quantitative Easing", *Economic Journal*, Vol. 122, pp. F385-F414.

Christensen, Jens, Jose. A. Lopez, and Glenn. D. Rudebusch (2010), "Inflation Expectations and Risk Premiums in an Arbitrage-Free Model of Nominal and Real Bond Yields", *Journal of Money, Credit and Banking*, Vol. 42, No. 1, pp. 143-178.

Cochrane, John and Monika Piazzesi (2005), "Bond Risk Premia", *American Economic Review*, Vol. 95, No. 1, pp. 138-160.

D'Amico, Stefania, Don H. Kim and Min Wei (2010), "Tips from TIPS: the Informational Content of Treasury Inflation-Protected Security prices", Finance and Economics Discussion Series 2010-19, Board of Governors of the Federal Reserve System.

D'Amico, Stefania and Thomas King (2013), "Flow and Stock Effects of Large-Scale Treasury Purchases: Evidence on the Importance of Local Supply", *Journal of Financial Economics*, Vol. 108, No. 2, pp. 425-448.

De Rezende, Rafael B. (2016), "The Interest Rate Effects of Government Bond Purchases Away from the Lower Bound", Working Paper No. 324, Sveriges Riksbank.

Diebold, Francis X., Monika Piazzesi and Glenn D. Rudebusch. (2005), "Modeling Bond Yields in Finance and Macroeconomics", *American Economic Review*, Vol. 95, No. 2, pp. 415-420.

Duffie, Darrell (2001). "Dynamic Asset Pricing Theory", Princeton and Oxford: Princeton University Press.

Fama, Eugene (1984), "Term Premium in Bond Returns", *Journal of Financial Economics*, Vol. 13, pp. 529-546.

Fama, Eugene and Robert R. Bliss (1987), "The Information in Long-Maturity Forward Rates", American Economic Review, Vol. 77, pp. 680-692.

Filipovic, Damir (1999), "A Note on the Nelson-Siegel Family", *Mathematical Finance*, vol. 9, No. 4, pp. 349-359.

Fisher, Mark, Douglas Nychka and David. Zervos (1995), "Fitting the Term Structure of Interest Rates with Smoothing Splines", Working Paper No. 95-1, Federal Reserve System.

Friedman, Milton and Leonard Savage (1948), "The Utility Analysis of Choices Involving Risk", *Journal of Political Economy*, Vol. 56, No. 4, pp. 279-304.

Gagnon, Joseph, Mathew Raskin, Julie Remache and Brian Sack (2011), "The Financial Market Effects of the Federal Reserve's Large-Scale Asset Purchases", *International Journal of Central Banking*, Vol. 7, No. 10, pp. 3-43.

Garcia, J. Angel and Thomas Werner (2010). "Inflation Risks and Inflation Risk Premia", Working Paper No. 1162, European Central Bank.

Greenwood, Robin and Dimitri Vayanos (2014). "Bond Supply and Excess Bond Returns", *Review of Financial Studies*, Vol. 27, No. 3, pp. 663-713.

Gürkaynak, Refet S., Brian P. Sack, and Eric T. Swanson (2007), "Market-Based Measures of Monetary Policy Expectations", *Journal of Business and Economic Statistics*, Vol. 25, pp. 201-212.

Gürkaynak, Refet S., Brian P. Sack, and Jonathan H. Wright (2007), "The U.S. Treasury Yield Curve: 1961 to the Present", *Journal of Monetary Economics*, Vol. 54, No. 8, pp. 2291-2304.

Haubrich, Joseph, George Pennacchi and Peter Ritchken (2012), "Inflation Expectations, Real Rates, and Risk Premia: Evidence from Inflation Swaps", *Review of Financial Studies*, Vol. 25, No. 5, pp. 1588-1629.

Joslin, Scott, Kenneth J. Singleton and Haoxiang Zhu (2011), "A Kew Perspective on Gaussian Dynamic Term Structure Models", *Review of Financial Studies*, Vol. 24, No. 3, pp. 1-45.

Joyce, Michael, Peter Lildholdt and Steffen Sorensen (2009), "Extracting Inflation Expectations and Inflation Risk Premia from the Term Structure: a Joint Model of the UK Nominal and Real Yield Curves", Working Paper No. 360, Bank of England.

Kim, Don H., and Jonathan H. Wright (2005), "An Arbitrage-Free Three-Factor Term Structure Model and the Recent Behavior of Long-Term Yields and Distant-Horizon Forward Rates", Finance and Economics Discussion Paper No. 33, Board of Governors of the Federal System.

Kim, Don H. and Athanasios Orphanides (2012). "Term Structure Estimation with Survey Data on Interest Rate Forecasts", Journal of Financial and Quantitative Analysis, Vol. 47, No. 1, pp. 241-272.

Krippner, Leo (2012). "Modifying Gaussian Term Structure Models when Interest Rates are Near the Zero Lower Bound", Discussion Paper No. 02, Reserve Bank of New Zealand.

Krippner, Leo (2014). "Measuring the Stance of Monetary Policy in Conventional and Unconventional Environments", Working Paper No. 6, Centre for Applied Macroeconomic Analysis.

Krishnamurthy, Arvind, and Annette Vissing-Jorgensen (2011), "The Effects of Quantitative Easing on Interest Rates", *Brookings Papers on Economic Activity*, Fall, pp. 215-265.

McCulloch, J. H. (1971), "Measuring the Term Structure of Interest Rates", *Journal of Business*, Vol. 44, pp. 19-31.

McCulloch, J. H. (1975), "The Tax-Adjusted Yield Curve", Journal of Finance, Vol. 30, pp. 811-830.

Nelson, Charles R. and Andrew F. Siegel (1987), "Parsimonious modeling of yield curves", *The Journal of Business*, Vol. 60, No. 4, pp. 473-489.

Pflueger, Carolin E. and Luis M. Viceira (2011), "Return Predictability in the Treasury Market: Real Rates, Inflation, and Liquidity", Working Paper No. 16892, National Bureau of Economic Research.

Piazzesi, Monika (2010), "Affine Term Structure Models", In *Handbook of Financial Econometrics, Volume 1: Tools and Techniques*, edited by Yacine Ait-Sahalia and Lars Peter Hansen, pp. 691–766, Amsterdam and Oxford: Elsevier, North-Holland.

Piazzesi, Monika and Eric T. Swanson (2008), "Futures Prices as Risk-adjusted Forecasts of Monetary Policy", *Journal of Monetary Economics*, Vol. 55, No. 4, pp. 677-691.

Sack, Brian and Robert Elsasser (2004), "Treasury Inflation-Indexed Debt: A Review of the U.S. Experience", *Economic Policy Review*, Vol. 10, pp. 47-63.

Shen, Pu (2006), "Liquidity Risk Premia and Breakeven Inflation Rates", *Economic Review Federal Reserve Bank of Kansas City*, Vol. 91, pp. 29-54.

Singleton, Kenneth J. (2006), "Empirical Dynamic Asset Pricing: Model Specification and Econometric Assessment", Princeton and Oxford: Princeton University Press.

Svensson, Lars (1994), "Estimating and Interpreting Forward Interest Rates: Sweden 1992-1994", NBER Working Paper No. 4871.

Stambaugh, Robert F. (1988), "The Information in Forward Rate: Implications for Models of the Term Structure", *Journal of Financial Economics*, Vol. 21, pp. 41-70.

Vasicek, Oldrich and H. Gifford Fong (1982), "Term structure modelling using exponential splines", *Journal of Finance*, Vol. 37, No. 2, pp. 339-348.

Vayanos, Dimitri and Jean-Luc Vila (2009), "A Preferred-Habitat Model of the Term Structure of Interest Rates", NBER Working Paper No. 15487.

Woodford, Michael (1999), "Optimal Monetary Policy Inertia". Working Paper No. 7261, National Bureau of Economic Research.

Wu, Cynthia and Fan D. Xia (2016), "Measuring the Macroeconomic Impact of Monetary Policy at the Zero Lower Bound", Journal of Money, Credit, and Banking, Vol. 48, No. 2-3, pp. 253-291.

Appendix A – the generalized affine term structure model

The generalized discrete-time Gaussian dynamic ATSM assumes that zero-coupon bond yields are functions of p pricing factors. More specifically, the $p \times 1$ vector of pricing factors X_t follows a VAR(1) process under the objective probability measure \mathbb{P} ,

(7)
$$X_{t+1} = \mu + \phi X_t + \sum \varepsilon_{t+1},$$

where $\varepsilon_{t+1} \sim iid N(0, I_i)$ and Σ is a $p \times p$ lower triangular matrix. The stochastic discount factor (SDF) that prices all assets under the absence of arbitrage is assumed to be conditionally lognormal

(8)
$$M_{t+1} = exp \left(-r_t - \frac{1}{2}\lambda_t'\lambda_t - \lambda_t'\varepsilon_{t+1}\right),$$

where $\lambda_t = \lambda_0 + \lambda'_1 X_t$ is a $p \times 1$ vector of risk prices. The short rate is allowed to vary freely, without imposing any restrictions or asymmetries in the conditional distributions of short-rate expectations. The short-term interest rate is then affine in the pricing factors, $r_t = \delta_0 + \delta'_1 X_t$. Under the risk-neutral measure \mathbb{Q} , the vector of pricing factors follows the dynamics,

(9)
$$X_{t+1} = \mu^Q + \phi^Q X_t + \sum \varepsilon_{t+1},$$

where $\mu^{Q} = \mu - \sum \lambda_{0}$ and $\phi^{Q} = \phi - \sum \lambda_{1}$.

Under no-arbitrage bond prices are then exponential affine functions of the state variables, $P_t^n = exp(A_n + B'_n X_t)$, where A_n is a scalar and B_n is a $p \times 1$ vector that satisfy the recursions

(10)
$$A_{n+1} = A_n + \mu^Q B_n + \frac{1}{2} B'_n \sum B'_n - \delta_0$$

$$B_{n+1} = \phi^{Q'} B_n - \delta_1,$$

which start from $A_1 = -\delta_0$ and $B_1 = -\delta_1$. Model implied yields are computed as $y_t^n = -n^{-1} \log P_t^n$ = $-n^{-1} (A_n + B'_n X_t)$.

It is interesting to note that the functions A_n and B_n are computed under the risk-neutral measure \mathbb{Q} and not under the objective probability measure \mathbb{P} . The difference is determined by the risk premium demanded by investors to invest in an n-year bond and that is embodied in X_t . Following this argument, the term premium is then defined as the return difference between buying and holding an n-year bond until maturity and rolling over the short-term interest rate,

(12)
$$TP_t^n = y_t^n - \frac{1}{n} \sum_{i=0}^{n-1} E_t^p(r_{t+1}).$$

Appendix B – the generalized shadow rate term structure model

Because the model described above is linear in Gaussian factors, it potentially allows nominal interest rates to go below its lower bound, facing difficulties in fitting the yield curve in a lower bound environment. One way of getting around this problem is to use shadow rate term structure models, an approach that has proven to be helpful for describing yields and the stance of monetary policy in a lower bound environment. This class of models posits the existence of a shadow interest rate that is linear in Gaussian factors, with the actual short-term interest rate being the maximum of the shadow rate and the effective lower bound. More specifically, the model assumes that the short-term interest rate is the maximum of the shadow rate *s*, and a lower bound *r*,

(13) $r_t = max(\underline{r}, s_t) \qquad s_t = \delta_0 + \delta'_1 X_t.$

A perspective on electronic alternatives to traditional currencies

Gabriele Camera*

Economic Science Institute, Chapman University and WWZ, University of Basel

The institution of money is rapidly evolving thanks to developments in computer-based cryptography. Technological advances have made possible the creation of cost-effective electronic alternatives to banknotes and coins, which are the traditional physical currencies. This document aims to describe — based on scientific literature — the use and characteristics of money, some of the problems associated with issuing a new currency or a new payment instrument, and the possible comparative advantages of a central bank in leading the way relative to private issuers.

1 Introduction

Conducting retail transactions costs about 1% of GDP per year to the average European country (Schmiedel et al. (2012), Segendorf and Jansson (2012)).¹ Half of this cost comes from commercial banks, which have a prominent role in settling payments, especially now that the use of cash is rapidly diminishing in some countries (Segendorf and Wretman 2015).² Moreover, a significant portion of payments is typically executed by exchanging demand deposits, instruments that are risky and therefore costly to insure.

Technological innovation has recently enabled alternatives to traditional currency instruments. Thanks to new developments in cryptography and computing, it is now possible to develop digital alternatives to traditional currencies that are as peer-to-peer as cash, as convenient as a debit card, and potentially cheaper to use and safer than deposits. As a result, there is currently significant interest—both from private and public financial institutions—in understanding whether or not there is scope for currency innovation.

Nowadays, the focus is on studying technologies that support the construction of cheap, safe and reliable *public ledgers*, essentially decentralized record-keeping systems that can be adopted to support the settlement of payments within large groups of traders who do not necessarily trust one another. Broadly speaking, such record-keeping systems can theoretically allow traders to accurately and quickly establish property rights over the instruments being traded, while, at the same time, eliminating or at least minimizing the traditional layer of services provided by trusted intermediaries, such as banks, in settling payments (Ali et al. (2014b), Barrdear and Kumhof (2016)).

A prominent candidate technology is "blockchain technology" or "distributed ledger" (Nakamoto (2008)), which was originally developed to support the Bitcoin network. This technology has spurred a number of private currency-like instruments, and is currently being tested for settlement of financial transactions (Bloomberg (2016a), The Economist (2015)). Importantly, this technological innovation is being studied for possible application in the

^{*} This overview, which has been prepared for Sveriges Riksbank, partly reflects content that has appeared in some of my own previous research, cited in this document. I thank, without implicating, Gabriela Guibourg, Erik Lenntorp, Jonas Milton, Kasper Roszbach, and, especially, Björn Segendorf at Sveriges Riksbank for many comments and stimulating conversations. The opinions expressed in this article should not be interpreted as reflecting the official views of Sveriges Riksbank. Address: G. Camera, Chapman University, Economic Science Institute, One University Dr., Orange, CA 92866. E-mail: camera@chapman.edu

¹ Defined as payments by cash, check debit and credit card, direct debit and credit transfer payments up to 50,000 Euros.

² This decline is not common to all countries. For the US, Klee (2008) reports that cash captures 54% of all transactions collected from scanner data at 99 grocery stores. Survey data from Austria and Canada shows that more than 50% of all consumption purchases are paid for with cash (Huynh et al. (2013)).

emission of "all-digital" cash substitutes by central banks (Brainard (2016), Broadbent (2016), Fan (2016), Skingsley (2016)). Throughout this document, I will call this type of instrument *e-cash* because, on the one hand, it is as peer-to-peer as physical cash, and, on the other hand, it has a digital representation and is electronically exchanged and stored, in much the same way as the main forms of digital money in use today (commercial bank money and bank reserves at the central bank).

The possible economic consequences of bringing to the market an electronic substitute for cash have not been systematically studied. Many questions are still open. Even so, the scientific literature has addressed some of the fundamental, and closely related, questions. For example, what is the role of a currency in society, and what supports its stability and value in the long-run? Should we move away from traditional currency systems to embrace new technologies? What problems or market failures can we foresee that are associated with introducing an alternative payment instrument? Should central banks play an active role or should private issuers lead the way? This document aims to describe—based on scientific literature—uses and characteristics of money, some of the problems associated with issuing a new currency or a new payment instrument, and the possible comparative advantages of a central bank in leading the way relative to private issuers.

To summarize, moving away from traditional physical cash and into e-cash offers several potential benefits. An improved currency system could be constructed that greatly reduces the costly layers of the financial institutions that we currently use to process and settle electronic payments. E-cash may also allow significant changes in the way in which currency is managed, as it is now technically feasible to allow households direct access to the central bank balance sheet as Tobin suggested (Tobin (1985)). This could revolutionize the way in which monetary policy is conducted, affecting the monetary transmission channels, and the speed and efficacy of intervention. However, there are also risks in moving away from traditional currency systems, which depend on how a new currency system would be designed and operated. Granting deposits at the central bank could have profound consequences for banks, their financing, and their asset-transformation role, which could possibly adversely impact financial volatility during a crisis or during the transition period. Understanding these issues should be one of the priorities of a central bank.

The paper proceeds as follows. Section 2 develops some basic knowledge about money and the role it serves in a society. Section 3 offers a simple characterization of the main monetary instruments used nowadays. Section 4 discusses the problems and implications for central banks associated with the introduction of electronic alternatives to cash. Section 5 touches upon considerations about privacy and crime-related externalities, and Section 6 offers some final comments.

2 Currency, money, and cash

Currency identifies an object that widely circulates to facilitate payments. The term is commonly used as a synonym for money. Although economic textbooks do not typically tell us what money *is* — academics are still debating a possible answer³ — there is consensus in the scientific literature about what money *does*. According to a view going back at least to Aristotle, money serves three basic functions. It facilitates trade by acting as a *means of payment* — e.g. we hand over banknotes for a coffee. It serves quantification purposes as a *unit of account* (or standard of value) — e.g. we choose our diet by comparing foods' prices. It is also a *store of value* — e.g. we hold a checking account balance to enable a future transaction or the repayment of financial and tax obligations. To perform these functions, societies have typically chosen currency instruments that are durable, highly portable,

³ Krugman (2010) writes: "But here's an even more basic question: what is money, anyway? It's not a new question, but I think it has become even more pressing in recent years."

divisible, easy to authenticate and difficult to reproduce. Coins and banknotes — commonly referred to as *cash* — are tangible monetary instruments and the ones that the public is most familiar with.

The cash in use today is a sovereign *fiat* money, meaning that these tangible monetary instruments are issued by a state authority but neither have intrinsic value — coins are not made of precious metals, for example — nor are explicitly convertible into real assets such as precious metals (ECB (2015b), McLehay et al. (2014)). However, cash has generally a special status: in most countries it is "legal tender," meaning that tendering banknotes and coins legally discharges financial obligations.⁴

But money is much more than cash. In particular, it includes two kinds of intangible monetary instruments: banks' reserves with the central bank (sovereign money), and commercial bank deposits (instruments that are privately issued by commercial banks). The main difference between these two kinds of money, sovereign and private, is on whom they are a claim. Sovereign money is a claim on the central bank, and is often called "outside money" or "central bank money"; commercial bank money is a claim on private domestic debt and is often called "inside money."⁵

2.1 The nature of money

To understand the role and the value of currency and monetary systems, we must answer two questions. Why do societies use money? Which economic problems does money ultimately solve?

Money is first and foremost a *social convention*, which emerges to build trust among strangers in their economic transactions, both intertemporal and in spot markets. A convention of monetary exchange facilitates valuable intertemporal exchanges that would not occur otherwise.

According to this view, individuals who may neither know nor trust each other choose to settle their transactions by offering symbolic objects—bank deposits or banknotes for instance—in exchange for labor, goods and services because they find this trading arrangement superior to the available alternatives (Camera, Casari and Bigoni (2013)). Hence, symbolic objects spontaneously become money when individuals share the belief that those objects can be quickly and easily exchanged for labor, goods and services in the foreseeable future. If no-one can personally gain from acting differently—demanding payment of a different kind, for instance—then those symbolic objects become money and support a currency system. The system is stable if everyone maintains their confidence in it.⁶

A monetary trading pattern resembles an intertemporal gift-giving scheme, where each gift is acknowledged by delivering a token. But, if tokens are intrinsically worthless, then why are they exchanged at all? The answer is that doing so resolves an underlying trust problem. Any transaction characterized by a mismatch between the timing of delivery of goods and of payment requires that counterparts trust each other. However, the most valuable trades involve specialized goods. This typically requires dealing with strangers, instead of trusted neighbors (Greif (2006)), which prevents reciprocity and makes contractual enforcement problematic (Milgrom et al. (1990)). Monetary exchange can overcome these contractual

⁴ Legal tender is roughly interpreted as obliging the economic agents to accept the instrument as payment, but this interpretation is not always fitting. For example, in the U.S. "legal tender discharges all debts for which the payment of money is specified when tendered in the appropriate amount and in the proper manner" (Konvisser (1997)). In Sweden everyone is obliged to accept banknotes and coins as payment, but only if the contracting parties have not made a different agreement (Segendorf and Wilbe (2014)).

⁵ This distinction was made by John Gurley and Edward Shaw in their book "Money in a Theory of Finance." Various measures of the money supply — typically, monetary base, M1 and M2 — account for the different components of the stocks of outside and inside money.

⁶ In the language of economics, money emerges as the solution to a non-cooperative game — a *Nash equilibrium*. Shapley and Shubik (1977), among the first to apply non-cooperative game theory to the study of money, put it as follows: "Although a person may view, say, fiat money as being of dubious value as a store of wealth, he knows that most others will continue to use it for trade, and he may be in no position to do otherwise himself."

difficulties as long as traders are confident that others will accept money in the future. Public confidence in the currency is thus key ingredient in a monetary system.

This problem is conceptually represented in Figure 1. Assume there are many individuals in the background who alternate between being producers and consumers of a non-storable good. They meet each other at random in each period. The figure shown represents one such meeting. The consumer benefits from receiving a gift of a good from the producer. Maximum welfare can only be attained if individuals coordinate on a norm of mutual support, wherein every person makes a gift of a good when they are a producer. However, people cannot guarantee they will reciprocate a gift in the future because meetings are random. Markets, that is, are incomplete. This norm of mutual support thus requires *trusting* that a gift made today corresponds to a gift in the future. However, building this kind of trust is practically feasible only in small groups, where individuals know each other very well.

Introducing a stable supply of symbolic tokens can resolve this market failure if people trust that others will sell *only* in return for a token. In this case, the token becomes a currency. Public confidence in the monetary system is thus inextricably linked to confidence in the currency issuer—which is why central banks' conduct is key for the stability of a currency system. A monetary system can thus be viewed as a social convention that emerges to build the trust needed to support valuable economic interactions among strangers. In a way, confidence in the institution of money can shore up the lack of trust in other members of society. Laboratory research provides some empirical support for this view (Camera and Casari (2014)).

Figure 1. How monetary exchange resolves trust problems

Each cell reports the outcome from a combination of actions (producer on the right, consumer on the left, and payoffs listed below the human figures). The shaded cells refer to outcomes without a monetary system. The other cells depict the additional outcomes possible when a monetary system is in place. The figure is an adaptation from Camera, Casari and Bigoni (2013).



Producer

Do informationally sophisticated societies need money?

Some economists have compared money to an information technology-a record-keeping device (Ostroy (1973), Ostroy and Starr (1974), Townsend (1987)). Kocherlakota (1998) suggested that money is a rudimentary public monitoring system. According to this view, if it is difficult to write and enforce contracts, then revealing others' past conduct is sufficient to deter opportunistic behavior in a community. According to Kocherlakota (1998), all that is needed to ensure that counterparts keep their promises is the possibility to publicly reveal departures from agreed-upon plans, because this information can be used to trigger punishment by the entire community (Abreu et al. (1990), Kandori (1992)). Thus, the theory says, monetary exchange has a role to play only if monitoring past conduct is difficult. This is the sense in which money is simply a substitute for public monitoring systems. According to this view, currency systems should have no role to play in informationally sophisticated societies (Kahn et al., (2005), Corbae et al. (2007)). Laboratory evidence does not support this assertion. Individuals who can see others' past conduct do not, in fact, frequently cooperate (Bigoni et al. (2015)). This suggests that money is likely to remain a valuable institution even as societies become more interconnected and informationally sophisticated.

2.2 A monetary system is a public good

The discussion above suggests that currencies and monetary systems are a public good, much as clean air, national defense, or national parks. In its most basic form, a monetary system is non-excludable — single individuals can hardly be prevented from using banknotes and coins.⁷ It is also non-rival because an individual's participation in the system does not impede another's use. In fact, it likely raises the value of the currency through network effects — a currency that is widely used is more valuable than one that is not, because it enables more trades. As is typical in public goods problems, self-interested individuals would rationally choose to free-ride by avoiding to privately contribute to this public good, reducing their input to building and maintaining "confidence in the currency." This socially inefficient provision would take the form of an excessive emission of currency instruments under a laissez-faire approach, which would reduce confidence in the currency, lowering the value of the currency up to the point where the monetary system would collapse because the future value of the currency would be too small (Ritter (1995)).⁸ This public goods aspect of monetary systems is one of the factors justifying the central role of public institutions in the provision of currency instruments (Tobin (1985)) and, consequently, in playing an active role in currency innovation.

⁷ In fact, this is true for domestic as well as foreign users. The U.S. dollar supports trade in many countries and U.S. authorities cannot effectively prevent this from happening.

⁸ This is exactly what happened with Stockholms Banco, the first bank in Sweden. The bank was established in 1656 but folded in 1664 after the general public lost confidence in the banknotes it issued. The bank was then rescued by the Swedish parliament in 1668, and became the Riksbank. See http://www.riksbank.se/en/The-Riksbank/History/.

3 Modern monetary instruments: physical vs. digital

There are many ways to classify the monetary instruments in use today.⁹ Table 1 adopts a conceptual classification based on two basic features: the denomination of the currency instrument — either a sovereign reference unit or not — and its type — physical or not. This is convenient because, on the one hand, modern currencies are typically sovereign but only in (small) part physical; on the other hand, the key technological innovation has been originally confined to instruments, such as Bitcoin, which are purely digital and are not denominated in sovereign reference units.

	Type: Physical	Type: Digital
Denomination: Sovereign reference unit	Notes and tokens (central bank coins & banknotes)	E-money (central bank reserves, commercial bank money) E-cash (RSCoin concept)
Denomination: Other reference unit	Notes and tokens (Ithaca HOURS) ¹⁰	Abstract currencies (Bitcoin, Ethereum)

Table 1. A basic classification	on of modern types o	f monetary instruments
	in or moutin types o	i monetary moti amend

The currencies in existence today are typically issued by a sovereign institution, such as a central bank or a national mint. This is especially true for physical currencies, coins and banknotes. But cash, which is synonymous for physical currency, is not the predominant form of money: for example, U.S. banknotes and coins comprise slightly more than 2/5 of M1, the smaller of the two money stock measures published by the Board of Governors and currently the narrowest monetary aggregate.¹¹ There is no consensus on the language used to describe the money component that lacks the physical structure of cash. I will use the term *digital currency*, to emphasize that the instrument is intangible, and is based on computer technology.

A characteristic of digital currencies is that — unlike banknotes and coins, settlement cannot be completed by a simple physical transfer of the instrument. A ledger — i.e. a record-keeping system — must be in place to establish property rights over the instrument.¹² As a result, users of digital currencies must rely on some trusted institution — an intermediary, a network of banks, or a group of fellow system participants — to help with the processing of transactions and the ledger updating. This is where innovation in cryptography and computing has recently made a big contribution, as I next explain.

3.1 Sovereign digital money: e-money

Most digital currencies are denominated in a sovereign unit, and issued by central banks as well as private institutions — such as commercial banks. I will define *electronic money*,

⁹ For example, the BIS identifies physical tokens, privately issued notes, cash, central bank deposits, commercial bank money, legally recognized e-money and digital currencies as being distinct types of assets (Bank for International Settlements (2015), Figure 1). Some are issued by a central bank, some are not. Some are centrally issued and some are not. Some are physical some are not.

¹⁰ *Ithaca HOURS* is a privately issued fiat currency that has circulated in the city of Ithaca, New York, since 1991 when a local resident issued the first notes. It is accepted by local businesses and residents. One hour is worth \$10 and its supply is currently valued at about \$100,000; see http://www.paulglover.org/hours.html.

¹¹ It includes cash held by the public and transaction deposits at depository institutions. The figure is not that different if we consider the sum of the Federal Reserve's monetary liabilities and the Treasury's monetary liabilities (the monetary base or "high-power money"), where the share of cash is slightly less than 40%. In the U.S., M1 is currently the narrowest monetary aggregate, about 10% smaller than the monetary base.

¹² Roughly speaking, a ledger is needed when physical possession and transfer of an instrument is impossible or insufficient to establish property rights over the instrument.

or *e-money* for short, as an electronic representation of a physical sovereign currency.¹³ As such, e-money has been around for a long time. The main forms of e-money are commercial bank reserves with the central bank and the money created by commercial banks when they make loans. E-money can generate revenue for the issuer, which roughly corresponds to the spread between the yields on securities bought and liabilities issued;¹⁴ the owner of e-money has a claim on the issuer's funds, while e-money represents a liability for the issuer.

Though e-money does not necessarily imply a legal right to a physical currency, it has so far typically implied, or is taken to imply, that owners of e-money can exchange the instrument at par for the underlying physical currency without restriction (e.g. demand deposits). This characteristic is behaviorally important because it may boost confidence in the currency system in periods of uncertainty, since individuals can disintermediate their savings and independently store value by physically hoarding the instrument.¹⁵

Broadly speaking, every financial institution participates in partly maintaining the ledger associated with an e-money system. This ledger is not public. Settlement relies on several layers of trusted institutions (banks, courts, central banks, etc.) and is ultimately accomplished by adjusting the reserves of commercial banks with the central bank (Broadbent (2016)). In this sense, the system is centralized and likely more expensive compared to systems that grant some decentralization. *Blockchain* technology—which essentially is a kind of database that can be easily shared—has made possible the creation of secure bookkeeping systems called *distributed* (or *public*) *ledgers* that can be publicly shared. According to some observers, this database-sharing innovation has the potential to raise the speed of settlement while dramatically lowering settlement costs compared to traditional payments systems (UK Government Office for Science, (2016)).¹⁶ I discuss this next.

3.2 Non-sovereign digital money: abstract currencies

The past ten years have seen the creation of a new class of digital instruments that are not issued by a sovereign institution or commercial bank, are not denominated in a sovereign unit, and do not have physical counterparts. Since these instruments may be used as a currency (though not everyone agrees, e.g., Krugman 2013, Rogoff (2014)), they are variously labeled "electronic cash," "digital currency," "virtual currency," "altcoins," or "cryptocurrencies."¹⁷ What are these digital instruments, why have they been created, and how do they differ from e-money?

The central innovation compared to traditional currencies and traditional digital payment instruments is most of them are based on a distributed ledger in order to avoid reliance on the traditional layers of formal institutions — such central banks, banking authorities, and commercial banks — to process transactions and update ledgers. I will collectively call

¹³ The CPMI's "A glossary of terms used in payments and settlement systems" defines e-money as "value stored electronically in a device such as a chip card or a hard drive in a personal computer" (Bank for International Settlements (2015)). The European Commission has a similar definition: "Electronic money is a digital equivalent of cash, stored on an electronic device or remotely at a server." (see http://ec.europa.eu/finance/payments/emoney/index_en.htm).

¹⁴ In the case of central bank money, this is called seigniorage. It roughly corresponds to the interest income earned from the assets on its balance sheet (Haslag (1998)). A way to empirically calculate it is to take the product between the yield on an appropriately chosen portfolio of securities (typically, government bonds) and base money deflated by the CPI. As the choice of portfolio is somewhat arbitrary, empirical work often measures seigniorage as the change in monetary base normalized by CPI or GDP (Klein and Neumann (1990)).

¹⁵ Ecuador's recently inaugurated Sistema de Dinero Electrónico is based on a mobile-phone electronic wallet denominated in US dollars. The Bank of Ecuador manages the system and backs it by holding 100% physical reserves of U.S. liquid assets (Ecuador Embassy in the US).

¹⁶ This cost-saving aspect is non-trivial. A recent study estimates that half of the social costs of retail payments — amounting to about 0.5% of GDP in the average European country — are incurred by banks (Schiedel at al., (2012)). Indeed, currently payments are settled by exchanging commercial banks' reserves, since these are the players who have sole access to the central bank's balance sheet.

¹⁷ The architect of Bitcoin called it "electronic cash" (Nakamoto (2008)). The European Banking Authority (2014) and European Central Bank (2015a) call the instruments based on blockchain technology "virtual currencies". Some prefer "digital currency" (Broadbent (2016), Ali et al. (2014), Bank for International Settlements (2015)). Others use the words "cryptocurrencies" or "altcoins" (Bitcoin Magazine (2016), Danezis and Meiklejohn (2016)).

this category of new currency instruments *abstract currencies*.¹⁸ They are *currencies* in the sense that they can be exchanged peer-to-peer, much as cash. They are *abstract* in the sense that they neither exist in space nor refer to an existing instrument, physical or financial (for example, deposits). Simply put, they are representations of numbers, i.e., abstract objects.

An abstract currency system is a self-enforcing system of property rights over an abstract instrument, which gives its owners the freedom to use and the right to exclude others from using the instrument. Using the instrument solely consists of digitally hoarding it or transferring ownership to other system participants, according to the system's built-in rules.

Bitcoin

Bitcoin is the first abstract currency system ever created. It appeared on the 3rd of January 2009, when the open source computer code was made public and the first ten bitcoins were created. The system allows the transfer of property rights over abstract objects called "bitcoins" among network participants. The system is built around the blockchain-based distributed ledger framework discussed in Nakamoto (2008). The emission of bitcoins is regulated by a mathematical algorithm that ensures a bounded, predictable bitcoin supply.

Unlike a traditional currency, an abstract currency is not issued by a central authority, is not a claim on any issuer, and is not backed by any central authority (through legal tender status, for example). Being a fiat instrument, an abstract currency acquires value only if its users are confident that the instrument is a safe store of value and its ownership can be easily transferred to someone else in the foreseeable future, in exchange for labor, goods, services, or other stores of value (e.g. other currencies or financial instruments). Since the instrument cannot be physically possessed, this means that property rights over the instrument must be established through some ledger system. The crucial innovation lies in how property rights are established and managed compared to traditional e-money systems.

Nowadays, the exchange of e-money relies on designated trusted intermediaries such as banks and central banks — to update electronic ledgers. Intuitively, this resolves a problem of trust. If counterparts have little or no trust in each other, then trade requires an intermediary that can be trusted *not* to falsify the ledger's records. In traditional currency systems, only specially designated intermediaries can access the ledger. Instead, the original idea behind an abstract currency system (Nakamoto (2008)) is to enable electronic payments *without* having to rely on designated intermediaries. The solution to this problem partly relies on making the history of all transactions completely public through the "blockchain database," also known as the "distributed ledger" ("distributed timestamp" in Nakamoto (2008)).

¹⁸ The term "abstract" uniquely differentiates these instruments from unrelated instruments. For example, stored-value cards are a form of currency that relies on cryptographic technology; commercial bank reserves represent currency in digital form. In the computer-based (i.e., virtual) reality called "Second Life" trades must be completed with Linden dollars; this "virtual currency" thus ends up being traded for US dollars. This is unlike Bitcoin, whose value is not tied to a virtual reality.

How the distributed ledger supports trade

Property rights over an instrument are established by making the history of all transactions public through the blockchain database. One can think of this public ledger as a system-wide database that is transparent and synchronized: every system participant locally stores the entire history of payments. A payment thus simply corresponds to a time-stamped change in record in the public ledger, which takes the form of an addition to the blockchain database. In a way, the blockchain records the ownership trajectory of each instrument over time, as if describing a long chain of events. A transaction is verified as having taken place if there is sufficient consensus among system participants that a proposed change in instrument's ownership does not conflict with the information stored in the database ("Nakamoto consensus"). All valid payments are peer-to-peer — as if exchanging physical cash — and are irreversible.

To build consensus, some system participants must be willing to verify the validity of transactions — impartially and honestly — using computational methods that are made costly and lengthy *on purpose*. Those who choose to verify transactions are called 'miners' because they are compensated with newly created currency. Money creation is tied to settlement. Miners act as private third parties that compete among themselves to provide settlement services but, unlike banks, are unsupervised, unregulated, and face no counterparty risk. Computational burdens, database transparency and competition to verify prevent fraud in the form of double-spending.

Abstract currency payments are not intermediated — although they take place over the internet, they are peer-to-peer like cash — they are settled as soon as enough system participants agree they are valid. A proposed change in the instrument's ownership is valid when there is enough consensus that the change does not conflict with the information contained in the public record.¹⁹ At that point, the transaction is made irreversible and is added to the public record in real time. Roughly speaking, the incentive to commit fraud — which simply means altering records to spend someone else's asset ("double spending") — is removed in two ways. First, validation work is randomly rewarded with a newly created instrument — thus promoting consensus-building through competition on validation. Second, the validation process is constrained to be computationally challenging — thus preventing record falsification by minority coalitions.

An advantage of an abstract currency is that transactions are peer-to-peer, thus avoiding the counterparty risk to which intermediaries are exposed in settling traditional payments. At the same time, an abstract currency grants the convenience of digital transactions with fast settlement²⁰ at a lower cost compared to the digital money currently in use in most countries. For example, the Automated Clearing House network used by U.S. depository institutions to make electronic transfers works through batch processing of transactions, and it only recently started to allow same day settlement (NACHA, (2016)).²¹ However, it

¹⁹ A straight majority of system participants must recognize the transaction as valid. An accessible technical description of the distributed ledger technology can be found in the UK Government Office for Science (2016), Ali et al. (2014a), or Boehme et al. (2015).

²⁰ Bitcoin is neither particularly fast nor easily scalable. Transactions take several minutes to be confirmed and the system, in its current form, is unlikely to scale beyond 100 transactions per second (Decker and Wattenhofer (2015)). Moreover, Bitcoin transactions are typically considered final only after six confirmations, which creates a delay of about an hour before the transaction is validated (Boehme et al. (2015)).

²¹ The U.S. ACH system is a nationwide network through which depository institutions send each other batches of electronic credit and debit transfers (Board of Governors, (2016)). The Federal Reserve Banks and Electronic Payments Network are the two national ACH operators.

must be noted that this characteristic is not unique to blockchain-based payments. Some countries already operate real-time settlement systems that are very fast and the speed-cost advantages of blockchain technology are less clear. For example, Sweden's cell phone-based "Swish" peer-to-peer payments service is supported by a real-time settlement system called BiR; that system could be possibly used for other payments services (Segendorf and Wretman (2015)).

There are also drawbacks in abstract currency systems like Bitcoin: (i) they can only generate a rigid currency supply, which is bounded above in the long-run,²² (ii) they may not be easily "scalable" in the sense that they can only handle low transaction volumes (7 transactions per second for Bitcoin, vs several thousand for Visa, for example), (iii) they are highly volatile instruments, partly because their value is not tied to a sovereign currency, and (iv) they tend to suffer from incentive problems as the network size increases. These practical considerations — as well as public confidence, coordination and stability challenges due to the lack of a central authority — partly motivate recent studies about the conceptual feasibility of sovereign digital currencies based on decentralized ledgers, as discussed below.

3.3 E-cash proposals between abstract currency and e-money

There is currently significant interest from academics and practitioners in the conceptual feasibility of sovereign digital currencies that could be issued by a central authority but that would exploit the flexibility of blockchain technology (Ali et al. (2014b), Barrdear and Kumhof (2016), Bank for International Settlements (2015), Danezis and Meiklejohn (2015)). We are starting to see some proof-of-concept currencies. One example is the Central Bank Digital Currency (CBDC) studied by the Bank of England (discussed below).

As in the case of banknotes and coins, the exchange of this new kind of currency from payer to payee would imply immediate settlement of the transaction. Unlike traditional currencies, and like abstract currencies, transactions would be broadcast to all system participants and would be validated through some consensus protocol. As a result, settlement would not require the exchange of bank reserves at the central bank.

Since these instruments are envisioned as a purely digital version of a coin or a banknote, I will use the terminology *electronic cash*, or *e-cash* for short, to differentiate them from both e-money and abstract currencies.

No e-cash system is yet in place, though some institutions are studying it. Examples include the Central Bank Digital Currency (CBDC) studied by the Bank of England (Broadbent (2016), Barrdear and Kumhof (2016)) and the proof of concept known as RSCoin (Danezis and Meiklejohn (2016)).

²² The rule regulating the emission of bitcoins is built into the system and cannot be altered without reaching consensus among system participants. Roughly speaking, instruments are emitted every time a transaction is validated. The emission rate is designed to decline over time until all emission stops, at which point the supply of instruments can no longer increase.

The RSCoin concept

The study in Danezis and Meiklejohn (2016) proposes an e-cash instrument, called RSCoin, to be issued by a trusted central institution (a central bank, for example). Unlike traditional e-monies, the transaction ledger would not be centrally maintained by the issuing institution. Instead, it would be partially distributed using blockchain technology. This, according to the authors, could allow high rates of transactions at low cost. To support the system, designated authorities called "mintettes" — basically, pre-existing intermediaries such as commercial banks — would be authorized to collect transactions and would ultimately be collectively responsible for producing a consistent, cross-referenced ledger. This ledger would then be sent back to the central institution for final validation. It is unclear if RSCoin would be exchangeable upon demand for physical sovereign currency.

The Bank of Canada is also studying a sovereign currency called CAD-COIN, which would adopt a distributed ledger based on blockchain technology. This instrument is being studied as a way to facilitate wholesale interbank payments, not for use by the general public, and its supply would be tied one-to-one to the amount of cash collateral pledged by system participants, and fully convertible into physical currency (Forbes (2016)). Bank of Tokyo-Mitsubishi is also studying a distributed ledger private currency fully backed by yen, as well as denominated in and convertible into yen (Reuters (2016)).

Recently, several central bankers have started to openly discuss the possibility and consequences of introducing an e-cash alternative to traditional physical currency. The Bank of England's deputy governor for monetary policy has noted that it is now conceptually and technically possible for a central bank to directly issue a new electronic currency in a manner that widens access to its balance sheet beyond commercial banks, not only to non-bank financial companies but even to individuals (Broadbent, (2016)). A deputy governor at the People's Bank of China wrote that central banks should take the lead in developing "digital legal tender of their own" (Fan (2016)). A Federal Reserve Board of Governors member remarked that the distributed ledger technology "may represent the most significant development in many years in payments, clearing, and settlement" (Brainard (2016)). In Sweden, the Riksbank is studying whether or not to meet the general public's need for central bank money by supplying it in some electronic form (Skingsley (2016)).

4 Electronic alternatives to cash: challenges and implications for central banks

Private issuers have readily exploited blockchain technology to offer electronic currencies of their own (collectively called "altcoins") such as *Ethereum*, and *Litecoin*,²³ partly to address some of the shortcomings identified with Bitcoin (Danezis and Meiklejohn (2016)). Given this, is there scope for a central bank to take a leading role in developing and issuing e-cash? This section helps form an answer by focusing on three classes of problem associated with issuing a new currency instrument—public confidence in the currency, avoiding coordination failures, and ensuring financial system stability—three problems that may give rise to market failures and create scope for a central bank-issued currency beyond the obvious benefit of obtaining seigniorage revenue.

²³ See https://coinmarketcap.com/ for a snapshot of current market capitalization of these altcoins. At the time of writing, more than 600 altcoins are being traded and the total market capitalization is \$11.4 billion, 80% of which is associated with Bitcoin.

4.1 Confidence

A currency system is self-sustaining when the public has trust in the feasibility of the underlying trading arrangement. In practice, this means that system participants must have confidence in the currency's future value and acceptability. Ultimately, this requires confidence in the issuer, so an essential characteristic of any currency is *on whom* it is a claim. Do private and public issuers have differential advantages in supporting confidence in a currency instrument?

Historically, public confidence in a currency largely referred to the quality of the coins that formed the basis of the currency. States had an obvious advantage in guaranteeing this quality over private issuers, not only because they could set and enforce quality standards more easily than private issuers, but also because states can internalize the long-run benefits of a stable currency, thus strengthening the incentive to avoid debasements (Goodhart (1998)).

Unredeemable currencies exhibit a similar confidence problem. In a fiat monetary system, the currency's value is a projection of its *expected* future acceptability and trading value. Confidence in a currency thus largely depends on expectations about the issuer's future actions. And here lies the central problem. Issuing currency generates a benefit for an issuer, through the interest income earned from the assets it acquires (seigniorage). There is thus a temptation to behave opportunistically and overissue currency. *Confidence* in a currency exists when the public believes that the issuer will not emit currency beyond the point where the currency's value will become unstable or rapidly decline. Lack of confidence in the issuer is a serious threat to a fiat currency. It can lead people to believe that the currency might no longer be accepted on some future date. If so, then we would witness a hyperinflationary spiral (Faust (1989)) or, at worst, the currency's value would immediately collapse (Cass and Shell (1980)).

Although current thinking in monetary theory pays little attention to the role of governments in establishing a currency,²⁴ some studies have emphasized that a credible public issuer might have a confidence advantage over private issuers.

First, currency systems are public goods and private issuers may not give sufficient weight to the externalities generated by money creation and so may end up oversupplying it. By contrast, governments can more easily internalize these externalities, and thus better mitigate the risk of a currency oversupply. If so, a sovereign currency system is less likely to suffer from confidence problems than a privately issued currency (Ritter (1995)). A related issue is enforcement of the quality of the currency. Governments typically control or operate the institutions that enforce the rules governing a society. Hence, there can be advantages from vertical integration of the two tasks of emitting currency and enforcing the currency emission rules. The design of Bitcoin reflects an attempt to resolve this crucial enforcement problem without relying on central institutions. In doing so, it creates other kinds of problems—for example, an inelastic currency supply and an inability to control illicit financial flows. This speaks in favor of a sovereign e-cash system.

Second, public monitoring of conduct is known to help mitigate temptations to behave opportunistically (Abreu, Pearce, and Stacchetti (1990)). The public can more easily monitor the actions taken by a central bank compared to those taken by a private issuer. This is likely to enhance the stability and value of the currency, because it allows a quick and coordinated response to socially undesirable policies, thus removing the incentives to stray from optimal policy in the first place.

Third, short planning horizons weaken the incentive to keep promises compared to having a long-run horizon (Friedman (1971)). Hence, the planning horizon affects the

²⁴ Goodhart (2009) notes: "economists have tended to ignore historical reality, to establish formal mathematical models of how private agents (with no government), transacting among themselves, might jointly adopt an equilibrium in which they all settle on a common monetary instrument."

incentive to manipulate the currency supply. A currency issuer that is motivated by shortrun objectives has stronger incentives to manipulate the currency supply to extract shortrun rents compared to an issuer pursuing long-run objectives. Central banks tend to have longer planning horizons compared to private issuers. This allows central banks to internalize the social costs that monetary instability has in the long run. This long-run perspective is reinforced for central banks that are independent of the political authorities, as political authorities may be more easily tempted by the possibility of attaining short-term gains. Having a long-run view seems especially important in periods of uncertainty, to maintain confidence in the currency and avoid self-fulfilling currency collapses.

Self-fulfilling currency collapses

The value of a fiat currency is linked to *expectations* about its future acceptability as a means of payment. If confidence in an existing currency rapidly deteriorates, or if there is no sufficient confidence in a new currency, then the currency value will collapse to zero. To illustrate this, note we accept a currency in exchange for goods and services only if we believe that the currency can be easily spent. If we all think this way, then the currency is broadly accepted, thus confirming (or fulfilling) the initial belief in the currency's value. On the other hand, we will *not* accept a currency if we doubt that others want it. If we all share this view, then the currency will not be broadly accepted, thus confirming the initial belief. Here, the currency's value collapses to zero. This outcome is self-fulfilling because it is entirely driven by initial beliefs. Simply put, if the public *doubts* that others will want a currency instrument, then that instrument's value will quickly collapse.

Finally, in many countries, sovereign currencies have a well-established history of use and monetary authorities are trusted; this may prove to be an advantage for a national e-cash system over privately issued alternatives. In countries with trusted and well-functioning monetary institutions, a sovereign issuer could leverage the pre-existing trust to more easily build confidence in a new currency instrument, compared to private issuers.²⁵

Overall, these considerations suggest that a sovereign issuer is in a unique position because it can more easily internalize the externalities associated with introducing a new currency, and can more easily build confidence in the instrument's stability compared to private issuers. However, additional research is needed on this topic. Empirical evidence would be especially valuable.

4.2 Coordination problems

When more than one instrument exists that can serve the role of a currency, then the choice of instrument to use may become a problem. The reason is that there could be miscoordination resulting in partial adoption of multiple instruments instead of the common adoption of a single one. This fragmentation of payment methods is a source of inefficiency because it complicates settlement and raises its cost.

To understand this point, suppose two fiat currency instruments exist in fixed supply and only differ in their color. Individuals independently select which one to adopt. Here, one of the two instruments may be accepted by everyone, but it may also happen that none are wholly accepted (Kiyotaki and Wright (1993)). This second scenario is inefficient because the instruments' fragmented use may sometimes prevent trade from taking place. In this sense, money shares many similarities with language (Polanyi, (1957)). Coordinating on a single

²⁵ This does not mean, of course, that states are necessarily trustworthy currency providers. The hyperinflationary experience in Zimbabwe in the first decade of this century, and the recent and sudden de-monetization in India come to mind.

language is beneficial because the greater the number of people who speak a language, the more valuable it is to speak *that* language. The same holds true for money. These are known as "network effects" or "strategic complementarities," meaning that individuals benefit from making identical choices (Cooper and John (1988)).

Coordination problems as a two-person game

Eva and Isabella must independently choose one of two communication systems, A or B. Their joint choices determine if a communication system will be set up, and how they will share a prize V from setting it up:

Outcome	Payoff
AA	Eva earns 60 percent of V, and Isabella earns 40 percent
AB	No communication system is set up and no prize is won, so both earn 0
BA	No communication system is set up and no prize is won, so both earn 0
BB	Eva earns 40 percent of V, and Isabella earns 60 percent

Eva and Isabella want to coordinate on *some* common system to avoid a total failure. In the language of economics there is a positive network externality. But there is also strategic uncertainty because, though *AA* and *BB* are both equilibria, neither Eva nor Isabella is sure what the other will do. In fact, their interests are conflicting because Eva prefers *AA*, but Isabella prefers BB. If either *AB* or *BA* is realized, then we have a *coordination failure*. Having a third party acting as a coordinator may help.

Numerous studies have found that miscoordination commonly occurs in simple coordination games (van Huyck et al. (1990)) as well as in more complex tasks. For example, payment arrangements may be inefficiently selected (Camera et al. (2016)) and it is difficult to coordinate on a smooth transition from an "inferior" to a "superior" currency (Camera at al. (2003)). Habit can play an important role in leading to an inefficient selection of payment methods (van der Horst and Matthijsen (2013)).

These observations suggest there is scope for a public institution to serve as the sole issuer of the currency. A sovereign issuer can help resolve coordination problems by granting legal tender status to a newly issued instrument. A drawback of granting legal tender status to a new instrument is that it effectively imposes a constraint on the choice of payment instrument, which may itself be suboptimal. A government can also set a standard by requiring a new state-issued currency in payment for taxes—something known as the tax-foundation theory of money (Starr (1974), Goldberg (2012)).

4.3 Stability

A major open question is whether introducing a digital alternative to a traditional currency can induce instability in the monetary and financial system, and why this may happen. Here, I consider four aspects of this problem that have been discussed but that should be more carefully studied.²⁶

Design of the instrument

Letting a central bank issue e-cash could induce instability by creating changes in the funding base of banks and would thereby alter the relation between banks and the central bank

²⁶ Barrdear and Kumhof (2016) discusses a wider variety of stability issues.

— possibly generating disintermediation in times of crisis. As an illustration, suppose that the central bank issues e-cash in a manner that gives direct access to its balance sheet to households — not only financial institutions. This could be as simple as a liquidity deposit, or could be more sophisticated. For example, central bank e-cash could pay some interest, thus coming into direct competition with the traditional role of commercial banks (Broadbent, (2016)). Either way, by design this instrument would be quickly and cheaply transferable from and to intermediaries. This might increase financial market volatility. In normal times, volatility could be induced by stochastic flows of deposits in and out of e-cash. In periods of uncertainty, households might seek the safety of the central bank, thus giving rise to rapid outflows of funds from commercial banks, as in a digital version of the classic bank run. This kind of volatility in funding liquidity would naturally have implications for the way banks fund their projects and for the cost of deposit insurance. On the other hand, interest-bearing e-cash could improve the stabilization of the business cycle (Barrdear and Kumhof (2016)).

The impact of interest-bearing e-cash is, for natural reasons, still an open question. Empirically, there are reasons to be cautious. I am not aware of historical examples in which an interest-carrying currency has been at the heart of a stable currency system, widely circulating side-by-side, or instead of, a non interest-bearing currency.²⁷ On the other hand, the technical opportunity to issue such an instrument has not emerged until now. The uncertain consequences of an interest-bearing currency may be purely behavioral: individuals might attempt to hoard it and speculate on its value (Camera et al. (2003)). The public may also perceive different currency instruments as being only partially fungible, leading to an inefficient use, for example using interest-paying e-cash to store value but not as a currency, as per some form of "mental accounting" (Thaler (1999)).²⁸ These kinds of problems can presumably be minimized by letting the central bank offer individual deposit accounts that are a modern version of Tobin's *deposited currency*: a plain, non-interest bearing cash-like instrument, 100% backed and payable on demand in cash (Tobin (1985)). Blockchain technology indeed seems to offer a cost-effective means to emit and manage this type of instrument.

Lack of explicit anchors

Letting private issuers provide e-cash may induce price instability, if price floors cannot be easily established. The experience with abstract currencies suggests that it may indeed be difficult to find price floors (a nominal anchor) with privately-issued electronic currencies. Bitcoin, for example, is very volatile and, for this reason, has been criticized for being an unstable store of value and, therefore, unsuitable as a currency (Krugman (2013)). Instability is a problem because it gets in the way of widespread adoption. One can apply evolutionary arguments to formalize this point by studying the stability of a fiat currency system when many individuals make independent adoption decisions. The system will collapse if the initial currency value has too low a price floor, as this negatively interferes with the dynamics of adoption and use (Camera et al. (2013)). Sovereign e-cash would reduce these risks, by providing explicit anchors such as making the new instrument legal tender, accepting it to discharge tax obligations, or accepting it in exchange for government debt. Central bank e-cash issued against government debt could also support financial stability (Barrdear and Kumhof (2016)).

²⁷ Arkansas offers one historical example where, for a couple of years during the Civil War, small denomination bonds circulated.
But that happened only after they became receivable for taxes at par (Burdekin and Weidenmier (2008)).
28 According to this theory, different types of economic activities are uniquely assigned to special accounts, each with its own

budget constraint. As a result, a dollar destined to be spent on a vacation is not perceived as being the same as a dollar to be spent on groceries.

The transition to a cashless society

Phasing out cash, to make space for e-cash, is another potential source of instability. Convertibility upon demand into banknotes or coins, or some other tangible store of value is important for traditional e-money, and it should remain an important element of competition between traditional and alternative currencies, especially in periods of financial instability. Cash is considered a "safe haven" in periods of crisis or negative interest rates. For example, some institutional investors are currently implementing physical cash-hoarding strategies and respectable fund managers are advocating storing physical currency to better diversity portfolios (Bloomberg (2016b), The Telegraph (2015)). However, if e-cash and cash coexist, then the tradeoff between e-cash and cash may create significant swings in currency flows in and out of depository institutions in periods of crisis. This concern may suggest a reason to gradually phase out physical currency, once an electronic alternative is made available. Another advantage of doing central banking without circulating coins and banknotes is that the liquidity would never leave the system. Depending on how the system is constructed, this might decrease vulnerability to bank runs. For example, Broadbent (2016) notes that, if the central bank engaged in deposit taking, then it might make deposits safer because "the central bank can't run out of cash and therefore can't suffer a 'run'." This would also affect other costs, as it would impact the way in which banks finance their lending activities. This is something that should be carefully studied.

Phasing out physical cash could also effectively remove the zero lower bound on interest rates — so central bank e-cash could easily support negative interest rates.²⁹ This is because current monetary models assume zero nominal interest rates as the lower bound of monetary policy. Below zero, there is an arbitrage opportunity available (Hicks (1935) and (1937)), as borrowing to buy cash is profitable and it is preferable to convert deposits into cash. Issuing e-cash while abolishing physical cash could thus — according to some observers — expand the set of monetary policy options. If policy is ineffective at the zero lower bound, then this could be an advantage in periods of crisis, as it would simplify the implementation of monetary policy. A caveat is that it is unclear whether the zero lower bound reduces the effectiveness of monetary policy (Swanson and Williams (2014)). Moreover, there already exists an array of non-standard policy instruments that offer opportunities for central banks to overcome zero lower bound constraints (Cœuré (2015)). Naturally, we do not yet know the consequences of charging rates below a negative value that accounts for the costs of storing and shipping cash for a prolonged period of time. Although some have noted this may create instability (Bech and Malkhozov (2016)),³⁰ this remains an important research question.

System security

Physical cash is subject to the problem of counterfeiting, but e-cash is unlikely to be immune from security problems either. An e-cash system would take the form of a network operating through internet connections. Governments have been known to purposefully shut down internet traffic on a regional or local scale to achieve political objectives.³¹ Large scale internet disruptions can also occur that are entirely accidental, as happened in Algeria in 2015 when an undersea cable was cut, or could be intentional. Another problem is the possibility of distributed-denial-of-service attacks that shut down specific internet sites. Attacks of this type are becoming increasingly sophisticated and common against governments and private companies alike (NYT (2016)), which is a concern because

²⁹ According to the deputy governor of the Bank of England: "[...] were a CBDC fully to displace paper currency, that would open the door to the possibility of materially negative interest rates [...] But that would require explicitly abolishing cash, not just introducing an electronic alternative." (Broadbent (2016)).

³⁰ The demand for cash has so far remained stable in those countries with negative interest rates; Bech and Malkhozov (2016) note that "the fact that retail bank customers have so far been shielded from negative rates has probably played a key role in keeping the demand for cash stable."

³¹ Recently, Bahrain shut down local internet access to thwart protests. https://bahrainwatch.org/blog/2016/08/03/bahraininternet-curfew/.

blockchain-based instruments such as Bitcoin are typically managed and stored using website-based applications. The security of protocols to avoid "double spending" of the instrument is also something that should be thoroughly investigated. On the positive side, an e-cash system has the potential to be rapidly put to use nationwide during a crisis, when the only alternative would be transporting and distributing physical cash over a large area. From this perspective, an e-cash system could increase stability in times of crisis and boost the overall resilience of the payments system. Naturally, the e-cash system should be designed to ensure wide and easy access to liquidity across the whole of society, including vulnerable citizens such as elderly or disabled people.

5 Additional considerations

There are two additional issues that a central bank should consider in studying the possibility of issuing e-cash. One is the size of externalities associated with the use of physical currency in illicit and criminal activities. The other involves the implications that e-cash would have for the privacy of individuals.

5.1 Cash and crime

Some observers have asserted that cash and, in particular, large denomination notes are empirically integral to crime and tax evasion, and so should be eliminated. Rogoff (2014) asserts that the "major uses [of cash] seem to be buried in the world underground and illegal economy." Sands (2016) claims that "Illegal money flows pose a massive challenge to all societies, rich and poor." Summers (2016) calls for "a global agreement to stop issuing notes worth more than say \$50 or \$100."

This newfound interest in the connection between cash and crime is noteworthy and puzzling at the same time. First, it seems to imply causality, that cash ultimately causes crime, when, in fact, we should be talking about correlation. Even so, it is hard to quantify how massive the "challenge to all societies" stemming from the correlation between crime and cash is relative to, say, crime and fraudulent accounting practices (e.g., Enron or Parmalat frauds) or crime and commercial bank money (e.g. lending by Italy's BNL branch in Atlanta during the 80s). It is true that increasing the costs from using cash could decrease the amount of crime correlated with it. However, on the one hand, this might as well lead to instrument substitution not problem resolution (e.g. consider the questionable uses of Bitcoin) and, on the other hand, if cash exists to facilitate trade, then it is an empirical question how the inefficiency induced by removing cash would stack against the efficiency gain from reducing cash-related negative externalities (Camera (2001)).

Second, the view that removing large denomination notes is instrumental to fighting crime seems naïve. Large denomination banknotes are usually the dominant component in the sovereign currency supply. In the U.S., \$100 bills represent about ¾ of the total currency supply. Prohibiting, or stigmatizing, possession of those notes would simply shift demand to the remaining ¼ of smaller-size banknote supply. This would surely increase the cost to criminals,³² but would also create shortages and increased cash-management costs for everyone else. Finally, there does not seem to be much empirical evidence that removing large denomination notes is instrumental in fighting crime: in the U.S., large denomination notes have been removed over time — this has also happened in Sweden — but one could hardly make the case that this ultimately led to a general decrease in criminal activity. Additional empirical research in this area would be beneficial.

³² One of the advantages of larger sizes is less onerous storage and transportation. One million dollars composed of \$100 bills fits in a small backpack.

5.2 Privacy

One of the unique traits of cash transactions is that they help preserve privacy, which is a basic human right.³³ It has been argued that, since cash enhances privacy, then cash must be primarily used to hide misconduct and so it should be eliminated. This argument suffers from a basic fallacy (not all those who prize privacy commit crimes) and again implies causality (privacy ultimately causes misconduct) that has not been established as far as I know. Furthermore, privacy is an important element of many activities — such as research with patent application potential or strategic business decisions — where economic agents have nothing to hide from enforcement agencies or contractual counterparties (Solove (2011)). As a result, the privacy offered by currency-based transactions may be beneficial if information is likely to be misused by opportunistic counterparties (Kahn et al. (2005)). In summary, the tradeoff between advantages and disadvantages of a currency that cannot guarantee privacy is potentially difficult, and should be carefully considered in setting up an e-cash system.

6 Conclusion

Technological innovation has opened the door to cash-like instruments that are electronic and no longer require the costly layers of financial intermediaries we use nowadays to settle payments. Instruments with features of this kind — variously called digital, crypto, and virtual currencies — have so far been supplied by private issuers. But currency systems are public goods, and private currencies are more likely to be associated with risks and inefficiencies, such as credibility, instability and volatility, compared to sovereign currencies issued by countries with historically efficient institutions. This suggests there could be societal benefits from public players — such as a trusted central bank — playing a primary role in currency innovation.

A central bank with a track record of being independent is in a unique position to ensure continuity and confidence in the payment system by providing a clear framework and price anchors for the new currency instrument, something that is an issue in the volatile world of privately-issued abstract currencies such as Bitcoin. To further increase trust, the framework should explicitly discuss — through legally binding agreements — if e-cash is convertible into cash upon demand, and if there are limits to the central bank's ability to charge negative interest rates or charge fees on e-cash accounts, as a way to limit the perceived downside risk of e-cash. A clear operating framework is also behaviorally important to maximize use and adoption of an electronic alternative to cash.

How should a new e-cash system be organized? I do not see many advantages in adopting a strongly centralized structure, one in which the central bank issues the currency instrument and *also* provides services or products that have been traditionally offered by commercial banks on currency deposits. In fact, depending on how the system is set up, there may not be a clear distinction between e-cash and deposits (Broadbent (2016)). It is reasonable to leverage the comparative advantage of the financial sector in providing financial services and to develop products that suit individuals and businesses' needs. In this scenario, the central bank would take the primary role of issuing the new currency instrument, designing the architecture of the system, and setting the operating standards.

Many questions, theoretical and empirical, remain open. Future central bank research should be devoted to (i) narrowing down a set of possible operating frameworks to set up an e-cash system, (ii) assessing and quantifying the possible risks during the transition period, (iii) studying the consequences for the structure of banks and the monetary transmission channels, and (iv) identifying new tools and procedures to manage those risks.

³³ Privacy is discussed in Article 12 of The Universal Declaration of Human Rights. http://www.un.org/en/universal-declarationhuman-rights/index.html.

One problem with providing answers to some of these questions is the lack of data. For example, how would the payment system function without traditional physical currency? And would it be optimal to simply remove all physical cash or could there be unintended repercussions for the stability of the monetary and financial system? Naturally, we have no field data that can shed empirical light on these kinds of questions. A viable solution would be for central banks to adopt the experimental methodology (Smith 1994) of collecting laboratory data to study a relevant theoretical operating principle, or to establish empirical regularities. For instance, if a theory suggests a given set of conditions under which phasing out physical cash is optimal, then laboratory experiments may help us validate that intuition, and determine if there are theoretically unforeseen aspects that should be taken into account.

The emergence of new currency-like instruments such as Bitcoin is a game-changer in our societies. It opens the door to transferring and storing value in ways that are simpler, faster and truly global. Many of the questions that revolve around this paradigm shift are still open, so the considerations I have made in this document should not be taken to be conclusive findings. My intention is to offer a perspective — at times speculative — which is based on existing theoretical and behavioral research in economics, which I hope can be helpful to those approaching the topic of currency innovation.
7 References

Abreu, D., D. Pierce and E. Stacchetti (1990), "Toward a Theory of Discounted Repeated Games with Imperfect Monitoring", *Econometrica*, Vol. 58, pp. 1041-1063.

Ali, R, J. Barrdear, R. Clews and J. Southgate (2014a), "Innovations in Payment Technologies and the Emergence of Digital Currencies", *Bank of England Quarterly Bulletin*, Vol. 54, No. 3, pp. 262-275.

Ali, R, J. Barrdear, R. Clews and J. Southgate (2014b), "The Economics of Digital Currencies", *Bank of England Quarterly Bulletin*, Vol. 54, No. 3, pp. 276-286.

Alsterlind, Jan, Hanna Armelius, David Forsman, Björn Jönsson and Anna-Lena Wretman (2015), "How Far can the Repo Rate be Cut?" Sveriges Riksbank Economic Commentaries, No. 11.

Bank for International Settlements (2015), *Digital Currencies*, Committee on Payments and Market Infrastructures.

Barrdear, John and Michael Kumhof (2016), "The Macroeconomics of Central Bank Issued Digital Currencies", Staff Working Paper No. 605, Bank of England.

Bech, Morten and Aytek Malkhozov (2016), "How have Central Banks Implemented Negative Policy Rates?", Bank for International Settlements Quarterly Review, pp. 31-44.

Bitcoin Magazine (2016), "Are Any Altcoins Currenty Useful? No, Says Monero Developer Riccardo Spagni", March 23rd, available at https://bitcoinmagazine.com/articles/are-any-altcoins-currenty-useful-no-says-monero-developer-riccardo-spagni-1458743546

Bigoni, M., Camera, G. and M. Casari (2015) "Money is More than Memory", Working Paper No. 14-17, Economic Science Institute, Chapman University.

Bloomberg (2016a), "Blythe Masters Firm Raises Cash, Wins Australian Contract", January 21, 2016.

Bloomberg (2016b), "Cash in Vaults Tested by Munich Re", available at www.bloomberg.com/news/ articles/2016-03-16/munich-re-rebels-against-ecb-with-plan-to-store-cash-in-vaults.

Board of Governors of the Federal Reserve System (2016), *Currency and Coin Services*, available at www.federalreserve.gov/paymentsystems/coin about.htm

Boehme, Rainer, Nicolas Christin, Benjamin Edelman and Tyler Moore (2015), "Bitcoin: Economics, Technology, and Governance", *Journal of Economic Perspectives*, Vol. 29, No. 2, pp. 213-238.

Brainard, Lael (2016), "Distributed Ledger Technology: Implications for Payments, Clearing, and Settlement", speech at Institute of International Finance Annual Meeting Panel on Blockchain.

Broadbent, B. (2016), "Central Banks and Digital Currencies", speech at London School of Economics on 2-3-2016.

Burdekin R. and M. Weidenmier (2008), "Can Interest-Bearing Money Circulate? A Small-Denomination Arkansan Experiment, 1861-63", *Journal of Money, Credit and Banking*, Vol. 40, No. 1, pp. 233-241.

Camera, G. (2001), "Dirty Money", Journal of Monetary Economics, Vol. 47, No. 2, pp. 377-415.

Camera, G. and M. Casari (2009), "Cooperation among Strangers Under the Shadow of the Future", *American Economic Review*, Vol. 99, No. 3, pp. 979-1005.

Camera, G. and M. Casari (2014), "The Coordination Value of Monetary Exchange: Experimental Evidence", *American Economic Journal: Microeconomics*, Vol. 6, No. 1, pp. 290-314.

Camera, G., M. Casari and M. Bigoni (2012), "Cooperative Strategies in Anonymous Economies: an Experiment", *Games and Economic Behavior*, Vol. 75, pp. 570-586.

Camera, G., Casari, M. and M. Bigoni (2013), "Money and Trust among Strangers", proceedings of the National Academy of Sciences, Vol. 110, No. 37 pp. 14889-14893.

Camera, G., Casari, M. and S. Bortolotti (2016), "An Experiment on Retail Payments Systems", *Journal of Money, Credit and Banking*, Vol. 48, No. 2-3, pp. 363-392.

Camera, G., C. Noussair, and S. Tucker (2003), "Rate-of-Return Dominance and Efficiency in an Experimental Economy", *Economic Theory*, Vol. 22, No. 3, pp. 629-660.

Cass D. and K. Shell (1980), "In Defense of a Basic Approach", *Models of Monetary Economies*, pp. 251-260, Ed. by Kareken, J. and N. Wallace, Minneapolis: Federal Reserve Bank of Minneapolis.

Cœuré, Benoît (2015), "How Binding is the Zero Lower Bound?", Conference speech, 18 May 2015, available at www.ecb.europa.eu/press/key/date/2015/html/sp150519.en.html.

Cooper, Russell and Andrew John (1988), "Coordinating Coordination Failures in Keynesian Models", *Quarterly Journal of Economics*, Vol. 103, No.3, pp. 441-463

Corbae, D, T. Temzelides and R. Wright (2003), "Directed Matching and Monetary Exchange", *Econometrica*, Vol. 71, No. 3, pp. 731-756.

Danezis, George and Sarah Meiklejohn (2016), "Centrally Banked Cryptocurrencies", available at www0. cs.ucl.ac.uk/staff/G.Danezis/papers/ndss16currencies.pdf.

Decker, Christian and Roger Wattenhofer (2015), "A Fast and Scalable Payment Network with Bitcoin Duplex Micropayment Channels", Stabilization, Safety, and Security of Distributed Systems, *Lecture Notes in Computer Science*, Vol. 9212, pp. 3-18. Springer International Publishing.

The Economist (2015), "The Great Chain of being Sure about Things", October 21st edition.

Ecuador Embassy in the US, "10 Things to Know about Ecuador's Electronic Payment System", available at www.ecuador.org/blog/?p=4184.

European Banking Authority (2014), EBA opinion on 'virtual currencies, EBA/Op/2014/08.

European Central Bank (2015a), *Virtual Currency Schemes – a further analysis*, available at www.ecb. europa.eu/pub/pdf/other/virtualcurrencyschemesen.pdf.

European Central Bank (2015b), "What is Money?", available at www.ecb.europa.eu/explainers/tellme-more/html/what_is_money.en.html.

Fan, Yifei (2016), "On Digital Currencies, Central Banks Should Lead", *Bloomberg View*, September 1, available at www.bloomberg.com/view/articles/2016-09-01/on-digital-currencies-central-banks-should-lead.

Faust, J. (1989), "Supernovas in Monetary Theory: Does the Ultimate Sunspot Rule out Money?" American Economic Review, Vol. 79, No. 4, pp. 872-881.

Friedman, James W. (1971), "A Non-Cooperative Equilibrium for Supergames", *Review of Economic Studies*, Vol. 38, pp. 1-12.

Goldberg, D. (2012), "The Tax-foundation Theory of Fiat Money", *Economic Theory*, Vol. 50, pp. 489-497.

Goodhart, Charles A.E. (1998), "The two concepts of money: implications for the analysis of optimal currency areas", *European Journal of Political Economy*, Vol. 14, pp. 407-432.

Greif, Avner (2006), "The Birth of Impersonal Exchange: The Community Responsibility System and Impartial Justice", *Journal of Economic Perspectives*, Vol. 20, No. 2, pp. 221-236.

Hancock, Diana and David B. Humphrey (1998), "Payment Transactions, Instruments, and Systems: A Survey", Journal of Banking & Finance, Vol. 21, pp. 1573-1624.

Haslag, Joseph H. (1998), "Seigniorage Revenue and Monetary Policy", Federal Reserve Bank of Dallas Economic Review, pp. 10-20.

Hicks, J.R. (1935), "A Suggestion for Simplifying the Theory of Money", *Economica*, Vol. 2, No. 5, pp. 1-19.

Hicks, J. R. (1937), "Mr. Keynes and the "Classics"; A Suggested Interpretation", *Econometrica*, Vol. 5, No. 2, pp. 147-159.

Humphrey, David B, Moshe Kim and Bent Vale (2001), "Realizing the Gains from Electronic Payments: Costs, Pricing, and Payment Choice", *Journal of Money, Credit and Banking*, Vol. 33, No. 2, pp. 216-34.

Humphrey, David B. (2010), "Retail payments: New contributions, empirical results, and unanswered questions", *Journal of Banking and Finance*, Vol. 34, pp. 1729-1737.

Huynh, Kim, Schmidt-Dengler, P., Stix, H. (2013), "Whenever and Wherever: The Role of Card Acceptance in the Transaction Demand for Money", unpublished manuscript, Bank of Canada.

Kahn, Charles M., James McAndrews and William Roberds (2005), "Money is Privacy", International Economic Review, Vol. 46, No. 2, pp. 377-399.

Kandori, M. (1992), "Social Norms and Community Enforcement", *Review of Economic Studies*, Vol. 59, No. 1, pp. 63-80.

Klee, E. (2008), "How People Pay: Evidence from Grocery Store Data", *Journal of Monetary Economics*, Vol. 55, pp. 526-541.

Klein, M. and M. Neumann (1990), "Seigniorage: What is it and Who gets it?", Weltwirtschaftliches Archiv, Vol. 126, 205-221.

Kocherlakota, Narayana R. (1998), "Money is Memory", *Journal of Economic Theory*, Vol. 81, No. 2, pp. 232-51.

Krugman, Paul (2010), "What Is Money?, New York Times, December 15th edition.

Krugman, Paul (2013), "Bitcoin is Evil", New York Times, December 28th edition.

McLeay, Michael, Amar Radia and Ryland Thomas (2014), "Money in the Modern Economy: an Introduction", Bank of England Quarterly Bulletin, pp. 4-13.

Milgrom, Paul R., Douglass C. North, and Barry R. Weingast (1990), "The Role of Institutions in the Revival of Trade: The Law Merchant, Private Judges, and the Champagne Fairs", *Economics and Politics*, vol. 2, No. 1, pp. 1-23.

NACHA (2016), "What is ACH?: Quick Facts About the Automated Clearing House (ACH) Network", available at www.nacha.org/news/what-ach-quick-facts-about-automated-clearing-house-ach-network.

Nakamoto, Satoshi (2008), "Bitcoin: A Peer-to-Peer Electronic Cash System", available at https://bitcoin. org/bitcoin.pdf.

New York Times (2016), "Australia's Controversial Census in Chaos After Possible Cyber Attack", August 10.

Ostroy, Joseph M. (1973), "The Informational Efficiency of Monetary Exchange", American Economic Review, vol. 63, No. 4, pp. 597-610.

Ostroy, Joseph M. and Ross M. Starr (1974), "Money and the Decentralization of Exchange", *Econometrica*, Vol. 42, No. 6, pp. 1093-1113.

Ostroy, Joseph M., and Ross M. Starr (1990), "The Transactions Role of Money", *Handbook of Monetary Economics*, Vol. 1, eds. Benjamin M. Friedman and Frank H. Hahn, pp. 3-62, Elsevier: Amsterdam.

Polanyi, Karl (1957), "The Semantics of Money Uses", reprinted in *Primitive, Archaic and Modern Economies: Essays of Karl Polanyi*, G. Dalton, ed. Garden City: Doubleday, pp. 175-190.

Ritter, J. A. (1995), "The Transition from Barter to Fiat Money2, *American Economic Review*, Vol. 85, No. 1, pp. 134-149.

Rogoff, Kenneth S. (2014), "Costs and Benefits to Phasing Out Paper Currency", Forthcoming, *NBER Macroeconomics Annual*, Vol. 29, ed. Jonathan Parker and Michael Woodford. University of Chicago Press: Chicago, IL.

Sands, Peter (2016), "Making it Harder for the Bad Guys: The Case for Eliminating High Denomination Notes", Harvard University, M-RCBG Associate Working Paper No. 52, Harvard Kennedy School.

Schmiedel, H., G. Kostova and W. Ruttenberg (2012), "The Social and Private Costs of Retail Payment Instruments – A European Perspective", Occasional Paper No. 137, European Central Bank.

Segendorf, Björn and Thomas Jansson (2012), "The Cost of Consumer Payments in Sweden", Working Paper No. 262, Sveriges Riksbank.

Segendorf, Björn and Anna Wilbe (2014), "Does Cash have Any Future as Legal Tender?", Sveriges Riksbank Economic Commentaries, No. 9.

Segendorf, Björn and Anna-Lena Wretman, (2015), "The Swedish Payment Market in Transformation", Sveriges Riksbank Economic Review, No. 3.

Skingsley, Cecilia (2016), "Should the Riksbank issue e-krona?", Speech at FinTech Stockholm on 16-11-2016.

Solove, D. J. (2011), Nothing to Hide: The False Tradeoff between Privacy and Security, Yale University Press.

Smith, Vernon L. (1994), "Economics in the Laboratory", *Journal of Economic Perspectives*, Vol. 8, No. 1, pp. 113-131.

Starr, R.M. (1974), "The Price of Money in a Pure Exchange Monetary Economy with Taxation", *Econometrica*, Vol. 42, pp. 45-54.

Summers, Larry (2016), "It's Time to Kill the \$100 Bill", The Washington Post, February 16.

Swanson, Eric T. and John C. Williams (2014), "Measuring the Effect of the Zero Lower Bound on Medium- and Longer-Term Interest Rates", *American Economic Review* Vol. 104, pp. 3154-3185.

The Telegraph (2015), "It's Time to Hold Physical Cash,' Says One of Britain's Most Senior Fund Managers." By A. Oxlade, 20 June 2015, available at www.telegraph.co.uk/finance/personalfinance/ investing/11686199/Its-time-to-hold-physical-cash-says-one-of-Britains-most-senior-fund-managers. html.

Townsend, R. (1987), "Economic Organization with Limited Communication", *American Economic Review*, Vol. 77, No. 5, pp. 954-971.

Tobin, James (1985), "Financial Innovation and Deregulation in Perspective", *Bank of Japan Monetary and Economic Studies*, Vol. 3, No. 2, pp. 19-29. Reprinted in Y. Suzuki and H. Yomo, eds., *Financial Innovation and Monetary Policy: Asia and the West*, Tokyo: University of Tokyo Press (1986), pp. 31-42.

UK Government Office for Science (2016), "Distributed Ledger Technology: Beyond Block Chain", UK Government Chief Scientific Adviser.

Van der Horst, Frank and Ester Matthijsen (2013), "The Irrationality of Payment Behavior", Occasional Studies, Vol. 11, No. 4, De Nederlandsche Bank.

Van Huyk, J., R. Battalio, and R. Beil (1990), "Tacit Coordination Games, Strategic Uncertainty, and Coordination Failure", *American Economic Review*, Vol. s. 80, 234-248.

World Bank (2011), "Payment Systems Worldwide: a Snapshot" – Outcomes of the global payment systems survey 2010, World Bank: Washington, DC.



SVERIGES RIKSBANK SE-103 37 Stockholm, Sweden (Brunkebergstorg 11)

Tel 08 787 00 00 Fax 08 21 05 31 registratorn@riksbank.se www.riksbank.se