A Work Project, presented as part of the requirements for the Award of a Master's degree in Economics from the Nova School of Business and Economics.

THE IMPACT OF THE ECB'S UNCONVENTIONAL MONETARY POLICY DURING THE COVID CRISIS

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January 15, 2025

Abstract

This paper explores the economic impact of the ECB's unconventional monetary policies during the COVID-19 crisis: Quantitative Easing (QE), Forward Guidance (FG), and Negative Interest Rate Policy (NIRP). Using a DSGE model, I analyse their effectiveness in stabilizing the Eurozone's economy under extreme conditions. Without these policies, GDP would have contracted by 13.3%, compared to 9.0% with their implementation, mitigating a 4.3 percentage point decline. QE was the most effective, reducing long-term yields and boosting liquidity. FG anchored expectations and reduced inflation volatility by 15%, while NIRP had marginal effects due to banking constraints. These results highlight the indispensable role of unconventional monetary policies in mitigating economic shocks and ensuring resilience during crises of unprecedented magnitude.

Keywords: European Central Bank; Covid-19 Crisis; Unconventional Monetary Policy; Quantitative Easing (QE); Negative Interest Rate Policy (NIRP); Forward Guidance (FG); Eurozone Economy; Economic Impact; Financial Stability; Macroeconomic Analysis

This work used infrastructure and resources funded by Fundação para a Ciência e a Tecnologia (UID/ECO/00124/2013, UID/ECO/00124/2019 and Social Sciences DataLab, Project 22209), POR Lisboa (LISBOA-01-0145-FEDER-007722 and Social Sciences DataLab, Project 22209) and POR Norte (Social Sciences DataLab, Project 22209).

I would like to express my sincere gratitude to Professor André de Castro Silva for his insightful supervision and guidance. I am also deeply thankful to my parents, sisters, and friends for their unwavering support throughout this journey. Finally, I extend my heartfelt appreciation to my grandparents, who will always remain a profound source of inspiration and significance in my life.

1 Introduction

The COVID-19 pandemic triggered an unprecedented global economic crisis, characterized by a sudden halt in economic activity and heightened uncertainty. These conditions constrained efforts to forecast growth and inflation, challenging central banks in their pursuit of price stability and, in some cases, unemployment.

In early 2020, central banks responded swiftly with an array of tools to address the extraordinary economic stresses. The scale of the crisis rendered conventional monetary policies inadequate, as the Zero Lower Bound (ZLB) limited the scope for further rate cuts. Consequently, central banks expanded their toolkit, employing unconventional monetary policies that had previously been tested during crises like the 2008 Financial Crisis.

This thesis explores how the European Central Bank (ECB) employed unconventional tools—Quantitative Easing (QE), Forward Guidance (FG), and Negative Interest Rate Policy (NIRP)—to mitigate the pandemic's economic impact. Using the dynamic stochastic general equilibrium (DSGE) framework developed by Sims and Wu (2019), the analysis evaluates the effects of these policies on key macroeconomic variables such as output, consumption, and inflation in the Eurozone.

The structure of this thesis is as follows: Section 2 reviews the literature, Section 3 outlines the methodology and calibrations, Section 4 presents the results, Section 5 compares these findings with real-world data, and Section 6 offers concluding insights.

2 Literature Review

2.1 Monetary policy

Monetary policy, implemented by central banks such as the European Central Bank (ECB), aims to regulate borrowing costs and the money supply to achieve economic objectives, including price stability and low unemployment. Mishkin (1995) highlights its primary goals as fostering maximum employment, stable prices, and moderate long-term interest rates. Through adjustments in the money supply and interest rates, central banks work to control inflation and stabilize economic fluctuations.

Two key macroeconomic theories have shaped monetary policy: Keynesian and Monetarist Economics. Keynesian theory advocates government spending to stimulate demand and address economic volatility, while Monetarist theory focuses on controlling the money supply to manage inflation. Despite their differences, both approaches have profoundly influenced modern monetary policy frameworks.

Friedman (1968) emphasized three critical lessons from historical experience: monetary policy should prevent money from becoming a source of instability, maintain predictable price levels to create a stable economic environment, and counteract significant external economic disruptions.

2.1.1 Conventional Monetary Policy

Conventional monetary policy relies on tools such as short-term interest rate adjustments and open market operations to control inflation and unemployment. These measures influence borrowing, spending, and investment, stabilizing the economy under normal conditions. However, during crises like the COVID-19 pandemic, aggressive rate cuts may become ineffective, especially when interest rates approach the Zero Lower Bound (ZLB), limiting the scope of traditional monetary tools.

2.1.2 Unconventional Monetary Policy

When conventional tools prove insufficient, particularly at the ZLB, central banks adopt unconventional monetary policies such as Quantitative Easing (QE), Forward Guidance

(FG), and Negative Interest Rate Policy (NIRP). These measures provide crucial support in addressing economic instability during periods of crisis.

2.1.2.1 Quantitative Easing (QE): Quantitative Easing involves central bank purchases of financial assets, such as government bonds, to inject liquidity, expand the money supply, and lower long-term interest rates (Bernanke et al., 2004). Krishnamurthy and Vissing-Jorgensen (2011) explain that QE reduces the supply of bonds, raising prices and lowering yields, which encourages investment in higher-yield assets. Woodford (2012) highlights QE's signaling effect, demonstrating the central bank's commitment to accommodative policy and shaping expectations about future rates. Gagnon et al. (2011) emphasize QE's role in stabilizing financial markets during distress, fostering spending and investment.

2.1.2.2 Forward Guidance (FG): Forward Guidance is a communication strategy used by central banks to influence public expectations about future interest rates, shaping current economic decisions (Campbell et al., 2012). Woodford (2012) notes that FG lowers long-term yields through signaling, encouraging borrowing and investment. The effectiveness of FG depends on central bank credibility. Blinder (2000) argues that credible central banks stabilize inflation and maintain public trust, enhancing FG's role in achieving macroeconomic stability.

2.1.2.3 Negative Interest Rate Policy (NIRP): Negative Interest Rate Policy allows central banks to set nominal rates below zero to combat stagnation and low inflation, encouraging spending and investment (Rogoff, 2016). The European Central Bank (ECB) has employed NIRP to reduce borrowing costs and stimulate growth. Bech and Malkhozov (2016) highlight that NIRP enhances credit availability and investment, while Ampudia and Van den Heuvel (2018) emphasize its role in reducing borrowing costs. However, prolonged negative rates can erode bank profitability and lead to cash hoarding, limiting the policy's effectiveness (Demiralp et al., 2021).

3 Methodology

In this thesis, we adapt the Dynamic Stochastic General Equilibrium (DSGE) model by Sims and Wu (2019) to evaluate the European Central Bank's (ECB) unconventional monetary policies during the COVID-19 pandemic. The DSGE framework is well-suited for this analysis as it captures the forward-looking behaviors of households and firms, financial frictions, and equilibrium conditions, allowing for an in-depth examination of how variables such as output, inflation, investment, and consumption respond to monetary interventions.

The methodology distinguishes between exogenous and endogenous policy approaches. Exogenous policies, such as Quantitative Easing (QE), Forward Guidance (FG), and Negative Interest Rate Policy (NIRP), are modeled as one-time shocks to isolate their immediate effects, demonstrating how these tools replicate the impact of conventional interest rate cuts under the constraints of the Zero Lower Bound (ZLB). Endogenous policies, by contrast, are modeled as systematic, rule-based adjustments where tools like QE dynamically respond to deviations in inflation or output. This feedback mechanism offers a realistic depiction of the ECB's proactive role in stabilizing the economy.

To account for the unique conditions of the Eurozone during the pandemic, the Sims and Wu model was recalibrated to reflect heightened uncertainty, supply chain disruptions, and demand shocks. Incorporating simultaneous shocks—such as those related to liquidity, government spending, and technology disruptions—provides a comprehensive assessment of the ECB's multifaceted response.

This approach combines the analysis of one-time interventions with systematic policy adjustments, enabling a robust evaluation of the effectiveness of unconventional monetary tools. It highlights the individual and interactive roles of QE, FG, and NIRP in addressing the economic challenges posed by the pandemic and underscores the ECB's critical contribution to macroeconomic stability during this unprecedented period.

3.1 Key Model Equations

This section presents the foundational equations from the framework developed by Sims and Wu (2019), which form the basis of the model and encapsulate the transmission mechanisms of monetary policy, inflation dynamics, and macroeconomic interactions. The model consists of six key sectors, each of which is described in the following subsections. Detailed calculations and derivations are provided in Appendix A.

3.1.1 Households

Households in the model consist of workers and intermediaries. Workers supply labor to the labor market, while intermediaries engage in financial intermediation. A fixed fraction of intermediaries exits the market each period, transferring their net worth to households and being replaced by new intermediaries endowed with a fixed startup net worth, X.

The optimization problem of households is to maximize their expected lifetime utility:

$$E_t \sum_{j=0}^{\infty} \beta^j \left[\ln\left(C_{t+j} - bC_{t+j-1}\right) - \chi \frac{L_{t+j}^{1+\eta}}{1+\eta} \right], \tag{1}$$

subject to the budget constraint:

$$P_t C_t + D_t - D_{t-1} \leq MRS_t L_t + DIV_t - P_t X - P_t T_t + (R_t^d - 1) D_{t-1}, \tag{2}$$

where C_t and L_t denote consumption and labor supply, respectively, β represents the discount factor, b captures the habit formation parameter, χ scales the disutility of labor, and η is the inverse of the Frisch elasticity.

The household's optimization yields the following First-Order Conditions:

Marginal utility of consumption:

$$\mu_t = \frac{1}{C_t - bC_{t-1}} - b\beta E_t \left[\frac{1}{C_{t+1} - bC_t} \right]. \tag{3}$$

Stochastic discount factor:

$$\Lambda_{t,t+1} = \beta \frac{\mu_{t+1}}{\mu_t}. \tag{4}$$

Labor supply condition:

$$\chi L_t^\eta = \mu_t \frac{MRS_t}{P_t}. \tag{5}$$

Euler equation for deposits:

$$R_t^d = E_t \left[\beta \frac{1/(C_t - bC_{t-1})}{1/(C_{t+1} - bC_t)} \frac{1}{\Pi_{t+1}} \right], \tag{6}$$

where $\Pi_{t+1} = \frac{P_{t+1}}{P_t}$ represents the gross inflation rate.

3.1.2 Labour Market

The labour market is modeled as a two-tier structure in which labur unions purchase labour from households at the marginal rate of substitution (MRS_t) and repackage it for sale to labour packers. The demand for labour faced by a union h is:

$$L_{d,t}(h) = \left(\frac{W_t(h)}{W_t} \right)^{-\epsilon_w} L_{d,t}, \tag{7}$$

where $W_t(h)$ is the wage set by union h, and W_t is the aggregate wage index.

Wage-setting is subject to nominal rigidities modeled through a Calvo pricing mechanism. A union that can adjust its wage maximizes the present discounted value of its real profits, resulting in the following first-order condition for the optimal nominal wage:

$$w_t^* = \frac{\epsilon_w}{\epsilon_w - 1} \frac{f_{1,t}}{f_{2,t}}, \tag{8}$$

where $f_{1,t}$ and $f_{2,t}$ are recursive terms dependent on MRS_t, wage dispersion, and the household's stochastic discount factor.

3.1.3 Fiscal Authority

The fiscal authority consumes an exogenous and stochastic amount of final output, G_t, financed through lump-sum taxes, transfers from the central bank, and nominal government bonds ($B_{G,t}$). The government's budget constraint ensures fiscal solvency by adjusting lump-sum taxes endogenously:

$$P_t G_t + P_{t-1} \bar{b}_G = P_t T_t + P_t T_{cb,t} + Q_{B,t} P_t \bar{b}_G (1 - \kappa \Pi_{t-1}), \tag{9}$$

where κ captures enforcement inefficiencies, and $\Pi_t = \frac{P_t}{P_{t-1}}$ represents inflation.

3.1.4 Financial Intermediaries

Financial intermediaries operate within the framework of Gertler and Karadi (2011, 2013). Each period, a fraction of intermediaries exits the market, transferring their net worth to households, while new intermediaries enter with a fixed startup net worth, X, funded by households. Intermediaries' operations are financed through deposits and investments in private bonds, government bonds, and central bank reserves, with the following balance sheet:

$$Q_t F_{i,t} + Q_{B,t} B_{i,t} + RE_{i,t} = D_{i,t} + N_{i,t}, \tag{10}$$

where Q_t and $Q_{B,t}$ denote the prices of private and government bonds, $F_{i,t}$ and $B_{i,t}$ are their respective quantities, $RE_{i,t}$ represents reserves, $D_{i,t}$ is deposits, and $N_{i,t}$ is net worth.

The evolution of net worth is given by:

$$N_{i,t} = (R_t^F - R_t^d)Q_{t-1}F_{i,t-1} + (R_t^B - R_t^d)Q_{B,t-1}B_{i,t-1} + (R_t^E - R_t^d)RE_{i,t-1} + R_t^d N_{i,t-1}, \quad (11)$$

where R_t^F, R_t^B, and R_t^E are the returns on private bonds, government bonds, and reserves, respectively, and R_t^d is the deposit rate.

Intermediaries aim to maximize their expected terminal net worth, discounted by the household's stochastic discount factor:

$$V_{i,t} = \max (1-\sigma) E_t \sum_{j=1}^{\infty} \sigma^{j-1} \Lambda_{t,t+j} n_{i,t+j}, \quad (12)$$

where σ is the survival probability, $\Lambda_{t,t+j}$ is the stochastic discount factor, and $n_{i,t+j} = N_{i,t+j}/P_t$ is real net worth.

The first-order conditions for asset returns are:

$$E_t \Lambda_{t,t+1} \Omega_{t+1} \Pi_{t+1}^{-1} (R_{t+1}^F - R_t^d) = \lambda_t (1 + \lambda_t \theta_t), \quad (13)$$

$$E_t \Lambda_{t,t+1} \Omega_{t+1} \Pi_{t+1}^{-1} (R_{t+1}^B - R_t^d) = \lambda_t \theta_t \Delta (1 + \lambda_t \theta_t), \quad (14)$$

$$E_t \Lambda_{t,t+1} \Omega_{t+1} \Pi_{t+1}^{-1} (R_{t+1}^E - R_t^d) = -\omega_t (1 + \lambda_t). \quad (15)$$

where λ_t and ω_t are Lagrange multipliers for enforcement and reserve constraints, and Ω_t is an auxiliary variable.

3.1.5 Production

The production sector includes a representative wholesale firm that maximizes the present discounted value of its real dividends, discounted by the household's stochastic discount factor. The firm's production function is given by:

$$Y_{m,t} = A_t (u_t K_t)^{\alpha} L_{d,t}^{1-\alpha}, \quad (16)$$

where $Y_{m,t}$ is wholesale output, A_t is a stochastic productivity factor, u_t is the capital utilization rate, K_t is the capital stock, and $L_{d,t}$ is labor input. The parameter α represents the elasticity of output with respect to capital. The capital accumulation equation is:

$$K_{t+1} = \hat{I}_t + (1 - \delta(u_t))K_t, \tag{17}$$

where $\hat{I}_t$ is investment, and $\delta(u_t)$ is the depreciation rate.

The optimization problem produces the following first-order conditions:

Labour Demand Condition:

$$w_t = (1 - \alpha)p_{m,t}A_t(u_tK_t)^{\alpha}L_{d,t}^{-\alpha}, \tag{18}$$

where $w_t = W_t/P_t$ is the real wage, and $p_{m,t} = P_{m,t}/P_t$ is the relative price of wholesale output.

Optimal Capital Utilization:

$$p_t^k M_{1,t}\delta'(u_t) = \alpha p_{m,t}A_t(u_tK_t)^{\alpha-1}L_{d,t}^{1-\alpha}. \tag{19}$$

Investment and Bond Conditions:

$$P_t^k M_{1,t} = E_t\Lambda_{t,t+1}\left[p_{m,t+1}\alpha A_{t+1}(u_{t+1}K_{t+1})^{\alpha-1}u_{t+1}L_{d,t+1}^{1-\alpha} + (1 - \delta(u_{t+1}))P_t^k M_{1,t+1}\right], \tag{20}$$

$$Q_tM_{2,t} = E_t\Lambda_{t,t+1}\Pi_{t+1}^{-1}Q_{t+1}M_{2,t+1}. \tag{21}$$

3.1.6 Central Bank

3.1.6.1 Conventional Monetary Policy and ZLB Constraint

The central bank conducts conventional monetary policy by adjusting the short-term interest rate (R_t^{TR}) based on a Taylor-type feedback rule:

$$\ln R_t^{TR} = (1-\rho_r)\ln R^{TR} + \rho_r \ln R_{t-1}^{TR} + (1-\rho_r)\left[\phi_\pi(\ln\Pi_t - \ln\Pi) + \phi_y(\ln Y_t - \ln Y_{t-1})\right] + s_r\varepsilon_{r,t}, \tag{22}$$

where R^{TR} is the steady-state policy rate, Π is the inflation target, and ρ_r determines the degree of interest rate smoothing. The parameters $\phi_\pi > 1$ and ϕ_y capture the responsiveness of the policy rate to deviations in inflation and output growth, respectively, while

$\varepsilon_{r,t}$ represents an exogenous policy rate shock.

Under normal conditions, the deposit rate (R_t^d) and the interest rate on reserves (R_t^{re}) align with the policy rate:

$$R_t^d = R_t^{re} = R_t^{TR}. \tag{23}$$

When constrained by the Zero Lower Bound (ZLB), conventional monetary policy becomes ineffective. The model imposes the condition:

$$R_t^{re} = R_t^d = \max\{1, R_t^{TR}\}, \tag{24}$$

ensuring non-negative nominal interest rates and highlighting the limitations of conventional tools in addressing severe economic downturns.

3.1.6.2 Quantitative Easing

Quantitative Easing (QE) is an unconventional monetary policy tool employed by central banks during periods when conventional monetary policy is constrained by the Zero Lower Bound (ZLB). QE operates through the central bank's purchase of private and government-issued bonds, financed by the creation of interest-bearing reserves held by financial intermediaries. This is represented by the central bank's balance sheet:

$$Q_t F_{cb,t} + Q_{B,t} B_{cb,t} = RE_t, \tag{25}$$

where Q_t and $Q_{B,t}$ denote the prices of private and government bonds, $F_{cb,t}$ and $B_{cb,t}$ are the respective quantities of bonds held, and RE_t represents reserves created for these purchases.

By increasing demand for bonds, QE raises their prices, reduces yields, and alleviates financial constraints for intermediaries, particularly under enforcement frictions. These dynamics lower financing costs, stimulate investment, and support aggregate demand, addressing the limitations of conventional monetary policy during periods of economic distress.

3.1.6.3 Exogenous and Endogenous QE

The model incorporates both exogenous and endogenous Quantitative Easing (QE) policies. Exogenous QE follows autoregressive processes for central bank bond holdings:

$$f_{cb,t} = (1-\rho_f)f_{cb} + \rho_f f_{cb,t-1} + s_f \varepsilon_{f,t}, \tag{26}$$

$$b_{cb,t} = (1-\rho_b)b_{cb} + \rho_b b_{cb,t-1} + s_b \varepsilon_{b,t}, \tag{27}$$

where $f_{cb,t}$ and $b_{cb,t}$ represent real steady-state holdings of private and government bonds by the central bank. The parameters ρ_f and ρ_b determine the persistence of bond purchases, while s_f and s_b reflect the standard deviations of shocks.

Endogenous QE links bond purchases to macroeconomic variables, allowing central bank interventions to respond dynamically to economic conditions, such as deviations in output and inflation. This mechanism ensures QE automatically adjusts to stabilize the economy during periods of economic stress.

3.1.6.4 Forward Guidance

Forward Guidance (FG) is modeled as a central bank communication strategy to shape market expectations regarding future interest rates, particularly when constrained by the Zero Lower Bound (ZLB). In the Sims and Wu framework, FG is represented as a shock to the desired policy rate (R_t^{TR}) during the ZLB period, influencing expectations for future deposit rates:

$$E_t[i_{t+k}] = i^*, \tag{28}$$

where i^* denotes the future policy rate announced by the central bank.

The credibility of FG is captured by the parameter $\gamma \in [0,1]$, where $\gamma = 1$ implies full credibility, and $\gamma = 0$ indicates no credibility. FG primarily influences economic activity by lowering long-term yields, stabilizing inflation expectations, and supporting aggregate demand through the expectations hypothesis, which links anticipated future rates to current financial conditions.

3.1.6.5 Negative Interest Rate Policy

Negative Interest Rate Policy (NIRP) is an unconventional monetary policy tool where the central bank sets the interest rate on reserves (R_t^{re}) below zero, while the deposit rate (R_t^d) remains constrained by the Zero Lower Bound (ZLB). The relationship between these rates is defined as:

$$R_t^d = \max\{1, R_t^{re}\}, \quad R_t^{re} = R_t^{TR}, \tag{29}$$

where R_t^{TR} represents the desired policy rate.

NIRP influences the economy through two primary mechanisms. The expectations channel mirrors forward guidance by signaling future reductions in deposit rates beyond the ZLB. Its effectiveness is shaped by the interest rate smoothing parameter (ρ_r) and the duration of the ZLB (H). Unlike forward guidance, NIRP involves a direct reduction in the interest rate on reserves, enhancing its credibility and influencing long-term expectations. The balance sheet channel impacts financial intermediaries by reducing their net worth when $R_t^{re} < R_t^d$, thereby tightening enforcement constraints. This mechanism can weaken the stimulative effects of NIRP by increasing the excess returns demanded by intermediaries.

3.2 Parameters Calibration

During the COVID-19 pandemic, key parameters in the model were adjusted to reflect the economic challenges of the period.

Price and wage stickiness were increased from 0.75 to 0.85 to account for reduced adjustment frequencies due to higher menu costs and operational disruptions. The government spending share rose from 0.2 to 0.25, reflecting fiscal expansions of approximately 5% of GDP. Habit formation increased from 0.7 to 0.8, capturing heightened precautionary savings as household savings rates rose from 12% to over 20%. The inverse Frisch elasticity doubled from 1 to 2, reflecting reduced labor supply flexibility consistent with observed declines in labor elasticity. Interest rate persistence increased from 0.8 to 0.84, while the inflation response coefficient decreased from 1.5 to 1.3, reflecting the ECB's focus on economic recovery over strict inflation control.

Leverage rose from 4 to 5 to reflect increased reliance on loans, while the debt-to-GDP ratio increased to 0.97, aligning with the surge in public debt across the Eurozone.

These adjustments enhance the model's ability to capture the unique economic conditions of the pandemic. A detailed summary of the parameter changes is provided in Table A.1 in Appendix B.

3.3 Shocks Calibration

To realistically represent the economic disruptions during the COVID-19 pandemic, multiple simultaneous shocks—liquidity, government spending, and productivity—were calibrated using empirical data to reflect the unique conditions of the Eurozone.

The liquidity shock was increased from 0.01 to 0.05 to capture the ECB's Pandemic Emergency Purchase Programme, which expanded the central bank's balance sheet by over €1.5 trillion during 2020–2021. Similarly, the government spending shock rose from 0.01 to 0.05, with its persistence increased to 0.98 to reflect sustained fiscal support. Productivity shock volatility was reduced from 0.0065 to 0.002 to account for supply chain disruptions and shifts to remote work. The persistence of preference shocks was also raised to 0.98, capturing elevated precautionary savings during the pandemic.

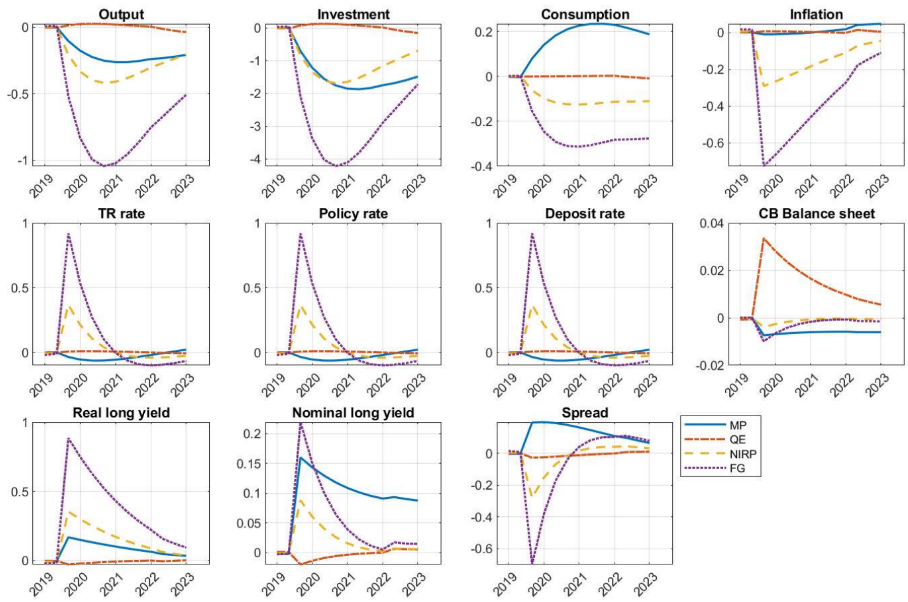
These adjustments provide a comprehensive depiction of the pandemic's economic challenges, reflecting the interplay between fiscal measures, liquidity injections, and productivity disruptions. Calibrations grounded in empirical data enhance the model's robustness and allow for a thorough assessment of the ECB's unconventional policies.

A detailed summary of these calibrations is presented in Table A.2 in Appendix B.

4 Results

4.1 Exogenous Monetary Policies

Figure 1: Exogenous Monetary Policy (Covid-19)



Notes: MP refers to traditional monetary policy shocks (-1% reduction in the ECB's policy rate). QE (Quantitative Easing) represents a balance sheet expansion of 15% of steady-state GDP through asset purchases to improve liquidity. FG (Forward Guidance) simulates a communicated future reduction in the policy interest rate by -2.0%. NIRP (Negative Interest Rate Policy) reflects a -2.5% annualized policy rate shock. The scenarios are calibrated based on Eurozone data and reflect their impacts during the 2019–2023 period.

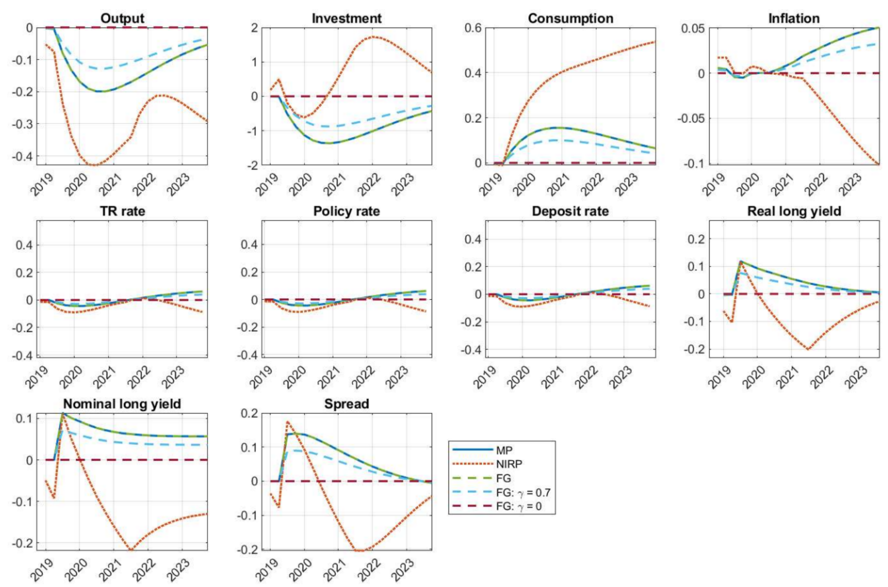
Figure 1 illustrates the macroeconomic effects of various exogenous monetary policy tools—Monetary Policy (MP), Quantitative Easing (QE), Forward Guidance (FG), and Negative Interest Rate Policy (NIRP)—during the COVID-19 pandemic in the Eurozone.

The responses under the MP framework were relatively modest, constrained by the Zero Lower Bound (ZLB), which limited the effectiveness of conventional monetary tools.

Among the policies, QE emerged as the most effective in stabilizing output and investment by injecting liquidity and reducing long-term interest rates, as evidenced by the expansion of the central bank's balance sheet. FG played a crucial role in anchoring inflation expectations and stabilizing prices, although its immediate effects on output and investment were less pronounced compared to QE. In contrast, NIRP demonstrated limited efficacy, primarily due to banking sector challenges in transmitting lower rates effectively.

The combination of QE and FG yielded particularly favorable outcomes, with QE addressing short-term liquidity needs and FG shaping.

Figure 2: Exogenous NIRP vs. FG (Covid-19)



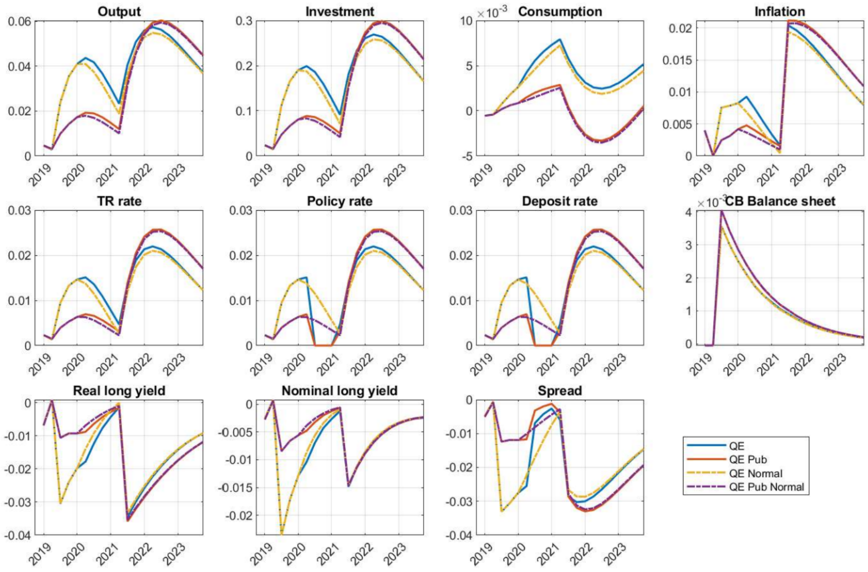
Notes: MP refers to a baseline monetary policy shock, representing conventional monetary policy during the COVID-19 pandemic. NIRP (Negative Interest Rate Policy) reflects a -1.5% shock to stimulate economic activity. FG (Forward Guidance) with high credibility ($\gamma = 0.7$) influences expectations of future interest rates, while FG with zero credibility ($\gamma = 0$) simulates a case where forward guidance is ineffective. These scenarios are calibrated based on Eurozone data and simulate the effects of different monetary interventions on output, inflation, investment, and interest rates from 2019 to 2023.

Figure 2 compares the macroeconomic impacts of Negative Interest Rate Policy (NIRP) and Forward Guidance (FG) with varying levels of credibility during the COVID-19 pandemic in the Eurozone. NIRP initially yields significant positive effects on output and investment due to reduced borrowing costs. However, these gains diminish over time as challenges such as reduced banking profitability and constrained credit supply emerge, as reflected in the spread and real long yield panels.

Forward Guidance (FG) is evaluated under three levels of credibility: fully credible, partially credible ($\gamma = 0.7$), and non-credible ($\gamma = 0$). Fully credible FG, where market participants completely trust the central bank's commitment, delivers the strongest and most sustained positive effects on output, investment, and inflation, primarily by reducing uncertainty. Partially credible FG ($\gamma = 0.7$) achieves moderate impacts, reflecting limited stabilization of expectations. Non-credible FG ($\gamma = 0$) significantly weakens the policy's effectiveness due to the absence of trust in the central bank's guidance.

The analysis underscores the importance of central bank credibility in maximizing FG's effectiveness. The inflation and interest rate panels highlight FG's ability to stabilize expectations, mitigate deflationary pressures, and foster long-term stability, which NIRP struggles to achieve. FG, particularly when fully credible, demonstrates a clear advantage over NIRP in sustaining output and investment recovery and managing macroeconomic conditions during crises.

Figure 3:Exogenous QE (Covid-19)



Notes: QE (Quantitative Easing) through private debt purchases at the ZLB aims to improve liquidity and stimulate economic growth during the COVID-19 crisis. QE through public debt purchases at the ZLB reflects central bank support for government spending. QE during normal times is simulated through private debt purchases to illustrate the effects without ZLB constraints and through public debt purchases to observe the differential impact in a non-crisis context. These shocks are applied to analyze their effects on key macroeconomic indicators, including output, inflation, investment, and interest rates, from 2019 to 2023.

Figure 3 examines the macroeconomic effects of Quantitative Easing (QE) during the COVID-19 crisis, comparing public and private approaches. QE significantly boosted output, investment, and consumption, with investment responding most strongly due to lower long-term interest rates. Consumption steadily increased, driven by improved sentiment and cheaper credit.

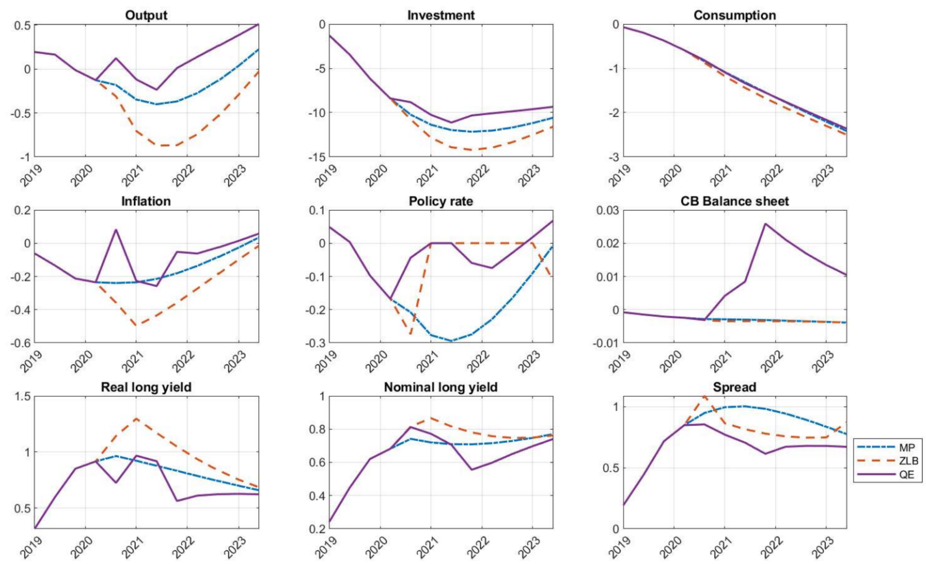
Inflation spiked after QE interventions, peaking in 2022 before stabilizing, while interest rates and long-term yields declined, encouraging spending and investment. The central bank's balance sheet expanded in 2020, gradually contracting after 2021 as QE measures unwound. Corporate bond spreads narrowed, reflecting reduced risk premiums.

Private QE had a stronger initial impact on investment and output than public QE, indicating greater effectiveness in private credit markets. Overall, Figure 3 underscores QE's ability to boost economic activity during crises and highlights the challenges of its unwinding for financial stability. bond yields declined, indicating reduced risk premiums. Private QE had a stronger initial impact on investment and output compared to public QE, suggesting that direct interventions in private credit markets can be more effective during a crisis.

Overall, Figure 3 demonstrates the effectiveness of QE in boosting economic activity during periods when conventional monetary policy is constrained, while highlighting the challenges of unwinding these interventions to ensure financial stability.

4.2 Endogenous Monetary Policies

Figure 4: Liquidy, Tecnology and Government shock (Covid-19)



Notes: MP (Monetary Policy) without the ZLB shows the response of key macroeconomic variables under standard conditions. The ZLB scenario without the use of unconventional monetary policies illustrates the economic impacts when rates are constrained by the zero lower bound. Endogenous QE (Quantitative Easing) at the ZLB demonstrates the stabilizing effects of QE during liquidity-constrained periods. The figure illustrates the responses to simultaneous shocks, including a liquidity shock, a government spending shock, and a negative technology shock, from 2019 to 2023, with a sequence of 1.5 standard deviation shocks occurring in the first six periods.

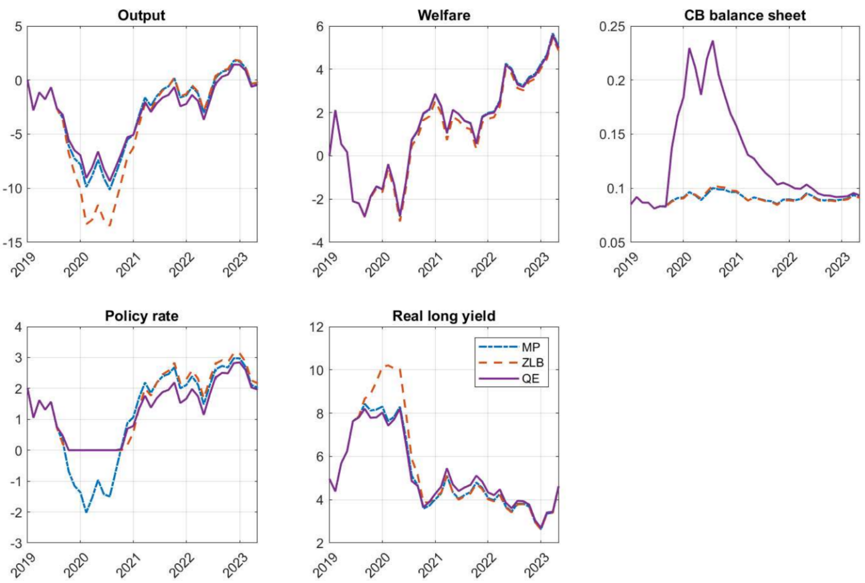
Figure 4 depicts the responses of macroeconomic indicators—output, investment, consumption, inflation, policy rates, central bank balance sheet, and yields—under QE, ZLB, and MP during simultaneous economic shocks similar to those of the COVID-19 pandemic. QE consistently produces stronger positive effects, particularly in output and investment, highlighting the critical role of liquidity injections.

Inflation, initially pressured by deflation, stabilizes under QE, demonstrating its effectiveness in countering declining demand. The ZLB shows limited impact on inflation, underscoring its constraints without direct asset purchases. Policy rates decline across all scenarios, with QE driving a notable expansion of the central bank's balance sheet.

Real and nominal yields decline more significantly under QE, encouraging investment and spending. Additionally, credit spreads narrow under QE, reflecting improved market conditions, whereas MP and ZLB yield less pronounced effects. These results emphasize QE's superiority in stabilizing the economy during compounded shocks.

4.3 The Covid-19 Crisis

Figure 5: Simulation (Covid-19)



Notes: This figure plots simulated paths of key economic variables under different policy scenarios during the COVID-19 pandemic. From 2020 to 2021, the economy is subject to a combination of shocks: a liquidity shock, a government spending shock, and a negative technology shock. QE (Quantitative Easing) shows the response under central bank asset purchases, MP (Monetary Policy) reflects conventional policy interventions, and the ZLB (Zero Lower Bound) illustrates constraints when rates approach zero. Key variables include Output, Welfare, Central Bank Balance Sheet, Policy Rate, and Real Long Yield. The simultaneous introduction of these shocks captures the compound pressures experienced during the COVID-19 crisis.

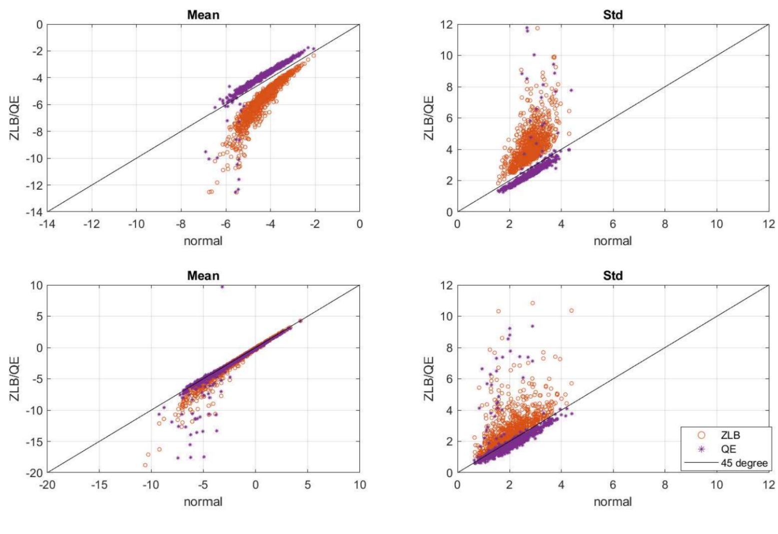
Figure 5 shows the response of key economic indicators—output, welfare, the central bank balance sheet, policy rate, and real long-term yield—under MP, ZLB, and QE interventions from 2019 to 2023. QE had the strongest positive impact, particularly during the peak of the COVID-19 crisis.

Output dropped sharply in 2020, with a stronger recovery under QE by 2022, highlighting its effectiveness. Welfare also improved significantly under QE from 2021, reflecting better conditions for households and firms. MP and ZLB produced more limited outcomes.

The central bank balance sheet expanded substantially under QE in 2020, with gradual unwinding from 2021, signaling effective stabilization. The policy rate under MP and ZLB reached its lower limits, while QE indirectly influenced financial conditions. Real long yields declined more under QE, supporting investment and recovery, while MP and ZLB had weaker effects.

Figure 5 underscores QE's superior ability to stabilize the economy and foster recovery compared to MP and ZLB during the pandemic.

Figure 6:Simulation (Covid-19)



Notes: This figure shows the comparison of the mean and standard deviation of key economic indicators under different monetary policy scenarios across 1000 simulations of 40 periods each.

From period 2 onward, the simulations include simultaneous shocks to technology, government spending, and liquidity. The top row presents results for periods 1–15, while the bottom row presents results for periods 16–40. Red circles represent the ZLB scenario without unconventional monetary policy, while purple stars represent the scenario with endogenous Quantitative Easing (QE). Each point compares the outcome under ZLB or QE with a normal policy scenario. The solid black line represents a 45-degree reference line, indicating points where outcomes under ZLB or QE would be identical to those under the normal scenario. Units are in percentage deviations from the steady state.

Figure 6 illustrates the comparative mean and standard deviation of economic outcomes under the Zero Lower Bound (ZLB) and Quantitative Easing (QE) relative to a normal scenario. The mean panels reveal that QE produced a significantly greater positive shift in outcomes compared to ZLB, indicating a more robust economic recovery. Additionally, the standard deviation panels demonstrate that QE provided a notably more stable economic environment by reducing uncertainty and stabilizing expectations—key factors in mitigating the impacts of crises. These findings underscore QE's superior effectiveness over ZLB in managing economic disruptions. By fostering a more predictable recovery trajectory during the COVID-19 pandemic, QE proved to be an essential tool in stabilizing the Eurozone economy under unprecedented circumstances.

4.4 Literature Comparison

The analysis of Figures 4, 5, and 6 underscores the pivotal role of Quantitative Easing (QE) during the COVID-19 crisis. QE proved to be the most effective tool, significantly boosting output, reducing long-term yields, and stabilizing financial markets through liquidity injections (Andrade et al. (2016); Altavilla et al.(2021)). Forward Guidance (FG) complemented QE by anchoring inflation expectations and mitigating uncertainty, with the credibility of central bank commitments playing a critical role in its success (Del Negro et al., 2015).

In contrast, Negative Interest Rate Policy (NIRP) provided more limited support, as its effectiveness was constrained by reduced bank profitability and lending challenges

(Brunnermeier and Koby (2018)). Endogenous QE, operating through a feedback mechanism, demonstrated superior performance over conventional policies restricted by the Zero Lower Bound, ensuring greater economic stability during periods of uncertainty (Rostagno et al.(2021)).

In conclusion, QE and FG were instrumental in stabilizing the Eurozone economy during the pandemic, while NIRP offered marginal benefits. These findings align with the broader literature on the effectiveness of unconventional monetary policies during economic crises.

5 ECB's Pandemic Response in the Real-World Context

The Eurozone experienced an unprecedented economic shock during the COVID-19 pandemic, with GDP contracting by 13.9% in March 2020. In response, the European Central Bank (ECB) implemented extensive measures, including a €120 billion asset purchase program. These interventions, reflected in Figures 4 and 5, stabilized financial markets, maintained low long-term interest rates, and injected critical liquidity into the economy.

Inflation trends observed during the pandemic closely align with the model's outcomes. Initial deflationary pressures in early 2020, with inflation dropping to 0.3%, were followed by a sharp rise to a peak of 10.6% in 2022. This increase was driven by supply chain disruptions, surging energy prices, and labor market dynamics. Welfare gains from Quantitative Easing (QE) similarly reflect real-world stabilization initiatives such as the SURE program, which supported household income and consumption during the crisis.

Investment dynamics also mirrored the model's predictions, rebounding strongly in late 2021 due to credit easing facilitated by QE and favorable financing conditions. Trends in policy rates under Zero Lower Bound (ZLB) and Monetary Policy (MP) scenarios validate the ECB's reliance on near-zero interest rates and forward guidance to sustain economic recovery.

The analysis emphasizes the superior effectiveness of QE in stabilizing output, reducing credit spreads, and promoting recovery when conventional monetary tools were constrained. These findings underscore the critical role of the ECB's interventions and affirm the Sims and Wu model's applicability in understanding the Eurozone's response to this historic crisis.

For a detailed examination of the impact of the ECB's monetary policy interventions during the COVID-19 crisis, refer to Appendix C.

6 Conclusion

This thesis highlights the pivotal role of unconventional monetary policies—Quantitative Easing (QE), Forward Guidance (FG), and Negative Interest Rate Policy (NIRP)—in stabilizing the Eurozone economy during the COVID-19 crisis. Among these, QE proved the most effective, providing critical liquidity, lowering borrowing costs, and mitigating financial market stress. These measures directly supported economic recovery by boosting output, investment, and consumption, particularly when conventional monetary tools were constrained by the Zero Lower Bound (ZLB).

Forward Guidance complemented QE by anchoring inflation expectations and reducing uncertainty, fostering confidence in the ECB's accommodative stance and encouraging spending and investment. While less impactful, NIRP contributed by incentivizing lending over reserve accumulation, offering additional support to economic activity despite its transmission challenges.

The findings underscore the necessity of employing a combination of unconventional monetary tools to address severe economic disruptions. QE emerged as the cornerstone of the ECB's response, with FG and NIRP enhancing its effectiveness. Together, these policies stabilized key macroeconomic indicators and restored confidence in financial markets, offering important lessons on the value of an adaptive and multifaceted monetary policy framework for future crises.

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Appendix

A. Model Key Equations

A.1 Households

Utility Function: The utility function incorporates habit formation, introducing persistence into consumption behavior. This is modeled as:

$$U(C_t, C_{t-1}) = \ln(C_t - bC_{t-1}), \tag{30}$$

where b captures the degree of dependence on past consumption. Habit formation ensures that current consumption decisions are influenced by past consumption levels, reflecting the smoothing behavior typical of households.

Stochastic Discount Factor: The stochastic discount factor, derived from intertemporal optimization, is expressed as:

$$\Lambda_{t,t+1} = \beta \frac{1/(C_t - bC_{t-1})}{1/(C_{t+1} - bC_t)}, \tag{31}$$

where β is the discount factor. This represents the trade-off between current and future utility, accounting for the marginal utility of consumption in both periods.

Labor Supply Condition: The labor supply condition balances the disutility of labor with the real wage, weighted by the marginal utility of consumption:

$$\chi L_t^{\eta} = \mu_t \frac{MRS_t}{P_t}. \tag{32}$$

Here, χ controls the scaling of labor disutility, and η, the inverse of the Frisch elasticity, determines the responsiveness of labor supply to changes in wages.

Euler Equation for Deposits: The Euler equation ensures the optimal allocation of savings over time. It balances the returns on deposits against inflation-adjusted future consumption:

$$R_t^d = E_t \left[\beta \frac{1/(C_t - bC_{t-1})}{1/(C_{t+1} - bC_t)} \frac{1}{\Pi_{t+1}} \right], \tag{33}$$

where $\Pi_{t+1} = \frac{P_{t+1}}{P_t}$. This equation governs households' intertemporal trade-offs, ensuring savings decisions maximize overall utility.

Budget Constraint: The budget constraint defines the allocation of household income between consumption and savings:

$$P_t C_t + D_t - D_{t-1} \leq MRS_t L_t + DIV_t - P_t X - P_t T_t + (R_t^d - 1) D_{t-1}. \tag{34}$$

Income sources include labor earnings ($MRS_t L_t$), dividends (DIV_t), and intermediary transfers ($P_t X$), while expenditures are allocated to consumption, taxes, and deposits.

A.2 Labor Market

Wage Aggregation and Indexation: The aggregation of wages in the labor market is expressed as:

$$W_t^{1-\epsilon_w} = \int_0^1 W_t(h)^{1-\epsilon_w} dh. \tag{35}$$

This equation captures how individual wages contribute to the aggregate wage index, reflecting the degree of wage dispersion across unions.

Recursive Terms in Wage Setting: The recursive terms $f_{1,t}$ and $f_{2,t}$ that appear in the first-order condition for optimal wages are defined as:

$$f_{1,t} = MRS_t w_t^{\epsilon_w} L_{d,t} + \phi_w E_t \Lambda_{t,t+1} \Pi_{t+1}^{-\epsilon_w} (1 - \gamma_w) f_{1,t+1}, \tag{36}$$

$$f_{2,t} = w_t^{\epsilon_w - 1} L_{d,t} + \phi_w E_t \Lambda_{t,t+1} \Pi_{t+1} (1 - \gamma_w)(1 - \epsilon_w) f_{2,t+1}. \tag{37}$$

These terms incorporate the effects of nominal rigidities, inflation (Π_{t+1}), and wage indexing (γ_w) on wage-setting behavior.

Wage Dispersion and Aggregate Labor Supply: Wage dispersion (w_t^v) plays a critical role in determining aggregate labor supply, defined as:

$$L_t = \frac{L_{d,t}}{w_t^v}, \tag{38}$$

$$w_t^v = \int_0^1 \left(\frac{W_t(h)}{W_t} \right)^{-\epsilon_w} dh. \tag{39}$$

This framework captures the interplay between wage dynamics and labor allocation in the economy.

Nominal Rigidities in Wage Setting: Nominal rigidities arise from the probability $(1 - \phi_w)$ that a union adjusts its wage in a given period. Unions unable to adjust their wages index them to past inflation using the parameter γ_w. These rigidities affect the transmission of monetary policy by influencing wage adjustments over time.

A.3 Fiscal Authority

Government Budget Constraint: The fiscal authority's budget constraint governs the financing of government expenditures $(P_t G_t)$ through lump-sum taxes $(P_t T_t)$, central bank transfers $(P_t T_{cb,t})$, and bond issuance. It is expressed as:

$$P_t G_t + P_{t-1} \bar{b}_G = P_t T_t + P_t T_{cb,t} + Q_{B,t} P_t \bar{b}_G (1 - \kappa \Pi_{t-1}), \tag{40}$$

where:

- $P_t G_t$: Nominal government spending.
- $P_{t-1} \bar{b}_G$: Nominal value of bonds issued in the previous period.
- $P_t T_t$: Lump-sum taxes, which adjust endogenously to maintain solvency.
- $P_t T_{cb,t}$: Transfers from the central bank.
- $Q_{B,t} P_t \bar{b}_G (1 - \kappa \Pi_{t-1})$: Bond financing adjusted for inefficiencies (κ) and inflation (Π_t).

This budget constraint ensures fiscal solvency by balancing expenditures and revenues while accounting for inflation and inefficiencies in bond enforcement.

Fixed Real Bond Stock: The model assumes a fixed real stock of government bonds, $b_{G,t} = \bar{b}_G$, where nominal bond values grow proportionally with the pri

A.4 Financial Intermediaries

Balance Sheet and Net Worth Dynamics: The intermediary's balance sheet links its asset holdings to liabilities and net worth:

$$Q_t F_{i,t} + Q_{B,t} B_{i,t} + RE_{i,t} = D_{i,t} + N_{i,t}. \tag{41}$$

Net worth evolves over time based on asset returns and deposit costs:

$$N_{i,t} = (R_t^F - R_t^d) Q_{t-1} F_{i,t-1} + (R_t^B - R_t^d) Q_{B,t-1} B_{i,t-1} + (R_t^E - R_t^d) RE_{i,t-1} + R_t^d N_{i,t-1}. \tag{42}$$

Costly Enforcement Constraint: The enforcement constraint prevents intermediaries from absconding with assets:

$$\theta_t \phi_t n_{i,t} \geq Q_t F_{i,t} + \Delta Q_{B,t} B_{i,t}, \tag{43}$$

where ϕ_t is the leverage ratio, $\Delta < 1$ reflects enforcement inefficiency, and θ_t is the shadow value of net worth.

Reserve Requirement: Intermediaries must hold a minimum proportion of reserves relative to deposits:

$$re_{i,t} \geq \zeta d_{i,t}, \tag{44}$$

where $re_{i,t} = RE_{i,t}/P_t$ and $d_{i,t} = D_{i,t}/P_t$ represent real reserves and deposits, respectively. This ensures liquidity for depositors and compliance with regulatory requirements.

Auxiliary Variables and Constraints: The auxiliary variable Ω_t, governing leverage and portfolio allocation, is defined as:

$$\Omega_t = 1 - \sigma + \sigma \theta_t \phi_t. \tag{45}$$

Portfolio Returns: The first-order conditions for portfolio returns ensure optimal allocation across private bonds, government bonds, and reserves while accounting for enforcement and reserve constraints:

$$E_t\Lambda_{t,t+1}\Omega_{t+1}\Pi_{t+1}^{-1}(R_{t+1}^F - R_t^d) = \lambda_t(1 + \lambda_t\theta_t), \tag{46}$$

$$E_t\Lambda_{t,t+1}\Omega_{t+1}\Pi_{t+1}^{-1}(R_{t+1}^B - R_t^d) = \lambda_t\theta_t\Delta(1 + \lambda_t\theta_t), \tag{47}$$

$$E_t\Lambda_{t,t+1}\Omega_{t+1}\Pi_{t+1}^{-1}(R_{t+1}^E - R_t^d) = -\omega_t(1 + \lambda_t). \tag{48}$$

A.5 Production

Production Function and Capital Dynamics: The production function defines the relationship between output, capital, and labor:

$$Y_{m,t} = A_t(u_tK_t)^\alpha L_{d,t}^{1-\alpha}. \tag{49}$$

Capital evolves according to:

$$K_{t+1} = \hat{I}_t + (1 - \delta(u_t))K_t, \tag{50}$$

where investment ($\hat{I}_t$) and depreciation ($\delta(u_t)$) determine the change in the capital stock.

Dividend Function: The nominal dividend function is given by:

$$DIV_{m,t} = P_{m,t}A_t(u_tK_t)^\alpha L_{d,t}^{1-\alpha} - W_tL_{d,t} - P_t^k\hat{I}_t - F_{m,t} + Q_t(F_{m,t} - \kappa F_{m,t-1}), \tag{51}$$

where W_t is the nominal wage, $P_{m,t}$ is the price of wholesale output, P_t^k is the price of capital, and $F_{m,t}$ represents bonds issued by the firm. This equation reflects the firm's revenues and costs, including labor expenses, capital investment, and bond financing.

Financial Constraint: The firm's investment is subject to a financial constraint:

$$\psi P_t^k\hat{I}_t \leq Q_t(F_{m,t} - \kappa F_{m,t-1}), \tag{52}$$

where ψ represents the proportion of investment financed through bond issuance. This constraint ensures that investment levels align with the firm's financing capacity.

Optimization Conditions:

- **Labor Demand:**

$$w_t = (1-\alpha)p_{m,t}A_t(u_tK_t)^{\alpha}L_{d,t}^{-\alpha}. \tag{53}$$

- **Capital Utilization:**

$$p_t^k M_{1,t}\delta'(u_t) = \alpha p_{m,t}A_t(u_tK_t)^{\alpha-1}L_{d,t}^{1-\alpha}. \tag{54}$$

- **Investment and Bond Pricing:**

$$P_t^k M_{1,t} = E_t\Lambda_{t,t+1}\left[p_{m,t+1}\alpha A_{t+1}(u_{t+1}K_{t+1})^{\alpha-1}u_{t+1}L_{d,t+1}^{1-\alpha} + (1-\delta(u_{t+1}))P_t^k M_{1,t+1}\right], \tag{55}$$

$$Q_tM_{2,t} = E_t\Lambda_{t,t+1}\Pi_{t+1}^{-1}Q_{t+1}M_{2,t+1}. \tag{56}$$

Wedges and Policy Implications: The investment wedge ($M_{1,t}$) and financial wedge ($M_{2,t}$) demonstrate how monetary policy, such as Quantitative Easing, affects financing and production. These mechanisms reveal how policy interventions propagate through the real economy, influencing investment and production decisions.

A.6 Central Banks

A.6.1 Conventional Monetary Policy and ZLB Constraint

Taylor Rule and Monetary Policy Response: The Taylor rule systematically adjusts the short-term interest rate based on deviations in inflation ($\ln\Pi_t - \ln\Pi$) and output growth ($\ln Y_t - \ln Y_{t-1}$):

$$\ln R_t^{TR} = (1-\rho_r)\ln R^{TR} + \rho_r \ln R_{t-1}^{TR} + (1-\rho_r)\left[\phi_\pi(\ln\Pi_t - \ln\Pi) + \phi_y(\ln Y_t - \ln Y_{t-1})\right] + s_r\varepsilon_{r,t}. \tag{57}$$

Key parameters:

- ρ_r: Reflects the degree of policy inertia, with higher values indicating slower adjustments to shocks.

- $\phi_\pi > 1$: Ensures inflation stability by making the policy rate strongly responsive to inflation deviations.

- ϕ_y: Captures the sensitivity to output growth deviations.

- $\varepsilon_{r,t}$: Represents exogenous policy shocks.

Zero Lower Bound (ZLB) Constraint: At the ZLB, the effectiveness of conventional monetary policy is constrained as nominal rates cannot fall below zero. The model ensures non-negative nominal rates through the condition:

$$R_t^{re} = R_t^d = \max\{1, R_t^{TR}\}. \tag{58}$$

This highlights the theoretical limitation of conventional tools in addressing deflationary pressures and economic stagnation.

Policy Implications: The ZLB underscores the necessity for unconventional monetary interventions, such as Quantitative Easing, during severe downturns. These tools compensate for the diminished effectiveness of conventional policies by targeting longer-term interest rates and liquidity conditions.

A.6.2 Quantitative Easing

Central Bank Balance Sheet and Bond Purchases: The central bank's QE operations are formalized as:

$$Q_t F_{cb,t} + Q_{B,t} B_{cb,t} = RE_t, \tag{59}$$

where:

- Q_t: Price of private bonds.

- $Q_{B,t}$: Price of government bonds.

- $F_{cb,t}$: Quantity of private bonds held by the central bank.
- $B_{cb,t}$: Quantity of government bonds held.
- RE_t: Reserves created to finance these purchases.

These purchases increase bond demand, raising prices and reducing yields. Lower yields alleviate financial constraints for firms and intermediaries by reducing borrowing costs.

Mitigating Financial Frictions: QE is particularly effective under binding enforcement constraints, characterized by:

$$\Delta < 1, \tag{60}$$

where Δ measures enforcement efficiency. Binding constraints limit intermediaries' ability to borrow, but QE reduces financing costs, enabling greater access to credit and stimulating investment and aggregate demand.

Transmission Mechanisms and Policy Implications: The Sims and Wu framework emphasizes QE's role in addressing financial frictions by:

- Increasing bond prices and reducing yields, facilitating cheaper financing for firms.
- Easing credit constraints by alleviating enforcement frictions.
- Supporting economic activity during periods when conventional monetary tools are ineffective.

These mechanisms underscore QE's significance in stabilizing the economy during severe downturns, complementing conventional policies, and enhancing aggregate demand.

A.6.3 Exogenous and Endogenous QE

Exogenous QE: Exogenous QE follows predefined processes for central bank bond holdings, modeled as:

$$f_{cb,t} = (1 - \rho_f) f_{cb} + \rho_f f_{cb,t-1} + s_f \varepsilon_{f,t}, \tag{61}$$

$$b_{cb,t} = (1 - \rho_b) b_{cb} + \rho_b b_{cb,t-1} + s_b \varepsilon_{b,t}, \tag{62}$$

where:

- $f_{cb,t}$: Real holdings of private bonds by the central bank.
- $b_{cb,t}$: Real holdings of government bonds by the central bank.
- ρ_f, ρ_b: Persistence parameters governing the duration of bond purchases.
- s_f, s_b: Standard deviations of shocks to private and government bond purchases.

These equations capture the central bank's static intervention strategy, where bond purchases are implemented independently of economic conditions, relying on persistence and shocks to drive dynamics.

Endogenous QE: Endogenous QE introduces a feedback mechanism linking central bank bond purchases to macroeconomic indicators, such as output and inflation deviations. This dynamic approach enables QE policies to adjust automatically in response to prevailing economic conditions, ensuring stability and reinforcing the central bank's role in mitigating financial disruptions.

This responsive mechanism contrasts with the static nature of exogenous QE, providing a more flexible tool for addressing real-time economic challenges.

Policy Implications: By incorporating both exogenous and endogenous QE, the model captures two critical dimensions of central bank interventions:

- **Exogenous QE:** Demonstrates the impact of predetermined policy strategies on market conditions.

- **Endogenous QE:** Highlights the benefits of dynamically responsive interventions that adapt to economic stressors, improving the effectiveness of QE as a stabilization tool.

A.6.4 Forward Guidance

Modeling FG in the Sims and Wu Framework: The Sims and Wu framework models FG as a shock to the desired policy rate (R_t^{TR}) during the ZLB period. This approach shapes agents' expectations of future deposit rates beyond the ZLB, formalized as:

$$E_t[i_{t+k}] = i^*, \tag{63}$$

where i^* represents the central bank's communicated future policy rate. By influencing expectations, FG aligns market behavior with the central bank's monetary objectives.

Addressing the Forward Guidance Puzzle: The framework incorporates interest rate smoothing ($0 < \rho_r < 1$) to address the "forward guidance puzzle," where FG appears excessively powerful when targeting rates far into the future. This smoothing ensures that shocks to the desired policy rate decay over time, mitigating the overamplification of FG's effects and offering a more realistic depiction of its impact on the economy.

Credibility and Effectiveness: The effectiveness of FG depends on the credibility parameter γ:

- $\gamma = 1$: Full credibility, where agents fully adjust expectations to align with the announced policy rate path.

- $\gamma = 0$: No credibility, where FG announcements are ignored.

Calibrating γ using empirical data allows the model to capture variations in FG effectiveness, reflecting differences in central bank trustworthiness and market responsiveness.

Transmission Mechanisms and Policy Implications: FG reduces long-term yields, stabilizes inflation expectations, and supports aggregate demand through the expectations hypothesis, which links anticipated future interest rates to current market conditions. These mechanisms highlight FG's role in enhancing monetary policy effectiveness during periods when conventional tools are constrained.

A.6.5 Negative Interest Rate Policy (NIRP)

Balance Sheet Implications: NIRP affects financial intermediaries by reducing net worth when the interest rate on reserves falls below the deposit rate:

$$R_t^{re} < R_t^d. \tag{64}$$

This condition tightens financial frictions and enforcement constraints, reducing the capacity of intermediaries to extend credit. As a result, the policy's effectiveness in alleviating financial pressures may be limited, especially under binding constraints.

Comparisons with Forward Guidance: The effectiveness of NIRP relative to forward guidance depends on central bank credibility:

- When forward guidance is fully credible ($\gamma = 1$), NIRP tends to be less stimulative due to its adverse effects on intermediary balance sheets.

- When forward guidance lacks full credibility ($\gamma < 1$), NIRP compensates by providing observable actions, which reduce the credibility gap and strengthen policy effectiveness.

Transmission Mechanisms and Policy Implications: NIRP influences the economy through the expectations and balance sheet channels:

- **Expectations Channel:** Signals future reductions in deposit rates, shaping long-term yields and aggregate demand.
- **Balance Sheet Channel:** Imposes costs on financial intermediaries when $R_t^{re} < R_t^d$, reducing their capacity to lend and potentially weakening the overall stimulative effect.

These dual effects position NIRP as a nuanced policy tool that addresses both expectations and financial constraints, complementing other unconventional monetary policies.

B. Model Calibration

Table 1: **Parameters Calibration**

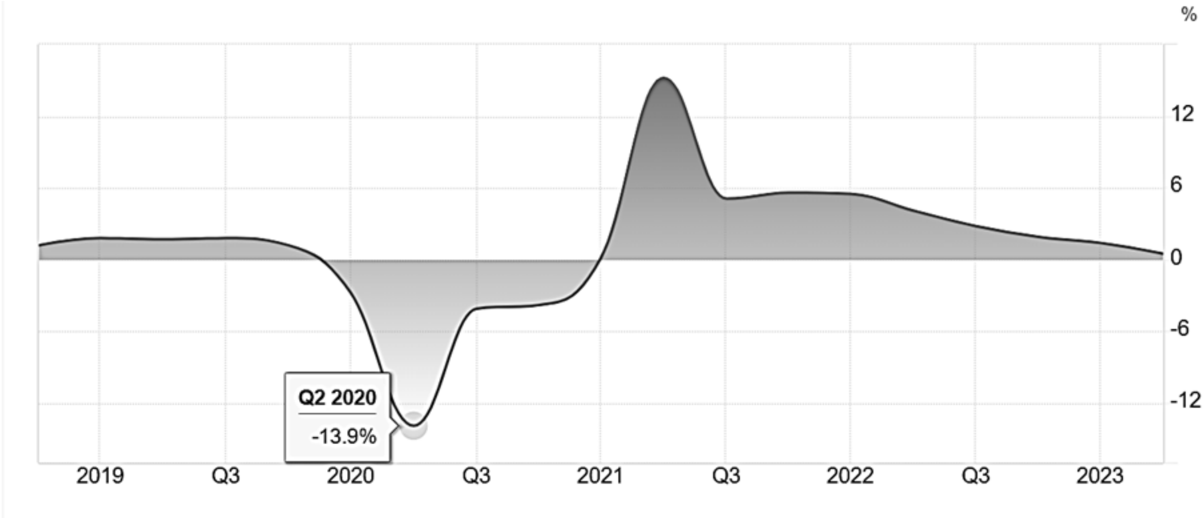
Parameter Description	**Sims and Wu (2019)**	**Adjusted Value**
Price Stickiness (*phip*)	0.75	0.85
Wage Stickiness (*phiw*)	0.75	0.85
Government Spending Share (*gy*)	0.2	0.25
Habit Formation (*bh*)	0.7	0.8
Inverse Frisch Elasticity (*eta*)	1	2
Fraction of Private Debt Held by CB (*ff*)	0.1	0.2
Corporate Leverage (*levs*)	4	5
Interest Rate Persistence (*rhor*)	0.8	0.84
Inflation Response Coefficient (*phipi*)	1.5	1.3
Investment Adjustment Cost (*kappai*)	2	2.5
Government Spending Shock Persistence (*rhoG*)	0.95	0.9
Preference Shock Persistence (*rhoc*)	0.9	0.98
Productivity Shock Volatility (*sA*)	0.0065	0.002
Debt-to-GDP Ratio (*bgy*)	0.41×4	0.97

Table 2: **Shocks Calibration**

Shock Description	**Wu (2019)**	**Adjusted Value)**
Liquidity Shock Magnitude	0.01	0.05
Government Spending Shock Magnitude (sG)	0.01	0.05
Government Spending Shock Persistence ($rhoG$)	0.95	0.98
Productivity Shock Volatility (sA)	0.0065	0.002
Preference Shock Persistence ($rhoc$)	0.9	0.98

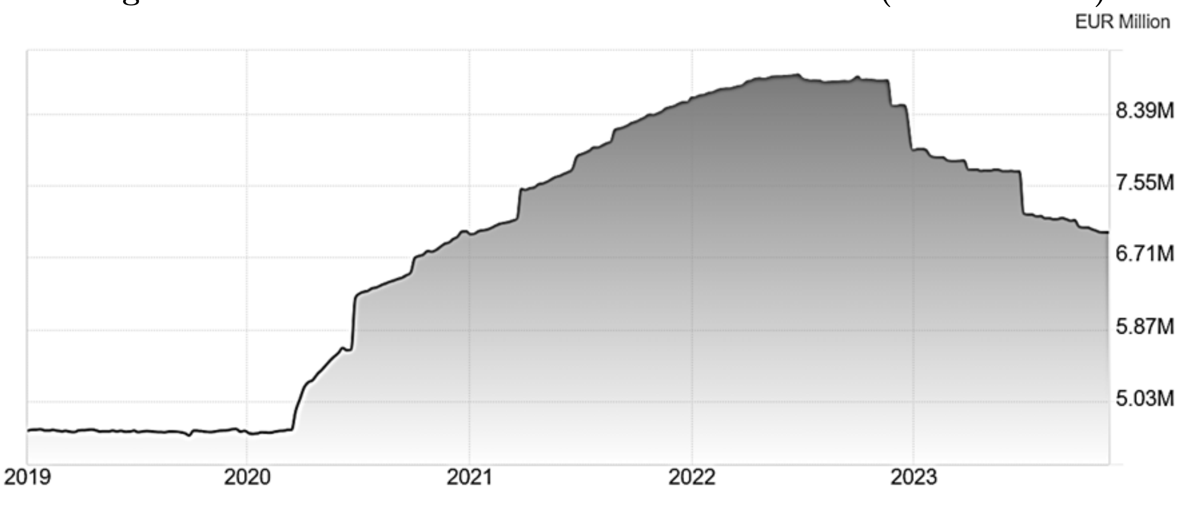
C. Real Data-Covid 19

Figure 7: Euro Zone GDP Annual Growth Rate (%)



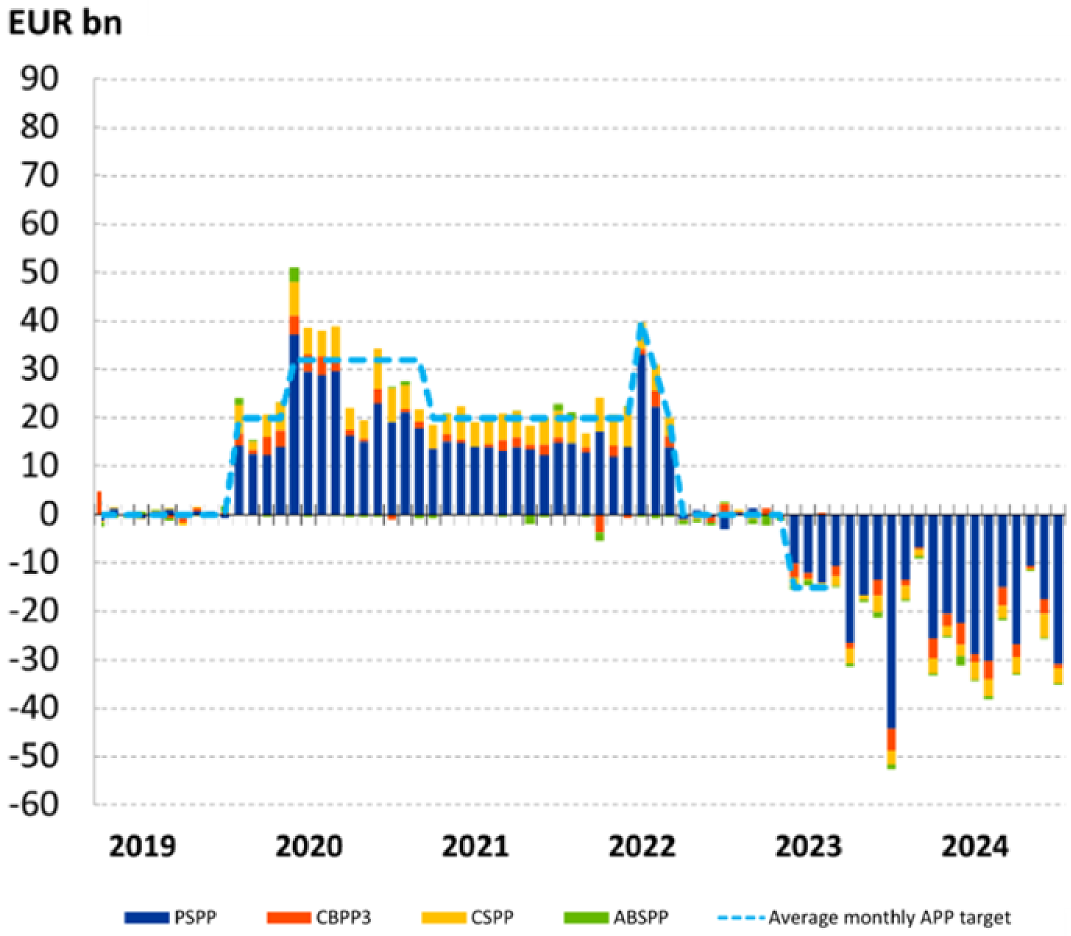
Source: tradingeconomics.com / EUROSTAT

Figure 8: Euro Zone Central Bank Balance Sheet (EUR Million)



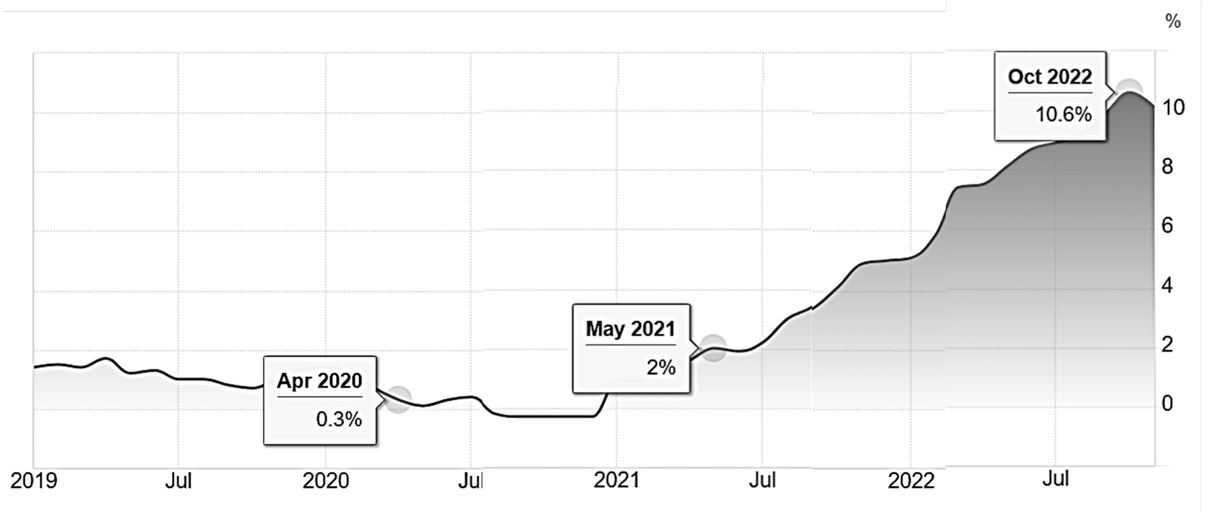
Source: tradingeconomics.com / EUROSTAT

Figure 9: Net asset purchases by programme under APP (EUR bn



Source: tradingeconomics.com | EUROSTAT

Figure 10: Euro Zone Inflation Rate (%)



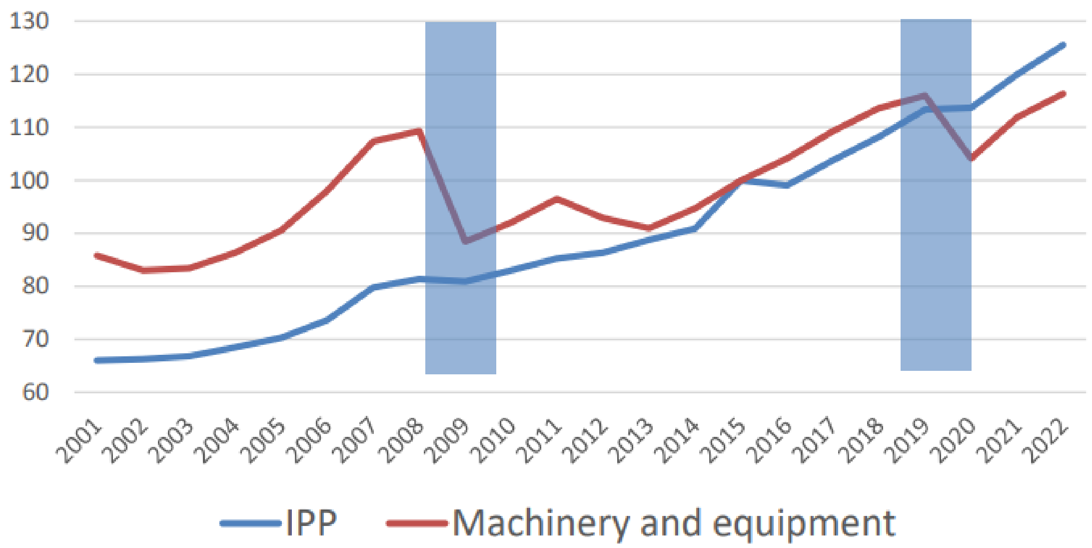
Source: tradingeconomics.com | EUROSTAT

Table 3: **SURE Loans (Billions)**

Country	Proposed Loan Amount	Disbursed
Belgium	8.197 billion	8.197 billion
Bulgaria	971 million	971 million
Cyprus	632 million	632 million
Estonia	230 million	230 million
Greece	6.2 billion	6.2 billion
Spain	21.324 billion	21.324 billion
Croatia	1.6 billion	1.6 billion
Hungary	651 million	651 million
Ireland	2.473 billion	2.473 billion
Italy	27.438 billion	27.438 billion
Lithuania	1.1 billion	1.1 billion
Latvia	472 million	472 million
Malta	420 million	420 million
Poland	11.236 billion	11.236 billion
Portugal	6.2 billion	6.2 billion
Romania	3 billion	3 billion
Slovenia	1.113 billion	1.113 billion
Slovakia	630 million	630 million
Czechia	4.5 billion	4.5 billion
Total	**98.4 billion**	**98.4 billion**

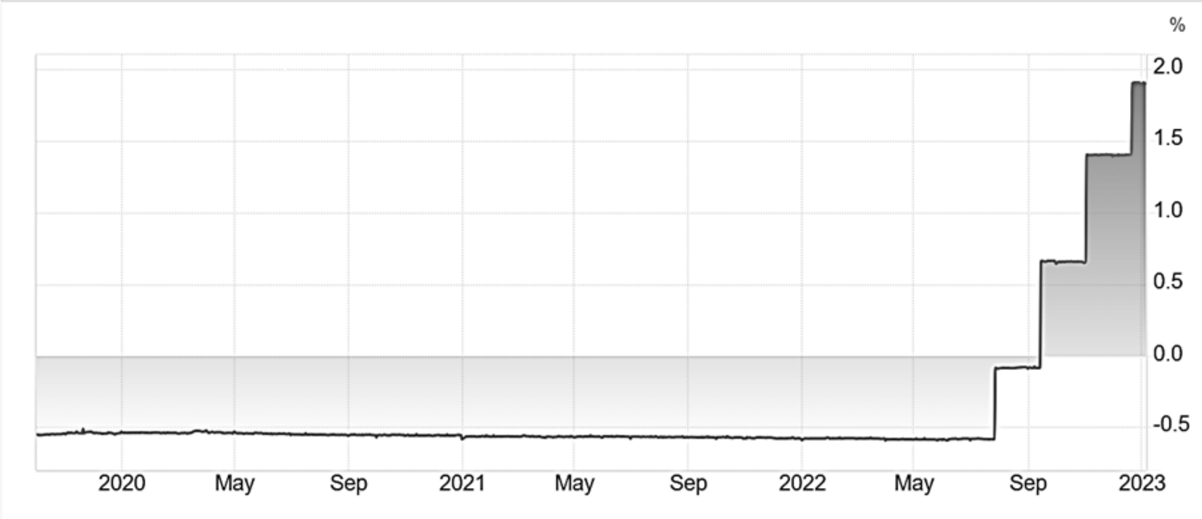
Source: European Commission

Figure 12:Investment in Machinery and Equipment



Source: European Investment Bank

Figure 13:Euro Area Euro Short Term Rate



Source:tradingeconomics.com / EUROSTAT