An Assessment of the ECB’s Unconventional Monetary Policies*

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Abstract

This study evaluates the effectiveness of the European Central Bank’s unconventional monetary policy. We assume Calvo-type friction and develop a forward-looking New Keynesian state-space model with an error correction term to address both unit roots and stationary variables at once. Subsequently, we decompose the nominal effects into asset pricing kernels and real effects. Thus, we show empirically that the corporate sector purchase program (CSPP) and CSPP-based bank lending to households positively affect trend inflation due to credit easing. However, due to asymmetric development within the European Union and the Euro area, there is no consensus on whether they should be continued after the crisis.

JEL classification: C32, E12, E52, E58, F33.

Keywords: ECB’s APP and Exchange Rate, Portfolio Rebalancing channel, Nominal–Real Asset Pricing Kernel channel, Calvo-type Friction, Forward-Looking New Keynesian State-Space Model with Error Correction Term.

1. Introduction

This study examines whether the European Central Bank (ECB) accomplishes a 2% inflation target and how and which transmission channels are effective for that purpose by presenting the hypotheses and empirical analyses of the transmission channels.

Most of the earlier studies addressing the effects of unconventional monetary policies (UMPs) without a corporate sector purchase program (CSPP) and pandemic emergency purchase program (PEPP) were conducted before the end of the asset purchase program (APP): The APP was concluded in December 2018. This study mainly addresses the period from the beginning of the public sector purchase program (PSPP) (from March 2015) to the

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end of APP (until December 2018), which is a full sample assessment of the effects of the especially quantitative PSPP as well as the newly added CSPP (from June 2016 to December 2018) and PEPP (the PEPP started in March 2020); during and after the time of the former ECB President Draghi.

The unique contribution of this study is that, based on the forward-looking new Keynesian model with Calvo-type friction, we unveiled the black box of the APP’s transmission of the real trend values (PSPP\textsuperscript{star}, CSPP\textsuperscript{star}, PEPP\textsuperscript{star}, Ex\textsuperscript{star}) on the (potential) economic growth rate or (trend) inflation rate using a state-space model, by accurately separating nominal values (PSPP, CSPP, PEPP, Ex). Earlier studies have not addressed the effects of growth rate and inflation rate on time-varying trends utilizing the state-space model. Most studies have utilized the VARs or VECM’s approach to assess the transmission among the concerned variables and have not considered the trend or potential variables directly. This is because only state-space models or DSGE models can address the challenges rationally and efficiently, owing to the estimation of the star variables.

Second, our model is original in that the state-space model impacts the effects of the nominal-real asset pricing valuation changes of the ECB’s APP on the economy, which we label as nominal-real “pricing kernel channels” for the (potential) economic growth rate as well as for the (trend) inflation rate. In addition, this analysis becomes feasible by utilizing state-space models. The pricing kernel in this context is defined as \textit{Nominal Effects} = \textit{Pricing Kernels} × \textit{Real Effects}, which means the pricing kernel between the nominals and the reals is the time-varying coefficient connecting them. Earlier studies of the ECB’s APP thus far address the effect of the nominals, particularly regarding the APP variables (PSPP, CSPP, PEPP, and Ex). However, the nominal-real “pricing kernel channels” of the APP may well have differences in their effects, which deserve further research and may possess some originality, at a minimum in December 2020.

Furthermore, in verifying them, we avoid the Lucas critique, (which indicates time-varying economic parameters with each policy regime change); incorporating the Markov chain in the model. The state-space model can also address structural breaks in the data often caused by a paradigm shift, regime switch and/or unexpected exogenous shocks, such as the COVID-19 pandemic crisis, which cannot be dealt directly with by standard VARs or VECMs. The state-space model employs a Markov chain in its system, as it can still estimate the transmission effect rigorously and rationally even with the structural breaks utilizing the Kalman filtering algorithm, which effectively treats processed random-walking (unobservable or latent) variables with the unit root.

The conclusions of this study are as follows: The ECB’s inflation target has been unaccomplished thus far. However, both trend and nominal HICP inflation rates are anchored around +1%. The ECB’s APP, especially a CSPP and CSPP-based increase of bank lending to households, contributes to inflation. In this study, we review some of the ECB’s UMPs or the APP and the exchange rate, which influences the (potential) economic growth rate and (trend) inflation rate.

We present the relevant hypotheses to be verified below.

1.1 Hypotheses

In normal times, the ECB’s conventional tool is the short-term rate. However, key short-
term rates return to their effective lower bound, which causes little effect.

Therefore, the ECB turns to non-standard and UMP measures to address the problem of long-term low inflation. The ECB aims to bring back inflation to low levels, however, it was close to 2% over the medium term until December 2018, when the APP program was concluded. The APP influences broader financial conditions and eventually influences the (potential) economic growth rate and (trend) inflation rate.

Subsequently, the ECB resumed the APP (from November 2019) beyond December 2020. Regarding the effects of the APP including the PEPP, we have three hypotheses concerning the effects of the ECB’s UMPs and exchange rate, as the APP measures bank lending, and consequently identifies the time-varying (trend) HICP inflation rate and potential economic growth rate in one year in the Euro Area:

1.1.1 Hypothesis 1: The corporate sector purchase program (CSPP) including the pandemic emergency purchase program (PEPP) has some influence on financial conditions and, eventually influences the (potential) economic growth rate and (trend) inflation rate

A direct pass-through channel is defined as the direct purchase of private sector assets by the ECB (i.e., the CSPP including a part of the PEPP in this study). The purchase increases the asset prices, which encourages private banks to increase loans to corporations and households, thus improving broader financing conditions. (from the ECB)

1.1.2 Hypothesis 2: The public sector purchase program (PSPP) including the pandemic emergency purchase program (PEPP) has some influence on the financial conditions and thereby on the (potential) economic growth rate and (trend) inflation rate

The APP has two transmission channels in this study: 1. Direct pass-through and 2. Portfolio rebalancing channels. Portfolio rebalancing channels are defined as the ECB’s purchase of public and private sector assets from pension funds, banks, and households. By increasing the demand for assets, it increases prices and the resultant yields decrease, even for assets that are not directly targeted by the APP. This compression of yields encourages banks to lend to firms or households. (from the ECB)

1.1.3 Hypothesis 3: The ECB’s asset purchase program (APP) has some influence on the exchange rate and eventually on the (potential) economic growth rate and (trend) inflation rate

The lowering of the cost of borrowing by portfolio rebalancing channels encourages investors to use extra funds to purchase higher yields assets outside the Euro Area. This may lead to a lower euro exchange rate, which tends to place upward pressure on inflation. (from the ECB)

1.2 Why Are We Concerned about These Hypotheses?

The reasons include: Some criticize the effectiveness of the APP and therefore, they encourage the ECB to conclude the implementation of the APP as soon as possible, due to its harmful effects and major costs to the economy.

Furthermore, some argue that buying assets largely causes only slight asset price changes. Thus, the almost negligible influence of asset prices on the economy is questioned and is used to assess whether it nevertheless deserves implementation due to the major costs.
on us which may be a burden in the future.

These concerns appropriately question the implementation and legitimacy of the ECB’s APP. This study addresses these concerns by disintegrating the nominal APP effects into the pricing kernel effects (which is an index of asset price changes) and the real APP effects, utilizing a state-space model instead of standard VARs or VECMs.

This study is original in that it is the first to address the problem by disintegrating the nominal APP (CSPP, PSPP, PEPP) with the exchange rate effects into the pricing effects and the real APP (CSPPstar, PSPPstar, PEPPstar) with the exchange rate effects on time-varying (potential) economic growth rate and (trend) inflation rate, including the periods post the major outbreak of COVID-19 in Europe since March 2020. In earlier studies, monthly data on the time-varying (potential) economic growth rate and (trend) inflation rate was unavailable as nominal and potential economic growth rate variables are usually available solely with quarterly based ones. However, we can obtain monthly data using the state-space model and Kalman filtering, which provides the expanded dimension of data (large samples), and early assessments of the past and the resumed APP (from November 2019 on), especially the newly added CSPP and PEPP.

The pricing kernel effects are important to consider for the following reasons: When we consider the disintegration of the nominal APP effects into the asset pricing effects and the real APP effects, we may obtain the opposite effects among the nominal APP and the real APP due to the unexpected asset pricing effects. For example, there are probabilities that the nominal APP raises the (potential) economic growth rate and (trend) inflation rate; however, the real APP may cause opposite results. If we have this type of opposition between the reals and the nominals, it would be necessary to modify our recognition of the APP’s influences and outcomes on the time-varying (potential) economic growth rate and (trend) inflation rate. These research questions also deserve verification, following the real APP effects.

The remainder of this study is organized as follows: Section 2 presents the literature review. Section 3 presents the assumed UMP transmission channels and variables testing of the unit root and cointegrating vector. Section 4 presents the model specifications and empirical methods. Section 5 describes the data. Section 6 presents the empirical results and discussion. Section 7 presents the conclusion and implications of the study.

2. Literature Review

The essence of the ECB’s non-standard and UMPs lies in direct “credit easing”, which is defined as new and additional creation of “credit demand” (and subsequently credit supply). Therefore, it is beneficial to briefly review the differences in the theories of 1. LSAP (SMP, OMT) (lowering the yield curve of government bond yields), and credit easing, 2. QE (including APP and LTRO) and 3. CSPP, respectively (See Table 1, Table 2).

First, regarding 1. lowering the yield curve of government bond yields, targeted purchases of troubled and non-performing assets in relatively emergent times, aiming to resolve sovereign debt crises and systemic risks among financial institutions. This type of measure is a temporary and contingent measure for the whole economy or for a state-level financial disorder. By doing so, the resultant decline of government bond yields helps the entire economy or the state recover some degree of indispensable trust in the financial market to be capitalized by
### Table 1: Unconventional Monetary Policy Effects in the Euro Area (An Augmented Survey)

| Study | notes | Government bonds yields | Real GDP | Prices | Other |
|-------|-------|--------------------------|----------|--------|-------|
| Darracq-Paries and De Santis (2015), December 2011-February 2012 | 3-year LTRO effects using a VAR model | | [+0.8%] | [+0.3%] | [+3%] credit, [-0.2%] lending spreads |
| Cahn, Matheron, and Sahuc (2014), January 1999-April 2007 | Effects of an LTRO of 2% of GDP. DSGE model with financial frictions. | | | | [+1%] |
| De Pooter, Martin, and Pruitt (2015), May 2010-December 2012 | Effects of the SMP on peripheral bonds liquidity premia | [-32] to [-40] bps on impact, [-13] to [-17] bps are lasting | | | |
| Ghysels, Idier, Manganelli, and Vergote (2016), SMP: May 2010-February 2012, GBY: October 2008-December 2011 | Effects of SMP with VAR model with high frequency data. | [-320] bps (Italy 2y), [-180] bps (Spain 2y), [-230] bps (Italy and Spain 10y), Similar results for Ireland and Portugal, not significant for Greece | | | |
| Eser and Schwaab (2016), SMP: May 2010-December 2012, GBY: October 2008-December 2011 | Cumulative SMP effects of purchases looking at high-frequency data | [-10] bps (5y), [-170] bps (Portugal 5y), [-190] bps (Spain 5y), [-210] bps (Italy 5y), [-330] bps (Greece 5y) | | | |
| Ferrando, Popov, and Udell (2015), Summer of 2009-March 2014 | OMT effects of SME access to credit in euro area distressed countries | | | | Probability of being credit constrained was reduced by [6.4%] |
| Altavilla, Giannone, and Lenza (2014), 1999Q1-2012Q3 | Effects of OMT announcements using event studies and VAR models | [-199] bps (Italy 2y), [-234] bps (Spain 2y), no effects in Germany and France | [+1.5%] (Italy), [+1.2%] (Spain) | [+0.74%] (Spain) | |
| Fratzscher, Lo Duca, and Straub (2016), May 2007-September 2012 | Effects of LTRO, SMP, and OMT announcements using high-frequency data | [-25] bps to [-121] bps (Italy and Spain 10y) | | | |
| Krishnamurthy, Nagel, and Vissing-Jorgensen (2018), January 2010-December 2012 | Effects of OMT, SMP, and LTROs | [-200] bps (Italy and Spain 2y), [-500] bps (Portugal and Ireland 2y), [-1,000] bps (Greece 2y) | | | |
| Kojien, Koulischer, Nguyen, and Yogo (2016), 2013Q4-2015Q4 | Effects of APP on portfolio holdings by institutional investors | Average [-13] bps. Range [-2] to [-60] bps (higher in distressed countries) | | | |
| Andrade, Breckenfelder, De Fiore, Karadi, and Tristani (2016), 9, March 2015-30, December 2015 | Effects of APP using time series and DSGE models | [-45] bps | [+1.1%] | [+0.4%] (actual), [+0.45%] (expectations) | |
| Mouabbi and Sahuc (2016), 2014Q1-2017Q2 | Effects of APP and TL TRO using a DSGE model with an estimated shadow rate | [+0.56%] (average of 2014-2016) | [+0.25%] (average of 2014-2016) | | [+400] bps (shadow rate) |
| Cova, Pagano, and Pisani (2015), Calibration: March 2015-September 2016 | Effects of APP in DSGE model | [+1.4%] | [+0.8%] | | |

Source: Author, Dell’Ariccia, Rabanal, and Sandri (2018), Lenza and Slacalek (2018) Continued
Table 2: Unconventional Monetary Policy Effects in the Euro Area (An Augmented Survey) Continued

| Study | notes | Asset Prices | Real GDP | Prices | Other |
|-------|-------|--------------|----------|--------|-------|
| Altavilla et al. (2016), 1999Q1-2012Q3 | Effects of OMT using VAR | [+0.2%] to [+1%] (DE, ES, FR, IT) | [+0.34%] to [+2.01%] | [+0.28%] to [+1.21%] | |
| Altavilla et al. (2015), January 2012-February 2013 | Effects of APP | [+0.3%] to [+0.5%] (EA, DE, ES, FR, IT) | [+1%] (UK) | |
| Joyce and Tong (2012), March 2009-January 2010 | Effects of APF1 | [+1%] (UK) | |
| Christensen and Rudebusch (2012), 2 January, 1985-31 December, 2010 | Effects of APF1 | [+0.43%] to [+0.89%] (UK) | |
| Altavilla et al. (2015), January 2012-February 2013 | Effects of APP | [+0.3%] to [+0.5%] (EA, DE, ES, FR, IT) | [+0.34%] to [+2.01%] | [+0.28%] to [+1.21%] | |
| Joyce and Tong (2012), March 2009-January 2010 | Effects of APF1 | [+1%] (UK) | |
| Christensen and Rudebusch (2012), 2 January, 1985-31 December, 2010 | Effects of APF1 | [+0.43%] to [+0.89%] (UK) | |
| Baumeister and Benati (2013), January, 1970-April, 2008 | Effects of LSAP using TVP VAR | \[+0.1\%\] to \ [+0.65\%\] (EA, EU countries) | \[+0.0\%\] to \ [+0.45\%\] (EA, EU countries) | \[-0.21\%\] to \ [+0.07\%\] (EA, EU countries) | unemployment rate peak \ [+10.6\%\] (UK) |
| Kapetanios et al. (2012), April 1993-September 2010 | Effects of BoE LSAP using TVP VAR | \[+0.25\%\] to \ [+0.58\%\] (UK) | \[+0.32\%\] to \ [+0.62\%\] (UK) | \[+0.32\%\] to \ [+0.62\%\] (UK) | |
| Weale and Wiedadek (2016), March 2009-May 2014 | Effects of LSAP using Bayesian VAR | \[+0.25\%\] to \ [+0.58\%\] (UK) | \[-0.12\%\] to \ [+0.10\%\] (EA, non-EA countries) | | |
| Gambacorta et al. (2014), January 2008-June 2011 | Various Effects using Panel VAR | \[-0.25\%\] to \ [+0.25\%\] (EA, non-EA countries) | | | |
| Bluwstein and Canova (2016), 18 December, 2008-10 May 2014 | Effects of ECB QE using Bayesian VAR | \[+0.1\%\] to \ [+0.65\%\] (EA, EU countries) | \[0\%\] to \ [+0.5\%\] (EA, EU countries) | | |
| Hachula et al. (2016), January 1999-June 2015 | Effects of LTRO using SVAR | \[+0.1\%\] to \ [+0.65\%\] (EA, EU countries) | \[0\%\] to \ [+0.45\%\] (EA, EU countries) | | |
| Behrendt (2017), August 2007-July 2016 | Effects of ECB QE using SVAR | \[-0.0006\%\] to \ [+0.0005\%\] (EA) | \[-0.0006\%\] to \ [+0.0005\%\] (EA) | | |
| Boexx et al. (2017), January 2007-December 2014 | Effects of 3y LTRO, CBPP1 using SVAR | \[-0.35\%\] to \ [+0.6\%\] (EA, EU countries) | \[-0.1\%\] to \ [+0.3\%\] (EA, EU countries) | | |
| Abidi and Miquel-Flores (2018), January 2013-May 2017 | Effects of CSPP by using Regression Discontinuity Design Approach | | bond yield spread \[-0.15\%\] | | |
| Betz and De Santis (2019), April 2015-March 2017 | Effects of CSPP by OLS and IV using fixed effects model | | credit constrained \[-0.016\] by increase of CSPP/GDP | | |

Source: Author, Dell’Ariccia, Rabanal, and Sandri (2018), Lenza and Slacalek (2018)
them.

By these measures, government bond yield declines and the GDP and/or prices rise. For empirical facts of type 1, the U.K. LSAP increased the GDP of the U.K. by about +0.25% to +1.42% (Baumeister and Benati (2013), Kapetanios et al. (2012), Weale and Wiedadek (2016)) and the U.K. LSAP also increased the prices by about +0.1% to +0.6% (Baumeister and Benati (2013), Weale and Wiedadek (2016)).

SMP increased government bond yields by an estimated –40 to –330 bps in the Euro Area (De Pooter et al. (2015), Ghysels et al. (2016), Eser and Schwaab (2016)).

OMT also increased government bond yields by about –25 to –1000 bps in the Euro Area (Altavilla et al. (2014), Fratzscher et al. (2016)).

The announcements of the non-standard monetary policy of the LTRO, SMP and OMT, and APP, increased government bond yields by about –200 to –1000 bps in the Euro Area (Krishnamurthy et al. (2018), Andrade et al. (2016)).

Second, type 2 concerns QE as a relatively reliable investment in eligible asset purchases in relatively normal times. Friedman (2014) established the theory of the QE, and showed that it assumes a new Keynesian model with price- and wage-stickiness to explain the effects of QE. It has steadily growing credit demand curves and steadily declining credit supply curves with a private interest rate on the vertical axis and with credit volume and aggregate demand on the horizontal axis. Therefore, if we increase the credit demand, it decreases the private interest rate and thereby increases the GDP; which is the theoretical effect of QE.

In reality, against the vast loss of credit demand resulting from the global financial crisis in 2008, in the credit market, increasing credit demand by QE shifts the credit demand curve to the right, which causes the interest rate to decline and the GDP to rise in the US, and thereafter, in the Euro Area. This channel is also utilized in the Euro Area in the implementation of QE (PSPP).

This credit easing after the crisis, however, in relatively normal times, lowers government bond yield and raises the GDP and prices. For type 2 empirical facts, on average, LTRO raised real GDP by about +0.6% to +0.8% in the Euro Area (Darraçq-Paries and De Santis (2015), Hachula et al. (2016), Boeckx et al. (2017)). LTRO also increased prices by an estimated +0.3% in the Euro Area (Darraçq-Paries and De Santis, 2015; Hachula et al., 2016; Boeckx et al., 2017).

QE raised prices by an estimated +0.0005% to +0.5% in the Euro Area (Bluwstein and Canova, 2016; Behrendt, 2017).

APP increased government bond yields by about –45 bps in the Euro Area. Furthermore, APP raised GDP by an estimated +0.5% to +1.4% in the Euro Area (Andrade et al. (2016), Mouabbi and Sahuc (2016), Cova et al. (2015), Gambacorta et al. (2014)). APP increased prices by about +0.25% to +0.8% in the Euro Area (Andrade et al. (2016), Mouabbi and Sahuc (2016), Cova et al. (2015), Gambacorta et al. (2014)). In addition, APP raised asset prices in the U.K. and in Euro Area by about +0.3% to +1% (Altavilla et al. (2015), Joyce and Tong (2012), Christensen and Rudebusch (2012)).

Third, regarding 3, CSPP, Abidi and Miquel-Flores (2018) explained and showed empirically in their paper that CSPP has two channels: (1) Credit easing channel, which declines the cost of borrowing: Bid-ask spreads deteriorated eligible corporate bonds liquidity on the announcement of CSPP and they were compressed in high-yield corporate bonds.
(2) Liquidity channel: After the ECB’s large-scale asset purchases of investment grade bonds on the secondary market, potential bond buyers are oriented to buy CSPP-eligible securities.

Furthermore, CSPP’s credit easing changes banks’ and firms’ approaches: The larger the Eurosystem’s corporate bond purchase volumes in a country, relative to its size, the stronger the increase (decline) in the change of the bank’s willingness to lend (credit-constrained) to firms of that country that do not have access to the corporate bond market (Betz and De Santis (2019)).

This credit easing, in almost normal times however, with some “secular stagnation” trend periods, suppressed bond yield spreads, and lowered credit constraint. For type 3 empirical facts, the bond yield spreads by an estimated $-0.15\%$ in the Euro Area (Abidi and Miquel-Flores (2018)). CSPP increased credit constraint by about $-0.016$ by increasing the economic scale of CSPP/GDP in the Euro Area (Betz and De Santis (2019)).

In summary, earlier studies address the effects of the ECB’s UMPs (LSAP, LTRO, OMT, SMP and APP (balance sheet expansion), QE, and CSPP) on government bond yields, real GDP, prices, asset prices, and so on. In general, they show that the ECB’s UMPs lower government bond yields, raise real GDP, raise prices, raise asset prices, and so on, which were also empirically estimated as effects of the ECB’s UMP on the Euro Area real economies.

2.1 Effects of CSPP in the Euro Area

CSPP was newly added to APP. The CSPP was implemented by the ECB’s purchases of investment-grade-guaranteed eligible corporate bonds by the ECB’s criteria listed as “above BB+ grade” from private secondary markets. Examples of credit easing are described below:

Abidi and Miquel-Flores (2018) show “the decline in the cost of borrowing after the announcement of the CSPP. The effects were more pronounced for the bonds that were located within the rating wedge and extended beyond the ECB’s eligibility criteria (i.e., toward riskier assets).”

Second, Abidi and Miquel-Flores (2018) show that “liquidity effects were ambiguous at the announcement of the corporate QE (i.e., March 10, 2016). Nevertheless, the dynamics of bid-ask spreads (despite its measurement limits) revealed that eligible corporate bonds seemed to have suffered from a deterioration of liquidity until the ECB’s effective purchase date (i.e., June 8, 2016). As the ECB was expected to reduce the stock of “investment grade” bonds on the secondary market, the corporate QE appeared to have altered the bargaining power of sellers toward buyers in the market for CSPP-eligible securities. A thorough examination highlights, however, that bid-ask spreads were compressed in the segment of “high-yield” corporate bonds.”

The newly added CSPP has been one of the new potential research objects for assessing the inflation target of the ECB, due to its credit easing transmission channels described in Section 2, especially CSPP’s transmission on increasing the inclination of banks to provide loans to households, as well firms, as discussed in the literature.

However, there are no studies that address the assessment of UMP effects on the (trend) HICP inflation rate, using the state-space model (with error correction term of VECM below), from the commencement of PSPP (from March 2015) to the end of APP (to December 2018); which is the full sample assessment of the effects of especially the quantitative PSPP
as well as the newly added CSPP (from June 2016 to December 2018) and PEPP (from March 2020 onward); during and after the time of the former ECB President Draghi.

2.2 COVID–19 Crisis in Europe Caused the ECB to Launch the Pandemic Emergency Purchase Program (PEPP) to Support the Economy

In March 2020, COVID–19 struck Europe, causing major unemployment and devastating economic catastrophes. The ECB explained that the resurgence of COVID–19 infections presented renewed challenges to the potential or trend growth rate in the Euro Area. Euro Area recovery was losing momentum more rapidly through the summer of 2020. Therefore, the ECB justified the PEPP under the ECB’s monetary policy measures that have been taken since March 2020 to help preserve favorable financing conditions in the Euro Area, thus providing essential support to sustain economic activity and anchor medium–term price stability.

3. ECB’s Unconventional Monetary Policy Transmission Channels

This study addresses the measure and disintegration of the ECB’s nominal (unconventional) monetary policy transmission (<Figure 1>) into the effects of both asset pricing changes as “pricing kernel channels” and real effects as “direct pass–through” and “portfolio rebalancing channels” which have not been sufficiently examined in the literature so far up until December 2020. The literature mostly focuses solely on nominal UMPs and not the disintegration of the UMP into them.

However, discerning them apart is essentially required to verify the effects of the ECB’s UMP to evaluate them quantitatively with ample asset pricing changes by the ECB’s APP implementation. In some cases, nominal–real effects may vanish and “direct pass–through” and “Portfolio Rebalancing” effects may only exist and vice versa. In the third case, both effects may coexist. Through this examination, we can accurately discern what degrees of “asset pricing changes” and “real effects” affect the Euro Area economy.

Specifically, the ECB decided to implement the APP, including the PEPP, to improve financing conditions in the open market in the Euro Area.

The ECB defines and expects the effects of the APP to act as “pricing kernel channels,” “direct pass–through” and “portfolio rebalancing channels”. The “pricing kernel channel” is defined as the APP’s downward pressure on sovereign bond yield curves in the Euro Area countries that are utilized to price the whole spectrum of financial institutions’, firms’ and household’ assets and credit (from the ECB).

The “direct pass–through channel” is defined as the direct purchase of private sector assets by the ECB (which is, the CSPP including a part of the PEPP in this study). The purchase increases their asset prices, which encourages private banks to increase loans to corporations and households, improving broader financing conditions (from the ECB).

The “Portfolio Rebalancing channel” is defined as purchases of sovereign public bonds and privately issued bonds in the private sector to reduce their term premium, which inducres investors to advance through the risks and maturity ladder, and which also leads them to up bid assets with higher risk-adjusted returns. Thereafter, it rebalances bank balance sheets toward more asset holdings and lending (from the ECB).

To ensure the effects, the ECB launched the APP below:
The ECB launched its UMP stating “Whatever it takes”, which altered the risk-taking attitude of banks in the Euro Area. The UMP is assumed to have five monetary policy transmissions (from ECB (2018)): 1. Interest rate channel, 2. Expectations channel, 3. Exchange rate channel, 4. Credit channel, and 5. Risk-Taking channel. We address the third to fifth transmission channels in this study because they are the main transmission channels of the ECB’s APP operations. The third to fifth transmission channels are concerned with financing conditions in open markets and they are also aimed at addressing disruptions in the
conventional monetary policy transmission channels. We review them further:

3. Exchange Rate channel: It has two main channels of exchange rate movement, which affect both 1. Domestic price of imported goods and external demand and, exchange rate channels 2. Asset pricing movements to decide whether domestic demand or wealth effects dominate, both of which are categorized as “pricing kernel effects.”

4. Credit channel: The credit channel places importance on the quantity of supplied credit to the private sector. It has two main channels. 1. It is a bank balance sheet channel, in which the ECB’s APP increases borrowers’ net worth (higher net present value, higher asset prices) and thus collateral values; leading to an increase in the ability to borrow. 2. The bank lending channel in which the ECB’s APP decreases the riskiness of loans (reduced likelihood of default of households and firms), leading to an increase in loan supply (keeping risk exposure constant). Both are classified as “portfolio rebalancing channels”.

5. Risk-Taking channel: Risk-Taking channel prompts financial institutions’ holding of riskier new loans. It has three expected aims. 1. Stretching collateral values, as the ECB’s APP boosts asset and collateral values. With these changes being sustainable, it leads borrowers and banks to accept higher risks. 2. Searching for yields, as the ECB’s APP makes riskier assets relatively more attractive, leading banks to moderate credit standards and to attempt to meet long-term return guarantees. 3. It has an analogous balance sheet channel for nonbanks (ex. firms and households), as the ECB’s APP may decrease the risk rating of assets, thus leading investors to possibly add more risky assets to maintain their desired risk exposure.

3.1 Economic and UMP Variables with Some Unit Roots and Varied Lags?

In assessing the data, there are some possibilities of those economic and UMP variables with some unit roots and varied lags. If so, we cannot evaluate them by using standard VARs or VECMs. Recently, many economic and financial variables have been established to be nonstationary or unit root rather than stationary. However, some of them appear to be I (1) or higher I (d): d ≥ 2 (we have indeed I (2) in this study, although we directly employ analysis of I (1) variables) rather than I (0), which is a standard assumption for the analysis of specific nonstationary time-series methods, such as standard VECMs with a cointegrating vector. I had I (2) because the two differenced variables \(y_t - y_{t-1}\) are determined to be stationary due to the existence of a cointegrating vector <Figures 12, 12-2>. In contrast, we do not have a cointegrating vector with first-differenced variables \(y_t = ln y_t - ln y_{t-1}\) (% change).

The biggest challenge is the uncertainty or impossibility of the detection to tell the unit root process and stationary process apart. Thus far, one of the most widely available unit root tests, such as (A)DF–GLS can never detect unit root process and stationary process without uncertainty. This issue should be resolved in the future or an alternative around the unit root process detection issue should be found and other nonstationary time-series methods, such as the state-space model with Kalman filtering, which can treat nonstationary variables directly using observation equations and state transition equations from the model and the data, should be employed.

However, first, we employ the (A)DF–GLS to powerfully test the null hypothesis of their unit root for the possibility of the effectiveness of the VECM with the aim of detecting nominal variable influences rather than real and state variables in the model. In doing so, we base this on the Schwert criterion (SIC) for the lag selections.
Augmented Dickey–Fuller unit root test is discussed below:

$$y^*_t = y_t - (\mu + \rho t)$$

$$\Delta y^*_t = \alpha (\beta y^*_{t-1}) + \left( \sum_{i=1}^{p-1} \Gamma_i \Delta y^*_{t-i} \right) + \epsilon_t$$

Here, $z = \beta (y_{t-1} + \mu + \rho t)$ are cointegrating equations with a constant and a trend. 

$\mu$ is a constant in cointegrating equations.

$\rho t$ is a trend in cointegrating equations.

To perform the (A)DF–GLS test, it presents a difference of $y^* = y_t - (\mu + \rho t)$ to de-trend it and compute $y^*_t = y_t - (\mu)$.

Then it tests the null hypothesis $H_0: \beta = 0$ using critical values.

Thereafter, we also test the cointegrating ranks by the Johansan cointegration test.

To put the results in advance, we have 1 cointegrating rank with lag 1 in the test.

Thus, with non-zero cointegrating ranks, we have a non-zero $\alpha (\beta' y^*_{t-1})$, such that we can clearly separate $\beta'$ from $\alpha$. However, despite standard VECMs assuming $I(0)$ with cointegrating vectors, we do not have $I(0)$. Instead, due to the results of the Johansen cointegration test with cointegration rank 1 and lag 1 of percent change representation of the variables, we have $I(2)$ with level variables (natural log (ln) variables being level variables) in the VECM. Therefore, we have $I(1)$ with percent (%) change variables and cannot directly employ standard VARs or VECMs to assess the ECB’s UMP with $I(2)$. However, we have $I(1)$ with percent (%) change variables (which is the variable differentiating level variables (In representation) by time t), so that they are all unit root processed variables $I(1)$ or stationary variables $I(0)$, which is an amply feasible condition for assessment in the study. Therefore, we use the model with some modifications.

### 3.2 Test Results of Unit Root, Johansen Cointegration Rank, Lag Selection and Cointegrating Vector for VECMs

#### 3.2.1 (A)DF–GLS test

However, following the results of (A)DF–GLS to evaluate whether they have some unit roots and varied lags, we can exactly acknowledge the problem statistically by indicating all the variables above with some unit roots $I(2)$ and varied lags (1–13). We omit the detailed results of the level variables due to the limited space.

Regarding pai (inflation rate compared with those of the same periods of the previous year) (%) (2001m1–2020m9, monthly, number of observations =222), the null hypothesis of a unit root is not rejected at the 1% level in all lags <Figure 3>.

As for Ex (effective exchange rate compared with the same periods of the previous year) (%) (2001m1–2020m9, monthly, number of observations =222), the null hypothesis of a unit root is not rejected at the 1% level in most lags. However, with four to five lags, the null hypothesis of a unit root is rejected at the 1% level. This case has some unit roots and some stationary periods (<Figure 4>).

Regarding PSPP (% change rate of compared with the same periods of the previous year) (2015m3–2020m9, monthly, number of observations =56), the null hypothesis of a unit root is
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not rejected at the 1% level in most lags. However, with 1–4 lags, the null hypothesis of a unit root is rejected at the 1% level. This case has some unit roots and some stationary periods. (<Figure 5>).

With respect to the CSPP (% change rate compared with those of the same periods of the previous year) (2016m6–2020m9, monthly, number of observations = 41), the null hypothesis of a unit root is not rejected at the 1% level in all lags (<Figure 6>).
Regarding PEPP (% representation as a ratio of nominal increases in the PEPP compared to all the cumulative PEPP volumes at the time) (2020m3–2020m9, monthly, number of observations =3 or 4), the null hypothesis of a unit root is not rejected at the 1% level in all lags (<Figure 7>).

With regard to LF (%) (bank lending to firms change rate compared with those of the same periods of the previous year) (2001m1–2020m9, monthly, number of observations =222), the null hypothesis of a unit root is not rejected at the 1% level in most lags. However, with 10 lags, the null hypothesis of a unit root is rejected at the 5% level. This case has some unit roots and some stationary periods (<Figure 8>).

Regarding LH (%) (bank lending to households change rate compared with those of the same periods of the previous year) (2001m1–2020m9, monthly, number of observations =222), the null hypothesis of a unit root is not rejected at the 1% level in all lags (<Figure 9>).
3.2.2 Johansen test for detecting Cointegration rank and lag selection

The Johansen test for cointegration (Johansen, 1991) is as follows:

\[ \Delta y_t = \alpha (\beta' y_{t-1} + \mu + \rho t) + \left( \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + \gamma + \tau t \right) \]

with \( I(1) \) with the level variable being In\( y_t \), first-differenced variable is \( (y_t = \ln y_t - \ln y_{t-1}) \) (% change), and twice differenced is \( y_t - y_{t-1} \) (differences of \( y_t \) and \( y_{t-1} \)).
An Assessment of the ECB’s Unconventional Monetary Policies

Here, \( z = \beta^t y_{t-1} + \mu + \rho t \) is cointegrating equations with a constant and a trend. 
\( \mu \) is a constant in cointegrating equations. 
\( \rho t \) is a trend in cointegrating equations. 
\( \gamma \) is a constant in irf in \( \Delta y_t \). 
\( \tau t \) is a trend in irf in \( \Delta y_t \).

\[
\Delta^2 y_t = \Psi \Delta y_{t-1} + \alpha (\beta^t y_{t-2} + \mu + \rho t) + \left( \sum_{i=1}^{p-2} \Gamma_i \Delta^2 y_{t-i} + \gamma + \tau t \right) \text{with I(2)}
\]

We have all the parameters set structurally to the non–zero restriction. 
The importance of the Johansen test for cointegration is one to detect \( \beta^t \) and \( \alpha \) separately from the model: \( \Pi = a \beta^t \). The existence of separability requires the incorporation of error correction terms into the model to provide a better fit for the model. 

By the Johansen cointegration test (<Figure 10>), and following the SIC above, we obtain cointegrating rank 1 and common lag of 1 (<Figure 11>) of VECM, which means I (2) described below. Thus, we can clearly separate \( \beta^t \) and \( \alpha \) from \( \Pi \) in the VECM. Based on the results, we incorporate \( \ln y_{t-1} \) but not \( \ln y_{t-2} \), due to the cointegrating rank one and appropriate lag one in the model. In addition, we do not have a cointegrating rank with the level variable (represented as a ln variable).

3.2.3 VECM Estimation of Cointegrating Vector Decomposition of \( \Pi \) into \( \beta^t \) and \( \alpha \)

We obtain the estimated values of \( \Pi \), \( \beta^t \), and \( \alpha \) <Figure 12>. However, from the results of the (A)DF–GLS unit root test, we do not have I (0); rather, we have I (2), due to the results of the Johansen cointegration test, which means that the two differenced ones are stationary, indicating I (2), and the first–differenced I (1) economic variables (represented as % change) are unit root processed. Therefore, the VECM with error correction terms is not stationary with I (1) (% change). This requires us to utilize the measures suitable to evaluate nonstationary models, such as in this case, using models, such as the state–space model, which

---

**Figure 9:** (A)DF–GLS test of LH

| [lags] | DF–GLS Tau Test Statistic | 1% Critical Value | 5% Critical Value | 10% Critical Value |
|-------|--------------------------|------------------|------------------|-------------------|
| 14    | -1.815                   | -3.400           | -2.011           | -2.532            |
| 13    | -1.734                   | -3.400           | -2.022           | -2.542            |
| 12    | -1.603                   | -3.400           | -2.032           | -2.551            |
| 11    | -2.200                   | -3.400           | -2.041           | -2.560            |
| 10    | -2.351                   | -3.400           | -2.051           | -2.569            |
| 9     | -2.507                   | -3.400           | -2.060           | -2.577            |
| 8     | -2.372                   | -3.400           | -2.069           | -2.585            |
| 7     | -2.576                   | -3.400           | -2.077           | -2.593            |
| 6     | -2.723                   | -3.400           | -2.086           | -2.600            |
| 5     | -2.439                   | -3.400           | -2.093           | -2.607            |
| 4     | -2.195                   | -3.400           | -2.090           | -2.614            |
| 3     | -2.133                   | -3.400           | -2.090           | -2.621            |
| 2     | -1.559                   | -3.400           | -2.105           | -2.627            |
| 1     | -1.263                   | -3.400           | -2.101           | -2.632            |

Opt Lag (Ng-Perron seq t) = 12 with RMSE .2514394
Min SIC = -2.693862 at lag 4 with RMSE .2704219
Min MAIC = -2.619338 at lag 12 with RMSE .2514394

Source: Author

---
is described in detail below, because an analysis based on $I(2)$ (differences of % change), instead of $I(1)$, demeans the economic implications from the model. Therefore, we directly employ $I(1)$ processes with unit root variables in the model. In the later section, $I(1)$ error correction term $ln_{g83} / g16_t$ is a constant trend. However, the assumption of a constant trend is unrealistic. Therefore, we regard it as a time-varying nominal trend differentiating it by time $t$ and we obtain the time-varying percent (%) change of the variable (because differentiating $ln_{g83} / g16_t$ with time $t$ equals $\pi_{t-1}$ (% change)). We incorporate the time-varying error correction term $\Pi_{g51/g83} / g16_t$ (% change) into the transitory and stationary parts of the state-space model.

Thus far, we have recognized the problem and empirical difficulties of economic and UMP variables with some unit roots and varied lags in this case, which makes it difficult to
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evaluate using standard VARs or VECMs. Regarding this problem, Sims et al. (1990) showed that by amply increasing sample sizes and with a cointegrating vector, the variables in linear equations with some unit roots and stationary variables comply with jointly normal asymptotic distributions, converging at the rate of $T^{1/2}$ with time $t \to \infty$. This secures the appropriateness of the analysis. Therefore, we also resolve this problem using a state-space model including broader VARs or VECMs essence therein. We employ the model with some modifications. In

Vector error-correction model

| Sample: 2001Q2 - 2020Q9 | Number of obs = 226 |
|-------------------------|---------------------|
| Log likelihood = -4384.519 | HQIC = 38.68754 |
| Det(Sigma_u) = 1.6e+07 | SBIC = 37.14880 |

| p1 | Coef. Std. Err. z P>|z| [95% Conf. Interval] |
|----|-----------------|----------|-----|--------------------------|
| D_pai Ex | -0.0002243 | 0.000882 | -2.73 | 0.006 | -0.003855 | -0.000031 |
| L1. PSPP | -0.000252 | 0.0008 | -3.21 | 0.002 | -0.00153 | -0.000072 |
| L1. CSPP | 0.000856 | 0.00021 | 2.73 | 0.006 | 0.000096 | 0.000056 |
| L1. D_pai | 0.001604 | 0.00030 | 2.73 | 0.006 | 0.000951 | 0.002257 |
| L1. LF | 0.0000449 | 0.0000156 | 2.73 | 0.006 | 0.0000124 | 0.0000757 |
| L1. LH | -0.001675 | 0.000876 | -2.73 | 0.006 | -0.003246 | -0.000464 |
| L1. pai | -0.005322 | 0.0015476 | -2.73 | 0.006 | -0.009123 | -0.001545 |

Source: Author

Figure 12-1: VEC Results

| alpha | Coef. Std. Err. z P>|z| [95% Conf. Interval] |
|-------|-----------------|----------|-----|--------------------------|
| D_pai _cel | -0.0002243 | 0.000882 | -2.73 | 0.006 | -0.003855 | -0.000031 |

Identification: beta is exactly identified
Johansen normalization restriction imposed

| beta | Coef. Std. Err. z P>|z| [95% Conf. Interval] |
|------|-----------------|----------|-----|--------------------------|
| _cel Ex | 1 | . | . | . | . | . | . | . | . |
| PSPP | .0741622 | .0045218 | 16.40 | 0.000 | 0.0052997 | 0.0038240 |
| CSPP | -0.2650341 | 0.3030282 | -0.85 | 0.390 | -0.005964 | 0.0040955 |
| CPEP | -0.7590032 | 0.307422 | -0.77 | 0.442 | -0.039312 | 0.030013 |
| LF | -1.965413 | 2.678469 | -0.74 | 0.462 | -7.199437 | 3.266861 |
| LH | 7.388003 | 5.230605 | 1.41 | 0.158 | -2.09982 | 17.84585 |
| pai | 0.025323 | 0.029808 | 0.08 | 0.425 | -0.049349 | 0.0155811 |
| _trend | .4297029 | . | . | . | . | . | . | . | . |
| _cons | -93.40314 | . | . | . | . | . | . | . | . |

Source: Author

Figure 12-2: VEC Results
the following section, we describe the model in detail from the new Keynesian model.

4. Economic Model Building and the ECB’s Unconventional Monetary Policy Transmission Channels

In this section, the construction of the new Keynesian model is based on Walsh (2017). We modify it in terms of time-varying trend stationary steady-state equilibrium instead of standard steady-state equilibrium. The other basic assumptions are the same as those of Walsh (2017).

4.1 Calvo-type Friction and the Central Bank Monetary Policy

In this model, assuming the ECB’s discretion of monetary policies, we analyze the two APP mechanisms using the state-space model. First, for the UMP, which or whether the real changes in exchange rate, PSPP, CSPP and PEPP cause its real value to change and consequently transfer to the permanent changes of the (potential) economic growth rate (gaps) and/or (trend) inflation rate, which we label as “direct pass-through” and “portfolio rebalancing channels”.

In this section, we also assume Calvo-type frictions (Calvo (1983)) and the new Keynesian model to keep the possibility of the effectiveness of monetary policy at this stage to test and assess the ECB’s APP empirically. We also utilize the central bank loss function to maximize the utility of the ECB implementing the APP by discretion.

Central banks have operational discretionary and loss functions with nominal inflation rates and GDP gap rates, both of which can be disintegrated into 1. The policy effect permanent and nonstationary, real, and trend variables, 2. Policy effect transitory and stationary, nominal variables, and 3. Potential (measurement-driven) error terms defined below: Central banks with operational discretion evaluate their monetary policy operation by minimizing the central bank’s loss function, obtaining a nominal inflation rate equal to the trend and real inflation plus stationary and transitory, nominal inflation rate; and the nominal GDP growth rate equals the real and trend GDP growth rate plus stationary, transitory and nominal GDP growth rate defined below:

4.2 ECB’s Targeted Functions

4.2.1 Central Bank’s Loss Function

\[ \mathcal{L} = -\frac{1}{2} \sum_{i=0}^{\infty} \beta^i \left( \left( \pi_{t+i} - \pi^*_t - \pi^e_t \right)^2 + \lambda \left( g_{t+i} - g^*_t - g^e_t \right)^2 \right) \]

Here, \( \pi_t \) is the HICP inflation rate, \( \pi^*_t \) is the real trend HICP inflation rate, \( \pi^e_t \) is the temporary HICP inflation rate, \( g_t \) is the nominal GDP growth rate, \( g^*_t \) is the real and trend GDP growth rate, \( g^e_t \) is the temporary GDP growth rate, \( \pi_t \), and \( \beta^i \) is the subjective discount rate.

To evaluate the central bank’s monetary policy, it is necessary to specify the preferences of the central bank. The specification of the study is that the central bank minimizes the expected value of a loss function that depends on output and inflation fluctuations. Therefore,
the loss function is quadratic for both output and inflation. The assumption is that the central bank stabilizes both output and inflation, nominal inflation rate ($\pi_t$) around trend ($\pi_t^*$) plus transitory ($\pi_t^e$) rate ones, and nominal output rate ($g_t$) around potential ($g_t^*$) plus transitory ($g_t^e$) rate ones; which is not a standard steady-state but time-varying trend stationary steady-state. This is also one of the discretionary inflation targets that considers the time-varying trend inflation rate.

### 4.3 Forward-Looking New Keynesian Model

The New Keynesian economic model formulated forward-looking Euler equations of consumption, or GDP, into Wicksell’s model (which formulates the natural interest rate into the model) as intertemporal substitution (IS) curves. The New Keynesian economic model also formulated forward-looking nominal price rigidities and the optimum price-setting mechanism of Calvo (1983) into the model as New Keynesian Phillips curves. The only challenge is that these formulations cannot close the economic system, although the IS curves and New Keynesian Phillips curves are two important pillars of the New Keynesian economic theory. Therefore, we need further forward-looking monetary policy specifications influencing the GDP gap and inflation determination.

An expectational forward-looking IS curve represents the demand side of the economy, while the new Keynesian Phillips curve corresponds to the supply side. In fact, both equations are derived from optimization problems with IS curves based on the Euler condition for the representative household decision problem, and a new Keynesian Phillips curve derived from the optimal pricing decision of individual firms. The parameters appearing in these equations are explicit functions of the underlying structural parameters of the production and utility functions and the assumed process for price adjustment.

The new Keynesian model commonly employs the Calvo model of sticky prices to dominate monetary policy analysis. Parameter $\kappa$ is an increasing function of the fraction of firms’ abilities to adjust each period, and $x_t$ is percent deviation around its potential ($g_t^*$) plus transitory ($g_t^e$) time-varying trend stationary steady-state. The equation is labeled the new Keynesian Phillips curve. In the new Keynesian Phillips curve, the current inflation rate ($\pi_t$) depends on expectations of future inflation ($E_t\pi_{t+1}$) and on the current output gap ($x_t$).

In general, the Calvo model implies that there is a tail of the distribution of prices that consists of prices that have remained fixed for many periods, which is the friction and is also critical for the effectiveness of UMP. The increase in the average time between price changes for an individual firm causes $\kappa$ in the new Keynesian Phillips curve to decrease.

The setup and original equations are ordinarily nonlinear, however, one reason for the popularity of the new Keynesian model is that it allows for a simple linear representation of private sector behavior in terms of an inflation adjustment equation or a Phillips curve that corresponds to the investment-saving curve of undergraduate macroeconomics.

To derive this linearized version, the nonlinear equilibrium conditions of the model are linearized around trend plus transitory time-varying trend stationary steady-state in this study, in which the nominal inflation rate ($\pi_t$) equals the time-varying trend ($\pi_t^*$) plus the transitory ($\pi_t^e$) one.
4.3.1 Intertemporal Substitution (IS) Curves

\[ x_t = E_t x_{t+1} - \frac{1}{\sigma} \left( EONIA_t - E_t \pi_{t+1} - n^* \right) + \epsilon_t \]

where \( x_t \) is the GDP gap rate, \( g_t \) is the growth rate, \( g^*_t \) is the potential growth rate, \( \pi_t \) is the inflation rate, \( n^* \) is the natural interest rate, \( EONIA_t \) is the nominal interest rate, \( e_t \) is the error term, and \( \sigma \) is the IS rate as \( \sigma = 1 \) in this study.

Here, \( x_t = g_{t-1} - g^*_{t-1} \), \( x_t \) is a state variable.

The first component of the new Keynesian model in this study is a linearized version of the household’s Euler condition. Since consumption is equal to output in this model (there is no government or investment since capital has not been incorporated), we can approximate it around its potential \( (g^*_t) \) plus transitory \( (g'_t) \) time-varying trend stationary steady-state. In the IS curve, the current output gap rate \( (x_t) \) depends on the expectations of the future output gap \( (E_t x_{t+1}) \) and on the current real and natural interest rate gap \( (EONIA_t - E_t \pi_{t+1} - n^*) \).

Furthermore, regarding the Lucas critique, this study utilizes a state-space model with time-varying variables (and some coefficients) with policy or regime changes and assumes equilibrium under the golden rule for deep parameters with household utilities and firms’ profit functions, considering and avoiding the Lucas critique: IS rate \( (\sigma = 1) \), and household discount rate \( (\rho_t = 0) \).

In microeconomics, research on heterogeneous agent models has recently been increasing. It, nevertheless, requires some improvement in the future for microeconomics and its application to macroeconomics as promising and realistically heterogeneous agent models of households’ and firms’ behaviors instead of representative ones. At this stage, we should assume that we have no amply stylized specification of the heterogeneous agent model in monetary policy analysis, which is a limited factor to monetary policy analysis in the study to avoid the Lucas critique fully and appropriately. This is because the improvement of the heterogeneous agent model is, as of as at December 2020, ongoing and underdeveloped in academics and in application to monetary policy analysis. Thus, the heterogeneous agent model in microeconomics and macroeconomics deserves further research.

4.3.2 New Keynesian Phillips Curves

\[ \pi_t = \beta E_t \pi_{t+1} + \epsilon_t + \kappa x_t = \pi^*_t + \pi^e_t + \kappa x_t + \epsilon_t \]

where \( \pi_t \) is inflation rate and \( E_t \pi_{t+1} \) are the expected inflation rate. \( \kappa \) is the structural parameter of the new Keynesian Phillips curve and \( x_t \) is the GDP gap rate.

As the other component of the new Keynesian model, by approximating it around a time-varying trend, the stationary steady-state of the nominal inflation rate \( (\pi_t) \) equals the trend \( (\pi^*_t) \) plus transitory \( (\pi^e_t) \) rate, we obtain the expression for aggregate inflation of the form. In the new Keynesian Phillips curve, the current inflation rate \( (\pi_t) \) depends on expectations of future inflation \( (E_t \pi_{t+1}) \) and on the current output gap \( (x_t) \). The new Keynesian Phillips curve has been derived explicitly from a model of optimizing on the part of price setters, conditional on the assumed economic environment (monopolistic competition, constant elasticity demand curves and randomly arriving opportunities to adjust prices). This derivation discloses how \( \kappa \), the impact of the GDP gap rate on inflation, depends on the structured parameters. When the
firm provides more weight to future expected profits, $\kappa$ declines, which signifies that inflation is less sensitive to the current GDP gap. In contrast, increased price rigidity reduces $\kappa$ with opportunities to adjust arriving less frequently, firms place less weight on the current GDP gap (and more on expected future GDP gap) when they adjust its price and fewer firms adjust each period.

Furthermore, we address the need to evaluate the impact of pricing kernels below.

We disintegrate the nominal variables ($\pi_t$) into: 1. Real and latent variables ($\pi^*_t$) and 2. Stationary variables ($\pi^s_t$) and error terms. We obtain the below:

$$
\pi_t = \pi^*_t + \sum_{i=1}^{P} \phi_i Z_{t-i} + \Pi_{\pi t-1} + K X_t + \epsilon_t
$$

Nominal Variables Real, Latent Variables Stationary Ones New Keynesian Phillips Curves Error Terms

However, following earlier sections, we have $\sum_{i=1}^{P} \phi_i Z_{t-i}$ as nominal nonstationary terms rather than nominal stationary, due to the results of the (A)DF–GLS test of (% represented) I (1) variables shown in <Figure 3–9>. Therefore, we incorporate nominal $\sum_{i=1}^{P} \phi_i Z_{t-i}$ into real and latent $\pi^*_t$, which can be disintegrated as a pricing kernel in this context defined as Nominal Effects$=\text{Pricing Kernels} \times \text{Real Effects}$. Therefore, real and latent $\pi^*_t$ includes nominal nonstationary $\sum_{i=1}^{P} \phi_i Z_{t-i}$ therein or otherwise significantly emanating and separating it from the residual $\epsilon_t$. However, we disintegrate the nominal HICP inflation rate into 1. Permanent, real and trend inflation rate ($\pi^*_t$); including nominal nonstationary $\sum_{i=1}^{P} \phi_i Z_{t-i}$, and 2. Transitory, stationary nominal inflation rate ($\Pi_{\pi t-1}$), estimated by the state-space model with VARs or VECMs represented as Markov chains that can address both unit root and structural break of data at once.

So, we get

$$
\pi_t = \pi^*_t + \Pi_{\pi t-1} + K X_t + \epsilon_t
$$

Nominal Variables Real, Latent Variables Stationary Ones New Keynesian Phillips Curves Error Terms

with nominal stationary $\Pi_{\pi t-1}$ because of “Granger representation theorem” of VECM and empirical details shown in <Figure 10–12>. For the disintegration of $\pi^*_t$, please see Section 4.8.

We assume the standard forward-looking new Keynesian model, because we assume Calvo-type friction and, consequently, regard UMPs as valid for explaining the HICP inflation rate. This is because, in theory, without any type of friction, the APP is naturally and totally invalid. In contrast, in the real world, it has some form of friction.

In addition, assuming rational expectations, we define the coming term “expected variables”, as the current latent or unobserved real variables and linearize them as $E_t y_{t+1} = y^*_t$ in general, $E_t \pi_{t+1} = \pi^*_t$ and $E_t g_{t+1} = g^*_t$. We linearize because directly modeling and estimating the coming term expected values in the state-space model causes problems of nonlinearity in
estimating latent and unobserved variables. This transformation allows us to address the estimation difficulty and develop an empirical model specification. Economically and intuitively, because the effects of the present term latent and unobservable real values are persistent, it is natural for rational economic persons to regard them as being taken over to the next term as it is intact and unchanged; which is the rational expected value in the next term.

This is how we can let the transition equation be linear, and it can be estimated using a Kalman filter (Kalman (1960)). The Kalman filter can only identify the latent or unobserved variables among the economic models composed of only linearized and simultaneous equations, including both observation equations and transition equations, thus meeting the appropriate observability conditions as described in detail in Section 4.9.4. Following these models, we then evaluate the central bank’s loss function below:

4.4 Optimization with Central Bank’s Loss Function

To minimize the loss function \( L \) utilizing discretion of monetary policies, we apply the Lagrangian multiplier and resolve it.

\[
L = -\frac{1}{2} \sum_{t=0}^{\infty} \beta^t \left( (\pi_{t+1} - \pi^*_t - \pi^*_{t+1})^2 + \lambda (g_{t+1} - g^*_t - g^*_{t+1})^2 \right) + \theta_{t+1} \left[ x_{t+1} - E_{t+1} x_{t+1} + \frac{1}{\sigma} \left( EONIA_{t+1} - E_{t+1} \pi_{t+1} - \pi^*_{t+1} \right) \right] + \psi_{t+1} \left( \pi_{t+1} - \beta E_{t+1} \pi_{t+1} - \sigma_{t+1} - \kappa x_{t+1} \right)
\]

With \( \frac{\partial L}{\partial EONIA_{t+1}} \), we get \( \sigma^{-1} E_{t+1} \theta_{t+1} = 0 \). So, we obtain \( \theta_t = E_{t+1} \theta_{t+1} = 0 \).

With \( \frac{\partial L}{\partial \pi_{t+1}} \), we get \( \pi_{t+1} + \psi_{t+1} = 0 \), and with \( \frac{\partial L}{\partial x_{t+1}} \), we obtain \( \lambda x_{t+1} - \kappa \psi_{t+1} = 0 \).

So, we get \( \lambda = -\kappa \frac{\pi_{t+1}}{x_{t+1}} \). Then, we replace \( \pi_{t+1} \) with \( \pi_{t+1} - \pi^*_t - \pi^*_{t+1} \) and also replace \( x_{t+1} \) with \( g_{t+1} - g^*_t - g^*_{t+1} \). Finally, \( \lambda = -\kappa \frac{\pi_{t+1} - \pi^*_t - \pi^*_{t+1}}{g_{t+1} - g^*_t - g^*_{t+1}} \).

If we have \( \lambda > 0 \), the ECB is concerned with both output and inflation, which we label as “flexible inflation-target regime.” If we have \( \lambda = 1 \), the ECB addresses output fluctuations and inflation fluctuations equally and fairly. If we have \( \lambda = 0 \), the ECB is only concerned with HICP inflation and not the GDP gap rate.

To advance the results, we have random-walking IS curves <Figure 13> and flat or null new Keynesian Phillips curves <Figure 14>.

Furthermore, from <Figure 14>, we obtain \( \kappa = -0.0938736^* \) (significant at 10% level), which indicates the probability: \( \lambda = 0 \). Thus, the Euro Area could fall in the flat Phillips curves. These facts are also presented in Suzuki (2020). This means that the GDP gap rate may not affect (trend) HICP inflation rate in the Euro Area because of the value of \( \kappa \) with significance at the 10% level. Thus, it indicates that the ECB’s APP can only transmit not through the (potential) economic growth rate, but through the APP and bank lending. Therefore, the ECB is concerned solely with the effects of the APP on the inflation rate and not the (potential)
growth enhancing effects on the (trend) inflation rate, and additionally and statistically possibly not on the (potential) economic growth rate (with uncertain flexible inflation-target regime).

To advance the results, even considering the trend inflation rate, the inflation-target outcome of the ECB’s UMP has been assessed as unaccomplished, although both trend and nominal inflation rates are anchored around +1%, which are measured by a comparison with those of the same periods of the previous year. Therefore, how can we disintegrate the trend inflation rate ($\pi_t^*$) into separate contribution factors, such as the APP and the exchange rate? We address this concern below:

### 4.5 ECB’s Unconventional Monetary Policies

We utilize state-space models to analyze the effects of the ECB’s UMPs on the trend inflation rate ($\pi_t^*$) and potential economic growth rate ($g_t^*$) because of the two specific concerns below.

First, we should distinguish between the unobserved trend components (e.g. (real and unobserved) trend inflation rate) and observed nominal components, which we label “pricing kernel” factor of nominal and real (and trend) inflation rate as the first ECB’s APP mechanism.

Second, we should distinguish the interaction and transmission relationship between nominal and real (and trend) variables of UMP and bank lending variables, which we label...
nominal–real bank lending transmission driven by the “direct pass-through” and “Portfolio Rebalancing” channels as the second ECB’s APP mechanism.

The state–space model enables us to conduct these tasks rationally and efficiently. The state–space model is defined as both “observation equations” and “state transition equations” below:

4.6 Nominal–Real “Pricing Kernel Channels”

4.6.1 Observation Equations

4.6.1.1 I= Unconventional Monetary Policy and Exchange Rate Channel

\[
\begin{align*}
E_X_t &= i_{Ex} \times E_{Xt}^* + \varepsilon_{E_{Xt}}^{Exchange \ Rate} \\
PSPP_t &= i_{PSPP} \times PSPP_t^* + \varepsilon_{PSPP_t}^{PSPP} \\
CSPP_t &= i_{CSPP} \times CSPP_t^* + \varepsilon_{CSPP_t}^{CSPP} \\
PEPP_t &= i_{PEPP} \times PEPP_t^* + \varepsilon_{PEPP_t}^{PEPP}
\end{align*}
\]

Here, \(E_X_t\) is the nominal exchange rate, \(E_{Xt}^*\) is the real exchange rate, \(PSPP_t\) is the nominal PSPP, \(PSPP_t^*\) is the real PSPP, \(CSPP_t\) is the nominal CSPP, \(CSPP_t^*\) is the real CSPP, \(PEPP_t\) is the nominal PEPP, \(PEPP_t^*\) is the real PEPP, \(i\) is each coefficient, and \(\varepsilon_t\) is each error term.

4.6.1.2 L=Bank Lending Channel

\[
\begin{align*}
LF_t &= l_{LF} \times LF_t^* + \varepsilon_{LF_t}^{Bank \ Lending \ to \ Firms} \\
LH_t &= l_{LH} \times LH_t^* + \varepsilon_{LH_t}^{Bank \ Lending \ to \ Households}
\end{align*}
\]

Here, \(LF_t\) is the nominal bank lending to firms, \(LF_t^*\) is the real bank lending to firms, \(LH_t\) is the nominal bank lending to households, \(LH_t^*\) is the real bank lending to households, \(l\) is each coefficient; and \(\varepsilon_t\) is each error term.

4.6.1.3 New Keynesian Phillips curves

\[
\begin{align*}
\pi_t &= \pi_t^* + \kappa x_t + \Pi \pi_{t-1} + \varepsilon_t^{\pi} \\
r_t &= r_t^* + \varepsilon_t^{r}
\end{align*}
\]

Here, \(\pi_t\) is the nominal inflation rate, \(\pi_t^*\) is the trend inflation rate, \(x_t\) is the GDP gap rate, \(\Pi\) is the error correction term, \(r_t\) is the real interest rate, \(r_t^*\) is the natural interest rate, \(g_t\) is the nominal GDP growth rate, \(g_t^*\) is the real GDP growth rate, and \(\varepsilon_t\) is each error term.

\[
\begin{align*}
g_t &= g_{t-1} + x_t \\
x_t &= g_t - g_t^* \\
r_t &= EONIA_t - \pi_{t+1}
\end{align*}
\]

The Fisher equation shows that the real interest rate \((r_t)\) equals the nominal interest rate \((EONIA_t)\) minus the expected inflation rate \((\pi_{t+1})\).

\[
EONIA_t = -x_t + 2\pi_t^* + r_t^* + \varepsilon_t^{EONIA},
\]

which is obtained by transforming the IS curves into the reduced form: \(x_t = E_t \cdot x_{t+1} \cdot EONIA_t - E_{t+1} \cdot x_{t+1} - r_t^* + \varepsilon_t\) with \(x_{t+1} = g_t - g_t^* = g_t^* - g_t^* + \pi_t = \pi_t = \pi_t^* \text{ and } \sigma = 1\).

Here, \(EONIA_t\) is the nominal EONIA rate.
4.7 Bank Lending Driven by “Direct Pass-through Channels” and “portfolio rebalancing channels”

4.7.1 State Transition Equations

\[
\begin{align*}
\pi_t^* &= \pi_{t-1}^* + g_{t-1}^* + \varepsilon_t^* \\
g_t^* &= g_{t-1}^* + E\pi_{t-1}^* + PSPP_{t-1}^* + CSPP_{t-1}^* + PEPP_{t-1}^* + LF_{t-1}^* + LH_{t-1}^* + \varepsilon_t^{E}\ \\
LF_t^* &= LF_{t-1}^* - LH_{t-1}^* + g_{t-1}^* + \varepsilon_t^{Lending to Firms} \\
LH_t^* &= LH_{t-1}^* + g_{t-1}^* + \varepsilon_t^{Lending to Households} \\
E_{t}^* &= E\pi_{t-1}^* + PSPP_{t-1}^* + CSPP_{t-1}^* + PEPP_{t-1}^* + \varepsilon_t^{E} \\
PSPP_t^* &= PSPP_{t-1}^* + PEPP_{t-1}^* + \varepsilon_t^{PSPP} \\
CSPP_t^* &= CSPP_{t-1}^* + PEPP_{t-1}^* + \varepsilon_t^{CSPP} \\
PEPP_t^* &= PEPP_{t-1}^* + \varepsilon_t^{PEPP} \\
\end{align*}
\]

Here, \( g_t^* = g_{t-1}^* + \pi_t \): \( g_t \) is the state variable and \( x_t = g_{t-1} - g_t^* \): \( x_t \) is the state variable.

\[
\hat{n}_t = \sigma^{-1} g_t^* + \varepsilon_t^*
\]

We assume that \( \hat{n}_t^* = g_{t-1}^* \), which means that we assume that the (long-run) natural interest rate equals the potential growth rate from rational expectation theory.

We also assume the zero-sum volume in reality between \( LF_{t-1} \) and \( LH_{t-1}^* \).

4.8 Monetary Policy Transmission Channels by Chain Rule with Nominal–Real “Pricing Kernel Channels,” “Direct Pass-through Channel” and “portfolio rebalancing channels” as ECB’s APP Transmission Mechanisms

4.8.1 Real to real “direct pass-through Channel” and “portfolio rebalancing channels”

\[
\begin{align*}
\pi_{t, t}^* &= \frac{\partial \pi_t^*}{\partial B_{t-1}^*} \frac{\partial B_{t-1}^*}{\partial \varepsilon_{t-1}} + \frac{\partial \pi_t^*}{\partial g_{t-1}^*} \frac{\partial g_{t-1}^*}{\partial \varepsilon_{t-1}} \\
B_{t-1}^* &= \frac{\partial I_{t-1}^*}{\partial \varepsilon_{t-1}} + \frac{\partial L_{t-1}^*}{\partial \varepsilon_{t-1}} \\
\end{align*}
\]

Policy Variables: UMP and Exchange Rate Variables
Bank Lending Variables
4.8.2 Real to real “direct pass-through Channel” and “portfolio rebalancing channels” with nominal-real “pricing kernel Channels”

\[ g^*_t = \frac{\partial g^*_t}{\partial E^-_t} + \frac{\partial g^*_{t-1}}{\partial L^-_t} \frac{\partial L^-_{t-1}}{\partial I^-_{t-1}} \frac{\partial I^-_{t-1}}{\partial E^-_{t-1}} \]

\[ V_{t-1} = \frac{\partial V_{t-1}}{\partial E^-_{t-1}} = \frac{\partial V_{t-1}}{\partial L^-_{t-1}} + \frac{\partial V_{t-1}}{\partial I^-_{t-1}} \]

where \( Nominal V = Pricing Kernel \times Real V = Nominal V (%) \times Pricing Kernel (%) + Real V (%) \)

As we utilize the state-space model, the increase in the time-varying trend inflation rate of time \( t \) is disintegrated into: 1. Non-growth-related effects of time \( t-1 \) and 2. Growth-related effects of time \( t-1 \). Furthermore, non-growth-related effects are disintegrated into the APP’s (and exchange rate’s) policy-related effects and bank lending effects to firms and households. Therefore, these quantitative decompositions of the influence of variables of time \( t-1 \) on the ones of time \( t \) are one of the (quantitative) causal inference methods, due to the state-space model specifications.

Likewise, we have a time-varying trend growth rate of time \( t \) disintegrated into trend economic growth rate of time \( t-1 \) and the APP’s (and exchange rate’s) policy-related effects and bank lending effects to firms and households at time \( t-1 \).

Thereafter, in modeling them in the state-space model, we assume exogenous stratification among them from a high exogenous assumption to a low one, as follows: APP (PEPP→CSPP, PSPP (equivalently exogenous))→exchange rate→bank lending to firms and households (equivalently exogenous)→(potential economic growth rate)→trend inflation rate.

We assume that the exogenous ECB’s APP credit easing may well lower the exchange rate, improving financing conditions in the private sector. This may increase bank lending to firms and households, which possibly increases the (potential) economic growth rate, consequently raising the (trend) inflation rate.

4.8.3 What is the definition of the direct and indirect effect?

We define the ECB’s direct purchase of private assets by the CSPP and a part of PEPP as the direct channel below: This is because the direct pass-through channel is defined as the direct purchase of private sector assets by the ECB (i.e., the CSPP including a part of PEPP in this study). The purchase increases their asset prices, which encourages private banks to increase loans to corporations and households, thus improving broader financing conditions (Hypothesis 1).
An Assessment of the ECB’s Unconventional Monetary Policies

We also define the public purchases of the PSPP and a part of PEPP and other effects in the study as indirect channels below: This is because portfolio rebalancing channels are defined as the ECB’s purchase of public and private sector assets from pension funds, banks, and households. By increasing the demand for more assets, it increases prices and yields decrease, even for assets that are not directly targeted by the APP. This compression of yields encourages banks to lend to firms or households (Hypothesis 2).

The lowering of the cost of borrowing by portfolio rebalancing channels encourages investors to use extra funds to purchase higher yields assets outside the Euro Area. This could lead to a lower euro exchange rate, which tends to place upward pressure on inflation (Hypothesis 3).

4.8.4 How do we test the hypotheses?

We have some model specifications to test these.

\( V_t^l \) indicates how much impact of the real UMP and exchange rate shocks of time \( t-1 \) influences the trend or potential inflation rate of time \( t \).

\( l \) indicates the pricing kernel, as to whether nominal bank lending rate impacts the real bank lending rate.

\( i \) indicates the pricing kernel, as to whether the nominal UMP impacts the real UMP.

With both \( i \neq 0 \) and \( l \neq 0 \), it signifies that pricing kernels (nominal–real asset pricing changes) statistically exist in the model; which indicates that we must consider the pricing kernel, as well as the real effects, based on Calvo-type friction: “Direct Pass–through channel” and “portfolio rebalancing channels.” In this case, we also have \( V_t^l(V_t) \) policy transmission effects.

4.9 State–Space Model Representation

Following the premises above, we have represented them as the below in the state–space model:

4.9.1 State–Space Model

\[
\begin{align*}
Y_t &= Z_t X_t + D_t W_t + A_t u_t \\
X_t &= T_t X_{t-1} + v_t
\end{align*}
\]

4.9.2 Observation Equations

\[
Y_t = \begin{bmatrix} E_t \\ PSPP_t \\ CSPP_t \\ PEPP_t \\ LF_t \\ LH_t \\ \pi_t \\ n \\ EONIA_t \end{bmatrix} = Z_t X_t + D_t W_t + A_t u_t
\]
4.9.3 State Transition Equations

\[ X_t = T_{t-1}^2 + v_t \]

\[
\begin{bmatrix}
  i_{Ex} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
  i_{PSPP} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
  0 & i_{CSPP} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
  0 & 0 & i_{PEPP} & 0 & 0 & 0 & 0 & 0 & 0 \\
  0 & 0 & 0 & 0 & l_{LF} & 0 & 0 & 0 & 0 \\
  0 & 0 & 0 & 0 & 0 & l_{LH} & 0 & 0 & 0 \\
  0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
  0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
  0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 2 \\
\end{bmatrix}
\cdot
\begin{bmatrix}
  E_{i_{Ex}}^* \\
  P_{i_{PSPP}}^* \\
  C_{i_{CSPP}}^* \\
  P_{i_{PEPP}}^* \\
  L_{i_{LF}}^* \\
  L_{i_{LH}}^* \\
  \pi_t^* \\
  r_t^* \\
  g_t^* \\
  x_t \\
\end{bmatrix}
\]

\[
\begin{bmatrix}
  E_{i_{Ex}}^* \\
  P_{i_{PSPP}}^* \\
  C_{i_{CSPP}}^* \\
  P_{i_{PEPP}}^* \\
  L_{i_{LF}}^* \\
  L_{i_{LH}}^* \\
  \pi_t^* \\
  r_t^* \\
  g_t^* \\
  x_t \\
\end{bmatrix}
\]

\[
\begin{bmatrix}
  E_{i_{Ex}}^* \\
  P_{i_{PSPP}}^* \\
  C_{i_{CSPP}}^* \\
  P_{i_{PEPP}}^* \\
  L_{i_{LF}}^* \\
  L_{i_{LH}}^* \\
  \pi_t^* \\
  r_t^* \\
  g_t^* \\
  x_t \\
\end{bmatrix}
\]

\[
\begin{bmatrix}
  E_{i_{Ex}}^* \\
  P_{i_{PSPP}}^* \\
  C_{i_{CSPP}}^* \\
  P_{i_{PEPP}}^* \\
  L_{i_{LF}}^* \\
  L_{i_{LH}}^* \\
  \pi_t^* \\
  r_t^* \\
  g_t^* \\
  x_t \\
\end{bmatrix}
\]

\[
\begin{bmatrix}
  E_{i_{Ex}}^* \\
  P_{i_{PSPP}}^* \\
  C_{i_{CSPP}}^* \\
  P_{i_{PEPP}}^* \\
  L_{i_{LF}}^* \\
  L_{i_{LH}}^* \\
  \pi_t^* \\
  r_t^* \\
  g_t^* \\
  x_t \\
\end{bmatrix}
\]

\[
\begin{bmatrix}
  E_{i_{Ex}}^* \\
  P_{i_{PSPP}}^* \\
  C_{i_{CSPP}}^* \\
  P_{i_{PEPP}}^* \\
  L_{i_{LF}}^* \\
  L_{i_{LH}}^* \\
  \pi_t^* \\
  r_t^* \\
  g_t^* \\
  x_t \\
\end{bmatrix}
\]

\[
\begin{bmatrix}
  E_{i_{Ex}}^* \\
  P_{i_{PSPP}}^* \\
  C_{i_{CSPP}}^* \\
  P_{i_{PEPP}}^* \\
  L_{i_{LF}}^* \\
  L_{i_{LH}}^* \\
  \pi_t^* \\
  r_t^* \\
  g_t^* \\
  x_t \\
\end{bmatrix}
\]

\[
\begin{bmatrix}
  E_{i_{Ex}}^* \\
  P_{i_{PSPP}}^* \\
  C_{i_{CSPP}}^* \\
  P_{i_{PEPP}}^* \\
  L_{i_{LF}}^* \\
  L_{i_{LH}}^* \\
  \pi_t^* \\
  r_t^* \\
  g_t^* \\
  x_t \\
\end{bmatrix}
\]

\[
\begin{bmatrix}
  E_{i_{Ex}}^* \\
  P_{i_{PSPP}}^* \\
  C_{i_{CSPP}}^* \\
  P_{i_{PEPP}}^* \\
  L_{i_{LF}}^* \\
  L_{i_{LH}}^* \\
  \pi_t^* \\
  r_t^* \\
  g_t^* \\
  x_t \\
\end{bmatrix}
\]

\[
\begin{bmatrix}
  E_{i_{Ex}}^* \\
  P_{i_{PSPP}}^* \\
  C_{i_{CSPP}}^* \\
  P_{i_{PEPP}}^* \\
  L_{i_{LF}}^* \\
  L_{i_{LH}}^* \\
  \pi_t^* \\
  r_t^* \\
  g_t^* \\
  x_t \\
\end{bmatrix}
\]

\[
\begin{bmatrix}
  E_{i_{Ex}}^* \\
  P_{i_{PSPP}}^* \\
  C_{i_{CSPP}}^* \\
  P_{i_{PEPP}}^* \\
  L_{i_{LF}}^* \\
  L_{i_{LH}}^* \\
  \pi_t^* \\
  r_t^* \\
  g_t^* \\
  x_t \\
\end{bmatrix}
\]

\[
\begin{bmatrix}
  E_{i_{Ex}}^* \\
  P_{i_{PSPP}}^* \\
  C_{i_{CSPP}}^* \\
  P_{i_{PEPP}}^* \\
  L_{i_{LF}}^* \\
  L_{i_{LH}}^* \\
  \pi_t^* \\
  r_t^* \\
  g_t^* \\
  x_t \\
\end{bmatrix}
\]

\[
\begin{bmatrix}
  E_{i_{Ex}}^* \\
  P_{i_{PSPP}}^* \\
  C_{i_{CSPP}}^* \\
  P_{i_{PEPP}}^* \\
  L_{i_{LF}}^* \\
  L_{i_{LH}}^* \\
  \pi_t^* \\
  r_t^* \\
  g_t^* \\
  x_t \\
\end{bmatrix}
\]

\[
\begin{bmatrix}
  E_{i_{Ex}}^* \\
  P_{i_{PSPP}}^* \\
  C_{i_{CSPP}}^* \\
  P_{i_{PEPP}}^* \\
  L_{i_{LF}}^* \\
  L_{i_{LH}}^* \\
  \pi_t^* \\
  r_t^* \\
  g_t^* \\
  x_t \\
\end{bmatrix}
\]

\[
\begin{bmatrix}
  E_{i_{Ex}}^* \\
  P_{i_{PSPP}}^* \\
  C_{i_{CSPP}}^* \\
  P_{i_{PEPP}}^* \\
  L_{i_{LF}}^* \\
  L_{i_{LH}}^* \\
  \pi_t^* \\
  r_t^* \\
  g_t^* \\
  x_t \\
\end{bmatrix}
\]

\[
\begin{bmatrix}
  E_{i_{Ex}}^* \\
  P_{i_{PSPP}}^* \\
  C_{i_{CSPP}}^* \\
  P_{i_{PEPP}}^* \\
  L_{i_{LF}}^* \\
  L_{i_{LH}}^* \\
  \pi_t^* \\
  r_t^* \\
  g_t^* \\
  x_t \\
\end{bmatrix}
\]
4.9.4 Observability Conditions

We have the simultaneous observability conditions of the full rank of the state-space model to identify all the state and unobservable real variables: \( i_{Ex} \neq 0 \), \( i_{PSPP} \neq 0 \), \( i_{CSPP} \neq 0 \), \( i_{PEPP} \neq 0 \), \( l_{LF} \neq 0 \), \( l_{LH} \neq 0 \). If not met, we cannot utilize the state-space model in this case.

To advance the results, we optimally obtain the results of the variables concerned all with a significance at 1%: \( i_{Ex} = 5.286212*** \), \( i_{PSPP} = -3621.009*** \), \( i_{CSPP} = 41.0616*** \), \( i_{PEPP} = -18.96414*** \), \( l_{LF} = -3.39153*** \), \( l_{LH} = 3.327311*** \). See Table 5.

Therefore, we have \( O = \text{rank } 9 \), which is the full rank that identifies all the state variables justly and exactly.

4.10 Empirical Methods of State–Space Model Foundations of the Kalman Filter

The empirical methods of the state-space model in this section are based on Suzuki (2020). For more details, please see Suzuki (2020).

\[
v_t = Y_t - Z_t X_t - D_t W_t \\
\bar{P}_t = H_t H_t' \\
F_t = Z_t P_t' + A_t A_t' \\
K_t = (T_t P_t Z_t' + A_t) F_t^{-1} \\
X_{t+1} = T_t X_t + K_t (Y_t - Z_t X_t - D_t W_t)
\]
Based on Francke et al. (2010), we expand on the models by De Jong (1991) in detail below: We have observation equations and transition equations with several assumptions.

**Observation Equation:** \( Y_t = Z_t X_t + D_t W_t + A_t u_t \)

**Transition Equation:** \( X_t = T_t X_{t-1} + \nu_t \)

**Assumptions:** The error terms are assumed to be zero mean, normally distributed, serially uncorrelated and uncorrelated with each other: \( \nu_t \sim N(0, \sigma^2 Q), \; u_t \sim N(0, \sigma^2 H), \; E[\nu_t u_t'] = 0 \) for all \( s \neq t \), and \( E[\nu_t u_t'] = 0 \) for all \( s \) and \( t \).

Furthermore, we have a scaling factor, \( \sigma \), and variance matrix, \( Q \) and \( H \), depending on the vector of nuisance parameters \( \omega \), which makes the parameter \( \Theta \) a diffused random vector below. Considering \( \omega \), we have \( u_t \sim N(0, \sigma^2 \Omega) \), which we write as \( \Omega = \Omega(\omega), X_t = X_t(\omega), W_t = W_t(\omega) \). \( \omega \) represents all other factors that impacts the variables of the model and can be estimated empirically.

Let \( \zeta \) : dimension of time-series vector \( y \), \( \phi \) : number of vectors of coefficient \( \Theta \), \( \mu \) : \( \mu = \zeta - \phi \), which is the \( \zeta \times \mu \) dimension of the transformation matrix \( J_t \).

The state-space model estimates the parameters of the linear state-space models using the maximum likelihood. The diffuse Kalman filter is a method for recursively obtaining linear, least squares forecasts of \( Y_t \) conditional on past information. These forecasts are used to construct the diffused log-likelihood when the model is nonstationary. When the model is stationary, we utilize the Kalman filter instead.

The state-space model usually assumes the one which is the normal distribution of error terms. In this case, the likelihood of the model is analytically valuable. In this study, percent (\%) change representation meets this requirement in the long term or with large samples, assuming the existence of non-exponential equilibrium. With the analytically measurable likelihood of the model, which is often represented as the problem of nonlinearity, we have to utilize such a particle filter instead of the Kalman filtering approach. The state-space model usually proposes the linearity of the model. This paper also meets this requirement by utilizing the rational expectation theory. If the model meets the normality of the error terms and linearity of the model (which we label as the linear Gaussian state-space model), the state-space model can utilize Kalman filtering, which justly identifies all the latent or unobservable variables of the model with the necessary observability conditions to be met, and also statistically estimates the coefficients of the model. These statistical estimations are extremely indispensable and feasible for analyzing the effects of the ECB’s UMP (APP in this study).

We require further explanation regarding Kalman filtering. In Kalman filtering, each time we obtain new observation equation values, it corrects the estimates of state variables. With new observations deviating from the estimated values from the model, Kalman filtering considers whether the deviations are emanating from the uncorrected estimates of state variables or from those of observation noises. Then, Kalman filtering updates the distributions of the averages and variances of the state variables. Of the signal-to-noise ratio, which is the ratio of state variable variances to forecast error variances, the larger the signal-to-noise ratio
becomes, the more efficient the Kalman filtering corrects estimates of state variables under the former uncorrected estimates of the state variables.

4.10.1 State-Space Model Initial State Vector

We have the initial conditions of the state vector $X_1$ below:

$$X_1 = t + \Theta \Gamma + \xi C, \Theta \sim N \left(0, \sigma^2 \Sigma\right), \xi \sim N \left(0, \sigma^2 Q_0\right)$$

Here, $t$ : vector; $\Gamma, C, Q_0$ : fixed system variables of appropriate dimensions; $\xi$ : random vector independent of the other disturbances; $\Theta$ : fixed and unknown diffuse random vector.

Based on the value of $X_1$, the state-space model estimates the coming term of $X_1$, utilizing the (diffuse) Kalman filter below.

4.10.2 Diffused log-likelihood of state-space model

We obtain general diffused likelihood functions that can be utilized and analyzed invariant to the nuisance term $\omega$ as follows:

$$
\log L = \ell^* \left( y; \sigma, \omega \right) = \lim_{\xi \to 0} \ell \left( y; \sigma, \omega \right) + \frac{1}{2} \log \left| 2\pi \sigma^2 \Sigma \right|
$$

$$
\ell \left( y; \sigma, \omega \right) = \ell \left( y|\Theta; \sigma, \omega \right) + \ell \left( \Theta|\sigma, \omega \right) - \ell \left( \Theta|y; \sigma, \omega \right)
$$

$$
-2\ell \left( \Theta|\sigma, \omega \right) = -2\ell \left( \Theta; \sigma, \omega \right)
$$

$$
= \zeta \log 2\pi + \zeta \log \sigma^2 + \log |F_t| + \sigma^{-2} (Y_t - Z_t X_t - D_t W_t) F_t^{-1} (Y_t - Z_t X_t - D_t W_t)
$$

$$
-2\ell \left( \Theta; \sigma, \omega \right) = -2\ell \left( \Theta; \sigma, \omega \right)
$$

$$
= \phi \log 2\pi + \phi \log \sigma^2 + \log \Sigma + \sigma^{-2} \Theta \Sigma^{-1} \Theta
$$

$$
-2\sigma^{-2} (Y_t - Z_t X_t - D_t W_t) F_t^{-1} W_t \Theta
$$

So, we get

$$
-2\ell \left( y; \sigma, \omega \right) = \zeta \log 2\pi + \zeta \log \sigma^2 + \log |F_t| + \log \Sigma + \log |\Sigma^{-1} + W_t F_t^{-1} W_t| + \sigma^{-2} (Y_t - Z_t X_t - D_t W_t)
$$

The diffuse log-likelihood functions are as follows:

$$
-2\log L^D = -2\ell^* \left( y; \sigma, \omega \right) = \zeta \log 2\pi + \zeta \log \sigma^2 + \log |F_t| + \log \left| W_t F_t^{-1} W_t \right| + \sigma^{-2} \text{RSS}
$$

Maximizing $-2\log L^D$ about parameter $\sigma^2$, we obtain the following.

$$
-2\log L^D = -2\ell^* \left( y; \hat{\sigma}, \omega \right) = \zeta \log 2\pi + \zeta \log \text{RSS} - \zeta \log n + \log |F_t| + \log \left| W_t F_t^{-1} W_t \right| + \zeta
$$

So, we get

$$
\log L^D = \ell^* \left( y; \sigma, \omega \right) = \lim_{\xi \to 0} \ell \left( y; \sigma, \omega \right) + \frac{1}{2} \log \left| 2\pi \sigma^2 \Sigma \right|
$$

4.10.3 Marginal log-likelihood of the state-space model

Why do we require marginal log-likelihood instead of diffuse log-likelihood? If we have
n nuisance parameter \( \omega \) and parameter vectors \( \Theta \), we must estimate and analyze them by utilizing the marginal log-likelihood below: Although the diffuse log-likelihood is not necessarily invariant to the nuisance parameter \( \omega \), the marginal log-likelihood in this study is always invariant to \( \omega \) when \( \omega \) is linearly dependent on \( W_t \) (that is, \( W_t = \delta(W, \omega) \)); which is required to analyze them with nuisance parameter \( \omega \).

To transform diffused ones into marginal ones, we let \( y^* = J_t y \). \( J_t \) does not depend on \( \Theta \) or \( \omega \). Furthermore, we have \( J_t W_t = 0 \), which means \( J_t \) and \( W_t \) are not correlated at all. Third, we replace \( \zeta \) with \( \mu \), and obtain the full rank \( J_t \). Finally, we let \( J_t^* J_t^* \) and \( W_t W_t \) be proportional to each other: \( \frac{J_t^* J_t^*}{W_t W_t} \).

Then, the marginal log-likelihood functions are obtained as follows.

\[
-2\ell\left(y^*, \sigma, \omega\right) = \mu \log 2\pi + \mu \log \sigma^2 + \log \left| J_t^* F_t J_t \right| + \sigma^{-2} \left( Y_t - Z_t X_t - D_t W_t \right)^\prime J_t \left( J_t^* F_t J_t \right)^{-1} J_t^\prime \left( Y_t - Z_t X_t - D_t W_t \right)
\]

As \( J_t W_t = 0 \), \( J_t (J_t^* F_t J_t)^{-1} J_t^\prime = F_t^{-1} M_t \)

where \( M_t = I - W_t (W_t^* F_t^{-1} W_t)^{-1} W_t^* F_t^{-1} \).

Therefore, \( \left| J_t^* F_t J_t \right| = \left| F_t \right| \cdot \left| J_t^* F_t J_t \right| \cdot \left| W_t W_t \right|^{-1} \cdot \left| W_t^* F_t^{-1} W_t \right| \)

As \( \left| J_t^* J_t \right| = 1 \), the marginal log-likelihood functions are defined as follows:

\[
-2\log L^M = -2\ell\left(y^*, \sigma, \omega\right) = \mu \log 2\pi + \mu \log \sigma^2 + \log \left| F_t \right| + \log \left| W_t^* F_t^{-1} W_t \right| - \log \left| W_t W_t \right| + \sigma^2 \cdot \text{RSS}
\]

Maximizing \( -2\log L^M = -2\ell\left(y^*, \sigma, \omega\right) \) about parameter \( \sigma^2 \), we obtain the following.

\[
-2\log L^M = -2\ell\left(y^*, \sigma, \omega\right)
\]

\[
= \mu \log 2\pi + \mu \log \text{RSS} - \mu \log m + \log \left| F_t \right| + \log \left| W_t^* F_t^{-1} W_t \right| - \log \left| W_t W_t \right| + \mu
\]

### 4.10.4 Evaluation of diffused and marginal log-likelihood

In evaluating diffused log-likelihood, we evaluate it using the methods below:

\[
\text{RSS} = q - s' S^{-1} s, q = \sum_{t=1}^{T} y_t^\prime F_t^{-1} y_t, s = \sum_{t=1}^{T} y_t^\prime F_t^{-1} v, S = \sum_{t=1}^{T} V_t F_t^{-1} V_t
\]

subject to \( v = L(Y_t - Z_t X_t - D_t W_t) \) and \( V = LW_t \).

As \( \Omega = L^\prime F_t L^{-1} \), or \( F_t = L \Omega L^\prime \), we get \( L = 1 \).

The maximizations of the diffused log-likelihood about parameter \( \Theta, \sigma^2 \) are shown as follows:

\[
\hat{\Theta} = S^{-1} s, \quad \hat{\sigma}^2 = \left(q - s' S^{-1} s\right) / \sigma^2
\]

Alternatively, to obtain marginal log-likelihood, with \( J_t^* J_t^* \propto W_t W_t \), we transform \( S, V, J \) into terms as defined below, maximizing the marginal log-likelihood regarding parameters
and $\sigma^2$ and estimate them.

$$V'_t = Z_t J'_t + D W_t$$

$$J'_{t+1} = T_t J'_t$$

$$v' = L \left( Y_t - Z_t J'_t - D W_t \right)$$

$$S' = W W_t = \sum_{i=1}^n V'_i V'_t$$

$$RSS = q^* - s^* S^{-1} s^*$$

$$q^* = \sum_{i=1}^T v'_i F^{-1} v'_t, s^* = \sum_{i=1}^T v'_i F^{-1} v'_t, S^* = \sum_{i=1}^T v'_i F^{-1} V'_t$$

$$\Theta = S^{-1} s^*, \sigma^2 = \left( q^* - s^* S^{-1} s^* \right) / \sigma^2$$

We employ these methods and procedures to estimate the parameter $\Theta$ and implement diffuse Kalman filtering.

5. Data Description

We utilize data in the state–space model mainly percent–represented ones by first taking
$\ln X$, then differentiating with time $t$ equals $(X_t - X_{t-1}) / X_t$, interchangeably. In the VECM
representation, we utilize $\ln X$ represented ones, because their differences, such as
$\ln X_t - \ln X_{t-1}$ equals the rate of change of $X_t$ compared with the same periods of the previous
year. Data are listed below:

1. (Ex(\%)) $\ln$ ECB nominal effective exch. rate of the US dollar against the EER–42
   group of trading partners: AU, CA, DK, HK, NO, SG, KR, SE, CH, GB, US, EA and BG,
   CZ, HU, PL, RO, CN, HR and DZ, AR, BR, CL, IS, IN, ID, IL, MY, MX, MA, NZ, PH, RU,
   ZA, TW, TH, TR, AE, CO, PE, SA, UA excluding the US dollar , average of observations
   through period (A), [99Q1=100] (from the ECB Statistical Data Warehouse) and percent (\%)
   change of compared with the same periods of the previous year.

2. (PSPP (\%)) $\ln$ public sector purchase program (PSPP) Stock Euro Millions (from
   the ECB) and percent (\%) change of compared with the same periods of the previous year.

3. (CSPP (\%)) $\ln$ corporate sector purchase program (CSPP) Stock Euro Millions (from
   the ECB) and percent (\%) change of compared with the same periods of the previous year.

4. (PEPP (\%)) $\ln$ pandemic emergency purchase program (PEPP) Stock Euro Millions
   (from the ECB) and percent (\%) change of compared with the same periods of the previous year.

5. (LF (\%)) $\ln$ Total Loans to the Euro Area Non–Financial Corporations adjusted for
   loan sales, securitization, and notional cash pooling (Million EUR) Stock (from the Euro Area
   Statistics) and percent (\%) change compared with the same periods of the previous year.

6. (LH (\%)) $\ln$ Total Loans to the Euro Area Households adjusted for loan sales, securiti-
   zation, and notional cash pooling (Million EUR) Stock (from the Euro Area Statistics) and per-
   cent (\%) change of compared with the same periods of the previous year.

7. (pai (\%)) $\ln$ HICP–All–items excluding energy and food, Monthly Index [2015 = 100]
   Average of observations through period (A) (from the ECB Statistical Data Warehouse) and
percent (%) change of compared with the same periods of the previous year.

(8) EONIA Rate–Historical close, average of observations through period Euro, provided by the ECB (from the ECB Statistical Data Warehouse)

6. Empirical Results

We have the results below by Stata 16:

6.1 Calvo-type Friction Nominal–Real Pricing Kernels are Indeed Existent and Changed Transmission Results among the ECB’s APP and the Real Economy

As noted, without any friction (such as nominal–real friction, which is modeled as pricing kernels in this study) in the real economy, the APP is by no means effective.

However, the empirical results show that we have the Calvo-type nominal–real friction statistically significant in all the variables in the model. This means that the APP and exchange rate channel may be effective to some extent due to the Calvo-type friction in the real economy.

We have some consistent effects among the variables in the model. We show them below:

\[
\begin{align*}
\text{Ex: } \text{Nominal} & = PK_{(+ \text{ and } -)} + \text{Real}_{(+ \text{ and } -)} , \\
\text{PSPP: } \text{Nominal} & = PK_{(+ \text{ and } -)} + \text{Real}_{(+ \text{ and } -)} , \\
\text{LF: } \text{Nominal} & = PK_{(\text{smaller})} + \text{Real}_{(\text{bigger})} , \\
\text{PEPP: } \text{Nominal} & = PK_{(\text{smaller})} + \text{Real}_{(\text{bigger})} , \\
\text{LH: } \text{Nominal} & = PK_{(\text{smaller})} + \text{Real}_{(\text{bigger})} , \\
\text{CSPP: } \text{Nominal} & = PK_{(\text{smaller})} + \text{Real}_{(\text{bigger})} .
\end{align*}
\]

Therefore, how many pricing kernels are there? We show them below:

We have an estimated positive 100% pricing kernel of the CSPP and PEPP at the commencement of their APP implementation, which gradually disappear. This indicates that the implementation of the CSPP and PEPP had some influence for the asset prices to increase, which brought portfolio rebalancing effects to the real economy.

In contrast, we have an unconvincing or null pricing kernel of the PSPP for all the periods. This indicates that null portfolio rebalancing effects were possible.

Moreover, we have an unconvincing pricing kernel of the exchange rate of an estimated +7.5% to +10% from March 2015 to December 2015, +0.5% to +2.5% from June 2016 (at the start of CSPP) to May 2017, gaining a negative value (−1% to −7%) from July 2017 to May 2018 and +1% to +3.5% from July 2018 to December 2018 (at the end of the APP), and +0% to +5.5% from January 2019 on (August 2020). Only with the empirical results, we cannot finalize the asset price raising effects of the exchange rate.

In contrast, we have consistently positive pricing kernel of LF: Around +0% to +1.5% from March 2015 to May 2016, +0.5% to +3% from June 2016 to February 2020, and around +4% to +7% from March 2020 on (which was when the outbreak of COVID-19 began in Europe and the start of the PEPP). This indicates that bank lending to firms caused asset prices to rise, which may present portfolio rebalancing effects to the real economy.

In contrast, we have consistently negative pricing kernel of LH. The negative values gradually strengthened from June 2015 to August 2020: around −1% to −3.5% from June
### Table 3: State Variables–1

| Variable       | Coef. | Std. Err. | z    | P>|z| | [95% Conf. Interval] |
|----------------|-------|-----------|------|-----|---------------------|
| Exstar         |       |           |      |     |                     |
| PSPPstar       |       |           |      |     |                     |
| PEPPstar       |       |           |      |     |                     |
| e.Exstar       |       |           |      |     |                     |
| L1.            | 1     | (constrained) |      |     |                     |
| CSPPstar       |       |           |      |     |                     |
| e.CSPPstar     |       |           |      |     |                     |
| L1.            | 1     | (constrained) |      |     |                     |
| PEPPstar       |       |           |      |     |                     |
| e.PEPPstar     |       |           |      |     |                     |
| L1.            | 1     | (constrained) |      |     |                     |
| LFstar         |       |           |      |     |                     |
| e.LFstar       |       |           |      |     |                     |
| L1.            | 1     | (constrained) |      |     |                     |
| LHstar         |       |           |      |     |                     |
| gstar          |       |           |      |     |                     |
| L1.            | 1     | (constrained) |      |     |                     |
| e.LHstar       |       |           |      |     |                     |
| L1.            | 1     | (constrained) |      |     |                     |
| Source: Author |

Note: Model is not stationary.
|                | Coef. | Std. Err. | z   | P>|z| | [95% Conf. Interval] |
|----------------|-------|-----------|-----|-----|----------------------|
| paistar        |       |           |     |     |                      |
| gstar          |       |           |     |     |                      |
| L1. (constrained) | 1     |           |     |     |                      |
| e.paistar      |       |           |     |     |                      |
| gstar          |       |           |     |     |                      |
| L1. (constrained) | 1     |           |     |     |                      |
| e.gstar        |       |           |     |     |                      |
| rstar          |       |           |     |     |                      |
| gstar          |       |           |     |     |                      |
| L1. (constrained) | 1     |           |     |     |                      |
| e.rstar        |       |           |     |     |                      |
| g              |       |           |     |     |                      |
| gstar          |       |           |     |     |                      |
| L1. (constrained) | 1     |           |     |     |                      |
| paistar        |       |           |     |     |                      |
| L1. (constrained) | 1     |           |     |     |                      |
| x              |       |           |     |     |                      |
| g              |       |           |     |     |                      |
| L1. (constrained) | 1     |           |     |     |                      |
| gstar          |       |           |     |     |                      |
| L1. (constrained) | -1    |           |     |     |                      |

Note: Model is not stationary.
Source: Author
### Table 5: Observation Variables Results: Nominal–Real Pricing Kernel

| Variable | Coef. | Std. Err. | z    | P>|z|  | [95% Conf. Interval] |
|----------|-------|-----------|------|-------|---------------------|
| **Ex**   |       |           |      |       |                     |
| Ex       | 5.286212 | .2496131  | 21.18 | 0.000 | 4.796979            | 5.775445          |
| e.Ex     | 1 (constrained) |           |      |       |                     |
| **PSPP** |       |           |      |       |                     |
| PSPP     | -3621.009 | 169.2203  | -21.40 | 0.000 | -3952.675          | -3289.344         |
| e.PSPP   | 1 (constrained) |           |      |       |                     |
| **CSPP** |       |           |      |       |                     |
| CSPP     | 41.0616 | 1.968679  | 20.86 | 0.000 | 37.20306          | 44.92014          |
| e.CSPP   | 1 (constrained) |           |      |       |                     |
| **PEPP** |       |           |      |       |                     |
| PEPP     | -18.96414 | .8741774  | -21.69 | 0.000 | -20.6775          | -17.25079         |
| e.PEPP   | 1 (constrained) |           |      |       |                     |
| **LF**   |       |           |      |       |                     |
| LF       | -3.391153 | .1452462  | -23.35 | 0.000 | -3.67583          | -3.106476         |
| e.LF     | 1 (constrained) |           |      |       |                     |
| **LH**   |       |           |      |       |                     |
| LH       | 3.327311 | .1386382  | 24.00 | 0.000 | 3.055585          | 3.599037          |
| e.LH     | 1 (constrained) |           |      |       |                     |
| **pai**  |       |           |      |       |                     |
| pai      | -.0938736 | .056076  | -1.67 | 0.094 | -.2037805        | .0160332          |
| x        |         |           |      |       |                     |
| L1.      | -.0053 | (constrained) |      |       |                     |
| e.pai    | 1 (constrained) |           |      |       |                     |
| **r**    |       |           |      |       |                     |
| r        | 1 (constrained) |           |      |       |                     |
| e.r      | 1 (constrained) |           |      |       |                     |
| **EONIA**|       |           |      |       |                     |
| x        | -1 (constrained) |           |      |       |                     |
| paistar  | 2 (constrained) |           |      |       |                     |
| rstar    | 1 (constrained) |           |      |       |                     |
| e.EONIA  | 1 (constrained) |           |      |       |                     |

Note: Model is not stationary.
Source: Author
2016 to August 2020. This indicates that bank lending to households had negative asset price changes and negative portfolio rebalancing effects on the real economy.

In summary, we had some positive asset pricing hike by (partly Ex and), CSPP, PEPP, and LF. In contrast, we had some negative asset pricing effects by (partly Ex and) LH.
Thereafter, do nominal policy and economic changes by the nominal APP and nominal exchange rate have any influence on financial conditions, real variables, and, eventually, the (potential) economic growth rate and (trend) inflation rate? We evaluate this concern below:
6.2 Growth–Related Channels to (Trend) Inflation Rate are not Repaired Due to the Flat New Keynesian Phillips Curve

The empirical results <Figures 13–14> indicate that: 1. IS curves are random–walking among the GDP gap rate \( (g_t - g^*_t = x_t = x_{t+1}) \) and interest rate gap \( (\kappa - \kappa^*) \) and 2. New Keynesian Phillips curves are flat or show no relation among inflation rate \( \pi_t \) and GDP gap rate \( (g_t - g^*_t = x_t^* = x_{t+1}) \) due to the parameter \( \kappa = -0.0938736^* \) and significant at the 10% level, which is regarded as uncertain in reality to some extent. IS curves indicate that easing monetary policy may well raise the nominal GDP growth rate, the potential GDP growth rate, or both. However, the increase in the nominal GDP growth rate, potential GDP growth rate, or both do not raise the inflation rate \( \pi_t \) statistically. Therefore, flat New Keynesian Phillips curves since the global financial crisis (from September 2008 on) are the fundamental causes hindering the transmission of GDP growth rate on inflation rate, which means that Growth–Related channels to (trend) inflation are not repaired due to the flat new Keynesian Phillips curve since then.

However, non–growth–related channels of the ECB’s APP are not impaired yet and are effective directly from the APP and exchange rate to (trend) inflation rate not through (potential) economic growth rate itself. We then examine these effects.

6.3 Non–growth–related Channels of the ECB’s APP are Feasible and Important for Determination of the Trend Inflation Rate and Trend Growth Rate by Public Policy

As we evaluate the APP by Nominal Effects (% = Pricing Kernel (%) + Real Effects (%)) above <Tables 3–5> <Figures 15–21>, and we show the pricing kernel effects in Section 6.1, we present the real effects of the ECB’s APP in this section. This evaluation directly answers the three hypotheses described in the Introduction in the paper, which we are mainly concerned with.

6.3.1 Hypothesis 1: The corporate sector purchase program (CSPP) including the pandemic emergency purchase program (PEPP) has some influence on the financial conditions and eventually on the (potential) economic growth rate and (trend) inflation rate

A direct pass–through channel is defined as the direct purchase of private sector assets by
the ECB (i.e., the CSPP including a part of PEPP in this study). The purchase increases the asset prices, which encourages private banks to increase loans to corporations and households, improving broader financing conditions.

The effects of the CSPP are described as follows: The real CSPP growth rate was consistently positive from June 2016 to December 2018 (from the start of the CSPP to the end of the APP, at that time, ranging from +0.6% to +2.4%). In addition, from March 2020 on (the outbreak of COVID-19 and the start of the PEPP), the real effects of CSPP have been around +0.3% to +0.5%. These results show that the real CSPP growth rate increasing policy has been effective on the (potential) economic growth rate and (trend) inflation rate.

Additionally, the empirical results show that if the CSPP increases LH, there are positive bank lending effects: Real LH was positive (ranging constantly from +0% to +1% at all times, and especially ranged from +0.2% (+0.5% in 6 months) to +1% after June 2016, which was the beginning of the CSPP) in all the periods from March 2015 to August 2020. This also means that it has some positive effects on the (potential) economic growth rate and (trend) inflation rate.

**Proposition 1:** Real CSPP and real CSPP driven increases of real bank lending to households have some feasible and positive influences on the (potential) economic growth rate and (trend) inflation rate.

6.3.2 Hypothesis 2: The public sector purchase program (PSPP) including the pandemic emergency purchase program (PEPP) influences financial conditions and eventually influences the (potential) economic growth rate and (trend) inflation rate

The APP has two transmission channels in this study: 1. Direct pass-through and 2. Portfolio rebalancing channels. Portfolio rebalancing channels are defined as the ECB’s purchase of public and private sector assets from pension funds, banks, and households. By increasing the demand for assets, it increases prices and decreases yields, even for assets that are not directly targeted by the APP. This compression of yields encourages banks to lend to firms or households.

The effects of PSPP are described as follows: The effects of PSPP have been uncertain; rather, they could have no effects at any given point of the time despite the massive implementation. Real PSPP growth was achieved for all periods except the periods from February 2019 to October 2019, which was after the conclusion of APP. However, the non-mute effect periods had irregular and unfixed effects, ranging both in positive and negative rates.

Additionally, the empirical results indicate that increases in the real PEPP growth rate have consistently negative influences on the (potential) economic growth rate and (trend) inflation rate. The scale ranges from −1% to −5%, with the effects gradually declining.

Furthermore, the empirical results demonstrate that PSPP has not raised lending to firms (LF) directly. However, raising LF by, for example, other portfolio rebalancing effects has had even consistently negative influences on (potential) economic growth rate and the (trend) inflation rate: Consistently −1.5% to 0% during all the periods, −1% to −1.5% from March 2020 (the period of the outbreak of COVID-19 in Europe and the start of the PEPP).
Proposition 2: Real PSPP growth has unconvincing or null effects on financial conditions and eventually on (potential) economic growth rate and the (trend) inflation rate. With the PEPP, the net effects are rather negative.

6.3.3 Hypothesis 3: The ECB’s asset purchase program (APP) influences the exchange rate and eventually the (potential) economic growth rate and (trend) inflation rate

The lowering of the cost of borrowing by portfolio rebalancing channels encourages investors to use extra funds to buy higher yields assets outside the Euro Area. This could lead to a lower euro exchange rate, which tends to place upward pressure on inflation.

As noted above, the real CSPP growth has positive effects on the exchange rate, real PSPP has unconvincing effects (both in the positive and negative value), and the PEPP has negative effects. The effects of real exchange rates are described as follows: Varying real exchange rate has had unconvincing effects during the periods: Approximately +1.5% to +2% from March 2015 to February 2016, around −0.5% to −1.5% from March 2016 to June 2018, around −1.5% to 0% from July 2017 to June 2018, and +0.5% to +1% from August 2018 to August 2020.

Proposition 3: The APP has some convincing effects on the exchange rate by the CSPP and PEPP to varying degrees (and unconvincing effects by PSPP) and eventually on the (potential) economic growth rate and (trend) inflation rate.

6.4 Summary of Empirical Results and Implications

The empirical results show that both the CSPP and CSPP-based bank lending to households are positively effective, especially with credit easing, on the (potential) economic growth rate and (trend) inflation rate, especially during crisis and even during some normal times. This is because credit easing decreases the risk premium of the broader assets and supports asset prices.

Thus far, before and during the emergent COVID-19 outbreak, the current APP implementation mostly met the ECB’s mandate requirement. However, confined to normal times (which are difficult to define due to the asymmetric and insufficient development in part of the underdeveloped Euro Area economy), we have not yet reached a unanimous consensus on whether we should continue to implement further credit easing, as the CSPP and bank lending to households in normal times under an economy with developed and underdeveloped countries in unity, needs future research.

7. Conclusion

In this paper, we assume Calvo-type frictions with a forward-looking New Keynesian state-space model instead of standard VARs or VECMs. We overcome the Lucas critique by utilizing a Markov chain in the state-space model with only one lag from the error correction term from the VECM, and allow their latent, trend, and real variables to vary with the time trend.

We obtain the empirical results. Calvo-type friction is indeed statistically significant among all the concerned variables. This indicates that there are nominal–real frictions defined as the pricing kernel or asset pricing term, which allow the monetary policy to be effective in
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reality.

Even considering the trend inflation rate, the inflation-target outcome of the ECB’s UMPs have been assessed as unaccomplished, although both trend and nominal inflation rates have been anchored at around +1%, which are measured by a comparison of the rates for the same periods of the previous year.

Furthermore, both the CSPP and CSPP-based bank lending to households are positively effective on the (potential) economic growth rate and (trend) inflation rate, especially with credit easing. These effects are seen particularly during crisis and sometimes even during normal times, and contribute to the trend inflation rate increase.

However, we have not yet reached a unanimous consensus on whether we should continue to implement credit easing as the CSPP and bank lending to households, even in normal times under an economy inclusive of the developed and underdeveloped countries in unity, such as in the EU and the Euro Area, needs to be further investigated.

8. References

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