Proceedings of ICFTBA 2024 Workshop: Finance in the Age of Environmental Risks and Sustainability
DOI: 10.54254/2754-1169/127/2024.OX18496

Analysis of Japan's Monetary Policy on Price Stability: A Vector Error Correction Model Approach

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Abstract: In response to prolonged deflation and economic stagnation, Bank of Japan implemented non-traditional easing monetary policies, including Quantitative Easing (QE) adopted in 2001 and Quantitative and Qualitative Easing (QQE) adopted in 2013. This paper aims to uncover the effectiveness of these policies using a Vector Error Correction Model with Johansen normalization restrictions. By analyzing the impact on Consumer Price Index, M2 Money Supply, and the Japanese yen to US dollar exchange rate from year 2000 to 2024, this research studies the short-term dynamics of Japanese economy and the long-term relationships among these variables. The results indicate that QQE was more effective than QE in stabilizing inflation and influencing the money supply, contributing to Japan's economic recovery in 2024. Moreover, the research shows that the impact on exchange rate was complex, reflecting the interplay between Japan's unique deflationary environment and global financial conditions. The findings of this research suggest that the Bank of Japan may need to conduct a more aggressive and diversified measures to effectively manage inflation and stabilize the economy.

Keywords: monetary policy, quantitative easing, quantitative and qualitative easing, vector error correction.

1. Introduction

In Japan's recent history, year 2024 is destined to be one of the most remarkable years. In March 2024, Bank of Japan first raised the short-term policy rate in seventeen years. At the Monetary Policy meeting held on July 1st, 2024, the policy board of Bank of Japan announced to increase the uncollaterized overnight call rate again from between 0.00 and 0.15 percent to remain at around 0.25 percent [1]. This is the second rate-lift in 2024. The same day, the bank also announced the plan for the reduction of purchase amount of Japanese Government Bonds (JGBs). Due to the released schedule, the Bank of Japan plan to reduce the monthly purchase amount from 6 trillion yen to 3 trillion yen ($19.9 billion) by the first quarter of 2026 [1]. Even though Bank of Japan has not officially announced to end the Negative Interest Rate Policy (NIRP), after decades of struggling, the world finally sees some positive signs of Japan overcoming its protracted era of deflation.

For years, discussions about Japan's economy have been dominated by negative words such as challenges, crisis, and stagnation [2, 3]. There is lively debate across the world questioning about the effectiveness of non-conventional monetary policy that the Bank of Japan was adopted. Japanese

DOI: 10.54254/2754-1169/127/2024.OX18496

researcher argues that the bank needs to adopt more comprehensive strategy to get out of deflation completely [4]. Recent study argues that it is a total failure of the attempts at Quantitative Easing (QE) in raising the equilibrium level of Japanese nominal Gross Domestic Product by any material magnitude [5]. Japan's economy has always been a hot topic, and numerous researchers have conducted in-depth research on Japan's monetary policy. This demonstrates how significant the Japanese experience is in the study of economic development.

In the face of prolonged deflation and economic stagnation, Bank of Japan have implemented several unconventional monetary policies over the past two decades. These included QE adopted in 2001 and Quantitative and Qualitative Easing (QQE) adopted in 2013. These policies aimed to combat deflation, stimulate economic growth, and stabilize the currency. This paper evaluates the effectiveness of these policies by analyzing their impact on three critical variables: Consumer Price Index (CPI), M2 Money Supply (M2), and the Japanese yen to US dollar exchange rate (EX). The analysis employs a Vector Error Correction Model (VECM) to explore both short-term and long-term relationships between these variables.

2. Methodology

2.1. Data and Variables

The analysis uses quarterly data on CPI, M2, and EX from 2000 to 2024. QE policy was first introduced in year 2001 and switched to QQE policy in year 2013. Thus, this paper chooses period from year 2000 to 2024 to examine the effectiveness of these unconventional practices. This research adopts CPI as a measure of inflation. The main aim of QE kind of policies is to inject liquidity directly into the financial system. Research often adopts M2 to measure the amount of money supply [6]. In this case, this research chooses M2 as a measure of monetary expansion. Finally, EX is used as a proxy for currency stability. The CPI and M2 data are sourced from Trading Economics and the yen to dollar exchange rate is collected from Federal Reserve Economic Data. All the data is from official publications and international financial databases, ensuring accuracy and relevance.

2.2. Vector Error Correction Model

VECM is good at explaining long-term relationships between cointegrated time series variables, meaning that there is stable and long-term relationship existed within the variables even after being non-stationary when taken individually. Many studies have adopted VECM approach to uncover relationships between multivariate time series variables [7, 8]. In this paper, the VECM is estimated with different lag structures to capture both immediate and delayed effects of the monetary policies. For QE period (2000 to 2012), the model is estimated with one and three lags. QQE Period (2013 to 2024) is estimated with one and two lags. The lag length selection is based on standard information criteria, such as Akaike information criterion, to ensures the model adequately captures the dynamics of the variables. The following equation (1) displays the model.

$$\Delta Y_t=\alpha\left(\beta' Y_{t-1}\right)+\sum_{i=1}^{p-1}\Gamma_i\Delta Y_{t-i}+\lambda ECT_{t-1}+u_t \quad (1)$$

In the equation above, Y_t is the vector of the variables (CPI, EX, M2). All variables in this study are defined in their logarithmic forms. The adjustment vector "α" is indicating how the variables correct any deviation from the long-term equilibrium. The cointegration matrix represented by β' measures the long-term relationships. Γ_i are matrices capturing the short-term effects. ECT_{t-1} is the error correction term which is the lagged value of the residuals. The error correction term contains

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long-run information derived from the long-run cointegrating relationship. Finally, u_t represents the residuals in the equation.

The Johansen cointegration test is adopted to examine long-term equilibrium relationship existence among variables. The test involves the following two steps. First step is to test for the degree of cointegrating relationships using trace and maximum eigenvalue statistics. The second step is to impose a normalization restriction on the CPI coefficient in the cointegration vector, setting it to 1. This allows for an easier interpretation of how changes in the yen to dollar exchange rate and M2 money supply relate to inflation in the long run.

3. Results

3.1. Quantitative Easing Period: 2000-2012

Table 1 shows the regression results on QE with one lag. Table 2 show the results with three lags. As shown in Table 1, the error correction term coefficient for CPI with one lag is -0.013 and it is not statistically significant. This result suggests that CPI did not significantly adjust back to its long-term equilibrium in the short run, or in one quarter during the QE period. In three-lags model, results shown in Table 2, the error correction term of CPI is -0.214, significant at the 1% level. The increased magnitude and significance indicate that the adjustment process for CPI was more pronounced when considering a longer lag structure. This suggests that QE's impact on inflation was gradual and took time to materialize, consistent with the delayed effects being often associated with monetary policy. This finding aligns with the difficulties the Bank of Japan faced in influencing inflation through its QE policies, reflecting the persistent deflationary pressures in Japan.

The error correction term coefficient for EX with one lag is -1.398, which significant at the 1% level. This strong negative coefficient indicates that an increase in the exchange rate is associated with a stronger yen. However, given the negative coefficient, the actual effect was that the exchange rate decreased, implying the Japanese yen is strengthened relative to the US dollar, likely due to the Bank of Japan's interventions aimed at stabilizing the currency. This is consistent with the bank's active management of the yen during the QE period, including currency market interventions. In the three-lags model shown in Table 2, the coefficient is not significant anymore. This lack of significance may reflect the influence of external factors on the exchange rate over a longer horizon, which could obscure the immediate effects of QE.

Table 1: Regression results on Quantitative Easing with one lag.

	(1) CPI	(2) EX	(3) M2
Error Correction Term	-0.013 (0.047)	-1.398*** (0.373)	-0.091* (0.055)
Constant	-0.001 (0.001)	-0.000 (0.005)	0.006*** (0.001)
Observations	51	51	51
Johansen Normality Test	1.000 (.)	0.127 (0.039)	0.361 (0.078)

Notes: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

For M2, the one-lag error correction term is -0.091, significant at the 10% level. This suggests a modest but statistically significant correction in the money supply, reflecting the incremental impact of QE on monetary expansion. In three-lags model, the coefficient of M2 is 0.153 and significant at

DOI: 10.54254/2754-1169/127/2024.OX18496

the 5% level. This positive coefficient suggests that QE had a more sustained impact on the money supply, reflecting the gradual absorption of liquidity into the economy over multiple periods.

Table 2: Regression results on Quantitative Easing with three lags.

	(1) CPI	(2) EX	(3) M2
Error Correction Term	-0.214***	0.764	0.153**
	(0.068)	(0.590)	(0.065)
CPI with 1 lag	0.004	-3.150***	-0.468***
	(0.138)	(1.201)	(0.131)
CPI with 2 lags	0.089	-2.684*	-0.211
	(0.167)	(1.455)	(0.159)
EX with 1 lag	-0.001	0.245*	0.009
	(0.017)	(0.148)	(0.016)
EX with 2 lags	-0.039**	-0.123	-0.006
	(0.017)	(0.151)	(0.016)
M2 with 1 lag	0.210	-2.638**	-0.000
	(0.136)	(1.180)	(0.129)
M2 with 2 lags	0.094	-0.899	-0.439***
	(0.128)	(1.110)	(0.121)
Constant	0.001	-0.001	0.005***
	(0.001)	(0.012)	(0.001)
Observations	49	49	49
Johansen normality Test	1.000	-0.077	-0.052
	(.)	(0.026)	(0.053)

Notes: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

3.1.1. Short Run Effect of QE

In Table 2, the first lag of CPI in the EX equation shown in column (2) has a coefficient of -3.150, statistically significant at the 1% level. The second lag of CPI in the EX equation also has a negative and significant coefficient. This indicates that in the short run, the past variations in price level significantly influenced the yen's appreciation. Particularly one percent of increase in CPI would causes yen to appreciate by 3.15 percent depending on US dollar exchange rate. This finding might seem contradict to the economic theory that higher inflation expectations led to a weaker yen. The strength of the yen in this case could be attributed to market expectations, the deflationary context of Japan, and possible shifts in interest rate expectations. In particular, the situation of Japan could be different due to the deflationary environment. The increase in M2 might be perceived as a signal that the Bank of Japan is effectively combating deflation, which could boost confidence in the yen, leading to its appreciation. In the M2 equation shown in column (3) of Table 2, the first lag of CPI is also significant, indicating that past inflation negatively impacted the money supply in short run, possibly reflecting the bank's response to inflationary pressures by adjusting monetary policy.

On the EX side, the first lag of EX in CPI equation shown in column (1) is not significant, but the second lag has a coefficient of -0.039, which is statistically significant at the 5% level. This indicates that in short run, past exchange rate movements had a delayed but significant impact on inflation, likely through the import price channel. In column (3), the lagged exchange rate is not statistically

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significant, suggesting that the impact of past exchange rate movements on the money supply was minimal.

For M2, as shown in column (2), the first lag of M2 has a significant and negative coefficient (-2.638), indicating that increases in the money supply led to a stronger yen. This might contradict to the expectation that an expanded money supply exerts downward pressure on the currency value. This might be due to the influence of external factors over a shorter horizon, for example, shocks from US dollar side, which could obscure the effects of exchange rate.

3.1.2. Long Run Effect of QE

The Johansen test confirmed the existence of a cointegrating relationship among CPI, EX, and M2 during the QE period. The normalization imposed on CPI (setting its coefficient to 1) allows for a clearer interpretation of the long run equilibrium, where changes in EX and M2 are viewed relative to CPI. For one lag model, refers to Table 1, the long run coefficients in the cointegration equation show that the exchange rate and money supply both have significant negative relationships with CPI. This suggests that in the long run, an increase in M2 and a depreciation of the yen are associated with lower inflation. For three lags model, refers to Table 2, the results are quite different comparing with the one lag model. In this case M2 is not statistically significant anymore and leaving EX still significant but positively related with CPI. This suggests that in the long run, an increase in M2 has no effect on inflation, and meanwhile, an appreciation of the yen is associated with higher inflation.

To summarize the findings in QE period, it indicates that there is a deviation from one lag and three lags model. In one-lag model, in short run, the QE policy implemented by the Bank of Japan had delayed, but there are significant effects on inflation and the exchange rate. In three-lags model, the finding suggests that M2 does not influence the inflation, but exchange rate does play a significant role in controlling the inflation. The stronger error correction term for CPI in the three-lags model suggests that the impact of QE on inflation was not very useful, reflecting the difficulty in reversing entrenched deflationary expectations.

3.2. Quantitative and Qualitative Easing (QQE) Period: 2013-2024

Table 3 shows the regression results on Quantitative and Qualitative Easing with one lag. Table 4 shows the results with two lags.

Table 3: Regression results on Quantitative and Qualitative Easing with one lag.

	(1) CPI	(2) EX	(3) M2
Error Correction Term	-0.164** (0.065)	0.433 (0.466)	0.191** (0.097)
Constant	0.007*** (0.002)	0.001 (0.013)	0.004* (0.003)
Observations	45	45	45
Johansen Normality Test	1.000 (.)	-0.224 (0.041)	-0.089 (0.036)

Notes: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

As indicated in Table 3, the error correction term of CPI is -0.164, significant at the 5% level. The coefficient remains significant in two-lags model shown in Table 4. This significant error correction term indicates that CPI adjusted more rapidly towards its long-term equilibrium during the QQE

DOI: 10.54254/2754-1169/127/2024.OX18496

period, suggesting that QQE was more effective in influencing inflation expectations and stabilizing prices, consistent with the Bank of Japan's objectives.

The error correction term for EX in one-lag model is 0.433 which is not significant, indicating that the immediate impact of QQE on the exchange rate was less pronounced. This may reflect the broader range of assets targeted by QQE and the complex global factors affecting the yen. However, in the two-lags model, the coefficient is significant at the 5% level. This strong positive coefficient suggests that the exchange rate corrected more aggressively over two periods, possibly due to the cumulative effects of QQE measures on global market perceptions of the yen.

The error correction term for M2 in one-lag model is 0.191, significant at the 5% level. This positive coefficient suggests that QQE had a significant and immediate impact on the money supply, reflecting the aggressive asset purchases and expanded monetary base under QQE. However, in two-lags model, the coefficient for M2 is not statistically significant, indicating that the effects of QQE on the money supply were more immediate rather than sustained over multiple periods.

Table 4: Regression results on Quantitative and Qualitative Easing with two lags.

	(1) CPI	(2) EX	(3) M2
Error Correction Term	-0.148* (0.084)	1.281** (0.521)	0.162 (0.114)
CPI with 1 lag	0.078 (0.158)	0.209 (0.986)	-0.533** (0.215)
EX with 1 lag	0.010 (0.026)	0.479*** (0.160)	-0.020 (0.035)
M2 with 1 lag	-0.087 (0.105)	-0.870 (0.657)	0.038 (0.143)
Constant	0.005*** (0.002)	-0.001 (0.010)	0.009*** (0.002)
Observations	44	44	44
Johansen normality Test	1.000 (.)	-0.210 (0.036)	-0.075 (0.029)

Notes: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

3.2.1. Short Run Effect of QQE

Table 4 shows the two-lags regression results of QQE period. First, the lagged CPI has a significant negative impact on M2 (-0.533) in column (3), indicating that rising inflation during the QQE period led to a contractionary response in the money supply. This could reflect the ban's cautious stance in preventing overheating of the economy once inflation began to rise. In the column (1), the lagged exchange rate is highly significant, suggesting that past currency movements had a strong influence on current inflation, likely through the import price channel.

The exchange rate exhibits strong autoregressive behavior, particularly in the column (2), where the first lag is significant. This indicates that the exchange rate during QQE was heavily influenced by its past values, reflecting the persistent impact of market expectations and the bank's signaling. The money supply's impact on other variables is less pronounced in the two-lags model, suggesting that the effects of QQE on the monetary base were more immediate and less persistent over time.

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3.2.2. Long Run Effect of QQE

The Johansen test confirmed cointegration during the QQE period, validating the existence of a long-term relationship among CPI, EX, and M2. The imposed normalization on CPI (set to 1) provides a benchmark for interpreting the long run effects of changes in EX and M2 relative to inflation. The long run coefficients in the cointegration equation show that the exchange rate and money supply both have significant positive relationships with CPI. This indicates that, in the long run, a depreciation of the yen and an increase in the money supply were associated with higher inflation during the QQE period, consistent with the Bank of Japan's policy objectives.

The VECM results for the QQE period indicate that this policy framework was more effective than QE in stabilizing inflation and influencing the money supply. The significant error correction terms for CPI and the immediate adjustments in M2 suggest that QQE was successful in achieving its policy goals. The more complex and delayed effects on the exchange rate reflect the broader impact of QQE on global financial markets and the bank's efforts to manage the yen in a highly interconnected world economy. It is worth mentioning that the residuals of QQE period models are not normally distributed. This might be due to the small sample size. Even though the residuals are not normally distributed, it the result can be taken as some reference value due to the newly achievement made by the Bank of Japan this year.

4. Discussion

The comparison of VECM results across different lag structures shows that QE had more delayed effects on inflation and the exchange rate, while QQE produced more immediate and robust results. This difference highlights the enhanced effectiveness of QQE in addressing Japan's economic challenges, particularly in stabilizing inflation. The consistent presence of cointegration in both periods underscores the long-term relationships between CPI, EX, and M2. The stronger adjustment terms during QQE suggest that this policy framework was more effective in achieving economic stability.

The more complex response of the exchange rate during QQE reflects the global nature of financial markets and the broader impact of Japan's monetary policy on global capital flows. This underscores the importance of considering external factors when evaluating the effectiveness of domestic monetary policies. This suggest that central banks may need to employ more aggressive and diversified measures, as seen in QQE, to effectively manage inflation and stabilize the economy. This finding is consistent with Shirai's research in 2014 [9]. The results also highlight the importance of a long-term perspective in evaluating monetary policy effectiveness. While QE had delayed and probably less pronounced effects, the more immediate impact of QQE suggests that policy timing and scope are crucial factors in achieving desired outcomes.

On the policy side, one hotly debated discussion is on why the 2 percent inflation target is still needed in Japan. Japanese researcher emphasized the importance of having the belief that deflation is more harmful to an economy than inflation [9]. On the presentation at Bank of Japan in 2017, Bernanke argues that achieving the 2 percent inflation target would help the central bank to gain back the ability of monetary policy on responding to recessionary shocks [10]. This paper aims to find out whether Japan is on the right track achieving this goal. The significant adjustments in CPI and M2 during the QQE period, coupled with the strong error correction terms, suggest that these policies were critical in driving Japan's economic recovery in 2024. The central bank's ability to influence inflation expectations and manage the money supply effectively was likely to have played a key role in this turnaround, setting the stage for sustained economic growth.

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5. Conclusion

In Japan's history, economic crisis has been persistent since 1990. Japan's experience of confronting economic downturn is very valuable for foreign countries to use for reference. Especially for nowadays, many countries are facing potential risks. This study provides a comprehensive evaluation of Japan's QE and QQE policies using a VECM approach with Johansen normalization restrictions. The results confirm that from year 2000 to 2012, QE's effect on promoting inflation might not be significant, and QQE was more effective than QE in stabilizing inflation and influencing the money supply, contributing to Japan's economic recovery in 2024. The findings underscore the importance of aggressive and well-targeted monetary policies in overcoming deflationary pressures and achieving long-term economic stability. Future research could explore the global implications of Japan's QQE policy and its relevance to other economies facing similar challenges.

However, the impact on the yen's exchange rate was complex, reflecting the interplay between Japan's unique deflationary environment and global financial conditions. While QQE effectively managed inflation expectations and the money supply, its influence on the yen was nuanced, driven by a combination of domestic and international factors. This complexity highlights the challenges central banks face when implementing unconventional monetary policies in an interconnected global economy.

Despite the robustness of the VECM approach, this study has several limitations. First, the model assumes linear relationships between the variables, which may not fully capture the complexities of economic dynamics under unconventional monetary policies. Non-linear models or structural vector autoregression (SVAR) approaches could provide additional insights. Second, the analysis is restricted to three key variables (CPI, M2, and EX), which, while important, do not encompass all the factors influencing Japan's economy during the study period. Future research could benefit from incorporating additional variables such as interest rates, fiscal policy measures, or global economic indicators to offer a more holistic view. Third, the study focuses on the period up to 2024, and it is important to consider that the long-term effects of QQE may continue to evolve beyond this timeframe. Continued monitoring and analysis are required to fully understand the enduring impact of these policies. Finally, the unique deflationary context of Japan during the study period may limit the generalizability of the findings to other economies.

Future research could explore the application of similar models in different economic environments, particularly in emerging markets or economies experiencing inflationary pressures, to assess the broader relevance of the conclusions drawn here. In conclusion, while this study provides valuable insights into the effectiveness of Japan's QE and QQE policies, it also highlights the need for continued research and model refinement to fully capture the complexities of monetary policy in a globalized economy.

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