The effect of the European Central Bank's non-standard monetary policy measures on the success of the mid-term inflation target

Lappeenranta–Lahti University of Technology LUT

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Examiner: Post-doctoral researcher, Timo Leivo

ABSTRACT

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Keywords: European Central Bank, monetary policy, inflation

The purpose of this bachelor's thesis is to study how the non-standard monetary policy measures of the European Central Bank have influenced the success of mid-term inflation target. The monetary policy measures studied in this thesis are asset purchase programme, negative rate on deposit facility and targeted long-term refinancing operations. The study examines the years 2009-2019. The research method is both a literature review and a quantitative study, more precisely linear regression analysis. The data for the quantitative part has been collected from the following sources: the European Central Bank's own website, the French Central Bank's website, Eurostat and the Federal Reserve Economic database.

Based on the quantitative research and literature review, the non-standard monetary policy measures can be considered to have had the desired effect on the inflation target. Especially the results obtained with long-term estimation support previous research results and the theory presented in this study. However, there are also factors that weaken the reliability of the results, due to which the results of the quantitative research are not completely truthful as such.

TIIVISTELMÄ

Lappeenrannan–Lahden teknillinen yliopisto LUT

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Kauppatieteet

Nelli Suvanto

Euroopan keskuspankin epätavanomaisten rahapolitiikan keinojen vaikutus keskipitkän aikavälin inflaatiotavoitteen onnistumisessa

Kauppatieteiden kandidaatintutkielma

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25 sivua, 3 kuvaa, 13 taulukkoa ja 2 liitettä

Tarkastaja: Tutkijatohtori Timo Leivo

Avainsanat: Euroopan keskuspankki, rahapolitiikka, inflaatio

Tämän kandidaatintutkielman tarkoituksena on tutkia kuinka Euroopan keskuspankin epätavanomaiset rahapolitiikan keinot ovat vaikuttaneet keskipitkän aikavälin inflaatiotavoitteiden onnistumisessa. Tutkimuksessa tarkasteltavat rahapolitiikan keinot ovat omaisuuserien osto-ohjelma, negatiivinen talletuskorko sekä kohdennetut pidempiaikaiset rahoitusoperaatiot. Tutkimus tarkastelee vuosia 2009-2019. Tutkimusmenetelmänä toimii sekä kirjallisuuskatsaus että kvantitatiivinen tutkimus, tarkemmin ottaen lineaarinen regressioanalyysi. Kvantitatiivisen osuuden tutkimusaineisto on kerätty seuraavista lähteistä: Euroopan keskuspankin omat nettisivut, Ranskan keskuspankin nettisivut, Eurostat sekä Federal Reserve Economic tietokanta.

Kvantitatiivisen tutkimuksen ja kirjallisuuskatsauksen perusteella epätavanomaisen rahapolitiikan voidaan katsoa vaikuttaneen halutulla tavalla inflaatiotavoitteeseen. Varsinkin pitkän aikavälin estimoinnilla saadut tulokset tukevat aikaisempia tutkimustuloksia sekä työssä esitettyä teoriaa. Tuloksissa esiintyy kuitenkin myös luotettavuutta heikentäviä tekijöitä, joiden vuoksi kvantitatiivisen tutkimuksen tulokset eivät ole sellaisinaan täysin totuudenmukaisia.

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1 Introduction

The primary goal of the European Central Bank, or ECB, is to keep the price level stable. This is to preserve the purchasing power of the euro (European Central Bank, 2023a). The ECB introduced its new monetary policy strategy in 2021, in which it set a medium-term inflation target of symmetric 2 percent inflation (Bank of Finland, 2023a) The previous strategy was last updated in 2003, where the inflation target was set at an annual increase of less than 2 percent (European Central Bank, 2003).

The key interest rates are considered as the primary and standard monetary policy instruments. The Governing Council of the European Central Bank determines the key interest rates for the euro area which are the following: The interest rate on the main refinancing operations, which is used for banks to borrow funds from ECB against collateral at a pre-determined interest rate. Second one is the rate on the deposit facility for banks to use to make overnight deposits, which uses a pre-set rate that is lower than the rate on the main refinancing operations. Third one is the rate on the marginal lending facility offering banks overnight credit, which uses a pre-set interest rate above the main refinancing operations rate. (European Central Bank, 2023b)

The changes that took place in the economy after the financial crisis led to the fact that the standard monetary policy instruments were no longer as successful in maintaining price stability. Because of this, so-called non-standard on unconventional measures were resorted to, which have since remained part of the ECB's monetary policy toolkit. The main non-standard measures are negative rate on deposit facility, asset purchase programs, targeted long-term refinancing operations and forward guidance (European Central Bank, 2023c) This study focuses on the first three measures, since forward guidance would not be suitable for the research method used in this study.

Non-standard monetary policy instruments can have multiple different effects on economy, and that is why it is important to study and understand them. First, it is important to understand how well the tools succeed in their goals. In addition, unconventional monetary policy instruments have potential risks and negative effects, that should be recognized. In

this way, it is possible to better predict what kind of tools should be used in the future. (Reichlin, 2020)

Previous research literature indicates that unconventional monetary policy methods have had a positive effect in achieving inflation targets. For example, the asset purchase program (APP) has been considered to have a significant impact on achieving inflation targets. (Neri & Siviero, 2018) In addition, Rostagno, Altavilla, Carboni, Lemke, Motto, Guilhem & Yiangou (2019) present their results, according to which inflation would have been on average a third of a percentage point lower in 2015-2018 without unconventional monetary policy measures.

The aim of this thesis is to study how the non-standard measures of the ECB's monetary policy have affected on the success of the mid-term inflation targets. This study focuses on viewing the harmonized index of consumer prices. The main research question is as follows:

How has the European central bank's non-standard measures of the monetary policy succeeded in the mid-term inflation targets?

To support the main research question, there is a sub question which is the following:

How do the effects of different non-standard measures differ from each other?

The research is limited to dealing with Europe and the Eurozone. The development of inflation is monitored by the harmonized consumer price index, also known as HICP, which is an index compiled by Eurostat. The ECB has stated that the HICP is suitable for measuring prices when considering the success of the price stability objective. (European Central Bank, 2021) Non-standard methods of monetary policy are studied from data that can be found on the ECB's website, Bank of France's website, Eurostat and Federal Reserve Economic Database. The study is limited in time from 2009 to 2019. In this period, the use of non-standard measures are taken into account, and the effect of the Covid-19 pandemic is ignored. Literature review is used to study the entire period, whereas the quantitative research of this study focuses on year 2014-2019. Although the non-standard measures of monetary policy discussed in this study were officially introduced in 2014, the ECB has been practicing non-standard monetary policy even before this. For example, during and after 2009, the deposit rate was significantly lower than in previous years. The ECB does not have an exact definition to what they consider is the medium

term. It is a flexible concept that always depends on the circumstances of each situation. (European Central Bank, 2023d).

1.1 Monetary policy

In this chapter the monetary policy tools of the ECB are introduced. Monetary policy tools can be divided into standard and non-standard measures. This study focuses on the non-standard monetary policy measures. Before taking a closer look at the measures, the transmission mechanism of the monetary policy is introduced.

Transmission mechanism

The monetary policy transmission mechanism is used to demonstrate how the monetary policy affects the inflation (and the real economy). The mechanism consists of several different mechanisms that affect simultaneously, some having direct effect on the inflation while the effects of some only occur over time. (Sveriges riksbank, 2022) While the transmission mechanism is not one universally valid method, a lot of similarities can be found to how central bank's monetary policy has been established to affect the economy. Below, a chart from ECB is shown to demonstrate the transmission mechanism.

Since central banks have monopoly power over money supply in the economy, they are capable of setting the interest rate. When interest rate changes it has a direct effect on money market interest rates and expectations. (European central bank, 2023e) Monetary policy can have a significant effect on for example individuals expectations of how inflation is going to develop. These expectations then can guide individuals behavior. (Pétursson, 2001) The interest rate then affects asset prices, bank rates and exchange rates. Inflation might be influenced immediately by changes in exchange rates, if imported goods are used in consumption directly. (European central bank, 2023f)

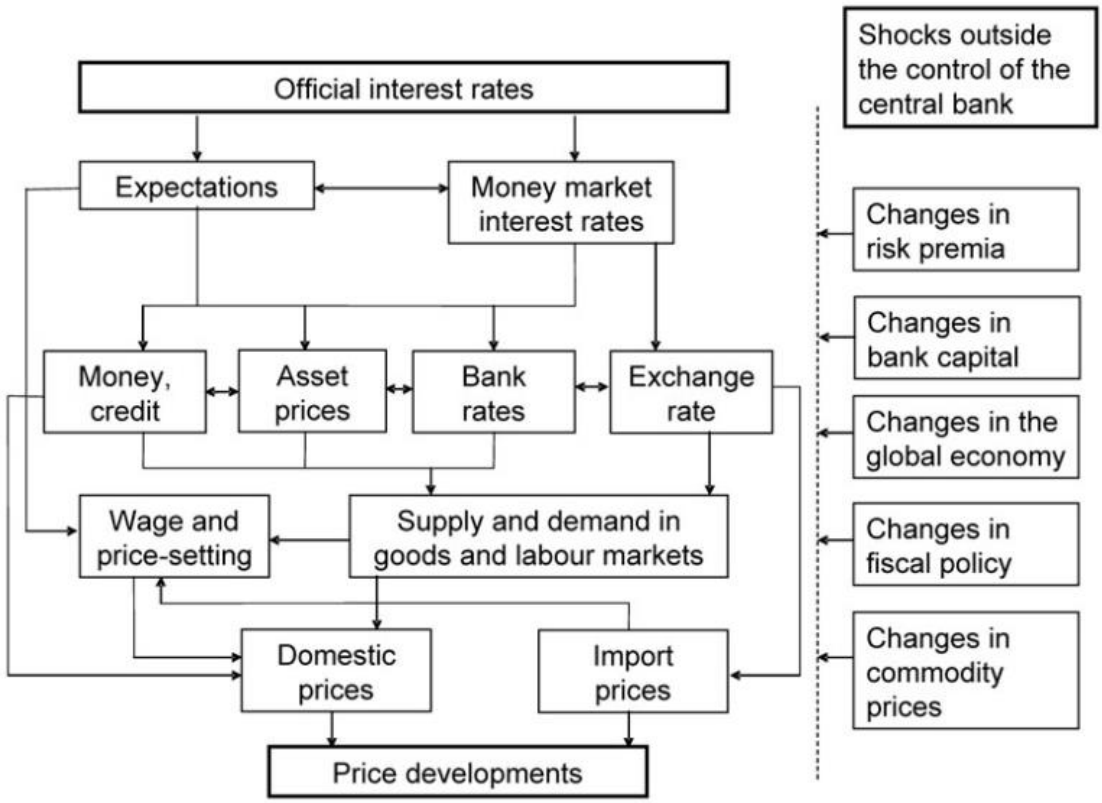

Figure 1 Transmission mechanism of monetary policy (European Central Bank, 2023)

Standard measures

The standard monetary measures involve open market operations, standing facilities and reserve requirements. Open market operations are used to steer the market rates, manage liquidities and signaling the monetary policy stance. Operations in the Euro system are divided as follows: main refinancing operations, longer-term refinancing operations, fine-tuning operations, and structural operations. (Bank of Finland, 2023b) Standing facilities consists of marginal lending facility and deposit facility, through which the liquidity in the banking system can be increased or decreased. Through marginal lending facility, banks may borrow overnight loans from ECB against eligible collateral. With deposit facility banks may place overnight deposits with a fixed interest rate below the target financing rate. (Mishkin, 2016, 432) ECB controls the structural demand for central bank money through reserve requirements. This means that credit institutions established in the euro area hold a certain amount of funds with their national central bank. (Bank of Finland, 2023c)

Non-standard measures

The financial crisis started in 2007 as a financial turmoil, which eventually lead to the global financial crisis in 2008, and later to the great recession in 2009-2010. Although the ECB's monetary policy managed to respond quickly to the challenges of the financial turmoil, the global financial crisis that started in September 2008 jeopardized the transmission of the monetary policy. (Camba-Mendez & Mongelli, 2018, 535-536) ECB's key interest rate was then reduced to a historically low level. The main refinancing rate was eventually lowered to 1% on May 2009 which was historically low. (Cour-Thimann & Winkler, 2013, 11) This then led to a problem described as zero lower bound. This problem occurs when interest rate is near or at zero and fails to stimulate the economy. (Protze, 2008, 1)

As a result of the great recession, the economic growth as well as the employment growth slowed down, and inflation sunk below the target levels. These phenomena led the ECB among other central banks to adopt non-standard monetary policy measures. What made these measures so unusual was especially the combinations of monetary policy measures, their wide scale, and the purposes for which the measures were used. (Potter & Smets, 2019, 6-8)

Transmission channels of non-standard monetary policy measures

Lewis & Roth (2019) explain that while the transmission channels of standard monetary policy can be considered extensively researched, the transmission channels of non-standard measures however are still being explored. European Central bank (2015) states that while several possible channels for non-standard measures have been identified, three main channels for transmission can be considered to be the direct pass-through, portfolio rebalancing and signalling channels.

Through the direct pass-through channel, it is anticipated that the non-standard measures relieve private non-financial sector borrowing terms and conditions. This encourages borrowing for investment and consumption. Direct pass-through channel applies to especially for targeted long-term refinancing operations since the measure is aimed to support banks lending to the real economy. (European Central bank, 2015)

With portfolio rebalancing channel the non-standard measures, especially the APPs, raise the asset prices and lowers their yields. Rise in the asset prices should increase the wealth of holders which then is expected to show as a boost in their spending. (Sahuc, 2016)

Signaling channel is based on underlining the central bank's commitment to its mandate. Signaling channel affects the market expectations of interest rates by committing to lower them. Central bank also can inform the market of possible policy interventions. Signaling channel has been interpreted to work best with measures that have a significant impact on central bank's balance sheet. (European Central Bank, 2015)

Asset purchase programme

On January 2015 the ECB announced the expanded asset purchase programme (APP). The APP consists of the following programmes: Public sector purchase programme (PSPP), Asset-backed securities purchase programme (ABSPP), corporate sector purchase programme (CSPP) and covered bond purchase programme (CBPP3). The first and second CBPP programmes were conducted in 2009-2012, and they are not considered to be part of the APP. Net asset purchases under the APP lasted from January 2015 to December 2018. (Bank of Finland, 2023) The program was introduced with the aim of reacting to the risk of low inflation continuing for too long (Gambetti & Musso, 2017, 4)

Negative rate on deposit facility

Negative interest rate policy (NIRP) was also a response to the low inflation. NIRP was introduced in June 2014, when ECB cut the rate on its deposit facility by 10 basis points making the rate negative. The Danish central bank had made a similar cut in July 2012, but before that there had not been any other major central bank who would have had introduced negative policy rates before. Therefore, ECB's decision was surprising. (Eisenschmidt & Smets, 2019) NIRP is considered to work through the bank lending channel of monetary policy transmission, exerting an easing effect. It is mainly due to the decrease in banks' funding costs. (Boucinha & Burlon, 2020)

Targeted long-term refinancing operations

Targeted long-term refinancing operations (TLTROs) were first announced by ECB in June 2014. TLTROs were introduced to provide support for bank lending in the Euro area private sector. These operations have been introduced in three different phases: operation I in June 2014, operation II in March 2016 and operation III in March 2019. Banks receive credit from the central bank at a lower interest rate if they can give more loans to the private sector. While the conditions and incentives for the operations have changed over time, the main goal for all three operations has remained the same. (Lähteenmäki, 2020) Andreeva and

García-Posada (2021) explain that by supporting banks lending to real economy, TLTROs reduce banks' incentives to use liquidity to buy sovereign debt.

This study consists of five main chapters which are following: introduction, theoretical framework, methodology and data, results, and conclusions. First, the introduction chapter explains relevant background information for the study such as the aim of the study, research questions and ECB's monetary policy. The second chapter introduces the theory used in this study, as well as literature review of previous studies. Third chapter consists of the data methods and more detailed description of the research data. Results chapter reveals the results of the quantitative study. In addition, the reliability of the research is evaluated and possible notes about the evaluation of the research results can be made. Finally with the conclusion chapter the research questions are answered.

2 Theoretical framework

This chapter introduces the quantity theory of money, Keynes's general theory and monetary policy theory, which together form the theoretical part of the study. Later in this chapter, the literature review is presented.

2.1 Quantity Theory of Money

According to the quantity theory of money, changes in the quantity of money define solely the nominal income. The theory measures demand for money since it presents how much money is held for a given amount of nominal spending. (Mishkin, 2016) Quantity theory of money also presents a relationship between inflation and the growth of money (Hillinger & Süssmuth, 2010). The first form of the equation for the quantity theory of money was introduced by Fisher in 1911. Mishkin (2015) presents the following equation:

$$P*Y = M*\bar{V} \qquad (1)$$

Where M is the quantity of money, $\bar{V}$ is the velocity which is assumed to be constant, P is the price level and Y is aggregate output. P*Y can be thought of as nominal GDP, and velocity is what creates the link between M and P*Y. Due to V and Y being constant in the short run, meaning that when M doubles P must double as well which is why according to classical economists' changes in the quantity of money result as proportional changes in the price level. (Mishkin, 2016)

Since the 1970s, the quantity theory of money has been considered as of the most remarkable theories for macroeconomics. However, the changes occurred after the financial crisis at the latest have changed the perspective on how this theory has succeed on explaining the events that have taken place in macroeconomics. The theory in brief, claims that when the quantity of liabilities of the central bank doubles, it doubles the price level as well (Friedman, 2015, 17).

Nowadays, there is enough empirical evidence to show that the theory has not worked as it should have when predicting the relationship between money and price level. This is not just by the European central bank, but also the bank of Japan and Federal Reserve. (Marcuzzo, 2017, 269-270) During, and after the 2007-2009 crisis, the liabilities of central banks increased significantly due to the increase in asset holdings. Against the expectations, this did not result as an, significant increase in inflation. This can be seen to be at variance with the quantity theory. (Friedman, 2015, 16-17) According to Mishkin (2016), the quantity theory of money offers a long run theory of inflation, since based on it the wages and prices are flexible. A strong positive relationship should occur between money growth and inflation in the long run. The same relationship does not exist in the short run. Therefore Mishkin (2016) states that the quantity theory of money manages to explain inflation in the long run but not in the short run.

According to Bordes & Clerc (2007) the central bank cannot completely determine the quantity of money, but it has power on controlling interest rates. Therefore, in consonance with the Quantity theory of money, the ECB can affect the price-level stability by keeping the interest rate at its equilibrium value.

2.2 Keynesian approach: The General Theory

The General Theory by Keynes presents a complementing approach to the quantity theory of money with his theory of the determinants of the price level. (Marcuzzo, 2017) According to the general theory, Causevic (2015, 62-64) states that changes in the quantity of money effecting the level of prices are the cause of the following five influences:

First influence is changes in effective demand. The quantity of money in circulation and the income velocity of money results as the effective demand. Second, the law of diminishing returns. Third, the influence of the fact that production resources cannot be replaced and the inelasticity of supply in certain sectors causes the excessive demand to be absorbed through rise in prices. Fourth, the changes in the unit wage. The discontinuous changes of wage-units money value results as a rise in prices. Finally, the fifth influence comes from the different marginal products of production's factors that enter marginal cost. (Causevic, 2015, 62-64)

2.3 Literature review

Although non-standard monetary policy measures are relatively new to the monetary policy tool kit, previous studies of their effects can still be found. There is plenty of research on the effects of asset purchase programs. The effect of negative interest rates has also been studied, but there are hardly any previous studies on the effect of targeted long-term refinancing operations on inflation. Altavilla, Lemke, Linzert, Tapking & von Landesberger (2021) explain that with the negative interest rates and the TLTROs it is not possible to study their macro effects as precisely as the APP since not many estimates are available. They also present a generalization of the combined effect of the measures stating that the inflation rate would have been markedly lower if these measures would not have been used since the year of 2014.

However, TLTRO shock which reduces the lending rate by 10 basis points was found to raise the inflation 0.1 percentage points respectively. A dissertation by Portela (2019) states that a very small increase was found in inflation expectations with TLTRO announcements. The reported increase was lower than 1% based on which the actual impact of the announcement cannot be assessed.

For the negative interest rate policy, several studies have suggested that it has not been able to affect the inflation in a desired way. Despite that, some results still indicate that the ECB's negative rate on deposit facility has been successful in effecting the inflation expectations and overcoming deflationary spiral (Czudaj, 2020).

A study made by Mandler & Scharnagl (2020) assessed the macroeconomic impacts of asset purchases in four countries at annual level. A slight effect was found on inflation. However, the effect was found to be much weaker when compared to other macroeconomic factors such as RGDP. Andrade, Breckenfelder, De Fiore, Karadi & Tristani (2016) suggest that after announcing the APP, inflation expectations increased clearly. APP was also found to reanchor the long-term inflation expectations.

As a summary from previous literature, it can be assumed that the effect of at least some of the non-standard monetary policy methods have succeeded in influencing inflation in the desired way. Next, a table of some earlier results is presented.

Table 1: Summary of previous research results

Author	Central bank	Results
Bulligan, 2018	European central bank	Statistically significant impact on inflation expectations with the first APP announcement
Burlon, Gerali, Notapietro & Pisani 2018	European central bank	APP was found to have a significant effect to inflation
de la Barrera, Falath, Henricot & Vaglio, 2017	European central bank	Over the periods of 2005-2009 and 2012-2017 results show little to no impact of

		interest rates on inflation expectations
Bartocci, Burlon, Notarpietro & Pisani, 2021	European central bank	CSPP is found to boost inflation
Van Riet, 2017	European central bank	Non-standard measures were considered successful in preventing deflation risk
Borrallo Egea & del Río López, 2021	Bank of Japan	Non-standard measures have been succesful to combat deflation, although the inflation targets have not been reached with non-standard measures
Michail, 2019	Bank of Denmark, bank of Sweden & bank of Switzerland	No significant effect found of negative interest rates on inflation
Rostagno, Altavilla, Carboni, Lemke, Motto, Guilhem & Yiangou (2019)	European central bank	Annual inflation would have been one third of a percentage point weaker during the years 2015-2018 without the measures

From the table 1 it can observed that overall the non-standard monetary policy measures are considered to be successful in achieving the inflation targets and thus the price stability target. However, it should be noted that for example Van Riet (2016) investigated the effect of forward guidance in addition to purchase programmes and refinancing operations. As mentioned before, this study does not focus on forward guidance.

It is possible that due to regional differences some of the study results would be different if they had been done in the Euro area. For example, Borrallo Egea & del Río López study from Japan. The measures effect on inflation and the price stability target were found to be

deficient, but it should be noted that Japan has a history of structural features such as population ageing which can have effects on achieving price stability.

The use of non-standard monetary policy measures is relatively new, which may explain the scarcity of previous research. For example, the studies of targeted long-term refinancing operations seem to focus on their effect on bank's lending policies. Many studies also emphasize how different measures can have synergistic effects. For example, the commitment to asset purchase programmes has been interpreted to be an element of also forward guidance (Van Riet, 2016).

While the purchase programmes especially have been found to stimulate the inflation in a desired way, no such result can be found from de la Barrera et al (2017) for interest rates. Similar results were found also outside the Euro area (Michail, 2019). These results give some direction to what can be assumed from the results of this study.

3 Methodology and data

For the quantitative study there is four sets of data. Harmonized consumer price index (HICP) is collected from Eurostat website. The index consists of all items used to measure HICP and the geopolitical entity consists of Euro area. HICP data is monthly for the APP and NIRP, and quarterly for the TLTROs. The data for the APPs is collected from ECB's own website. Data for refinancing operations is collected from the website of bank of France and it is quarterly. Data for the negative interest rate on deposit facility is from Federal reserve economic database. The research period in this study covers the years 2009 to 2019 with the literature review. However, the empirical part of this study focuses only on the time of June 2014 to December 2019.

Table 2: Definitions of variables and variable transformations

HICP	Harmonized consumer price index
APP	Sum variable of asset purchase programme
NIRP	Negative interest rate on deposit facility
TLTRO	Targeted long-term refinancing operations

D1	First difference of the variable
ln	Natural logarithm of the variable
D1 ln	First difference of the logarithmic variable

Table 3: Univariate summary statistics of variables

	OBS	MEAN	STD.DEV.	MIN	MAX
APP	63	1549868	913292.2	9536	2595075
HICP	63	120.27	2.41	115.87	124.35
NIRP	67	-0.34	0.11	-0.5	-0.067
HICP	67	120.11	2.40	115.87	124.35
TLTRO	14	90950.36	108480.6	3396	399289
HICP	14	1.20	0.18	0.92	1.49

For the APP the data is from October 2014 to December 2019, and it consists of the cumulative net purchases. A sum variable is used in the analysis of APP. For the rate on deposit facility the data is from June 2014 to December 2019, and data for TLTROs is from September 2014 to December 2019. As can be seen from table 2, the observations of the variables are rather small, especially for the TLTRO. This can affect the reliability of the analysis. The data used in this study is time series data, which means that the data is characterized by a natural order of observations. Linear regression analysis will be used as the study method to explore how the different non-standard monetary policy measures affect the inflation. Linear regression analysis will be conducted with Stata.

3.1 Linear regression analysis

Montgomery, Peck & Vining (2021) explain that linear regression analysis is a statistical method for studying the relationship of variables. The method can be considered as one of the most popular statistical techniques since it can be suitable for a wide range of problems. The effect of different ECB's non-standard monetary policy measures on the mid-term inflation is studied with a single-explanator linear regression model. According to Mellin (2006, 286), a single-explainer linear regressions model seeks to explain the variation in the

observed values of the explanatory variable by means of the variation in the observed values of the single explanatory variable. A single-explainer linear regression model can be formed as following:

$$y = \beta_0 + \beta_1 x_i + \varepsilon_{i,}, \quad i= 1,2\ldots,n \text{ (Mellin, 2006, 287)} \qquad (2)$$

Where β_0 is the standard term, β_1 is the regression coefficient of the exponent x, x_i is the explanatory variable and ε_i is the residual term.

A single-explanatory linear regression analysis is used to answer the second research question:

How do the effects of different non-standard measures differ from each other?

There are six assumptions for the linear regression analysis which should be true so that the coefficients of the estimated model are correct and reliable. According to Puumalainen (2018), these are:

I. The relationship is linear

II. The expected value of the residual term is E(e)=0

III. The variance of the residual term is constant var (e) = σ^2 = var (y)

IV. the covariance of a pair of residual terms is cov(e,e) = cov(y,y) = 0

V. There must be variation in the explanatory variable

VI. The residual terms follow a normal distribution if y follows a normal distribution (and vice versa)

The prerequisite for time series regression is that the time series is stationary. Stationarity means that the mean and variance of the time series are constant over time. In addition, instead of the covariance between two time periods depending on time itself, it should depend only on the distance between the two time periods. It is important to study the stationarity of time series data, since using non-stationary data can cause spuriousness in

regressions in which case the results are not reliable. Non-stationarity is a feature that often occurs, especially in economic time series. (Baumöhl & Lyócsa, 2009, 3-4)

The basic test for stationarity is called the Augmented Dickey-Fuller test, that is based on a unit root testing. The null hypothesis of the test is that a unit root exists in a model which implies that the time series is non-stationary. Stationarity can also be seen from a graph, and that is why it is recommended to look at a graph of the time series before doing the test. (Mushtaq, 2011) A line graph made of variables can be found from Appendix 1.

There are different ways to deal with non-stationary data to use it in analysis. Possibly the simplest way is to take the first difference of the time series. If taking the first difference makes the time series stationary, it is "integrated of order one". It is common to also take natural logarithms of the data to increase the stationarity. (Baumöhl & Lyócsa, 2009, 3)

When using non-stationary variables in a regression model, different estimations can be used depending on the qualities of the variables. The figure below presents the options when choosing the right estimation. The cointegration test is performed later in this chapter to find out the correct estimation model.

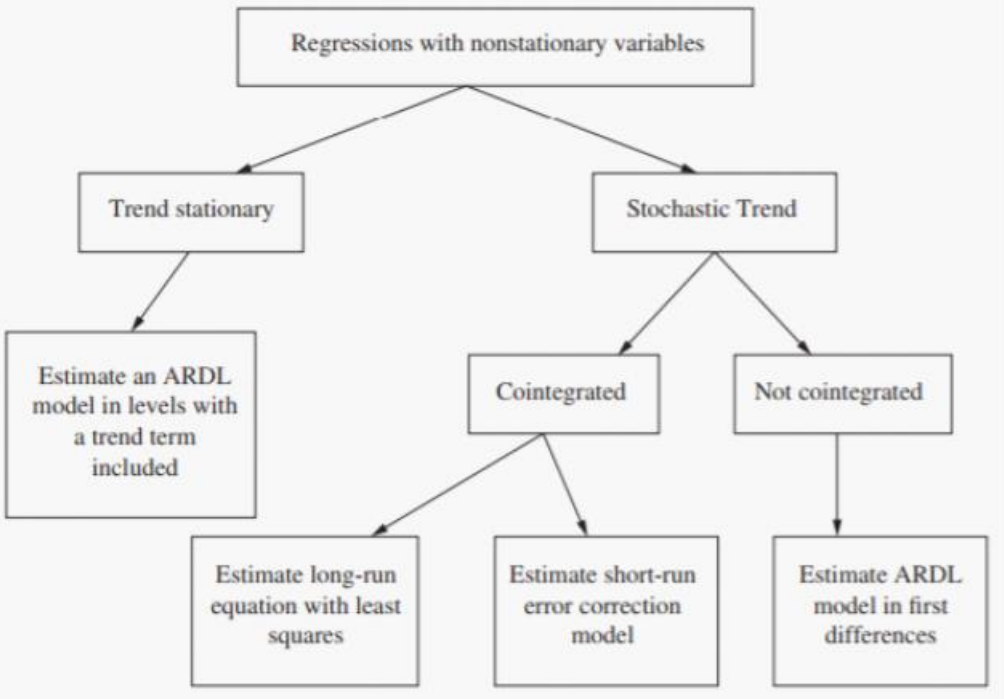

FIGURE 12.7 **Regression with time-series data: nonstationary variables.**

Figure 2: Test selection diagram for non-stationary time series variables by Hill, Griffiths & Lim (n.d. cited in Arminen, 2021)

Next, the results from the Dickey-Fuller tests are presented. Non-stationarity in test results is marked with red color. The number of lags used in the tests were obtained from DF-GLS tests using the Schwert criterion. With the APP and HICP variables, it was required to use the first difference of the logarithmic variables to make both variables stationary.

Table 4: Augmented Dickey-Fuller tests for original variables, differenced variables, logarithmic variables and first differences of logarithms of app and hicp.

	Lags (Min Schwert)	Z(t)	1% critical value	5% critical value	10% critical value	p-value
APP	4	**-0.314**	-4.132	-3.492	-3.175	0.9892
HICP	2	**-1.989**	-4.128	-3.490	-3.174	0.6077
D1 APP	3	**-1.226**	-3.569	-2.924	-2.597	0.6624
D1 HICP	1	**-4.432**	-3.566	-2.922	-2.596	0.00
ln APP	3	**-8.578**	-4.130	-3.491	-3.175	0.00
ln HICP	2	**-2.075**	-4.128	-3.490	-3.174	0.5601
D1 ln APP	4	**-19.294**	-4.135	-3.493	-3.176	0.00
D1 ln HICP	1	**-4.449**	-3.566	-2.922	-2.596	0.00

With the NIRP and HICP variables, it was required to take the first differences of the variables to obtain their stationarity.

Table 5: Augmented Dickey-Fuller tests for original variables and differenced variables of nirp and hicp.

	Lags (Min Schwert)	Z(t)	1% critical value	5% critical value	10% critical value	p-value
NIRP	3	**-1.840**	-4.121	-3.487	-3.172	0.6851
HICP	1	**-3.479**	-4.117	-3.485	-3.171	0.0417
D1 NIRP	2	**-3.867**	-3.562	-2.920	-2.595	0.0023
D1 HICP	5	**-2.638**	-2.616	-1.950	-1.610	-

With the TLTRO and HICP variables, it was required to take the first differences of the variables to obtain their stationarity.

Table 6: Augmented Dickey-Fuller tests for original variables and differenced variables of tltro and hicp.

	Lags (Min Schwert)	Z(t)	1% critical value	5% critical value	10% critical value	p-value
TLTRO	4	**-1.436**	-3.750	-3.000	-2.630	0.5651
HICP	1	**-2.426**	-3.759	-3.000	-2.630	0.1344
D1 TLTRO	1	**-3.706**	-2.660	-1.950	-1.600	-
D1 HICP	1	**-6.610**	-2.660	-1.950	-1.600	-

Next table presents the results for the test results of cointegration for each variables residuals with the hicp. As can be seen from the table, each of the residuals are cointegrated.

Table 7: The results of the cointegration test.

	Lags (Min Schwert)	Z(t)	1% critical value	5% critical value	10% critical value
APP	2	**-2.617**	-2.616	-1.950	-1.610
NIRP	1	**-4.710**	-3.559	-2.918	-2.594
TLTRO	1	**-3.607**	-2.660	-1.950	-1.600

4 Results

This chapter presents the results from the linear regressions analysis which have been made separately for each explanatory variable using the linear regression model. Finally, the validity and reliability of the results is discussed later in this chapter. In the following results, six lags are decided to be used for the monthly data which are the APP and NIRP data. For the data of TLTROs, three lags are added to the model since the data is quarterly. Since Table 5 shows that all the variables are cointegrated. From figure 2 it can be noticed that if variables are cointegrated, there are two possible estimations, the least squares model and the error correction model. The least squares model is suitable for long run estimation and

the error correction is considered suitable for short run estimation (Arminen, 2021). Both estimations are used in this research in order to obtain more comprehensive results.

4.1 The effects of the Asset purchase programme

The estimated results of APPs effect on inflation are collected in tables 6 (least squares) and 7 (error correction model). The tables show the coefficients of the variables, and the standard errors are in parentheses. Statistical significance at 1% risk level is reported with (*). In the least square model, explanatory power of the model is quite large. This means that for example with zero lags, APP explains almost 58 percent of the variation in inflation. As lags are added to the model, the explanatory power increases slightly. The APP and the constant are also statistically significant at 1% risk level. In this long-term model, APP has a positive effect on inflation.

Table 8: Effect of the APP – least squares

Lags	0	1	2	3	4	5	6
APP	0.01* (0.00)	0.01* (0.00)	0.01* (0.00)	0.01* (0.00)	0.01* (0.00)	0.01* (0.00)	0.01* (0.00)
Constant	4.62* (0.02)	4.62* (0.02)	4.62* (0.02)	4.63* (0.02)	4.63* (0.02)	4.63* (0.02)	4.64* (0.02)
R^2	0.58*	0.58*	0.59*	0.59*	0.60*	0.60*	0.61*

In the error correction model, the explanatory power of APP is significantly smaller. In addition, the R-squares are not statistically significant. The APP and the constant are also not statistically significant. When lags are used in the model, the effect of APP turns negative which was not expected. According to these results, APP does not have a significant effect on inflation in the short-term period.

Table 9: Effect of the APP – Error correction model

Lags	1	2	3	4	5	6
D1 APP	0.0011593 (0.0009403	0.0002126 (0.0013808)	-0.0000602 (0.0014177)	-0.0003165 (0.0014389)	-0.0012929 (0.0010457)	-0.0048547 (0.0022671)
L.ehat	-0.0012187 (0.0006044	-0.001033 (0.0006261)	-0.0013683 (0.000627)	-0.0015465 (0.0006365)	-0.0006758 (0.0004583)	-0.0005594 (0.0004465)
Constant	0.001046 (0.0002041	0.0011068 (0.0002151)	0.0011284 (0.0002136)	0.0011544 (0.0002149)	0.0010495 (0.0001528)	0.0011949 (0.0001745)
R^2	0.0874	0.0467	0.0780	0.0962	0.0504	0.0886

4.2 The effects of negative rate on deposit facility

The estimated results of NIRP on inflation is collected in tables 8 (least squares) and 9 (error correction model). Against the expectations, the R-squares in least squares model are statistically signicant at 1% risk level, as well as NIRP variable and the constant. When lags are added to the model, the explanatory power decreases. The NIRP variable has a negative effect on inflation.

Table 10: Effect of the negative interest rate on deposit facility – least squares

Lags	0	1	2	3	4	5	6
NIRP	-15.44* (2.07)	-15.04* (2.11)	-14.59* (2.14)	-14.19* (2.19)	-13.69* (2.18)	-13.32* (2.14)	-12.98* (2.11)
Constant	114.85* (0.74)	114.96* (0.74)	115.08* (0.75)	115.19* (0.76)	115.31* (0.76)	115.38* (0.74)	115.44* (0.72)
R^2	0.46*	0.44*	0.42*	0.40*	0.39*	0.39*	0.39*

With the error correction model, the results are more as expected. The R-square is statistically significant with one and two lags, but it is not when more lags are added. In this model the R-square decreases as lags are added just like it did in least square model.

Table 11: effect of the negative interest rate on deposit facility – Error correction model

Lags	1	2	3	4	5	6
NIRP	2.30	3.46	-0.15	0.93	-0.66	0.72
	(4.27)	(4.68)	(4.78)	(5.52)	(5.68)	(5.67)
ehat	-0.43*	-0.37*	-0.23	-0.12	0.15	0.16
	(0.10)	(0.11)	(0.11)	(0.12)	(0.12)	(0.12)
Constant	0.10	0.12	0.01	0.10	0.10	0.12
	(0.08)	(0.08)	(0.09)	(0.09)	(0.09)	(0.09)
R^2	0.22*	0.15*	0.06	0.02	0.03	0.03

4.3 The effects of targeted long-term refinancing operations

The estimated results for TLTROs are presented in tables 10 (least squares) and 11 (error correction model). With least squares model, the r-squares and the tltro variable are not statistically significant. Adding lags to the model first decreases the r-square then increases it, so it is not possible to evaluate whether lags have an improving effect. Fewer lags have been used with TLTROs since the data is already significantly smaller.

Table 12: effect of the TLTROs – least squares

Lags	0	1	2	3
TLTRO	-3.47	-3.48	-2.17	-4.59
	(4.56)	(4.76)	(4.81)	(5.02)
constant	1.23*	1.23*	1.20*	1.20*
	(0.06)	(0.07)	(0.07)	(0.07)
R^2	0.05	0.05	0.02	0.09

With the error correction model, the r-square is statistically significant and surprisingly high when using one lag. However, considering the small number of observations the result is likely to not be reliable. The r-square decreases significantly when more lags are used and is no longer statistically significant.

Table 13: effect of the TLTROs – Error correction model

Lags	1	2	3
TLTRO	-5.16	-6.00	-4.92
	(2.13)	(4.35)	(4.33)
L.ehat	-1.36*	0.43	0.45
	(0.23)	(0.48)	(0.49)
constant	0.00	0.02	0.00
	(0.04)	(0.08)	(0.08)
R^2	0.81*	0.21	0.22

4.4 Validity and reliability

This subchapter deals with the assumptions that should be fulfilled when using the least squares model and the error correction model as an estimation method. If the assumptions are met, the validity and reliability of the estimate is ensured.

Using the Ramsay Reset test, the specification of the model is investigated. As it shows in Appendix 2, there is variety in test results between the different models. The null hypothesis of the test is that the model has no omitted variables (Ereeş & Demirel, 2012). According to the results, the null hypothesis is not rejected in most models, which means that the specification of the models can be considered successful. However, the results for NIRP and APP least squares show that the null hypothesis is rejected and therefore specification of the model cannot be considered correct.

Homoscedasticity is tested with White's test and the results can be found from appendix 2. The null hypothesis is that the model is homoscedastic, meaning that the variance of the residuals is constant (Soininen, n.d.). Again, the hypothesis remains valid for most of the models, however the results of least squares for NIRP indicate that the null hypothesis is

rejected. Heteroscedasticity can also be found from some of the results for the APP error correction model.

The residuals should be normally distributed. This assumption can be tested with the Shapiro-Wilks test. Test results can be found from appendix 2. The null hypothesis for the test is residuals normal distribution (Soininen, n.d.). According to the test results, the residuals are normally distributed in all the models except for both NIRP models.

The reliability of the research results is affected, for example, by the small number of observations, especially in TLTROs model. In addition, the specification of the model could be improved at least with the model for NIRP, by adding variables to the model for example. For that reason, the results made in this study with linear regression analysis for the TLTROs and NIRP should be interpreted with caution. Since many of the non-standard measures have been used at the same time, it is difficult to assess the effects of a single non-standard measure.

5 Conclusions

The study examines the effects of the European Central Bank's non-standard monetary policy measures on the success of the mid-term inflation target. The effects were studied with literature review of previous studies as well as using a linear regression model. This study focuses on the time period of 2009-2019. The non-standard measures used in this study are the asset purchase programme (APP), the negative rate on deposit facility (NIRP) and targeted long-term refinancing operations (TLTROs).

Based on the literature review, the first research question can be answered. The first research question is: How has the European central bank's non-standard measures of the monetary policy succeeded in the mid-term inflation targets? The success of the non-standard measures on achieving the inflation targets is different with each measure. There are studies that have showed how the inflation would have been weaker if these measures were not used

during the time period, for example Rostagno et al. (2019) The results used in the literature review indicate that general effect of the measures can be considered successful in affecting the mid-term inflation target. It should be noted that many of the studies also examined effects of forward guidance, a measure that was not considered in this study. Based on previous research, the effect of APP was studied the most and the effects of the program seemed the most to have the desired support on the inflation target. As mentioned in the literature review of this study, the effects of NIRP and TLTRO cannot be studied as deeply as the APP due to their qualities.

The previous research indicate that non-standard monetary policy measures have succeeded in affecting the mid-term inflation target which was set to be an annual increase of less than 2 percent in the period of 2009-2019. A figure below presents the annual inflation in the Euro area over the research period.

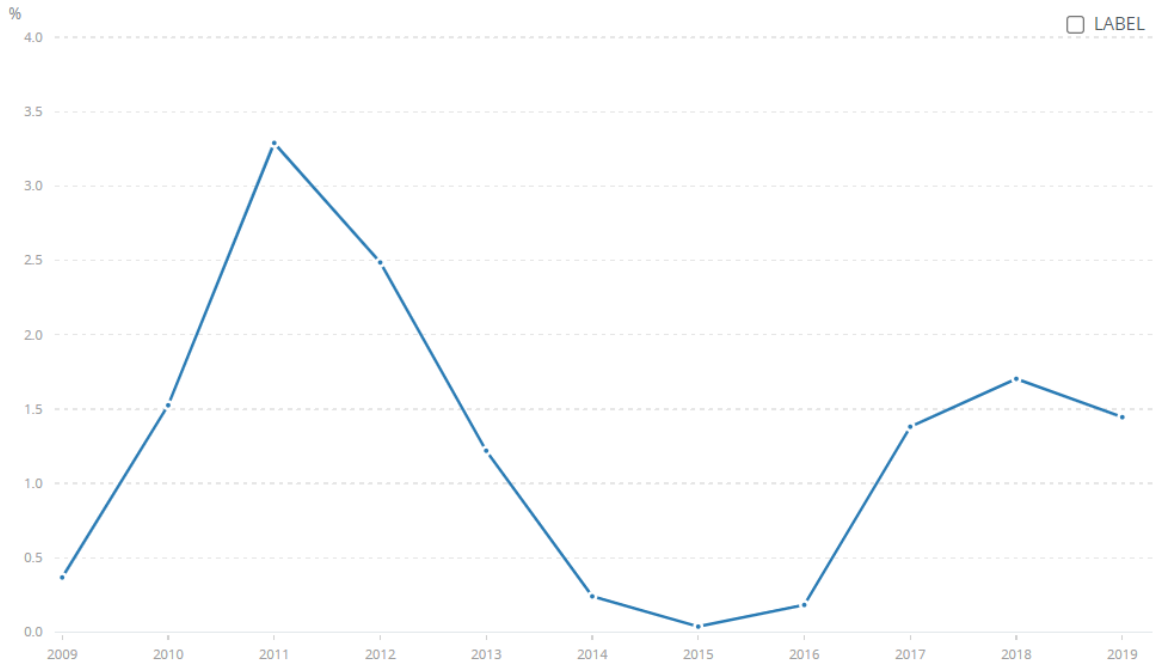

Figure 3: Inflation, consumer prices (annual %) – Euro area (The World Bank)

The linear regressions analysis was used to study the second research question, which is: How do the effects of different non-standard measures differ from each other? The

estimation was made using a long run and a short run model. Since the data used in the analysis is time series data, certain changes were made to variables to ensure their stationarity and thus making sure the results would be more reliable.

With the APP, the impact on inflation in the long run estimation is quite large and statistically significant. The APP variable is also statistically significant and has a positive impact. The r-squares increase slightly with lagged variables. In the short run estimation, the r-squares are markedly smaller, also they are not statistically significant. The impact of APP turn negative as lagged variables are used.

The effects of the NIRP in the long run were quite strong with r-squares being in between of 39 and 46 percents. The explanatory power of the model is the highest without lags (46 percent) and it decreases as lags are added. NIRP is also statistically significant and has positive impact. The effects of the NIRP on inflation in the short run suggested that NIRP has a moderate impact on inflation. The r-squares were statistically significant only without lags and with one lag, and that is when the impact of NIRP is positive.

The results of the TLTROs can should be interpreted with caution since the size of the data is extremely small. The results in the long run model were not statistically significant, and the r-squares remain low with and without lags. The same kind of results are made from the short run model, except the r-square for the result without lags is statistically significant and strong. However, there are no prerequisites that the result would correspond to the actual effect.

The results are at least partially in line with the quantity theory of money which was discussed in the theoretical framework of this study. The results for APP especially and NIRP also seem to match the expectations of the theory's ability to explain long-term inflation. The results of this study can be also considered to be partially in line with the previous research results. As previously stated, Bulligan (2018) and Burlon et al. (2018) have for example found in their studies the effects of APP to have significant impact on inflation, and the same conclusion can be made from the long-term estimation for APP in this study. With NIRP the results from this study and previous studies are more contradictory. While some research indicates that negative interest rate on deposit facility has had a successful impact on inflation, most of the previous research seem to state that the impact cannot be considered significant. The results of the short-term estimation in this study

supports the earlier results for the most part, but in the long-term estimation the results indicate that NIRP would have a significant effect. However, as stated in previous chapter where the validity and reliability of the results were studied, there were few qualities in the estimation models which weaken the reliability of the results. Reliability is also an issue with the results for TLTROs effects. This is due to the small size of the data. The results seem to support the earlier research results introduced in the literature review which indicated that TLTRO might have a slight impact on inflation. However, as said, the results are not completely reliable. In further studies it could be justified to use bigger data or add more explanatory variables to receive more reliable results. Also, it is possible that with different estimation methods some of the results could be more reliable.

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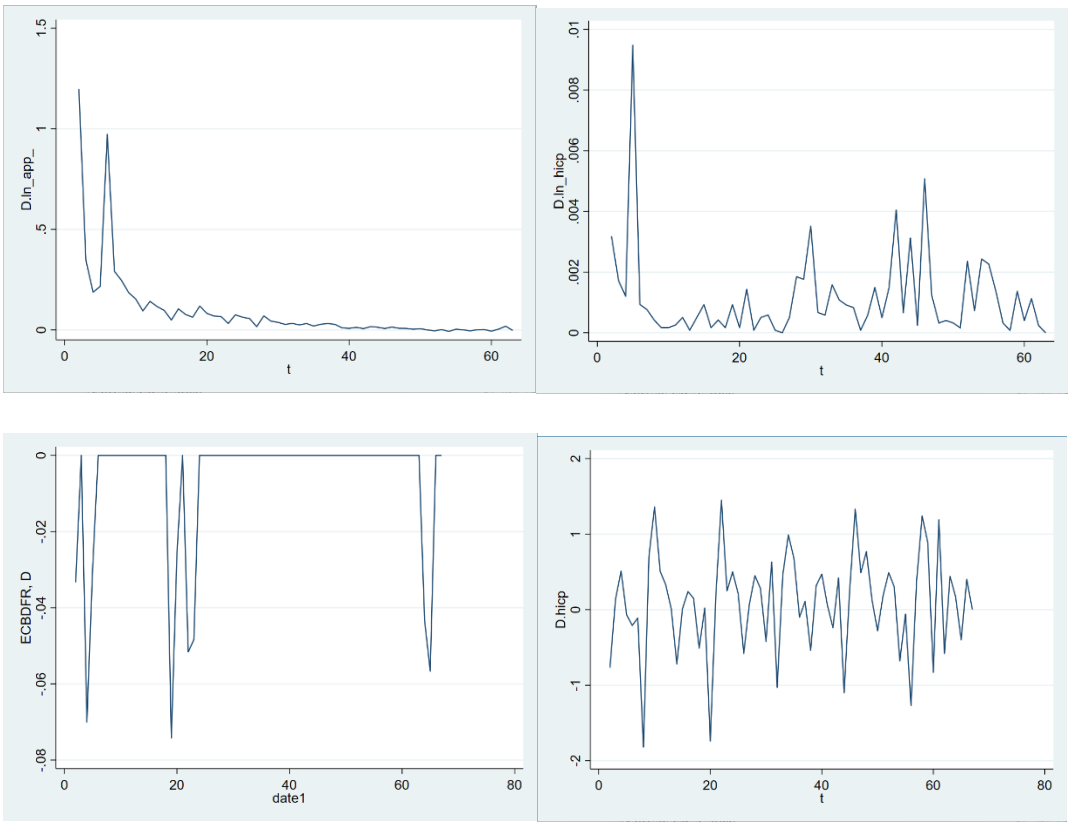
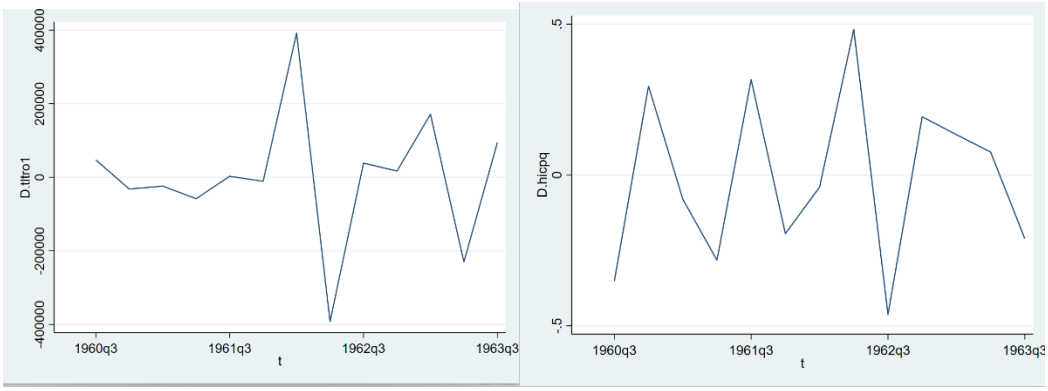
Appendices:

Appendix 1: Line graphs of variables





Appendix 2: Results of Ramsay reset test, White's test and Shapiro-Wilks test

APP least squares

	RESET test	White's test	Shapiro-Wilks test
0	0.00	0.20	0.16
1	0.00	0.20	-
2	0.00	0.21	-
3	0.00	0.23	-
4	0.00	0.23	-
5	0.00	0.25	-
6	0.00	0.25	-

APP error correction model	RESET test	White's test	Shapiro-Wilks test
1	0.48	0.34	0.16
2	0.59	0.22	-
3	0.83	0.07	-
4	0.02	0.00	-
5	0.45	0.51	-
6	0.67	0.51	-

NIRP least squares

	RESET test	White's test	Shapiro-Wilks test

0	0.00	0.04	0.00
1	0.00	0.03	-
2	0.01	0.02	-
3	0.00	0.01	-
4	0.01	0.02	-
5	0.01	0.03	-
6	0.01	0.03	-

NIRP error correction model

	RESET test	White's test	Shapiro-Wilks test
1	0.38	0.25	0.00
2	0.03	0.30	-
3	0.33	0.29	-
4	0.97	0.17	-
5	0.51	0.31	-
6	0.46	0.18	-

TLTRO least squares

	RESET test	White's test	Shapiro Wilks-test
0	0.75	0.39	0.34
1	0.78	0.48	-
2	0.78	0.61	-
3	0.31	0.21	-
4	0.37	0.24	-
5	0.55	0.24	-
6	0.31	0.52	-

TLTRO error correction model

	RESET test	White's test	Shapiro-Wilks test
1	0.89	0.36	0.34

2	0.52	0.89	-
3	0.57	0.45	-
4	0.30	0.78	-
5	0.46	0.16	-
6	0.69	0.25	-