Macroeconomic Shocks and Monetary Policy
Analysis of Sweden and the United Kingdom

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2012-06-07
Abstract

External economic shocks cause domestic macroeconomic aggregates to fluctuate. This may call for a macroeconomic policy intervention. Since the early 1990s an increasing number of countries have adopted an inflation targeting framework. In reality, inflation targeters do not have perfect information when determining the interest rate in order to maintain their goal of price stability and stable economic growth. Therefore it is relevant to understand how shocks affect the domestic macroeconomic aggregates theoretically and investigate whether the theoretical predictions hold empirically. I use the New Keynesian model by Clarida, Galí and Gertler from 1999 and investigate explicitly the theoretical effects of expected and unexpected supply and demand-side shocks on the monetary policy instrument and the two monetary policy target variables – the interest rate, output gap and inflation rate. By analysing the impulse-response functions of a structural VAR model applied to quarterly Swedish and British data from 1994 to 2011, I test empirically the theoretical predictions according to the New Keynesian model. I find that the empirical results are in line with the theoretical predictions.

Keywords
Cost-push, demand-pull, impulse-response, monetary policy, New Keynesian theory, shocks, structural VAR.
Acknowledgements

This thesis has highly benefitted from comments by my advisor Professor Nils Gottfries. I would also like to thank the seminar participants at Uppsala University for valuable constructive feedback.

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1 Introduction

No country is immune to external economic shocks which cause fluctuations of domestic macroeconomic variables like output and inflation. Economic shocks to the supply-side or demand side of the economy may cause unpredictable changes in aggregate supply and aggregate demand and therefore require some sort of macroeconomic policy response. In small open economies with flexible exchange rate regimes, monetary policy has leverage over the short-term course of the real economy. The monetary authority has expectations of the source and magnitude of external economic shocks, and it acts to mitigate their impact. It does so by varying its monetary policy instrument - the short-term nominal interest rate. This in turn affects the target variables of monetary policy - the output gap and the inflation rate.

In practice, no monetary authority has a perfect information set at the time it determines the monetary policy instrument, the short-term nominal interest rate (Clarida et al, 1999). In a setting with imperfect information, central banks’ expectation of supply and demand-side shocks may not equal their true values, unlike in the case of perfect information, in which central banks are able to anticipate, and therefore offset, all shocks. Varying the interest rate, while taking inaccurately estimated economic shocks into account, in the model significantly affects the output gap and inflation rate. However, unexpected shocks affect the domestic macro economy too, causing a greater volatility of the variables. Monetary policy can only respond to unexpected economic shocks first after they have happened.

This paper studies the theoretical relationship between supply and demand-side shocks, the monetary policy instrument and the target variables of monetary policy. The theory is based on the New Keynesian framework presented in a previous paper by Clarida et al (1999). The theoretical study is limited to the model with forward-looking variables, imperfect information and without commitment to a monetary policy rule (discretion) (Clarida et al, 1999). The empirical part of this paper is a study of commodity price inflation in conjunction with the inflation rate, the real GDP growth rate and the short-term nominal interest rate. This is done by examining the impulse-response functions of a structural vector autoregression (SVAR) model for the exemplary cases of Sweden and the United Kingdom, chosen for their status as inflation-targeting net commodity importers and price takers, using quarterly data from 1994 until 2011.

The contribution of this paper is to develop the New Keynesian model used by Clarida et al (1999) to make explicit the impact of expected and unexpected supply and demand-side shocks on the monetary policy instrument and the target variables of monetary policy. The theoretical framework in the previous study by Clarida et al (1999) presents the effects of supply-side and demand-side shocks in a setting of imperfect information under discretion. I use the model in Clarida et al (1999), and take it one step further and investigate explicitly the effects of the expected and unexpected components of the actual supply and demand-side shocks.

The purpose of this paper is also to do an empirical test of the theoretical framework with the use of a structural VAR model. Studying the effect of macroeconomic shocks on country’s domestic macroeconomic variables empirically is interesting in economies which have adopted an inflation targeting framework. This is because inflation targeter’s goal is to maintain price stability and economic growth, which demands an understanding of the dynamics which govern these aggregates.
The New Keynesian theoretical framework used is general and applicable to all inflation targeting economies. It would be interesting to study all inflation targeting countries empirically. Many countries adopted inflation targeting beginning in the early 1990s (Fromlet, 2010). However, due to the time constraint, the empirical study will be limited to the cases of Sweden and the United Kingdom. These countries are interesting to study for several reasons. First, according to a finding in Fromlet’s (2010) study, the variance of inflation around the target value is the lowest for countries, such as Sweden and the UK, which started at lower inflation rates when adopting the inflation targeting framework, and which have had more constant inflation targets or inflation targeting ranges during the studied time period. The absence of excessive fluctuations in the macro economy of these two inflation targeters implies that they have stable monetary systems. Second, they are both small open economies and net importers of commodities meaning that they participate in the international trade of commodities but are small enough compared to their trading partners that they are not able to alter world commodity prices i.e. they are price takers (Bhattacharya & Quadros, 2011).

Commodity prices are determined on world "auction" markets, in reality world financial markets that trade commodity contracts. The impact of changes in commodity prices on the macro economy can be expected to vary significantly across countries, depending on the patterns of consumption and production, which in turn reflect natural endowments and the impact of domestic policies. Small open economies such as Sweden and the UK cannot be expected to be able to alter world commodity prices. Both countries are also “all-in-all” net importers of commodities, meaning that they are net exporters for some commodity classes but broadly speaking they are net-importers. Since their domestic demand is relatively small, changes in commodity prices can primarily be assumed to affect the supply-side of these economies. Hence, a broad commodity price index for all commodities will be used in this study.

The empirical relationship between commodity price inflation with the inflation rate, the real GDP growth rate, and the short-term nominal interest rate is studied using a vector autoregression (VAR) model (Amisano & Giannini, 1997). The VAR summarizes the joint processes of time series and allows for analyses of the dynamic impact of random disturbances (shocks) on the system of variables if a set of identifying restrictions are imposed on the observed residuals. The latter is what gives the VAR a structural interpretation, and is known in practise as a structural VAR (SVAR) (Stock & Watson, 2001). SVARs allow for impulse-response analysis which in this setting gives an opportunity to study the effects of unexpected supply and demand-side shocks empirically. However, since the VAR is an atheoretic model, i.e. it is not explicitly based on the New Keynesian theory provided here, the identifying restrictions cannot be given a proper structural interpretation, since they are not defined according to the underlying theory. I however choose to give them a structural interpretation, since the restrictions implicitly capture the essence of the theory.

Section 2 provides the reader with a background of the inflation targeting framework in Sweden and the United Kingdom and the observed links between commodity prices and inflation which vary depending on the underlying reason to the change in commodity prices. Section 3 begins with a brief introduction to the New Keynesian framework presented in Clarida et al (1999). It focuses on the underlying assumptions of this framework, continuing with a derivation of how the target variables of monetary policy and the monetary policy instrument depend on expected and unexpected supply and demand-side shocks. Section 4 explains the choice of data and presents the empirical patterns of the variables used during the studied time period 1994:1-2011:IV. Section 5 begins with a brief and general introduction to structural VARs and then specifies the model used. Section 6 presents the results. Section 7 discusses the results and provides suggestions for future research. Section 8 concludes.
2 Background

In this section a brief overview will first be given of the inflation targeting framework in Sweden and the United Kingdom. Second, a theoretical description of how commodity prices can be expected to affect inflation through the supply-side and the demand-side of the economy is presented. The latter theory will not be used as a base for the VAR analysis; its purpose is to inform the reader of the channels commodity prices work through.

2.1 The inflation targeting framework

Inflation targeting is a framework for monetary policy involving a target market variable, the nominal interest rate on overnight debt to banks (which will be referred to as the short-term nominal interest rate or simply interest rate in this paper) and a medium-term objective, a commitment to price stability as the primary goal of monetary policy, to which other goals are subordinated. The institutional commitment to price stability is in practice expressed as a public announcement of a numerical target or target range for the inflation rate over one or more time horizons (Fromlet, 2010).

Fromlet (2010) evaluates inflation targeting for the first ten countries in the world who adopted an inflation targeting framework starting off in the early 1990’s (excluding the countries that joined the Euro project during the time period studied)\(^1\). In all of these inflation targeting countries, there was a public announcement of numerical targets for inflation. Of the ten countries in Fromlet’s study, Canada, Sweden and the United Kingdom are the only countries that adopted inflation targeting starting off at a point in time with low inflation rates. They are also the countries which have had more constant inflation targets over time since then. A result in Fromlet’s (2010) study is that these three countries also have the lowest variance of inflation around target. This suggests that the countries have had a stable domestic monetary system i.e. a well functioning inflation targeting framework. Since Canada is a net-exporter of commodities it is not included in the empirical analysis in this paper. This is because an increase in commodity prices could lead to positive reactions on the supply side in companies that export commodities. This however should not be a problem when considering Sweden and the UK because they are net importers of commodities (Bhattacharya & Quadros, 2011).

Inflation targeting in Sweden

According to Swedish law the main objective of monetary policy is to maintain price stability. The Riksbank’s (the central bank of Sweden) interpretation of this goal is that the consumer price index (CPI) inflation should be low and stable. More precisely, the Riksbank has a CPI inflation target of two percent with an acceptable error band of plus/minus one percent over the target horizon of two years. In addition, the Riksbank should support the goals of the government that are to achieve sustainable growth and high employment (Fromlet, 2010).

Inflation targeting in the United Kingdom

The Bank of England’s (the central bank of the United Kingdom) monetary policy objective is to deliver price stability – low inflation – and, subject to that, to support the British government’s economic objectives including those for growth and employment. From October 1992 until April 2003 the retail price index (RPIX) was the index specifying the inflation target of the Bank of England.

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\(^1\) The first ten countries adopting inflation targeting are New Zealand, Chile, Canada, Israel, United Kingdom, Sweden, Australia, Czech Republic, Korea and Poland. Finland and Spain which became inflation targeters in 1994 and 1995 respectively are excluded in Fromlet’s analysis because they became members of the Euro project in 1999.
Price stability is since then defined by the British government’s CPI inflation target of two percent at all times (Fromlet, 2010).

2.2 Supply-side and demand-side links between commodity prices and inflation
A previous study by Furlong and Ingenito (1996) examines the statistical relationship between changes in non-oil commodity prices and inflation both as stand-alone indicators of inflation and in conjunction with other leading indicators of inflation. The study is done on monthly data for the US for the time period 1947:01 to 1995:12. Relevant from this previous study is a set of examples of how commodity prices are linked to inflation. The theory clearly indicates that the relationship between the movements in commodity prices and inflation depends on what is driving commodity price changes (Furlong & Ingenito, 1996).

On the supply side movements in the price of a commodity could be positively related to overall prices. Movements in the price of a commodity can be expected in the case of a direct shock to the supply of the commodity. The changes in the price of the commodity affected would then depend on the relative importance of the commodity being shocked and the flexibility of other prices. Furlong and Ingenito (1986) use an example to illustrate the matter. Due to bad weather conditions the supply of agricultural products would decline which would push up their prices on the world market. The higher prices on the world market would in turn reflect in higher overall prices of the related final food products bought by consumers. This holds to the extent that the supply-side shock affects aggregate supply in the economy and if there is stickiness in the prices of other consumer goods limiting their adjustment. Only in this case will a rise in the prices of the affected agricultural commodities be larger than the effect on overall prices, causing supply-side inflation pressure. This means that the relationship between the level of prices of the affected commodities and overall prices would be affected (Furlong & Ingenito, 1986).

The described effect on the overall price level above according to Furlong and Ingenito (1996) can only be expected to hold for commodities that are important final goods and/or important inputs into industrial products (such as agricultural commodities). To explain this, consider the case when the metal gold experiences a supply shock. From the supply-side the price of gold can be volatile due to the capital-intensive nature of mining. It may take many years from the planning stage until a gold mine can be set up and even longer before the investment yields increased output. Therefore during times of shortage, gold prices increase sharply. Once new mines are completed and start operating there will be a surplus and prices will plunge. In other words, gold prices are volatile due to supply-side shocks but are hardly a very important final good or input in industrial goods. Gold is therefore not a commodity that could easily be suspected to drive overall prices in the economy, even though its price may be volatile.

Furlong & Ingenito (1996) refer to previous literature when they turn to the demand side. The strongest starting point here is that commodity prices are seen as indicators of future inflation because commodity prices generally are set in highly competitive financial markets and therefore tend to be more flexible than overall prices. Because of the general high volatility of commodity prices relative to the volatility of general price indexes used to measure inflation, movements in commodity prices would be expected to lead and be positively related to changes in aggregate price inflation in response

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2 In the United Kingdom, the harmonised index of consumer prices (HICP) is used to set the inflation target of the Bank of England. As of December 2003 the BoE renamed the harmonized index of consumer prices (HICP) to the consumer price index (CPI). The European Central Bank (ECB) uses the HICP as an indicator of inflation and price stability since it is an index which is compiled according to a methodology that has been harmonised across EU member states (Bank of England).
to aggregate demand shocks. Furlong and Ingenito (1986) also add that the levels of commodity prices and overall prices will be linked, if demand shocks are not sector-specific.

The positive correlation between commodity prices and inflation only exists in the case where there is a big relative demand for the commodity. If there is no big non-sector specific relative demand for a commodity there is no obvious positive correlation between the change in the price of the commodity and overall inflation (Furlong & Ingenito, 1996). However, even if there is a big economy-wide relative demand for a commodity, such as agricultural products, if for some reason that relative demand shifts away to other goods when prices rise, the otherwise positive correlation will dampen due to the shift of relative demand away from that commodity. Under these circumstances commodity prices would not be positively related to inflation. Also, the levels of prices of the affected commodities and overall prices would drift apart (Furlong & Ingenito, 1996).

These examples clearly indicate that the relationship between the movements in commodity prices and inflation depends on what is driving commodity price changes. Since commodity prices are set on highly competitive world markets. Small open economies which are prices takers, such as Sweden and the UK, cannot be expected to be able to influence world prices. Their domestic aggregate demand is small relative to that of the other trading partners. Since both economies are net-importers of commodities they are dependent of a big inflow of commodities. For these reasons, changes in commodity prices on the world market can be argued to primarily be causing supply-side shocks to these economies. Higher commodity prices cause higher real marginal production costs for firms, which are passed on to consumers in the form of higher product prices. This causes a pressure on inflation.
3 Theory

First, the important assumptions underlying the New Keynesian model in Clarida et al (1999) are provided. The New Keynesian model presented there with money and temporary nominal price rigidities is widely used for both theoretical analysis and applied work of monetary policy. Second, the impact of expected and unexpected supply and demand-side shocks on the two target variables of monetary policy and the monetary policy instrument is presented.

3.1 A brief introduction to the New Keynesian framework

The baseline New Keynesian framework for analysis of monetary policy provided in Clarida et al (1999) is a small dynamic stochastic general equilibrium (DSGE) model in a forward-looking setting. As in all DSGE models macroeconomic theory is underpinned with microeconomic foundations so that the analysis can be based upon frameworks that incorporate the recent methodological advances in empirical macroeconomic modelling.

The New Keynesian theoretical framework is based on the conceptual framework of the traditional Keynesian IS/LM framework, where the economy is divided into three blocks: 1) the supply-side including a Phillips curve (PC) that relates inflation positively to the output gap, 2) the demand side including an Investment-Saving curve (IS) that relates the output gap inversely to the real interest rate, and 3) monetary policy including the monetary policy objective function which translates the behaviour of the target variables, the inflation rate and output gap, into a welfare measure to guide the monetary authority’s policy choice when deriving the interest rate rule. Within the model the short-term nominal interest rate is the instrument of monetary policy.

The approach taken by Clarida et al (1999) is based on the idea that temporary nominal price rigidities provide the key friction that gives monetary policy influence over the short-term course of the real economy. With nominal price rigidities present, the inflation targeting monetary authority (central bank) can effectively change the short-term real interest rate by varying their monetary policy instrument, the short term nominal interest rate. The size of the central bank’s leverage over the near-term of the economy is, as Clarida et al (1999) point out, still open to debate. A key difference of the New Keynesian framework from the traditional IS/LM framework is the microeconomic foundation. The aggregate behavioural equations evolve explicitly from optimization by forward-looking economic agents, households and monopolistic firms. This means that private sector beliefs about how the central bank will set the interest rate in the future matters. The implication of this is that private sector behaviour (current price setting of households and firms) depends on the expected course of monetary policy, as well as on current policy.

Whether or not the central bank binds the future course of monetary policy to a rule or not matters because the two cases differ in their implications for the link between policy intentions and private sector beliefs (Clarida et al, 1999). I choose to focus on the case of discretion because as Clarida et al (1999) point out it is the setting that captures reality the best. This is because in reality no central bank makes any binding commitment for the future course of its monetary policy. In the absence of commitment the credibility of the monetary authority’s intent to maintain inflation low in the future becomes relevant, since there is no binding commitment constraining the future course of monetary policy. Under discretion the central bank is free to re-optimize in every time period while a perceptive private sector forms its expectations taking into account how the central bank adjusts policy. Thus, a
rational expectations equilibrium in this setting has the property that the central bank has no incentive to change its plans in an unexpected way, even though it has the discretion to do so (Clarida et al, 1999). Rational expectations and strict inflation targeting means that the monetary authority’s expectations of the future deviation of the inflation rate from its target, given all available information today, should be equal to zero (Fromlet, 2010).

### 3.2 Explicit analysis of expected and unexpected supply-side and demand-side shocks

Let $\Omega_t$ denote the monetary authority’s information set at the time it sets the interest rate that prevails at time $t$. The information set used when setting the policy instrument includes many variables and not just monetary aggregates or the exchange rate. Individual firms can observe their current marginal costs. The central bank does not have up-to-date information of firms’ marginal costs at the time it sets the interest rate. Neither firms nor households can observe contemporaneous aggregate variables since they are not available in real time. Hence, in a setting with imperfect information the central bank cannot accurately anticipate the actual supply-side and demand-side shocks to the monetary policy target variables - the output gap and the inflation rate. Therefore within the model the central bank determines the interest rate based on its expectations of the current domestic output gap and inflation rate in the economy.

The central bank’s monetary policy objective function translates the behaviour of the two target variables, the output gap, $x_t$ and the inflation rate, $\pi_t$, into a welfare measure to guide the policy choice. In a setting with imperfect information the central bank does not know real time values of the output gap and the inflation rate, but it does have an expectation of them. The objective function takes the form

$$\text{min } E_t^c (\alpha x_t^2 + \pi_t^2) \quad (1)$$

where the parameter $\alpha$ is the relative weight on output deviations and $x_t$ is the output gap defined as $x_t \equiv y_t - z_t$ where $y_t$ and $z_t$ are the level of output and the natural level of output. In each time period the central bank re-optimizes the monetary policy objective function in order to determine the value of the interest rate, $i$, conditional on the optimal values of $x_t$ and $\pi_t$. The central bank’s expectation of the Phillips curve can be expressed in the following way

$$\pi_t^e = \lambda x_t^e \beta + \pi_{t+1}^e + u_t^e \quad (2)$$

where the central bank’s expectation of the current inflation rate, $\pi_t^e$, depends on the gain in reduced inflation per unit of output loss, $\lambda$, the central bank’s expectation of the output gap, $x_t^e$, and the central bank’s expectation of the inflation rate in the next time period, $\pi_{t+1}^e$. The disturbance term, $u_t^e$, is assumed to be serially uncorrelated, i.e. the error is assumed to be independent of its past; it has no memory of its past values. In this setting it is interpretable as the central bank’s expectation of the supply-side shock. The output gap captures movements in marginal costs associated with variation in excess demand. The supply-side shock captures anything else that might affect expected marginal costs. Since the supply-side shock shifts the Phillips curve this error term is referred to as “cost-push” shock (Clarida et al, 1999). The intuition behind the Phillips curve has to do with the Calvo formulation which underlies the specific derivation of the equation (see Calvo, 1983). In the setting monopolistic firms more or less set nominal prices based on the expectations of future marginal costs. Inflation will tend to rise when real marginal costs rise and when expectations of future marginal costs
and inflation rises, as firms pass on higher costs in the form of higher prices and as firms raise their prices today if anticipating higher prices tomorrow.

The central bank’s expectation of the IS curve in the New Keynesian framework takes the form

\[ x_t^e = -\varphi (i_t - \pi_{t+1}^e) + x_{t+1}^e + g_t^e \]  
(3)

where the central bank’s expectation of the current output gap, \( x_t^e \), depends on the intertemporal substitution of consumption, \( \varphi \), the short-term nominal interest rate, \( i_t \), and the central bank’s expectation of the output gap in the next time period, \( x_{t+1}^e \). The disturbance term, \( g_t^e \), is assumed to be serially uncorrelated. In this setting it is interpretable as the central bank’s expectation of the demand-side shock. The demand-side shock is labelled “demand-pull” shock since it shifts the IS curve and it is a function of expected changes in government purchases relative to expected changes in potential output (Clarida et al 1999). The resulting IS curve shows that higher expected future output raises current output. This is because individuals tend to smooth consumption. Expectations of higher consumption in the next time period leads consumers to want to consume more today, which raises current output demand. There is a negative effect on current output by the short-term real interest rate reflecting the intertemporal substitution of consumption, \( \varphi \) (Clarida et al, 1999).

Since both the cost-push shock, \( u_t^e \), and the demand-pull shock, \( g_t^e \), are assumed to be serially uncorrelated for ease of description (as in Clarida et al, 1999) the implication to the model is that shocks in the current time period do not affect the economy in future. Given this, and given that the central bank’s intent is to keep both the future inflation rate low and the future output gap as narrow as possible, the central bank’s expectation of the inflation rate and output gap in the next time period can be considered equal to zero, \( x_{t+1}^e = 0 \) and \( \pi_{t+1}^e = 0 \). Capital accumulation and investments are abstracted from the model, meaning that the central bank does not need to consider the capital stock. These assumptions allow for the central bank’s expectation of the Phillips curve and the IS curve to be expressed as

\[ \pi_t^e = \lambda x_t^e + u_t^e \]  
(4)

and

\[ x_t^e = -\varphi i_t + g_t^e \]  
(5)

where the central bank’s expectation of the current inflation rate depends positively on the gain in reduced inflation per unit of output loss, its expectation of the current output gap and its expectation of the supply-side shock. The central bank’s expectation of the current output gap depends negatively on the product of the intertemporal substitution of consumption and short-term nominal interest rate, and positively on its expectation of the demand-side shock.

Substituting the central bank’s expectation of the Phillips curve, equation (4), into the monetary policy objective function, equation (1), and differentiating with respect to the expectation of the output gap, \( x_t^e \), yields the following expression

\[ x_t^e = -\frac{\lambda}{\lambda^2 + \alpha} u_t^e \]  
(6)
where the central bank’s expectation of the current output gap, $x_t^e$, is related to its expectation of the current supply side-shock, $u_t^e$, when the latter is assumed to be serially uncorrelated. The expression shows that the higher the expectation of the cost-push shock is the lower the expectation of the output gap is. Substituting the obtained expression, equation (6), into the equation of the central bank’s expectation of the Phillips curve, equation (4), yields the following expression

$$\pi_t^e = \frac{\alpha}{\lambda^2 + \alpha} u_t^e$$

where the central bank’s expectation of the current inflation rate, $\pi_t^e$, is related to its expectation of the current supply-side shock, $u_t^e$, when the latter is assumed to be serially uncorrelated. The expression shows that the higher the expectation of the cost-push shock the higher the expectation of the inflation rate is.

By substituting equation (6) into the central bank’s expectation of the IS curve, equation (5), and solving for the interest rate the following expression is obtained

$$i_t = \frac{\lambda}{\varphi(\lambda^2 + \alpha)} u_t^e + \frac{1}{\varphi} g_t^e$$

where the monetary policy instrument is related to the central bank’s expectation of the supply-side shock, $u_t^e$, and the demand-side shock, $g_t^e$. The precise size of the raise of the interest rate due to the expectation of the supply-side shock also depends on the gain in reduced inflation per unit of output loss, $\lambda$, and on the central bank’s relative weight placed on output losses, $\alpha$. The precise size of the raise of the interest rate due to the expectation of the demand-side shock also depends inversely on the size of the intertemporal substitution of consumption, $\varphi$. Clearly, if the central bank expects a supply-side and/or demand-side shock in the current time period it will respond by raising the short-term nominal interest rate in the current time period, given the value of the other three parameters.

The central bank only adjusts the interest rate according to its expectations of the supply-side and demand-side shock. In a setting with imperfect information the central bank’s expectation of the shocks does not necessarily coincide with the actual size of the supply-side shock, $u_t^e$, and demand-side shock, $g_t^e$. Therefore the real time output gap and inflation rate are affected by both changes in the interest rate due to expected shocks, and by unexpected supply-side and demand side shocks. To obtain an expression for the real time output gap as a function of all potential shocks the central bank’s interest rate rule, equation (8), is substituted into the IS curve, the latter expressed in realised as opposed to expected values in order obtain an expression with the real time output gap as the dependent variable. The resulting expression takes the following form

$$x_t = -\frac{\lambda}{\lambda^2 + \alpha} u_t^e + g_t^e$$

where the unexpected demand-side shock, $g_t^e$, is equal to the actual demand-side shock, $g_t^a$, minus the expected demand side shock, $g_t^e$, i.e. $g_t^e = g_t^a - g_t^e$. The central bank raises the interest rate according to its expectations of the demand-side shock and thereby offsets its effect on the output gap. Unexpected cost-push shocks do not affect the output gap in the same time period because unexpected price level changes do not affect output in the same time period (Clarida et al, 1999).
Finally, substituting equation (9) into the Phillips curve, the latter expressed in realised as opposed to expected values, yields the following expression

\[ \pi_t = \frac{\alpha}{\lambda^2 + \alpha} u_t^e + u_t^u + \lambda g_t^u \]  

(10)

where the unexpected supply-side shock, \( u_t^u \), is equal to the actual supply-side shock, \( u_t^q \), minus the expected supply-side shock, \( u_t^e \), i.e. \( u_t^u = u_t^q - u_t^e \). The real time inflation rate depends positively on the expected and unexpected supply-side shocks and unexpected demand-side shocks. The inflation rate does not depend on the expected demand-side shock because the central bank anticipates it and adjusts the interest rate accordingly, offsetting the shock.

Equations (8), (9) and (10) show what the central bank is up against under discretion in a setting of imperfect information. The monetary policy objective function is reassessed each period since the information set changes in each period. The central bank tries to keep the output gap narrow, whilst also keeping inflation in check, given the available information set. If world commodity prices rise unexpectedly, commodity price inflation will cause inflationary pressure through the supply-side of the economy. How monetary policy should respond in the short-run to shocks that buffet the economy is a nontrivial decision under discretion and imperfect information. Imperfect information clearly implies greater volatility of inflation and the output gap since the central bank cannot offset the unexpected supply-side and demand side shocks. The implications of how expected and unexpected supply and demand-side shocks affect the two monetary policy target variables and the monetary policy instrument is summarized in Table 1.

### Table 1
Overview over how the unexpected and expected shocks in the New Keynesian model affect the interest rate, output gap and inflation rate respectively.

<table>
<thead>
<tr>
<th>Dependent variables</th>
<th>Independent variables</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Supply side: cost-push shock</td>
</tr>
<tr>
<td>interest rate, ( i_t )</td>
<td>( u_t^u )</td>
</tr>
<tr>
<td>inflation rate, ( \pi_t )</td>
<td>0</td>
</tr>
<tr>
<td>output gap, ( x_t )</td>
<td>1</td>
</tr>
</tbody>
</table>

Note: \( i_t \): short-term nominal interest rate, \( \pi_t \): inflation rate, \( x_t \): output gap, \( u_t^q \): unexpected cost-push shock, \( u_t^e \): expected cost-push shock, \( g_t^u \): unexpected demand-pull shock, \( g_t^e \): expected demand-pull shock.

**Unexpected cost-push shock**

Looking at Table 1, according to New Keynesian theory an unexpected cost-push shock, \( u_t^u \), causes the inflation rate to increase proportionally to the size of the unexpected cost-push shock. On the other hand, an unexpected cost-push shock does not cause the output gap or interest rate to change. This makes sense because the central bank only changes the interest rate according to anticipated supply-side shocks. Since it does not change the interest rate there will be no effect on the output gap in the same time period, since prices and output do not respond to supply-side shocks contemporaneously.
**Expected cost-push shock**

Expected cost-push shocks have an impact on the inflation rate, output gap and interest rate, as Table 1 illustrates. According to the theory, the impact of an expected cost-push shock on the interest rate is positive which makes sense because the central bank increases the interest rate in order to offset expected supply-side shocks which threaten to push inflation above the target level. The size of the impact depends on the relative size of the gain in reduced inflation per unit of output loss, $\lambda$, on the relative weight placed on output losses, $\alpha$, and inversely on the intertemporal substitution of consumption, $\varphi$. Expected cost-push shocks cause inflation to rise and the size of the impact depends on the gain in reduced inflation per unit of output loss, $\lambda$, and on the relative weight placed on output losses, $\alpha$. The impact of an expected cost-push shock to the output gap is negative because the central bank increases the interest rate in response to an expected cost-push shock causing the output gap to narrow. The size of the impact of the expected cost-push shock on the output gap depends on $\alpha$ and $\lambda$.

**Unexpected demand-pull shock**

As illustrated in Table 1, unexpected demand-pull shocks have no impact on the interest rate. This is logical since the central bank cannot react to what it cannot anticipate. The inflation rate increases when there is an unexpected demand-pull shock and the size of the impact depends on the parameter $\lambda$. The higher the gain in reduced inflation per unit of output loss, $\lambda$, the higher the inflation rate will be due to an unexpected shock from the demand side of the economy. The impact on the output gap of an unexpected demand-pull shock is positive and proportionate to the size of the shock, causing the growth of aggregate demand to outpace the growth of aggregate supply.

**Expected demand-pull shock**

Expected demand-pull shocks cause the interest rate to increase. The size of the increase depends inversely on the intertemporal substitution of consumption; $\varphi$. Demand-pull shocks that the central bank expects have no impact on the output gap or inflation rate, because the central bank can anticipate and offset them.
4 Data

First, the choice of the variables used in the empirical part of this paper is explained. Second, the variables used are plotted over the time period studied and the general empirical patterns are mentioned.

4.1 Choice of data
Quarterly data is used for the time period 1994 to 2011, 1994:I-2011:IV. The reason why the studied time period does not correspond to the dates when Sweden (January 1993) and the United Kingdom (October 1992) adopted inflation targeting is because it takes some time for this regime change to fully affect the economy (Fromlet, 2010). In this paper this time period of adjustment is assumed to take about one year. The variables chosen to be included in the VAR model are commodity price inflation (the percentage change in the Thomson Reuters headline index for all commodities), the inflation rate (the CPI inflation rate), the growth rate of real GDP (the percentage change in real GDP) and the short-term nominal interest rate. For detailed information about the data series used and calculations done when constructing the variables see the Data Appendix.

The commodity price inflation rate is included instead of the commodity price index series because an inflation rate reflects the change (rise or fall) in the level of prices of commodities which is what affects general prices unlike changes in the level of the commodity price index. Since the commodity price index used is a world index denominated in US dollars I have chosen to convert it so that it is denominated in terms of the domestic currencies of Sweden and the United Kingdom, the Swedish Krona (SEK) and the Pound Sterling (GBP). I do this because exchange-rate movements may also affect the global supply and demand for commodities, apart from causing a direct valuation effect.

The main measure of general price inflation is the inflation rate of a general price index. In this paper the quarterly percentage change in the consumer price index (CPI) is used to calculate the inflation rate. This is done because the inflation targets in Sweden and the UK are expressed as a given rate of change in this index. I choose to disregard the fact that the inflation rate in the UK was expressed as a given rate of change in the retail price index (RPIX) until April 2003.

The real GDP growth rate is included as a measure of aggregate activity in the economy. In the theoretical model the output gap is used. I have chosen to use the percentage change in real GDP because the output gap (actually potential GDP) is just made up. It cannot be directly observed and measured (Fromlet, 2010). However swings in nominal GDP affect inflation and the central bank can affect aggregate demand through the money supply and interest rate. Real GDP is used because it is adjusted for price changes (inflation) and therefore better captures changes in the actual quantities of goods and services produced and their respective prices that are due to changes in aggregate demand.

The central bank’s monetary policy tool in an inflation targeting framework is the short-term nominal interest rate (in practice the interest rate on overnight debt to banks) which it can change in order to affect other short term interest rates and by that the real interest rates in the economy. With the interest rate as the policy instrument what the central bank does in practice is that it adjusts the money supply to meet the interest rate target. In this instance, the money market equilibrium condition, that money demand equals money supply, simply decides the value of the money supply that meets this criterion.
4.2 The commodity price inflation rate - empirical patterns 1994:I-2011:IV

The commodity price inflation rate (dv) used for Sweden (expressed in terms of SEK) and the United Kingdom (expressed in terms of GBP) are plotted in Figure 1A and 1B respectively. Commodity price inflation is clearly quite volatile over the whole time period studied. Commodity price inflation rate has varied between approximately plus twelve percent and minus ten percent during the studied time period.

Figure 1A The commodity price inflation rate (dv) when the underlying commodity price index is denominated in SEK, 1994:I-2011:IV (the vertical axis unit is in percentages).

Figure 1B The commodity price inflation rate (dv) when the underlying commodity price index is denominated in GBP, 1994:I-2011:IV (the vertical axis unit is in percentages).
4.3 The inflation rate - empirical patterns 1994:I-2011:IV

The inflation rates (dp) in Sweden and the United Kingdom respectively during the studied time period are plotted in Figure 2A and 2B. When looking at the case of Sweden in Figure 2A the inflation rate was below zero on several occasions during the studied time period, most noticeably in the beginning of 1998 and during 2003 and 2008. When looking at the case of the UK in Figure 2B the inflation rate has been kept between zero and two percent during the whole time period. However, it was just below zero in the end of the year 2000 and was close to zero both in the beginning and in the end of the year 2008. These dips below zero, like in the case of Sweden are not persistent dips, just quarter-long drops.

Figure 2A The CPI inflation rate (dp) in Sweden, 1994:I-2011:IV (the vertical axis unit is in percentages).

Figure 2B The CPI inflation rate (dp) in the United Kingdom, 1994:I-2011:IV (the vertical axis unit is in percentages).
4.4 The real GDP growth rate - empirical patterns 1994:I-2011:IV
The real GDP growth rate (dy) in Sweden and the United Kingdom are plotted in Figure 3A and 3B respectively. For Sweden, the overall trend in the growth rate of real GDP is stable, varying around one percent with a noticeable plunges in 1996, a few downturns during 2000-2003 and finally a big downturn in the third and fourth quarters of 2008. The latter is most likely due to the recent global financial crisis 2007-2012. In the case of the UK, the real GDP growth rate varied around one percent preceding the plunge in year 2008 which was followed by a recovery in 2009.

Figure 3A The real GDP growth rate (dy) in Sweden, 1994:I-2011:IV
(the vertical axis unit is in percentages).

Figure 3B The real GDP growth rate (dy) in the United Kingdom, 1994:I-2011:IV
(the vertical axis unit is in percentages).
4.5 *The short-term nominal interest rate - empirical patterns 1994:I-2011:IV*

The short-term nominal interest rate in Sweden and the United Kingdom are plotted in Figure 4A and 4B respectively. The empirical pattern of the development of the interest rate during the studied time period shows no clear pattern or trend.

**Figure 4A** The short-term nominal interest rate (i) in Sweden, 1994:I-2011:IV (the vertical axis unit is in percentages).

**Figure 4B** The short-term nominal interest rate (i) in the United Kingdom, 1994:I-2011:IV (the vertical axis unit is in percentages).
5 Estimation method

First, I will briefly introduce the concept of VAR models. Second, I will specify the structural VAR model that is to be estimated for the empirical purpose of this paper.

5.1 A brief and general introduction to VAR econometrics

Large scale structural simultaneous models were widely used for analysis of the interactions between macroeconomic variables until the 1970s. In these structural simultaneous models economic theory and institutional knowledge is needed to spell out the assumptions underlying the joint behaviour of the macroeconomic variables. The specification and estimation methodology of these large scale macroeconometric models was deeply criticised, notably by Sims (1980, 1982) who emphasized two major shortcomings of these models, 1) economic theory is not rich enough to provide a dynamic specification that identifies all of the underlying relationships, and 2) estimation and inference are complicated because endogenous variables may appear on both sides of equations, causing simultaneity problems. On the basis of these criticisms Sims suggested vector autoregression (VAR) models whose specification is founded on the analysis of the statistical properties of the data under study, i.e. the method is atheoretic (Amisano & Giannini, 1997). In practice VAR models underlie most applied work in atheoretical macroeconometrics (Cooley & LeRoy, 1985).

In a VAR a set of n economic times series variables are represented using a column vector which possesses a finite order (p) autoregressive representation. Each times series (n) is regressed on a finite number of lags (p) of all the series jointly considered. Clearly, VARs circumvent the problem with simultaneity among variables since the left hand-side variables are dependent of lags of itself and the other variables included. The simultaneity problem is, as Amisano and Giannini (1997) put it, “hidden” in the instantaneous correlation structure of the error terms. However, the interpretation of these instantaneous correlations hidden naturally among error terms, and therefore among observable variables, is the main conceptual problem in the use of VARs. Hence, a VAR model of this kind, where no explanations of the instantaneous relationships among variables are provided, has to be considered as a reduced form model. Therefore, a reduced-form VAR model can only be correctly used for dynamic simulations if interpretation of the instantaneous correlations among the error terms is provided. This interpretation imposed on the instantaneous correlations among the error terms in a (reduced-form) VAR is called structuralisation of the VAR, the resulting VAR then called a structural VAR (SVAR) (Amisano & Giannini, 1997).

VAR models are atheoretic macroeconometric models because they do not require very specific assumptions derived from economic theory and institutional knowledge (Cooley & LeRoy, 1985). The first thing needed to be decided when constructing a VAR model is to decide which variables are endogenous and which are exogenous. In a VAR model it is the endogenous variables that interact and influence each other. The exogenous variable(s) are just variables that affect the model without being affected by it. They are used for setting arbitrary external conditions and not for achieving more realistic model behaviour. A VAR model consists of as many equations as there are variables. Every

---

3 The explanation of VAR econometrics here is based on Amisano and Giannini’s (1997) 2nd edition textbook on SVAR econometrics mostly because the class of SVAR models that the statistical package EViews estimates follows it but also because the models are put in a historical context and are not explained in a too mathematically advanced way. Also, concrete applied examples are provided. For readers interested in simpler reading a tutorial of VARs is provided in Stock and Watson’s (2001) article.
endogenous variable in the system is a function of the lagged values of all of the endogenous variables in the system, the exogenous variables and a disturbance term (Stock & Watson, 2007).

The number of lagged values of each variable (p) to include in a VAR model can be determined by a number of different methods. This is an empirical question where some trial and error is inevitable. A good tool in the process of choosing the maximum lag length is to use information criteria such as the Akaike or the Schwarz criteria. The model with the lag length that provides the lowest values of the criterion is the best model according to these criteria (Gujarati & Porter, 2009). There is a slight difference in the Schwarz information criterion (SIC) and the Akaike information criterion (AIC), the difference being that the AIC will overestimate the lag length with non-zero probability in large samples. So if it is believed that the SIC yields a model with too few lags the AIC provides a reasonable alternative (Stock & Watson, 2007).

Structural VARs can be used to perform dynamic solutions, via impulse-response analysis. This was introduced by Sims (1980). Impulse-response analysis is a descriptive device representing in graphs the reaction of each variable to shocks in the different equations of the system. For this to be possible to do, the shocks need to be orthogonal. This condition is almost never fulfilled in reality so the reduced-form VAR residuals need to be orthogonalized when structuralising them (Amisano & Giannini, 1997).

5.2 Specification of structural VAR

In essence, I estimate two SVAR models, one for Sweden and one for the United Kingdom. Commodity price inflation, the inflation rate, real GDP growth rate and the short-term nominal interest rate are jointly determined in each VAR and a constant is the only exogenous variable. The equation by equation notation of the reduced-form VAR is written as follows

\[
dv_t = \beta_1 + a_{11} dv_{t-1} + a_{12} dp_{t-1} + a_{13} dy_{t-1} + a_{14} i_{t-2} + b_{111} dv_{t-2} + b_{112} dp_{t-2} + b_{113} dy_{t-2} + b_{14} i_{t-2} + e_{1t}
\]

(11)

\[
dp_t = \beta_2 + a_{21} dv_{t-1} + a_{22} dp_{t-1} + a_{23} dy_{t-1} + a_{24} i_{t-2} + b_{211} dv_{t-2} + b_{221} dp_{t-2} + b_{223} dy_{t-2} + b_{24} i_{t-2} + e_{2t}
\]

(12)

\[
dy_t = \beta_3 + a_{31} dv_{t-1} + a_{32} dp_{t-1} + a_{33} dy_{t-1} + a_{34} i_{t-2} + b_{311} dv_{t-2} + b_{321} dp_{t-2} + b_{333} dy_{t-2} + b_{34} i_{t-2} + e_{3t}
\]

(13)

\[
i_t = \beta_4 + a_{41} dv_{t-1} + a_{42} dp_{t-1} + a_{43} dy_{t-1} + a_{44} i_{t-2} + b_{411} dv_{t-2} + b_{421} dp_{t-2} + b_{433} dy_{t-2} + b_{44} i_{t-2} + e_{4t}
\]

(14)

where the a’s and b’s are unknown coefficients, the β’s are the intercepts in each equation, and the e’s are the reduced-form error terms. The error terms in reduced form VARs are the “surprise” movements in the variables after taking its past values into account. Because the different variables used in the VAR are correlated with one another, the error terms in the reduced form model are also correlated across equations.

Since I want the VAR to estimate the major characteristics of the joint processes of the four macroeconomic variables all variables will be entered into the VAR as endogenously given though intuitively, commodity prices which are determined on a world market are likely to be exogenously given. The lag length of both the VAR model for Sweden and the UK are chosen according to the
Akaike information criterion (AIC) to be two endogenous lags. The ordering of the variables in the VAR is chosen to be as follows:

1) Commodity price inflation (dv) is assumed to contemporaneously affect all other variables, but the other variables are not assumed to be able to contemporaneously affect commodity price inflation. Hence, commodity price inflation is ordered first. In the VAR, this means that a shock to commodity price inflation in the first equation will contemporaneously affect the inflation rate, the real GDP growth rate and the short-term nominal interest rate in all equations in the VAR, but a shock in the latter variables will not contemporaneously affect commodity price inflation.

2) The inflation rate (dp) is ordered next because cost-push shocks primarily cause a change in aggregate supply and thereby prices in and affect demand with a lag. For the model, this means that a shock to the inflation rate will contemporaneously affect the real GDP growth rate and the short-term nominal interest rate, but a shock in the latter variables will not contemporaneously affect commodity price inflation or the inflation rate.

3) The real GDP growth rate (dy) is ordered third due to aggregate demand being more sluggish than the firms marginal costs on the supply-side in responses to cost-push shocks (here commodity price inflation). In the VAR this means that a shock to the real GDP growth rate will contemporaneously affect the short-term nominal interest rate, but a shock in the latter variable will not contemporaneously affect commodity price inflation, the inflation rate or the real GDP growth rate.

4) The short-term nominal interest rate (i) is ordered last because a shock to the interest rate will not affect any of the other variables contemporaneously, but shocks to all the other variables contemporaneously change the interest rate. Empirical findings suggest that there is a lag in the transmission of monetary policy. There is a lag of about a year and a year-and-a-half in the effect of a shift in the interest rate on inflation and a lag of about six to nine months in the effect of a shift in the interest rate on the output gap (Clarida et al, 1999).

The four-variable SVAR I use has the following mathematical notation

\[ y_t = \beta + Ay_{t-1} + By_{t-2} + Ce_t \]  \hspace{1cm} (15)

where \( \beta \) is a vector with four exogenously determined constant terms, \( y_t \) is a vector with the four endogenous variables, A and B are matrices of the coefficients to be estimated, and \( e_t \) is a vector of the observed (or reduced-form) innovations/residuals where the shocks on the error term C map the contemporaneous impact of shocks to the other variables in the SVAR. Following Amisano and Giannini (1997), the class of SVAR models that EViews estimates may be written as

\[ Ce_t = D\epsilon_t \]  \hspace{1cm} (16)

where the unobserved structural innovations are denoted \( \epsilon_t \). Both \( e_t \) and \( \epsilon_t \) are vectors of length k where the first is the observed residuals and the latter is the unobserved (or structural) innovations/residuals. C and D are the \( k \times k \) matrices to be estimated. The structural innovations \( \epsilon_t \) are assumed to be orthonormal, i.e. their variance-covariance matrix is an identity matrix \( E[u_t u_t'] = I_k \).
The assumption of orthonormal innovations $\epsilon_t$ imposes the following short-run identifying restrictions on the C and D matrix respectively

$$C' \Sigma C = DD'$$  \hspace{1cm} (17)

Since C is chosen to be lower triangular and D diagonal, all structural shocks can be recovered by a Cholesky decomposition of the matrix $\Sigma$, as in Sims (1980). The large-matrix notation of equation (15) is written as follows where the elements assigned “NA” are the responses estimated by EViews

$$
\begin{bmatrix}
v_{t} \\
p_{t} \\
\gamma_{t} \\
\delta_{t}
\end{bmatrix} = 
\begin{bmatrix}
  \beta_1 \\
  \beta_2 \\
  \beta_3 \\
  \beta_4
\end{bmatrix} + 
\begin{bmatrix}
  a_{11} & a_{12} & a_{13} & a_{14} & [v_{t-1}] \\
  a_{21} & a_{22} & a_{23} & a_{24} & [p_{t-1}] \\
  a_{31} & a_{32} & a_{33} & a_{34} & [\gamma_{t-1}] \\
  a_{41} & a_{42} & a_{43} & a_{44} & [\delta_{t-1}]
\end{bmatrix}
\begin{bmatrix}
  b_{11} & b_{12} & b_{13} & b_{14} & [v_{t-2}] \\
  b_{21} & b_{22} & b_{23} & b_{24} & [p_{t-2}] \\
  b_{31} & b_{32} & b_{33} & b_{34} & [\gamma_{t-2}] \\
  b_{41} & b_{42} & b_{43} & b_{44} & [\delta_{t-2}]
\end{bmatrix}
+ 
\begin{bmatrix}
  1 & 0 & 0 & 0 & e_{1t} \\
  NA & 1 & 0 & 0 & e_{2t} \\
  NA & NA & 1 & 0 & e_{3t} \\
  NA & NA & NA & 1 & e_{4t}
\end{bmatrix}
\begin{bmatrix}
  e_{1t} \\
  e_{2t} \\
  e_{3t} \\
  e_{4t}
\end{bmatrix}
$$

(18)

The first two observed error terms, $e_{1t}$ and $e_{2t}$, capture the spirit of an unexpected cost-push shock. The first error term, $e_{1t}$, maps the contemporaneous impact of a shock to commodity price inflation to the inflation rate, real GDP growth rate and inflation rate (the elements assigned “NA” in the first column in the C-matrix). The second error term, $e_{2t}$, maps the contemporaneous impact of a shock to the inflation rate to the real GDP growth rate and interest rate (the elements assigned “NA” in the second column in the C-matrix). The third observed error term, $e_{3t}$, captures the spirit of an unexpected demand-pull shock. It maps the contemporaneous impact of a shock to the real GDP growth rate to the interest rate (the element assigned “NA” in the third column in the C-matrix).

The first three errors cannot be said to correctly identify the shocks as defined in the New Keynesian theory by Clarida et al (1999) because the short-run identifying restrictions have no explicit economic rationale. However, I choose to give them a structural interpretation accordingly. From an economic point of view the last observed error term, $e_{4t}$, correctly identifies monetary policy shocks by the assumption they have no affect on the commodity price inflation rate, inflation rate or real GDP growth rate within the same time period (no elements are assigned “NA” in the fourth column in the C-matrix).
6 Results

Based on data for the time period 1994:1-2011:IV, and using an Augmented Dickey-Fuller (ADF) test, I find that all variables except the interest rate are stationary at level, for both Sweden and the United Kingdom. When looking at the empirical pattern in Figures 4A and 4B there does seem to be a stochastic tendency. However, I choose to use the times series for the interest rate at level because using differences would mean that information will be lost, since it is the level of the interest rate and not the change (increase or decrease) of it that matters when economic agents optimize. Also, there is no maintained general assumption in economics that the interest rate is not a stationary series at level. When looking at the roots of the characteristic polynomial of the SVARs all the roots lie inside the unit circle meaning that the two SVARs satisfy the stability condition.

Granger causality testing is common in the VAR literature. It is a statistical hypothesis test for determining whether the lags of one of the included regressors have useful predictive content of another included times series (Stock & Watson, 2007). Since the SVARs in this paper are not used for forecasting the times series are not tested for Granger causality. Further, there is no economic reason to believe that commodity price inflation, inflation rate, real GDP growth rate and interest rate are cointegrated i.e. that they have the same stochastic trend in common and that there is a long-run equilibrium between the variables. Therefore the variables will not be tested for cointegration.

The impulse-response functions of the structural VARs are presented in Figure 5A for Sweden and Figure 5B for the United Kingdom. The structural VAR estimates can be seen in Appendix A. The impulse-response functions in Figure 5A and 5B on the diagonal between the upper left corner and the lower right corner illustrate the response of the variables to a shock in the variable itself.

When looking at the impulse-response functions on the diagonal, the figure suggests that a onetime shock in commodity price inflation, the inflation rate and real GDP growth rate in itself leads to an immediate positive effect which fades away after two quarters. The response of the short-term nominal interest rate to a shock in the variable itself is also positive but more persistent over time; it becomes statistically insignificant first ten quarters after the initial response. Below follow the results of the impulse-response functions which are below the diagonal. They will be presented column-wise. I choose to see the simulated responses in the first two columns as responses to an unexpected cost-push shock. The response of the interest rate to the real growth rate of real GDP is chosen to be seen as an unexpected demand-side shock.

Cost-push shock
When looking at the impulse-response functions beneath the diagonal, the first column shows the response of the inflation rate, the growth rate of real GDP and the interest rate to a one standard deviation shock to commodity price inflation. According to the theoretical prediction, an unexpected supply-side shock has no impact on the interest rate or the output gap but it does have a positive impact on inflation. The empirical results for both Sweden and the United Kingdom are in line with the theoretical prediction. The initial response of the inflation rate to a shock in commodity price inflation is statistically significant and positive. After two quarters the response is no longer significant and after that the impulse-response function stabilizes around zero. This means that there is no persistent effect on the inflation rate due to an unexpected supply-side coming from commodity prices.
The responses of the real GDP growth rate and the interest rate to a shock to commodity price inflation are not significant.

The impulse-response functions below the diagonal in the second column in Figure 5A and 5B show the response of the real GDP growth rate and the interest rate to a one standard deviation shock to the inflation rate. According to the theoretical prediction the response of the output gap to an unexpected cost-push shock is zero. In the case of Sweden, the response of the real GDP growth rate to a shock in the inflation rate is initially positive in the first quarter thereafter turning to a statistically significant negative response during the second and fourth quarter. There is no statistically significant persistent effect. For the UK on the other hand, the initial response of the real GDP growth rate is just slightly negative, with no persistent effect since the impulse-response function stabilizes around zero. According to the theoretical prediction the response of the interest rate to an unexpected cost-push shock is zero. In the case of Sweden, the response of the short-term nominal interest rate to a shock in the inflation rate shows a significant positive response of the interest rate during the first three quarters. For the UK the initial response is slightly positive and significant but then dies out and no longer is significant. The signs of the responses are in line with the theoretical prediction. However, in the case of the UK the initial response is very close to not being significant.

**Demand-pull shock**

When looking at the impulse-response functions beneath the diagonal, the third column shows the response of the interest rate to a shock to the growth rate of real GDP. The theoretical prediction says that the output gap responds positively to unexpected demand-side shocks. The empirical results show that the response of the real interest rate to a one standard deviation shock to the real GDP growth rate is statistically significant and positive for both Sweden and the UK. The responses are also persistent since the standard error bands touch the zero-line after nine quarters.
Figure 5A Response functions of the dependent variables in the SVAR for Sweden to Cholesky one standard deviation innovations to the error terms (blue line).

Plus/minus two standard error bands are included (red lines). The vertical axis units are in absolute percentages.
Figure 5B Response functions of the dependent variables in the SVAR for the United Kingdom to Cholesky one standard deviation innovations to the error terms (blue line).


Plus/minus two standard error bands are included (red lines). The vertical axis units are in absolute percentages.
7 Discussion

The impulse-response functions in the first column below the diagonal in Figure 5A and 5B suggest that the central banks adhere to their commitments i.e. managing to offset unexpected supply-side shocks. This is evident, as there is no persistent higher level of the inflation rate after a shock to commodity price inflation. The statistically significant positive response of the inflation rate to a shock to commodity price inflation only lasts for a period of two to three quarters. The insignificant responses of the real GDP growth rate and interest rate to a shock to commodity price inflation suggests that movements of output and the interest rate are not dominated by supply-side shocks, at least in the short-run.

The impulse-response functions in the second column below the diagonal in Figure 5A and 5B illustrates the response of the real GDP growth rate to a shock to the inflation rate. Everything else held constant, the real GDP growth rate should remain constant or possibly be affected negatively by a shock to inflation, since real GDP is the price adjusted version of the nominal GDP. The reason why the Swedish and British impulse-response functions here have different signs might be due to the fact that this impulse does not capture a pure supply-side shock. Real GDP better captures prices changes that are due to changes in aggregate demand than nominal GDP. According to the theory the output gap is affected by both unexpected supply-side and demand-side shocks. However, the initial tendency of the response of the real GDP growth rate is negative which is in line with what can be expected.

The impulse-response functions in the third column below the diagonal in Figure 5A and 5B illustrates the response of the short-term nominal interest rate to a shock to the real GDP growth rate. The positive and persistent responses suggest that the central bank responds strongly to demand-side shocks.

Since no economic theory underlies the identifying restrictions imposed on the error terms it is not entirely clear that the shocks transmitted to the variables are reflecting unexpected supply-side and demand-side shocks. The SVAR model specified does capture the theory essentially, so the results are not totally misleading. For future studies the VAR-framework specified here could if applied in a more advanced statistical software be given explicit structural interpretation according to the equations of the New Keynesian theory, which would give the model a particular economic rationale.

According to the theoretical prediction, the unpredictable nature of supply-side and demand-side shocks in a setting with imperfect information clearly has the potential to create a fluctuating rate of economic growth and unstable price levels in the short-run. However, whether these shocks have any significant long-lasting impact on output and inflation raises questions about how much a central bank can and should do in order to mitigate the impact of the shocks in the short-run.
8 Conclusion

The purpose in this study was to develop the New Keynesian model used by Clarida et al (1999) to make explicit the impact of expected and unexpected supply and demand-side shocks on the monetary policy instrument and the target variables of monetary policy. The New Keynesian framework in Clarida et al (1999) constitutes the theoretical core in this paper.

The theory predicted that unexpected supply-side shocks affect the inflation rate positively. Expected cost-push shocks affect the interest rate and inflation rate positively, and the output gap negatively, the actual size of the effect depending on the size of some parameters. These parameters are the gain in reduced inflation per unit of output loss, the central bank’s relative weight placed on output losses, and in the case of the interest rate the intertemporal substitution of consumption. According to the theory, unexpected demand-side shocks affect the inflation rate and output gap positively, the first also depending on the size of the central bank’s gain in reduced inflation per unit of output loss. Expected demand-side shocks do not affect the inflation rate or output gap but they do affect the interest rate positively, the size depending inversely on the intertemporal substitution of consumption.

I used Swedish and British quarterly data from 1994 until 2011. Both countries are small-open economies, stable inflation targeters and net-importers of commodities. A structural VAR model was applied to do an empirical test of the theoretical framework. The dynamics of commodity price inflation, inflation rate, real GDP growth rate and short-term nominal interest rate were studied with the use of a structural VAR. The impulse-response functions of the structural VAR allowed studying the response of each of the four mentioned variables to a shock in the error term in each of the equations of the SVAR. The responses of a shock to commodity price inflation and the inflation rate were chosen to be interpreted as unexpected supply-side shocks. The response of a shock to the real GDP growth rate was chosen to be interpreted as an unexpected demand-side shock. Besides the fact that the responses of the real GDP growth rate and nominal interest rate to a shock to commodity price inflation were statistically insignificant, I found that the empirical findings are in line with the theoretical predictions.
Appendix A

Structural VAR estimates for Sweden

Sample (adjusted): 1994Q3 2011Q4
Included observations: 70 after adjustments
Estimation method: method of scoring (analytic derivatives)
Convergence achieved after 8 iterations
Structural VAR is just-identified

Model: Ce = Du where E[u'u]=I
Restriction Type: short-run pattern matrix

\[
C = \begin{bmatrix}
1 & 0 & 0 & 0 \\
C(1) & 1 & 0 & 0 \\
C(2) & C(4) & 1 & 0 \\
C(3) & C(5) & C(6) & 1 \\
\end{bmatrix}
\]

\[
D = \begin{bmatrix}
C(7) & 0 & 0 & 0 \\
0 & C(8) & 0 & 0 \\
0 & 0 & C(9) & 0 \\
0 & 0 & 0 & C(10) \\
\end{bmatrix}
\]

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Std. Error</th>
<th>z-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C(1)</td>
<td>-0.028122</td>
<td>0.010390</td>
<td>-2.706660</td>
</tr>
<tr>
<td>C(2)</td>
<td>-0.007814</td>
<td>0.021486</td>
<td>-0.363666</td>
</tr>
<tr>
<td>C(3)</td>
<td>-0.537668</td>
<td>0.830942</td>
<td>-0.647058</td>
</tr>
<tr>
<td>C(4)</td>
<td>-0.702647</td>
<td>0.235168</td>
<td>-2.987851</td>
</tr>
<tr>
<td>C(5)</td>
<td>-29.26989</td>
<td>9.648321</td>
<td>-3.033677</td>
</tr>
<tr>
<td>C(6)</td>
<td>-14.95037</td>
<td>4.618066</td>
<td>-3.237366</td>
</tr>
<tr>
<td>C(7)</td>
<td>0.044257</td>
<td>0.003740</td>
<td>11.83216</td>
</tr>
<tr>
<td>C(8)</td>
<td>0.003847</td>
<td>0.000325</td>
<td>11.83216</td>
</tr>
<tr>
<td>C(9)</td>
<td>0.007570</td>
<td>0.000640</td>
<td>11.83216</td>
</tr>
<tr>
<td>C(10)</td>
<td>0.292467</td>
<td>0.024718</td>
<td>11.83216</td>
</tr>
</tbody>
</table>

Log likelihood: 638.0807

Estimated A matrix:
\[
\begin{bmatrix}
1.000000 & 0.000000 & 0.000000 & 0.000000 \\
-0.028122 & 1.000000 & 0.000000 & 0.000000 \\
-0.007814 & -0.702647 & 1.000000 & 0.000000 \\
-0.537668 & -29.26989 & -14.95037 & 1.000000 \\
\end{bmatrix}
\]

Estimated B matrix:
\[
\begin{bmatrix}
0.044257 & 0.000000 & 0.000000 & 0.000000 \\
0.000000 & 0.003847 & 0.000000 & 0.000000 \\
0.000000 & 0.000000 & 0.007570 & 0.000000 \\
0.000000 & 0.000000 & 0.000000 & 0.292467 \\
\end{bmatrix}
\]
Structural VAR estimates for the United Kingdom

Sample (adjusted): 1994Q3 2011Q4
Included observations: 70 after adjustments
Estimation method: method of scoring (analytic derivatives)
Convergence achieved after 8 iterations
Structural VAR is just-identified

Model: Ce = Du where E[u'u']=I
Restriction Type: short-run pattern matrix
C =

\[
\begin{bmatrix}
1 & 0 & 0 & 0 \\
C(1) & 1 & 0 & 0 \\
C(2) & C(4) & 1 & 0 \\
C(3) & C(5) & C(6) & 1 \\
\end{bmatrix}
\]

D =

\[
\begin{bmatrix}
C(7) & 0 & 0 & 0 \\
0 & C(8) & 0 & 0 \\
0 & 0 & C(9) & 0 \\
0 & 0 & 0 & C(10) \\
\end{bmatrix}
\]

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Std. Error</th>
<th>z-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C(1)</td>
<td>-0.025881</td>
<td>0.008094</td>
<td>-3.197693</td>
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<tr>
<td>C(2)</td>
<td>-0.004543</td>
<td>0.013174</td>
<td>-0.344804</td>
</tr>
<tr>
<td>C(3)</td>
<td>0.911409</td>
<td>0.940041</td>
<td>0.969543</td>
</tr>
<tr>
<td>C(4)</td>
<td>0.421374</td>
<td>0.181730</td>
<td>2.318680</td>
</tr>
<tr>
<td>C(5)</td>
<td>-30.29877</td>
<td>13.44456</td>
<td>-2.253608</td>
</tr>
<tr>
<td>C(6)</td>
<td>-15.17066</td>
<td>8.521239</td>
<td>-1.780335</td>
</tr>
<tr>
<td>C(7)</td>
<td>0.043518</td>
<td>0.003678</td>
<td>11.83216</td>
</tr>
<tr>
<td>C(8)</td>
<td>0.002947</td>
<td>0.000249</td>
<td>11.83216</td>
</tr>
<tr>
<td>C(9)</td>
<td>0.004481</td>
<td>0.000379</td>
<td>11.83216</td>
</tr>
<tr>
<td>C(10)</td>
<td>0.319444</td>
<td>0.026998</td>
<td>11.83216</td>
</tr>
</tbody>
</table>

Log likelihood 688.4480

Estimated A matrix:

\[
\begin{bmatrix}
1.000000 & 0.000000 & 0.000000 & 0.000000 \\
-0.025881 & 1.000000 & 0.000000 & 0.000000 \\
-0.004543 & 0.421374 & 1.000000 & 0.000000 \\
0.911409 & -30.29877 & -15.17066 & 1.000000 \\
\end{bmatrix}
\]

Estimated B matrix:

\[
\begin{bmatrix}
0.043518 & 0.000000 & 0.000000 & 0.000000 \\
0.000000 & 0.002947 & 0.000000 & 0.000000 \\
0.000000 & 0.000000 & 0.004481 & 0.000000 \\
0.000000 & 0.000000 & 0.000000 & 0.319444 \\
\end{bmatrix}
\]
Data Appendix

**Consumer Price Index (CPI)**
The Consumer Price Index (CPI) is used to calculate the inflation rate for Sweden where 1994:I equals index=100. The inflation rate was then calculated as the percentage change between quarters.
Source: OECD iLibrary
Data series used: CPI: Consumer price index

**Harmonized Index of Consumer Prices (HICP)**
The Harmonized Index of Consumer Prices (HICP) is used to calculate the inflation rate for the United Kingdom where 1994:I equals index=100. The inflation rate was then calculated as the percentage change between quarters. In the United Kingdom, the HICP is called the CPI by the Bank of England. In OECD iLibrary the index series is called the Harmonized Consumer Price Index (CPIH).
Source: OECD iLibrary
Data series used: CPIH: Consumer price index, harmonized, quarterly sa

**Short-term nominal interest rate**
The short-term nominal interest rate (in absolute percentages) is the rate at which short-term borrowings are affected between financial institutions.
Source: OECD iLibrary
Data series used: IRS: Short-term interest rate

**Commodity Price Index**
The Thompson Reuters Headline Index (the former Commodity Research Bureau (CRB) Spot Index) consists of 19 commodities: aluminium, cocoa, coffee, copper, corn, cotton, crude oil, gold, heating oil, lean hogs, live cattle, natural gas, nickel, orange juice, silver, soybeans, sugar, unleaded gas and wheat. The index is weighted with the use of a four-tiered grouping system designed to reflect the significance of each commodity: energy (39%), agriculture (41%), precious metals (7%) and base/industrial metals (13%). For more than 50 years this index has been used as a global benchmark for global commodity markets. The index is originally denoted in US dollars. I have converted it to Swedish Kronor and Pound Sterling terms respectively. This was done for daily data as a menu option in Datastream Advance 4.0. Thereafter the average index was calculated for each quarter. This quarterly commodity price index series is then modified so that 1994:I equals index=100. I believe this gives a better representative picture of the commodity price index each quarter then the index value per the first trading day in each quarter (which is the data obtained when directly converting this index to quarterly data in Datastream Advance 4.0).
Source: Datastream Advance 4.0
Data series used: CRBSPOT: The Thompson Reuters/Jefferies CRB Spot Index (year 1967 = index 100)

**Real Gross Domestic Product (GDP)**
Real GDP is calculated by dividing the (nominal) GDP at market prices by the GDP deflator. The percentage change of real GDP was then calculated as the percentage change between the quarters.
Source: OECD iLibrary
Data series used: GDP: Gross domestic product, value, market prices; PGDP: Gross domestic product, deflator, market prices
References

Academic papers


Books


Electronic sources

http://www.bankofengland.co.uk/education/Pages/targettwopointzero/mpframework/currentinflationtarget.aspx (2012-05-06)