The relationship between monetary policy rate decision, inflation and unemployment in the euro area

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Abstract

This study examines the relationship between the interest rate on main refinancing operations which is one of the ECB's key rates and inflation, and also the key rate and unemployment in the euro area from the quarterly data from the first quarter of 2009 to the first quarter of 2021 by Granger causality test. A pre-condition for a Granger Causality test is that the data is stationary, so we first test whether our sample data is stationary by the Augmented Dickey-Fuller (ADF) test with Schwarz Information Criterion (SIC) which also known as Bayesian Information Criterion (BIC).

As the main refinancing operation rate, the Harmonised Index of Consumer Prices (HICP) inflation and the unemployment rate data of the eurozone is non-stationary, we use the first-order difference method to make the data stationary. Then, we check again whether the data at first difference is stationary by the ADF test with the SIC. The results show that the data become stationary. Therefore, the Granger causality test is adopted to investigate the relationship with these variables.

The findings show that the past 8-lag value of the HICP inflation can be used to predict the monetary policy rate decision represented by the interest rate on main refinancing operations and the past 10-, 11- and 12-lag value of the unemployment rate is useful to forecast the rate on main refinancing operations while the past 10-lag value of the unemployment has the strongest prediction power. Conversely, a change in main refinancing operation rate does not improve the inflation and the unemployment rate.

Keywords: the interest rate on main refinancing operations, HICP inflation, unemployment

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Glossary

Augmented Dickey-Fuller (ADF) test - A test used to check the stationarity of data

ECB's key rates – Three key interest rates for the euro area set by the Governing Council of the European Central Bank (ECB): the interest rate on the main refinancing operations, the rate on the deposit facility and the rate on the marginal lending facility

Federal funds rate - The monetary policy interest rate in the United States set by the Federal Open Market Committee (FOMC) of the Federal Reserve.

Full employment – The situation that there exist enough job opportunities for job seekers (when the economy operates at full capacity).

Granger causality – A test for determining whether one time series is useful for predicting another

HICP inflation – The inflation measure in the euro area

Natural rate of unemployment – The unemployment rate when the economy operates at full capacity which means the output level is the potential level of output

Okun's law – The relationship between the output growth and the change in the unemployment rate

Output gap – The deviation between actual output and potential output

Potential level of output - The output that one economy can achieve when it operates at full pace by using up available resources in the economy

Taylor rule – A rule that recommends a central bank how to adjust the monetary policy interest rate in response to deviations of inflation from its target, and the output gap for the output-gap version while replaces the output gap with the unemployment gap for the unemployment-gap version of the rule

The interest rate on main refinancing operations – The interest rate banks pay when they borrow money from the ECB for one week

Unemployment gap – The deviation between the actual unemployment rate and the natural rate of unemployment

Chapter 1 Introduction

The primary objective of many central banks to conduct the monetary policy is to maintain price stability in order to achieve sustainable economic growth and full employment (European Central Bank 2021; Mathai 2020). When one economy achieves the full employment, it means that the economy reaches its best performance based on its structure. In the labour market term, it indicates that the number of job opportunities matches with the number of job seekers, but it does not mean that all people in the labor force will be employed as some people are moving between jobs or there is a mismatch of skills (Reserve Bank of Australia, 2021). Under this circumstance monetary policy cannot propel the economic growth in such a way more than maintain the price stability (Meyer, 2001) and the only way to attain a higher level of full employment is a structural change in the economy like technological disruption.

Regarding the importance of the price stability of goods and services, it helps create economic growth and full employment because individuals and firms allocate their intertemporal choices of consumption, saving and investment based on the price level (Santomero 2002; Poole and Wheelock 2008). In the same time, changes in an overall price of goods and services will impact the value of money and therefore purchasing power of customers and firms. As a result of this, price instability might cause confusion for households who make a price comparison which lead to an error of their subsequent decisions such as the amount they allocate for consuming, saving, investing or borrowing while firms may mistakenly project their sales revenue due to unclear market supply and demand for their goods and services (Gerdesmeier, 2009) which in turn distorts efficient capital investment and worker recruitment (Poole and Wheelock, 2008). Moreover, the fluctuation of the prices influences financial stability since lenders would like to have a higher rate of return to compensate them in case of a rise in the price of goods and services because no lenders want to have less value of money being repaid. Then, it puts the cost of capital higher (Gerdesmeier, 2009). Hence, a monetary policy that can maintain the price stability in the medium term is essential for the economy (European Central Bank, 2021) as a short statement from Gabriel Makhlouf (2021), the governor of the Central Bank of Ireland that "stable prices matter. Positive, low and predictable inflation helps households and businesses plan their spending and investment, helps the economy grow and creates employment." Put another way, ensuring the stability of prices is a prerequisite for achieving economic growth and full employment (European Central Bank, 2021).

In practice, central banks use inflation targeting as the benchmark to measure the price stability of overall goods and services (Guy Debelle *et al*., 1998). For instance, the ECB quantitatively gauges the price stability in the euro area by the Harmonised Index of Consumer Prices (HICP) inflation rate and commits the inflation target of below, but close to 2% over the medium term to prevent both a persistently price hike known as hyperinflation and a continuously price reduction dubbed deflation (European Central Bank, 2021). However, in July 2021, the ECB agreed to elevate its new inflation target to an exact 2% because in a low-inflation and lower-bound interest rates environment, it requires persistent accommodative monetary policy action whereby the key policy interest rates are still the main tool while forward guidance, asset purchases and longer-tern refinancing operations act as complementary tools to support the limitation that the policy nominal interest rate is near or at zero. Therefore, the ECB's governing council anticipates the key ECB interest rates to remain unchanged or be lower until the inflation reaches and persists at 2% over the medium term according to the press release from the ECB on 22 July 2021 (European Central Bank, 2021). In the U.S., the Federal Reserve set its 2% inflation target by measuring the annual change in the personal consumption expenditures (PCE) price index. Similar to the ECB, it adapted the inflation framework from its traditional flexible inflation targeting to average inflation targeting as there exists the increasing awareness that the inflation is less sensitive to economic activities resulting from the Great Recession (Martínez-García, Coulter and Grossman, 2021) and the inflation rate is one of the main factors used to determine changes in the monetary policy rate (Silvia, J. and Iqbal, A., 2014).

Apart from the inflation rate, economic growth, mostly represented by the real GDP, and the unemployment rate are crucial factors that impacts the central banks' policy implementation as illustrated by macroeconomic projections of central banks that always focus on the real GDP, unemployment and inflation rate. For example, under the covid-19 pandemic situation, the central banks adjust their stimulus measure such as the frequency and the volume of the asset purchase programme following their forecast about economic recovery represented by the real GDP and unemployment rate and do the sensitivity analysis for the most likely, best and worst scenarios of economic outcome (Board of governors of the Federal Reserve system, 2021; European Central

Bank, 2021; Reserve Bank of Australia, 2021; Bank of England, 2021) under diverse assumption; an acceleration of the vaccine rollout (Reserve Bank of Australia, 2021), a faster-than-expected solution of the covid-19 pandemic, or a prolonged period of the spread of the covid-19 which results in more lockdowns (European Central Bank, 2021). Moving backward in time, the Federal Open Market Committee (FOMC) also stressed the importance of the employment by an announcement for continuing injecting additional liquidity to the economy as long as the outlook of the labor market condition did not outstandingly improve in September 2012 (Willis and Cao, 2015). In the United Kingdom context, the Bank of England keeps the bank rate at 0.1% together with £895 billion of a quantitative easing program to support the recovery of domestic spending, incomes and job creation to the pre-covid-19 level and raise the inflation to the low and stable 2% of inflation target since the covid-19 has made many people lose their job while companies lack cash flows (Bank of England, 2021). Thus, changes in the policy short-term interest rate by the central banks are expected to have impacts on economic growth, employment and in turn inflation (European Central Bank, 2021), and the relationship between these variables and the monetary policy rate decisions are anticipated to be observable. Furthermore, referring to the literature review, the evidence of the causal relationship between the monetary policy rate and these main economic variables and vice versa is still mixed and there is few studies to examine the Eurozone as one monetary union which has 19 member countries that adopt the same monetary policy implemented by the European Central Bank, so this research attempts to fill this gap.

The paper is organized as follows. Chapter 2 provides insights of previous studies. Chapter 3 outlines the proposed hypotheses and give details about the sample period, observed variables, and the methodology used. Then, findings are presented in Chapter 4. Finally, we discuss about the findings and limitations of this research in Chapter 5 and conclude in Chapter 6.

Chapter 2 Literature review

Owing to the focus of the research on the relationship between the monetary policy interest rates, unemployment and inflation, studies with diverse contexts and approaches are reviewed and categorised into the following topics: the derivation of recommended monetary policy interest rates; the transmission mechanism of the monetary policy interest rate; the relationship between the central bank policy rate decision, inflation, and unemployment; and the effectiveness of monetary policy rates to promote price stability, economic growth and employment; market reaction toward changes in the central bank's key interest rate, inflation data, the unemployment rate

2.1 The derivation of recommended monetary policy interest rates

One traditional tool that the central bank use to affect the behaviors of the economic agents is a change in the policy interest rates. The change of the policy rates was aimed to influence aggregate demand in order to limit the deviation between the current output and the potential level of output (the level of output when the economy operates at a full capacity, normally in a long run). In other words, the central bank adjusts the interest rates to prevent an economy from a sharp swing which results from adverse phenomena and to smooth the price stability which is a critical factor that influences consumption and investment decisions of individuals, households and firms.

Otherwise, if the effects of the adverse event persist, it might cause structural changes which affect production capacity of the economy. For instance, unemployed workers permanently drop out of the labour force or the foreign companies move production base out to other countries as relevant skills disappear. From this perspective, the reaction of the monetary policy, which affects economic variables such as output and prices in the short run, helps to protect the economy from structural damage and a permanent reduction of the potential output (Central Bank of Malta, 2017).

A range of monetary policy rates is recommended by the Governing Council of the ECB before the policy rate decision based on the idle amount of resources in the economy measured by the output gap and the unemployment gap (Elias, Irvin and Jordà, 2014). The output gap shows whether the economy is underheating or overheating as it is the deviation between the level of potential output defined by the output that one economy can achieve when it operates at full pace through using up all available resources in the economy, and the actual output. Given that the potential output is not influenced by a rise or fall in prices of goods and services, a positive or negative value of the output gap is able to express the relative demand and supply in the economy which result in price acceleration or price deceleration and short-term overproduction or underproduction (Jahan and Mahmud, 2013) and in turn impacts employment. In short, there is a link between the output gap and the unemployment gap.

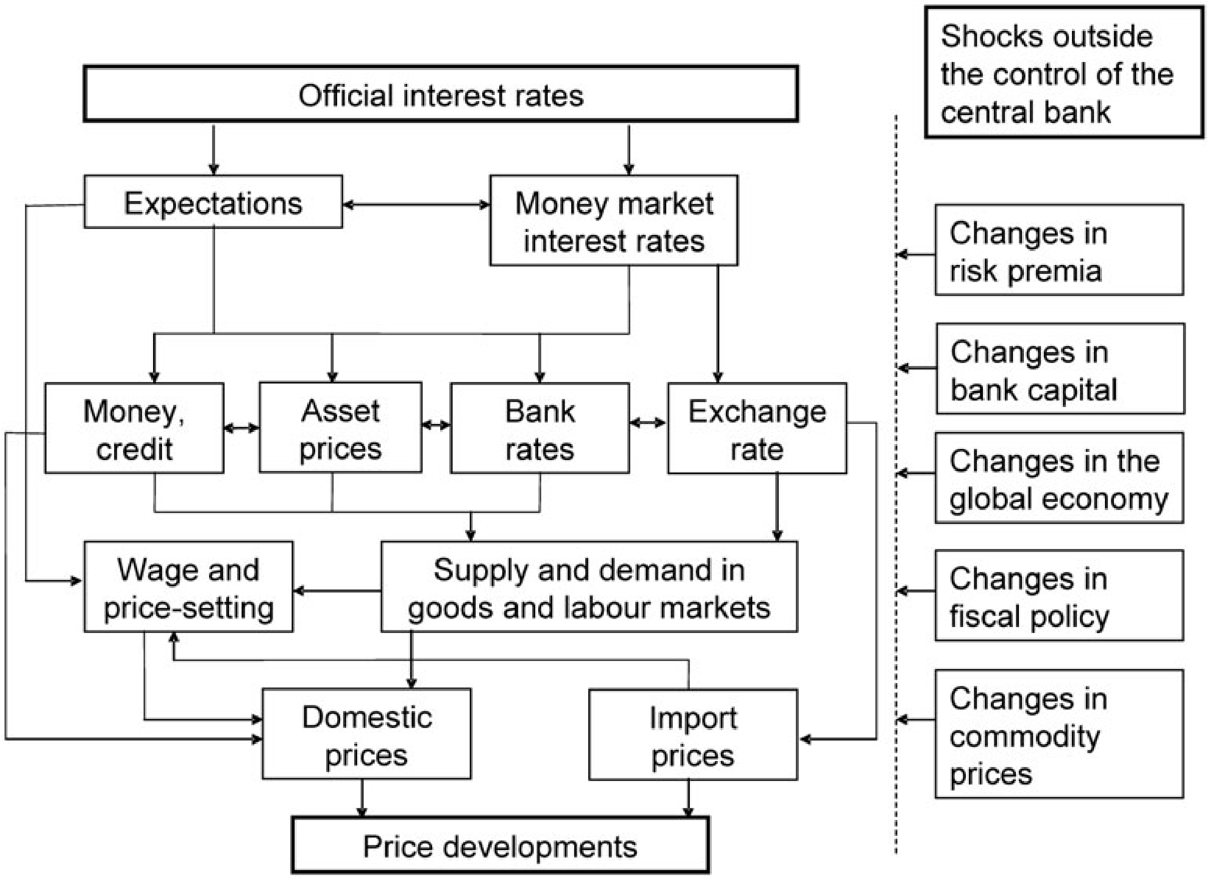
The unemployment gap is theoretically measured by the deviation between the natural rate of unemployment and the actual unemployment rate. The natural rate of unemployment is the rate when the economy operates at full capacity which means the output level equals the potential level of output and there is no cyclical movement in demand for goods and services as a result of the business cycle (Walsh, 1998). In addition to be the measure of the idle amount of human capital in an economy that the central bank considers prior to the monetary policy decision, the unemployment rate is always in public interest because it can address the well-being of people in one country.

Therefore, we will examine a bidirectional relationship between the monetary policy interest rates, the unemployment rate and the inflation rate. First, we investigate whether the central bank takes the unemployment rate and inflation into account for its interest rate change decision as expected, since numerous central banks undertake an analysis of monetary and economic conditions including macroeconomic projections before coming up with monetary policy decisions. For instance, according to the press release of the ECB's monetary policy decisions on 22 July 2021, "The Governing Council expects the key ECB interest rates to remain at their present or lower levels until it sees inflation reaching two per cent" (European Central Bank, 2021). Then, we study whether a change in the interest rates, which is the conventional monetary policy tool, can improve employment and price stability.

2.2 The transmission mechanism of the monetary policy interest rate

As the central bank is the sole issuer of banknotes and can impact amount of cash holding by a commercial bank as well as the amount of cash that the commercial bank would like to deposit with the central bank, it can influence the condition at which banks trade with each other in the money market and therefore economic agents in the economy (European Central Bank, 2021).

Chart 1 The transmission mechanism of the ECB's key rate



Source: The European Central bank (2021)

Changes in the monetary policy interest rate can be transmitted through various channels. The transmission mechanism of the European Central Bank (ECB)'s monetary policy is illustrated by Chart 1. The first channel of the official rate transmission is directly through the interest rate in the money market as they influence the cash holding behavior of the commercial banks leading to changes in lending and deposit rates the banks offer to their customers which in turn impact households' and firms' consumption and investment decisions.

Moreover, the expected changes in the monetary policy can move asset prices such as stock prices and exchange rates since investors always seek a higher rate of return. Then, the exchange rate will directly affect demand for imported goods and in turn the price level. Similarly, the movement of the asset prices also cause changes in the level of consumption and investment in the economy through the wealth effect and the effects of collateral value. For example, if the asset price rises, stock investors will feel richer and are willing to spend more on goods and services. In addition, as the collateral value grows as a result of an increase in asset prices, borrowers will get more money to spend or vice versa.

Further, a higher rate of interest adds more risks that borrowers cannot repay their loans which cause banks to probably reduce the lending amount for households and companies, resulting in a decline in aggregate consumption and investment. Conversely, low interest rates may lead to an increase in loan supply since the banks tend to accept a higher risk to boost revenue and investors search for a higher return.

Regarding expectations, future interest-rate expectations partly shape medium and long-term interest rates. Then, the long-term interest rates have impacts on producers' investment decisions and consumers' decision, for example, building a new factory or purchasing a house. Additionally, these changes in monetary stance can reflect how the central bank thinks about future economic outlook, so people in the market will absorb these signals at some degree, interpret whether the central bank's action results from the anxiety of the overall price increase or decrease in goods and services, and adjust their inflation expectation together with their economic decision. Subsequently, the actual prices change according to market participants' expectation.

Overall, the monetary policy is transmitted via several channels to make changes in aggregate consumption and investment in the economy which results in the level of aggregate demand for goods and services compared to aggregate supply and then the prices of goods and services including the wage setting in the market.

2.3 The relationship between the central bank policy rate decision, inflation, and unemployment

To investigate whether the actual unemployment rate and inflation impact the policy rate decision, we apply the rewritten version of the Taylor rule by Okun's laws which includes the unemployment and inflation or price stability in the policy rate decision. Although the unemployment rate temporarily deviated more than a two-to-one ratio from Gross Domestic Product (GDP), the rule of thumb of the Okun's law, during the Great Recession occurring from December 2007 to June 2009, it is still useful as it acted in the similar fashion of prior recessions following the dynamics of economy before coming back to the stable state (Daly, Fernald, Jordà and Nechio, 2014).

Regarding the Taylor rule, the rule that recommends the monetary policy rate by taking aggregate output in the economy and inflation into consideration for the output-gap version and considering the unemployment and inflation for the unemployment-gap modification, almost the same policy interest rates were recommended from both concepts of the Taylor rule before the emergence of the Great Recession in December 2007 (Daly, Fernald, Jordà and Nechio, 2014). However, they resulted in 3 basis points apart for the interest rate projection of 2010 in the period of the Great Recession (Elias, Irvin, and Jordà, 2014). Referring to Rudebusch (2009), the federal funds rate was set corresponding to the unemployment and the inflation rate over twenty years. The financial crises were responded by a sharp cut of the federal funds. The inflation lower than the target was stimulated by a reduction in the policy rate. Besides, the actual federal funds rate was slightly different from the approximated rate by the Taylor rule except around 1995 to 1998 (Rudebusch, 2009). Consequently, we will examine whether the central bank follows the Taylor rule which inputs the actual unemployment and inflation as the main factors for changes in the policy interest rate.

For empirical evidence, most studies find that inflation, the output gap (the difference between the current level of aggregate output in an economy and its potential level), and the unemployment gap (the deviation between the actual unemployment rate and the natural unemployment rate which is the rate corresponding with the potential output) are useful to predict the policy rate decision. First, Castro (2011) demonstrates that the European Central Bank (ECB), the Bank of England (BoE) and the Federal Reserve's monetary decisions follow the Taylor rule by adopting a forward-looking function estimated by the generalized method of moments (GMM) and revised monthly data to make the results of the three central banks comparable. Although the findings reveal the nonlinear relationship for the ECB and the BoE, the linear relationship can be observed from the federal funds rate which is the monetary policy interest rate of the Federal Reserve. Nonetheless, the beginning point of the sample periods applied is different: the establishment of the ECB, the Volcker disinflation in the U.S., and the start of the inflation targeting regime in the UK.

Extended from Castro (2011), Nikolsko-Rzhevskyy and Papell (2012) estimate the Taylor rule by real data which is the available data when the Federal Open Market Committee (FOMC) make the interest rate decision with four versions of the output gap: linear detrended which is the approach to remove the differences from the regression line that estimated by the least squares method, quadratic detrended that is similar to the linear detrended except the assumption that the data follows an exponential pattern, detrended Hodrick-Prescott (HP) calculated by the HP filter, and published by the Council of Economic Advisors (CEAs) by using the nonlinear least squares technique. The findings are that the actual policy rate is lower in case of linear, quadratic, or HP detrended output gaps and consistent in case of the output deviation computed by the CEAs. In addition, the forecasted inflation is effective to predict changes of the interest rate by the Federal Reserve instead of the actual one, in line with Bu, Rogers, and Wu (2020) that a monetary policy should be forward-looking because there is a lag for the monetary policy to affect the economy and inflation. Moreover, the unemployment-gap version of the Taylor rule built up by the Okun's law has the predictive power consistent with the detrended linear and quadratic output gaps.

On the other hand, some researchers divide the sample period into the full sample and the subsamples to investigate the effects of the Great Recession toward the relationship of these variables. Arnolda and Vrugtb (2012) compare the predictability of the Taylor rule with the Survey of Professional Forecasters (SPF) from the first quarter of 1993 to the fourth quarter of 2010 and the sub-period before and after the collapse of Lehman Brothers. The quarterly data of the 3- month Treasury-bill rate, the Consumer Price Index (CPI), the level of real Gross Domestic Product (GDP), and the unemployment rate in the United States is used to examine the efficiency of the Taylor rule to project for short-term interest rate by the Henriksson–Merton market timing test, the Stock–Watson forecast combination test, and the Diebold–Mariano predictive accuracy test. The results indicate that both the output-gap and the unemployment-gap forms of the Taylor rule are valid even in the period of the Great Recession and the deviation of the unemployment has the most predictive accuracy during the recession period.

Similarly, Silvia and Iqbal (2014) conduct the study about the relationship between the federal funds rate, inflation represented by changes in Personal consumption expenditures (PCE) price index on an annualised basis, the unemployment rate measured by the proportion of the unemployed defined as people who are actively finding a paid job in comparison with the labor force which comprises the full-time and part-time employed by categorizing the sample periods into four groups in concern of a possible structural change in the relationship of these macroeconomic variables. After testing the Granger causality, for the period of 1971 to 2014, the federal funds rates can be used to predict the inflation and the unemployment rate and in turn the inflation and the unemployment rate can indicate the change of the federal funds rate (Silvia and Iqbal, 2014). Nonetheless, the findings of the Granger causality are inconsistent when the researchers select the subperiods within the period of 1971 to 2014 and run the model again. For example, only inflation is statistically useful in forecasting the federal funds rate in the period of 1990 to 2014 whereas the inflation and unemployment has no predictive power in the period of 1990 to the third quarter of 2007 and the fourth quarter of 2007 to the first quarter of 2014. In other words, the results vary with the chosen sample period.

Another analysis in the U.S. context is carried out by Nikolsko-Rzhevskyy, Papell and Prodan (2014). However, this analysis is different from previous studies in terms of variables and framework as the authors perform restricted and unrestricted structural tests to determine the deviation from the actual fed funds rate from three types of the Taylor rule: the original Taylor rule, a modified Taylor rule whose the output gap coefficient is higher by 0.5, and a Taylor rule estimated by the real data from the fourth quarter of 1965 to the fourth quarter of 2013 to mark the rule-based and discretionary periods while real data of the GDP deflator represents inflation and detrended quadratic output gaps stand for economic growth. The rule-based period is when the actual policy interest rate has a small deviation from the Taylor rule while a large deviation from the rule is deemed as the discretionary period which is the period that the central bank rely more on expert judgment than the rule for any given circumstances. The results of the study show that the rule-based monetary policy in the U.S. was implemented from the fourth quarter of 1965 to 1974 and from 1985 to 2000 while the discretionary monetary policy was pursued from 1974 to 1985 and from 2001 to 2013 when considering the original Taylor rule. When putting more weight on the output gap than the deviation between the actual inflation and the inflation target, the evidence reveals the rule-based monetary policy from the fourth quarter of 1965 to 1977 and the start of 2006. Nevertheless, there is an unclear empirical result for the Taylor rule estimated by the real-time data from the fourth quarter of 1965 to the fourth quarter of 2013.

In Australia, there is a very small deviation between the Reserve Bank of Australia policy rate and the Taylor rule's recommended rate except the fourth quarter of 2008 which is 1.45 percentage point apart when approximating the rule by quarterly data of the headline Consumer price index

(CPI), trimmed mean CPI and weighted median CPI together with the linear detrended output gap, the Hodrick-Prescott (HP) filter output gap and the unemployment gap through the Ordinary least squares (OLS) approach (Hudsona and Vespignanib, 2018). However, the rate suggested by the Taylor rule have been continually above the Australian cash rate after the third quarter of 2011 due to an attempt to put more weight on economic growth and less on inflation (Hudsona and Vespignanib, 2018).

Moving to Southeast Asian countries, Tan and Mohamed (2020) find that one-quarter lagging inflation in Thailand and Malaysia is useful to predict the monetary policy rates. For Singapore, the forecasted inflation for one-quarter ahead has predictive power for changes in the policy interest rates. Moreover, the policy rate of the Bank of Thailand is sensitive more than a one-to-one relationship with the output gap and has the highest level of the sensitivity to the output gap compared to Malaysia and Singapore. In addition, this study suggests the inclusion of exchange rates and government spending in the Taylor rule model to improve the accuracy of prediction of these three countries after investigating 5 modifications of the Taylor rule.

2.4 The effectiveness of monetary policy rates to promote price stability, economic growth and employment

As addressed by monetary policymakers that the monetary tool is implemented to counter unfavourable economic phenomena and stimulate the economy by promoting employment, economic growth and price stability, the persistency of its effects are still debated, either the monetary policy has only short-term and temporary impacts on the economic activities or it can also trigger a permanent change for the real economic variables in the long run, for example, the production capacity of firms when they operate at full capacity.

On the one hand, it is widely accepted that the monetary policy cannot lead to the long-lasting development of real output and unemployment in the long run when the economy returns to its equilibrium with the output reaching its potential level. The factors that can induce a permanent rise in the potential level of output and employment, entirely are structural transformations such as technological changes, demographic trends, labor force participation rates, productivity of capital and labour, the transformation of savings into investment, and the level of education of the workers, which are unable to achieve by the scope of monetary policy. Thus, any expansion in the quantity of money in the long run merely elevates the overall price level or inflation (Lacker 2016;

Central Bank of Malta 2017; Mathai 2020; European Central Bank 2021). In other words, a central bank can only support the economy by keep the settings of stable prices when the economy reaches the long-run equilibrium whereas it cannot drive the economic growth or impact real output and unemployment by reducing its short-term monetary policy rates (European Central Bank, 2021).

However, economists all agree that as the adjustment of prices and wages is sticky in the short run, any changes in quantity of money in the economy by lowering the policy rates have impacts on the actual production of goods and services and employment (Mathai, 2020). Nonetheless, they also entail an upward pressure on prices as a result of the increasing money supply. For instance, an increasing demand require the firms to hire more labour and purchase more resources to create goods and services which in turn push up the input costs such as wages that is what we know as cost-push inflation. From another point of view, workers spend their increased income to purchase more goods and services which in turn pull up the price level of those goods and services that is what we know as demand-pull inflation. Concisely, the general price of goods and services is lifted.

On the other hand, some researchers come up with evidence that the monetary policy has long-run effects on the economy. First, the effects of monetary policy on some real economic variables can accumulate as time passes (Irandoust, 2020) because the transitory increase in investment in the short term as a result of expansionary monetary policy induces a permanent growth of capital stock and in turn a new potential level of output and employment (Collignon, 2007). In addition, the empirical results of nine Organisation for Economic Cooperation and Development (OECD) countries outside the European Union conducted by likelihood-based panel cointegration indicate that a tight monetary policy is more effective than the expansionary one. In short, economic conditions and the monetary policy stance whether to tighten or to stimulate the economy influence the effectiveness of the monetary policy (Irandoust, 2020).

Furthermore, Jordà, Sanjay and Alan (2020) demonstrate that the monetary policy shocks have lasted for many years since they affect total factor productivity (TFP), capital stock, and the productivity of the economy by using the impossible trinity framework, which is the concept that one country cannot adopt free capital flow, fixed exchange rate and independent monetary regimes at the same time, together with the monetary policy impulse response function estimated by local projections. In an exogenous growth model, the effects of the monetary policy shock on capital accumulation consisting of machines and buildings, output and TFP persist for almost six years before returning to their long-run levels while the capital stock and output do not recover to the long-term trend if taking the TFP as an endogenous variable. Briefly, a contractionary monetary policy shock lowers output, which temporarily decelerates TFP growth, but causing a permanent lower level of capital and output, even though labor returns to the previous long-run equilibrium.

Similarly, Kam, Smithin, and Tabassum (2019) also find that a decision to increase the monetary policy interest rates succeeds in permanently reducing the inflation rate and increase the total holdings of the financial asset. However, the capital stock and the potential level of output in the long run are permanently reduced as illustrated by a dynamic general equilibrium (DGE) model with microfoundations which examine the behaviors of an agent who is a worker and consumer and has to trade off between consuming the current output that they produced or spending it to purchase machines to produce more output in the future.

2.5 Market reaction toward changes in the central bank's key interest rate, inflation data, the unemployment rate

Our study about whether we can use changes in central bank's key interest rate to predict changes in inflation and the unemployment rate and whether we can forecast the inflation and the employment rate is quite important for investors and market participants because the monetary policy rate directly affect the money market interest rate and therefore the long-term interest rates, so it will impact bondholders' behaviors, company's investment decision, and households' consumption. Moreover, as the monetary policy rate influences the risk-free rate paid on government bonds, it can guide the direction of capital flows between markets. For instance, when the risk-free rate rises as a result of a hike in the monetary policy rate, the capital will flow from the stock market to the bond market since it bears less risks or theoretically no risks at the same level of returns. Conversely, if the rate is so low, the capital will flow to the stock exchange to find a higher return. For instance, Bernanke and Kuttner (2005) find that a 0.25% decrease in the federal funds rate results in around 1% increase in the stock market in line with Kim and Nguyen (2009) who illustrate that the Federal Reserve and the ECB's unexpected rate rises impact 8 out of 12 Asian stock market returns and return volatilities. Similarly, Ioannidis and Kontonikas (2006) indicate that the monetary policy rate shifts significantly affect stock returns in 13 OECD countries regardless of how to measure the stock return. In addition, changes in the monetary policy interest rate in eight small open countries also impact the volatility of returns in local stock markets; for example, a 1% unexpected rate rise causing a fall in the stock price from 0.5% to 1% (Pennings, Ramayandi and Tang, 2015). Consequently, investors can make profits from correctly forecasting changes in the policy rate while companies can more efficiently manage their cost of finance since they know the timing they should raise funds from the market or sell their shares to the public as they will get more capital when the stock price is high.

On the other hand, the inflation and the unemployment rate data are closely monitored by investors and economic agents as they are main factors that the central bank considers for the policy interest rate adjustment. Additionally, people might keep more money in the form of financial assets because rising inflation reduces their purchasing power, so the asset prices soar. From the evidence in the stock market, Boyd, Hu, and Jagannathan (2005) find that the release of the unemployment rate influences the S&P 500 stock index movement since it affects the components used to value a stock: the risk-free interest rate, the equity risk premium, and company future earnings and dividends. In short, the prediction of changes in the monetary policy interest rate is an essential piece of information for investors and so do the inflation and unemployment rate.

According to the literature review, previous research gives mixed results about the relationship between the central bank's monetary policy interest rate and inflation, and also the policy rate and the unemployment. Some research found a strong influence of the inflation and unemployment on the monetary policy decision (Castro 2011; Nikolsko-Rzhevskyy and Papell 2012; Arnolda and Vrugtb 2012; Tan and Mohamed 2020) while a few studies point out that the influence of the inflation and the unemployment rate was not consistent throughout the sample period or there was only a weak effect on the monetary policy rate decision (Silvia and Iqbal 2014; Hudsona and Vespignanib 2018; Tan and Mohamed 2020). From another perspective, there is also a debate that changes in the monetary policy rate is effective to improve the inflation in the long term, but not for the employment (Lacker 2016; Central Bank of Malta 2017; Mathai 2020); however, several studies proved that it was not always the case (Collignon 2007; Kam, Smithin, and Tabassum 2019; Irandoust 2020).

Consequently, this research will provide an alternative approach to investigate whether unemployment rate and inflation are the crucial factors that the central bank considers before making changes in the policy interest rate and conversely the effectiveness of changes in the policy rates for promoting employment and maintaining price stability in its target range. Moreover, to the best of our knowledge, no studies investigates the relationship between the policy interest rate and inflation, and also the interest rate and the unemployment by treating the euro area as one united economy whose member countries share the same monetary policy governed by the European Central Bank (ECB); normally the countries in the eurozone were investigated separately, so this research also help complement this gap.

Chapter 3. Methodology

In this study, the quantitative approach is conducted to examine the relationship between the monetary policy interest rate, inflation, and unemployment. A pre-condition for a Granger Causality test is that the data is stationary, so it is necessary to first test whether our sample data is stationary or not. If it is stationary, we can proceed the Granger causality test. If not, data transformation is needed to make it stationary before performing the Granger causality test between each variable.

3.1 Stationarity and non-stationarity tests for time series data

The data is stationary if its statistical properties, namely mean and variance, do not vary over time. Put differently, although each data point is not the same, the overall data behaves in a constant pattern (Rasheed, 2020). From a visual observation, the time series plot of one variable that do not display any trends which is an indefinite increase or decrease from one data point to another or seasonality which is a recurring data pattern on a yearly, quarterly or monthly basis, can basically be deemed stationary. Nevertheless, the purely visual assessment from the data plot is likely to be error-prone because of misjudgment. Consequently, the Augmented Dickey-Fuller (ADF) test is a requisite to confirm whether the time series data is stationary.

Moreover, most time series methodologies used for forecast or prediction rely on the assumption that each data point is independent which can be indicated by the stationarity of historical data (Rasheed, 2020). That is why the stationarity of data is important for the analysis. In other words, we cannot use non-stationary data for prediction in the traditional time series models, so data transformation such as first difference is required to make the data stationary before being applied in the time series model and this is also the case for the Granger causality. At first-order difference, the current data is subtracted by the data of the previous period ($\Delta y = y_t - y_{t-1}$) to remove trends and seasonality in the series to make the data stationary; in other words, transforming the data to have constant mean and variance.

3.1.1 Time series plot

To preliminarily check the stationarity and non-stationarity, we can plot a graph to see the movement of one data series. Generally, a non-stationary series consists of a deterministic trend and a stochastic trend (Adam and Owusu, 2017). The deterministic trend shows indefinite upward or downward movement of the data while the stochastic trend expresses random movement of the data. As the graph roughly draw the overall picture and the characteristics of data which may be misjudged by eyes, the stationarity test like the Augmented Dickey-Fuller test is applied to ensure whether the data is stationary or not.

3.1.2 Augmented Dickey-Fuller test

Since the Granger causality test assumes that data is stationary, we need to test whether our time series data is stationary before proceeding with the Granger causality test. Otherwise, the results are likely to be misleading if non-stationary time series data is applied in the model. To examine the stationarity of the data in this study, the Augmented Dickey-Fuller (ADF) test is considered to be the appropriate approach. The ADF test was developed from the Dickey-Fuller (DF) test, which are also used to test the stationarity of the data, with the aim to resolve the limitation of the DF test regarding the assumption that there is no serial correlation in the error term which is not always the case when the dependent variable has autocorrelations by adding the lagged value to the test. For choosing the optimal lag to test the ADF test, Schwarz Information Criterion (SIC) which also known as Bayesian Information Criterion (BIC) is adopted to select the best-fit model for our observations. The hypothesis testing of the ADF test is below.

The null hypothesis (H_0): the series has unit root; non-stationary

The alternative hypothesis (H_1): the series does not have unit root; stationary.

To reject the null hypothesis and infer that the data series is stationary, the Augmented Dickey Fuller t-test statistic must be more negative than the t-critical value at any level of significance or the p-value of the ADF statistic is less than the level of significance. For example, we are testing the data series of the HICP inflation by the ADF test at the 95% level of confidence which is a 5% level of significance. Assuming the ADF t-test statistic is -1.71 whereas the t-critical value at the 5% level of significance is -2.92, the test statistic is less negative than the critical value, so we fail to reject the null hypothesis that the series is non-stationary. Alternatively, the p-value of the ADF test statistic is 0.42 while the level of significance is 0.05, the p-value is more than the level of significance, so we also fail to reject the null hypothesis that the series is non-stationary. After finding that the data is non-stationary, data transformation is required to make it stationary by computing its first difference. Then, we test again whether the transformed data becomes stationary through the ADF test. If it is still non-stationary, the second-order difference is needed. Alternatively, if solely differencing data does not work, we can transform the data by taking logarithm and then differencing it (Rasheed, 2020).

3.2 Granger causality

Granger causality is a quantitative approach that applies statistical hypothesis testing for determining whether one time series data can be better predicted from another. In other words, if a variable X Granger-causes another variable Y, Y can be better forecasted from the past value of X and Y than the lagged value of Y alone (Adam and Owusu, 2017). Put differently, changes in one variable precede those of the other. In addition, the Granger causality test can show the direction of prediction whether it is a one-way or bidirectional causality. For instance, Y can be better predicted by the lagged value of X and Y instead of the lagged value of Y alone and vice versa (Silvia, J. and Iqbal, A., 2014). To examine the two-way Granger causality, the hypothesis testing of the Granger causality is as follows.

Hypothesis 1

The null hypothesis (H_0): X does not Granger-cause Y

The alternative hypothesis (H_1): X Granger-causes Y

Hypothesis 2

The null hypothesis (H_0): Y does not Granger-cause X

The alternative hypothesis (H_1): Y Granger-causes X

To reject the null hypothesis and infer that one variable Granger-causes the other variable, the p-value needs to be less than 0.05 which is the acceptable significance level for this type of research. Alternatively, you can compare the F-test statistic and the F-test critical value. If the F statistic is greater than the F critical value at the 5% level significance, the null hypothesis is rejected, and we can infer that a variable Granger-causes another. From empirical evidence, this approach is widely used to predict the economic variables, for example, the causality of banking sector development, stock market development, the Gross Domestic Product (GDP) per capita, foreign direct investment inflows, trade openness, a percentage change of the Consumer Price Index (CPI) and government final consumption expenditure for the ASEAN countries (Pradhan et al., 2014), the impacts of oil shocks toward government expenditure, real GDP, inflation, net exports and real exchange rate and vice versa (Itta, Miar and Tiawon, 2020), and Granger causality between the DAX index, a German stock index comprising the 30 largest German blue-chip companies' shares trading on the Frankfurt Stock Exchange, and industrial production index, the Consumer Price Index (CPI), money supply, interest rate, trade balance and exchange rate (Plíhal, 2016).

To test the Granger causality between the interest rate on the main refinancing operations and the HICP inflation as well as the unemployment rate and vice versa, we first set up the null hypothesis that there is no Granger-causality between them at the 5% significance level. Next, we will try a number of different lags to see whether there is an impact of changing lags and find the best-fitted lag length to observe the monetary policy effect on real economic variables such as unemployment rate and inflation as suggested by Willis and Cao (2015) that changes in the monetary policy rate affect the employment at 12 lags or 3 years.

3.3 Taylor rule

As the central bank affects aggregate spending of the economy through its interest rates, Taylor (1993) proposed the Taylor rule which is the monetary policy rule that suggest the central bank to adjust the policy interest rate in response to changes in the inflation and changes in real output as a result of changing economic conditions. In other words, the Taylor rule can be used to predict the monetary policy interest rate or guide the interest rate adjustment. Here is the traditional equation of the Taylor rule.

$$i = r* + \pi + 0.5(\pi - \pi^*) + 0.5y \qquad (1)$$

Where i = nominal interest rate, r* = real interest rate, π = inflation rate, π* = inflation target, y = the percentage deviation of real GDP from the potential level of real GDP. To establish a link with the unemployment, we rewrite the Taylor rule by the Okun's law to get equation (2).

$$i = i^* + a(\pi - \pi^*) - b(u - u^*) \qquad (2)$$

where i = the nominal interest rate, i* = the nominal interest rate corresponding with the inflation target, π = inflation rate, π* = inflation target, u = the unemployment rate, u* = the natural rate of unemployment.

From the unemployment version of the rule, we can investigate the relationship between the policy interest rate, the inflation and the unemployment rate and examine whether that relation is truly valid.

3.4 Proposed Hypotheses

To examine whether the ECB's policy interest rate is effective to bring the inflation back to the inflation target in order to maintain the price stability in the economy and to improve the employment condition, the proposed hypotheses are as below.

Hypothesis 1:

H_0: The ECB's key interest rate on the main refinancing operations does not Granger-cause the HICP inflation.

H_1: The ECB's key interest rate on the main refinancing operations Granger-causes the HICP inflation.

Hypothesis 2:

H_0: The ECB's key interest rate on the main refinancing operations does not Granger-cause the unemployment rate.

H_1: The ECB's key interest rate on the main refinancing operations Granger-causes the unemployment rate

Conversely, we analyse whether inflation and unemployment influence changes in the ECB's policy interest rate.

Hypothesis 3:

H_0: The HICP inflation does not Granger-cause the ECB's key interest rate on the main refinancing operations.

H_1: The HICP inflation Granger-causes the ECB's key interest rate on the main refinancing operations.

Hypothesis 4:

H_0: The unemployment rate does not Granger-cause the ECB's key interest rate on the main refinancing operations.

H_1: The unemployment rate Granger-causes the ECB's key interest rate on the main refinancing operations.

In short, we examine two-way causality between the ECB's policy rate and the inflation, and also between the ECB's rate and the unemployment rate.

3.5 The sample period

As the global crisis hit the economy sharply and deeply and it requires several years for economic growth to return to the pre-crisis level, many central banks review their monetary policy operations to examine whether the occurrence of the global crisis have impacted the economic structure such as the transmission mechanism of the monetary policy and the interaction among economic variables like the inflation and the unemployment rate. According to Martínez-García, Coulter and Grossman (2021), there are three structural changes of the economy as a consequence of the global financial crisis: a diminished sensitivity of inflation to excess economic resources or unemployment; for example, when there is an excess demand in goods, the price increases by less than the level it should be before the crisis, a decline in the natural rate of unemployment which is the unemployment rate when the economy operates at full capacity, and a drop in the neutral federal funds rate, the federal funds rate (the monetary policy rate of the Federal Reserve) when the actual inflation is in the Federal Reserve's target.

There are various factors that encourage the structural transformation of the economy. For instance, an increase in the average age of the population and rising educational attainment causes the natural rate of unemployment to decline, so the idea to test changes in one economic structure is quite popular especially in the post-Great Recession. Silvia and Iqbal (2014) investigate the structural change in the U.S. economy after the Great Recession (December 2007 to June 2009) and find that the relationship between the federal funds rate and inflation, and also the federal funds rate and unemployment might be so weakened that the econometric model cannot detect the relationship between these variable in the post-Great Recession period in comparison with the previous period.

Thus, we test whether the finding of Silvia and Iqbal (2014) about the relationship of these three variables is still valid in the context of the euro area by applying quarterly data of the official interest rate on the main financing operations, the HICP inflation and unemployment rate published on the ECB statistical data warehouse from the first quarter of 2009 to the first quarter of 2021.

3.6 Variables

4.6.1 Measures of key ECB interest rates

The Governing Council of the ECB meet every six weeks to make the decision about its three key interest rates for the euro area: the interest rate on the marginal lending facility, the interest rate on the main refinancing operations, and the interest rate on the deposit facility. The first one is the interest rate that banks need to pay when they borrow funds from the ECB overnight and they have to deposit collateral at the ECB to guarantee that the funds will be repaid. The second one is the interest rate that banks needs to pay for borrowing funds from the ECB for one week, cheaper than borrowing overnight. Like the interest rate on the marginal lending facility, they need to deposit collateral at the ECB to guarantee that the funds will be repaid. The third one is the interest rate on the deposit facility that banks receive or pay in a negative-interest-rate environment for depositing funds with the ECB overnight. In addition, the deposit facility rate and the marginal lending facility rate form the upper and lower bound within which money market rates fluctuate overnight (Euro area statistics, 2021). In this study, we will use the main refinancing operation rate as a key observed variable to examine changes in the monetary policy rate as it is the most likely to affect the interest rates of commercial banks and therefore impact consumption and investment decisions of economic agents in line with Castro (2011) who investigate the linearity and non-linearity of the ECB's monetary policy rule by applying the interest on the main refinancing operations. Additionally, Gerstenberger (2020) uses this key rate to test the effectiveness of the interest rate channel on German small and medium-sized enterprises (SMEs) after the financial crisis in 2008 and Creel, Hubert and Viennot (2016) also apply the same key rate to explore the effects of the ECB's monetary policy on housing loans, the volumes and yields of 6-month, 5-year and 10-year government bonds in France, Germany, Italy and Spain.

4.6.2 Measures of inflation

We use the percentage change of the Harmonised Index of Consumer Prices (HICP) as the inflation variable because the HICP measures changes in the prices of goods and services by European households. Furthermore, the ECB uses the year-over-year change of the HICP as an indicator for the price stability whether it is above or below the inflation target (European Central Bank, 2018) and take the path of the forecasted HICP into account before finalising monetary policy decisions. Additionally, it is one of measures to assess the readiness of a country to join the euro area (European Central Bank, 2021).

4.6.3 Measures of unemployment

The unemployment rate used is measured by the percentage of the unemployed divided by the labor force which is the sum of the unemployed and employed people, age 15 to 74 using the data from the ECB statistical data warehouse while the unemployed are defined as people who are actively searching for a paid job or work less than one hour per week (European Central Bank, 2001).

3.7 Model

From the hypothesis 1 - 4, we translate into mathematical statement for the Granger causality test as equation (3) – (6).

$$i_t = a_0 + a_1 i_{t-1} + \ldots + a_p i_{t-p} + b_1 HICP_{t-1} + \ldots + b_p HICP_{t-p} + \varepsilon_t \quad (3)$$

$$i_t = a_0 + a_1 i_{t-1} + \ldots + a_p i_{t-p} + b_1 U_{t-1} + \ldots + b_p U_{t-p} + \varepsilon_t \quad (4)$$

$$HICP_t = a_0 + a_1 HICP_{t-1} + \ldots + a_p HICP_{t-p} + b_1 i_{t-1} + \ldots + b_p i_{t-p} + \varepsilon_t \quad (5)$$

$$U_t = a_0 + a_1 U_{t-1} + \ldots + a_p U_{t-p} + b_1 i_{t-1} + \ldots + b_p i_{t-p} + \varepsilon_t \quad (6)$$

Where i_t = the interest rate on main refinancing operations, $HICP_t$ = the percentage change of the Harmonised Index of Consumer Prices, U_t = the unemployment rate, a, b = the coefficients, p = the lag length

To test whether the past values of the HICP inflation and the unemployment rate can be used to predict the rate on main refinancing operations as expressed in equation (3) and (4) and the past values of the rate on main refinancing operations are helpful to forecast the HICP inflation and the unemployment rate as manifested in equation (5) and (6), the Granger causality test applies the F-test for the hypothesis testing to examine whether the past values of another variable together with the past values of the variable itself can add more explanatory power to the model than only the past values of the variable itself. In other words, the past values of two variables better explain the movement of the variable than only the past values of the variables itself. The hypothesis testing are as follows.

The null hypothesis (H_0): $b_1 = b_2 = b_3 = \ldots = b_p = 0$

The alternative hypothesis (H_1): At least one of them is non-zero.

Taking equation (3) as an example, if at least one b is not zero, it means that the data of the past value of the HICP inflation is useful for predicting the current value of the rate on main refinancing operations. This does not suggest that the HICP inflation causes changes in the rate on main refinancing operation, but it means that changes in the HICP inflation come before changes in the main refinancing operation rate as the definition of Granger causality. Put differently, the HICP inflation Granger-causes the interest rate on main refinancing operations.

Chapter 4 Findings

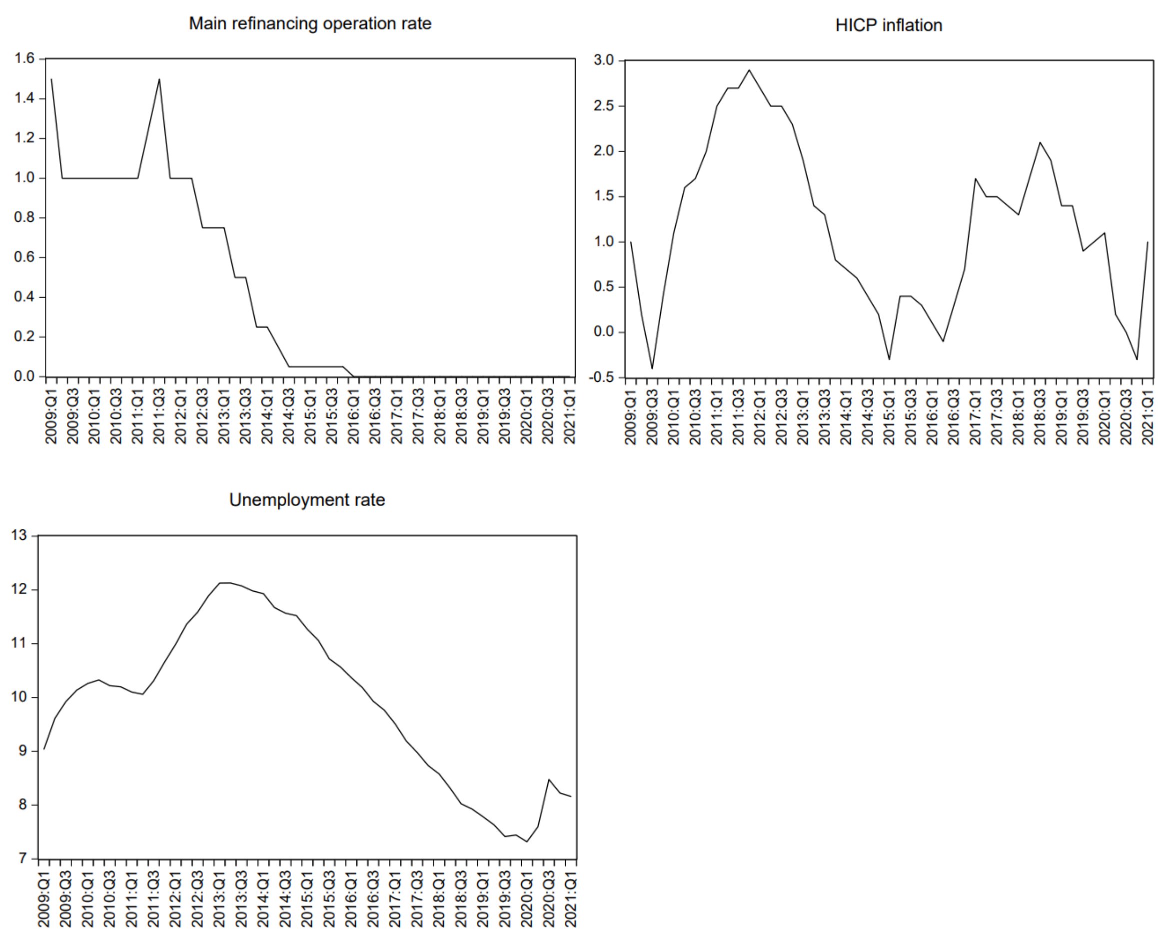
To find the relationship between the ECB's key interest rate represented by the rate on main refinancing operation, the HICP inflation and the unemployment rate, the time series data is analysed by the Augmented Dickey-Fuller test (ADF) for its stationarity and then by the Granger causality after the data is stationary to assess the relationship of these variables through EViews.

4.1 Stationarity and non-stationarity tests for time series data

4.1.1 Graphical method

According to the line graph plots, the data of the main refinancing operation rate, HICP inflation and the unemployment rate seem to be non-stationary as the graph comprise continuously upward, downward or random movement in some subperiods, so our next step is to confirm the stationarity or non-stationarity of the data series by the formal test which is the Augmented Dickey-Fuller test.

Chart 2 The level of main refinancing operation rates, HICP inflation and the unemployment rate



4.1.2 Augmented Dickey-Fuller test

To check whether our preliminary analysis from data visualisation that the data series of all three variables is non-stationary, is true, the Augmented Dickey-Fuller (ADF) test with Schwarz information criterion (SIC) or Bayesian information criterion (BIC) which assists to select the optimal lag length is used. The results are presented in Table 1, 2 and 3.

Table 1 The ADF test with the SIC optimal lag for the main refinancing operation interest rate

Null Hypothesis: MAIN REFINANCING OPERATION RATE has a unit root
Exogenous: Constant
Lag Length: 8 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.667912	0.4394
Test critical values:	1% level	-3.605593	
	5% level	-2.936942	
	10% level	-2.606857	

*MacKinnon (1996) one-sided p-values.

Table 2 The ADF test with the SIC optimal lag for the HICP inflation

Null Hypothesis: HICP INFLATION has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.710635	0.4196
Test critical values:	1% level	-3.574446	
	5% level	-2.923780	
	10% level	-2.599925	

*MacKinnon (1996) one-sided p-values.

Table 3 The ADF test with the SIC optimal lag for the unemployment rate

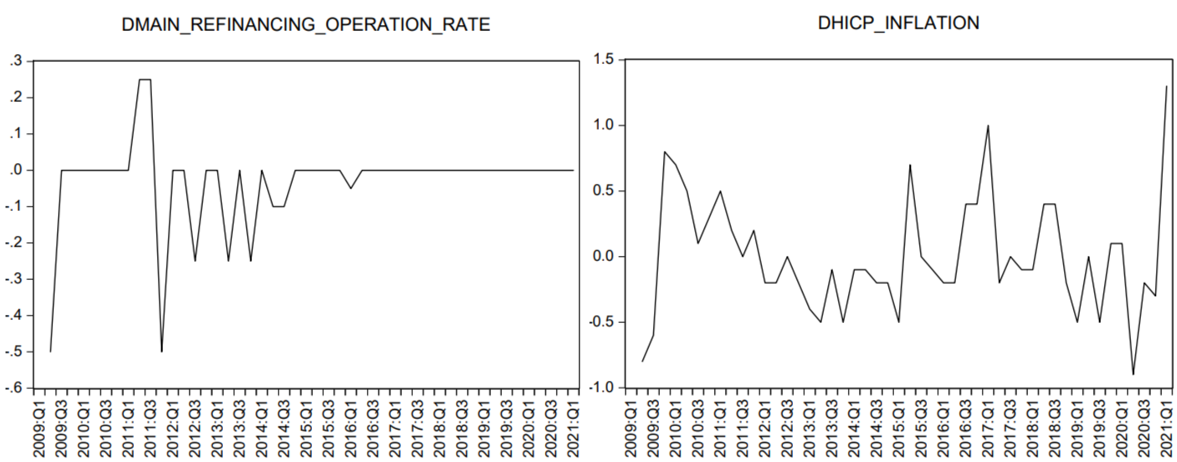
Null Hypothesis: UNEMPLOYMENT RATE has a unit root
Exogenous: Constant
Lag Length: 3 (Automatic - based on SIC, maxlag=10)

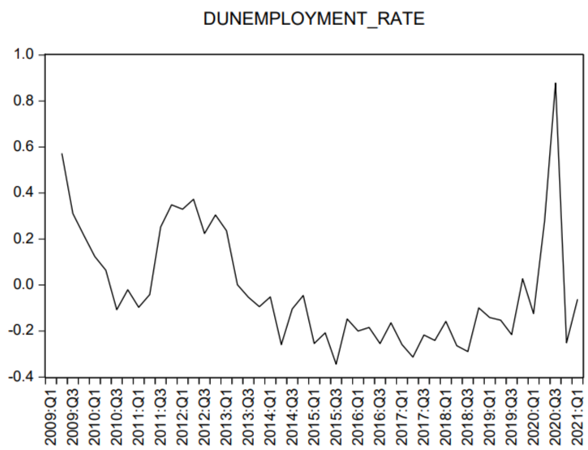
		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.573651	0.4876
Test critical values:	1% level	-3.584743	
	5% level	-2.928142	
	10% level	-2.602225	

*MacKinnon (1996) one-sided p-values.

Although the best lag chosen from Schwarz information criterion (SIC) or Bayesian information criterion (BIC) is applied, 8 lag length for the rate on main refinancing operations, no lag length for the HICP inflation and 3 lag length for the unemployment rate, the p-value of the level of these variables is more than 0.05 (5% is the appropriate level of significance for hypothesis testing of this type of research), so we fail to reject the null hypothesis that the time series data of each variable is non-stationary. Alternatively, we can state that as the t-test statistic is less negative than the t-critical value obtained from the 5% level of significance, so we infer that the data series is non-stationary. Additionally, the data of the rate on main refinancing operations, HICP inflation and the unemployment rate are also non-stationary at the 1% and 10% level of significance or at a 99% and 90% level of confidence. As a result of this, we need to make the data stationary by transforming it through the first difference method, otherwise we are unable to perform the Granger causality test. The movement of data of each variable at first difference is presented in Chart 3.

Chart 3 The main refinancing operation rate, HICP inflation and the unemployment rate data at first difference





At first difference, some trends and seasonality are removed. In addition, changes of the data are investigated instead of the raw data since the first difference is the method which subtracts the current data with the previous data. As we can observe in Chart 3, most data of each variable is more likely to move within a range than the data in Chart 2 which implies that the data series has more constant mean and variance. However, to be sure that the data is definitely stationary, we test the first difference of the rate on main refinancing operation, HICP inflation and the unemployment rate again with the ADF test. The results are shown in Table 4, 5 and 6.

Table 4 The ADF test with the SIC optimal lag for the difference of the main refinancing operation interest rate

Null Hypothesis: DMAIN REFINANCING OPERATION RATE has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-8.848197	0.0000
Test critical values:	1% level	-3.577723	
	5% level	-2.925169	
	10% level	-2.600658	

*MacKinnon (1996) one-sided p-values.

Table 5 The ADF test with the SIC optimal lag for the difference of the HICP inflation

Null Hypothesis: DHICP INFLATION has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.988806	0.0002
Test critical values:	1% level	-3.577723	
	5% level	-2.925169	
	10% level	-2.600658	

*MacKinnon (1996) one-sided p-values.

Table 6 The ADF test with the SIC optimal lag for the difference of the unemployment rate

Null Hypothesis: DUNEMPLOYMENT RATE has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.993881	0.0032
Test critical values:	1% level	-3.577723	
	5% level	-2.925169	
	10% level	-2.600658	

*MacKinnon (1996) one-sided p-values.

The p-value of the difference of the rate on main refinancing operations, HICP inflation and the unemployment rate is less than 0.05 (5% is the appropriate level of significance for hypothesis testing of this type of research), so we can reject the null hypothesis that that the time series data of each variable is non-stationary and infer that the data series is stationary at the 95% level of confidence. In fact, all variables are still stationary even at the 1% level of significance.

4.2 Granger Causality test

After getting the stationary data, we run the Granger causality test from using one lag to twelve lags. Unlike Willis and Cao (2015)'s findings that changes in the federal funds rate have impacts on the employment in context of the U.S. after applying 12 lags of quarterly data during the period of January 1960 to December 2007, this research (see Table 7, 8, 9, 10 and 11) finds no evidence that the main refinancing operation interest rate which is the key rate for the ECB help improve the HICP inflation and the employment rate when considering the euro area as a whole from the first quarter of 2009 to the first quarter of 2021. Similar to Silvia and Iqbal (2014) who investigate the relationship of these three variables in the U.S. by the Granger causality, this study demonstrates that changes in the monetary policy rate is irrelevant with the inflation and unemployment rate. Unlike their analysis that only inflation is useful for predicting the federal funds rate, we find that both inflation and the unemployment rate help forecast the ECB's key interest rate which corroborates the belief that the ECB take inflation and unemployment into consideration for the monetary policy rate decision and consistent with the concept of the Taylor rule that central banks should adjust the interest rate corresponding to economic conditions.

Table 7 Summary of the Granger-Causality test

Granger Causality Tests with different lags				
Lag	Main Refinancing rate Granger-causes HICP Inflation	HICP Inflation Granger-causes Main Refinancing rate	Main Refinancing rate Granger-causes Unemployment rate	Unemployment Rate Granger-causes Main Refinancing rate
1	0.1887	0.1709	0.9322	0.0867
2	0.6493	0.1149	0.9140	0.1767
3	0.3615	0.3250	0.3694	0.4230
4	0.5699	0.5864	0.5633	0.3913
5	0.6957	0.5450	0.5958	0.3522
6	0.4310	0.7288	0.6218	0.3998
7	0.5258	0.4994	0.3395	0.4051
8	0.8396	0.0144	0.4817	0.5724
9	0.8110	0.2885	0.7539	0.1077
10	0.9862	0.1133	0.8858	0.0000
11	0.9755	0.5616	0.9771	0.0003
12	0.9906	0.992	0.9818	0.0106

Table 7 summarises the p-value results of the Granger causality for each pair variable from 1 lag to 12 lags. A value below 0.05 (5% is the appropriate level of significance for hypothesis testing of this type of research) indicates that the relationship is significant at the 5% level and therefore proven. The number highlighted in yellow indicate significance at the 5% level and the number highlighted in green are the best result in each case. As can be seen, the relationship between the HICP inflation and the main refinancing operation rate is significant at 8 lags and the relationship between the unemployment rate and the main refinancing operation rate is significant at 10, 11 and 12 lags while the best result is found at 10 lags because of the smallest number of the p-value below 0.05. More details and interpretation of the statistically significant results and the best result are as follows.

Table 8 Granger causality test with 8 lags

Pairwise Granger Causality Tests
Date: 08/01/21 Time: 18:00
Sample: 1 49
Lags: 8

Null Hypothesis:	Obs	F-Statistic	Prob.
DMAIN_REFINANCING_OPERATION_RATE does not Granger Cause DHICP_INFLATION	40	0.50554	0.8396
DHICP_INFLATION does not Granger Cause DMAIN_REFINANCING_OPERATION_RATE		3.16554	0.0144

Table 9 Granger causality test with 10 lags

Pairwise Granger Causality Tests
Date: 08/01/21 Time: 18:22
Sample: 1 49
Lags: 10

Null Hypothesis:	Obs	F-Statistic	Prob.
DUNEMPLOYMENT_RATE does not Granger Cause DMAIN_REFINANCING_OPERATION_RATE	38	23.9209	5.E-08
DMAIN_REFINANCING_OPERATION_RATE does not Granger Cause DUNEMPLOYMENT_RATE		0.47217	0.8858

Table 10 Granger causality test with 11 lags

Pairwise Granger Causality Tests
Date: 08/01/21 Time: 18:22
Sample: 1 49
Lags: 11

Null Hypothesis:	Obs	F-Statistic	Prob.
DUNEMPLOYMENT_RATE does not Granger Cause DMAIN_REFINANCING_OPERATION_RATE	37	8.01937	0.0003
DMAIN_REFINANCING_OPERATION_RATE does not Granger Cause DUNEMPLOYMENT_RATE		0.29052	0.9771

Table 11 Granger causality test with 12 lags

Pairwise Granger Causality Tests
Date: 08/01/21 Time: 18:23
Sample: 1 49
Lags: 12

Null Hypothesis:	Obs	F-Statistic	Prob.
DUNEMPLOYMENT_RATE does not Granger Cause DMAIN_REFINANCING_OPERATION_RATE	36	4.33011	0.0106
DMAIN_REFINANCING_OPERATION_RATE does not Granger Cause DUNEMPLOYMENT_RATE		0.27616	0.9818

Table 8 shows that the HICP inflation is statistically significant to Granger-cause the rate on main refinancing operations at 8 lags while Table 9, 10 and 11 present the results that the unemployment rate Granger-causes the rate on main refinancing operations at 10, 11 and 12 lags at the 5% level of significance because the p-value is less than 0.05 (5% is the appropriate level of significance for hypothesis testing of this type of research). In short, the past 8-quarter values of the HICP inflation can be used to predict the main refinancing operation rate and the past 10-, 11- and 12-quarter values of the unemployment rate are helpful to forecast the rate on the main refinancing operations while the past 10-quarter values of the unemployment rate has the strongest relationship with this ECB's key rate with the p-value of 0.00000005.

Chapter 5 Discussion

This chapter will discuss our findings with the debate that the monetary policy can only support the economy by maintain price stability but cannot impact the level of output in the long run. Moreover, we will mention about the issue of the likely underestimated HICP inflation due to insufficient inclusion of the housing cost which may change the result of the future research. Furthermore, we will present other authors' perspective toward the monetary policy in a low-interest and low inflation environment or the zero lower bound period.

5.1 The debate that the monetary policy can merely support the economy by maintaining price stability but cannot improve the growth of the economy in the long run

Although the European Central Bank (2021) addresses that a central bank can only support the economy by keep the settings of stable prices when the economy reaches the long-run equilibrium whereas it cannot drive the economic growth or impact real output and unemployment by reducing its short-term monetary policy rates, many studies disprove this statement (Collignon 2007; Kam, Smithin, and Tabassum 2019; Irandoust 2020; Jordà, Sanjay and Alan 2020). For example, Jordà, Sanjay and Alan (2020) prove that the monetary shock from changes in the monetary policy interest rate can impact the productivity of economies in 17 countries: Australia, Belgium, Canada, Switzerland, Germany, Denmark, Spain, Finland, France, UK, Italy, Japan, Netherlands, Norway, Portugal, Sweden, USA and its impact lasts for more than 10 years.

Referring to our results, we find that the ECB's key rate cannot improve both inflation and unemployment condition after using the sample period after the Great Recession and the past 12-lag or 3-year data. Nonetheless, we are unable to compare our findings with Jordà, Sanjay and Alan (2020)'s and claim that the difference of the results come from a different method used because they investigate the impact of the monetary policy decision on only a few member countries in the euro area separately, whereas we examine the relationship between the ECB's monetary policy interest rate and the inflation, and also the interest rate and the unemployment rate of the whole eurozone. Moreover, the statement of the ECB that the central bank can steer the policy rate to maintain price stability does not hold in our research. Consequently, future studies about the relationship between the ECB's key rate, the HICP inflation and the unemployment rate in the whole euro area in the post-Great Recession are needed to clarify whether there is a change of monetary policy effects on the inflation and unemployment including the change in the transmission mechanism.

5.2 The possibility that the HICP inflation is underestimated

Although our findings demonstrate that the HICP inflation can be used to predict the main refinancing operation rate which is the ECB's key interest rate while the policy interest rate is not useful for forecasting the HICP inflation, there are debates that the HICP inflation is underestimated and should be revised. The essence of the debates is that the HICP inflation only includes actual rentals for housing which accounts for around 6.5% of the total weight (Houte, 2020) whereas most citizens prefer having their own house to renting a place which means that high housing price has more impacts on the cost of living of most population than the rental costs. However, owner-occupied housing costs are not still added into the HICP inflation for the euro area which the ECB uses as the inflation measure between the actual inflation and the inflation target, even though some countries, namely the United States, Japan, Sweden and Norway, include it in their reference inflation indices, so many researchers raise concerns that there might be a gap between the HICP inflation and the inflation perceived by households and in turn mitigates the monetary policy communication effects (European Central Bank, 2020). In terms of discrepancy, the HICP inflation including owner-occupied housing costs would lift the inflation in the euro area around 0.2% to 0.5% and 1.3% or above for the long-term core inflation and thereby have effects on the monetary policy decisions. Hence, if the ECB adopts a new methodology to measure the HICP inflation in the future, the results of the study in the euro area may be different.

5.3 The interpretation of the zero lower bound period toward the monetary policy

In the post-Great Recession, central banks are facing the low-interest-rate and low-inflation environment. The low policy interest rate is sometimes interchangeably described as the zero lower bound rate because the monetary policy interest rate is cut and maintained to nearly zero. Therefore, a further downward shift in the central bank's key rate to stimulate the economy is limited. From this limitation, the studies about the monetary policy rate during this period express different opinions about this traditional monetary policy tool. For instance, Silvia and Iqbal (2014) address that the Federal Reserve employs a mix of conventional and unconventional tools, namely the federal funds rate, the asset purchase programme and forward guidance as an effect of structural changes in the U.S. economy after the crisis while Willis and Cao (2015) exclude the period after

2007 because the federal funds rate has been constrained at the zero lower bound in examining the response of the employment represented by total nonfarm payroll employment toward changes in the federal funds rate. In other words, they consider that the monetary policy interest rate is ineffective to boost the economy and then employment and inflation in the low-interest-rate settings. Although our findings also state the ineffectiveness of the monetary policy rate to improve the employment and inflation conditions in the euro area in line with the argument of Willis and Cao (2015) in the U.S. context, the rationale behind these results is worth for future research.

Chapter 6 Conclusion and recommendation

This chapter is the summary of our findings in relation to each hypothesis posed, the comparison with previous empirical results and recommendation for future research.

6.1 Conclusion

Although the monetary policy interest rate is a main traditional tool that central banks adopt for promoting price stability and improve employment condition, this study does not find its efficacy in the euro area from the first quarter of 2009 to the first quarter of 2021 while examine the predictability of the ECB's main refinancing operation rate toward the movement of the HICP inflation and the unemployment rate by the Granger causality test from 1 lag to 12 lags which is the suitable number of lags to observe the effect of the monetary policy rate suggested by the literature. In other words, we cannot find the evidence that changes in the ECB's key interest rate lead to changes in the HICP inflation which is the inflation measure for the euro area or improvements in the unemployment rate. Put differently, the variation of the policy rate does not precede the fluctuation in price stability and the unemployment. On the other hand, our empirical result indicates that the central banks take the inflation and unemployment data into account before deciding the policy rate shifts as expected. As the monetary policy must be forward-looking because its mechanism needs time to transmit to the economy, we find that the HICP inflation with 8 lags and unemployment with 10 lags are helpful to forecast the policy rate decision. Overall, this study test two concepts: whether the ECB's key rate is predicted by the HICP inflation and the unemployment rate in the euro area which is the rationale of the modified Taylor rule and whether the effectiveness of the policy rate aligns with the central bank's intentions to promote the full employment and maintain price stability.

Our finding that the policy rate can be forecasted by the inflation and unemployment rate following the Taylor rule is consistent with most empirical studies from the literature despite different approaches and countries conducted (Castro, 2011; Nikolsko-Rzhevskyy and Papell, 2012; Hudsona and Vespignanib, 2018; Tan and Mohamed, 2020). A slight deviation of the Taylor rule from the actual policy rate depend on the version of the Taylor rule used such as the output-gap or the unemployment-gap (Arnolda and Vrugtb, 2012) since the unemployment-gap form of the Taylor rule performs better in the Great Recession, data transformation (Nikolsko-Rzhevskyy and Papell, 2012) or the choice of coefficients between economic growth and inflation or unemployment and inflation (Hudsona and Vespignanib, 2018). Regarding the studies about the Eurozone, we still find the same outcome with Castro (2011) that the policy interest rate is recommended by the Taylor rule, although the different period and components of the Taylor rule is conducted as we focus on the unemployment rate while the author emphasises the output. Nonetheless, there is a few studies in the U.S. finding no evidence that the central bank relies on the concept of the Taylor rule that the policy rate should be derived from the economic condition measured by the inflation and the unemployment rate in a similar sample period (Silvia and Iqbal, 2014; Nikolsko-Rzhevskyy, Papell and Prodan, 2014), but relies more on expert opinions (Nikolsko-Rzhevskyy, Papell and Prodan, 2014).

On the other hand, this study cannot indicate that the ECB's key rate partly help to reduce the unemployment rate or bring the inflation to its target, although we run the model from 1 lag to 12 lags or 3 years through the Granger causality which contrast the belief of economists that when the prices and wages is sticky in the short run, changes in the monetary policy interest rate will affect aggregate demand and then output and employment (Mathai, 2020). In addition, we cannot find the adjustment of the inflation as a result of changes in the policy rate over a medium and a long term in the observed period as suggest by many studies (European Central Bank, 2021). However, it is similar to Silvia and Iqbal (2014)'s findings that the federal funds rate is not effective to predict the inflation and the unemployment from the fourth quarter of 2007 to the first quarter of 2014 which they assume that it is because of the structural change in the U.S. economy after the Great Recession that complicate the relationship between the monetary policy rate and these economic variables. Consequently, future research may be needed to explain whether the relationship between the ECB's key rate and the inflation as well as the unemployment rate in the euro area is changing after the impacts of the European sovereign debt crisis, the global financial crisis and the Great Recession. Furthermore, since the ECB lifts its inflation target from below but close to 2% to an exact 2% over the medium term, which is the clearer inflation targeting, the future study may be likely to find stronger relationship between the monetary policy and inflation.

6.2 Recommendation

As this study investigates the two-way relationship between the rate on main refinancing operations in the post-Great Recession and the inflation, and also the rate and the unemployment, future research can examine the rate on the deposit facility or the rate on the marginal lending facility which is also the ECB's key rate and then compare and contrast whether there is a difference in the results and how the interest rate is transmitted to the wider economy. Besides, different time period, other versions of the Taylor rule and the HICP inflation including owner-occupied housing costs are worth monitoring as well.

Appendix A

The Granger causality test results for different lags (1-12 lags)

Lags: 1

1. d(main refinancing operation rate) does not Granger-cause d(HICP inflation) and vice versa.

Pairwise Granger Causality Tests
Date: 07/27/21 Time: 19:58
Sample: 3/01/2009 3/01/2021
Lags: 1

Null Hypothesis:	Obs	F-Statistic	Prob.
DMAIN_REFINANCING_OPERATION_RATE does not Granger Cause DHICP_INFLATION	47	1.78242	0.1887
DHICP_INFLATION does not Granger Cause DMAIN_REFINANCING_OPERATION_RATE		1.93756	0.1709

2. d(unemployment rate) does not Granger-cause d(main refinancing operation rate) and vice versa.

Pairwise Granger Causality Tests
Date: 07/27/21 Time: 20:03
Sample: 3/01/2009 3/01/2021
Lags: 1

Null Hypothesis:	Obs	F-Statistic	Prob.
DUNEMPLOYMENT_RATE does not Granger Cause DMAIN_REFINANCING_OPERATION_RATE	47	3.07070	0.0867
DMAIN_REFINANCING_OPERATION_RATE does not Granger Cause DUNEMPLOYMENT_RATE		0.00732	0.9322

Lags: 2

1. d(main refinancing operation rate) does not Granger-cause d(HICP inflation) and vice versa.

Pairwise Granger Causality Tests
Date: 07/31/21 Time: 18:47
Sample: 1 49
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.
DHICP_INFLATION does not Granger Cause DMAIN_REFINANCING_OPERATION_RATE	46	2.28197	0.1149
DMAIN_REFINANCING_OPERATION_RATE does not Granger Cause DHICP_INFLATION		0.43640	0.6493

2. d(unemployment rate) does not Granger-cause d(main refinancing operation rate) and vice versa.

Pairwise Granger Causality Tests
Date: 07/31/21 Time: 18:49
Sample: 1 49
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.
DUNEMPLOYMENT_RATE does not Granger Cause DMAIN_REFINANCING_OPERATION_RATE	46	1.80879	0.1767
DMAIN_REFINANCING_OPERATION_RATE does not Granger Cause DUNEMPLOYMENT_RATE		0.09007	0.9140

Lags: 3

1. d(main refinancing operation rate) does not Granger-cause d(HICP inflation) and vice versa.

Pairwise Granger Causality Tests
Date: 07/31/21 Time: 19:03
Sample: 1 49
Lags: 3

Null Hypothesis:	Obs	F-Statistic	Prob.
DHICP_INFLATION does not Granger Cause DMAIN_REFINANCING_OPERATION_RATE	45	1.19410	0.3250
DMAIN_REFINANCING_OPERATION_RATE does not Granger Cause DHICP_INFLATION		1.09879	0.3615

2. d(unemployment rate) does not Granger-cause d(main refinancing operation rate) and vice versa.

Pairwise Granger Causality Tests
Date: 07/31/21 Time: 18:58
Sample: 1 49
Lags: 3

Null Hypothesis:	Obs	F-Statistic	Prob.
DUNEMPLOYMENT_RATE does not Granger Cause DMAIN_REFINANCING_OPERATION_RATE	45	0.95680	0.4230
DMAIN_REFINANCING_OPERATION_RATE does not Granger Cause DUNEMPLOYMENT_RATE		1.07940	0.3694

Lags: 4

1. d(main refinancing operation rate) does not Granger-cause d(HICP inflation) and vice versa.

Pairwise Granger Causality Tests
Date: 07/31/21 Time: 19:05
Sample: 1 49
Lags: 4

Null Hypothesis:	Obs	F-Statistic	Prob.
DHICP_INFLATION does not Granger Cause DMAIN_REFINANCING_OPERATION_RATE	44	0.71642	0.5864
DMAIN_REFINANCING_OPERATION_RATE does not Granger Cause DHICP_INFLATION		0.74185	0.5699

2. d(unemployment rate) does not Granger-cause d(main refinancing operation rate) and vice versa.

Pairwise Granger Causality Tests
Date: 07/31/21 Time: 18:59
Sample: 1 49
Lags: 4

Null Hypothesis:	Obs	F-Statistic	Prob.
DUNEMPLOYMENT_RATE does not Granger Cause DMAIN_REFINANCING_OPERATION_RATE	44	1.05893	0.3913
DMAIN_REFINANCING_OPERATION_RATE does not Granger Cause DUNEMPLOYMENT_RATE		0.75228	0.5633

Lags: 5

1. d(main refinancing operation rate) does not Granger-cause d(HICP inflation) and vice versa.

Pairwise Granger Causality Tests
Date: 07/31/21 Time: 19:05
Sample: 1 49
Lags: 5

Null Hypothesis:	Obs	F-Statistic	Prob.
DHICP_INFLATION does not Granger Cause DMAIN_REFINANCING_OPERATION_RATE	43	0.81934	0.5450
DMAIN_REFINANCING_OPERATION_RATE does not Granger Cause DHICP_INFLATION		0.60611	0.6957

2. d(unemployment rate) does not Granger-cause d(main refinancing operation rate) and vice versa.

Pairwise Granger Causality Tests
Date: 07/31/21 Time: 18:59
Sample: 1 49
Lags: 5

Null Hypothesis:	Obs	F-Statistic	Prob.
DUNEMPLOYMENT_RATE does not Granger Cause DMAIN_REFINANCING_OPERATION_RATE	43	1.15564	0.3522
DMAIN_REFINANCING_OPERATION_RATE does not Granger Cause DUNEMPLOYMENT_RATE		0.74481	0.5958

Lags: 6

1. d(main refinancing operation rate) does not Granger-cause d(HICP inflation) and vice versa.

Pairwise Granger Causality Tests
Date: 07/31/21 Time: 19:06
Sample: 1 49
Lags: 6

Null Hypothesis:	Obs	F-Statistic	Prob.
DHICP_INFLATION does not Granger Cause DMAIN_REFINANCING_OPERATION_RATE	42	0.59882	0.7288
DMAIN_REFINANCING_OPERATION_RATE does not Granger Cause DHICP_INFLATION		1.02171	0.4310

2. d(unemployment rate) does not Granger-cause d(main refinancing operation rate) and vice versa.

Pairwise Granger Causality Tests
Date: 07/31/21 Time: 19:00
Sample: 1 49
Lags: 6

Null Hypothesis:	Obs	F-Statistic	Prob.
DUNEMPLOYMENT_RATE does not Granger Cause DMAIN_REFINANCING_OPERATION_RATE	42	1.07536	0.3998
DMAIN_REFINANCING_OPERATION_RATE does not Granger Cause DUNEMPLOYMENT_RATE		0.74008	0.6218

Lags: 7

1. d(main refinancing operation rate) does not Granger-cause d(HICP inflation) and vice versa.

Pairwise Granger Causality Tests
Date: 08/01/21 Time: 17:59
Sample: 1 49
Lags: 7

Null Hypothesis:	Obs	F-Statistic	Prob.
DMAIN_REFINANCING_OPERATION_RATE does not Granger Cause DHICP_INFLATION	41	0.89354	0.5258
DHICP_INFLATION does not Granger Cause DMAIN_REFINANCING_OPERATION_RATE		0.93134	0.4994

2. d(unemployment rate) does not Granger-cause d(main refinancing operation rate) and vice versa.

Pairwise Granger Causality Tests
Date: 08/01/21 Time: 18:09
Sample: 1 49
Lags: 7

Null Hypothesis:	Obs	F-Statistic	Prob.
DUNEMPLOYMENT_RATE does not Granger Cause DMAIN_REFINANCING_OPERATION_RATE	41	1.07806	0.4051
DMAIN_REFINANCING_OPERATION_RATE does not Granger Cause DUNEMPLOYMENT_RATE		1.19623	0.3395

Lags: 8

1. d(HICP inflation) Granger-causes d(main refinancing operation rate), but d(main refinancing operation rate) does not Granger-cause d(HICP inflation).

Pairwise Granger Causality Tests
Date: 08/01/21 Time: 18:00
Sample: 1 49
Lags: 8

Null Hypothesis:	Obs	F-Statistic	Prob.
DMAIN_REFINANCING_OPERATION_RATE does not Granger Cause DHICP_INFLATION	40	0.50554	0.8396
DHICP_INFLATION does not Granger Cause DMAIN_REFINANCING_OPERATION_RATE		3.16554	0.0144

2. d(unemployment rate) does not Granger-cause d(main refinancing operation rate) and vice versa.

Pairwise Granger Causality Tests
Date: 08/01/21 Time: 18:09
Sample: 1 49
Lags: 8

Null Hypothesis:	Obs	F-Statistic	Prob.
DUNEMPLOYMENT_RATE does not Granger Cause DMAIN_REFINANCING_OPERATION_RATE	40	0.84700	0.5724
DMAIN_REFINANCING_OPERATION_RATE does not Granger Cause DUNEMPLOYMENT_RATE		0.97156	0.4817

Lags: 9

1. d(main refinancing operation rate) does not Granger-cause d(HICP inflation) and vice versa.

Pairwise Granger Causality Tests
Date: 08/01/21 Time: 18:01
Sample: 1 49
Lags: 9

Null Hypothesis:	Obs	F-Statistic	Prob.
DMAIN_REFINANCING_OPERATION_RATE does not Granger Cause DHICP_INFLATION	39	0.56306	0.8110
DHICP_INFLATION does not Granger Cause DMAIN_REFINANCING_OPERATION_RATE		1.31802	0.2885

2. d(unemployment rate) does not Granger-cause d(main refinancing operation rate) and vice versa.

Pairwise Granger Causality Tests
Date: 08/01/21 Time: 18:10
Sample: 1 49
Lags: 9

Null Hypothesis:	Obs	F-Statistic	Prob.
DUNEMPLOYMENT_RATE does not Granger Cause DMAIN_REFINANCING_OPERATION_RATE	39	1.91947	0.1077
DMAIN_REFINANCING_OPERATION_RATE does not Granger Cause DUNEMPLOYMENT_RATE		0.63568	0.7539

Lags: 10

1. d(main refinancing operation rate) does not Granger-cause d(HICP inflation) and vice versa.

Pairwise Granger Causality Tests
Date: 08/01/21 Time: 18:02
Sample: 1 49
Lags: 10

Null Hypothesis:	Obs	F-Statistic	Prob.
DMAIN_REFINANCING_OPERATION_RATE does not Granger Cause DHICP_INFLATION	38	0.24324	0.9862
DHICP_INFLATION does not Granger Cause DMAIN_REFINANCING_OPERATION_RATE		1.92171	0.1133

2. d(unemployment rate) Granger-causes d(main refinancing operation rate), but d(main refinancing operation rate) does not Granger-cause d(unemployment rate).

Pairwise Granger Causality Tests
Date: 08/01/21 Time: 18:22
Sample: 1 49
Lags: 10

Null Hypothesis:	Obs	F-Statistic	Prob.
DUNEMPLOYMENT_RATE does not Granger Cause DMAIN_REFINANCING_OPERATION_RATE	38	23.9209	5.E-08
DMAIN_REFINANCING_OPERATION_RATE does not Granger Cause DUNEMPLOYMENT_RATE		0.47217	0.8858

Lags: 11

1. d(main refinancing operation rate) does not Granger-cause d(HICP inflation) and vice versa.

Pairwise Granger Causality Tests
Date: 08/01/21 Time: 18:03
Sample: 1 49
Lags: 11

Null Hypothesis:	Obs	F-Statistic	Prob.
DHICP INFLATION does not Granger Cause DMAIN REFINANCING OPERATION RATE	37	0.90150	0.5616
DMAIN REFINANCING OPERATION RATE does not Granger Cause DHICP INFLATION		0.29602	0.9755

2. d(unemployment rate) Granger-causes d(main refinancing operation rate), but d(main refinancing operation rate) does not Granger-cause d(unemployment rate).

Pairwise Granger Causality Tests
Date: 08/01/21 Time: 18:22
Sample: 1 49
Lags: 11

Null Hypothesis:	Obs	F-Statistic	Prob.
DUNEMPLOYMENT RATE does not Granger Cause DMAIN REFINANCING OPERATION RATE	37	8.01937	0.0003
DMAIN REFINANCING OPERATION RATE does not Granger Cause DUNEMPLOYMENT RATE		0.29052	0.9771

Lags: 12

1. d(main refinancing operation rate) does not Granger-cause d(HICP inflation) and vice versa.

Pairwise Granger Causality Tests
Date: 08/01/21 Time: 18:04
Sample: 1 49
Lags: 12

Null Hypothesis:	Obs	F-Statistic	Prob.
DHICP INFLATION does not Granger Cause DMAIN REFINANCING OPERATION RATE	36	0.22446	0.9920
DMAIN REFINANCING OPERATION RATE does not Granger Cause DHICP INFLATION		0.23352	0.9906

2. d(unemployment rate) Granger-causes d(main refinancing operation rate), but d(main refinancing operation rate) does not Granger-cause d(unemployment rate).

Pairwise Granger Causality Tests
Date: 08/01/21 Time: 18:23
Sample: 1 49
Lags: 12

Null Hypothesis:	Obs	F-Statistic	Prob.
DUNEMPLOYMENT RATE does not Granger Cause DMAIN REFINANCING OPERATION RATE	36	4.33011	0.0106
DMAIN REFINANCING OPERATION RATE does not Granger Cause DUNEMPLOYMENT RATE		0.27616	0.9818

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