Asymmetric effects of monetary policy

An analysis of asymmetric effects on output and unemployment in Western economies 1996-2017

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Abstract

This thesis analyses if macroeconomic policy has asymmetric effects on output and unemployment, comparing the effectiveness of monetary policy when the output gap is positive to when it is negative. Asymmetric effects may be present due to uncertainty and loss aversion, the downward-stickiness of prices, or financial market imperfections. The empirical analysis is conducted through a panel data regression, with data from Sweden, Norway, the UK, the Czech Republic, Canada, and the US, spanning from 1996Q1 to 2017Q4. The results show that monetary policy is more effective when the output gap is positive, and that the monetary policy conducted when it is positive is contractionary, and thus that contractionary monetary policy seems more effective than expansionary, although the empirical study presents certain problems that bring the results into question.

Keywords: Asymmetric effects, monetary policy, the real interest rate, uncertainty.

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1. Introduction

“We should be clear, however, that monetary policy and these last-minute rescues can only prevent a meltdown of the economy; it can't resuscitate it. As Keynes pointed out, it's like pushing on a string…”

- Joseph Stiglitz (2008)

The financial crisis of 2007-8 shook large parts of the Western world: economic theories that had long been prudently adopted as policy advice were suddenly up for debate, as the crisis came rather unexpectedly (Skidelsky, 2010). As the crisis lingered, despite attempt to get rid of it through monetary policy, a debate about the effectiveness of monetary policy surfaced. While inflation targeting through the interest rate has been one of the most widely adopted monetary policy tools in the Western world in recent history, the crisis seemingly brought about a need for new tools, such as quantitative easing (Ibid.). The possiblity of the interest rate to restabilize the economy in a recession was thus questioned.

One possible explanation of these difficulties associated with the effectiveness of monetary policy, perhaps especially within the context of a crisis, is that monetary policy has asymmetric effects. In short, asymmetric effects is the hypothesis that monetary policy is not equally successful in affecting output or unemployment over the course of the business cycle, though economists disagree as to whether this is due to contractionary monetary policy inherently being more effective or recessions being more sensitive to changes in policy regardless of the direction. These asymmetric effects are often said to be caused by risk or loss aversion by both commercial banks and agents, or due to uncertain expectations during a downturn, as well as downward stickiness of prices (Barnichon, R., Mathes, C. & Sablik, T., 2017). Similar to the metaphor mentioned by Stiglitz above, it is said to be easier for a central bank to cool down the economy by raising interest rates than it is to bring about economic activity by lowering them, that is, “pushing on a string”.

Though economic crises have different origins, and therefore possibly different remedies, monetary policy is often advocated to be used as aid for the economy in its recovery, something which also happened in the aftermath of the most recent crisis. But how effective were central bank policies with regards to their use of the policy rate in the aftermath of the crisis, and can we discern any asymmetric effects? Has the transmission of monetary policy using the interest rate changed with the crisis, or has it been constant over time? And if asymmetric effects indeed are present, does this have any possible policy implications?

This thesis analyses macroeconomic data to discern if any asymmetric effects on output and unemployment are present during the period of 1996-2017 in non-eurozone Western economies, as well as if there are any structural breaks in the effectiveness of monetary policy during this period. In doing this, it excludes the eurozone as the sovereign debt crisis makes it difficult to isolate the effects of monetary policy. The paper will thus attempt to answer the following research question:

Did changes in the real interest rate have a larger effect on output and/or unemployment when the output gap was positive than when it was negative in Western countries between 1996-2017, and has this relationship changed over the time period considered?

The thesis will attempt to answer this question by constructing a regression model simulating an augmented IS-curve with panel data based on the quarterly national accounts of 6 countries: the US, Canada, Norway, Sweden, and the Czech Republic. The time period has been selected both due to availability of high quality data, as well as to enable us to focus more on if the effect has changed in light of the recent financial crisis.

Answering this question is important both policywise due to the significance of properly managing economic crises, as well as to the discipline of economics, given the foundational nature of the questions asked regarding uncertainty and predictability. Given that rather few studies have been published regarding asymmetric effects on output during the financial crisis, this alone makes the study worthwhile of conducting academically.

The results of the investigation show that there indeed are asymmetric effects present in the models concerning output, but not concerning unemployment. The results are thus in line with the theory about asymmetric effects on output when monetary policy is countercyclical, as this expects monetary policy to be more effective when the output gap is positive. Furthermore, regarding the effects on output, the results also point in the direction of both announcement effects as well as lagged effects on the real economy, but do not indicate the presence of a structural break with the financial crisis of 2007-2008.

The rest of the thesis has the following disposition. It will first introduce the concept of asymmetric monetary policy, along with theoretical considerations and previous research. Then, the empirical analysis will follow, with a presentation of the method and the empirical model, data, and descriptive statistics. Next follows the results of the econometric analysis, a discussion of the findings, and finally, a conclusion.

2. Asymmetric monetary policy

2.1 Theoretical considerations

2.1.1 Expectations and savings

Monetary policy can have asymmetric effects due to several reasons. One of the main possible reasons is that expectations change with the business cycle, both for consumers and for businesses: when the economy is performing well, agents tend to be more positive with regards to the economy, when it is doing badly, people tend to be cautious (Keynes, 2016). This could cause asymmetric effects if pessimism is a stronger driving force than optimism, because of loss aversion. Low expectations and loss aversion make consumers hold on to their money for security reasons, while businesses and investors are less likely to employ or invest when the economy is in a recession. This can cause business cycle asymmetries, as seen in Chen (2015), and asymmetric effects of monetary policy in Santoro et. al. (2014) and Florio (2004), as expectations are lower during recessions and negative output gaps. Pessimism would have to affect the economy more than optimism for expectations to be a reasonable explanation for asymmetric effects (Barnichon et. al., 2017), something which is incorporated in the loss aversion models of Chen (2015).

The uncertainty of expectations and loss aversion can be linked to precautionary savings, meaning that people tend to save money when their future income is uncertain, in order to smoothe consumption. This can occur due to imperfect insurance markets, and is in the case of the individual caused by the inability to spread the effects of a negative economic shock (Carrol & Kimball, 2001, p.1). The effects of precautionary savings can thus also be seen to be countercyclical, as individuals who face larger risks with regards to the state of the economy tend to save more and consume less (Challe & Ragot, 2014; Carrol et. al., 2012).

Moreover, and connected to precautionary savings, the actual amount of resources can change over the business cycle. Given that unemployment is correlated with the business cycle, consumption possibilities decrease when the output gap is negative (Christiano et. al., 2018). Though automatic stabilizers may decrease this effect, it can still be seen, although to a varying degreee for different groups of consumers (De Giorgi & Gambetti, 2016).

2.1.2 Sticky prices

Another possible explanation for asymmetric effects of monetary policy is that of asymmetry in the stickiness of prices, suggesting that prices are more flexible upwards than downwards, and that money is not neutral in the short run (Ball & Mankiw, 1994). This has been suggested as a possible reason for asymmetric effects in recessions, because businesses would tend to maintain their prices during recessions, while raising them to counteract inflation in booms, thus causing an asymmetry over the course of the business cycle. Ball & Mankiw base this theoretical approach on the presence of menu costs, and that firms tend to withhold such costs during recessions. Furthermore, though this sticky-down asymmetry may not be true for small business owners, larger firms with more market power might have more leverage in doing so (Rosenberg, 2018). In this sense, consumption possibilities would be lower in a recession, ceteris paribus, thus worsening the effect of a downturn, rather than adjusting with the change in consumption possibilities. Evidence of such downward stickiness has been found, for example, by Álvarez et. al. (2005) and Schenkelberg (2013).

This can also be modelled as a short-run convex aggregate supply curve: during expansions, monetary policy measures are thus mostly translated into effects on wages and prices, while in a recession, monetary policy effects the real economy in a stronger sense. A convex aggregate supply curve might also imply that contractionary monetary policy has more of an effect on the real economy than expansionary policy (Kakes, 1998). Weise (1999) and Lo & Piger (2005) have confirmed in empirical studies that monetary policy is more effective in recessions, though Weise offers no theoretical explanation for the effect. Lo & Piger (2005) also find that monetary policy effects are stronger during recessions when using the monetary base as a measurement of monetary policy, but find no such evidence for the direction or size of the policy changes, and no effect at all when the policy rate is used as measurement. Ravn & Sola (2004) use a similar menu cost-based model, and find no clear asymmetries when using M1 as the independent variable, but finds strong evidence that only small negative interest rate shocks have real effects on the economy. Though this thesis explores the real effects of monetary policy effectiveness, comparing a positive and negative output gap rather than specifically recessions and booms, the effect of a monetary policy tightening in relation to a convex aggregate supply curve is an important theoretical consideration to bear in mind.

2.1.3 Financial market imperfections

Furthermore, financial market imperfections may cause monetary policy to have asymmetric effects. For example, these effect may arise due to credit rationing. In this case, as tight monetary policy (ie. the central bank raising the policy rate) causes market rates to rise, banks would not be as prone to giving loans to customers they deem risky, given their decreased possibility of paying their debt, as this might lead to the bank going bankrupt due to defaults. Thus, constraining the budget of some borrowers would increase the effects of contractionary monetary policy, while the opposite situation would create no such effect or even increase the effect, such as during the subprime mortgage crisis (Barnichon et. al., 2017). However, this behaviour by banks is not necessarily caused by changes in the policy rate. It can also be due to changing credit demands by politicians, for example in the possibly overheated Swedish housing market (Frid, 2018), or autonomous credit changes by the central banks itself, such as changes in the banking regulations by the FED (Romer & Romer, 1993). However, these effects tend to coincide with changes in the policy rates.

This line of thought is further developed by Bernanke & Gertler (1989), and Bernanke & Blinder (1992), who discuss the presence of a “financial accelerator” regarding firms. This accelerator means external financing are both more costly (due to a higher finance premium) and more important for firms during recessions than during booms, and that monetary policy shocks during recessions thus can aggrevate the intial downturn asymmetrically. Bernanke & Blinder (1992) find a significant effect for the recomposition of bank assets in response to changes in monetary policy, affecting the balance sheet channel, thus suggesting the possibility of asymmetric effects of monetary policy. Lo & Piger (2005), Florio (2004), as well as Peersmann & Smets (2001), see the balance sheet channel as a possible cause of asymmetries, and Kakes (1998) points to the financial accelerator and firms’ investment behaviour in explaining the asymmetric effect.

2.1.4 Liquidity traps

Another possible reason for asymmetric effects is if the economy is in a so-called liquidity trap. A liquidity trap is a scenario in which the real interest rate is so low that no one is motivated to hold debt and a further decrease of it would not spur on anyone to do so (Hicks, 1937), something which has been suspected in the financial crash of 2007-2008 due to the low levels of policy rates. A liquidity trap may come in to place either because of uncertainty of expectations (as discussed in section 2.1.1) or due to low inflation or deflation (Akram, 2016) Therefore, a liquidity trap, and the

Keynesian IS-LM framework, includes the possibility of asymmetric effects as monetary policy is potentially ineffective in a recession (Morgan, 1993). If monetary policy were to become completely ineffective in the crisis, this might also present itself as a structural break in the model, as the variables would possibly behave differently.

Liquidity traps is an explanation of ineffective monetary policy which has gathered in importance since the financial crisis of 2007-2008 (Krugman, 2010), as well as in Japan (Akram, 2016).

2.2 Effect on unemployment

The theoretical considerations above mostly concern asymmetric effects on output, but there is also the possibility of asymmetric effects on unemployment. According to Okun's law, there is a negative relationship between a change in output and a change in unemployment, where an increase in output is correlated with a decrease in unemployment (Ball et. al., 2012; Christiano et. al., 2018). However, it is also possible that companies could tend to hold on to workers during recessions as a matter of keeping good workers, possibly counteracting Okun's law. If output and unemployment are indeed correlated via Okun's law, however, then if output has asymmetric effects, so might unemployment. Though Okun's law is not what this thesis primarily investigates, this correlation and the idea that decisions regarding employment made by firms are based on expectations warrant the idea that asymmetric effects on unemployment is worth investigating (Barnichon et. al., 2017; Garibaldi, 1997).

2.3 Summary of empirical evidence

Many studies detect some kind of asymmetric effects of monetary policy, but not all (Sripinit, 2012). Those who do find asymmetric effects, however, often disagree with regards to when and how this happens: some papers find results confirming that monetary policy indeed has asymmetric effects on output, as contractionary policy is seen to be inherently more effective than expansionary policy (Cover, 1992; Peersman & Smets, 2001; Santoro et. al., 2014; Florio, 2004; Ülke & Berument, 2016; Karras, 2013) - thus, in the case of Cover, for example, positive money supply shocks do not affect output as much as negative money supply shocks do. Others, however, rather find that asymmetric effects of monetary policy depends much more on the state of the economy than the direction, as monetary policy is seen to be more effective in a recession (Weise, 1999; Lo & Piger, 2005). In particular, Ravn & Sola (1996) show that when taking the regime shift in 1979 of US monetary policy into account, no asymmetries are present in Cover's original data, and Weise finds that monetary policy is more effective in a recession than in a boom regardless of the direction of change, contradicting some of Cover's claims (Weise, 1999). Arden. et. al. (2000) instead find significant effects that depend on both the direction of the change, as well as the state of the economy. Other significant effects found in empirical studies are that the size of the shifts affects output asymmetrically, with large changes causing disproportionately large changes compared to small changes (Ravn & Sola, 2004; Ülke & Berument, 2016; Karras, 2013), or that the asymmetry depends on the the intitial level of output growth (Weise, 1999; Arden et. al., 2000).

Therefore, as this thesis analyses if monetary policy is conducted countercyclically or not, and if the effects are stronger when monetary policy is contractionary, its starting point is more in line with Cover (1992) and a classical Keynesian analysis than papers suggesting independence of the direction of change and focusing specifically on recessions and booms.

3. Empirical Analysis

The existence of asymmetric effects of monetary policy is studied using a panel data model. The model is based on an augmented IS-curve inspired by Goodhart & Hofman (2005) to measure real effects in the economy. The model is expanded by including an interaction effect between the output gap and the real interest rate to caputre a potential non-linear effect.

3.1 Econometric model and method

To encapsulate the theory presented above, we use an augmented version of the IS-curve created by Hicks as the model for the empirical analysis (Hicks, 1937). The IS-curve is chosen as we are interested in the real effects on the economy and its connection to changes in the real interest rate, and thus in how monetary policy is transmitted. Thus, the dependent variables used to test for asymmetric effects in this thesis are the growth rate in GDP, as well as unemployment, accounting for two different aspects of real macroeconomic activity related to consumption and investment. The independent variable which is of interest for the purpose of this thesis is the real interest rate, measured as the policy rate minus inflation, as it is transmitted through the interest rate channel. As many modern central banks tend to use the policy rate as their main monetary policy tool, this has been deemed the most prudent choice of independent variable, rather than using a measurement of the monetary base. Furthermore, to control for shifts of the IS-curve, the change in the real exchange rate, representing international trade, and the change in real public expenditure are used as control variables. This is because these variables in themselves can cause an increase in output independently of a change in the real interest rate, public expenditure as demand by the government, and the real exchange rate as an increase in international trade volumes. As mentioned in the method section, using the growth rates in this way eliminates interference from country-specific effects, such as different levels of public expenditure. In order to measure any possible asymmetric effects we use a dummy variable for the output gap where

$$\delta = \begin{cases} 1 & \text{if } output - gap \geq 0.0\,\% \\ 0 & \text{if } output - gap < 0.0\,\% \end{cases}$$

We also assume that there are some kind of lag in the effect of the independent variables, as the monetary policy transmission mechanism does not work instantly, and therefore the following two models are used as a starting point.

$$\Delta y_t = \beta_1 + \beta_2 r_{t-x} + \beta_3 \delta_{t-x} + \beta_4 \Delta\sigma_{t-x} + \beta_5 \Delta g_{t-x} + \beta_6 \delta_{t-x} \cdot r_{t-x} + \epsilon_t$$
$$\Delta u_t = \beta_1 + \beta_2 r_{t-x} + \beta_3 \delta_{t-x} + \beta_4 \Delta\sigma_{t-x} + \beta_5 \Delta g_{t-x} + \beta_6 \delta_{t-x} \cdot r_{t-x} + \epsilon_t$$

where y denotes real output, t denotes the time period (measured quarterly), β denotes parameter, the integer x denotes the variable lag ($1 \leq x \leq 6$), r denotes the real interest rate, σ denotes the real exchange rate, g denotes public expenditure, u denotes unemployment, Δ denotes the growth rate of a variable, δ denotes the dummy variable for the output gap, and ϵ denotes the error term.

Thus, the models for both output and unemployment will be tested according to the following hypotheses:

$$H_0 : \beta_6 = 0 \qquad (*)$$
$$H_0 : \beta_6 = \beta_2 = 0 \qquad (**)$$

The first null hypothesis, (*) tests if the parameter of the interaction term r*dummy is different from zero: this hypothesis measures if the central banks behave differently when the output gap is positive compared to when it is negative, that is if central banks follow a countercyclical monetary policy, a procyclical monetary policy, or none at all, depending on the slope. The second null hypothesis tests if the parameter of the interaction variable r*dummy is significantly different from the effect of the real interest rate in itself, that is, if the effect of the real interest rate in general is different from the effect of the real interest rate controlling for the state of the economy, thus controlling for presence of asymmetric effects.

The models will also be tested for a different number of time lags (as denoted by the subscript x in the formulas), to see the if this has any effect on the results; this is prudent as effects on output and unemployment might not show until several quarters have passed after a monetary policy change, and indeed even several years (Gruen et. al., 2007; Havranek & Rusnak, 2013). In this way, one to four lags will be the standard procedure, and more lags will be added if it is deemed fruitful. It is also interesting to take into account the possibility of announcement effects, if the effects should be non-linear over time. The number of lags used was limited to a maximum of six to keep the number of models down to make the results more perspicuous. To test for a possible structural break, the same models will be run with the data divided into two time periods, 1996Q1-2006Q4 and 2007Q1-2017Q4.

To operationalize the model described in the previous section, a regression model using panel data is estimated in Stata. Panel data can be described as the combination of time series and cross sectional data, thus observing the same variables and their interaction over time. It has the advantage of obtaining accurate estimators using a shorter period of time than a single time series, given the number of observations, as well as accounting for country specific effects rather than grouping all observations together, like in a standard linear regression or separate time series (Verbeek, 2016, p. 374). Though this may lead to being less sensitive to some country specific differences, such as differences in effects of the interest rate on savings and investment, using this approach can instead provide a more general view of the efficacy of the real interest rate.

The most common methods when analysing asymmetric effects are different types of vector autoregressions with switching mechanisms, many of them based on Cover (1992). However, measuring the monetary policy transmission mechanism and its real effects can be done lucidly by an augmented IS-curve using a model for panel data. Moreover, we can still determine the presence of asymmetric effects, though not determine the connection to different sized changes to the same degree.

There are many different ways to conduct a panel data analysis, all depending on how the interaction between the panels is to be handled. Due to the clarity and simliarities between results in different models, a pooled OLS regression is primarily used. As all variables except the real interest rate are measured by their different growth rates, panel data with fixed effects are not necessarily the most prudent choice as we do not need to account for different levels of variables (Verbeek, 2016, p. 384).

Furthermore, to test that the models can be used for inference, a Breusch-Pagan test is used to test for heteroscedasticity, a Levin-Lin-Chu test for unit roots, and a test by Woolridge and Drukker for autocorrelation (Wooldridge, 2002, pp. 282–283). Should any of these tests indicate issues with any of the Gauss-Markov assumptions or the requirement of stationarity, the models will be adjusted accordingly. Furthermore, if autocorrelation should be present, the model will be changed to a panel FGLS regression using an AR(1)-process to simulate the autocorrelation.

3.2 Data

The panel data set consists of data from Sweden, Norway, the UK, the Czech Republic, Canada, and the US, spanning from 1996Q1 to 2017Q4, or 88 time periods per country. The data includes measurements of real GDP, unemployment, public expenditure, the national policy rates, the inflation rate, the real exchange rate, and the output gap. Thus, there are a total of 528 observations for each of these variables, making the data set sufficently large for the investigation (Park, 2011). The data was gathered primariliy from the Federal Reserve Bank of St. Louis' Economic Database, the respective national central banks, as well as from the OECD economic database (For data sources and calculations, see the appendix).

The countries were selected on the basis of data availability, while avoiding eurozone-countries in order to lessen the effects of the sovereign debt crisis, as this would provide causality issues (Reinhart & Rogoff, 2010). This creates better opportunities to focus on the financial crisis and recent possible asymmetric effects on its own, though the sovereign debt crisis might still affect the results through, for example, international trade. Furthermore, Western economies seem to have handled the crisis worse than, for example, emerging economies in Latin America and Asia, which further warrants a deeper investigation into Western economies if the financial crisis is to be the focal point (Wise et al., 2015).

The time period itself was chosen as this has been a period of relatively crisis free growth for the selected countries, except for the financial crisis of 2007-2008, thus avoiding the crisis in the Swedish housing market in the early 90s (Dougherty, 2008). Furthermore, due to data availability on public expenditure in the Czech Republic, and a desire to keep a balanced panel for methodological considerations, the year 1995 was excluded from the analysis. Quarterly data was selected, which not only gives more precision than a yearly average, but also because this means more observations during the selected period of time and possibilities of statistical significance. Where daily and monthly data has been found (such as for the different policy rates) it has been converted into a quarterly mean, and where seasonally adjusted and calendar corrected data has been found it has been preferred to unadjusted data.

The different policy rates were found as nominal data from the respective national central banks, and to control for the effect of inflation they have been converted to the real interest rate according to the Fisher hypothesis, which states that the real interest rate is equal to the the nominal interest rate (in our case the policy rate set by the central banks) minus the expected rate of inflation, or $r = i - \pi$ (Berument & Jelassi, 2010). As expectations variables are more difficult to come by for many of the countries, the ex-post rate of inflation has been used instead as a best approximation in order to make the data more comparable. Furthermore, as the growth rates of the variables have been of primary interest, the variables have been selected in their percentual change form from the FRED database, and no calculations have therefore been necessary. However, using the growth rate of the real interest rate proved difficult, as percentual growth rates would become nonsensical when policy rates shift between negative and positive figures, a scenario which has become prevalent during the time period considered.

As for selection and handling of the data, several choices have been made to best simulate the real economy. For reasons of uniformity, much of the data has been taken from similar datasets, which could lessen the effect in differences of measurement. For that reason, and for reasons of accessibility, most of the data has been gathered from the Federal Reserve Bank of St. Louis' database, FRED, for example the real broad effective exchange rate and the harmonized unemployment rate. Though the unemployment rate need not be harmonized considering the use of growth rates as variables, this was selected, as well, for reasons of uniformity, and to control for eventual changes in the national measurements of unemployment during the time period considered. However, one must remember that the data collected in FRED is also dependent on the different national institutions for statistics, and thus does not necessarily entail complete uniformity of measurement.

Furthermore, as measuring the output gap is fraught with measurement difficulties and different model choices, special consideration has to be taken with this data. Therefore, the selection process of the data has been done with extra care and valuation of the different possible models to best estimate the output gap (for more information on this issue, see for example Hjelm & Jönsson, 2010). The measurements of the output gap have been those chosen by the central banks or other other institutions as the best representation of the state of the economy, thus constituting a best approximation. Furthermore, if the measurement differences mostly concern the volatility of the variable rather than breaking points, systematic errors within countries, or non-linear trends, this can be forgiven as the data is converted into a dummy variable. As for the output data, GDP by an expenditure approach has been used for all countries. For more information regarding the specific datasets and any calculations made, see the appendix.

3.3 Descriptive statistics

In figure 3.1 we can see the progression of the real interest rate in the six countries used for the empirical analysis (for more information about the data sources, see the appendix; for more information about the data selection, see the previous section). What we can see from the data is that, except for a dramatic spike in the Czech Republic in 1997 caused by a dramatic increase in the policy rate, the graphs for all the different countries tend to follow a negative path for much of the time period. Later on in the empirical analysis, it will be important to control for this time effect, as it might otherwise lead to spurious correlations.

As is also seen, the graph includes negative real interest rates, which have been present in all of the countries after 2008. This is important, because negative real interest rates have since the crisis constituted attempts by the central banks to boost the economy. Out of 88 observations for each country, Sweden had 21 cases of negative interest rates, Norway had 24, the UK had 33 (all of them after the crisis), the Czech Republic had 46 (and several of those before the financial crisis set in, indicating unrelated economic disturbances), Canada had 29, and the US had 45 (likewise, some of them before the crisis). Thus, negative real interest rates constitute between one fourth and half of all observations per panel. However, negative interest rates have been present before the time period used in the empirical analysis, and are therefore not necessarily a continuing trend, although its causation is important. Furthermore, the graphs seem to be more in unison and stable, albeit at a lower level, after the financial crisis in 2007-2008, possibly indicating the presence of heteroscedasticity. Though this is more thoroughly investigated through the econometric models, a measurement of the standard deviations are reported in table 3.1, grouping the data into two time periods, 1996-2006 and 2007-2017. These numbers show that all countries except for the UK have larger standard deviations before the financial crisis than after; though the data for the Czech Republic should be observed with caution due to the spike in 1997, this effect might overall signal a more stable inflation or monetary policy in the last 10 years.

In figure 3.2 we see the estimated output gap for the six economies, which was converted into a dummy variable for the empirical investigation. The downturn with the financial crisis of 2007-2008 can be seen clearly, as well as the boom leading up to it. What can also be distinguished is the differences in fluctuations, which is shown in table 3.1 as the differences in standard deviations between 1996Q1-2006Q4 and 2007Q1-2017Q4. Sweden can be seen to have a much larger standard deviation than the other countries; whether this is due to real effects or due to measurement differences is difficult to say. Furthermore, we can see that the Norwegian curve is much smoother than the others, at least from 2003 onwards. This also most likely reflects measurement differences, both in comparison with the other countries, as well as perhaps to their own earlier measurements.

Table 3.1 presents standard deviations of select variables, chosen either because there are large differences between the countries, or because heteroscedasticity was suspected within them, for which variables the data has been divided into two time periods (1996Q1-2006Q4 and 2007Q1-2017Q4). The data regarding the real interest rate and the output gap has already been discussed above, but there are other interesting variables in this tablevas well. When looking at the GDP growth rate, we see that the data fluctuates more for Sweden, Norway and the Czech Republic: qualified guesses suggest this might be explained by dependence on international trade for Sweden in the oil price in Norway, but no conclusions are drawn from this. For the growth rate of unemployment, large fluctuations can be seen mostly in the Czech Republic and Norway, thus possibly relating to the similar fluctuations in the growth rate of real GDP. Regarding the growth rate in public expenditure heteroscedasticity was suspected, and therefore the data is divided into two time periods: looking at the different standard deviations, we can see that all countries except for the US show smaller deviations in the growth of public expenditure during the last ten years than during the previous ten, and quite notable so. Thus, we will have to control for heteroscedasticity in the empirical analyis.

The variable for the real exchange rate provided no descriptive characteristics of interest for the analysis upon inspection, and is thus not included.

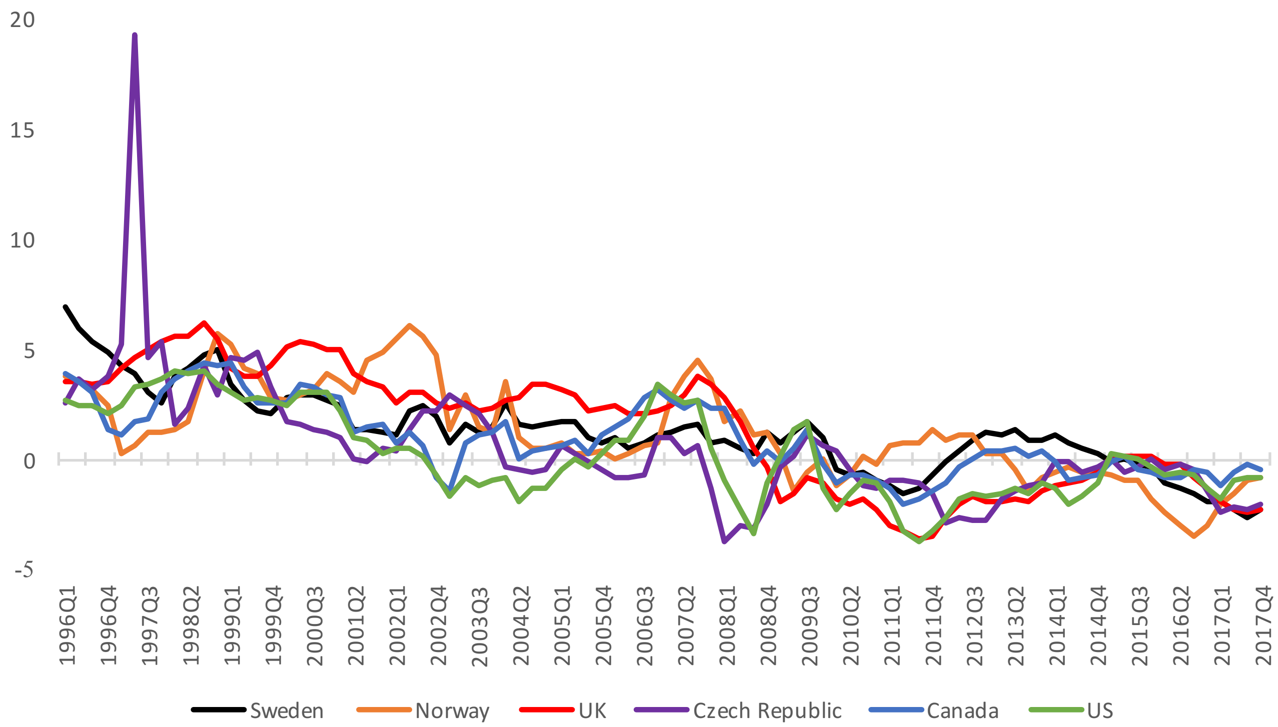

Figure 3.1: the real interest rate, percent

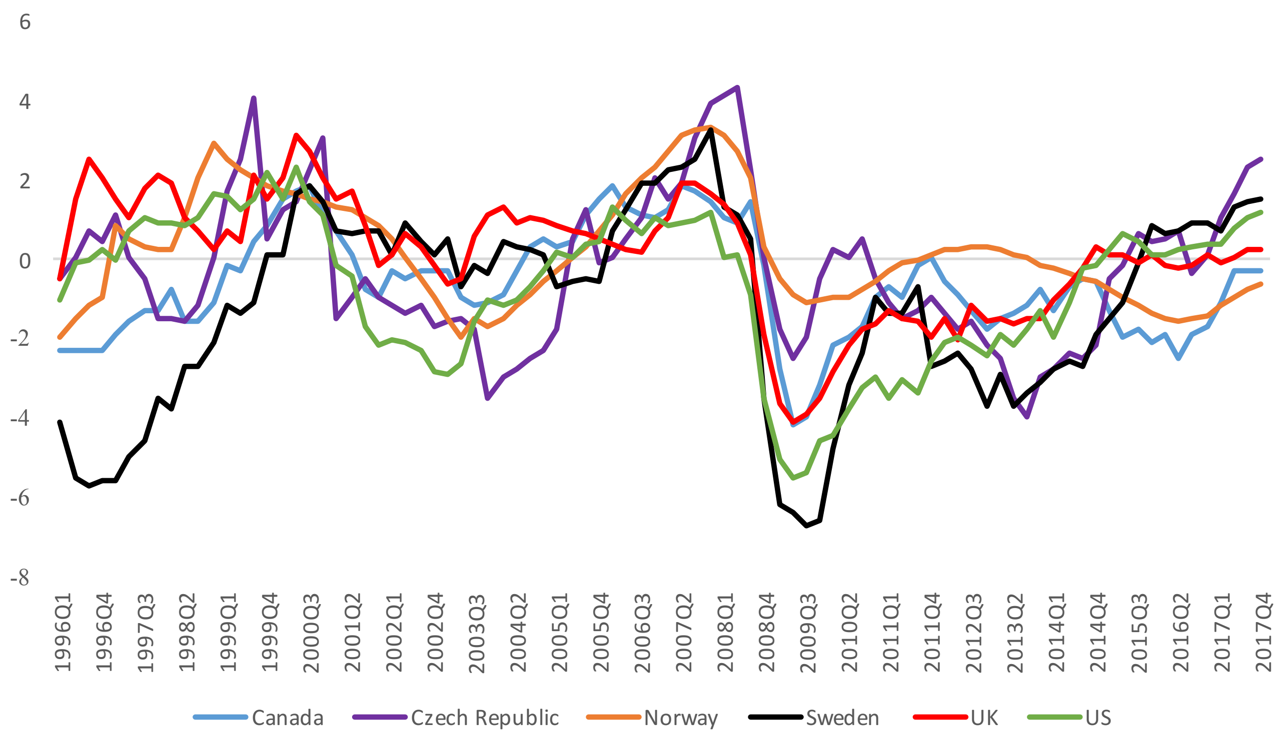

Figure 3.2: Output gap, percent

	Sweden	Norway	UK	The Czech Republic	Canada	US
Output gap	2.433	1.390	1.521	1.874	1.347	1.852
Growth rate of GDP	.9073	1.148	.5876	.8780	.6217	.6206
Growth rate of unemployment	4.212	5.481	3.505	6.187	3.472	4.912
The real interest rate 1996-2006	1.523	1.813	1.183	3.214	1.414	1.799
The real interest rate 2007-2017	1.201	1.750	1.813	1.205	1.138	1.507
Growth rate of public expenditure 1996-2006	.8074	1.578	1.267	2.187	.7145	.6827
Growth rate of public expenditure 2007-2017	.5323	.7648	.7864	1.078	.5991	.6910

Table 3.1 - standard deviations of select variables

4. Results

4.1 Effects on output

After performing the panel level Woolridge and Drukker test for autocorrelation, no serial correlation was found to be present in either of the variables, and as a Breusch-Pagan test showed signs of heteroscedasticity robust standard errors are used in all models. Though this might lead to larger confidence intervals, it is a necessary choice if our inference is to be correct. Therefore, moreover, no residual sum of squares is reported in the table below, as we have corrected the standard errors for heteroscedasticity. Performing Levin-Lin-Chu unit root tests on all the variables included in the regressions showed, after including linear time effects on both the real interest rate and the interaction term r*dummy, that there was no presence of unit roots, thus eliminating the risk of spurious regressions. After the models had thus been investigated, the pooled OLS was preferred as the poolability of the data could not be rejected through a Breusch Pagan LM-test, and no fixed effects could be observed.

In table 4.1, the models regarding asymmetric effects of monetary policy on output are reported. First, looking at the F-tests for $H_0(*)$, we can see that we can reject the null hypothesis for all models, but that it is strongest in models 1 and 4. Given the negative parameter of the interaction variable, this indicates that governments tend to pursue countercyclical monetary policy. While this may be self-evident to some, it sheds light on the debate regarding how asymmetric effects take place mentioned above. It also indicates that there is a transmission lag in the efficiency of monetary policy, as the effect becomes stronger in models 4.

Looking at the interaction variable r*dummy itself, we can see that it is statistically significant in all four models, but that it attains the highest levels of significance in models 1 and 4. This might indicate that we are dealing with an announcement effect in the first model, while the effect on the real economy increases over time in models 2 to 4. Looking at the parameter estimates for the variable, we can see that it is negative in all four models. What does this mean in an economic sense?

When a dummy variable and a continuous variable interact, the parameter of the interaction variable refers to a change in the slope. Thus, the augmented IS-curve is significantly more steep when the output gap is positive. In other words, the effectiveness of monetary policy is much higher when the output gap is positive than when it is negative, approximating the theory regarding asymmetric effects being due to contractionary policy being more efficient than expansionary, building upon what was discovered in H_0(*). Conducting an F-test for H_0(**) to test for asymmetric effects, we reject H_0(**) in all four models, thus concluding that the effects of the real interest rate are indeed asymmetric on output in the data. Furthermore, the results are strongest in model 1 and 4, indicating the presence of an announcement effect on GDP, while the effect of the monetary policy shock on the real economy is spread out over the year and increases over time.

Looking at the control variables, we can see that public expenditure is highly significant in model 1. This means that the government reacts to central bank policy rather quickly, which might come as a surprise. However, it most likely does not mean that the government changes their budget every quarter in response to central banks, rather the effect might possibly be due to the changes in the structure of the government debt.

We also see significant results for the real interest rate in itself in models 1 and 4. This means that there is a positive relationship between the growth rate of GDP and the real interest rate on a four-quarter lag. Though we have controlled for time effects in the model, it was deemed possible that this parameter is significant due to such effects still appearing in the model when the lag becomes longer. However, when modelling for 5 and 6 lags to control for this, we saw the effect of the interest rate fade away, while the effect of the interaction variable remained.

Furthermore, looking at the R-squared we can see that the values in the models are rather similiar, all having somewhat low values around .45. This is to be expected, given that there are other possible variables not included in the model which can affect the output growth rate, as well as the possibility of measurement errors.

4.2 *Effects on output with a structural break*

The same model was used to test if the financial crisis constituted a structural break in the data, using the time periods 1996Q1-2006Q4 and 2007Q1-2017Q4 for two separate regressions with one to four lags. As can be seen in table 4.2, however, no structural break was detectable as we could not detect any significant effect except for an asymmetric announcement effect in the time period 2007Q1-2017Q4. Therefore, it is possible that the results attained above were partly due to sheer size of the data sample. In any case, it does not seem that the financial crisis in itself changed the effectiveness of the real interest rate for the data sample.

It is noticable, however, that much of the announcement effect in public expenditure remains in the 1996Q1-2006Q4 sample. It is, however, difficult to speculate as to why this has changed.

4.3 Effects on unemployment

The same models used with output as the dependent variable were tested with unemployment. Similar to the tests above, conducting F-tests and Breusch-Pagan LM-tests showed presence of neither fixed nor random effects, and as a a Breusch-Pagan test confirmed the presence of heteroscedasticity in the data robust standard errors were used for these models as well. However, unlike the models for output, the model failed the Woolridge and Drukker test for autocorrelation as well, and showed signs of serial correlation on the 1% level. To best simulate the model, a panel FGLS model with an AR(1)-process is assumed, using a common AR(1) coefficient. Unfortunately, this removes the possibility of measuring goodness-of-fit through R-squared, but was deemed better than ignoring the autocorrelation.

As presented in table 4.3, running the full model with unemployment as the dependent variable, we find no statistically significant effect on the interaction variable. Therefore, we can see that unemployment is not as sensitive to changes in the real interest rate as can be expected, when we control for autocorrelation. Thus, interpreting the null hypotheses seems irrelevant, given that no clear inference can be done based on the results, and no asymmetric effects of monetary policy can be found with regards to unemployment.

Table 4.1: Asymmetric effects of monetary policy on output

Model (n lags on IVs)	1	2	3	4	5	6
1. Real interest rate	.0087 (.0288)	.0017 (.0295)	.0478 (.0280) *	.0743 (.0285) ***	.0614 (.0321) **	.0490 (.0316)
2. Dummy variable	.1379 (.0827) *	-.0129 (.0823)	-.0798 (.0821)	-.0576 (.0816)	-.0470 (.0862)	-.0299 (.0906)
3. r*dummy	-.0917 (.0291) ***	-.0548 (.0304) *	-.0770 (.0302) **	-.0950 (.0300) ***	-.0756 (.0325) **	-.0798 (.0323) **
4. Real exchange rate	.0010 (.0126)	-.0020 (.0112)	-.0003 (.0124)	-.0010 (.0123)	.0038 (.0129)	-.0037 (.0127)
5. Public expenditure	-.1020 (.0325) ***	-.0023 (.0325)	.0067 (.0298)	.0411 (.0302)	-.0648 (.0345) *	-.0051 (.0288)
Intercept	.4390 (.3556)	1.132 (.4510) **	.1978 (.4261)	.8537 (.3847) **	.9683 (.3833) **	.4000 (.3169)
F-test	4.56 ***	4.11 ***	4.06 ***	4.10 ***	3.99 ***	4.25 ***
DF	430	425	420	415	410	405
R-squared	.4662	.4476	.4582	.4712	.4721	.4698
N	522	516	510	504	498	492
H_0(*): r*dummy is different from zero	9.92 ***	3.26 *	6.48 **	10.07 ***	5.40 **	6.11 **
H_0(**): r*dummy is different from r	8.29 ***	2.83 *	3.25 **	5.22 ***	2.82 *	3.11 **

Standard errors are reported within parentheses after each parameter estimate.

All numbers are reported with 4 significant figures, up until the 4th decimal place.

Statistical significance: * <.1, **<.05, ***<.01

Table 4.2: Asymmetric effects of monetary policy on output with a structural break

	1996-2006				2007-2017			
Model (n lags on IVs)	1	2	3	4	1	2	3	4
1. Real interest rate	-.0500 (.0386)	-.0608 (.0385)	.0218 (.0364)	.0450 (.0354)	.0887 (.0445) **	.0706 (.0465)	.0399 (.0469)	.0977 (.0536) *
2. Dummy variable	.0782 (.1255)	-.1557 (.1338)	-.2154 (.1299) *	-.1326 (.1233)	.0652 (.1312)	-.0316 (.1209)	.0313 (.1252)	-.0205 (.1212)
3. r*dummy	-.0473 (.0410)	.0034 (.0412)	-.0370 (.0414)	-.0704 (.0373) *	-.1280 (.0682) *	-.0831 (.0821)	-.0470 (.0825)	-.0225 (.0900)
4. Real exchange rate	-.0150 (.0204)	-.0126 (.0192)	-.0195 (.0187)	-.0081 (.0184)	.0138 (.0150)	.0060 (.0137)	.0104 (.0166)	.0082 (.0170)
5. Public expenditure	-.1034 (.0387) ***	-.0014 (.0333)	-.0268 (.0329)	.0349 (.0338)	-.1052 (.0706)	-.0013 (.0851)	.1233 (.0655) *	.0378 (.0644)
Intercept	.6635 (.3436) *	1.378 (.4643) ***	.3278 (.4438)	.9749 (.3944) **	.6678 (.2177) ***	.9079 (.2615) ***	.7845 (.2814) ***	-.5914 (.3276) *
F-test	3.48 ***	2.69 ***	2.80 ***	3.15 ***	5.38 ***	4.87 ***	5.21 ***	4.67 ***
DF	210	205	200	195	210	205	200	195
R-squared	.2817	.2458	.2651	.2691	.5484	.5338	.5400	.5409
N	258	252	246	240	258	252	246	240
H_0(*): r*dummy is different from zero	1.33	.01	.79	3.57 *	3.52 *	1.03	.33	.06
H_0(**): r*dummy is different from r	6.56 ***	2.64	.41	1.86	2.54 *	1.21	.39	1.97

Standard errors are reported within parentheses after each parameter estimate.

All numbers are reported with 4 significant figures, up until the 4th decimal place.

Statistical significance: * <.1, **<.05, ***<.01

Table 4.3: Asymmetric effects of monetary policy on unemployment

Model (number of lags on IVs)	1	2	3	4
1. Real interest rate	.3587 (.1839) *	.2500 (.1854)	.1683 (.1868)	.1669 (.1865)
2. Dummy var.	-.7889 (.5287)	-.9798 (.5466) *	-.2121 (.5587)	.8849 (.5720)
3. r*dummy	.0477 (.1958)	.2431 (.1996)	.1813 (.2029)	.1062 (.2064)
4. Real exchange rate	-.1030 (.0559) *	.0425 (.0570)	.0522 (.0577	-.0286 (.0577)
5. Public expenditure	-.0014 (.1193)	.1398 (.1182)	-.0317 (.1207)	.0833 (.1219)
Intercept	-.5075 (1.440	-1.470 (1.454)	-.5059 (1.460)	-3.252 (1.449) **
Wald chi2	368.7 (0.000)	358.3 (0.000)	351.0 (0.000)	361.9 (0.000)
DF	91	90	89	88
R-squared	-	-	-	-
N	522	516	510	504
AR(1) coefficient	.3934	.3934	.3934	.3934
H0(*): AV different from zero	0.06	1.48	0.8	0.26
H0(**): AV different from r	7.82 **	9.72 ***	4.62 *	2.85

Standard errors are reported within parentheses after each parameter estimate.

All numbers are reported with 4 significant figures, up until the 4th decimal place.

Statistical significance: * <.1, **<.05, ***<.01

5. Discussion

With regards to the asymmetric effects of monetary policy on output, we can reject both of the null hypotheses posited. We thus found indications that governments tend to pursue countercyclical monetary policy, and that the effects of monetary policy using the real interest rate is asymmetrical, with the effectivness of monetary policy being higher when the output gap is positive. Thus, this is in line with the results presented by Cover (1992), which suggest that contractionary monetary policy is more effective than expansionary. Furthermore, not only was a possible announcement effect suggested, but a lagging effect on the real economy as well. The results, however, should be interpreted with some caution, as there is always the danger of model misspecification, or endogenous variables when dealing with macroeconomic questions, especially as the results did not attain statistical significance for the models when assuming a structural break in conjunction with the financial crisis. It is also possible that, although the effects of the financial crisis waned outside of the eurozone, the six countries used in the empirical analysis may still have been affected by the sovereign debt crisis; as the real exchange rate variable does not rech any significance level in our model, changes in international trade flows may have been absorbed elsewhere, affecting GDP more than is recognized in the model. Furthermore, this thesis uses the output gap as the dummy variable rather than recessions and booms; this affects the interpretation of some of the theories about asymmetric effects of monetary policy themselves to some degree, although many of the concepts derived from recessions, such as risk aversion and imperfect financial markets, can to some extent be applied to a negative output gap and vice versa.

Connecting the results to the theoretical considerations, it is difficult to isolate any specific reason why asymmetric effects could be found in the data. Though many of the theoretical explanations base themselves on the fact that both consumers and commercial banks tend to be risk averse, there could also be the possibility of downward stickiness of prices. This might be possible to be controlled for using the change in inflation as an independent variable in a continuation of this study, as we have only considered real effects. Furthermore, to analyse the possibility of financial market imperfections, taking asset prices and credit rationing into account may present substantial results.

However, some substantial results can be drawn regarding how asymmetric effects seem to work. Much of the different views concerning comes down to if asymmetric effects exist because contractionary policy is inherently more effective (due to expectations and loss aversion), or if the state of the economy is more important regardless of the direction of the change, as monetary policy is more effective in a recession than in a boom. As both null hypotheses were rejected, indicating the presence of both countercyclical monetary policy and asymmetric effects, we follow Florio (2004) in her conclusion: assuming that central banks follow a countercyclical monetary policy, as shown in our empirical analysis and which is not a too controversial statement, the direction of the monetary policy change is inherent in the state of the economy, rather than being arbitrary. Thus, we can point to uncertainty and risk or loss aversion, and possibly a liquidity trap, as reasons for why the results show possible asymmetric effects of monetary policy, though to conclude that a liquidity trap existed one would have to include other measurements as well, as the results here merely cannot reject its existence.

Relating this to the convex aggregate supply curve which shows larger real effects during a recession, we can see that the real effects in our empirical analysis are stronger when the output gap is positive - which would mean either when cooling off a boom or in the beginning of a recession. However, as we saw evidence of countercyclical policy in one of our null hypotheses, and because of the possibility of a recognition lag in central banking, we seem to have a larger real effect with a positive output gap as a result of contractionary monetary policy trying to cool down the economy rather than an expansionary response on part of the central bank due to a beginning recession. This might be argument against the possibility of conducting expansionary policy at least in the beginning of a recession, although any results regarding either the shape of the aggregate supply curve, how monetary policy is conducted in a recession, or its possible effects, cannot be drawn from this empirical study. Furthermore, the empirical results only pertain to real effects, and thus, further studies taking both inflation and recessions and booms into account, rather than output gaps, would be necessary to fully investigate possible asymmetric effects. Therefore, the results should be interpreted with some caution.

Our results regarding asymmetric effects of monetary policy on unemployment did not attain any significance level. The lack of asymmetric effects on unemployment perhaps supply us with more information regarding the reasons why they do exist for output. As unemployment is mainly based on the decisions by firms (assuming that people who resign tend to leave for a different job rather than prefer being unemployed), this purely economic decision may be less affected by the proclivities of the employers, instead being based on their profit maximizing behaviour. This would make unemployment procyclically correlated with the business cycle, as Okun's law suggests. In contrast, consumers might be less consistent in their decisions, or to the very least, have a decision making structure taking more variables into account to maximize their utility, such as security and stability. Consumers would therefore tend to prefer security and keeping their precautionary savings, which also would be a reason for them to continue their current employment should the future of the economy become more uncertain.

Given the results, and the fact that the global economy has seemingly been difficult to restart after the financial crisis, the theoretical explanations and the empirical results presented above indicate a possible reason for this difficulty. Policywise, the central banks have long tried to inspire confidence in their power, often through the goal of price stability. However, if pessimism is a stronger driving force than belief in the central bank, this may not be enough. Moreover, given that the use of the policy rate shows signs of asymmetric effects, perhaps unconventional monetary policy tools such as purchasing government bonds, or a stronger use of fiscal policy, is advisable to better counteract the negative parts of the business cycle or a long-lasting crisis. However, given that no structural break could be found in the data, it does not seem as if the asymmetric effects were stronger during the financial crisis than during regular movements of the business cycle, possibly indicating that the duration of the crisis is to be explained in some other way.

For economics as a science, the issues of expectations and consumer confidence have long been discussed and have been central to many debates regarding both monetary policy as it is conducted, as well as its theoretical implications for economics in itself. Though the author does not expect this Bachelor’s thesis to bear that kind of weight, its implications are clear: asymmetric effects of monetary policy is still a viable theory.

6. Conclusion

In conclusion, the empirical investigation shows presence of asymmetric effects of monetary policy on output, as monetary policy is seen to be more effective when the output gap is positive. As monetary policy also was found to be countercyclical, this further suggested that contractionary policy is more effective than expansionary. Several models were used in investigating this, possibly discovering an announcement effect as well as lagged effects on the real economy. Regarding a possible structural break in the effectiveness of monetary policy in conjunction with the financial crisis of 2007-2008 we could not reject the null hypotheses, and neither could the results measuring asymmetric effects of monetary policy on unemployment.

There could be many possible reasons for the existence of asymmetric effects, with risk aversion and uncertainty, downward-stickiness of prices, imperfect financial market and liquidity traps comprising the most important ones. No clear conclusions can be drawn as to the exact reasons why we can observe asymmetry in the data, but risk aversion and uncertainty, both regarding consumers and commercial banks, are deemed as the explanations that fit the data best.

7. Appendix - calculations and data descriptions

Canada

Growth rate of output

The quarter-on-quarter real growth rate of output of Canada (seasonally adjusted) was collected from OECD, from the dataset regarding quarterly national accounts (OECD, 2018f).

Growth rate of unemployment

The data for the percentage change in the rate of unemployment for Canada was gathered from the FRED Economic Data database, seasonally adjusted (OECD, 2018r).

Real interest rate

The Canadian nominal interest rate was calculated as a quarterly average of the official Bank Rate, from the Bank of Canada (2018b). A consumer price index from the FRED database denoting the rate of inflation (OECD, 2018a) was then used to calculate the real interest rate according to the following formula $r = i - \pi$.

Real public expenditure

The data for the Canadian real public expenditure in constant prices was gathered from the FRED Economic Data database (OECD, 2018g)

Real exchange rate

The data for the Canadian real broad effective exchange rate was gathered from the FRED Economic Data database, not seasonally adjusted (BIS, 2018a), denoting the percentage change.

Output gap

The data for the output gap (integrated framework) was collected from bank of Canada (2018a).

The Czech Republic

Growth rate of output

The quarter-on-quarter real growth rate of output of the Czech Republic (seasonally adjusted) was collected from OECD, from the dataset regarding quarterly national accounts (OECD, 2018f).

Growth rate of unemployment

The data for the percentage change in the rate of unemployment for the Czech Republic was gathered from FRED, denoting the change in the harmonized unemployment rate for all persons in the Czech Republic, seasonally adjusted (OECD, 2018l).

Real interest rate

The data for the nominal interest rate was accessed through data from the Czech National Bank (CNB, 2018). The nominal repo-rate being the main policy instrument, this was then discounted by a Consumer Price Index taken from the FRED database (OECD, 2018b) according to the formula $r = i - \pi$.

Real public expenditure

The data for real public expenditure, measured in constant prices, was gathered from the FRED database ().

Real exchange rate

The data for the real broad effective exchange rate was collected from the FRED database, not seasonally adjusted (BIS, 2018b), denoting the quarterly percentage change.

Output gap

The dummy variable for the output gap was estimated from data from the Czech statistical office through Adamec and Strelec (2011; CSO, 2018), as well as complementary data from the Deloitte from 2011 onwards (Deloitte, 2017).

Norway

Growth rate of output

The quarter-on-quarter real growth rate of output of Norway (seasonally adjusted) was collected from OECD, from the dataset regarding quarterly national accounts (OECD, 2018f).

Growth rate of unemployment

The data for the percentage change in the rate of unemployment for Norway was gathered from the FRED database, seasonally adjusted (OECD, 2018m).

Real interest rate

The Norwegian nominal interest rate (styrningsrente) was obtained from Norges Bank as a monthly average, which in turn was transformed into a quarterly average (Norges Bank, 2018b). To calculate the real interest rate, the inflation was adjusted for using a consumer price index from the FRED database (OECD, 2018c) according to the formula $r = i - \pi$.

Real public expenditure

The percentage change quarterly real public expenditure of Norway in constant prices was gathered from FRED, seasonally adjusted (OECD, 2018i).

Real exchange rate

The data for the real broad effective exchange rate for Norway was collected from FRED (BIS, 2018c), denoting the quarterly percentage change.

Output gap

The data concerning the output gap in Norway are based on the estimations produced in the Monetary Policy Reports produced by Norges Bank, from the data series of Monetary Policy Report 2/07 (1996Q1-2006Q4), 2/09 (2007Q1-2007Q4), 2/15 (2008Q1-2011Q4), 2/18 (2012Q1-2017Q4) (Norges Bank, 2018a).

Sweden

Growth rate of output

The quarter-on-quarter real growth rate of output of Sweden (seasonally adjusted) was collected from OECD, from the dataset regarding quarterly national accounts (OECD, 2018f).

Growth rate of unemployment

The data for the percentage change in the rate of unemployment was gathered from FRED, seasonally adjusted (OECD, 2018n).

Real interest rate

The data for the nominal interest rate, the repo rate, was gathered from the Swedish Riksbank, and calculated as a monthly average (Sveriges Riksbank, 2018). This was then adjusted for inflation through a consumer price index from the FRED database (OECD, 2018d) according to the formula $r = i - \pi$.

Real public expenditure

The data for the growth rate of real public expenditure in constant prices was gathered from FRED, seasonally adjusted (OECD, 2018j).

Real exchange rate

The data for the real broad effective Swedish exchange rate was gathered from FRED (BIS, 2018d), denoting the quarterly percentage change.

Output gap

The data for the Swedish output gap was collected from konjunkturinstitutet table "potential output and resource utilization" (Konjunkturinstitutet, 2018).

United Kingdom

Growth rate of output

The quarter-on-quarter real growth rate of output of the United Kingdom (seasonally adjusted) was collected from OECD, from the dataset regarding quarterly national accounts (OECD, 2018f).

Growth rate of unemployment

The data for the percentage change in the rate of unemployment was collected from FRED, seasonally adjusted (OECD, 2018o).

Real interest rate

The nominal official bank rate of the UK, the repo rate, was collected from the Bank of England (2018). This was then adjusted for inflation through a CPI from the FRED database (OECD, 2018e), and calculated according to the formula $r = i - \pi$.

Real public expenditure

The data for the growth rate in real public expenditure in constant prices for the UK was gathered from FRED, seasonally adjusted (OECD, 2018k).

Real exchange rate

The real broad effective exchange rate for the UK was collected from FRED (BIS, 2018e).

Output gap

The data for the UK output gap was collected from the Office of Budget Responsibility, 1996Q1-2002Q4 from Pybus (2011) and 2003Q1-2017Q4 from the Economic and fiscal outlook tables (OBR, 2018).

United States

Growth rate of output

The quarter-on-quarter real growth rate of output of the United States (seasonally adjusted) was collected from OECD, from the dataset regarding quarterly national accounts (OECD, 2018f).

Growth rate of unemployment

The percentage change in the rate of unemployment for the US was collected from FRED, seasonally adjusted (OECD, 2018p).

Real interest rate

The data for the nominal exchange rate of the US, the effective federal funds rate, was collected from FRED (Board of Governors, 2018). This was then adjusted for the annual growth rate of inflation through a Consumer Price Index collected from the OECD database (OECD, 2018q), according to the formula $r = i - \pi$.

Real public expenditure

The data for the percentage change in real public expenditure was gathered from FRED, with a seasonally adjusted annual rate (US Bureau of Economic Analysis, 2018).

Real exchange rate

The data for real broad effective exchange rate of the US was gathered from FRED (BIS, 2018f), adjusted for changes in percent from quarter to quarter.

Output gap

The data for the US output gap was collected from FRED (US Congressional Budget Office, 2018).

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